ANACOM
AUTORIDADE NACIONAL DE COMUNICAÇÕES

STUDY FOR THE EVALUATION OF THE QUALITY OF SERVICE OF BROADBAND INTERNET ACCESS

(technical parameters)

ICP - ANACOM

Report

(March 2009)

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1. General Framework

Motivations for conducting the study

For the third consecutive year, ICP-ANACOM carried out a quality assessment study, from the residential or private user's standpoint, of Internet access services in Portugal. The study was prepared and conducted in collaboration with QMETRICS – Serviços de Consultadoria, S.A., with the cooperation of FCCN – Foundation for National Scientific Computation, APRITEL – Telecommunications Operators Association, DGC – General Directorate for Consumer, and the studied internet access service providers (ISPs and mobile operators) were also involved, their suggestions and critical opinions being considered in connection with the definition of the study's methodology.

Quality regulation covers the fundamental principles for preserving the quality of life, including aspects such as the environment, regional planning and consumption. This study in particular regards the use of the Internet access service. In general, quality law covers the prevention of the malfunctions and risks of the goods and services, and the responsibility for repairing damages caused by defective goods or services. However, its scope if frequently reduced to the first aspect, i.e., covering prevention. In order to implement the previously mentioned requirement, the regulatory authority of the communications sector, ICP-Anacom, usually issues mandatory technical regulations aiming at the protection of the general interest (consumers, users). However, the particular case of Internet access requires a complementary approach in line with the evolution of quality demand, considering the growing implementation rate of new applications over the Internet, which consequently induces new consumption habits among users.

Therefore, under a scope of objectivity and association to the dynamics that characterizes this market, quality of service studies have been carried out as a way to monitor and publicize the actual performance of the service providers. The studies are not limited to information purposes and are complemented with a pedagogic approach, in order to stimulate the consumer to value the characteristics shown in the available offers that will best match his/her usage profile.

The Internet, an essential vehicle for information circulation, as previously mentioned, has been increasingly supporting a wider range of applications, from the common Web page browsing (Web Surfing), to social networks (Web 2), including voice communications (VoIP), file and content sharing

(file sharing, P2P), and real time viewing of multimedia contents (music and video streaming). In this context, the demand for quality in the operation of the network and of the services circulating therein increasingly assumes an adaptive character, i.e., the quality of service demand level varies depending on the applications used by the consumers.

Until very recently, the quality of service demand level focused mainly on the actual availability of the service and on the speed reached by the transmission line. Currently, demand standards vary considerably, given the volume and complexity of the applications circulating over the Internet and the diversity of access types available to consumers (Cable, ADSL, mobile). Communications delay, usually called latency, as well as the loss of data packages (transmitted IP datagrams), among other indicators, currently assume the same importance that access velocity, since they are network performance parameters, critical for the quality of the applications running in real time (VoIP, online Games, etc…). In fact, the quality variation reached by these applications results from the combined performance of these network indicators and is seldom the reflex of the isolated performance of a single indicator.

Following the studies on the quality of the Internet access service previously carried out by ICP-Anacom, 3G mobile access is the novelty. The mobile access penetration rate has had an exponential increase since January 2007, stimulated by the e-initiatives programme. Mobile Internet accesses represent around 40%[1] of total Internet accesses and might be seen as an alternative or complement to fixed access, therefore consumers should be also informed about the particulars, the capacities and performances of this type of access.

Assessed indicators and testing architecture

The quality perceived by the Internet access service's users is linked to a mix of technical, commercial and customer service factors, frequently named QoE - Quality of end-user experience. Technical factors stand out among those listed. They are currently the factors most valued by ISPs in the promotion of their offers, namely the download speed, which is usually associated to its corresponding price component. The performance of the technical factors is usually designated the quality of provision of the network service (QoS - Quality of Service). The association of technical

[1] Source: ICP-Anacom, 4th Quarter 2008

and non-technical aspects to the quality of end-user experience can be represented in the following way (Figure 1):

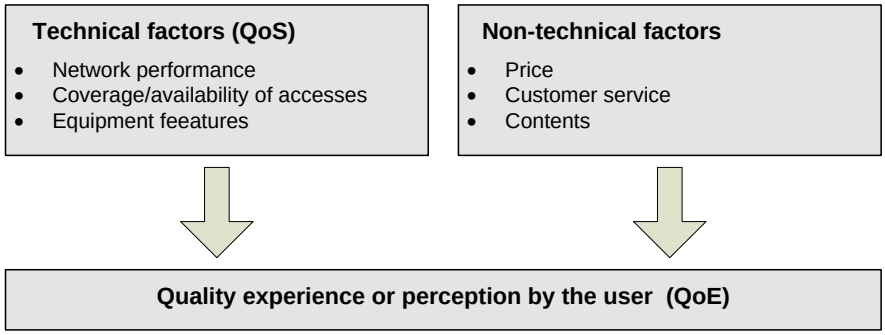


Figure 1 – Association of technical and non-technical aspects QoE

Technical factors (*QoS*) are quite objective and can be evaluated quite rigorously, in opposition to non-technical factors, characterized by some subjectivity, since they depend on the interpretation of consumers. Within this framework, the current study presents the result of the evaluation of technical parameters, which were considered to have higher relevance for the network's performance and with greater perception by consumers, and also considering the ISP's communication and marketing strategies. Thus, the following indicators were evaluated:

- Availability and reliability of the network during access (only for mobile networks);
- Web page download time;
- File download and upload speed using FTP;
- Communication delay or Latency[2];

The influence of the network performance (QoS) on the performance of the most popular applications used over the Internet can be summarized in terms of sensitivity level, for each evaluated indicator, as shown on Figure 2.

[2] Latency or communication delay of a package during the transmission between the sender and the receiver, defined as half of the response time to an ICMP ECHO or RTT package (Round Trip Time) / 2.

Applications' sensitivity to network performance		
Application	Speed	Latency
Voice over IP	Low	High
Streaming	High	Medium
Web browsing	Medium	Medium
E-mail	Low	Low
File download	High	Low

Figure 2 – Levels of applications' sensitivity to network parameters (transmission speed and latency)

As previously mentioned, ISP's commercial promotion mainly focuses on the download speed reached by the access. From the evaluated applications, download file transfer by FTP is the one that maximizes[3] the bandwidth available on the same direction, therefore being the best indicator of the bandwidth that is actually available for download, and it may be used to compare with the maximum speed advertised in each commercial offer (see Figure 3).

An active testing architecture was implemented in order to conduct the study and for both types of access (fixed and mobile), i.e., the real use of Internet access was closely replicated, by automatically generating test traffic between "client systems" and target servers (client-server structure). Tests were carried out during pre-determined schedules, during the day and during the seven days of the week. For that purpose and for each type of access (fixed and mobile), a panel of real users was drafted, representative of each ISP's residential[4] commercial offers (offers with the highest customer rate). From here and based on the use of two specific testing "client systems" to simulate fixed and mobile access, the testing sessions begun aiming at the target servers.

In order to create optimal testing conditions, in terms of harmonizing the national destination point and eliminating bandwidth constraints on the access, a server was installed for the termination of test sessions on an adjacent network to the GigaPix (interconnection platform for IP traffic exchange between national and international networks), located at FCCN. For the international tests, four

[3] This situation results from a greater efficiency of the related communication protocol, in terms of actual usage of the available bandwidth.

[4] In the mobile, the offering is designated: for individuals

additional servers were installed on different locations in Europe and the United States (2 in the UK and 2 in the USA). The study included the three mobile operators with UMTS access technology and the four ISPs which, together, represent about 90% of the fixed access market share (Cable and ADSL).

Figure 3 presents a summary of the Internet access providers and the corresponding commercial offers under study, reflecting some tariff modifications introduced in the market by the corresponding operators while the tests were under way (see technical specification/methodology).

Provider	Access type	Access technology	Commercial Offer			
			Initial Download speed	Final Download speed	Initial Upload speed	Final Upload speed
ZON/TVCabo	Fixed	Cable	8Mbps	8Mbps	512kbps	512Kbps
Cabovisão[5]			10Mbps	10Mbps		512Kbps
Sapo/PT[6]		ADSL	6Mbps	8Mbps		1024Kbps
Clix/Sonaecom[7]			4/6Mbps	4/6Mbps		512Kbps
TMN[8]	Mobile	UMTS	1Mbps	1/2Mbps	384kbps	384/512Kbps
Vodafone[9]				2Mbps		512Kbps
Optimus				1Mbps		384Kbps

Figure 3 – Summary of the Internet access service providers under study

[5] Initial 5Mbps offer that was migrated to 10Mbps download before the beginning of the tests.

[6] Based of the information received from the operator, the 6Mbps offer was selected for this study. However, drafting the user panel showed that it is considerably difficult to draft panel customers of this type of commercial offer. After analysing the situation, it was concluded that the operator had started a process for the automatic migration from 6Mbps to 8Mbps. Therefore, to conclude the study, it was considered necessary to mirror this evolution and test users were recruited to conduct measurements for both offers.

[7] Based on the initial information received from the operator, the 4Mbps offer was selected for this study. However, it was considerably difficult to recruit the user panel among this commercial offer's customers, and the option was to also include the 6Mbps offer, since, according to the operator, this offer's customers had been considered in the tariff scheme corresponding to 4Mbps.

[8] Initial offer that was partially migrated to a 2Mbps download and 512kbps upload while the tests were taking place, reflecting on 9 of the 25 SIM cards under test, at the study's final stage.

[9] Initial offer that was fully migrated to a 2Mbps download and 512kbps upload while the testes were taking place.

2. Executive Summary

The purpose of this study is to analyze the results obtained from a technical approach, that may lead to conclusions close to reality concerning the performance levels perceived by the residential/private user, namely through the most used applications, such as WEB Browsing and file transfer by FTP (File Transfer Protocol).

The study includes two types of broadband access: 3G mobile and fixed (cable and ADSL). Within the scope of 3G mobile access, tests were carried out indoors (private households) and outdoors (including public locations, such as commerce and leisure areas, airports, schools, where there is a high usage of mobile broadband Internet), in the areas of greater Lisbon and Porto, where measurements were collected during seven consecutive days.

In order to evaluate the fixed accesses, a panel was set up with 203 users (51 Cabovisão, 50 Zon, 50 Cylix, 52 Sapo), randomly selected from contact databases obtained for that purpose. The study[10] was carried out between 5 November 21 December 2008, for mobile accesses, and between 30 October 2008 and 8 February 2009, for fixed accesses.

The different sample sizings considered for the mobile access and the fixed access are justified by the greater variability of the indicators expected for the mobile access. That was the reason why the size of the mobile access sample is higher in regards to the fixed access. For the same reason, different geographic municipalities (Lisbon and Porto) were also considered for the mobile access. This difference makes it possible to increase the precision of the results achieved in the mobile access, thus achieving the same precision level recorded in the fixed access.

The performance measurements were conducted using a technological platform able to simulate the reality for each of the two types of access (3G mobile and fixed), through the autonomous implementation of active tests (traffic generated automatically on pre-determined schedules). Two different “client systems” were used for this purpose, one for mobile broadband and the other for fixed broadband, given each access technology’s technical specifications. Both systems were

[10] With interruption of the tests during school’s Christmas holidays (between 14 December 2008 and 3 January 2009).

installed in randomly chosen locations, in order to comply with the requirements of statistical validity desired for the study.

For fixed broadband and considering a broader analysis in terms geographical distribution, including the entire Mainland Portugal territory, the personal computers of the service subscribers of each operator were used, by installing a software package for managing the tests to be carried out.

The analyzed commercial offers were selected according to the information provided by the operators, following the criteria of greater representatively regarding their customer universe. This way and given the variety of the offers, particularly in the case of fixed broadband, the studied tariff schemes have different advertised maximum speeds. Regarding mobile broadband operators, tariff schemes were chosen with similar advertised maximum speeds, thus being comparable, although the market's natural dynamics has determined some modifications to these characteristics during the study, which were considered in this report.

Main results

The main results obtained from each operator's individual performance are presented under a comparative approach between fixed and mobile technology operators, and between operators of the same technology.

The indicators presented in this summary represent the most relevant results. Therefore, we analyze the indicators concerning FTP file download and upload speeds, Web page download times, and the network's latency. Other indicators may be seen in the results section (e.g. 3G mobile networks' availability and reliability indicators).

Comparison of results between access technologies

Regarding file download speeds, from fixed accesses, since the tariff schemes under study offer advertised maximum speeds higher than their counterparts in mobile access, higher average speeds were obtained, as expected, for all destinations, as shown on Figure 4 and Figure 5. Nonetheless, differences recorded among mobile and fixed are less relevant for international accesses, with particular highlight to the sessions with destinations in the United States (see Figure 33 and Figure 55).

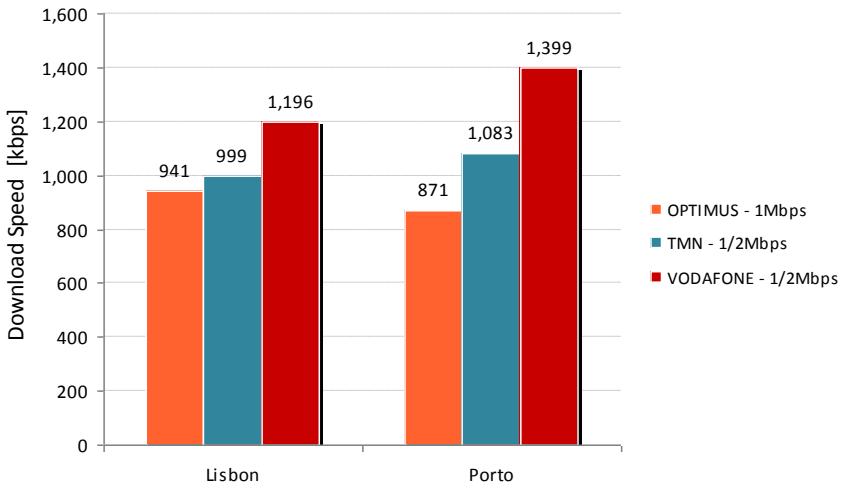


Figure 4 – Average file transfer Download speed per mobile access provider

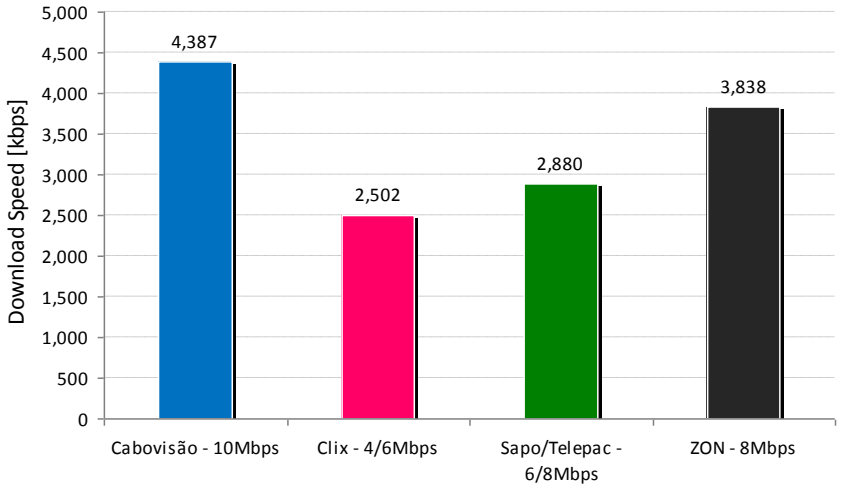


Figure 5 – Average file transfer Download speed per fixed access provider

In opposition to the records concerning file transfer download speeds, mobile technology's upload speeds are usually higher than fixed technology's. The mobile tariff schemes under analysis indicate a 512kbps maximum uplink value, however presenting considerably higher average values, depending on the operator and the municipality under analysis. The fixed tariff schemes analyzed, in spite of advertising a 512kbps maximum uplink value (except Sapo/Telepac, which advertises 1Mbps upload in the 8Mbps tariff scheme), do not reach this value, on average. These differences accentuate when considering exclusively the accesses to the national server, where mobile technology reaches values much higher than 1 Mbps, while fixed values continue at an average record below 512kbps (see Figure 70 and Figure 92).

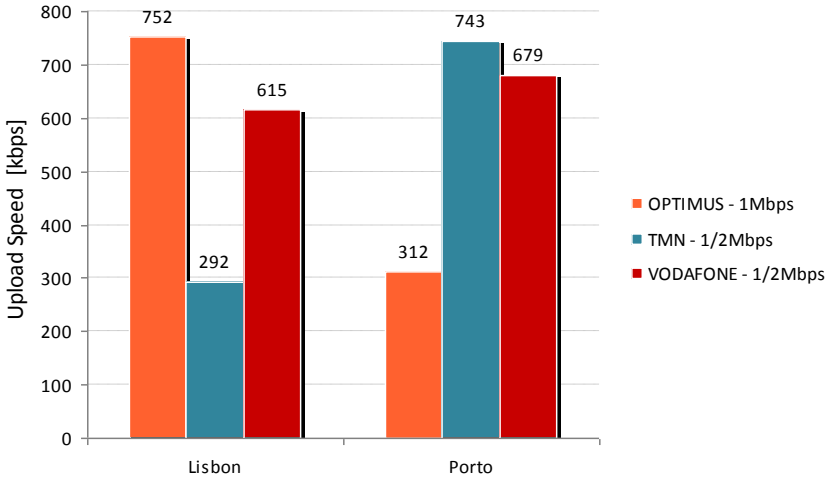


Figure 6 – Average file transfer Upload speed per mobile access operator

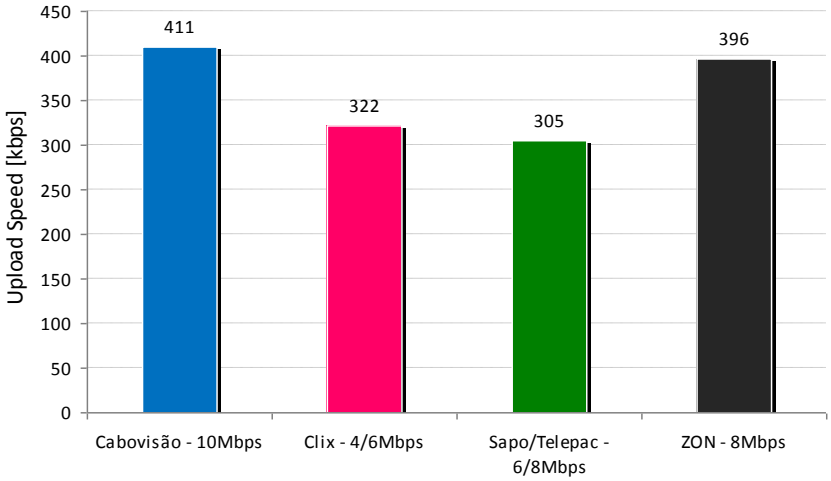


Figure 7 – Average file transfer Upload speed per fixed access operator

The quality perceived during WEB browsing is usually associated to the time needed to locate and download a Web page. Besides the DNS server's response speed (IP address solution) and the network's latency, the connection speed is one of the factors that contribute to the overall experienced quality. Usually, fixed accesses provide average Web page download speeds lower than mobile technology. However, as what happens with file download for international accesses, the difference between technologies is considerably reduced for the accesses to the United States, particularly to server USA2 located on the west coast. For this destination, the average recorded

values are similar to mobile values, the difference of access speeds not being noticed (see Figure 8 and Figure 9). However, for national accesses and to the United Kingdom, the fixed technology provides, in some cases, less than half of the average download speeds during web browsing when compared to the mobile technology's performance.

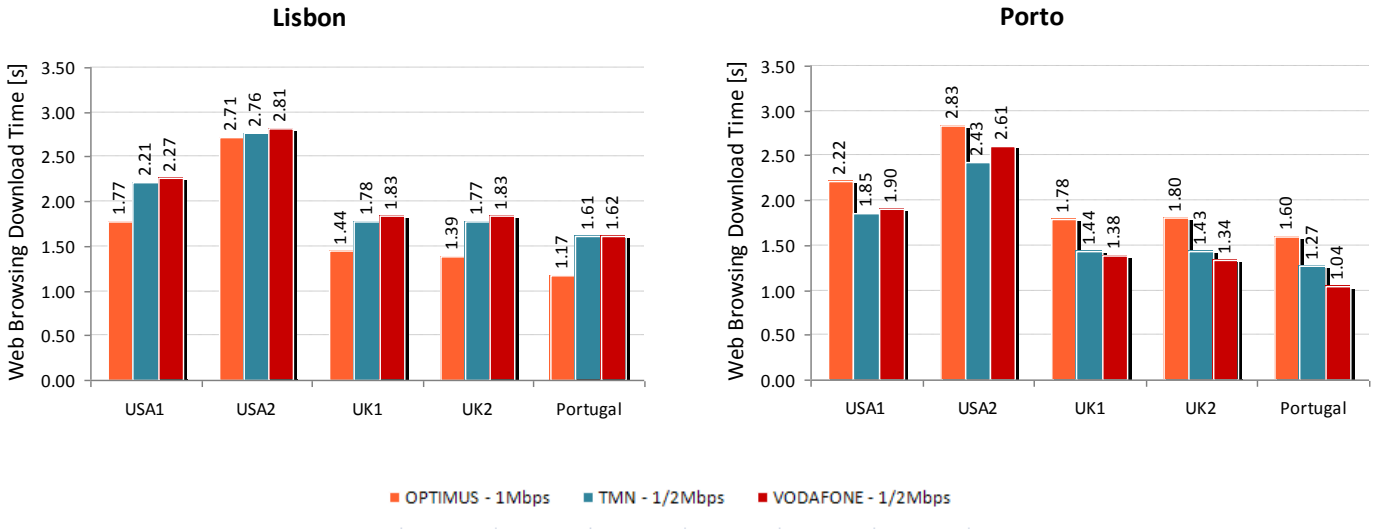


Figure 8 – Average Download speed of a page during WEB Browsing per mobile operator, destination server and municipality

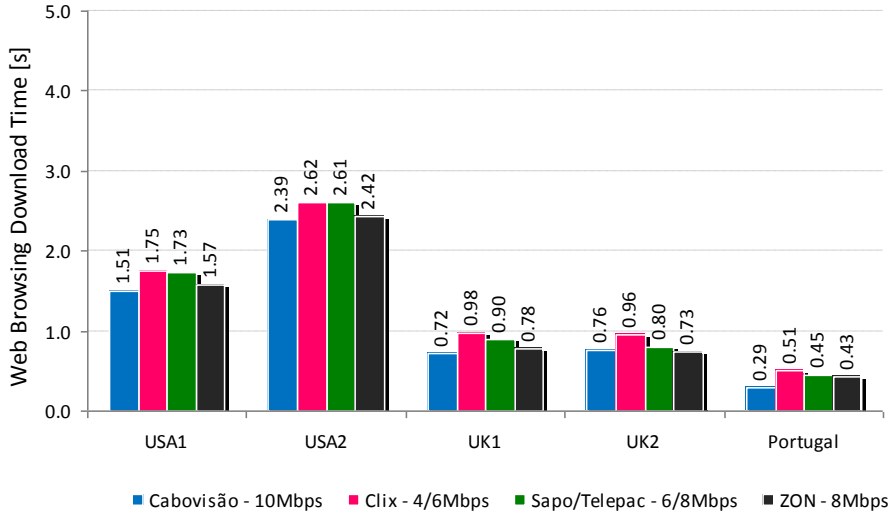


Figure 9 – Average Download time during Web Browsing per fixed operator and destinations operator

In terms of latency, Figure 10 and Figure 11 show the average values for all destinations, for the mobile and fixed access, respectively. The main differentiating factor between fixed and mobile technologies, in terms of results, is specially noticed in the network latency (delay in the transmission of IP packages), which has a significant impact on interactive applications such as VoIP[11] and online gaming[12].

The latency results presented in this report correspond to the time used by a data package to go from the origin to its destination. As an example, for a latency value of 150ms, the quality degradation for VoIP is practically unnoticed. Above that value, considerable quality degradation starts to be felt. In the same context, for values above 300ms, quality becomes impossible. The effects of latency in VoIP quality translate into considerable voice delays, echo, and overlapping noises, causing the interruption of conversation between participants.

Mobile broadband presented higher latency values for all destinations. Nonetheless, the values recorded for the worst case (server USA2 in Seattle) did not render VoIP impossible. However, it did not allow for interactive online games that are more sensitive to this parameter (online games with several simultaneous players). The values recorded for mobile broadband latency are, on average, about twice the values recorded for fixed broadband, as shown on Figure 10 and Figure 11.

[11] VoIP - voice over the Internet (voice over IP).

[12] Particularly for online games with several simultaneous players (multiplayer online gaming).

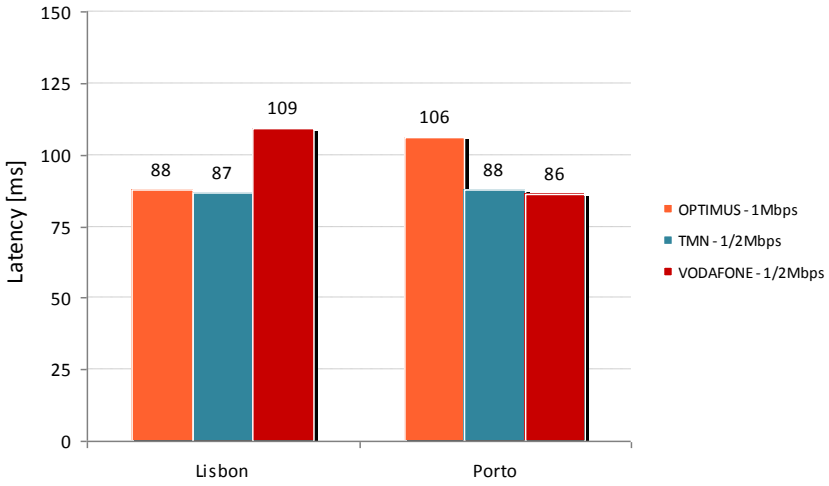


Figure 10 – Average latency per mobile access operator

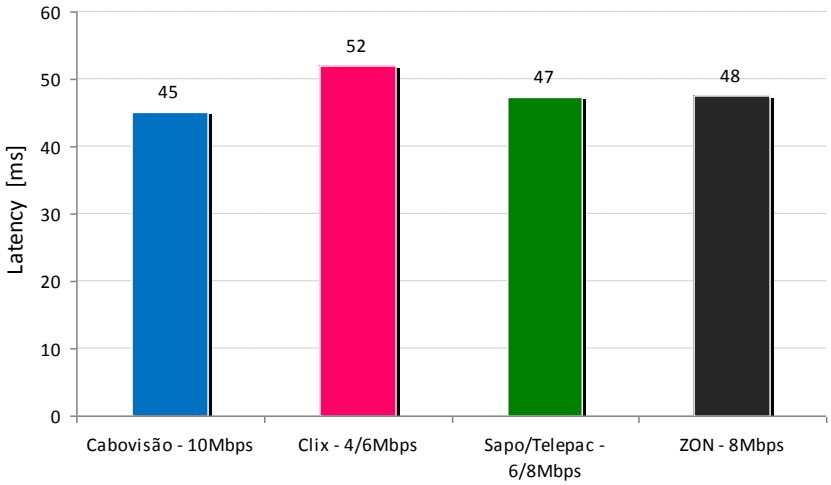


Figure 11 – Average latency per fixed access operator

Comparison of results for mobile access

Comparing the results of the performances of the mobile operators among themselves and within the scope of the tariff schemes under analysis, regarding the maximum file transfer download speeds (see Figure 4), the conclusion is that Vodafone presents the best average values in Lisbon and Porto, although these results are characterized by a wide dispersion. This behaviour, shown in Figure 12 and Figure 13, could be partially associated to the modifications occurred in the maximum speeds during the period while the study was carried out, and to considerable performance variations along the day (see Figure 30 and Figure 31). TMN presented the most regular behaviour during the day, which reflects a lower variation of the download time. Optimus, although recording

the lowest values among the three operators in this context, still presents a more stable performance. The speeds achieved by Optimus were comparatively lower, given that this operator made no automatic speed modifications during the period while the study was being conducted. However, in Lisbon, this operator shows a lower amount of records with low speeds, in comparison with Vodafone and TMN. In Porto, although with different records, it maintains, in general terms, a similar performance (Figure 12 e Figure 13).

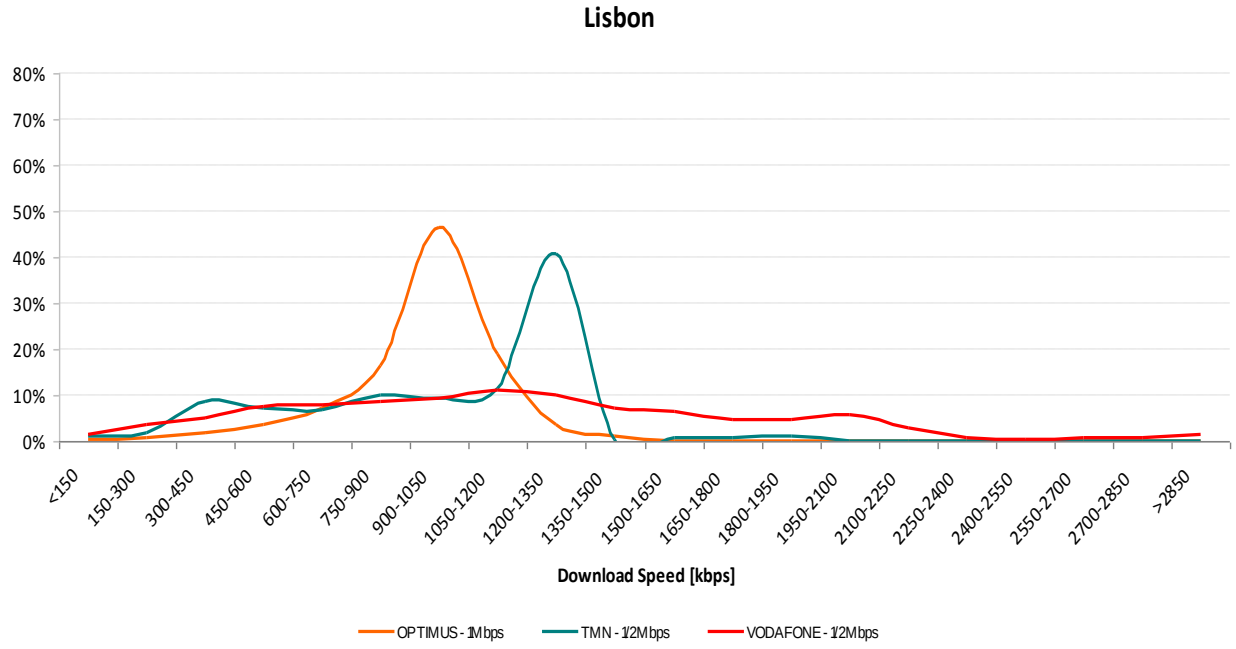


Figure 12 – Frequency distribution per mobile access operator and Download speed category for the municipality of Lisbon

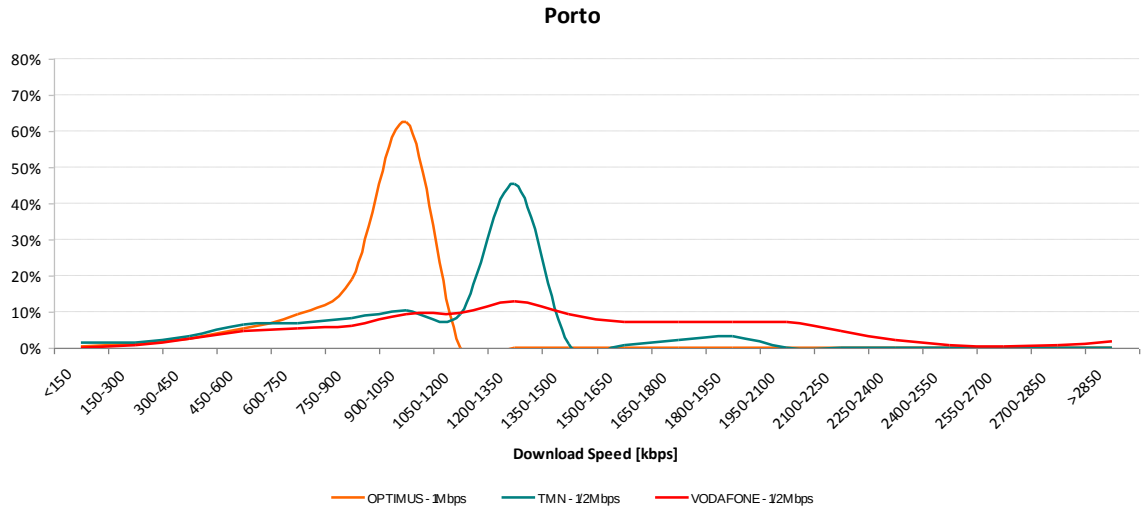


Figure 13 – Frequency distribution per mobile access operator and Download speed category for the municipality of Porto

In terms of file upload, the results of each operator in Lisbon and Porto, according to Figure 6, register considerable differences, except for Vodafone. Optimus presents much better results in Lisbon than in Porto, while TMN registers better results in Porto than in Lisbon. According to Figure 14 and Figure 15, Optimus presents a considerable rate of speeds above 1Mbps in Lisbon, similar to what occurs with TMN in Porto.

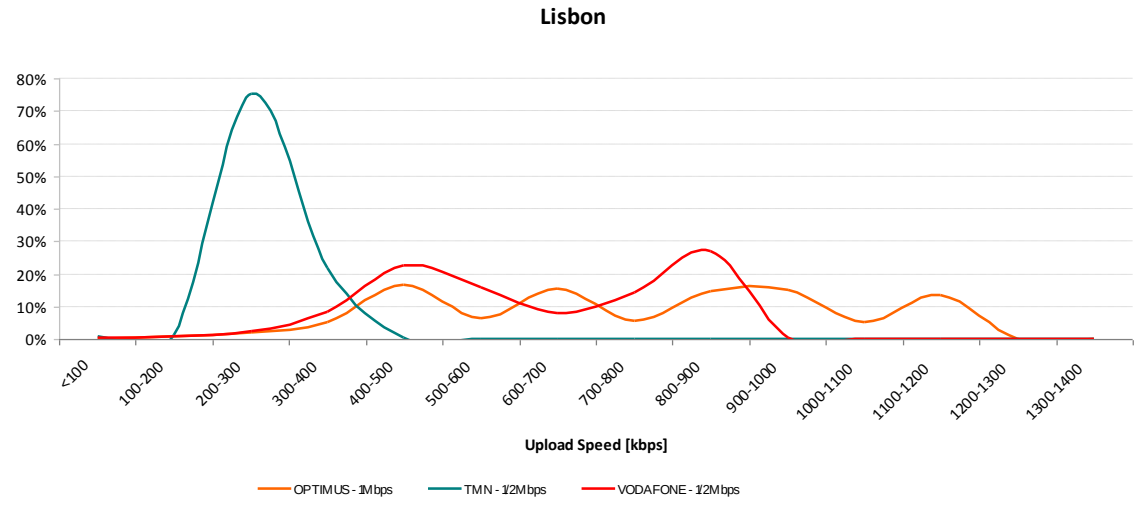


Figure 14 – Frequency distribution per operator and Upload speed category for the municipality of Lisbon

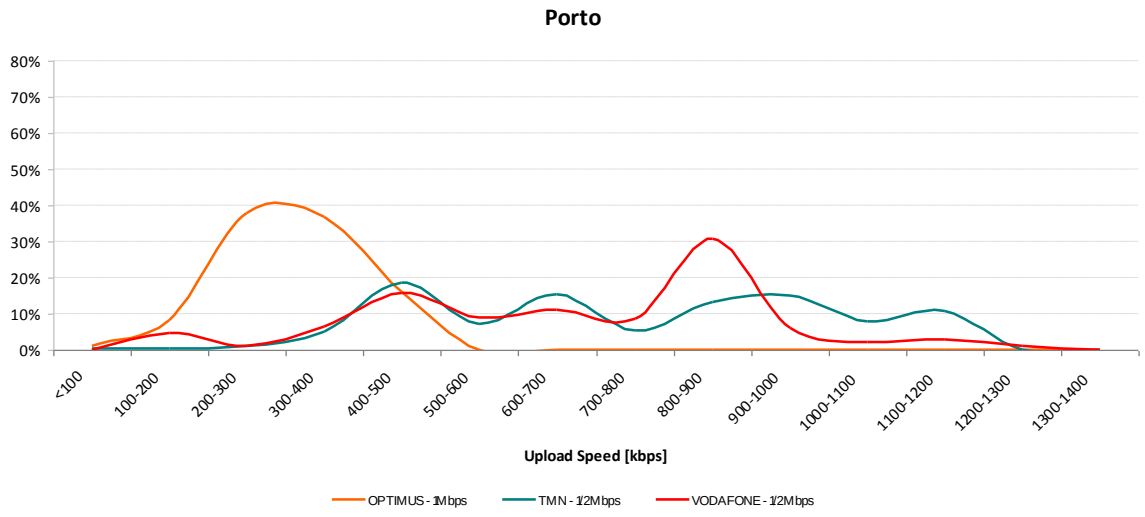


Figure 15 - Frequency distribution per operator and upload speed category for the municipality of Porto

The fact that two of the three operators under study upgraded the speed of the tariff schemes under analysis[13] while the tests were being carried out makes it harder to establish direct comparisons. Thus, in order to facilitate that task, results were standardized by creating a **Relative Speed Index** (**RSI**) for the national server (average speed recorded/maximum contracted speed[14] x 100), reckoned by measurement and according to the tariff scheme provided for each test panel user).

[13] Speed upgrades made by Vodafone, covering all 25 SIM cards, and by TMN, covering only 9 of the 25 SIM cards used in the tests.

[14] Maximum advertised speed associated to the speed designated in the contracted tariff scheme corresponding to the service level provided in the SIM card.

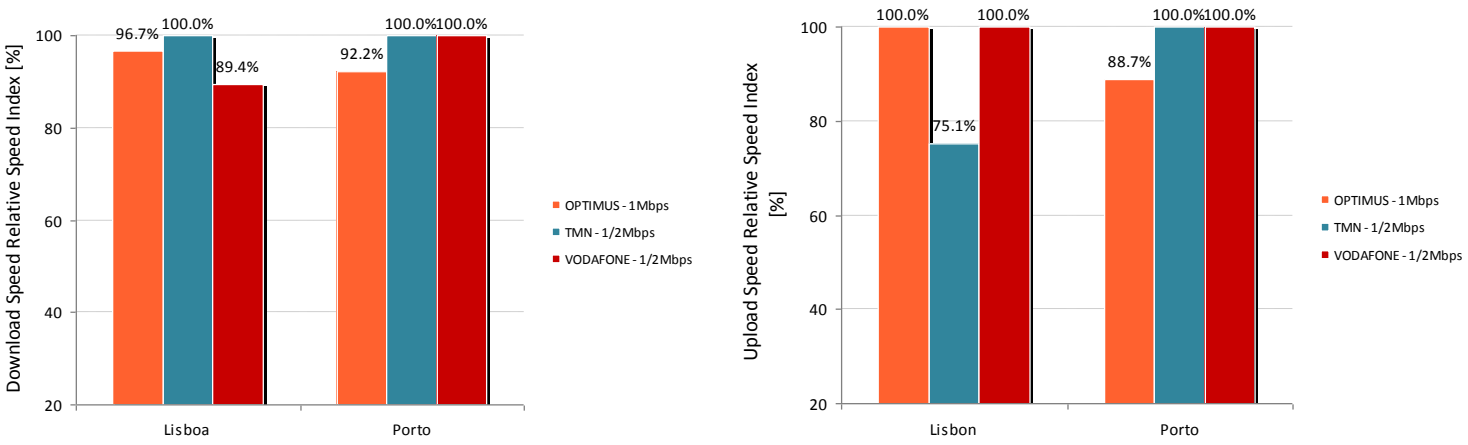


Figure 16 - Relative Speed Index for the national server for file download and upload speed

Analysing Figure 16 leads to the conclusion that mobile broadband users in Lisbon and Porto, on average, reach 89.4% to 100% of the maximum contracted bandwidth, and 75.1% to 100% of the upload speed. TMN's download performance stands out reaching 100% RSI in both cities, similar to Vodafone's upload performance.

Regarding Internet browsing, as shown on Figure 8, the user's experience during Web browsing shows no major differences between the web page download times of the three operators, for the same destination. In general, web page download times double, regarding the national server, when the destination is the United State's West coast (server USA2). The highest absolute average values recorded for all destinations ranges between 2 and 3 seconds[15], which is still considered within the comfort zone, usually below 4 seconds (8 seconds is considered the limit for abandoning the session).

[15] Tests made for the standard test page, with an approximate size of 128KB.

Comparison of results for fixed access

Regarding fixed access and the respective tariff schemes under study, taking into account the offer diversity (different maximum speeds), results were standardized in order to facilitate the comparative analysis. Therefore, the **Relative Speed Index** (**RSI** = average speed recorded/maximum contracted speed[16] x 100) was only reckoned for national accesses. According to Figure 17, the records for the Relative Speed Index are located between 55% and 77%, i.e., the actual average speed values obtained stood between 55% and 77% of the maximum speeds advertised for each tariff scheme.

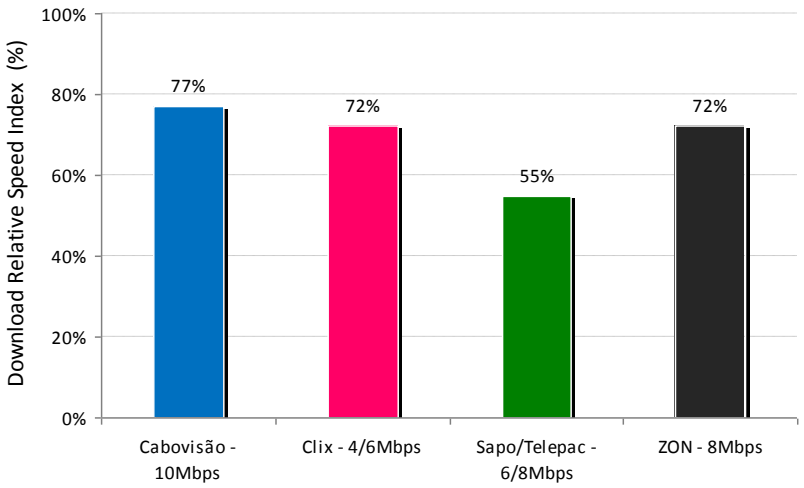


Figure 17 – Relative Speed Index of Download file transfer per fixed access operator

Also regarding fixed access but in the scope of file transfer speed in the upload mode, the values recorded for the RSI stood between 45% and 95%, respectively, for Sapo and Cabovisão. It should be mentioned that these values are higher than the download records for all operators, except Sapo (Figure 94).

Under another performance perspective regarding this indicator, Cabovisão registers 70% of all measurements above 75% of the Relative Speed Index, while Sapo only registers 10% of the measurements above this level (see Figure 18).

[16] Maximum speed advertised in the traffic scheme contracted by the test panel member.

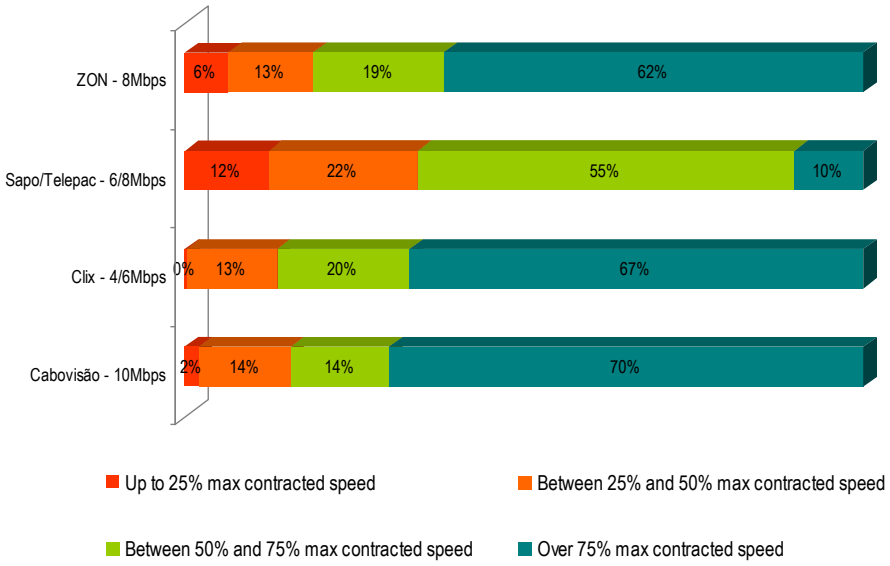


Figure 18 – Frequency distribution per category of Relative Speed Index of Download File Transfer per fixed access Operator for the National server

The user WEB Browsing experience for the fixed access is considerably different whether the pages are located on national or international servers, which translates into great differences in the waiting times for page viewing (see Figure 8 and Figure 9). Download times are considerably larger for pages hosted on servers of the United States West coast, where mobile accesses even surpass the performance obtained with fixed technology. Nonetheless, the average values for all destinations stand around 1 second below those recorded by mobile access (Figure 110 and Figure 127).

Main conclusions

- ✓ The **download speeds** achieved for international servers, for both types of access (fixed and mobile), tend to converge, with a stronger trend on Web browsing and for Seattle (the most remote destination);

- ✓ The **upload speeds** of the mobile access are, on average, higher that those provided by fixed technology, even surpassing 1Mbps for access to the national server;

- ✓ The **Web page download times** provide a good Internet browsing[17] experience, since they are considerably close among the operators of the same technology, being quite within the comfort limit for both types of access. Therefore, it is possible to conclude that the global performance of the evaluated operators is considerably positive.

- ✓ The international[18] routes are the main cause for the dispersion of results recorded for the **download speed** for fixed accesses, hindering the final average for all destinations.

- ✓ The dispersion of the values recorded for the **download speed** of mobile accesses is less influenced by the international routes, when compared to fixed accesses. However, this dispersion is particularly influenced by the radio access element, since it is a means of shared access via radio[19] that renders high variation to the transmission rates provided;

- ✓ The **latency** values registered for the mobile access in the accesses to the United States, particularly to the server in Seattle, surpassed the average of 150 milliseconds, a figure which conditions or prevents the use of some more demanding applications in terms of interactivity, such as multiplayer online games;

[17] Conclusion applicable to the standard Web page used for testing hosted on dedicated servers. The values cannot be extended to any Internet page; these are influenced by the server's loading conditions (hardware, number of simultaneous sessions, and optimization of the HTML page), among other aspects, which are not of the ISP's responsibility.

[18] Considering the high strangulation of bandwidth for the international accesses when compared to the speed achieved for download of the national server.

[19] Transmission means conditioned by the signal's propagation conditions (clutter) and by the system's usage load.

- ✓ On fixed accesses, the average **latency** values for the server in Seattle stand around 100 milliseconds, thus reaching, when compared to mobile accesses, a user experience on multiplayer online games that is considerably more interactive between players in Portugal and in the United States;

- ✓ Mobile access users in Lisbon and Porto experience on average **89.4% to 100% of the maximum speed contracted for download**;

- ✓ Fixed access users experience, on average, from **55% to 77% of the maximum speed contracted for download**, with highlight to Cabovisão's very positive performance. This operator concentrated 70% percent of the measurements made above 75% of the maximum contracted speed. On the otter hand, Sapo was the operator with the lowest performance, concentrating 10% of the measurements above that level.

3. Results

3.1 3G Mobile Accesses – Service Availability and Reliability

3.1.1 Success in the Access to the Service

Internet usage in mobile networks implies the previous establishment of a connection to the operator's network for the allocation of the network resources and for authentication purposes, i.e., the establishment of a PDP[20] Context. This is followed by the establishment of the service at issue (for example, FTP, http), herein mentioned as the establishment of an IP connection.

Success in the establishment of this connection gives the user the perception of service availability, while the typical values for this indicator stand above 99%. Establishment failures may be due to several reasons, namely those associated to the network's capacity and/or to a temporary malfunction.

Analysing this indicator on Figure 19, according to the records obtained, leads to the conclusion that all operators ensure a high level of service availability, registering values within the expected limits. Optimus presents slightly higher values than TMN and Vodafone in both municipalities. There are minor differences between TMN and Vodafone, which differ up to 0.2 per cent, at the most.

[20] PDP - Packet Data Protocol

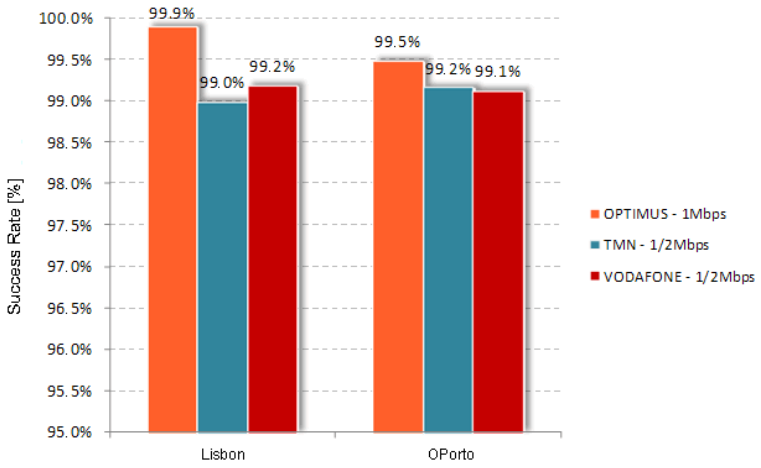


Figure 19 – Service Access Success Rate per operator and municipality

Service availability values vary slightly during the day and along the week, due to occasional problems, from the operators, in some of the areas being subject to measurements. As shown by the analysis of Figure 20, in the case of Vodafone and for both municipalities, there is a higher degradation in the successful access to the service during the 22h-00h period. Variations along the day are smaller for Optimus and TMN.

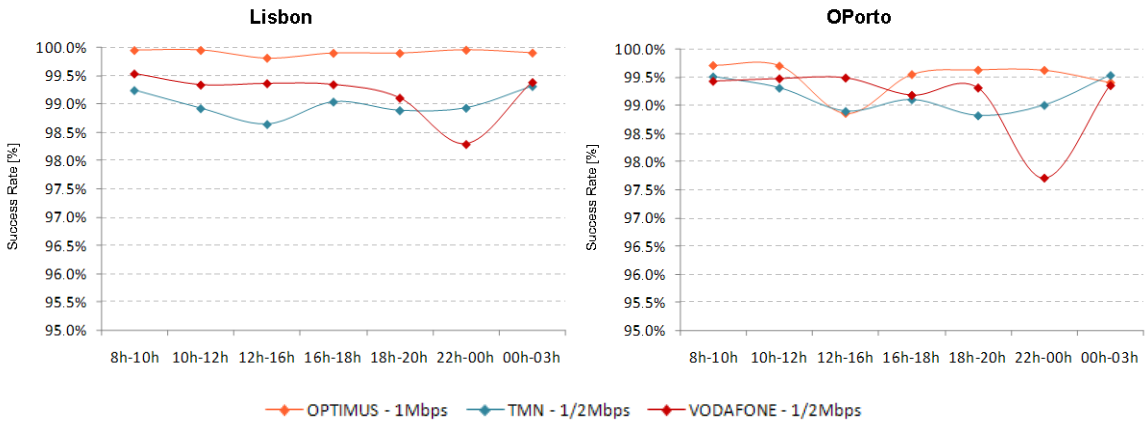


Figure 20 – Service Access Success Rate per operator, time period and municipality

Some more accentuated variations were also recorded along the week for TMN and Vodafone (Sunday), as shown on Figure 21.

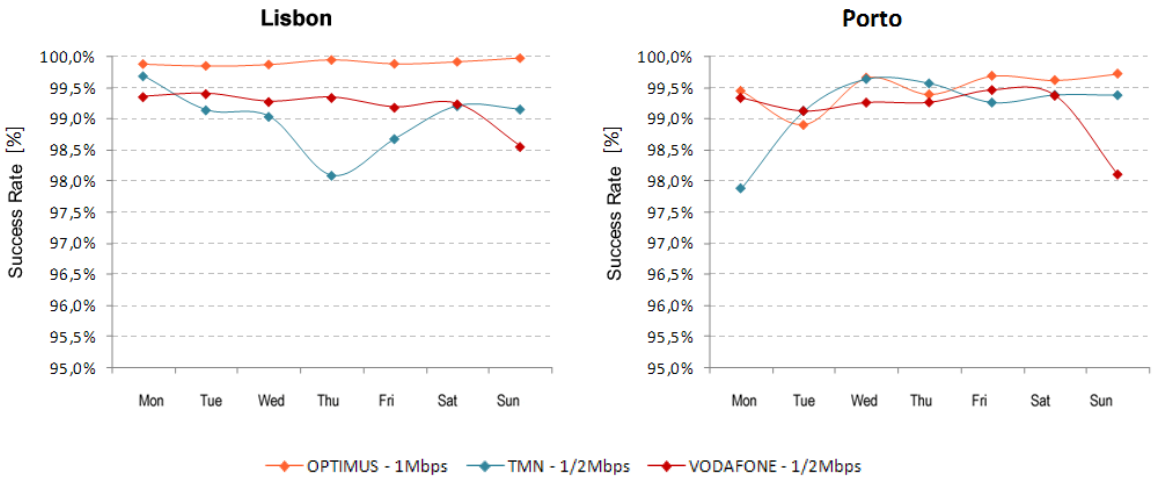


Figure 21 – Service Access Success Rate per operator, day of the week and municipality

3.1.2 Causes for Service access failure

The causes for service access failure, due to a fault in the establishment of the DPD Context or the IP connection, are represented on Figure 22. It may be concluded that the majority of TMN's failure cases in Lisbon, which register the highest value, is mainly due to faults in the establishment of the DPD Context, while the IP failure rate is only 0.1% on average.

However, it should be noted that even in the situation with the highest failure rate (TMN), the average value only registers 1%, showing a high level of service accessibility for all operators.

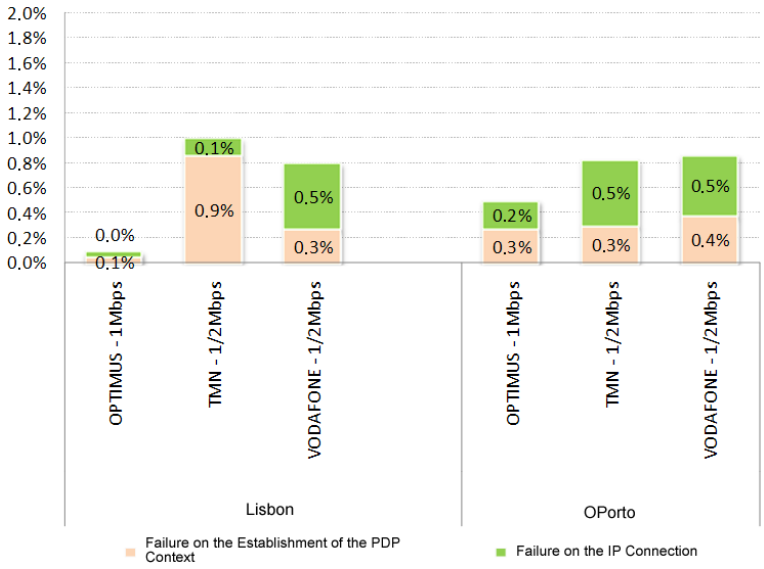


Figure 22 – Failure rate per cause, operator and municipality

3.1.3 Connection Activation/Establishment Time

The time needed to establish a connection is perceived by the end user as a delay on the start of any Internet transaction. This varies per operator and depends on several factors, namely the network's architecture and its usage rate.

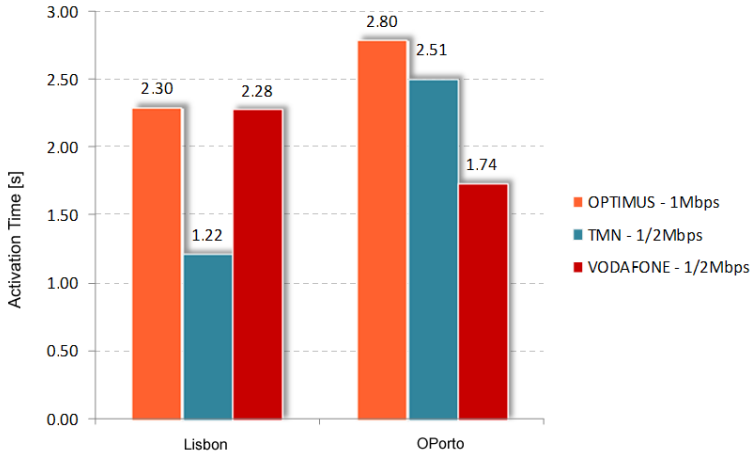


Figure 23 – Connection Activation/Establishment Time

In this context and analysing Figure 23, it may be concluded that, in Lisbon, TMN records the lowest values, and therefore, the best values among the three national mobile operators. These values represent about half of the figures presented by Optimus and Vodafone in this municipality. However in Porto, Vodafone registered the best access time, followed by TMN and Optimus. Optimus presents the highest average value among the three operators for the municipalities of Lisbon and Porto.

Explaining Figure 23 a little further, it means that TMN users in Lisbon wait, on average, 1.22 seconds to start an Internet transaction, while Optimus users in Porto wait, on average, 2.80 seconds to start an identical connection.

According to Figure 24, the connection establishment time presents no major variation during the day, in spite of a time increase for Vodafone in the 22h-00h schedule, in both municipalities. We remind that this is also the period when Vodafone registers a slight decrease in the service establishment success rate, as represented on Figure 20.
The analysis of Figure 25 shows that there is no significant variation during the week in the connection establishment times.

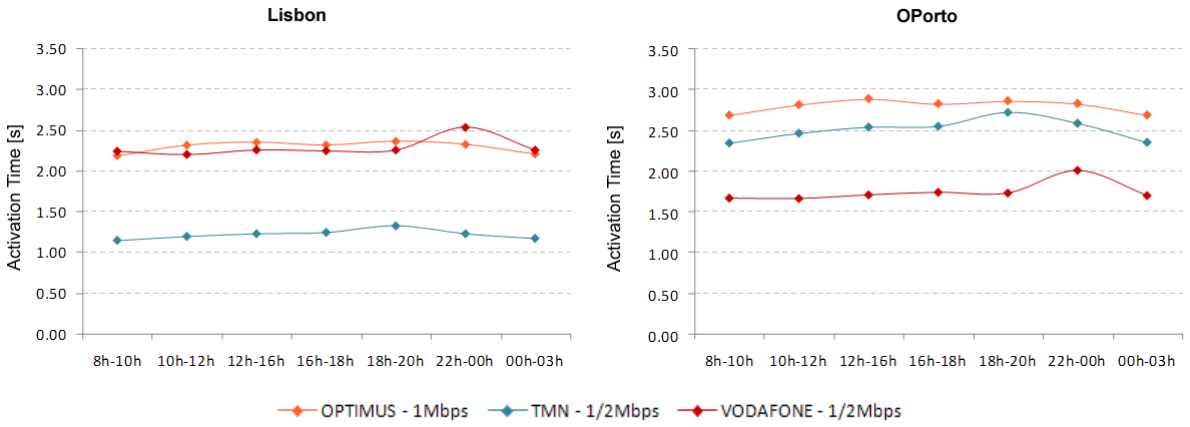


Figure 24 – Average Time for Connection activation/establishment, per operator, time period and municipality

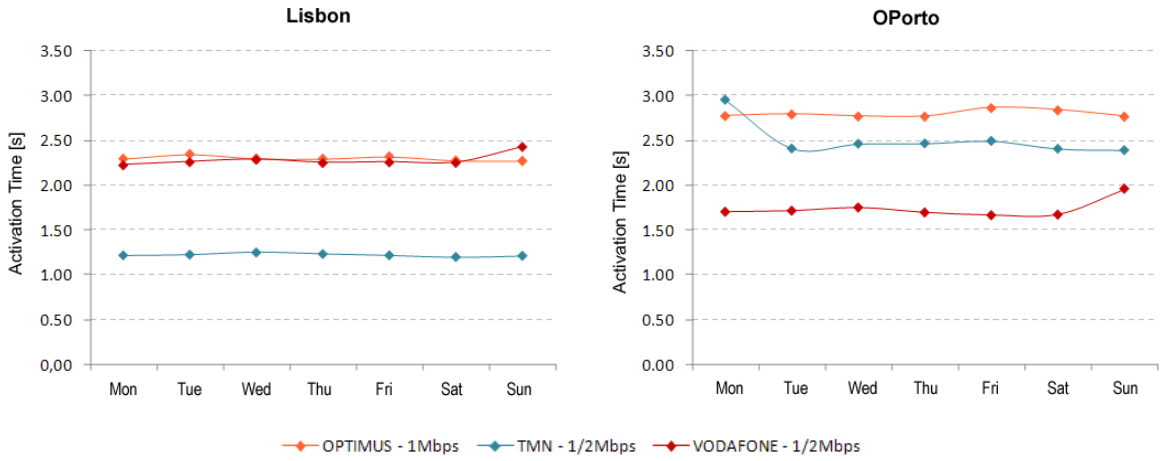


Figure 25 – Average time for Connection activation/establishment per operator, weekday and municipality

3.2 User's Perception of File Transfer (Download)

3.2.1 3G Mobile Accesses

3.2.1.1 File Transfer Speed (Download)

The evolution of HSDPA technology announces the soon release in Portugal's mobile broadband market of download speed offerings above 20Mbps. Download speeds still aren't considered the main differentiator of the service provided by mobile operators. However, the majority of customers are still included in tariff schemes with speeds considerably under 20Mbps. The study focused on this framework, having considered the tariff schemes that were most representative of the usage of mobile Internet access, under the perspective of covering the greatest rate of customers in each operator.

The file transfer download times presented in the following section register with a good approximation the time perceived by the user to conclude the file transfer at issue, and is generally an indicator that is closer to the user's experience. The highest the file transfer speed, the less time will they take to transfer.

Figure 26 shows that the file transfer average speeds are higher for Vodafone, in the two municipalities under study, with a larger difference in the municipality of Porto, recording 1399kbps. These values mainly result from the modifications to the tariff schemes made by operators during the study, except for Optimus, which made no change during the period while the tests were being carried out[21] (since it was not an automatic migration process), maintaining the same speed of 1024kbps, a figure close to the average actually recorded, particularly in Lisbon. The tariff modification made by TMN covered only 9 of the 25 SIM cards, having been implemented by stages and close to the end of the study. During the measurement period, Vodafone made two modifications to the maximum values advertised for the tariff scheme under analysis, with a considerable impact on final results.

This market dynamics had positive reflexes for the end user, namely through the provision of higher speeds for the same commercial offer, a behaviour which is reflected on the study's results.

Also according to Figure 26, TMN and Optimus show similar performances in Lisbon and Porto, and below Vodafone's. Except for Optimus, it is also possible to conclude that actual download transfer speed is much higher in Lisbon than in Porto.

[21] The Optimus' SIM Cards associated to the 1Mbps tariff scheme used in the study were not subject to automatic modification of the service's characteristics.

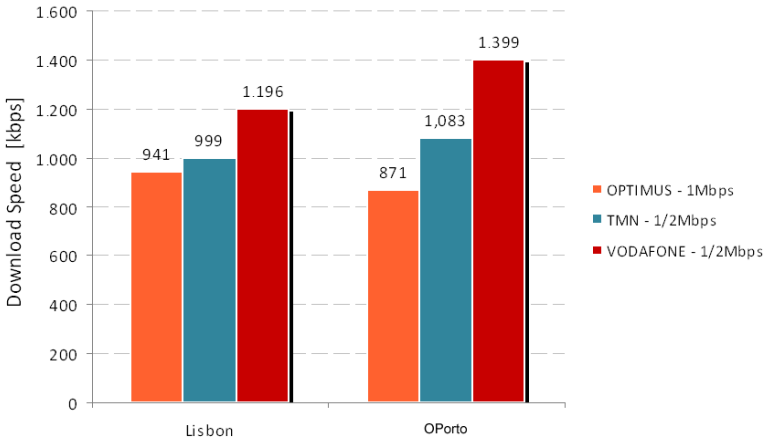


Figure 26 – Average file transfer Download speed per operator and municipality

The analysis of Figure 27 and Figure 28 shows that about 46% of Optimus' measurements in Lisbon are concentrated between 900kbps and 1050kbps. However there's a larger concentration in Porto, with 62% of measurements within this interval, being the operator with the lowest measurement dispersion and, consequently, with a more stable service. For the end user, this means that during the period of the measurements and for the municipalities at issue, there was a high probability to achieve file transfer download speeds between 900kbps and 1050kbps, for the tariff scheme under study.

In Lisbon and Porto, TMN presents a concentration above 40% of measurements in the interval close to 1200-1350kbps, also recording in Lisbon some concentration of values in the 300-400kbps interval. This fact could be associated to the existence of some test locations where this Operator has a lower performance.

Vodafone, in spite of recording average speed values above Optimus and TMN in the municipalities of Lisbon and Porto, does not present a relevant concentration of measurements in any interval, i.e., for the end under user, this translates into a high variation of file transfer download speeds, which can be higher or lower than the speed provided by Optimus and TMN.

It should be mentioned that the stability of speed performance progresses with the concentration level of the measurements obtained, while the user can expect the actual performance to stand close to the speeds with higher concentration levels. Thus, it may be concluded that it may be harder for the user to determine an expected speed for this Vodafone's tariff scheme, in Lisbon and Porto.

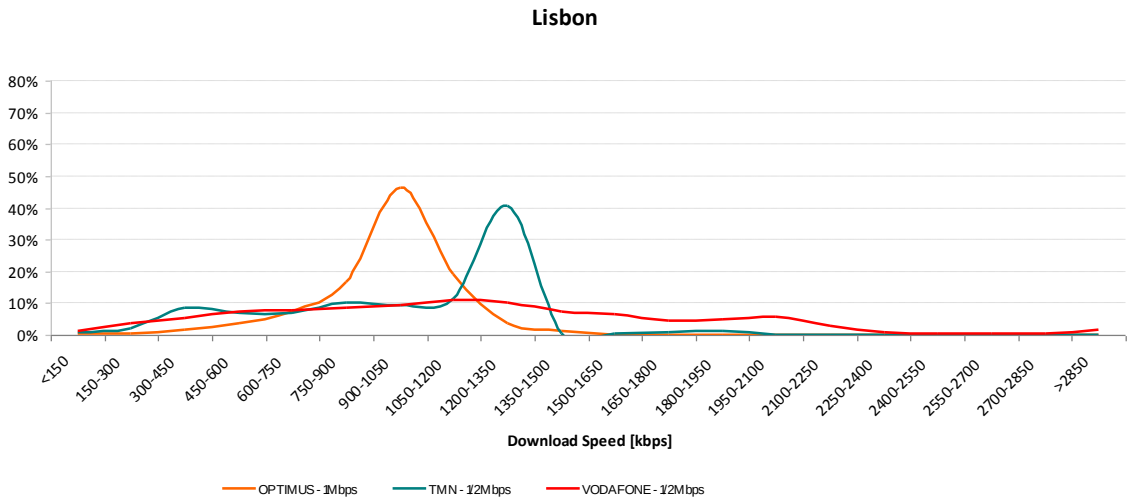


Figure 27 – Frequency distribution per operator and *Download* speed category for the municipality of Lisbon

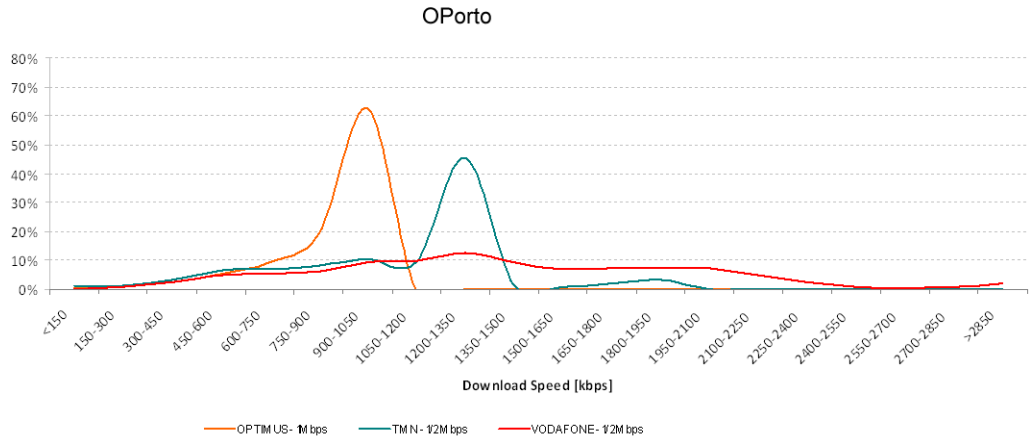


Figure 28 – Frequency distribution per operator and Download speed category for the municipality of Porto

Distributions presented on Figure 29 and Figure 30, represent the concentration of each operator's measurements in the intervals of file transfer download speeds along the day. In the situations where these distributions do not vary along the day, it is expectable for the speeds perceived by the user to be stable during that period. Any variation in these distributions will have impacts on the speed perceived by the user during that period. Distributions presented on Figure 29 and Figure 30 are reflected in the average speed values on Figure 31.

Therefore, on Figure 29 and Figure 30, although no major variation is shown on the distributions of the speed values perceived during the day, the average records are clearly affected, as can be seen on Figure 31, with a higher expression for Vodafone in Lisbon, with variations between 1461kbps in the 8h-10h period, and about 1000kbps in the 22h-00h period. This fact was probably due to a greater network usage during these periods and to the consequent decrease of its capacity. Overall, these variations are smaller for Optimus and TMN.

Variations are not so accentuated during the week, as shown on Figure 32, although there is a slight speed increase for Vodafone, on Saturday, which can be due to a lower service usage.

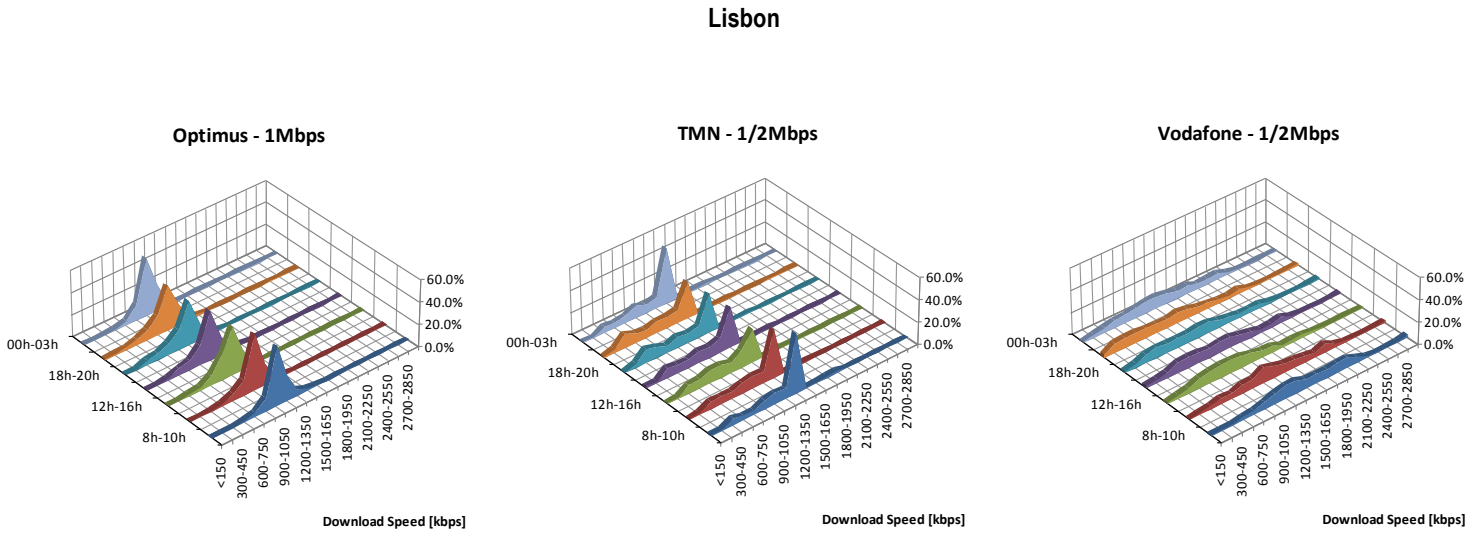


Figure 29 – Frequency distribution per operator, time period and Download speed category for the municipality of Lisbon

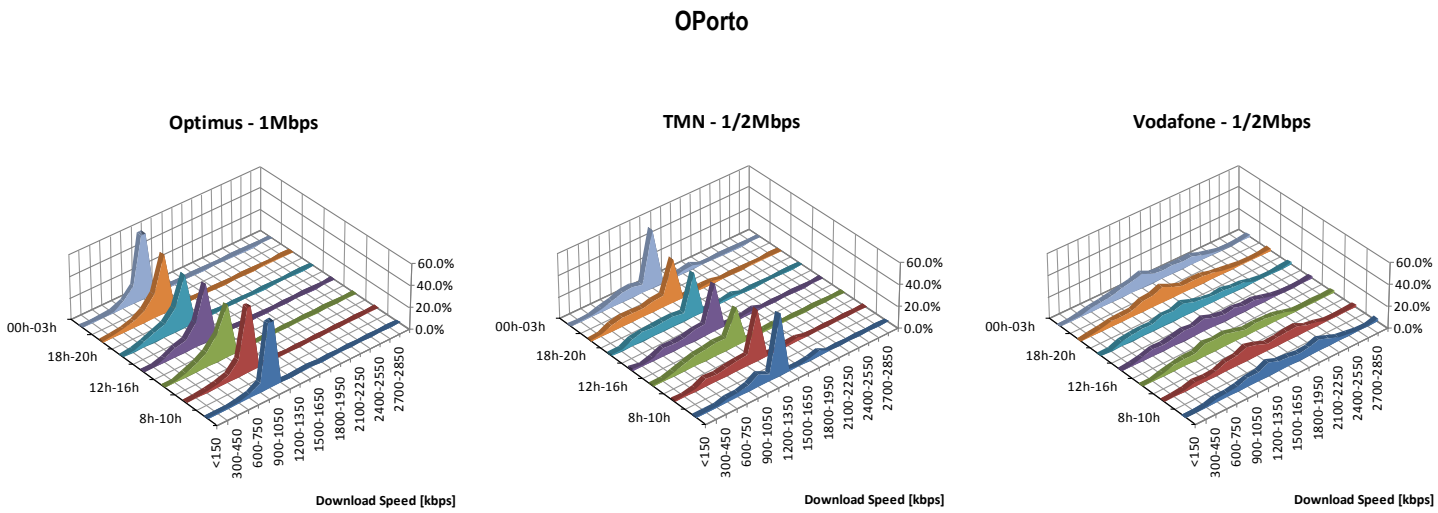


Figure 30 - Frequency distribution per operator, time period and Download speed category for the municipality of Porto

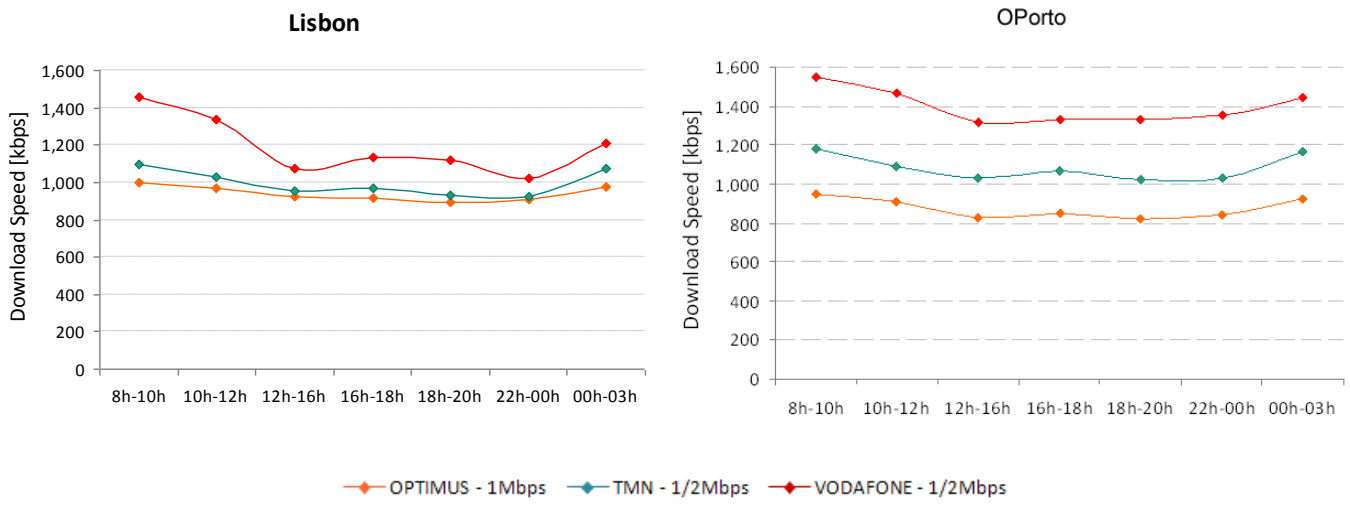


Figure 31 – Average file transfer Download speed per operator, time period and municipality

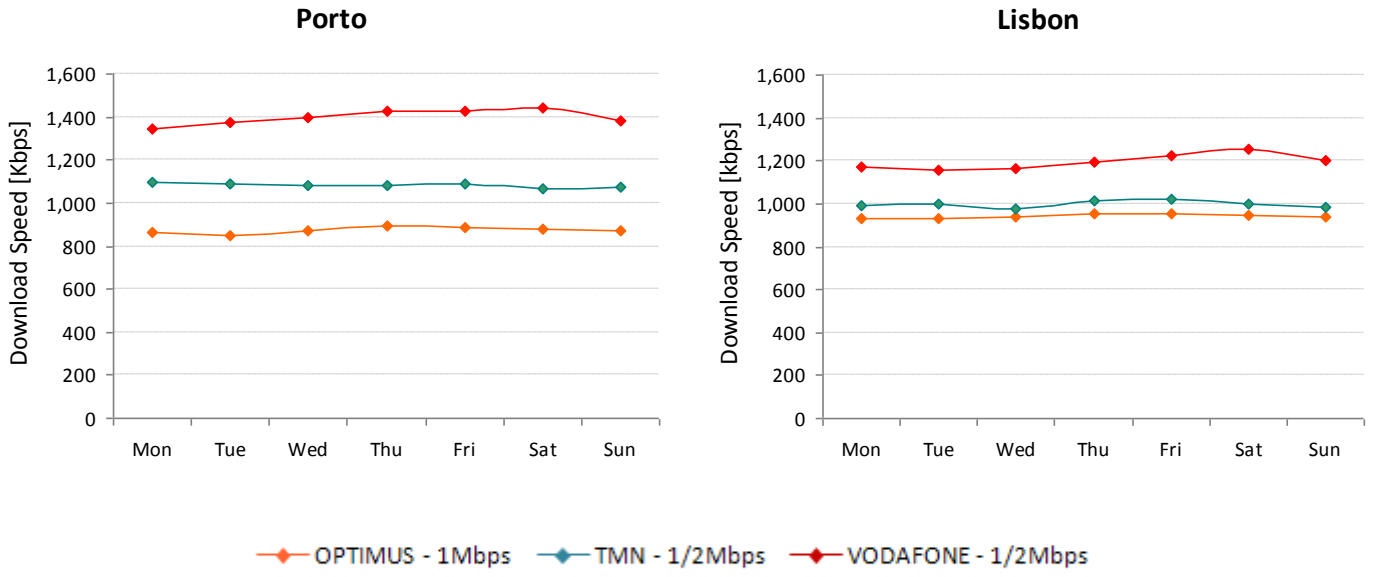


Figure 32 – Average file transfer Download speed per operator, weekday and municipality

Also for this indicator and according to Figure 33, the speed actually measured is usually higher for the National and United Kingdom servers. In both municipalities, TMN's speeds for connections to the USA2 server are lower than for the remaining servers.

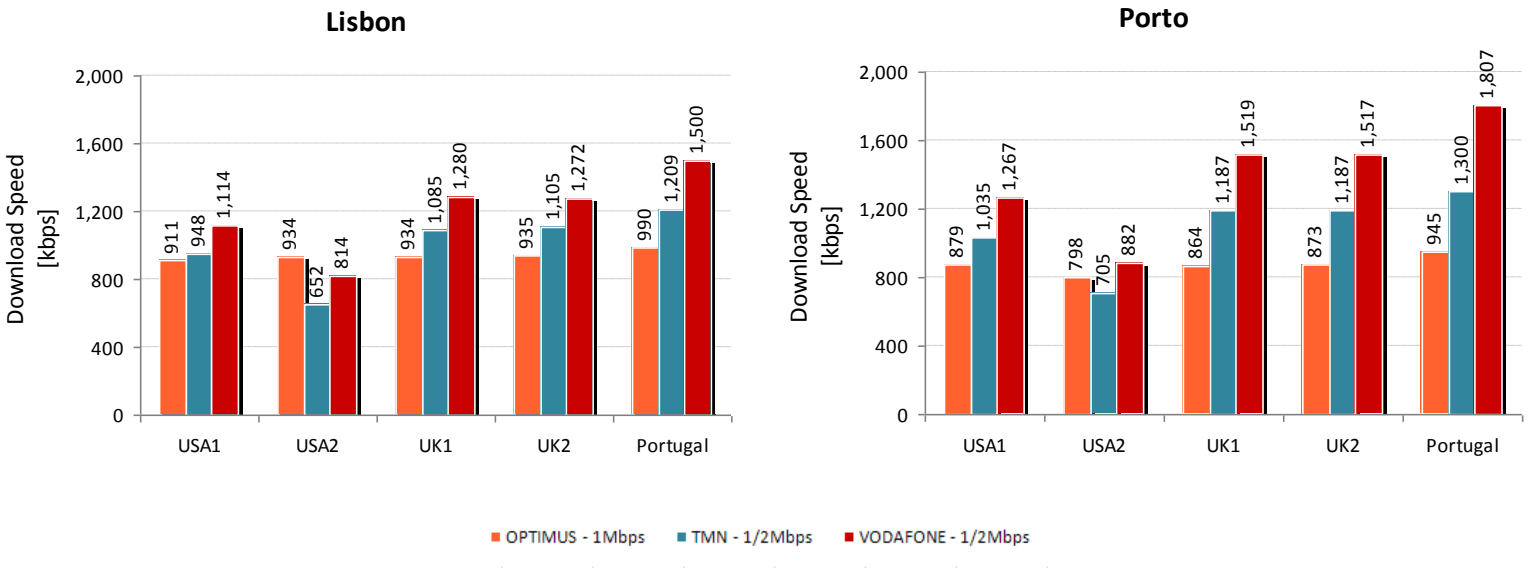


Figure 33 – Average file transfer Download speed per operator, server and municipality

Due to the different speeds obtained for the different destinations presented on Figure 33, an analysis similar to the one conducted for Figure 27 and Figure 28 was carried out, only for the National server, trying to isolate the effect of the factors related to the higher use of international routes. Thus, the national server (see Figure 34 and Figure 35) maintains the trend registered for the set of servers overall, Optimus and TMN showing a higher concentration of records on the same intervals. Vodafone presents considerably variable records. This approach makes it possible to conclude that the measurement dispersion is determined by the performance of the national server and less influenced by the access to international servers. This behaviour can be due to the variety of the speeds provided by the radio network.

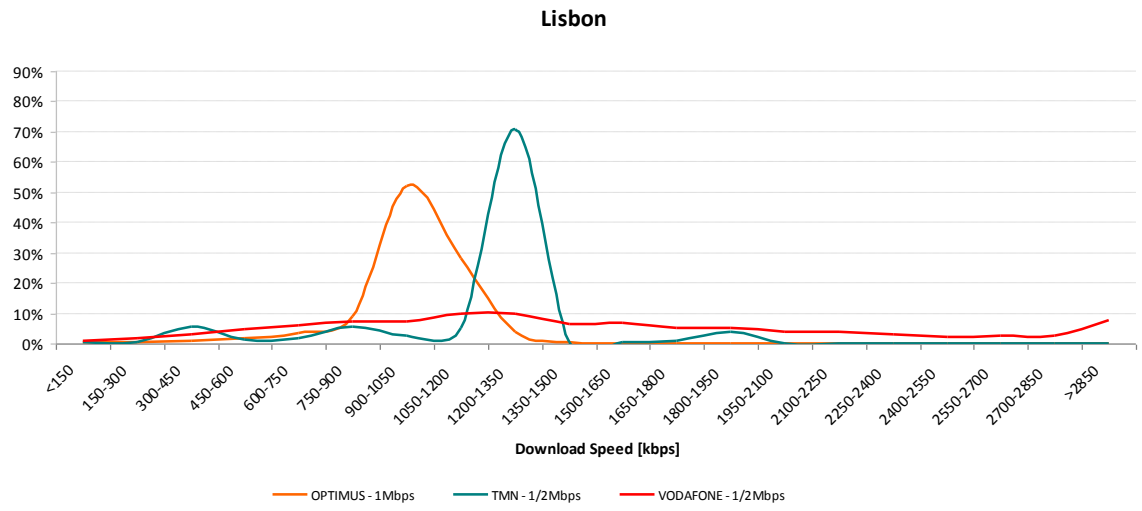


Figure 34 – Frequency distribution per operator and Download speed category for the municipality of Lisbon for the National server

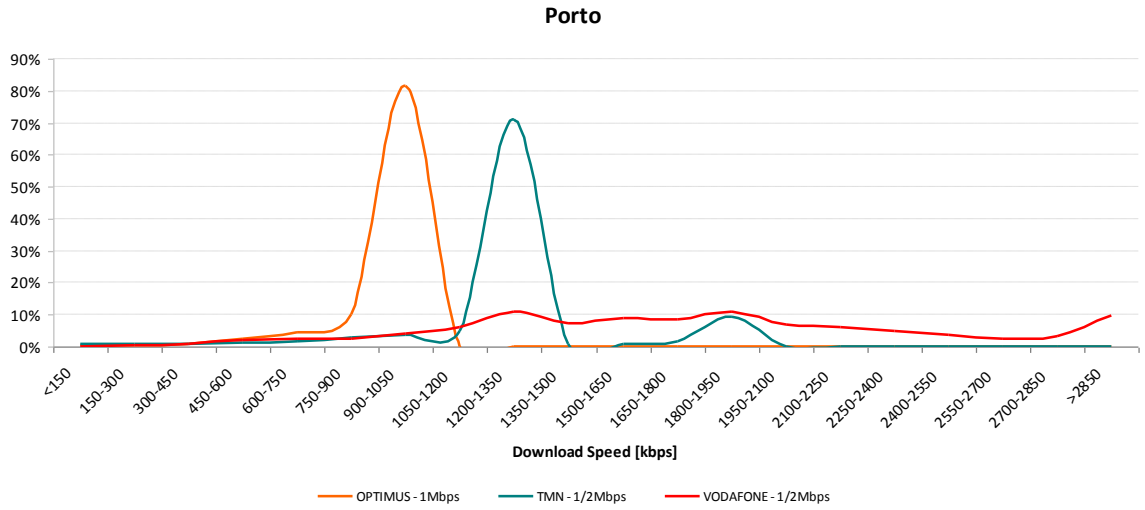


Figure 35 – Frequency distribution per operator and Download speed category for the municipality of Porto for the National server

The fact that there were speed upgrades in the tariff schemes under analysis for two of the three operators under study[22], while the tests were ongoing, makes it harder to conduct a comparative analysis. In order to facilitate this task, results were standardized by creating a **Relative Speed Index** (**RSI**) for the national server (average speed recorded/maximum contracted speed[23] x 100, reckoned by measurement and according to the tariff scheme provided to each test panel member). The results are presented on Figure 36.

[22] Speed upgrades made by Vodafone, covering all 25 SIM cards, and by TMN, including 9 of the 25 SIM cards used for the tests.

[23] Maximum advertised speed related to the speed designated in the contracted tariff scheme corresponding to the service levels provided in the SIM card.

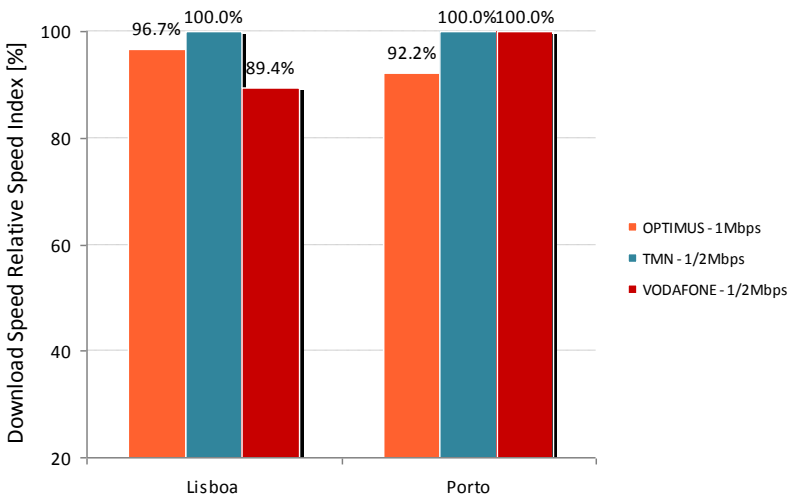


Figure 36 - Relative Speed Index of FTP file transfer Download - Mobile Accesses

The analysis of the previous Figure makes it possible to conclude that, on average, mobile Internet access service users in Lisbon and in Porto obtain from 89.4% to 100% of the maximum contracted speed during file downloads. In Lisbon, TMN presents a 100% RSI followed by Optimus and Vodafone, with 96.7% and 84.9% respectively. In Porto, Vodafone and TMN present 100%, followed by Optimus with 92.2%. It should also be mentioned that mobile operator TMN achieved a 100% RSI in both cities.

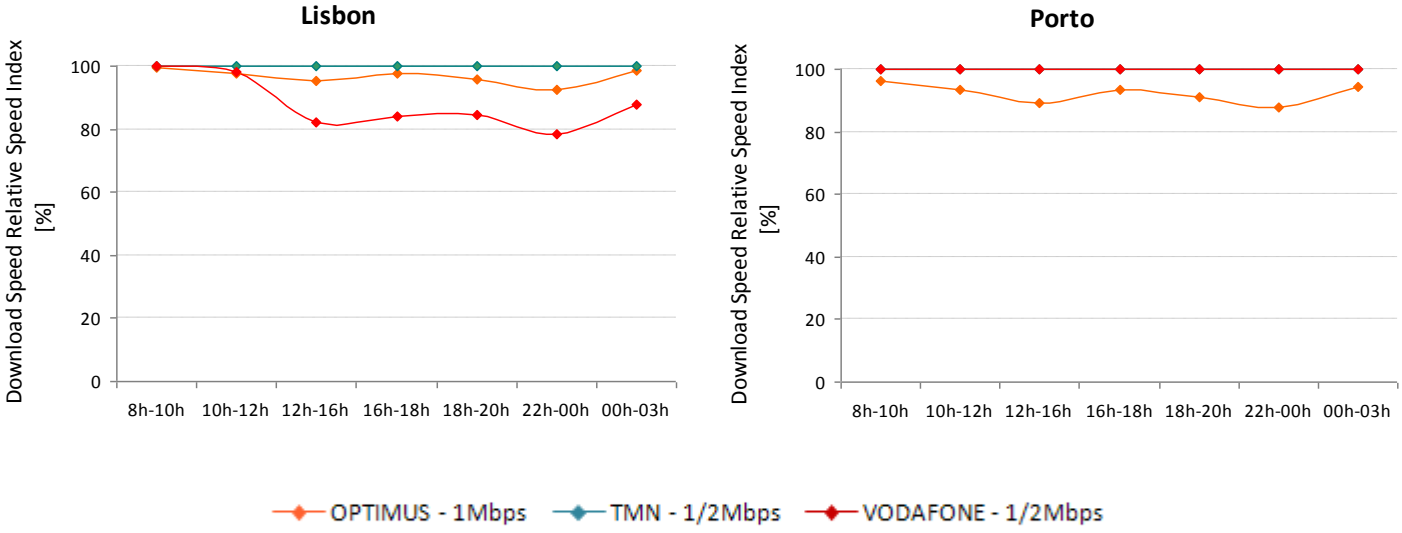


Figure 37- RSI variation of FTP download along the day for mobile accesses

The analysis of the results obtained along the day (see Figure 37) shows a sharp decrease (around 20%) for Vodafone in Lisbon, during the 12-16h and 22-00h periods, regarding the early day. This decrease is reflected on the global average presented on Figure 36. The same reading can be made for Optimus in Lisbon, although with a much lower degradation than Vodafone (around 5%). TMN presents a 100% RSI during the whole day. In Porto, TMN and Vodafone always present 100% during the day, with only a slight degradation of this indicator for Optimus in the 12-16h and 22-00h intervals (around 10%).

The analysis of Figure 38, shows that there is no major RSI variation for FTP download along the week in both cities and for all operators, with highlight to TMN's high stability in Lisbon and Porto, and Vodafone in Porto (with records of 100%).

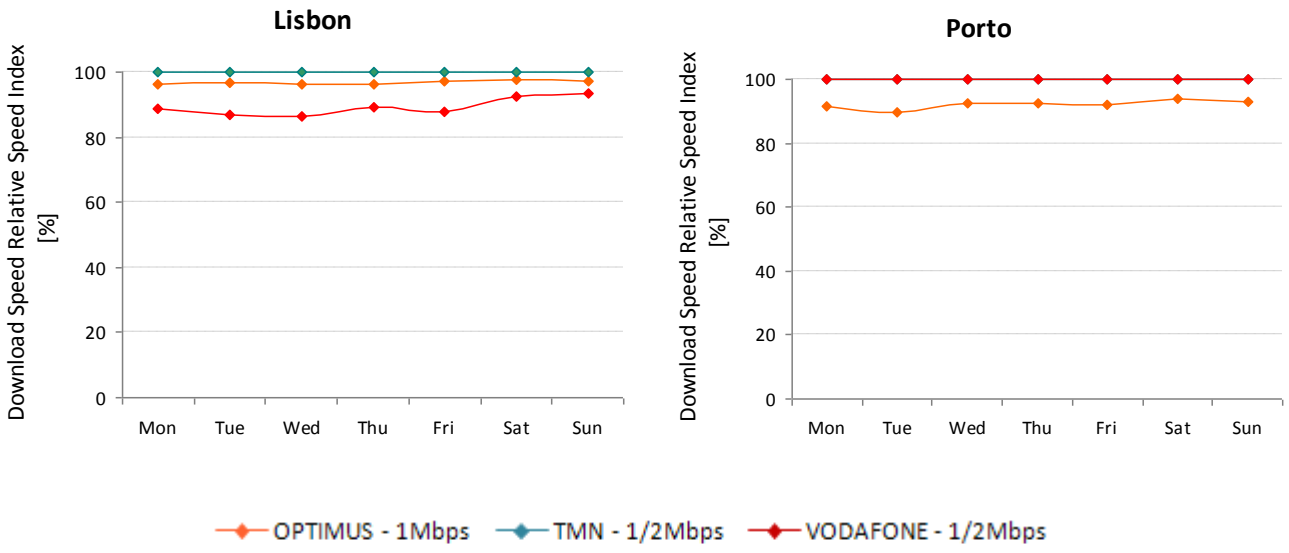


Figure 38 – RSI variation for FTP download along the week for mobile accesses

Figure 39 presents the frequency distribution per RSI category. Its analysis highlights Optimus' performance, which presents in both cities over 90% of the recorded values above 75% of the RSI. On the other hand, Vodafone presents the lowest number of measurements among all operators in Lisbon and Porto above 75% RSI, registering 58% and 76% of total measurements above this level in each city, respectively.

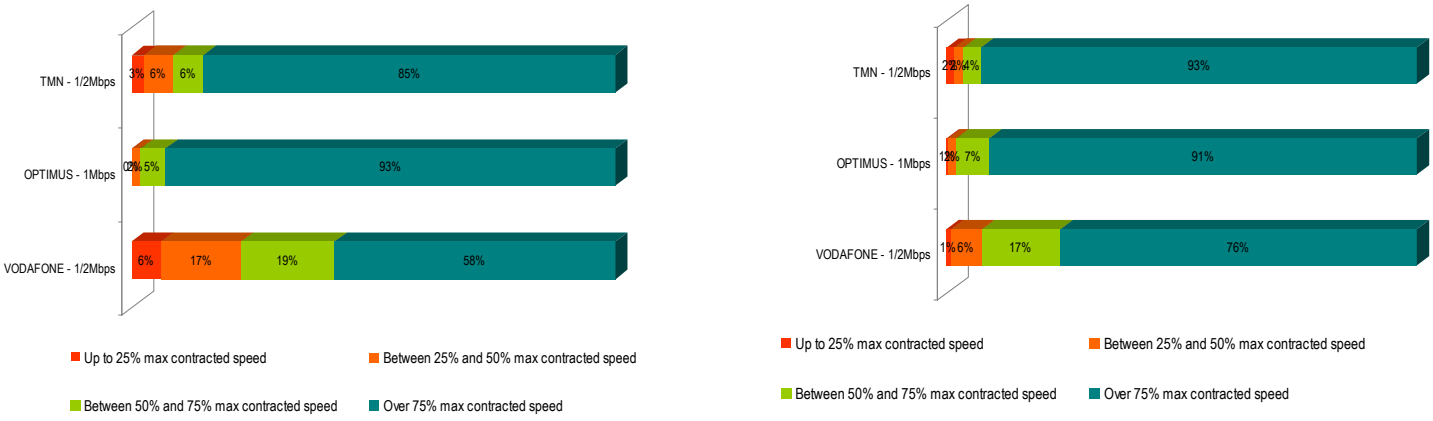


Figure 39 – Frequency distribution per RSI category for file transfer Download for the national server.

3.2.1.2 File Download Time

This indicator reflects the user's experience of file transfer download, i.e., the waiting time until the transfer is concluded.

According to Figure 40, the average download times present no major differences among operators, overall, except in Porto, where Vodafone's times are considerably lower.

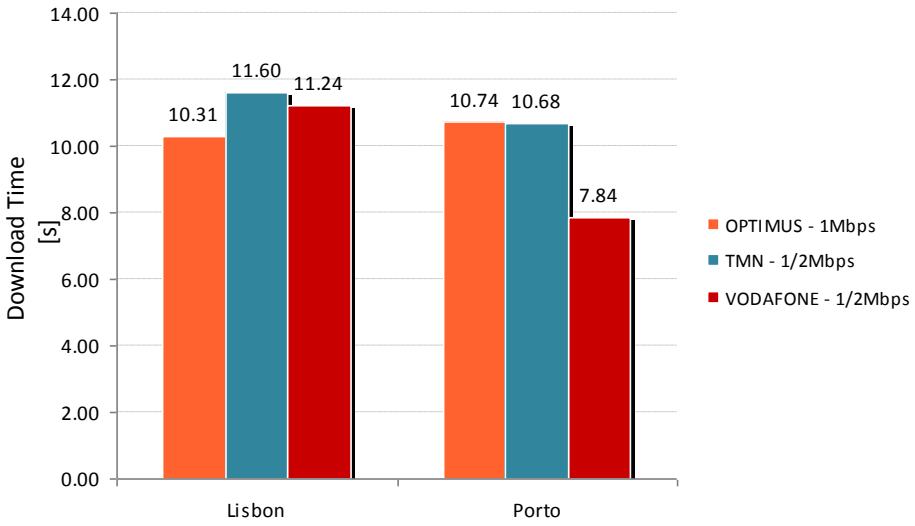


Figure 40 – Average file Download Time per operator and municipality

The considerable dispersion of download speeds presented on Figure 27 and Figure 28 have a correspondence in the transfer times, as shown on Figure 41 and Figure 42.

As observed, about 40% of Optimus' measurements in Lisbon record average times between 8 and 9 seconds, and overall only 22% exceeded 10 seconds. In the same municipality and for TMN, 40% of the measurements stand between 6-7 seconds. In Porto, these trends are even more accentuated. Regarding Vodafone, no category stands out, since download speeds display a more irregular behaviour.

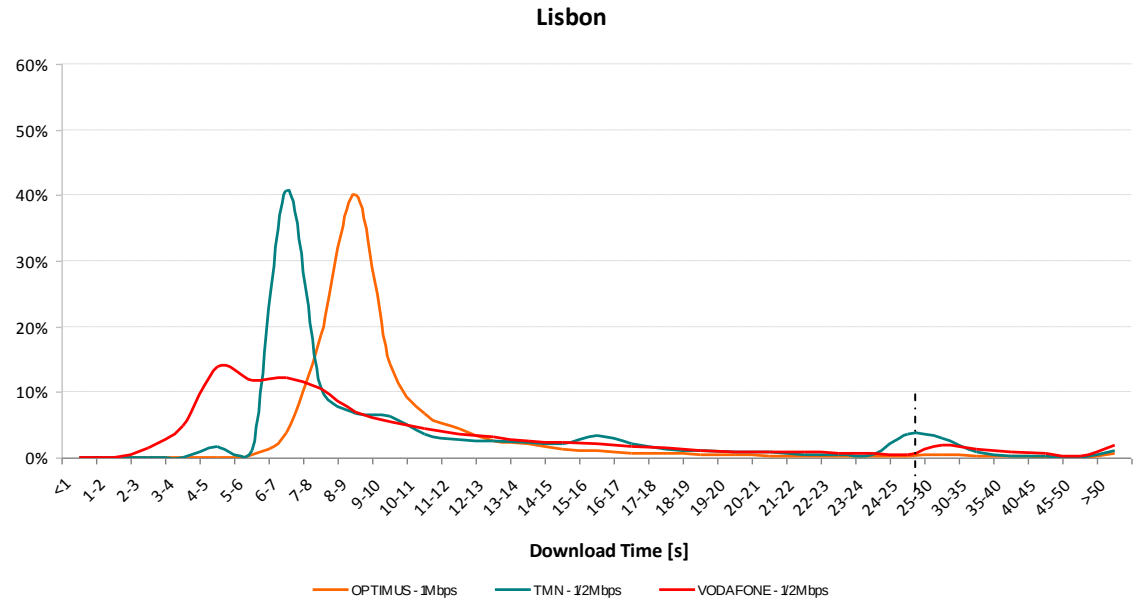


Figure 41 – Frequency distribution per operator and Download Time category for the municipality of Lisbon

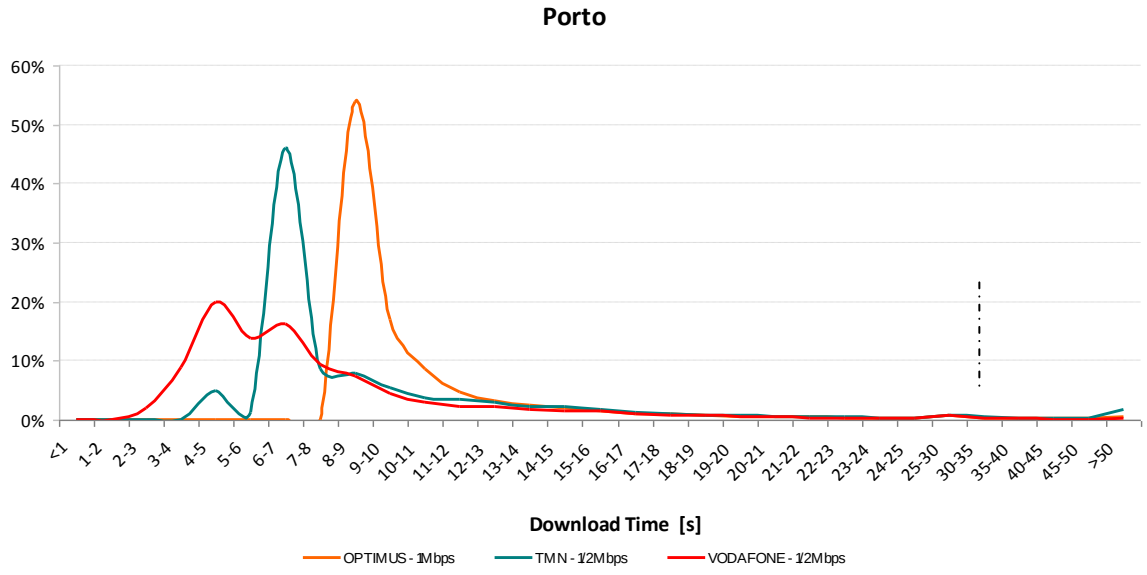


Figure 42 – Frequency distribution per operator and Download Time category for the municipality of Porto

According to Figure 45, which reflects the average values associated to Figure 43 and Figure 44, download times vary considerably during the day, with records ranging from 7.4 to 15.2 seconds

along the day for the same file, i.e., more than twice the time for a transfer in the 22h-00h period than in regards to the 08h-10h period. In Porto, TMN presents the records with the highest variation, ranging from 8.8 to 12.3 seconds along the day.

Variations are less significant along the week, as shown on Figure 46.

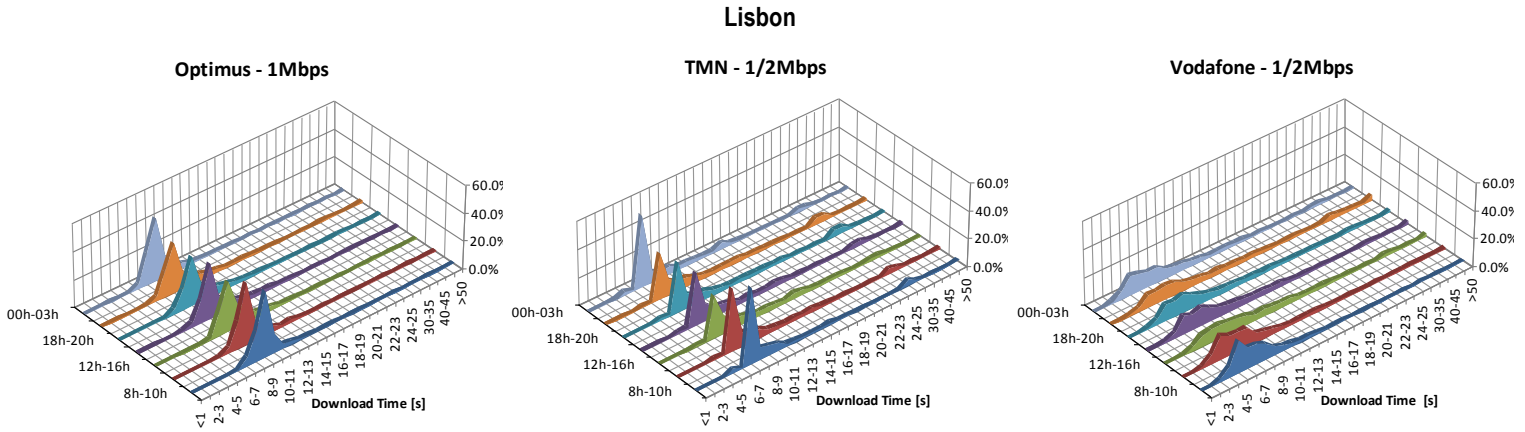


Figure 43 – Frequency distribution per operator, time period and Download Time category for the municipality of Lisbon

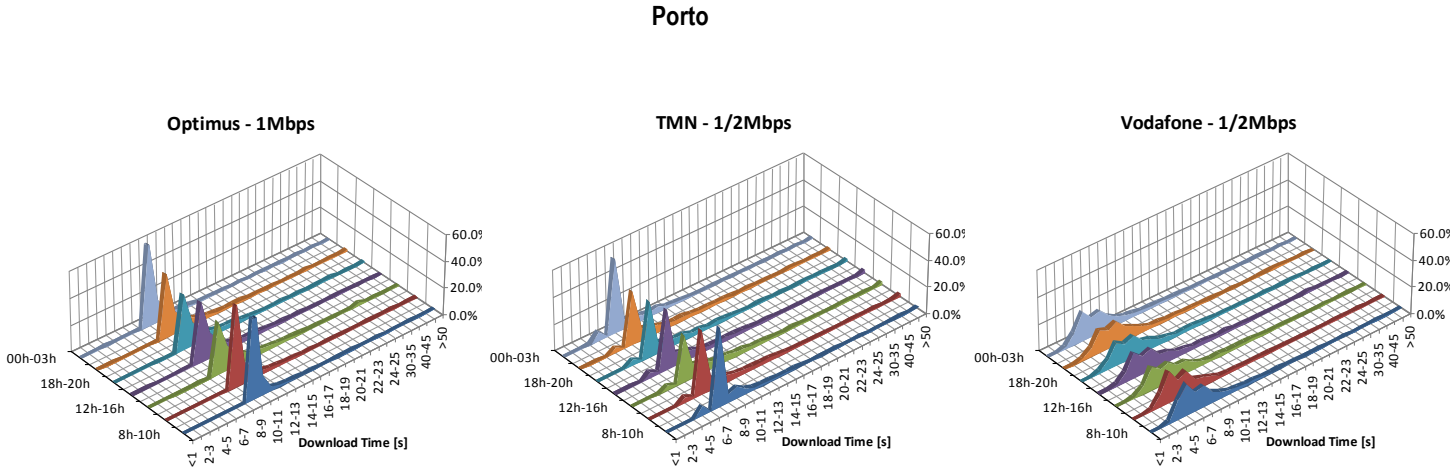


Figure 44 – Frequency distribution per operator, time period and Download Time category for the Municipality of Porto

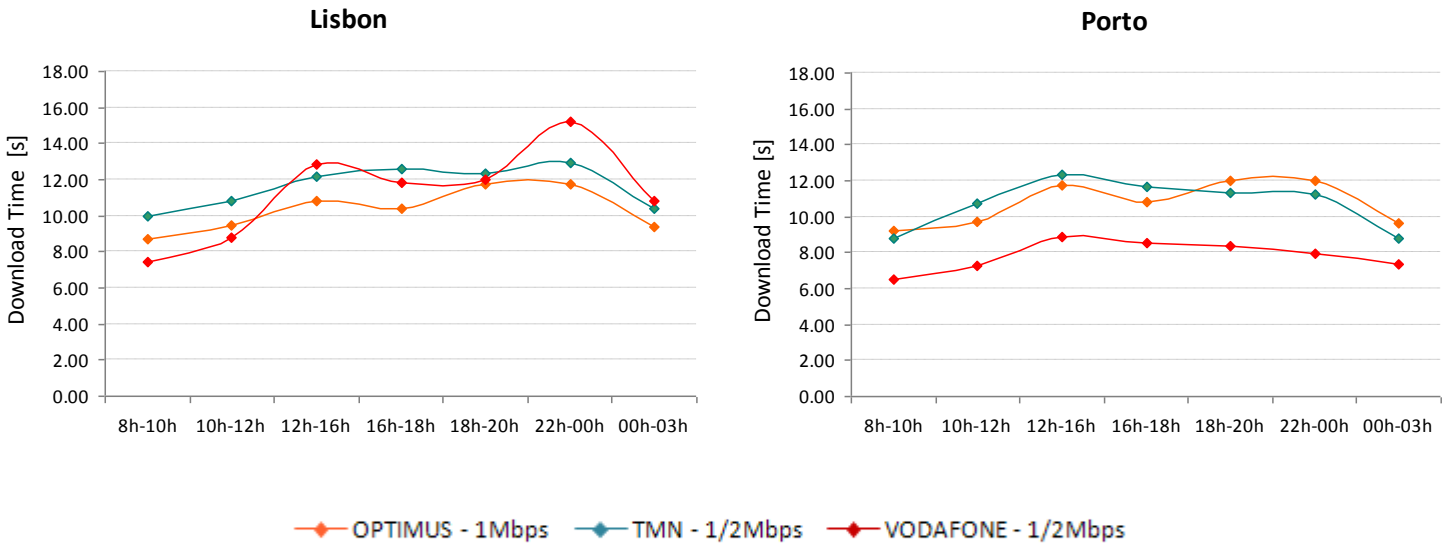


Figure 45 – Average file Download time per operator, time period and municipality

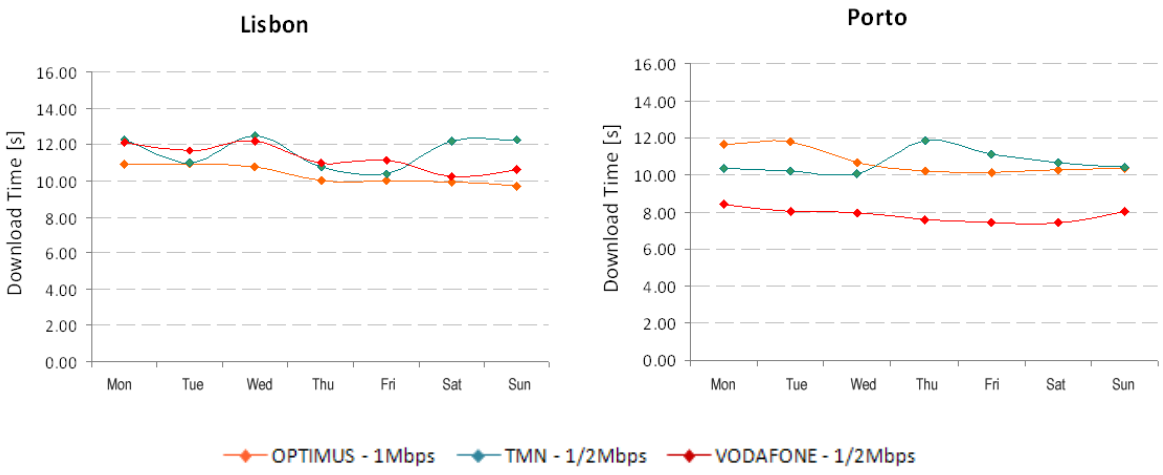


Figure 46 – Average file Download time per operator, weekday and municipality

Differences between the average values of file transfer download, per operator and destination server, are less relevant than those recorded for the corresponding speed. Even so, depending on the operator and on the location of the target server, the same file may take on average between 5.83 and 16.43 seconds to transfer (Figure 47), which are quite different values, considering it is the same technology and that tariff schemes are similar.

In short, when compared with the values recorded in Lisbon and Porto, these values are quite close among them, except for Vodafone in Porto, which presents considerably lower average times for all servers.

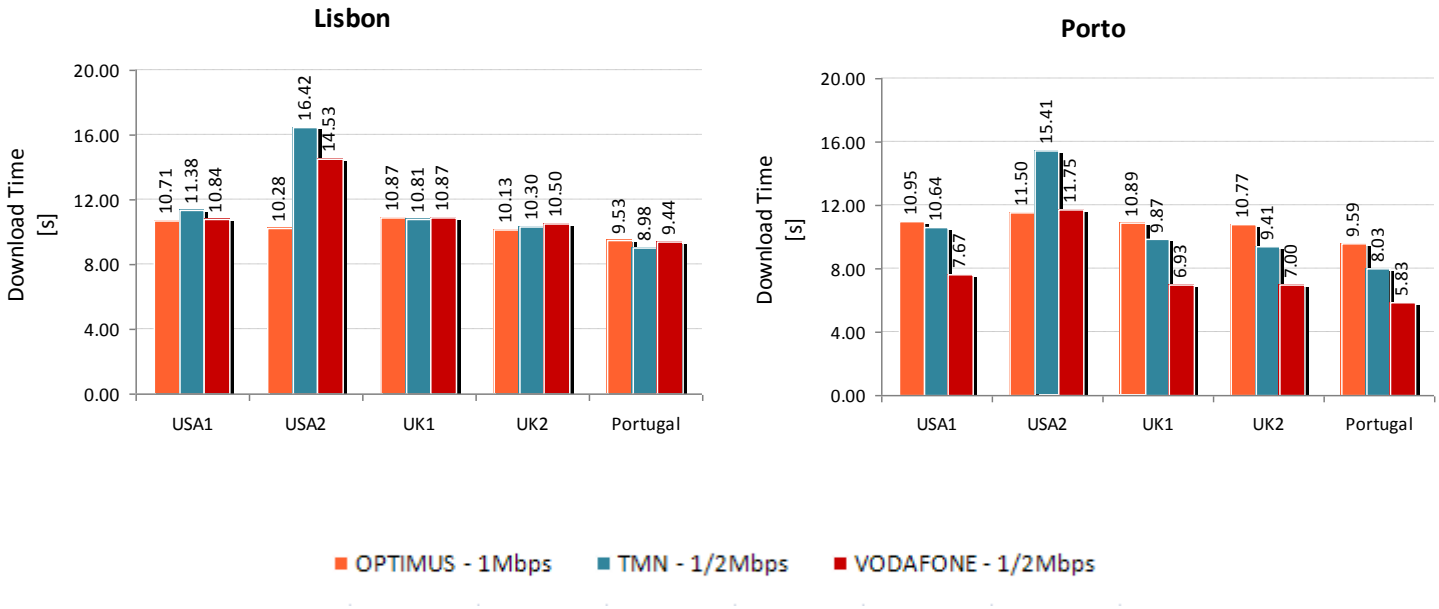


Figure 47 – Average file Download time per operator, server and municipality

Isolating the measurements obtained for the National server, Figure 48 and Figure 49, there are virtually no transfer times above 10 seconds for the three operators, Vodafone maintaining the tendency for having a lower record of concentration in particular intervals.

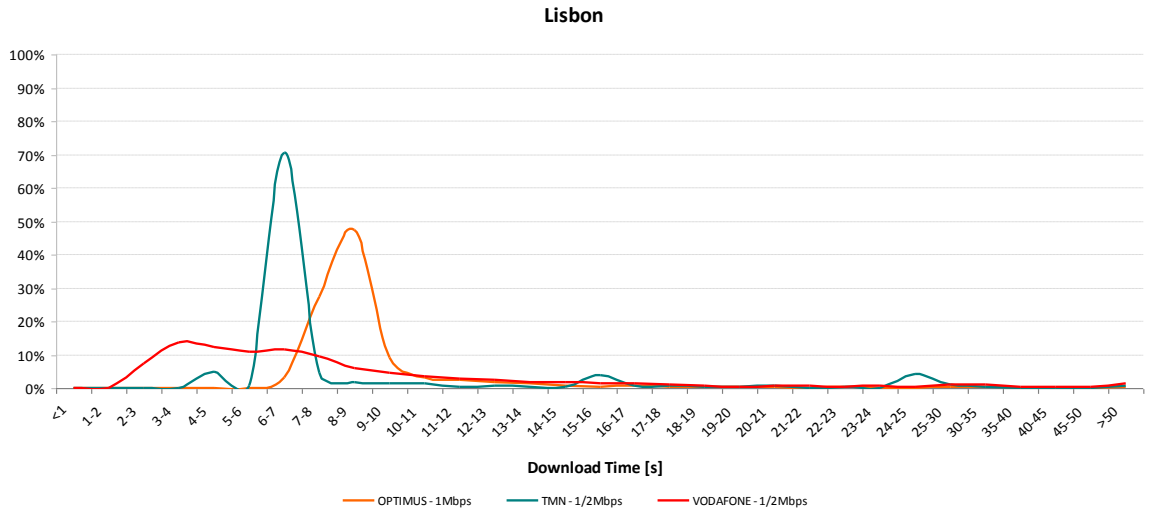


Figure 48 – Frequency distribution per operator and Download Time category for the municipality of Lisbon for the National server

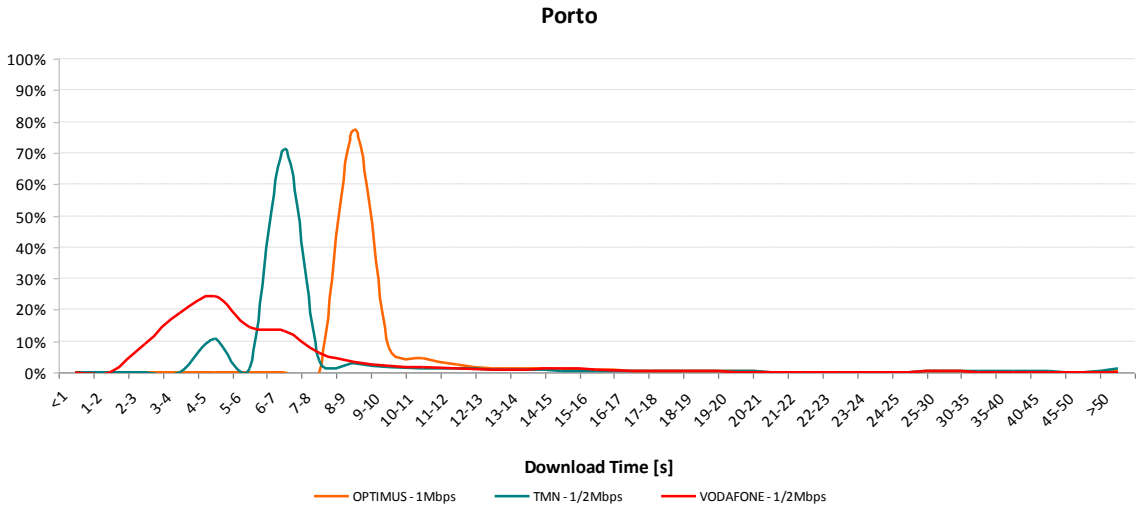


Figure 49 – Frequency distribution per operator and Download Time category for the municipality of Porto for the National server

3.2.2 Fixed Access – File Transfer Speed (*Download*)

The actual file transfer speeds are correlated to the maximum speeds advertised by the tariff schemes. Within this context, Cabovisão registers the highest values, since it is also the tariff scheme under study with the highest maximum speeds, of 10Mbps in this case. Likewise, the tariff scheme offering the lowest speeds, Clix 4/6Mbps, registers the lowest file transfer download speed.

The average values presented on Figure 50 aggregate the file transfer download speeds recorded for all national and international servers.

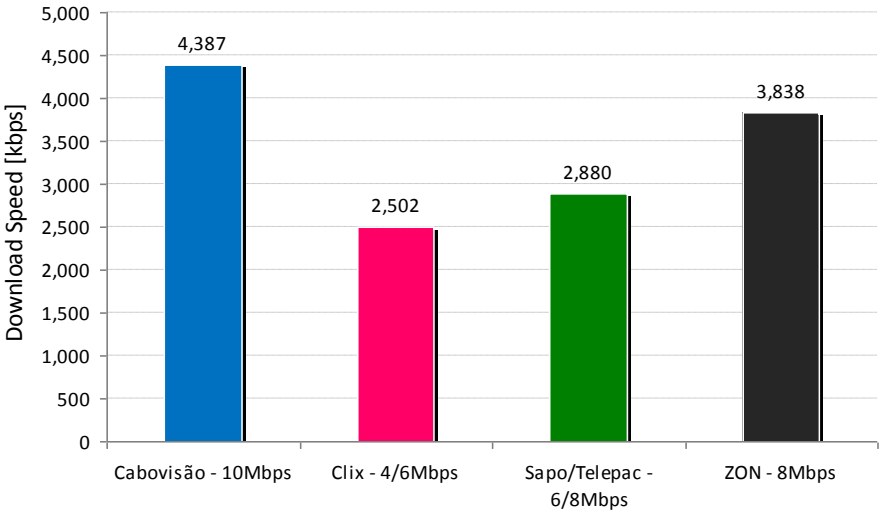


Figure 50 – File Transfer Download Speed per Operator

Figure 51 shows that the distribution of measurements for file transfer download speed presents a considerable dispersion for all operators, i.e., it means that the user has the possibility of obtaining very diverse file transfer speeds on these tariff schemes. Clix and Sapo present peak variations between 1000kbps and 5250kbps, while ZON and Cabovisão reach higher values, with peaks up to 8000kbps in the case of ZON, and 9500kbps of Cabovisão.

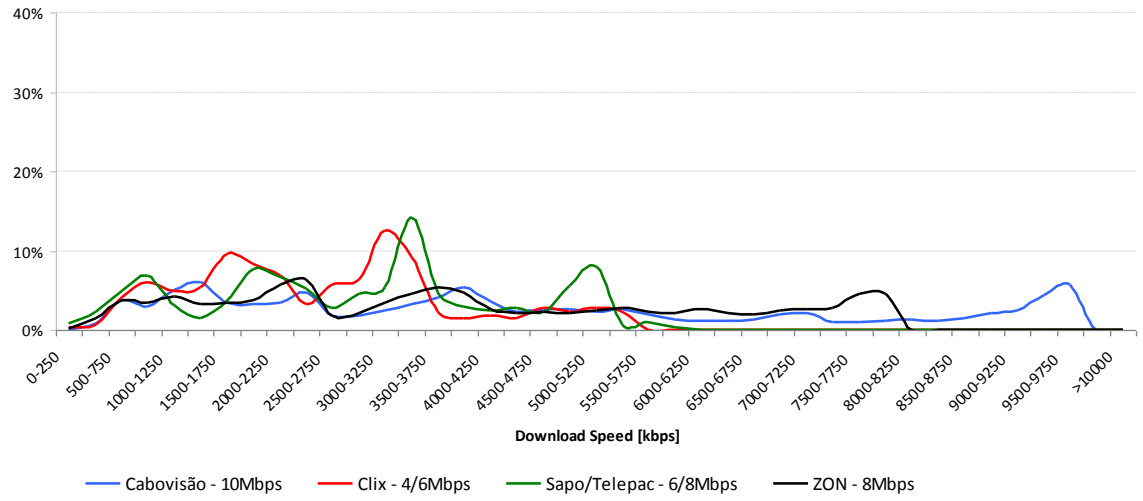
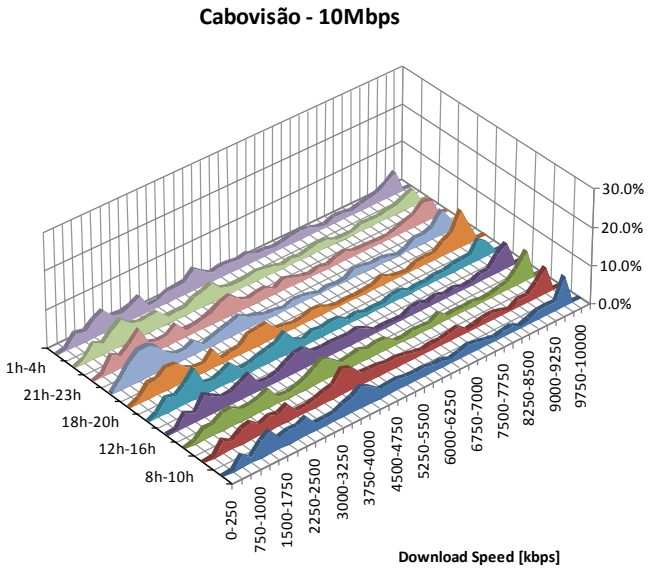
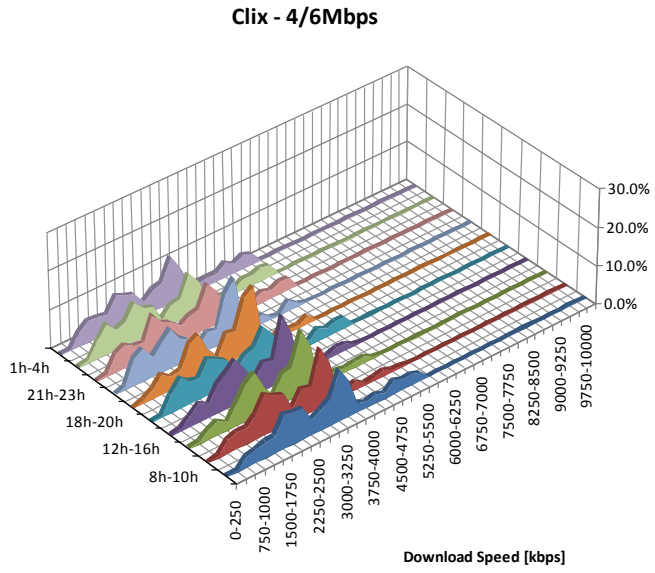


Figure 51 – Frequency distribution per operator and Download speed category

Figure 53 shows a fluctuation of the average file transfer download value along the day, for operators Cabovisão and ZON. These fluctuations are more relevant in the 18h-20h and 21h-23h periods, being possibly related to a higher usage rate. No major variations were recorded along the day for operators Clix and Sapo.





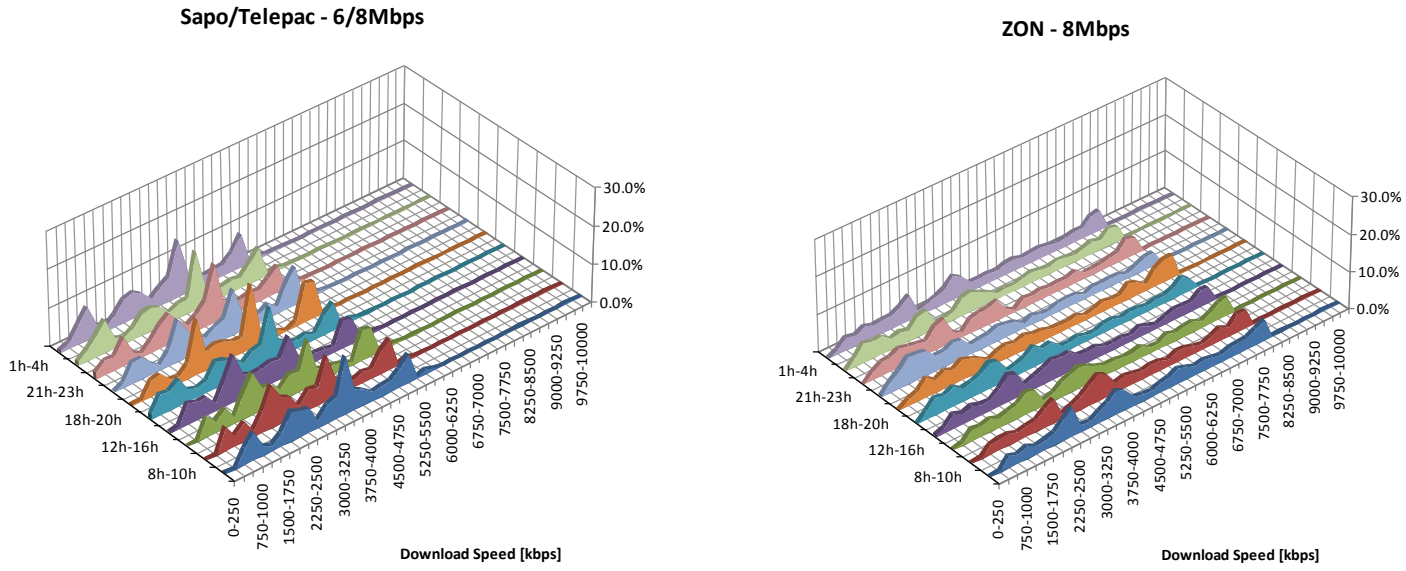


Figure 52 – Frequency distribution per operator, time period and Download speed category

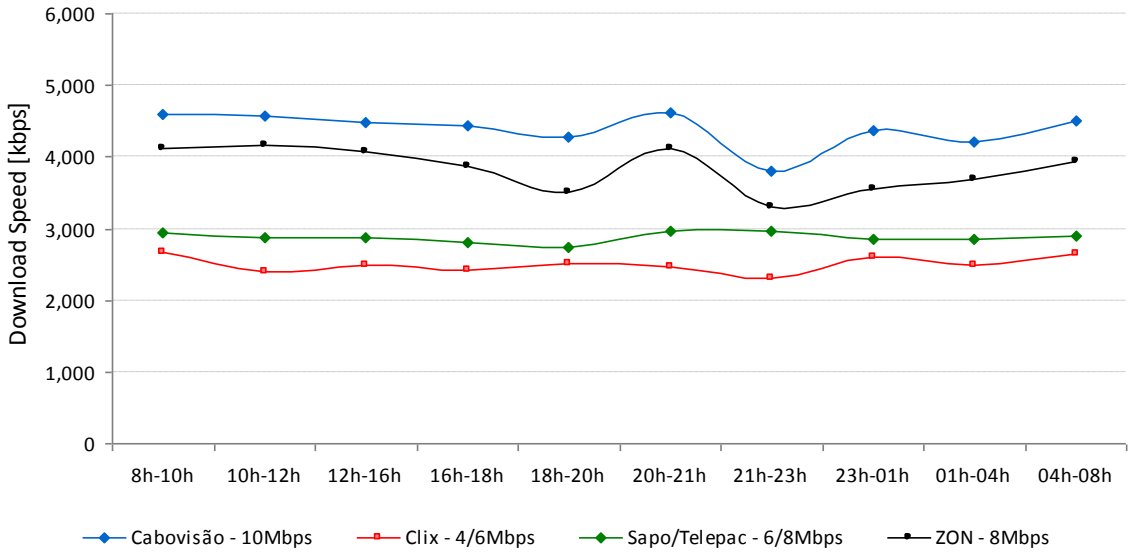


Figure 53 – Average file transfer Download speed per operator and time period

Regarding this indicator's weekly evolution, practically no variations were registered in operators Clix and Sapo. Zon and Cabovisão presented slight variations, both recording the best results on the middle of the week, and the worse results on Sunday, as shown on Figure 54.

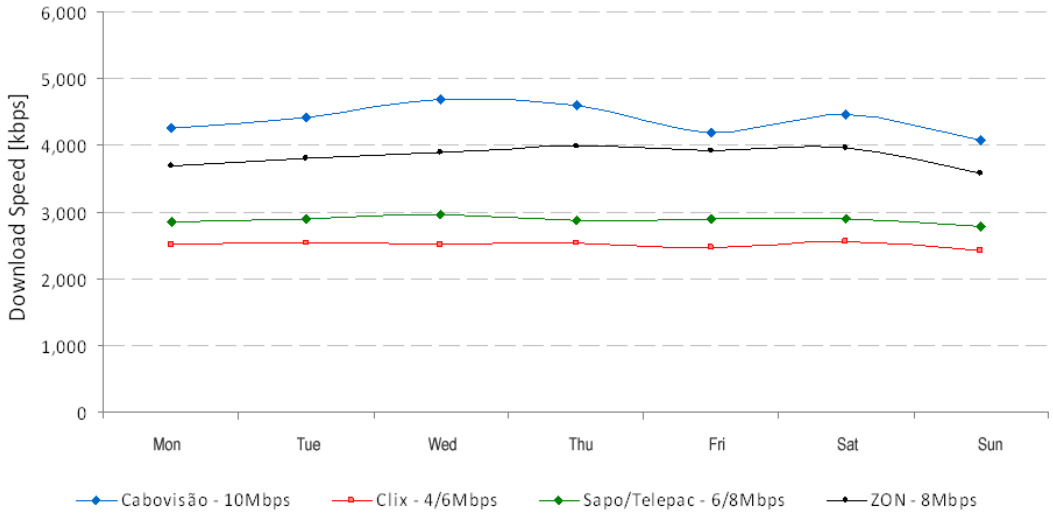


Figure 54 – Average file *Download* transfer speed per operator and weekday

Analyzing file transfer download speeds per operator and per server, and according to Figure 55, it shows once again that the highest values are obtained for the national server. The differences recorded in the average speeds obtained are again in line with the differences of the maximum advertised speed.

For the national server, Cabovisão achieves the highest actual value, of approximately 8Mbps, followed by ZON, with approximately 6Mbps, and by Sapo and Clix, which achieved below 4Mbps.

It should be noted that the values measured for file transfers from the USA2 server in Seattle, present no major differences between operators, i.e., the operator and tariff scheme factors are not noticed when transferring files from this region of the United States. Values are similar for all fixed operators, standing in the 1483-1636 Kbps interval, roughly twice the figure recorded for mobile operators with 1Mbps tariff schemes, which average speed values for transfers to this server stand between 800kbps and 900kbps.

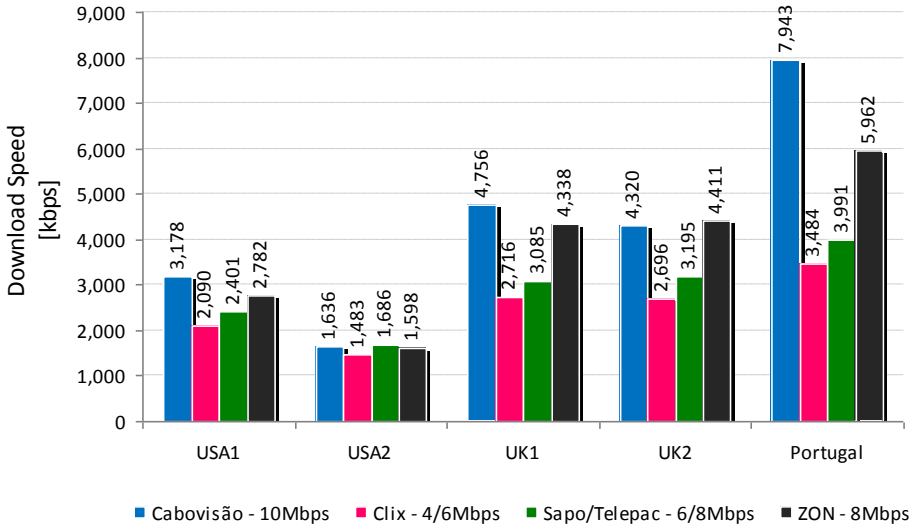


Figure 55 – Average file transfer Download speed per operator and server

In terms of dispersion of the values obtained during file transfers for the national server, according to Figure 56, its shows that Sapo concentrates its records in two intervals, 3250-3500kbps and 5250-5000kbps. This fact reflects the migration of the Sapo 6Mbps tariff scheme to 8Mbps.

For the national server, it shows that all operators presented some measurement concentration on the speed intervals close to the maximum intervals advertised for the tariff scheme, i.e., in the 5000-5250kbps interval, since some users subscribing the tariff scheme under analysis achieved speeds close to 6Mbps.

Comparing distributions (Figure 51) for all destinations with the distribution for the national server (Figure 56), it is also possible to infer that international connections considerably contribute to the dispersion of the recorded values. The reason for this could be related to the large asymmetry between the access speeds recorded for the national server and the speeds achieved for the international servers, particularly for Zon and Cabovisão (operators with the highest speed tariff schemes).

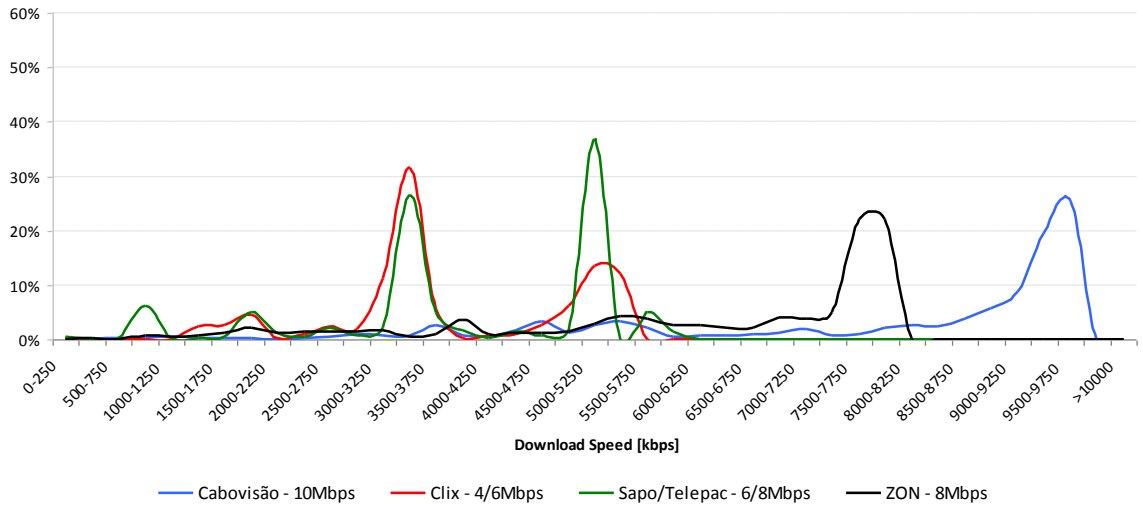


Figure 56 - Frequency distribution per operator and Download speed category for the national server

The diversity of the tariff schemes under study for the fixed access makes it harder to conduct a direct comparative analysis. Thus, in order to facilitate this task, results were standardized by creating a **Relative Speed Index** (RSI) for the national server (average speed recorded/maximum advertised speed x 100, reckoned by measurement and according to the tariff scheme provided for each test panel user). The results are presented on Figure 57, making it possible to conclude that only Sapo, with 55%, presents a register below the average, against the remaining operators, which register values above 70%. Cabovisão presents the best results, with a RSI of 77%, i.e., from all measurements made to this operator, on average, the speed accomplished is equivalent to 77% of the maximum advertised speed.

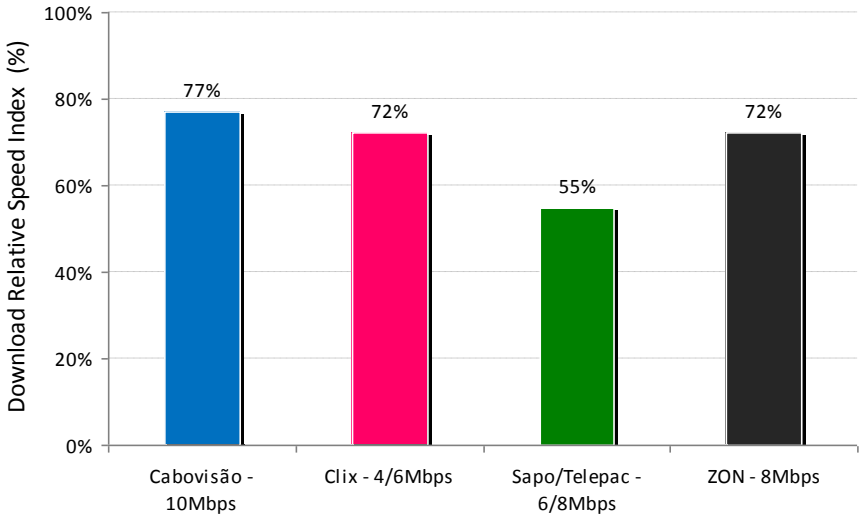


Figure 57 - Relative Speed Index of File Transfer Download per operator for the national server

According to Figure 58, the distribution of **Relative Speed Index** values presents a value concentration for Cabovisão and for ZON that corresponds, respectively, to 45% and 30% of all records, around the 90%-95% RSI interval. Clix presents a concentration with about 32% of the records around the 80%-85% RSI interval. Sapo presents more variable results. Results show that operators Cabovisão, ZON and Clix present the highest **Relative Speed Index** values.

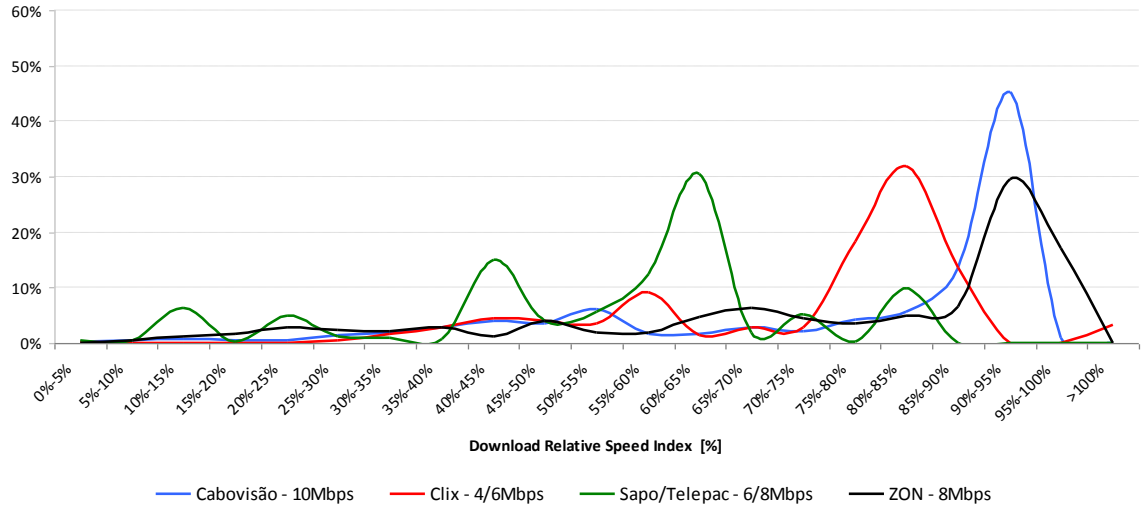


Figure 58 - Frequency distribution of the Relative Speed Index of File Transfer Download per operator for the national server

According to Figure 59, Cabovisão, Clix and ZON offer, on average, over 75% of the contracted speed, respectively, 70%, 67% and 62% of the measurements recorded.

Sapo only provides, on average, 10% of the records over 75% of the maximum contracted speed. The same analysis makes it possible to conclude that 65% of measurements recorded actual average file transfer download speeds above 50% of the maximum speed advertised by the Sapo tariff scheme under study.

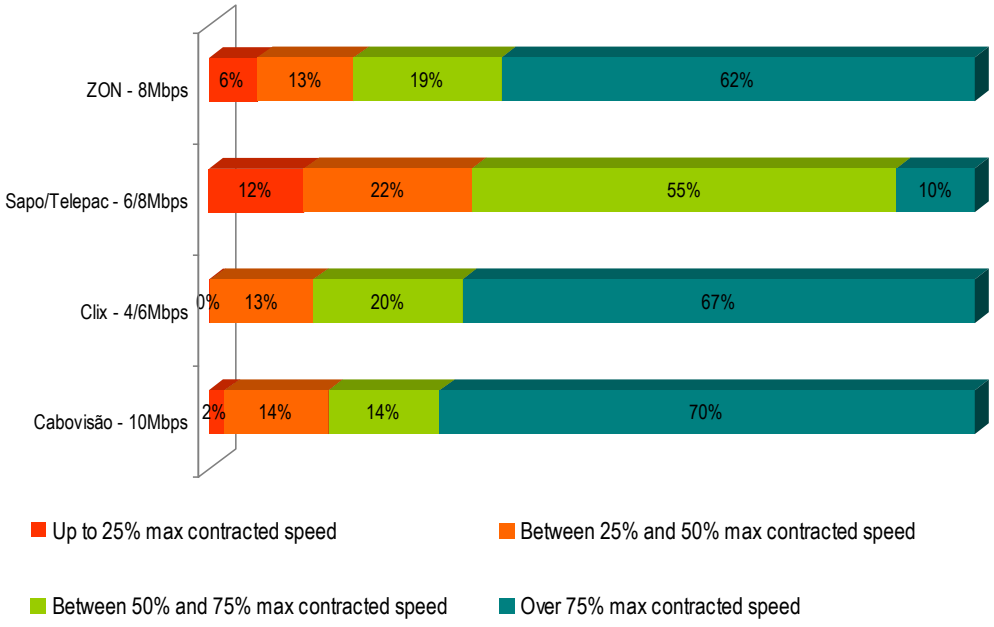


Figure 59 - Frequency distribution per Relative Speed Index categories of File Transfer Download per operator for the National server

According to Figure 60 and Figure 61, there is a greater variation of the average **Relative Speed Index** value along the day for operator ZON, with a decrease trend from 16h to 23h. Concerning the remaining operators, distributions during the day (Figure 60) and the corresponding average values (Figure 61) present smaller variations.

The analysis per weekday shows that the existing variations are considerably small, as shown on Figure 62.

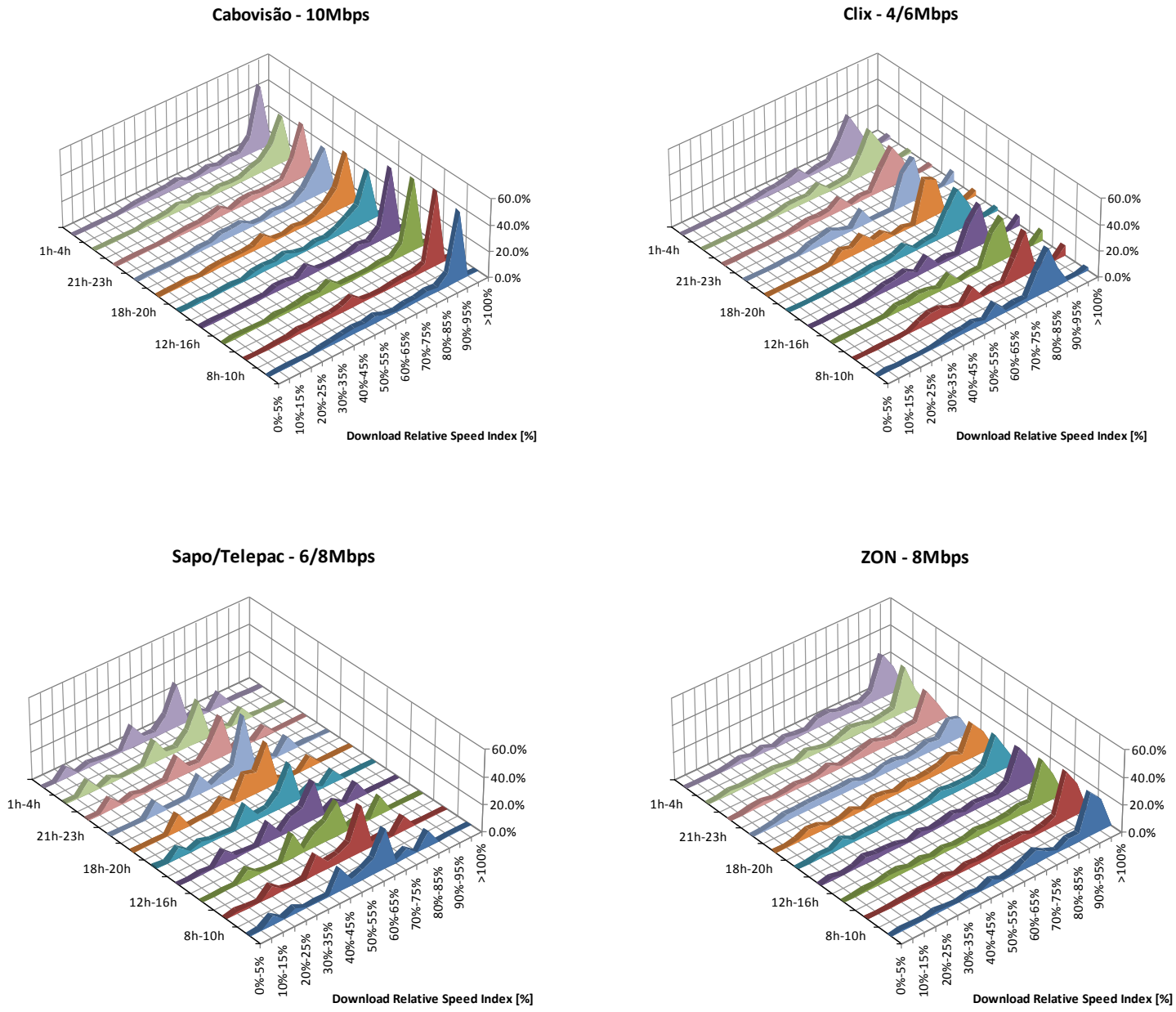


Figure 60 - Frequency distribution per operator, time period and Relative Speed Index Download speed category for the National server

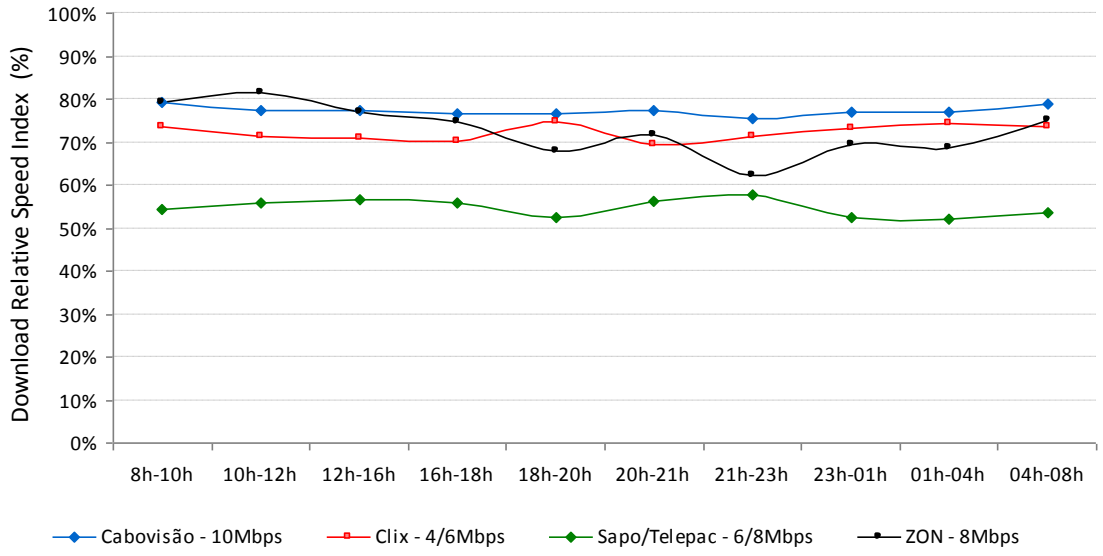


Figure 61 – File Transfer Download Relative Speed Index per operator and time period for the national server

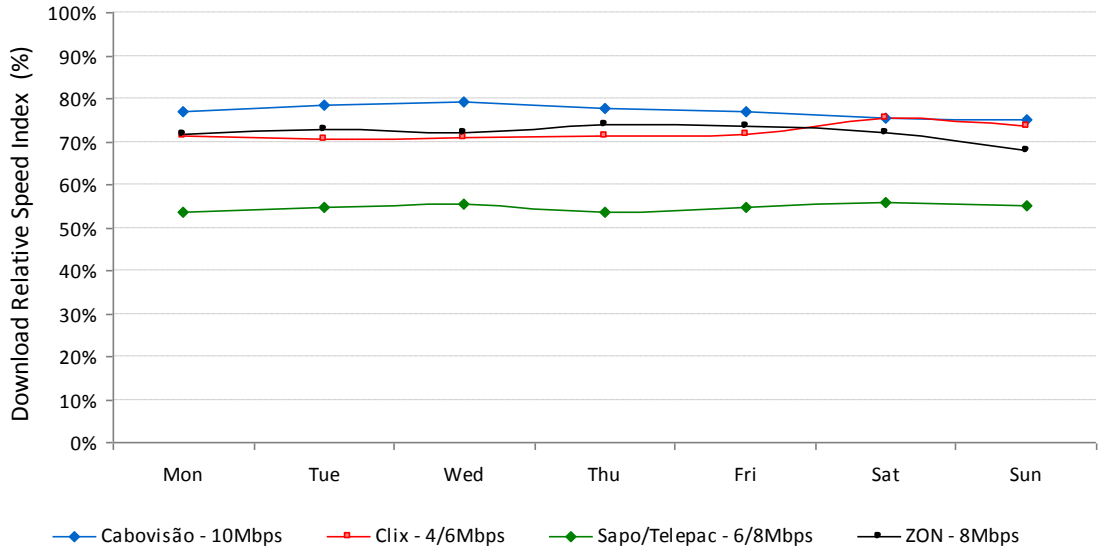


Figure 62 - File Transfer Download Relative Speed Index per operator and weekday for the national server

3.3 User's Perception of File Transfer (Upload)

3.3.1 3G Mobile Accesses

3.3.1.1 File Transfer Speed (Upload)

Within the context of Internet transactions, the uplink has an important role in the user experience. E-mail sending and file upload waiting times are the type of applications that are most affected by the uplink speeds achieved, i.e., applications which communication has a more symmetric operation than Web browsing (an asymmetric application from the communication perspective, regarding the volume of transferred data).

The uplink speeds advertised in the offerings supporting this study were also subject to modifications during the measurements for the three National mobile operators, namely from 384kbps to 512kbps, although this modification had no major impact on the values obtained.

According to Figure 63, Optimus presents the best values for this indicator in Lisbon, where the uplink speeds greatly surpass the advertised values, reaching 752kbps on average. In Porto, however, it is the operator with the lowest values, around 312kbps.

TMN, in Lisbon, registers the lowest value among the three operators, with 292kbps, having the opposite performance in Porto, where it this the best operator regarding this indicator, with an average value of 743kbps.

Vodafone is the second operator in both municipalities for the tariff scheme under study, with values of 615kbps and 679kbps in Lisbon and Porto, respectively.

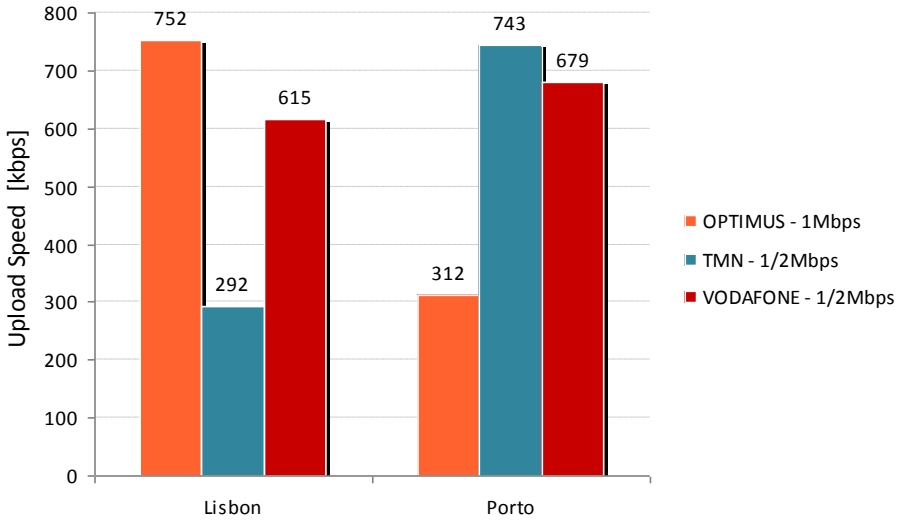


Figure 63 – Average file transfer Upload speed per operator and municipality

According to Figure 64 and Figure 65, operators Optimus and Vodafone present higher average file transfer upload speed values than TMN, in the municipality of Lisbon. However, value distribution is quite varied for the set of national and International servers, a situation which means the end users have the possibility of obtaining extremely diverse speed values, particularly for Optimus. TMN presents the lowest value for this indicator, registering a high concentration of records around the 200-300kbps interval.

In the municipality of Porto, Optimus reverses the trend and achieves the lowest values in the municipality, with a lower concentration of records at 200-400kbps. Once again, the operators with higher average values on this municipality, TMN and Vodafone, present a more irregular set of records, particularly TNN.

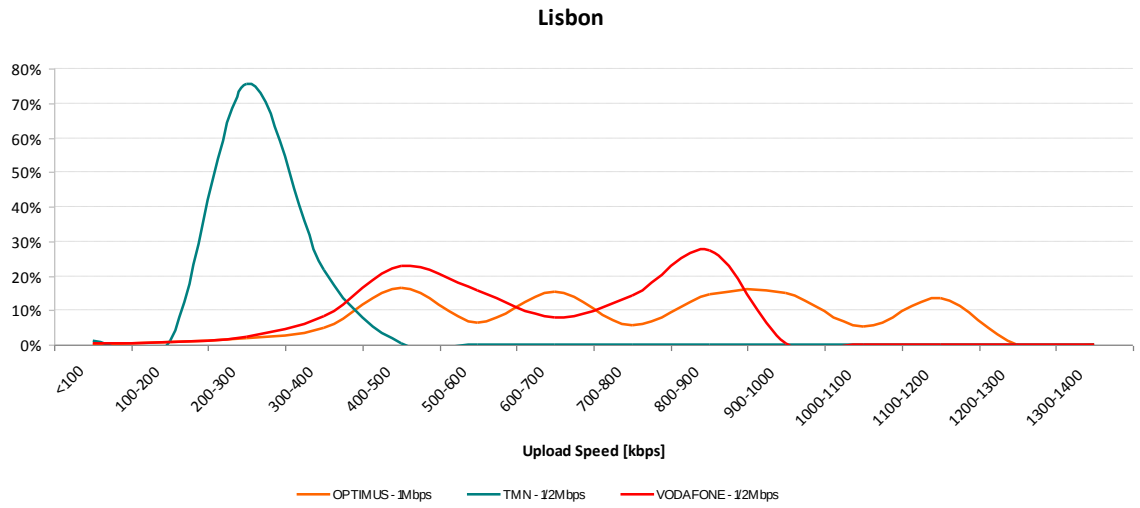


Figure 64 - Frequency distribution per operator and Upload speed category for the municipality of Lisbon

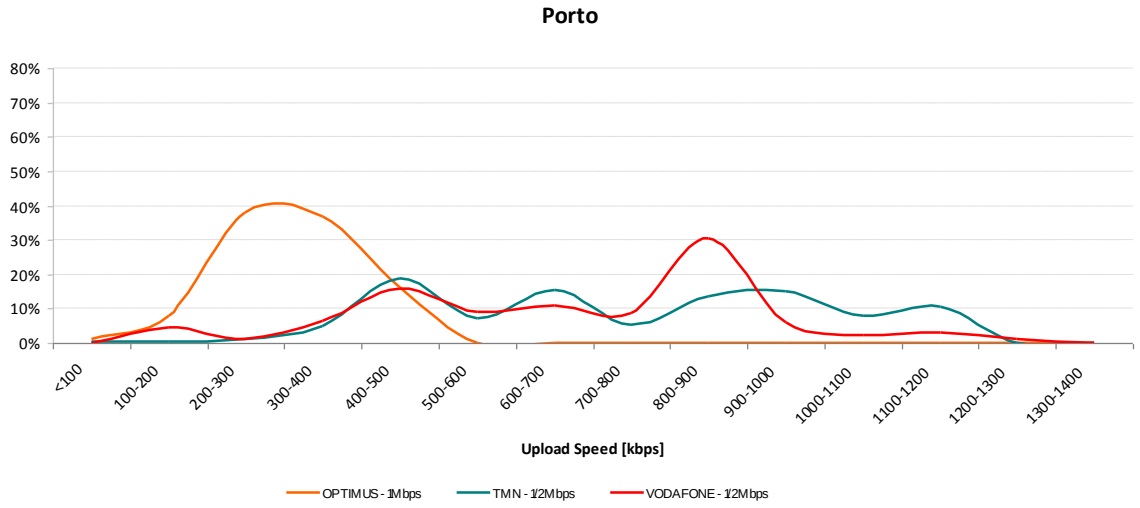


Figure 65 - Frequency distribution per operator and Upload speed category for the municipality of Porto

Distributions presented on Figure 66 and Figure 67 show little variations of the actual average speed during the several time periods of the day. This is confirmed by the steady average values presented on Figure 68 and Figure 69, which translate a similar behaviour along the several weekdays.

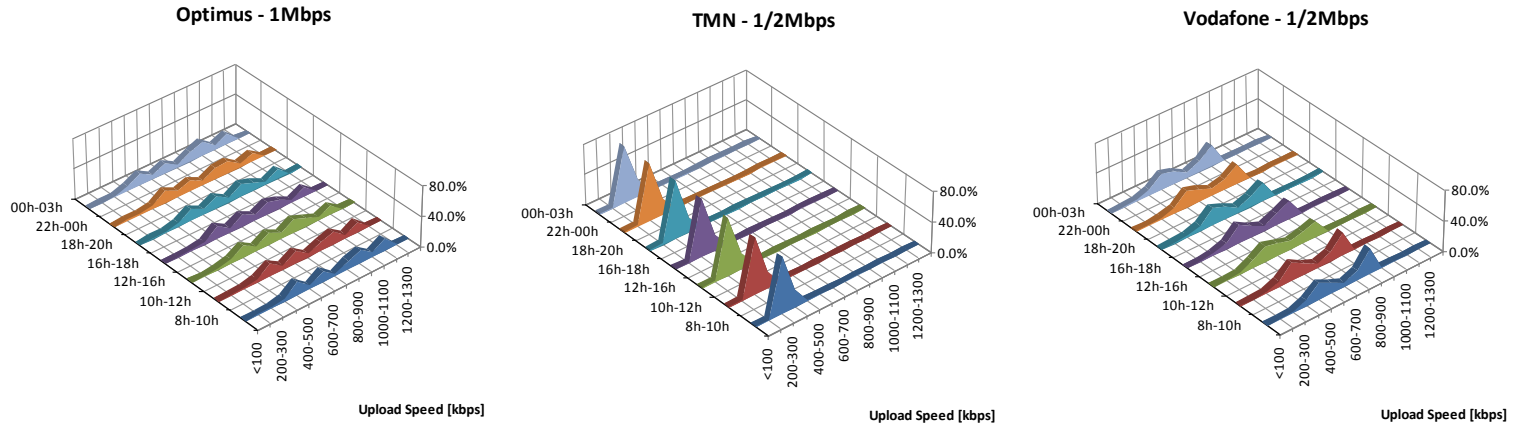


Figure 66 - Frequency distribution per operator, time period and Upload speed category for the municipality of Lisbon

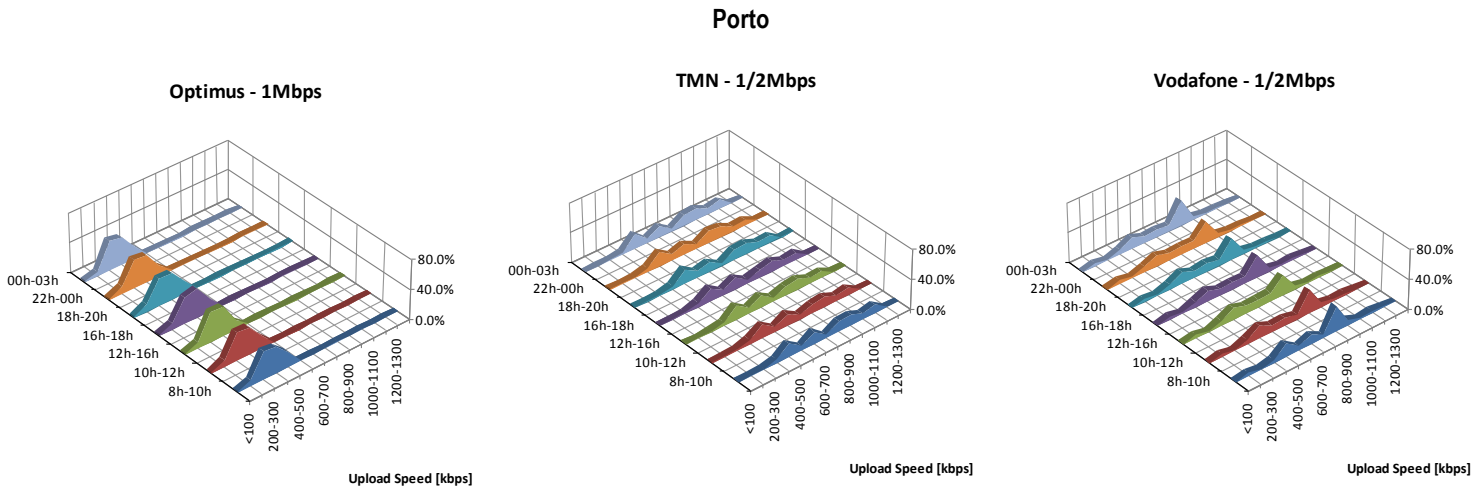


Figure 67 - Frequency distribution per operator, time period and Upload speed category for the municipality of Porto

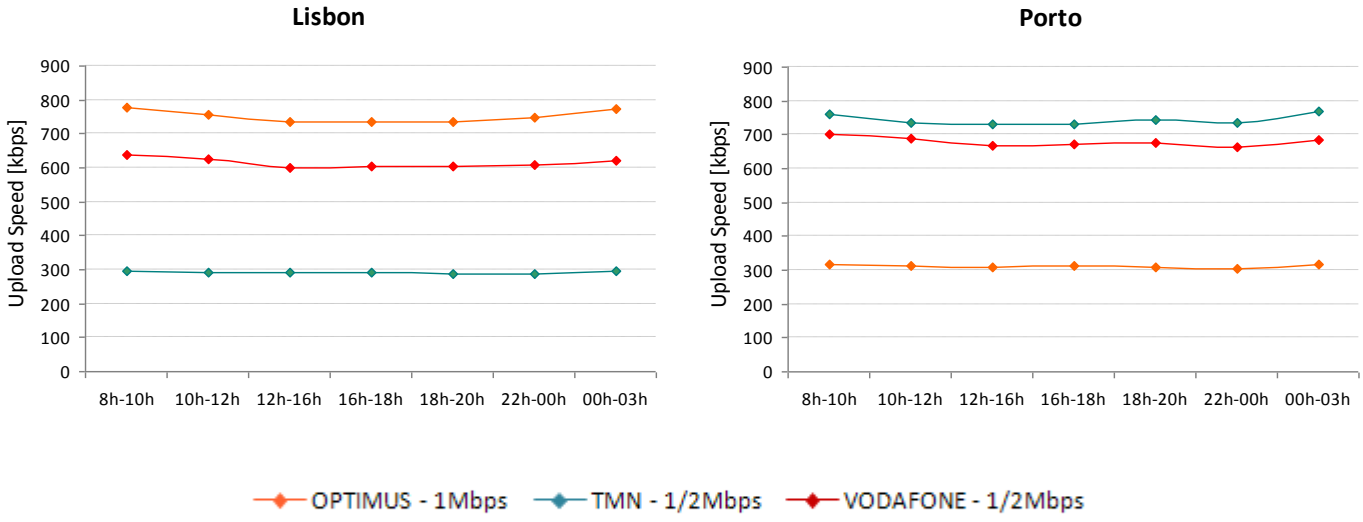


Figure 68 – Average file transfer Upload speed per operator, time period and municipality

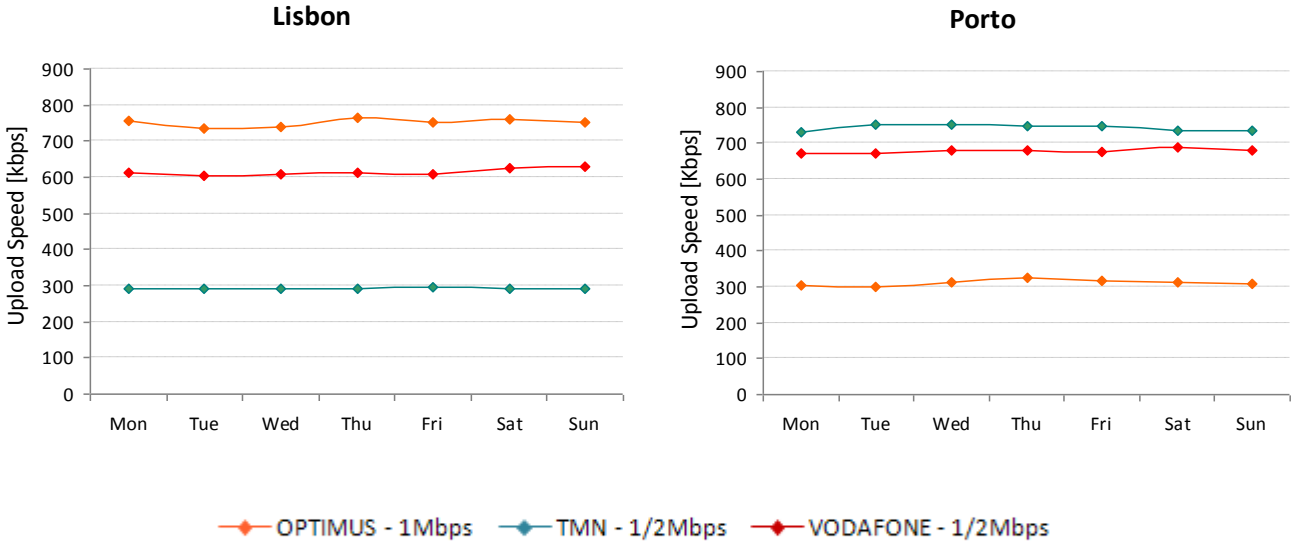


Figure 69 – Average file transfer Upload speed per operator, weekday and municipality

The effect of the location of the server subject to the tests is also noticed in the upload transfer speed, with all operators recording the highest values for the national server and considerably lower values for the United Kingdom and United States servers, by this order and according to Figure 70.

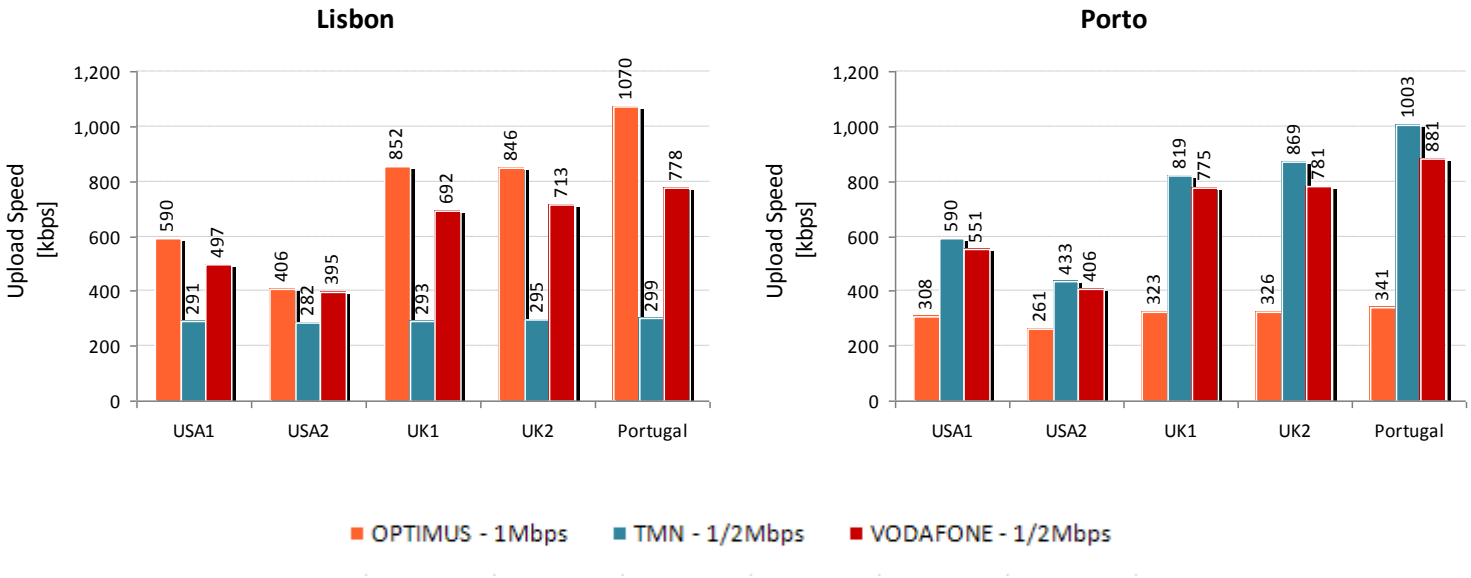


Figure 70 – Average file transfer Upload Speed per operator, server and municipality

Analysing measurement distribution in the municipality of Lisbon, only for the national server (Figure 71), it shows that most measurements are concentrated within clearly identified intervals for the three operators, opposite to the behaviour registered for Optimus and Vodafone in the dispersion results for all destinations (see Figure 64). Optimus registers about 68% of measurements in this municipality in the 1100-1200kbps interval; Vodafone registers around 64% between 800-900kbps, and TMN registers about 72%, at 200-300kbps.

In Porto, comparing Figure 71 and Figure 72, TMN reverses its performance with Optimus, achieving the best results with about 52% of measurements at 1100-1200kbps, Vodafone concentrates most records (around 55%) in the 800-900kbps interval, and Optimus has its records mostly distributed within the 400-500kbps and 200-300kbps measurement intervals.

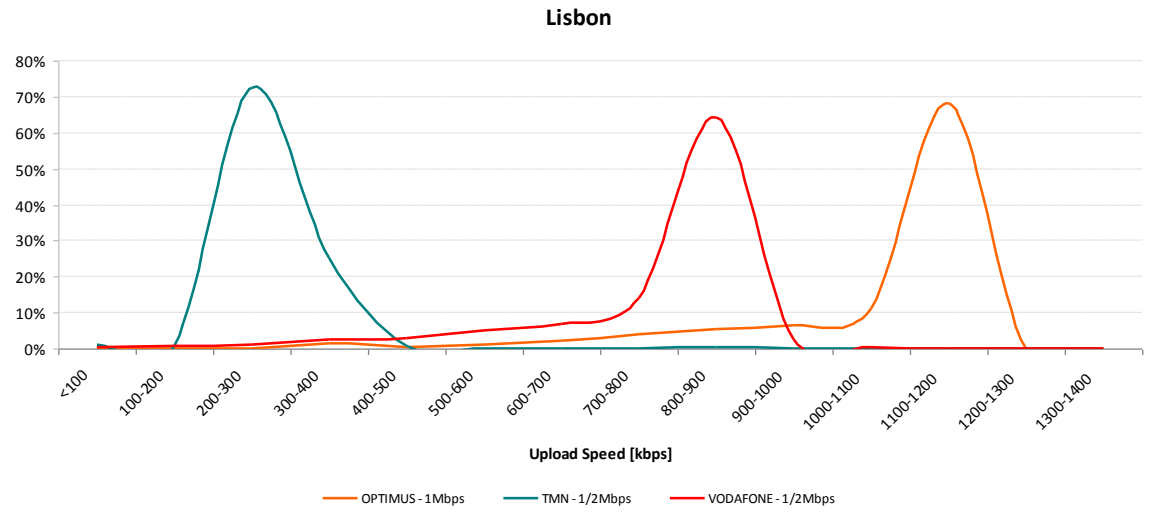


Figure 71 - Frequency distribution per operator and Upload speed category for the municipality of Lisbon for the national server

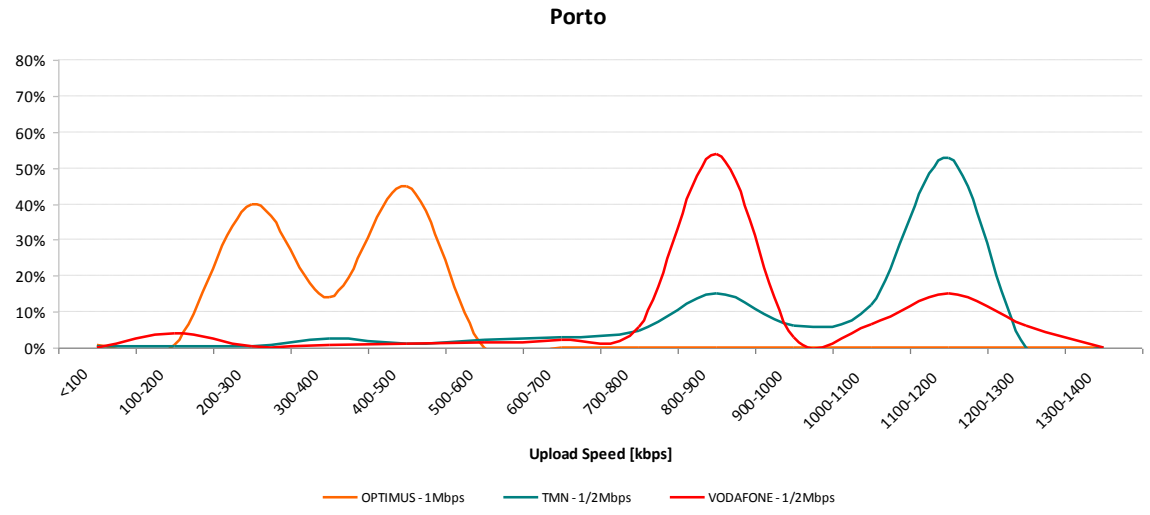


Figure 72 - Frequency distribution per operator and Upload speed category for the municipality of Porto for the national server

The RSI (Relative Speed Index) results for upload file transfers are also presented on Figure 73.

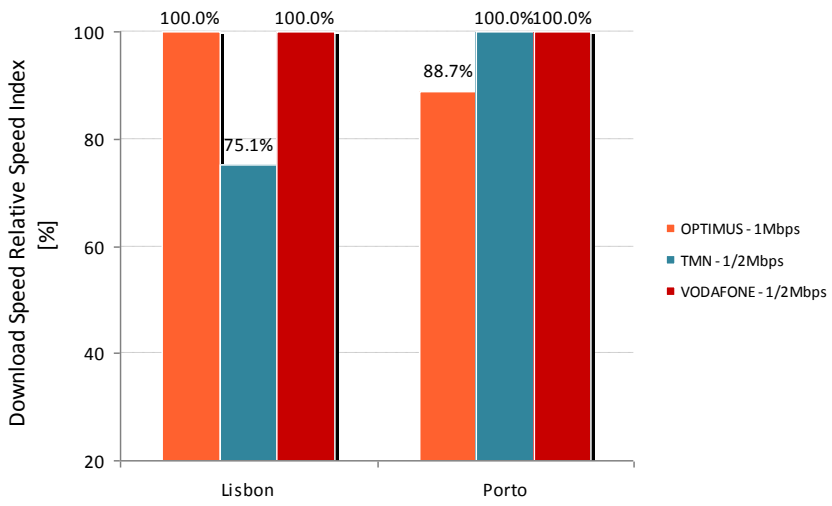


Figure 73 - Relative Speed Index of FTP File Transfer Upload – Mobile Accesses

In general, mobile broadband users in Lisbon and Porto experience 75.1% to 100% of the maximum file upload speed contracted. Among the performances of the three operators, Vodafone stands out achieving a 100% RSI in Lisbon and in Porto. Optimus obtained a 100% RSI in Lisbon and 88.7% in Porto. TMN obtained an opposite result from Optimus, with 100% in Porto and 75.1% in Lisbon.

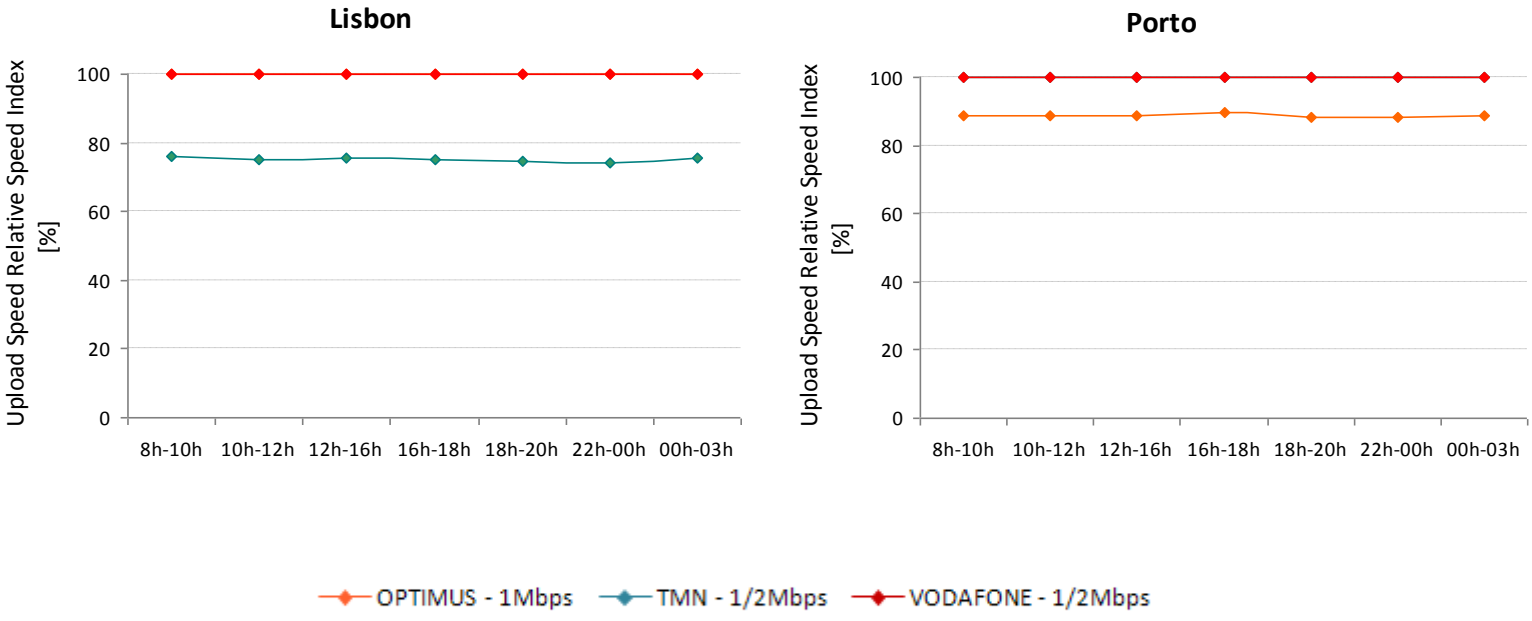


Figure 74 – RSI variation for FTP upload along the day for mobile accesses

Regarding RSI's evolution along the and during the week, Figure 74 and Figure 75 show that there are no major variations on this indicator, all operators maintaining a steady performance.

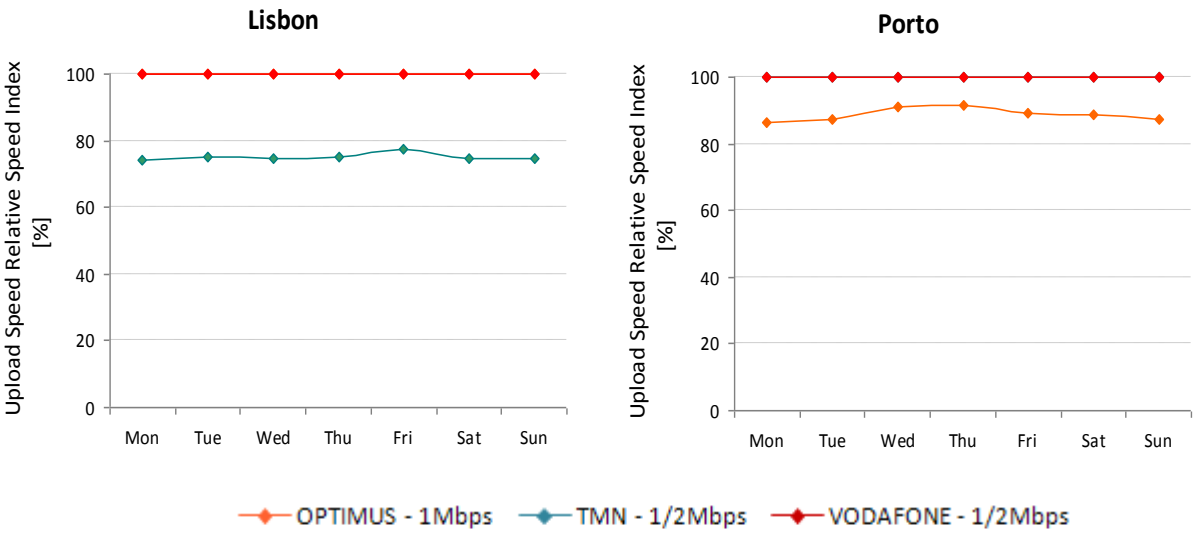


Figure 75 – RSI variation for FTP download along the week for mobile accesses

Figure 76 shows the detailed RSI distribution per category. Therefore, in Lisbon, Optimus obtained the highest RSI value, achieving 100% of measurements above 75% of the maximum contracted speed, followed by Vodafone with 96%. In this city, TMN obtained 74% of measurements above that level. In Porto, TMN obtained the highest value, achieving 99% of measurements above 75%, closely followed by Vodafone, with 95%. Also in Porto, Optimus presented only 59% of measurements above 75% of the maximum contracted speed. Standing out is Vodafone's considerably stable performance in both cities, for FTP file transfer upload.

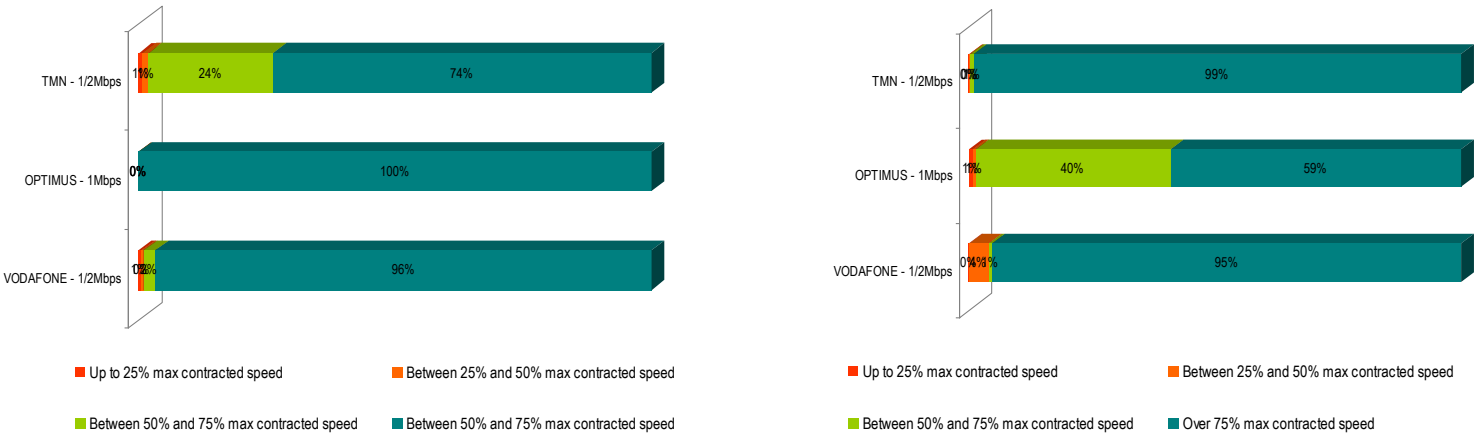


Figure 76- Frequency distribution per RSI category for File Transfer Download for the national server.

3.3.1.2 File Upload Time

The file transfer upload times presented for mobile operators, on Figure 77, reflect the average upload speeds obtained and analysed in the previous section. This indicator counts the average waiting time for the upload of the same file, for the test servers, in both municipalities.

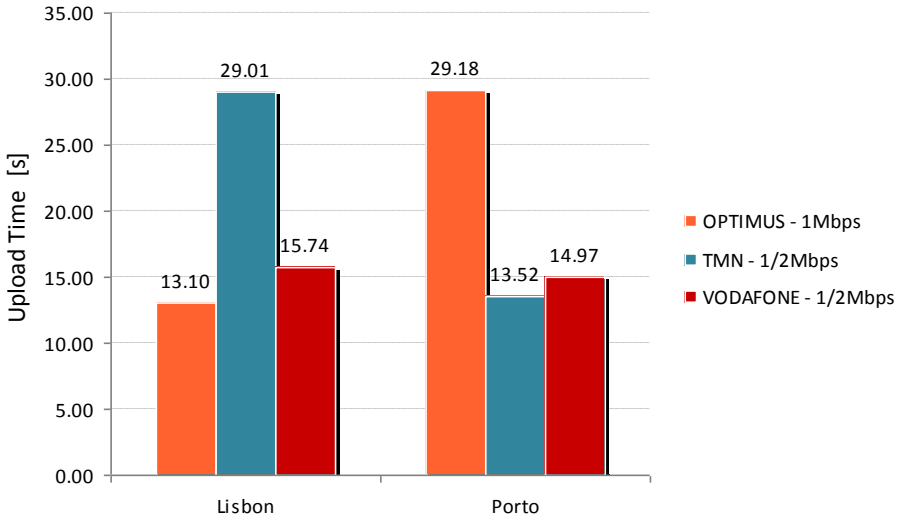


Figure 77 – Average file Upload time per operator and municipality

Conclusions indicate that for Optimus, in Lisbon, the same file takes an average of 13.10 seconds to upload, while in Porto it takes an average of 29.18 seconds to transfer.

TMN shows a better performance in Porto, recording a 13.52 second average transfer time, and a worse performance in Lisbon, registering 29.02 seconds.

Among the three operators, Vodafone presents the most stable values between municipalities, with an approximately 15 to 16 seconds average file transfer time, albeit not obtained the best result in none of the municipalities.

According to Figure 78 and Figure 79, file upload time distributions reflect the average values presented on Figure 77 and are consistent with the speed distributions analysed in the previous section. These figures reflect all servers, resulting in a high dispersion of values, except for TMN, which in Lisbon concentrates about 67% of the records within the 28-30 seconds interval, and for Optimus, which in Porto concentrates about 38% of the records within the 20-22 seconds interval.

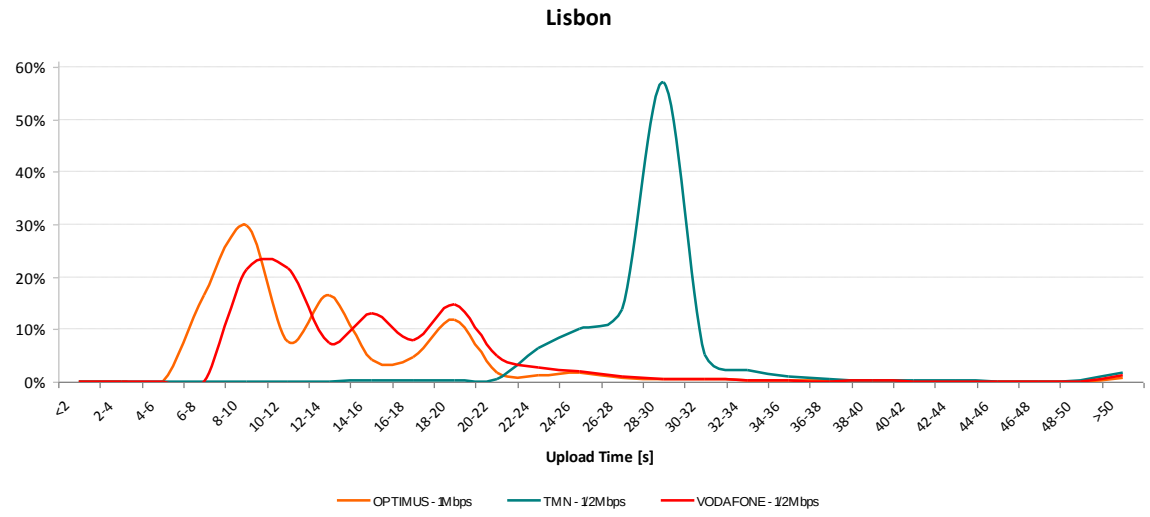


Figure 78 - Frequency distribution per operator Upload Time category for the municipality of Lisbon

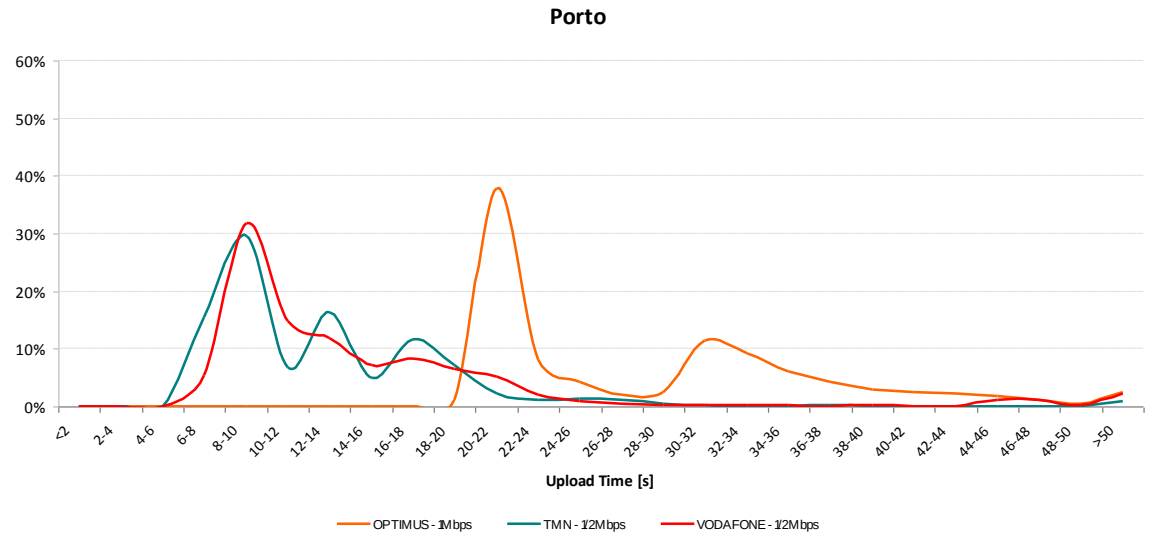


Figure 79 - Frequency distribution per operator and Upload Time category for the municipality of Porto

File transfer upload speed distributions per operator show a stable behaviour during the day, as shown on Figure 80 and Figure 81 and their respective averages (Figure 82), as what occurs with the corresponding speed indicator. The same behaviour is displayed during the week, according to Figure 83.

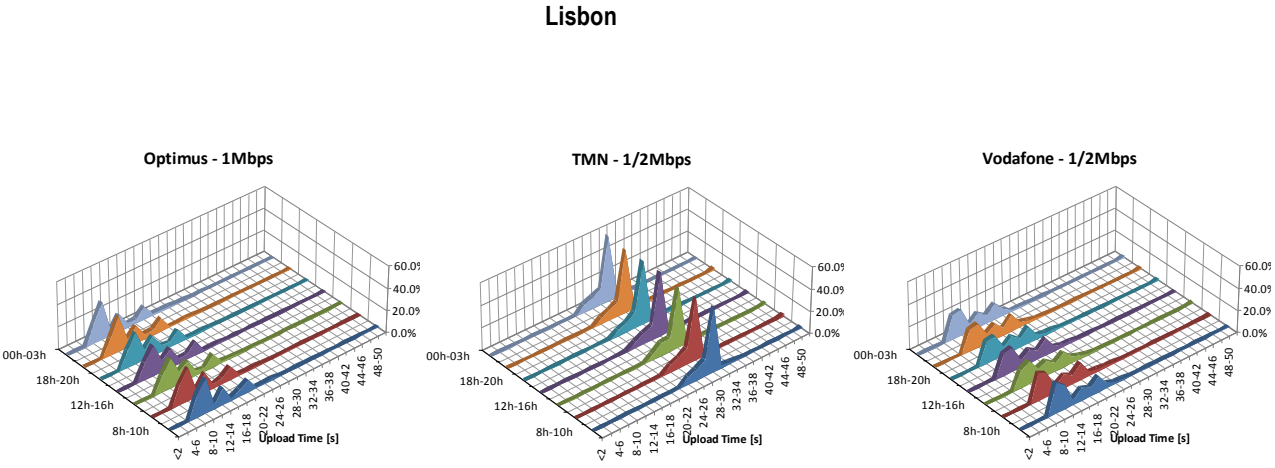


Figure 80 - Frequency distribution per operator, time period and Upload Time category for the municipality of Lisbon

Porto

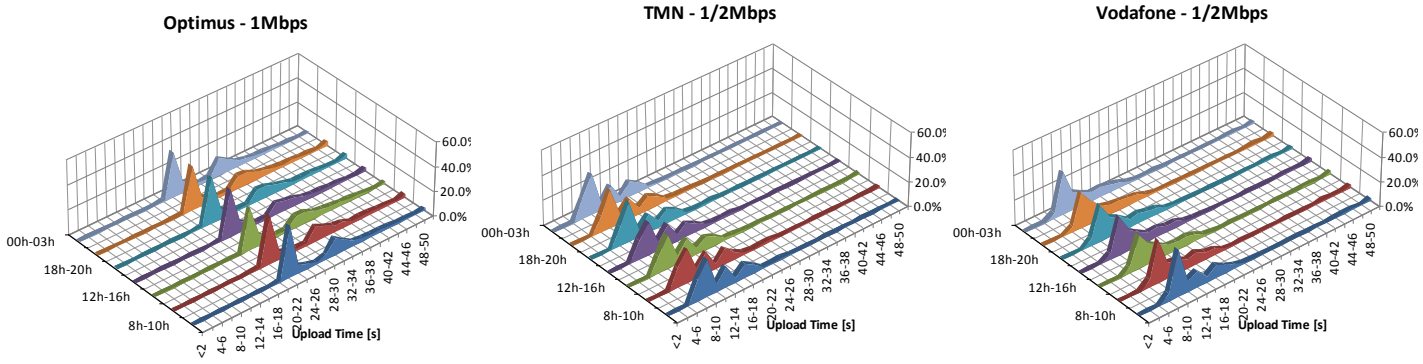


Figure 81 - Frequency distribution per operator, time period and Upload Time category for the municipality of Porto

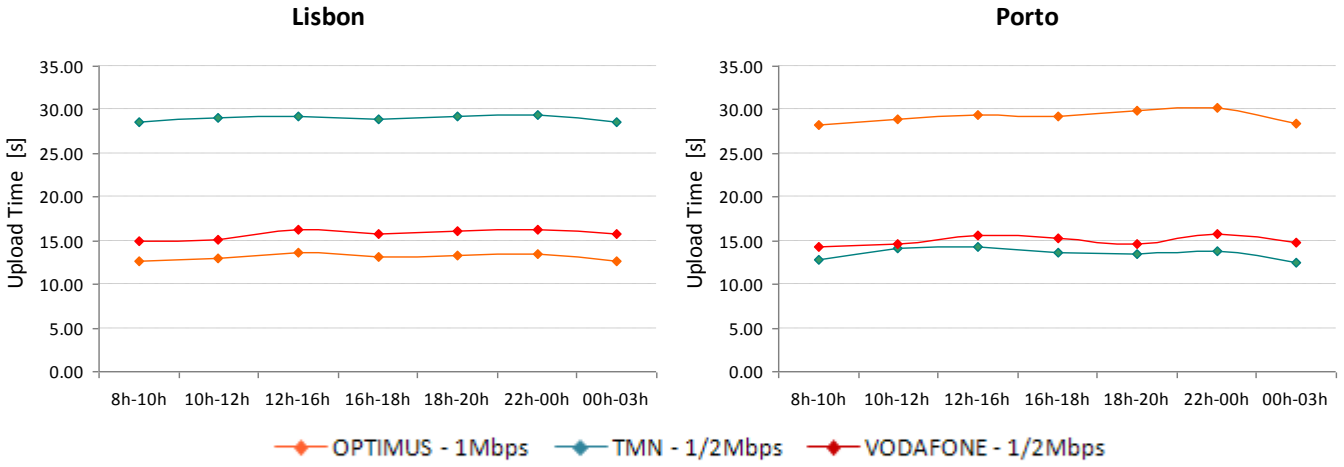


Figure 82 – Average file Upload time per operator, time period and municipality

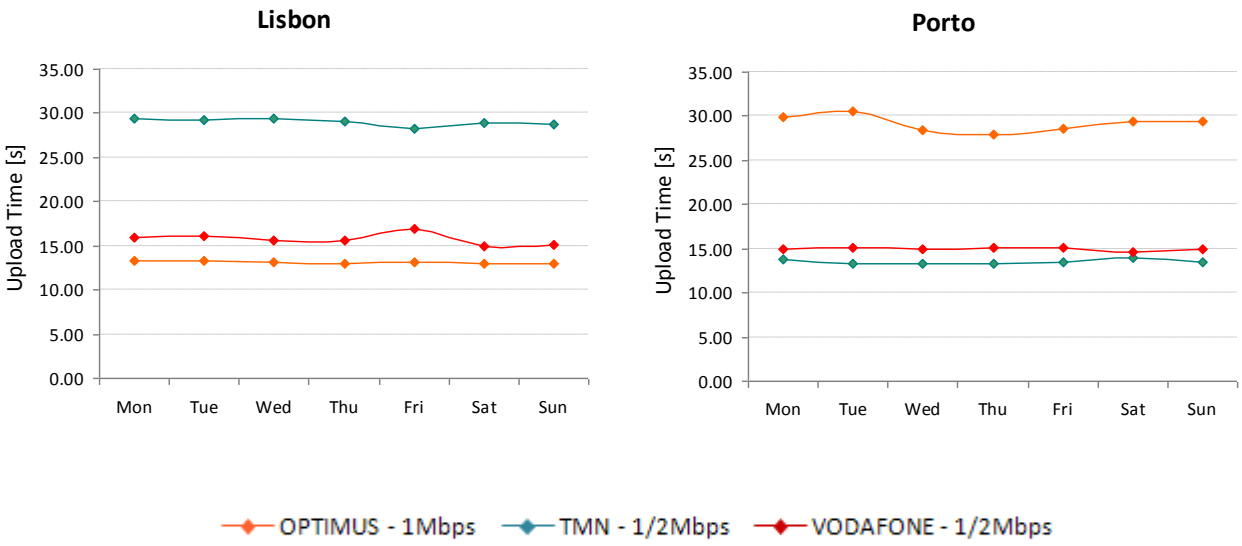


Figure 83 – Average file *Upload* time per operator, weekday and municipality

Figure 84 represents the average file upload time for each of the corresponding servers, with no differences regarding the analysis of the corresponding speed indicator.

Thus, the lowest upload time values, therefore corresponding to the best results, were recorded for Optimus, in Lisbon, for the National server, with an 8.27 seconds average; the highest value, for the USA2 server, was recorded for TMN, in Lisbon, with the average record of 30.0 seconds. In Porto, the highest upload times were recorded for the server in Seattle (USA2), with values of 35.16 seconds in Optimus and, on the opposite side, the lowest value was recorded for TMN, for the national server (9.59 seconds, on average).

In short, for the upload of a 1MB file, depending on the operator and the location of the target server, the transfer may take an average of 8.27 seconds or 35.16 seconds, values that are also very diverse considering similar tariff schemes and technologies.

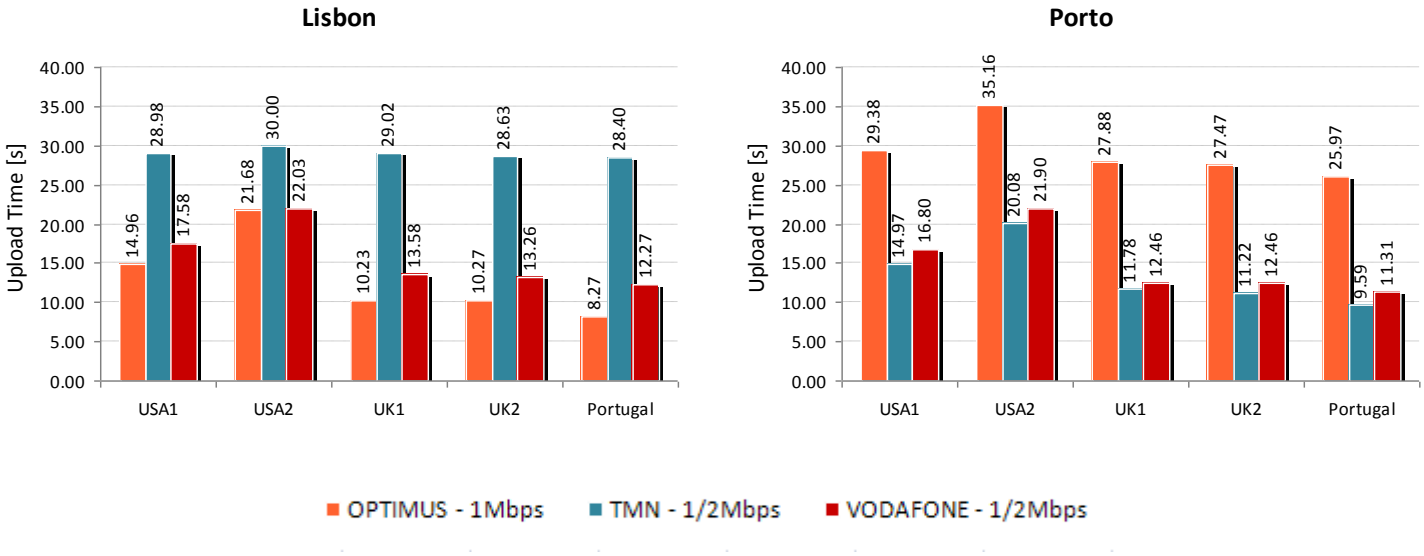


Figure 84 – Average file Upload Time per operator, server and municipality

The distribution of measurements presented on Figure 85 and Figure 86 for the national server reflects, in terms of upload time, the highest speeds achieved by Optimus, in the municipality of Lisbon, as well as the highest speeds achieved by TMN, in the municipality of Porto.

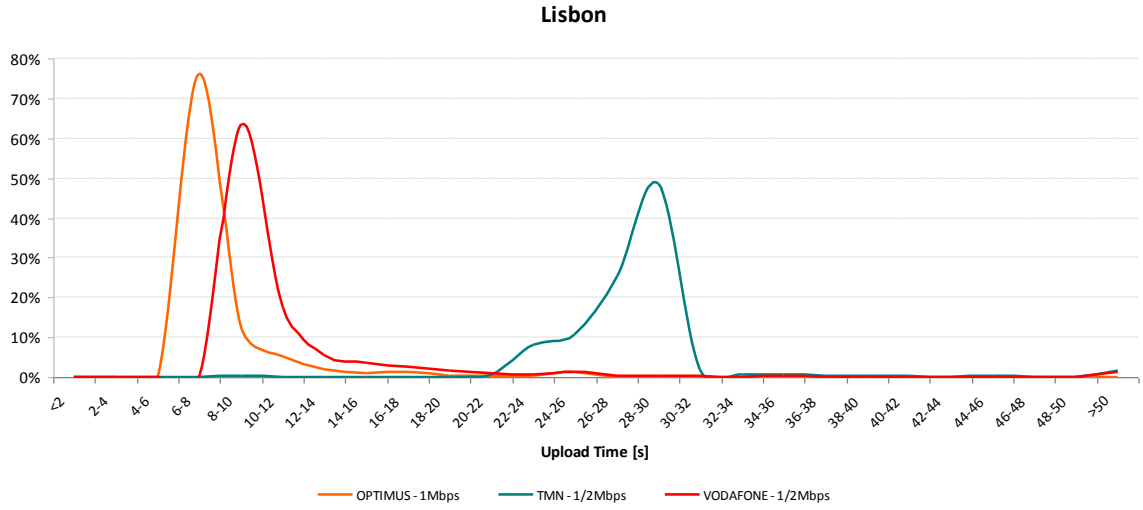


Figure 85 - Frequency distribution per operator and Upload Time category for the municipality of Lisbon for the National server

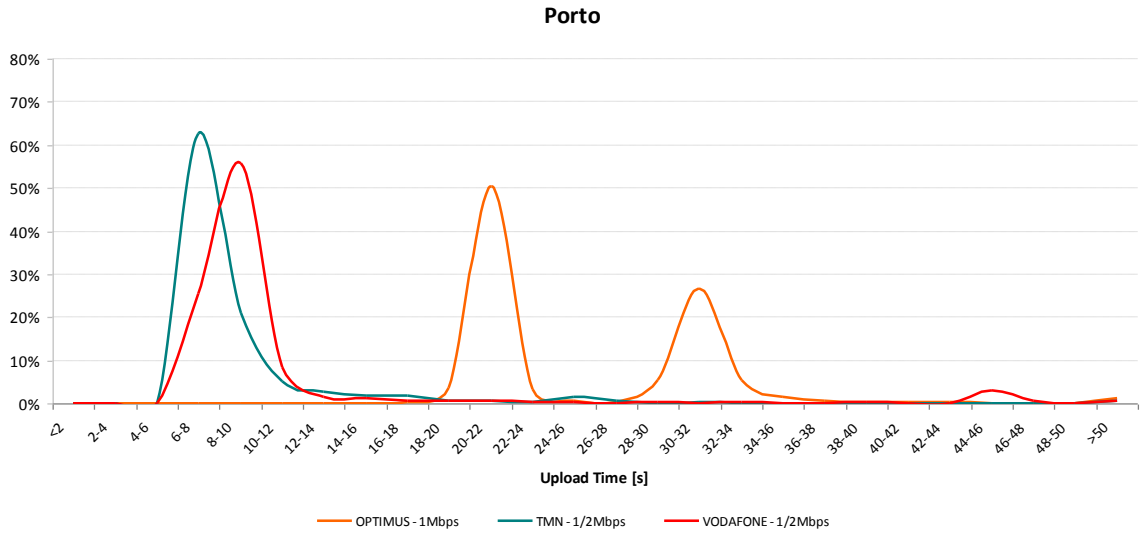


Figure 86 - Frequency distribution per operator and Upload Time category for the municipality of Porto for the National server

3.3.2 Fixed Accesses – File Transfer Speed (Upload)

On fixed accesses, the maximum upload speeds advertised correspond to a maximum value of 512kbps for all operators, except for Sapo, which advertises a higher value, 1024kbps, following the tariff scheme's alteration to 8Mbps. According to the analysis carried out and to Figure 87, Cabovisão presents the highest values, achieving on average 411 Kbps, followed by ZON and Clix. Sapo presents the lowest value of the study, with 305 Kbps.

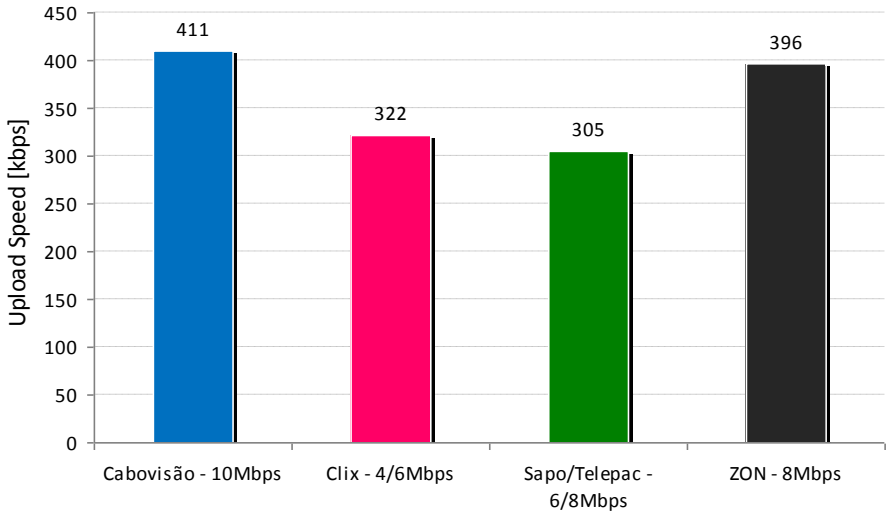


Figure 87 – Average file transfer Upload speed per operator

From Figure 88 it is possible to conclude that Cabovisão and ZON present a higher concentration of values at 400-500kbps, above those achieved by Clix and Sapo, with values distributed within intervals below 500kbps. This means that cable operator's customers obtain, on average, higher upload speeds.

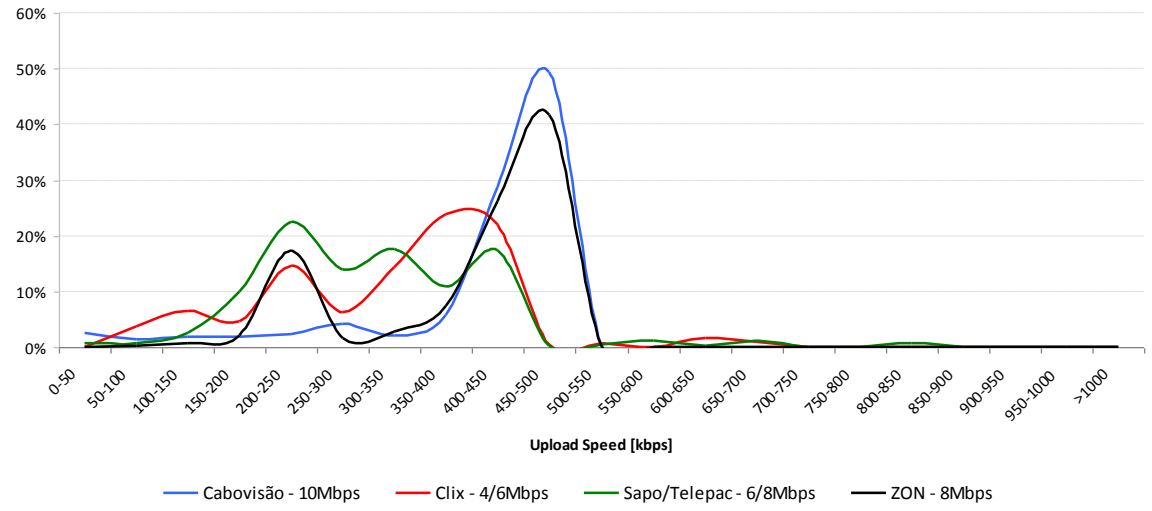
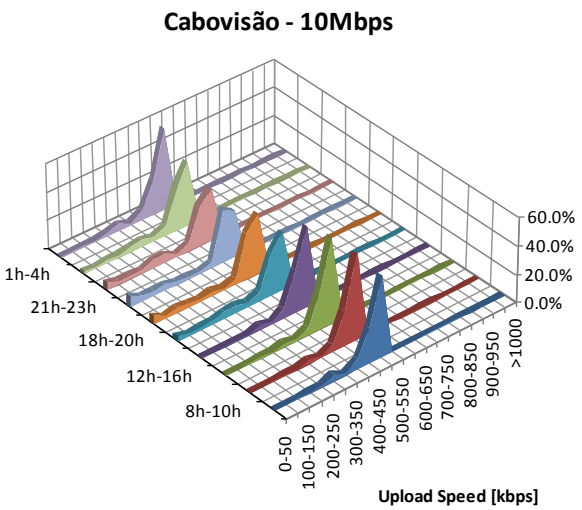
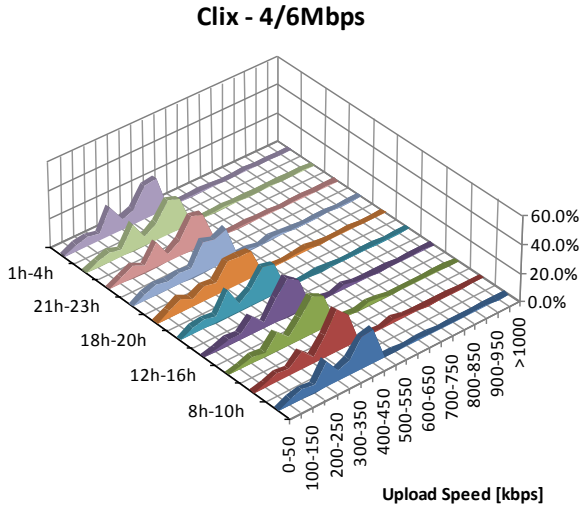


Figure 88 - Frequency distribution per operator and Upload speed category

Analysing Figure 89 and Figure 90 there are, in general, no major variations in the distribution of upload speeds during the day. However, a slight reduction of the average speed for Cabovisão, in the 18h-01h period, should be mentioned

During the week, variations are very small, as can be concluded from the analysis of Figure 91.





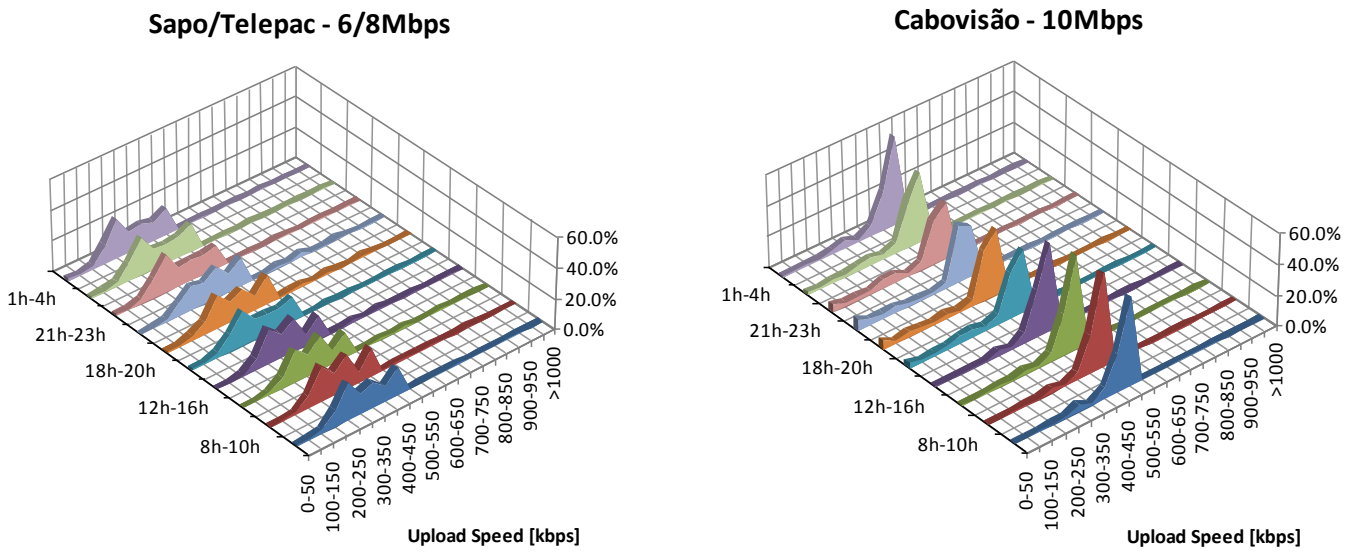


Figure 89 - Frequency distribution per operator, time period and Upload speed category

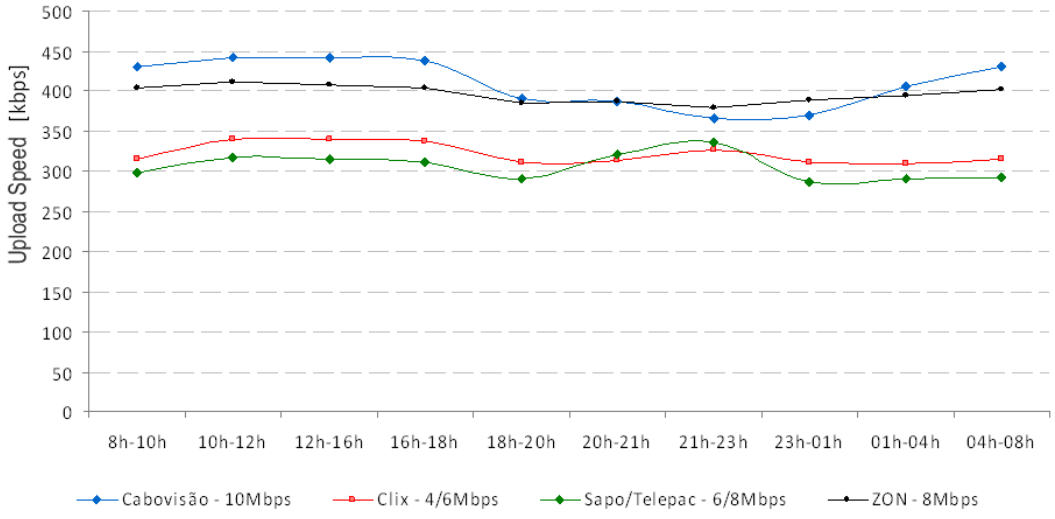


Figure 90 – Average file transfer Upload speed per operator and time period

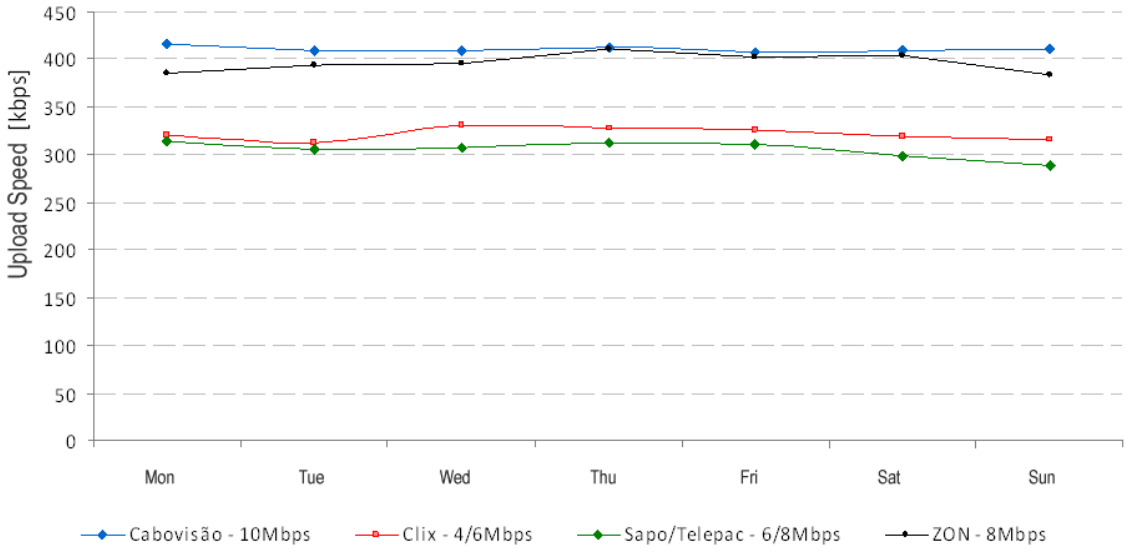


Figure 91 – Average file transfer Upload speed per operator and weekday

Upload speeds present no considerable differences between operators of the same technology, according to Figure 92. The highest speeds in all operators are recorded for the national server, as usual; the lowest speeds are recorded for the servers located in the United States. Sapo always presents the lowest values for each destination.

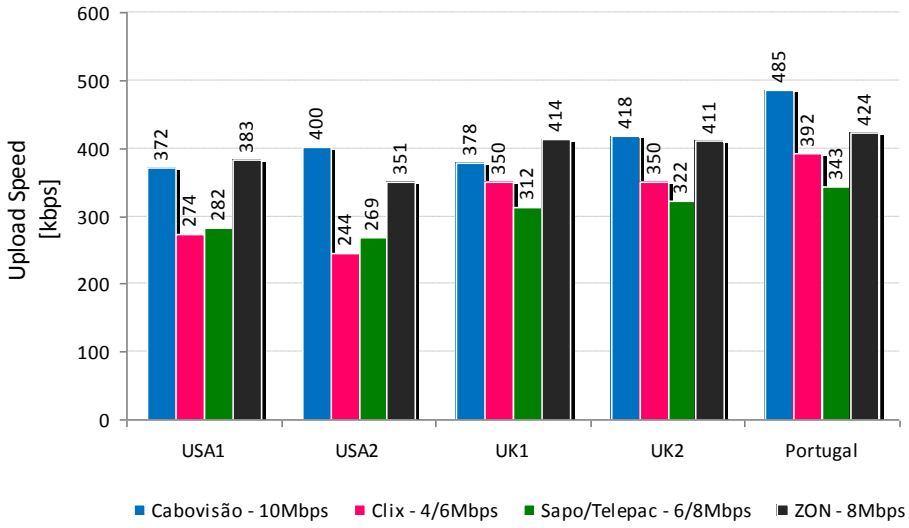


Figure 92 – Average file transfer Upload speed per operator and server

As shown on Figure 93, representing the distribution of upload transfer speed measurements per operator, for the national server, Cabovisão reaches values close to its 512kbps maximum limit, such as ZON.

Clix presents values that are lower than the maximum limit advertised, in the 400-450kbps interval. Nonetheless, some lower values were recorded around 300kbps, as well as some values above the theoretic maximum, close to 700kbps.

Sapo presents a considerable dispersion, with a high incidence on value intervals below 350kbps.

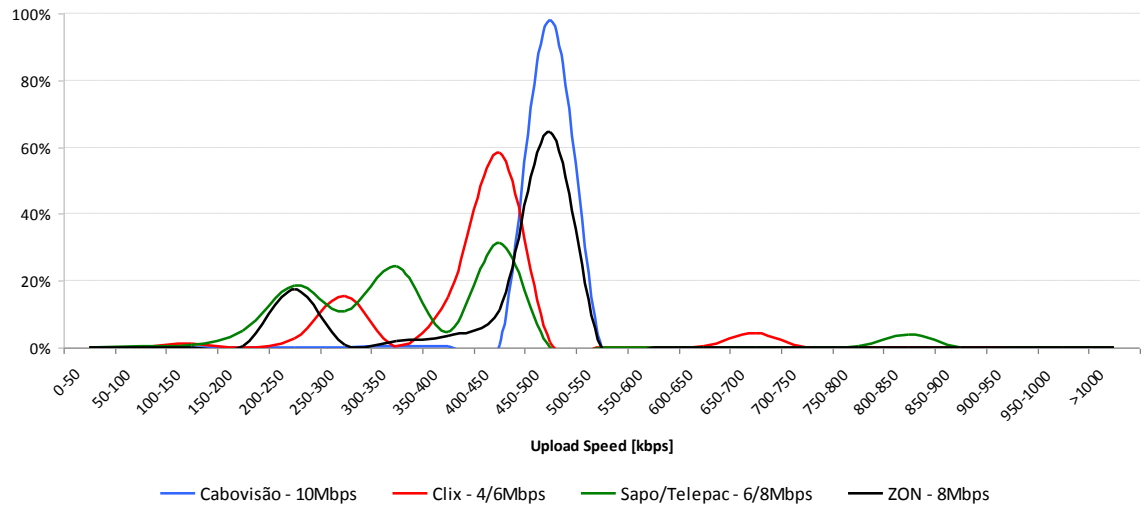


Figure 93 - Frequency distribution per operator and Upload speed category for the National server

As with the Download Transfer Speed indicator, Figure 94 presents the **Relative Speed Index** for file transfer Upload. Cabovisão presents the best results, with 95% of the maximum advertised level. ZON also presents high values. Clix registers 76%, a value that is similar to the one obtained for Download, while Sapo registers the lowest value among the four operators, with a 45% **Relative Speed Index**.

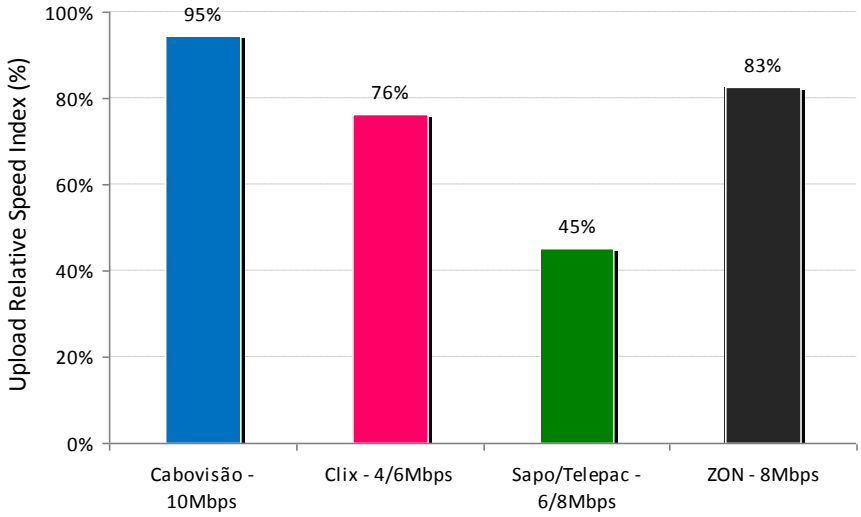


Figure 94 – File Transfer Upload Relative Speed Index per Operator for the National server

Analysing the distribution of the **Relative Speed Index** on Figure 95, it shows that Cabovisão concentrates about 70% of measurements in the 95%-100% RSI interval, showing a low dispersion. ZON, on the same interval, only concentrates 33%, contributing to reduce the final average. Clix concentrates around 45% in the 80%-85% RSI interval, also being negatively affected in the final average due to this indicator's 12% concentration in the 50%-55% interval. In Sapo, over 30% of measurements presented speed records between 40 and 45% of the maximum advertised value.

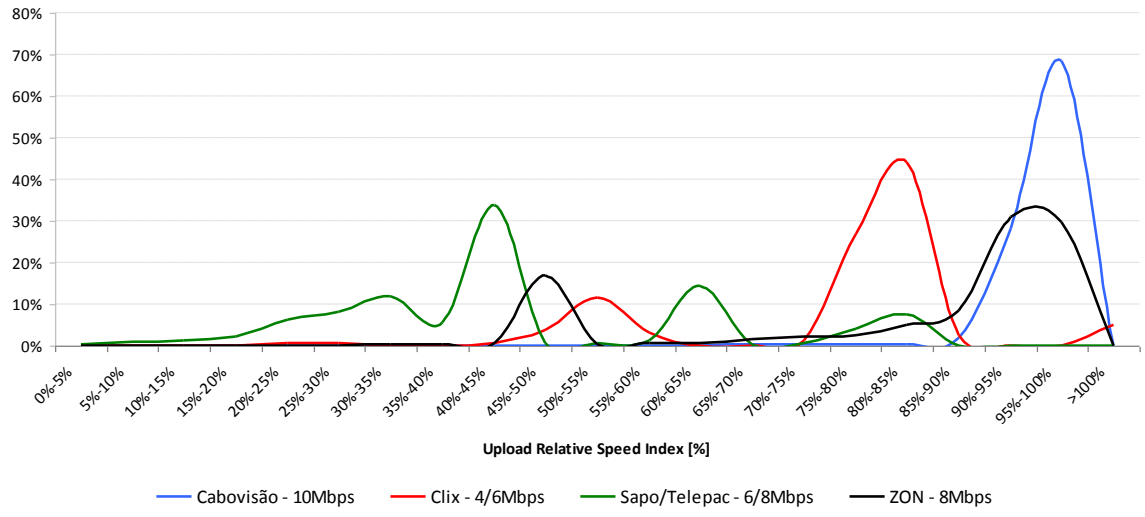


Figure 95 - Frequency distribution of the File Transfer Upload Relative Speed Index per Operator for the National server

Cabovisão obtained the best frequency distribution per category, as shown on Figure 96, providing over 75% of the maximum contracted speed in 99% of the measurements. Clix and ZON present similar distributions, although ZON has a slightly higher rate of lower speed measurements, below than 25% of the maximum speed. In Sapo, 60% of the measurements recorded a **Relative Speed Index** between 25 and 50% of the maximum speed.

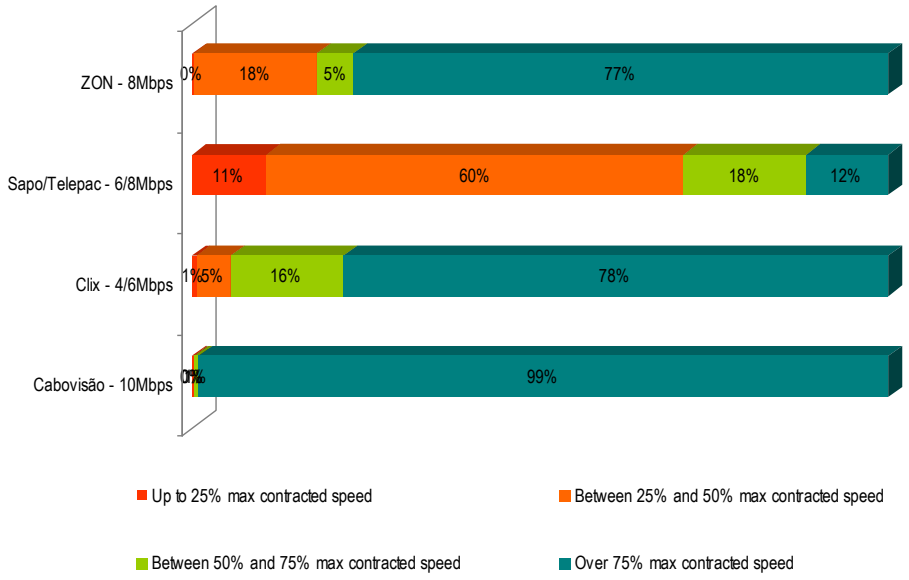


Figure 96 - Frequency distribution per File Transfer Upload Relative Speed Index category per Operator for the National server

Distributions presented on Figure 97 reflect a stability of values in all operators, except for Sapo, which register a lower RSI in the 18h-20h and 23h to 8h periods. This behaviour influences the average recorded and presented on Figure 98.

It is possible to conclude from Figure 99 that there are no major variations during the several weekdays.

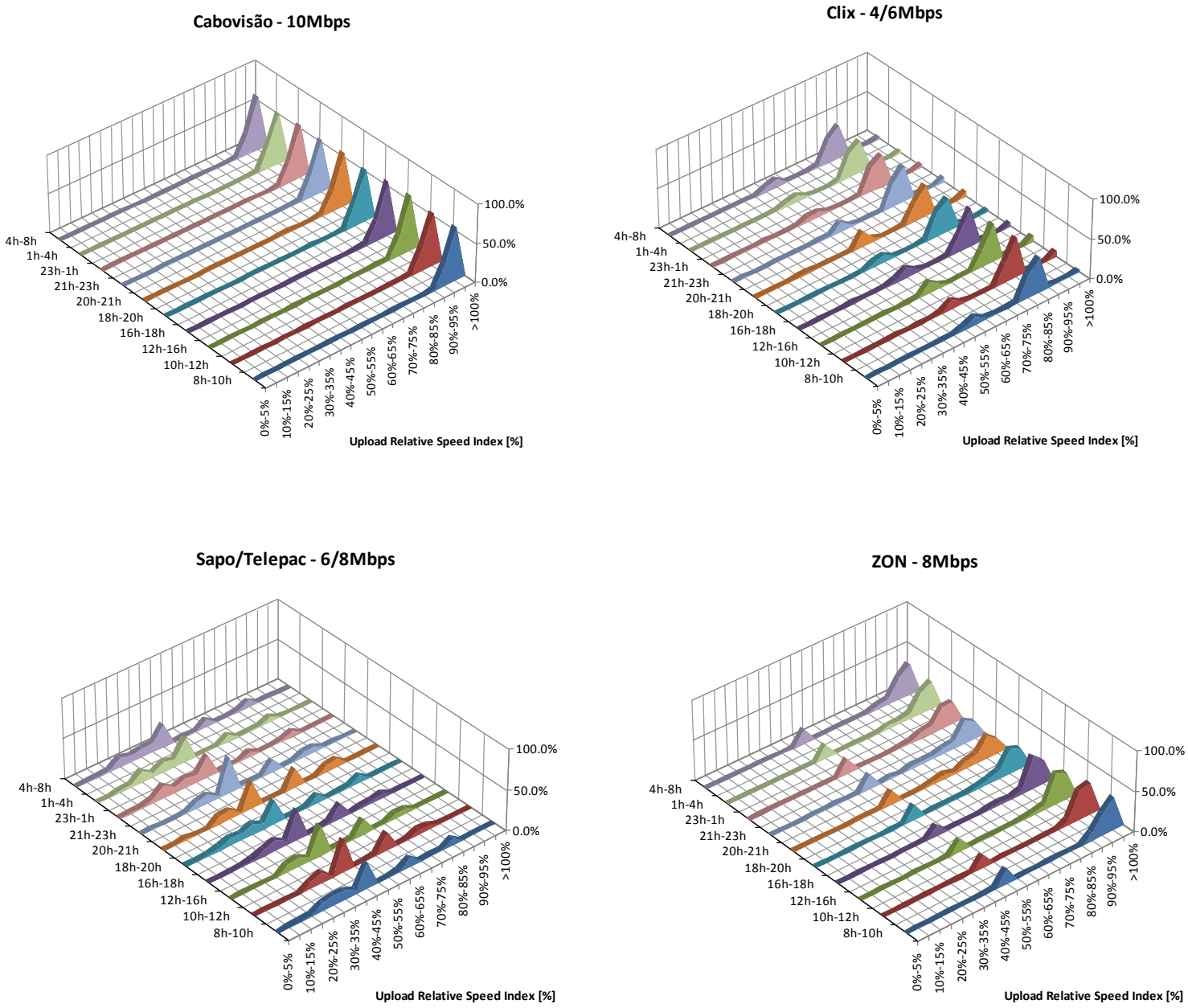


Figure 97 - Frequency distribution per Operator, time period and Relative Speed Index Upload speed category for the National server

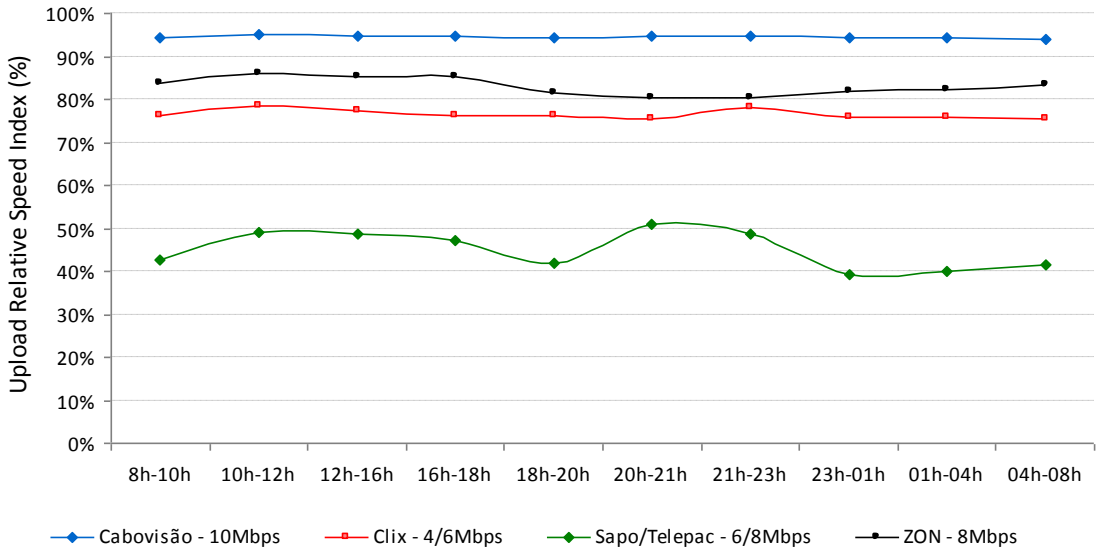


Figure 98 - File Transfer Upload Relative Speed Index per Operator and time period for the National server

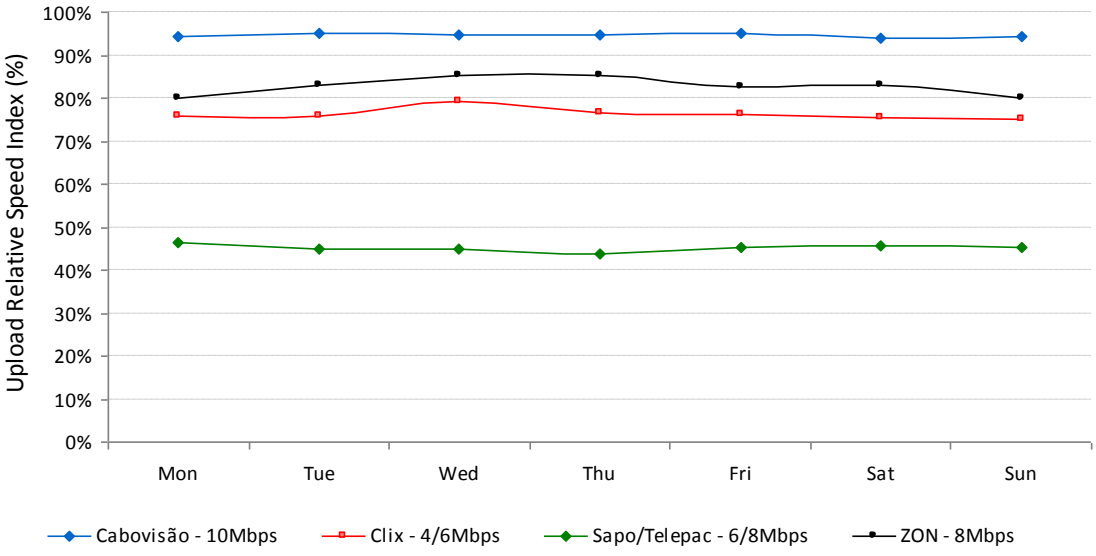


Figure 99 - File Transfer Upload Relative Speed Index per Operator and weekday for the National server

3.4 User's Perception of WEB Browsing

3.4.1 3G Mobile Accesses

3.4.1 WEB Browsing Speed

The Web page browsing experience may differ considerably from the experience of data file transfers. Web Browsing transfer speed, besides the download time, is also a reference indicator concerning the user's perception of Internet browsing. This application's performance depends on the individual performance of the protocols involved during the process of downloading a Web page. These processes can be divided into three main components: the resolution of the IP address (DNS - Domain Name System resolution), the establishment of a logical transport connection (TCP handshake), and the download of the page's HTML content itself, through the HTTP protocol. All these processes have related delay times or latencies that depend from different factors, such as the response time of the DNS servers, the network latency and the available bandwidth. The sum of all these latencies, besides corresponding to the page's total download time, is also considered in the reckoning of its transfer speed.

WEB Browsing transfer speeds presented on Figure 100 show opposite results in Lisbon and Porto, with Optimus presenting the highest values in Lisbon, and the lowest ones in Porto. Vodafone registers the opposite trend. TMN presents a more homogeneous behaviour between Lisbon and Porto. For the same access speed, this application's performance tends to worsen when the network displays higher latency values (in the case of the more remote destinations). For this reason, we recommend that these results be analysed together with the latency values presented for the several destinations, besides the speed achieved for file transfers, particularly on *downlink* (closest indicator of the bandwidth actually available).

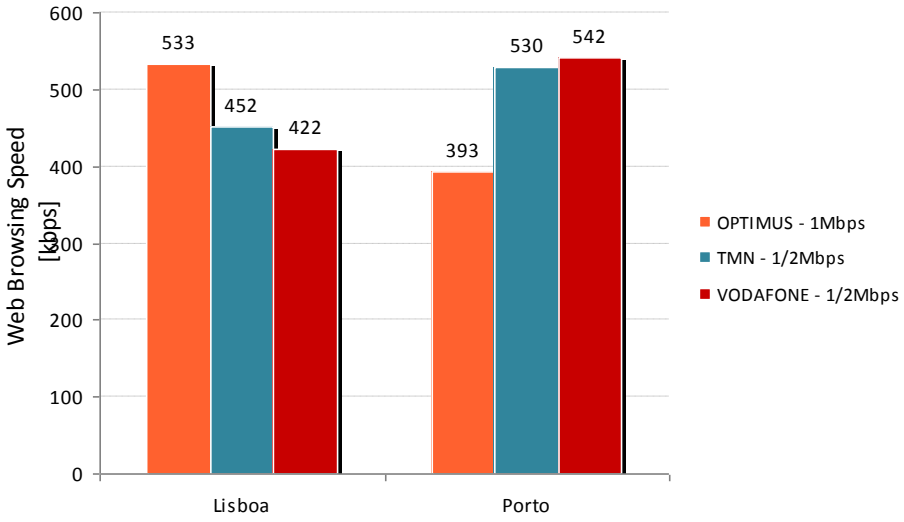


Figure 100 – Average WEB Browsing speed per operator and municipality

The histograms presented below (Figure 101 and Figure 102) confirm the averages previously presented. In terms of dispersion, no speed category clearly stands out, with a concentration of values between 200-600kbps for Vodafone, and between 200-700kbps for Optimus and TMN, in the municipality of Lisbon. In Porto, the intervals with the highest number of measurements are located, for Vodafone and TMN, at 200-800kbps and 300-800kbps, respectively.

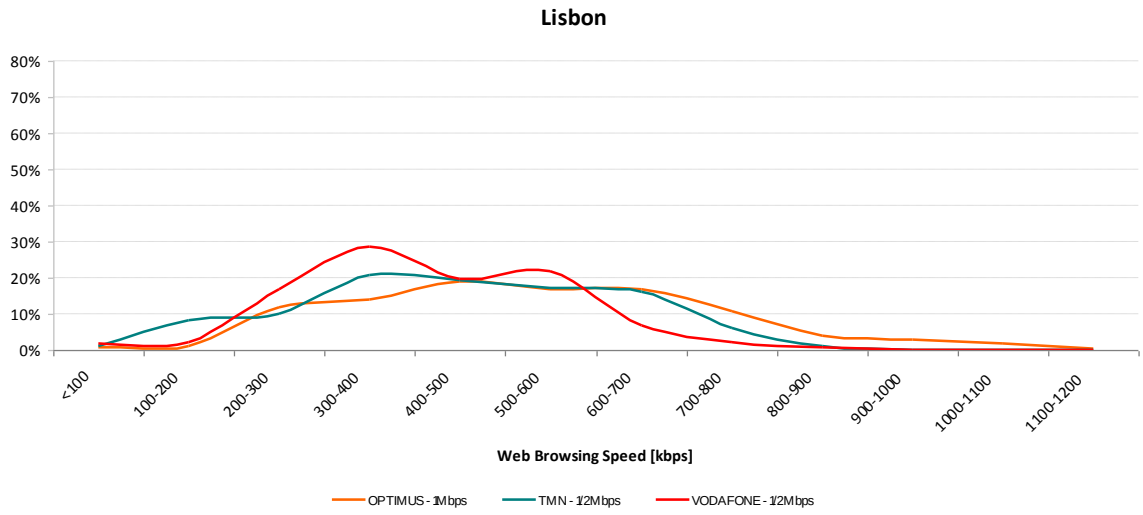


Figure 101 - Frequency distribution per operator and WEB Browsing speed category for the municipality of Lisbon

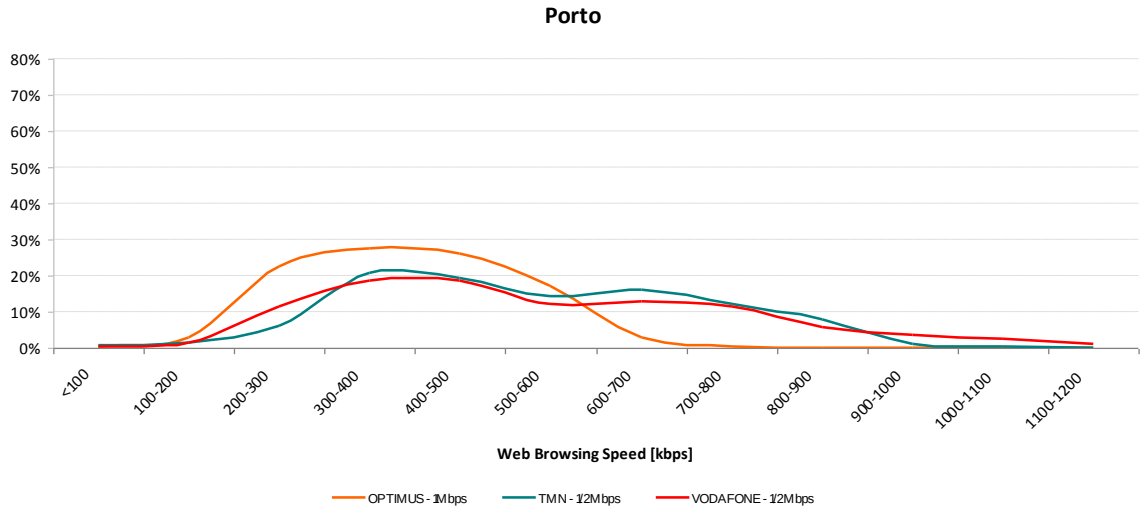


Figure 102 - Frequency distribution per operator and WEB Browsing speed category for the municipality of Porto

Web Browsing speed distributions on Figure 103 and Figure 104 show a slight decrease of distributions along the day, in both municipalities, for the three operators, from 22h to 00h. This fact is probably due to the decrease on the transfer speed registered in 3.2.1.1, on the same schedule, since the latency presents minor variations along the day. The impact of the Web page download times can be seen on the following section.

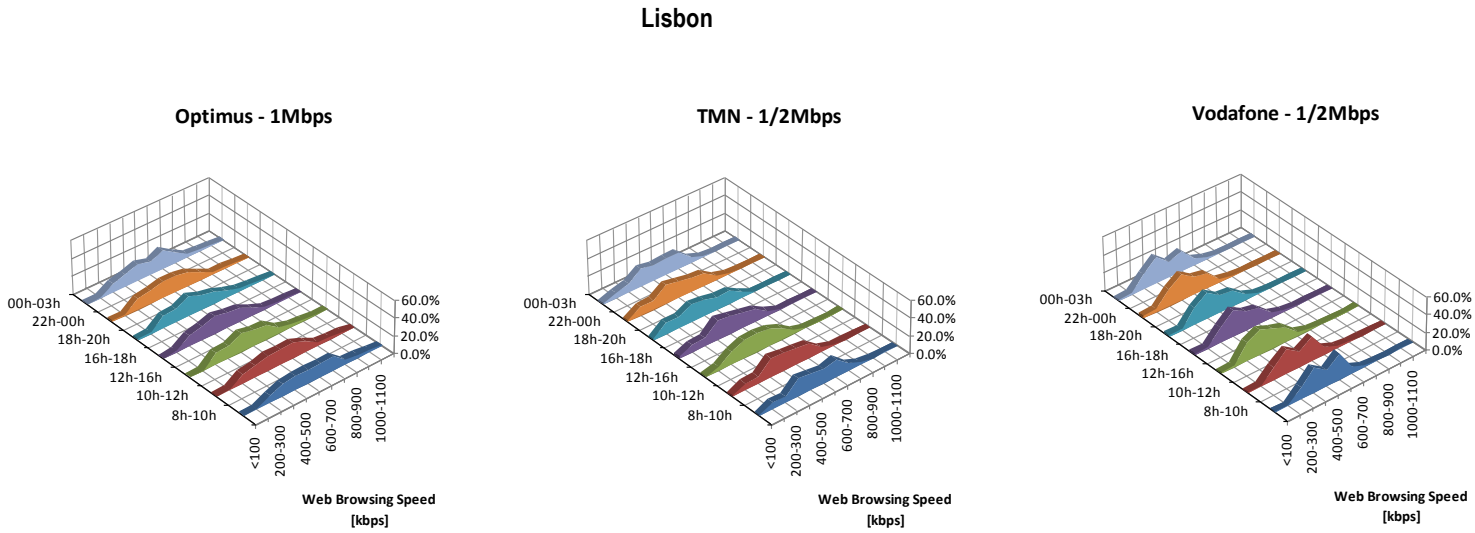


Figure 103 - Frequency distribution per operator, time period and WEB Browsing speed category for the municipality of Lisbon

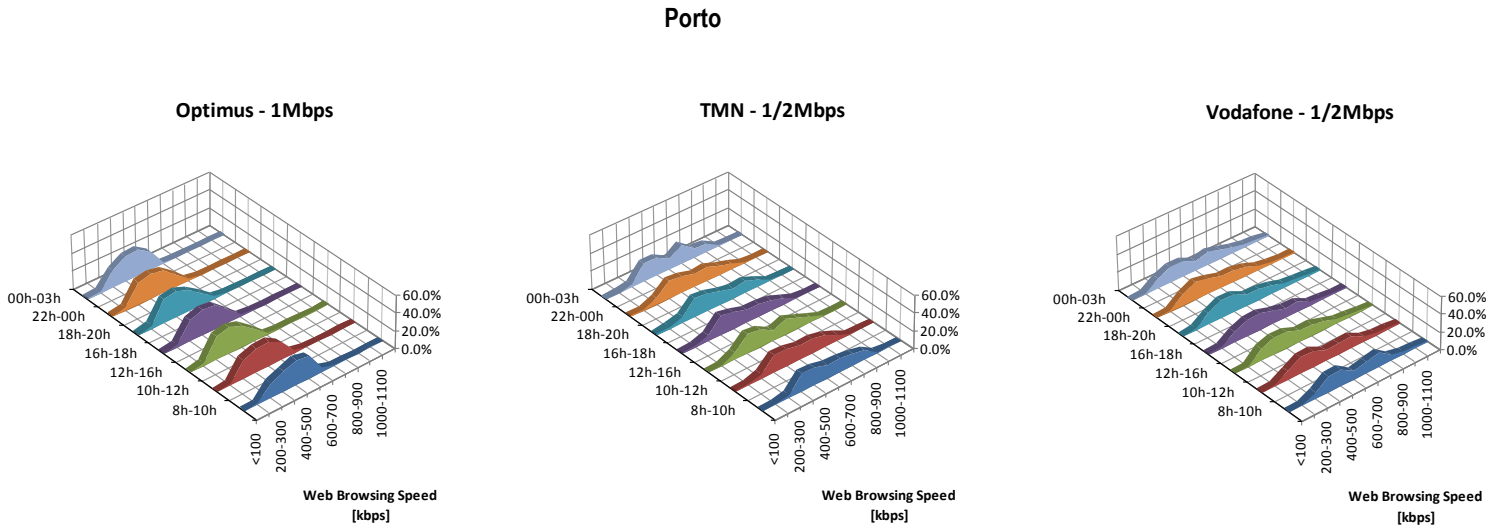


Figure 104 - Frequency distribution per operator, time period and WEB Browsing speed category for the municipality of Porto

The performance of the three operators is relatively constant during the week. The distribution pattern along the day continues slightly unchanged in both municipalities, for TMN (see Figure 105 and Figure 106).

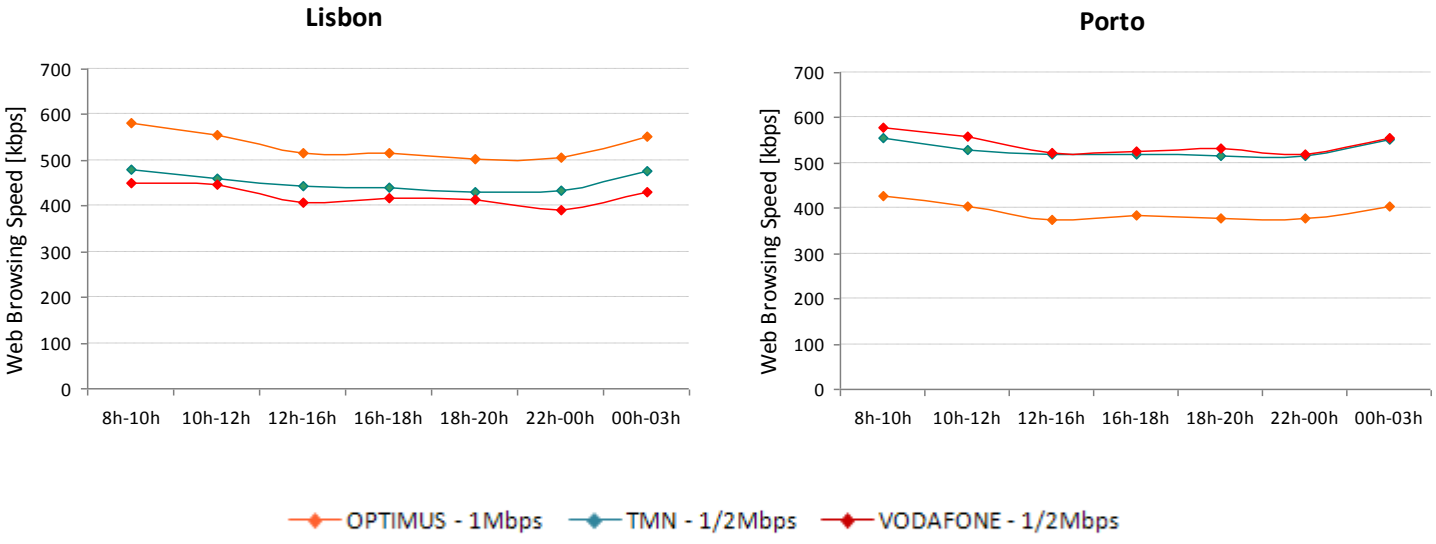


Figure 105 – Average WEB Browsing speed per operator, time period and municipality

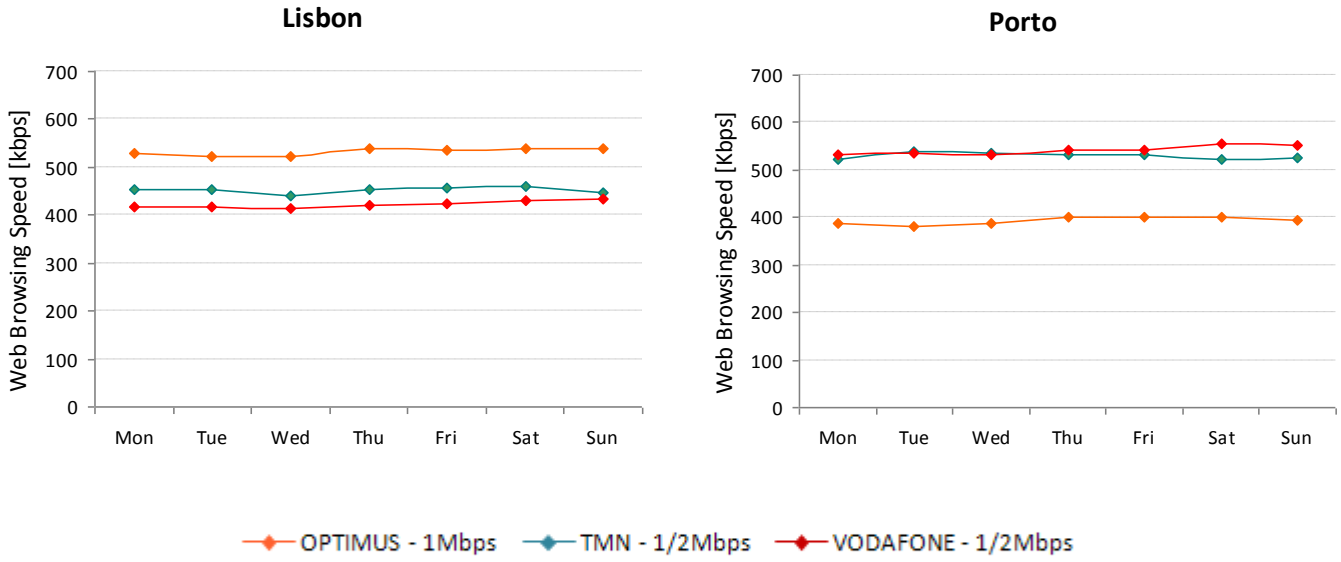


Figure 106 – Average WEB Browsing speed per operator, weekday and municipality

Web Browsing average speeds vary depending on the Web page and on the available access speed, among other aspects, as already mentioned. Thus, the highest values per operator, on average, were recorded for the Web page hosted on FCCN's server, followed by the servers located in the United Kingdom and in the United States. The lowest value was recorded for server USA2, located on the West coast of the United States.

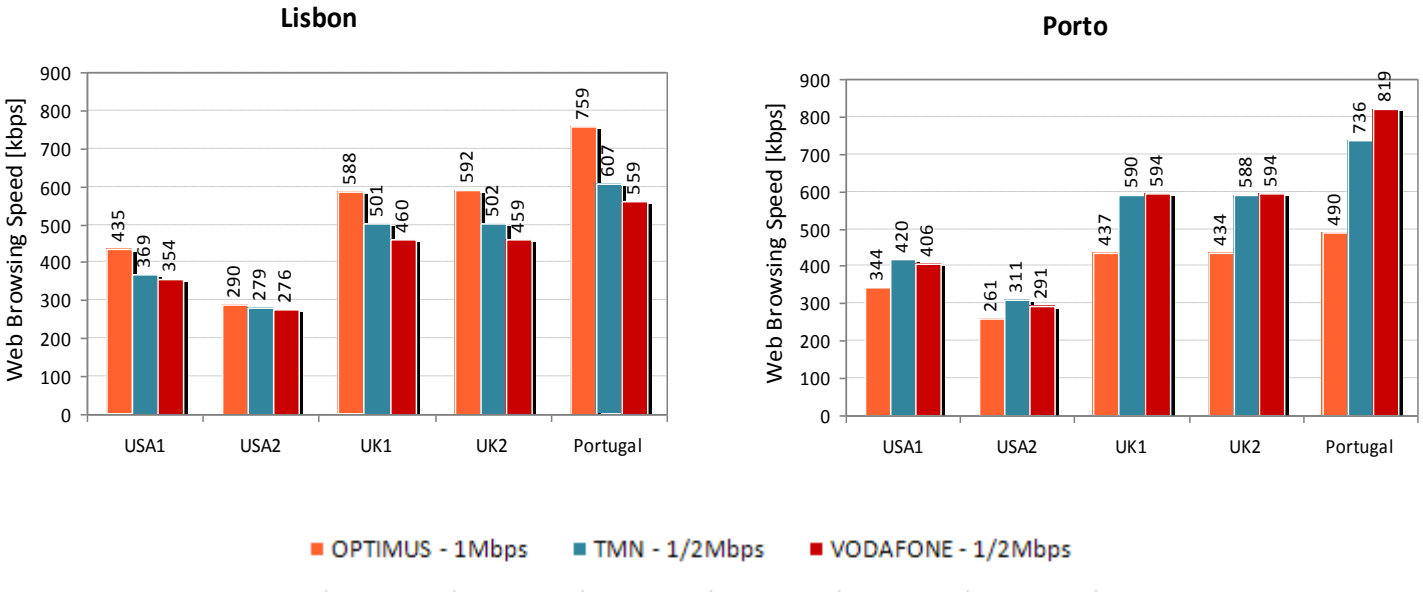


Figure 107 - Average WEB Browsing speed per operator, server and municipality

Analysing the WEB Browsing speed's frequency distribution, per municipality, for the national server, on Figure 108 and Figure 109, it shows that Optimus presents the highest dispersion of values in Lisbon and the lowest in Porto, while presenting the highest speeds in Lisbon and the lowest in Porto, which may be related to the high latency recorded by this operator, for this municipality.

Vodafone presents a considerable dispersion in the municipality of Porto, where it also presents, on average, the highest speed and the best global result of this study, in terms of WEB Browsing speed, which may be related to the low latency values recorded, together with a larger available bandwidth (registered on 3.2.1.1).

TMN registers a similar dispersion on both municipalities presenting, however, higher average speeds in the municipality of Porto than in Lisbon.

Comparing the distribution of average values for all destinations (Figure 108 and Figure 109) and only the distributions for the national server (Figure 101 and Figure 102), it is possible to conclude that the international accesses are, in fact, responsible for the great dispersion of results, simultaneously diverting the concentration of measurements made for lower values.

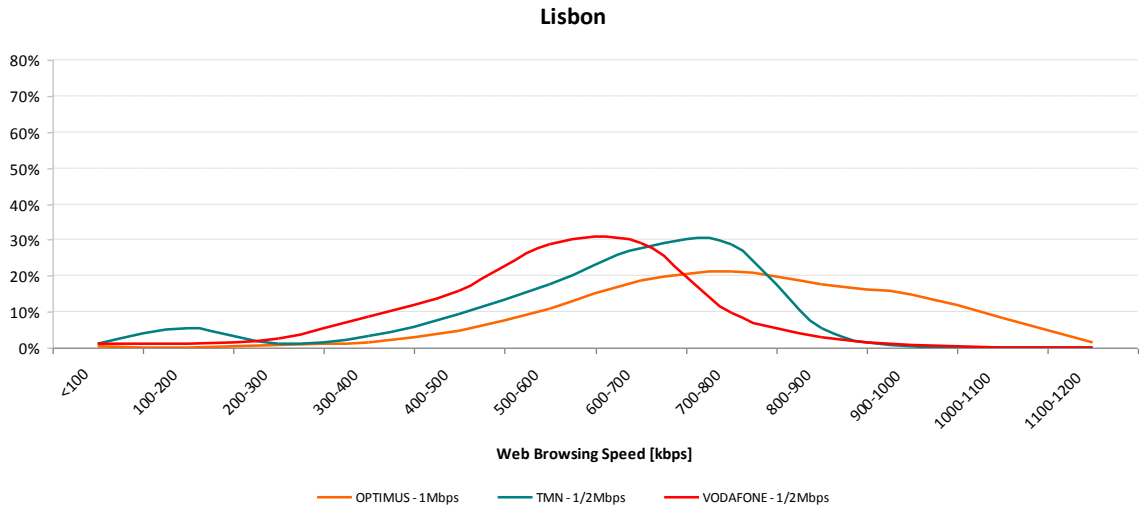


Figure 108 - Frequency distribution per operator and WEB Browsing speed category for the municipality of Lisbon for the National server

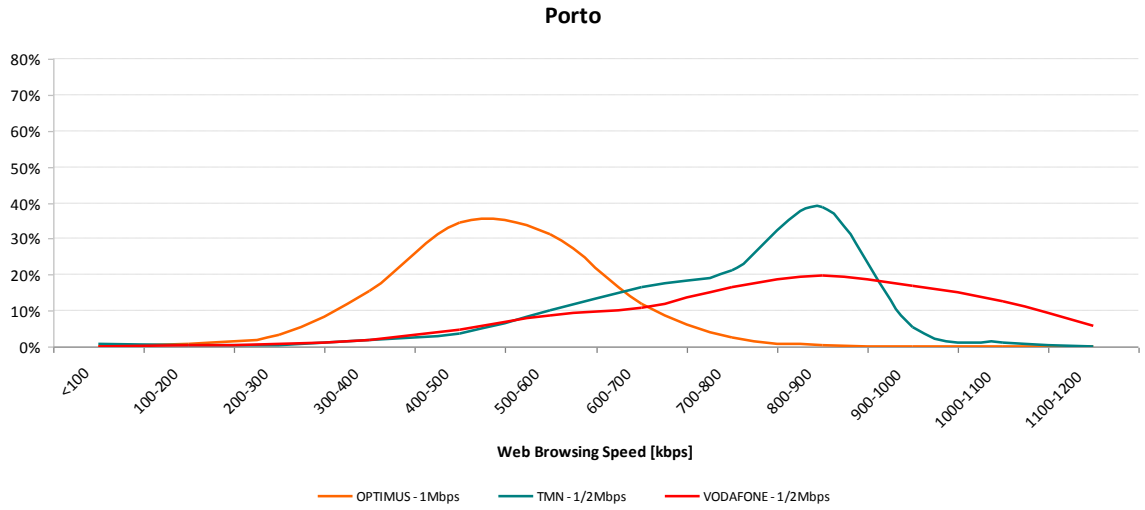


Figure 109 - Frequency distribution per operator and WEB Browsing speed category for the municipality of Porto for the National server

3.4.2 Web page download time during WEB Browsing

Web page download times during Web Browsing are in general more perceivable to the end user, since they represent the waiting time for viewing the whole page he/she desires. This indicator is related to the one previously presented, within the scope of the Web page's download speed during Web browsing.

According to Figure 110, in spite of the differences registered in terms of transfer speed for a standard WEB page, Optimus presents an average record of 1.7 seconds in Lisbon, obtaining the lowest time among the three national operators, in this municipality. In Porto, the opposite happens, with Optimus recording an average value of 2.5 seconds. TMN and Vodafone also present differences for Lisbon and Porto, although reaching very similar figures in both cities.

In general, for the standard WEB page, maximum time differences represent about 0.4 seconds, and do not seem to be perceivable during the usage experience.

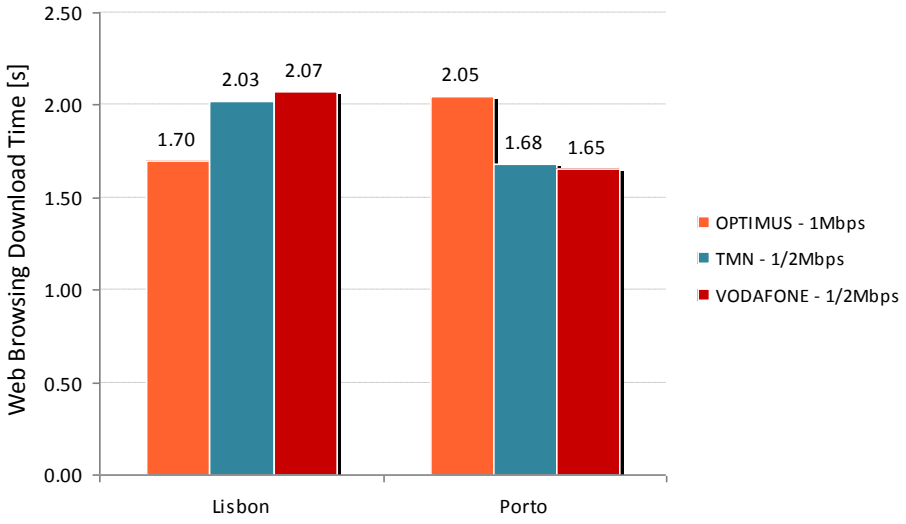


Figure 110 – Average Web page Download Time during WEB Browsing per operator and municipality

As shown on the distributions below (Figure 111 and Figure 103), for both cities under study, Vodafone and TMN present very similar download time values, although TMN, in Lisbon, shows about 4% of measurements in the 5-6 seconds interval, a value which stands beyond the perceived comfort zone (4 seconds). Even so, Optimus registers the greatest difference, in Porto, with a highest dispersion than in Lisbon and showing, even towards its competitors, some download time records in the 4-5 seconds interval.

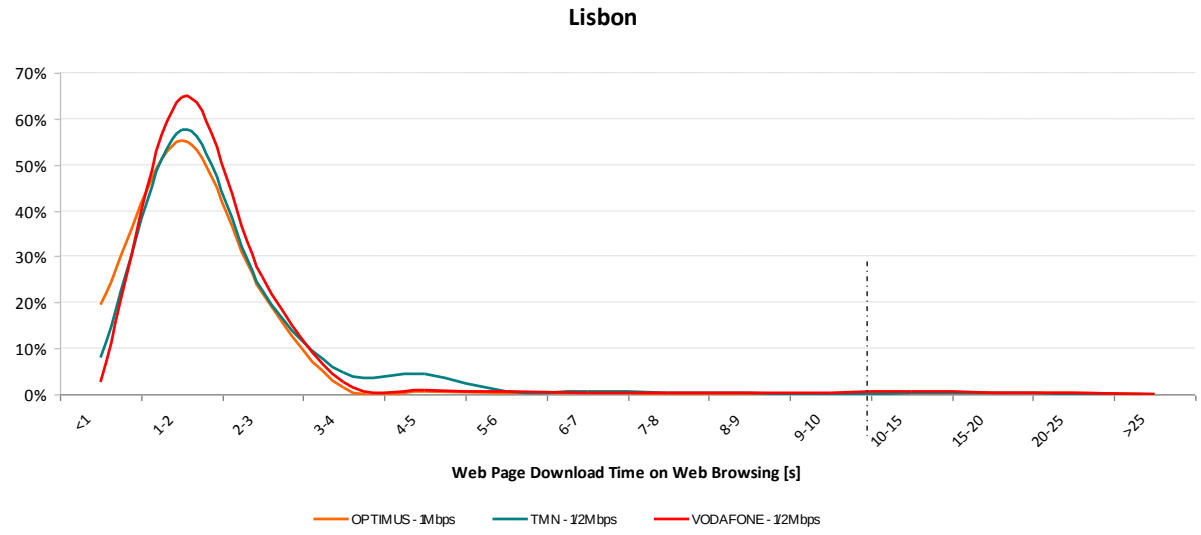


Figure 111 - Frequency distribution per operator and Web page Download time category during WEB Browsing for the municipality of Lisbon

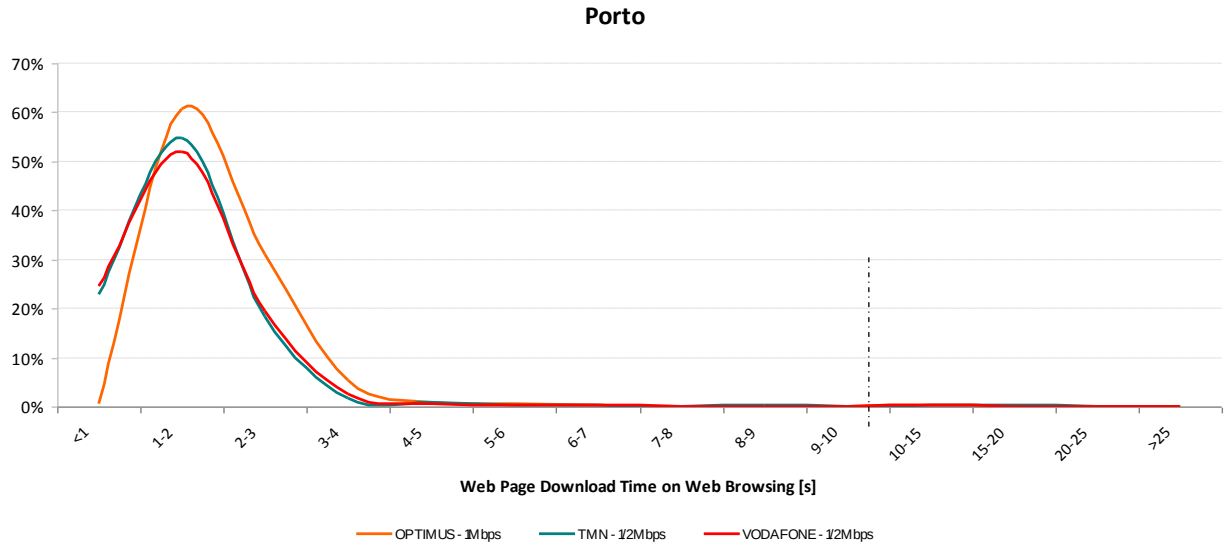


Figure 112 - Frequency distribution per operator and Web page Download time category during WEB Browsing for the municipality of Porto

The transfer time varies along the day. The greatest variation was recorded for Vodafone, in Lisbon, with a 0.6 seconds difference between the fastest and the slowest period of the Web page transfer; and of 0.4 seconds in the case of Optimus. These differences, however, are not perceivable during the end user's final experience (Figure 115). The same conclusion may be reached for the values registered along the week (Figure 116).

Lisbon

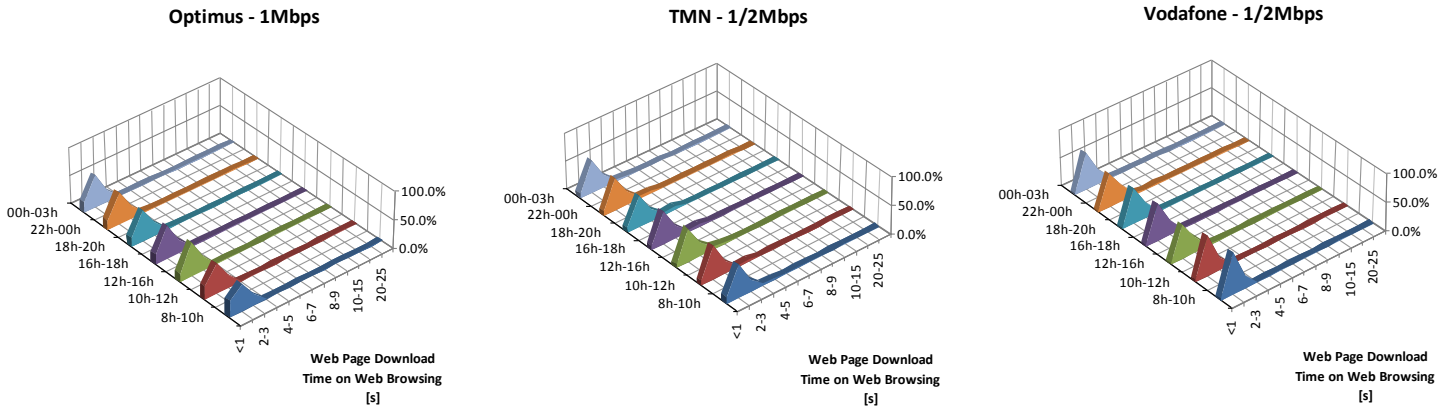


Figure 113 - Frequency distribution per operator, time period and Web page Download time during WEB Browsing for the municipality of Lisbon

Porto

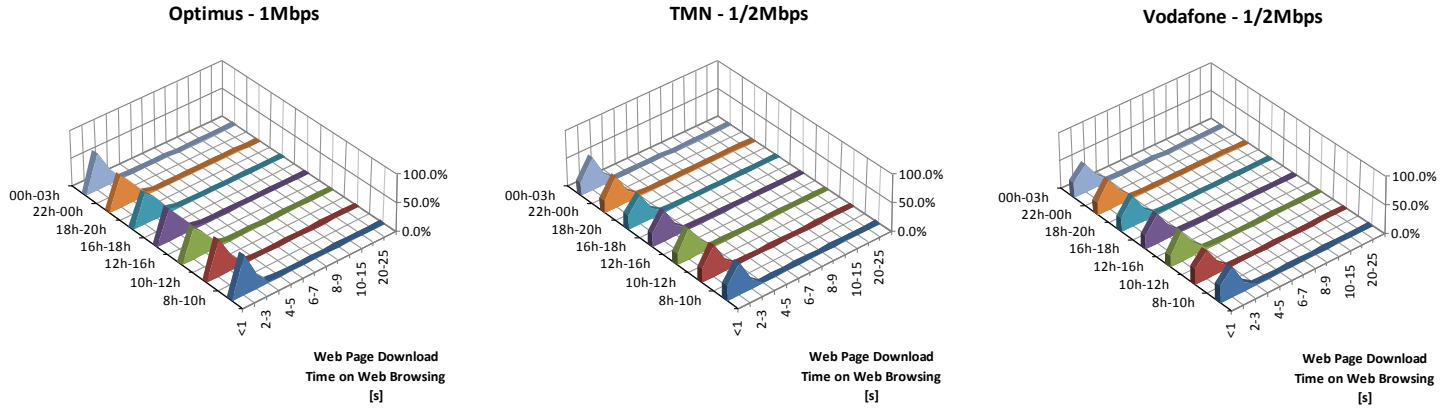


Figure 114 - Frequency distribution per operator, time period and Web page Download time during WEB Browsing for the municipality of Porto

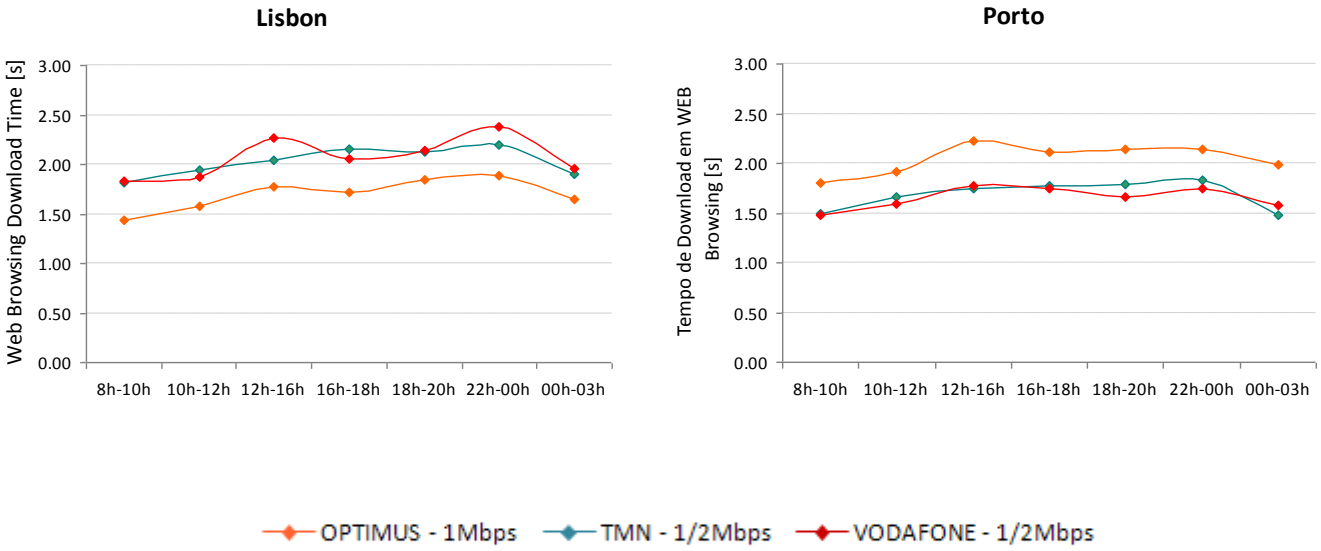


Figure 115 – Average Web page download time during WEB Browsing per operator, time period and municipality

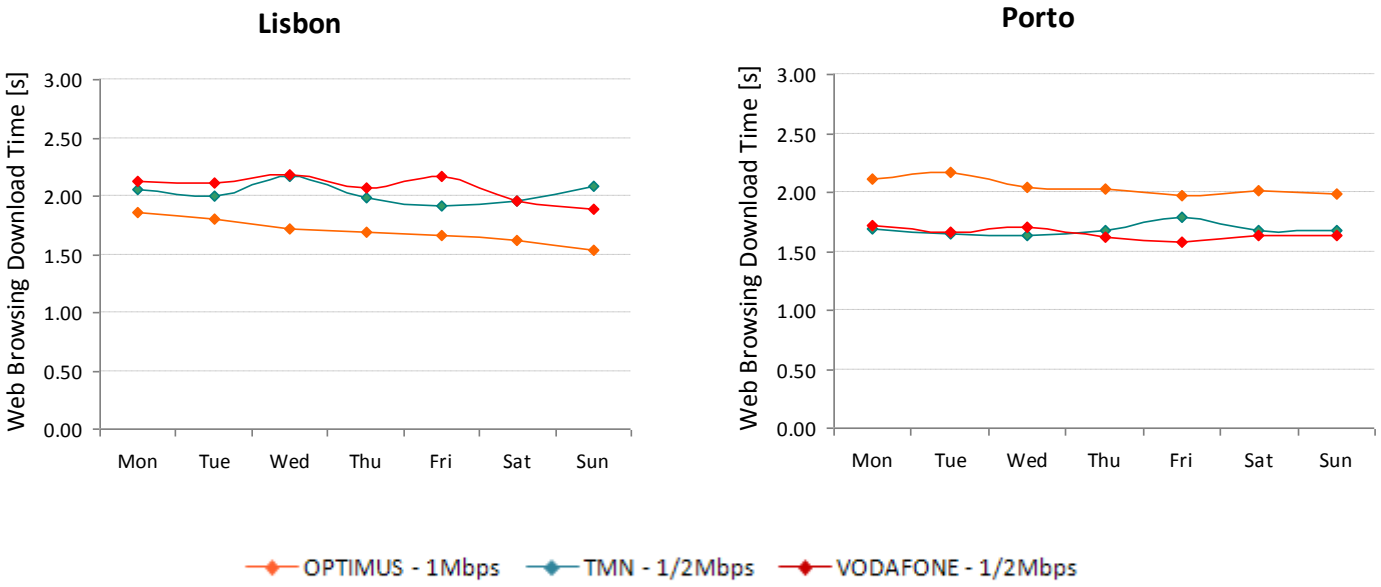


Figure 116 – Average Web page Download time during WEB Browsing per operator, weekday and municipality

As with the Web page download speed during Web Browsing, the download times of the standard Web page present higher values for the servers located in the United States (see Figure 117), which could be due to the greater latency for these servers, together with the bandwidth constraints on the international accesses.

For example, a Vodafone user in Porto, waits an average 1.04 seconds to totally view the test Web page hosted at FCCN, while the same page, hosted by server USA2 in Seattle, takes 2.61 seconds (on average) to totally download, i.e., more than 1.6 seconds. In this municipality, all operators registered a similar behaviour as previous described.

Regarding accesses to the national server, in the Municipality of Lisbon, Vodafone and TMN present similar values, of around 1.6 seconds. Also in this municipality, Optimus achieves the lowest time with 1-17 seconds.

The situation reverses for Optimus in the municipality of Porto, where it presents the highest time. Vodafone achieves the best result in this municipality with the average download time of 1.04 seconds.

The same ranking per municipality is valid for the remaining servers, except for the connections to the United States in the municipality of Porto, where TMN obtains the best results, although with a negligible difference.

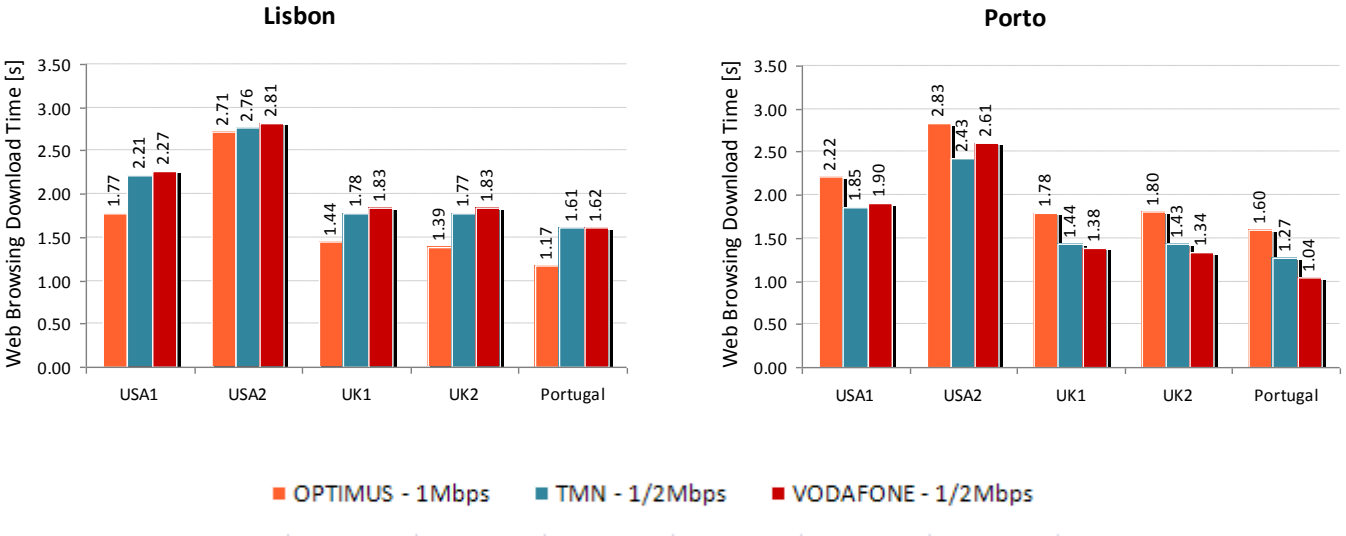


Figure 117 – Average Web page Download time during WEB Browsing per operator, server and municipality

The analysis of Figure 118 and of Figure 119, for the operators with highest Web page download times in Lisbon and Porto, Vodafone and Optimus respectively, makes it possible to verify that almost all measurements are concentrated above 1 second.

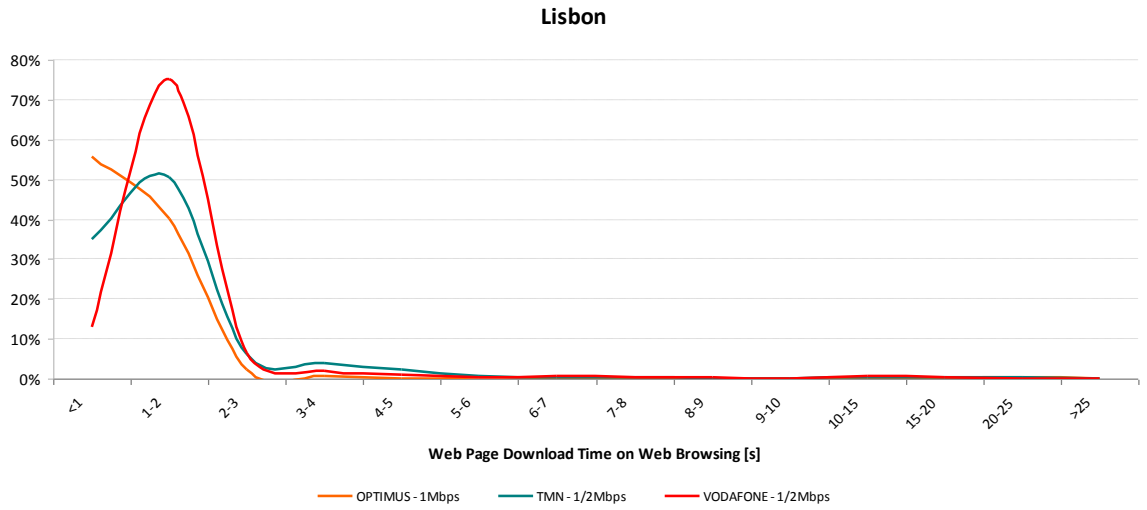


Figure 118 - Frequency distribution per operator and Web page Download time category during WEB Browsing for the municipality of Lisbon for the National server

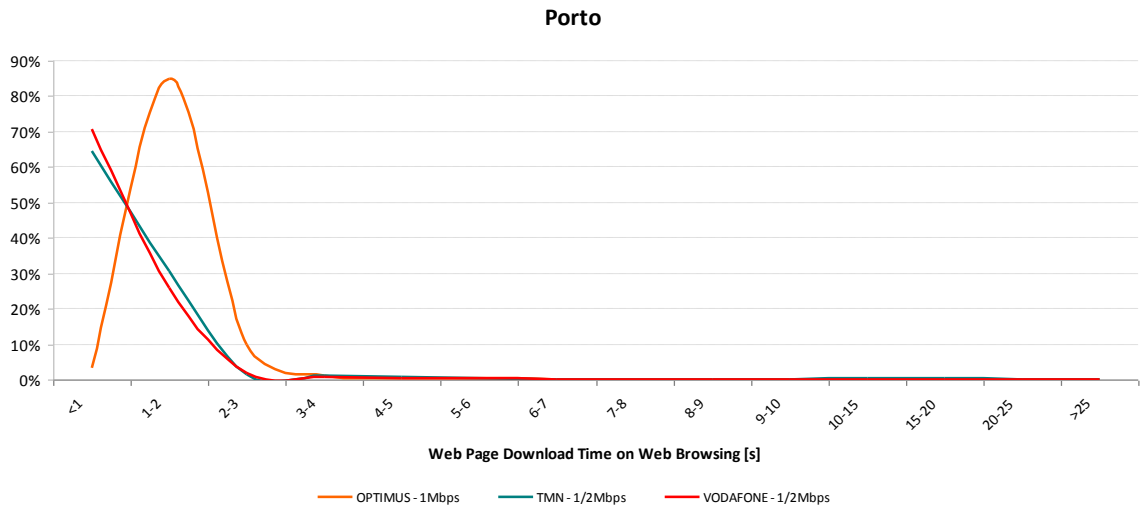


Figure 119 - Frequency distribution per operator and Web page Download time during WEB Browsing for the municipality of Porto for the National server

3.4.2 Fixed Accesses

3.4.2.1. WEB Browsing Speed

The average transfer speed during WEB Browsing, on Figure 120, shows results that are consistent with the maximum speed advertised by each tariff scheme, i.e., the ones that provide higher speeds are also the ones enabling higher WEB Browsing speeds.

The WEB Browsing speed, however, should not be compared with the maximum advertised speed, since the type of application used for WEB Browsing does not make it possible to exploit the whole speed provided in theory.

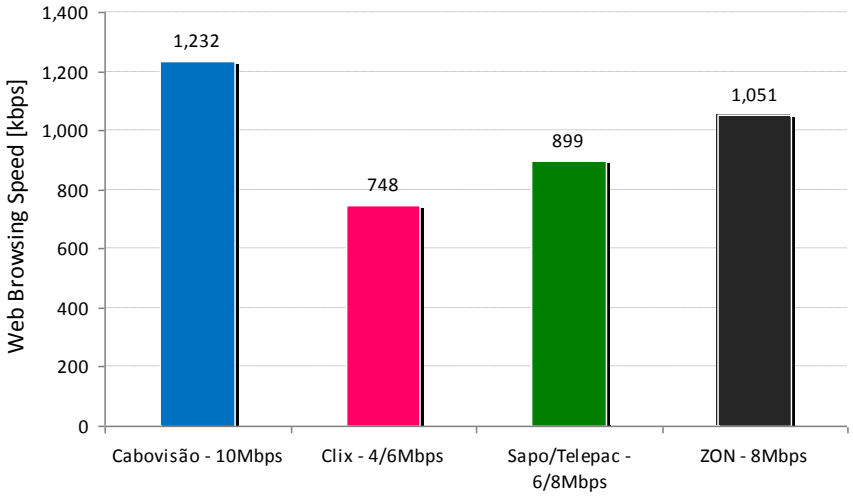


Figure 120 – Average speed during WEB Browsing per operator

Analysing Figure 121, concerning the frequency dispersion per operator and per WEB Browsing speed category, it shows that most accesses present records in the speed ranges between 250 and 1750Kbps. The lowest values are due to the accesses to the United States, with a particular influence of the server located in the West coast. The values around the 750-1000kbps range mostly refer to the accesses to servers in the UK, and the remaining distribution, up to the highest values, refers to the accesses to the National server, which a registers a greater variety of experienced

speeds. The concentration pattern, considerably close for all operators in the lowest speeds, confirms the convergence of speed values during WEB browsing for the servers located in the United States, as can be verified by the viewing the averages per destination server, on Figure 125.

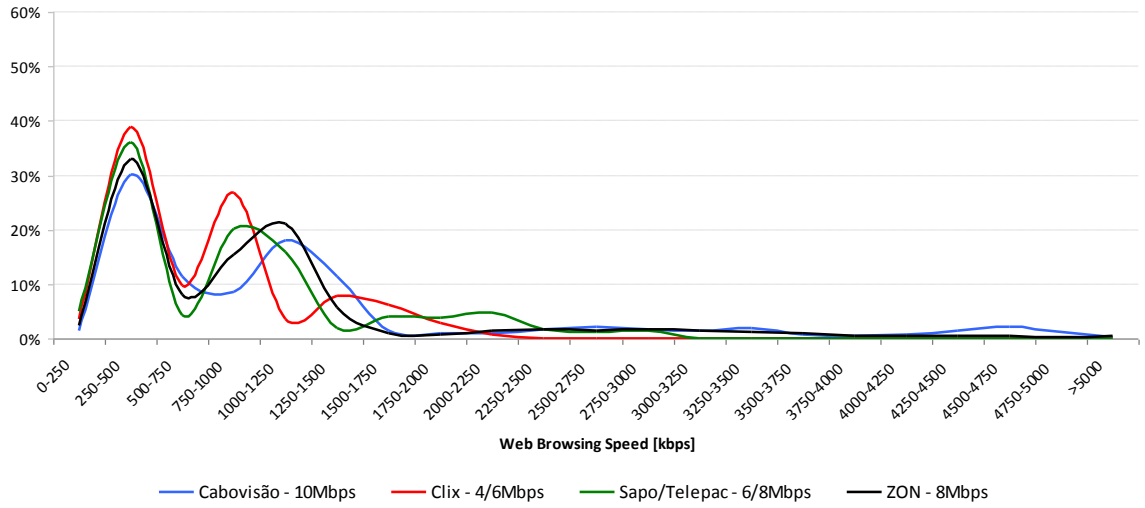
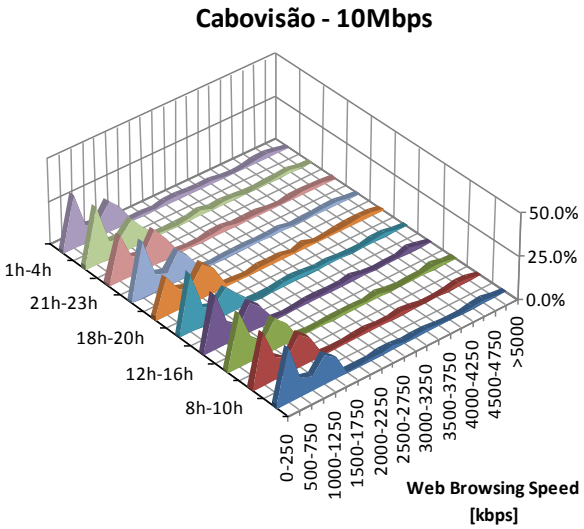
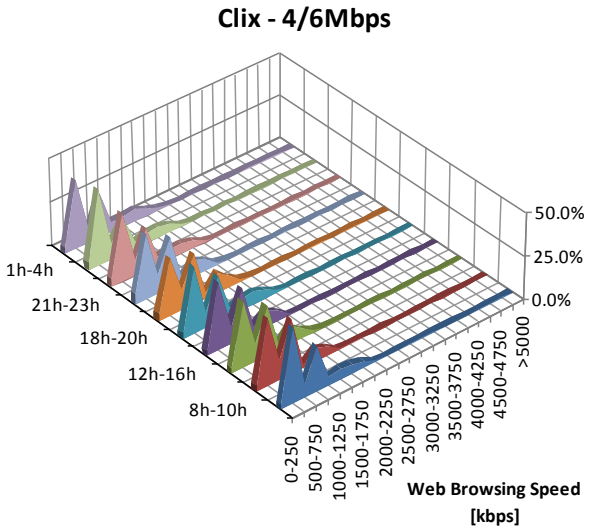


Figure 121 - Frequency distribution per operator and WEB Browsing speed category





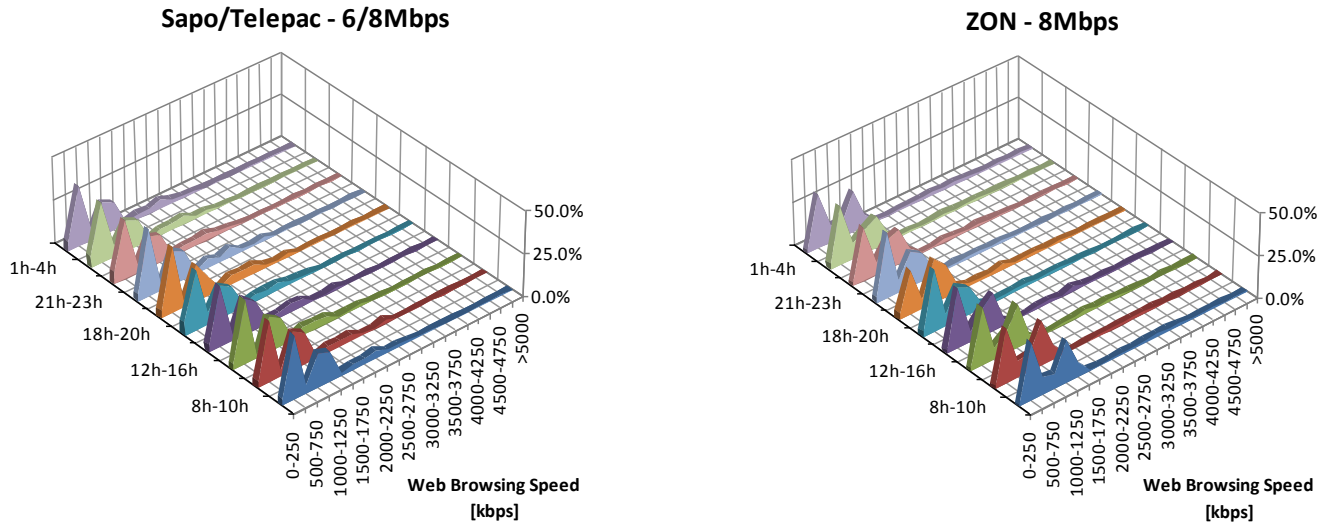


Figure 122 - Frequency distribution per operator, time period and WEB Browsing speed category

No major WEB Browsing speed differences were recorded, either along the day, or during the week, for any operator. It should be noted that Sapo presented an almost constant value (see Figure 123 and Figure 124).

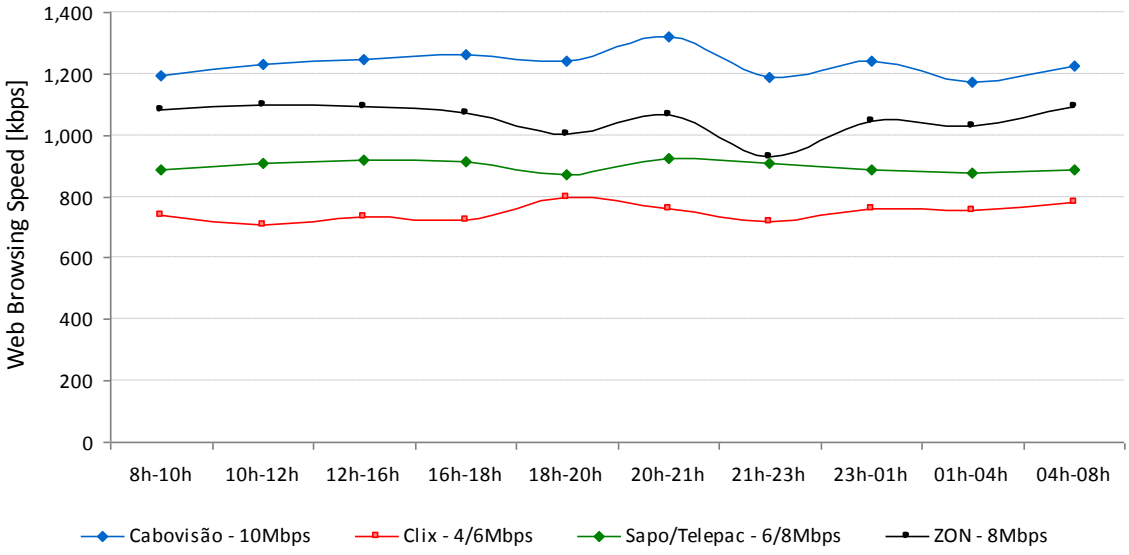


Figure 123 – Average WEB Browsing speed per operator and time period

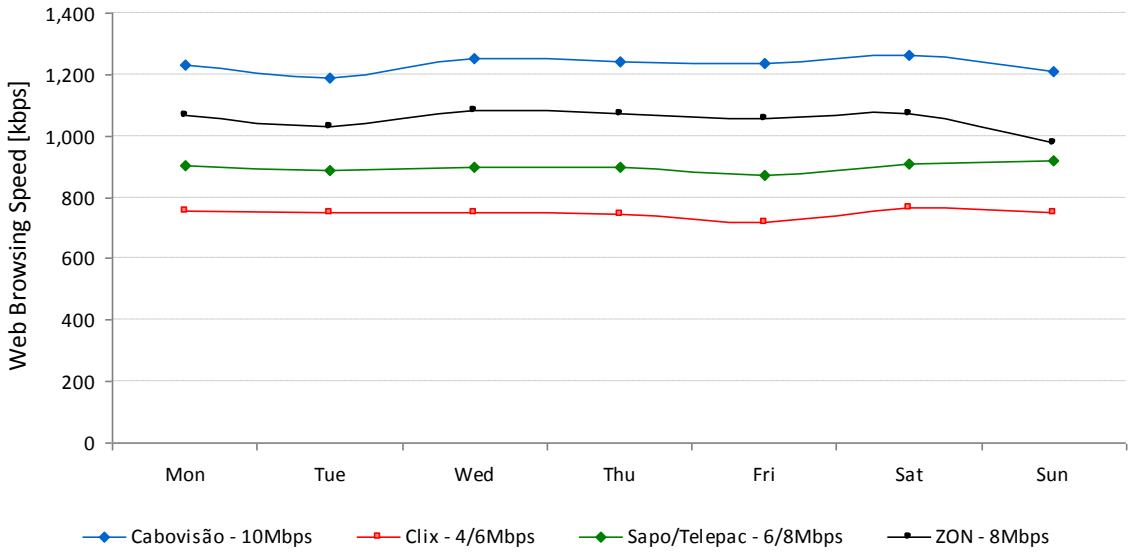


Figure 124 – Average WEB Browsing speed per operator and weekday

Figure 125 shows that the highest speeds are reached when the WEB page is hosted on the national server, as with the mobile access. It should be noted that the differences between operators are lower for international servers, particularly on the servers located in the United States, where all operators present very similar WEB Browsing speeds.

For the national server, the value differences recorded confirms the difference of maximum speeds of the corresponding tariff schemes.

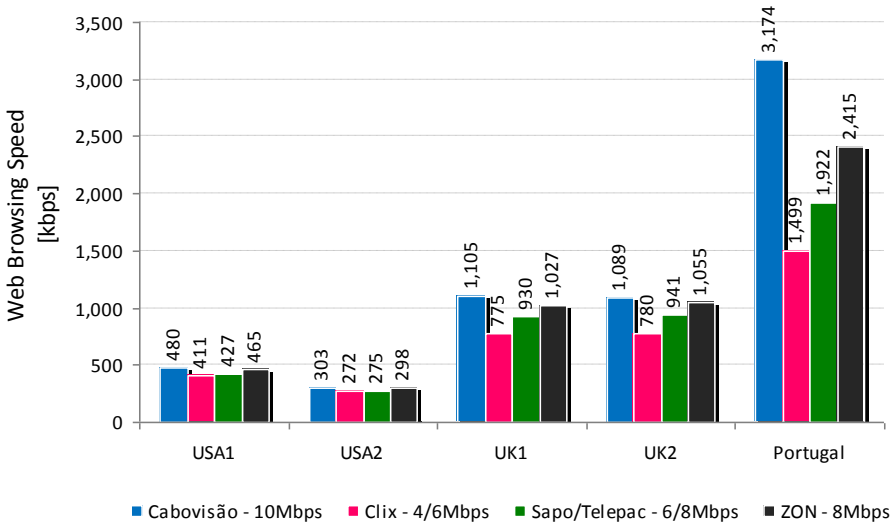


Figure 125 - Average WEB Browsing speed per operator and server

In terms speed distribution during WEB browsing for the national server, different behaviours were recorded among operators. Clix presents about 40% of measurements within a clearly defined interval (1250 - 2250 Kbps). The remaining operators present considerable dispersions, with some predominance of Sapo in the 1750-2500 Kbps interval. Operators Cabovisão and ZON, with a similar technology, present the greatest dispersions.

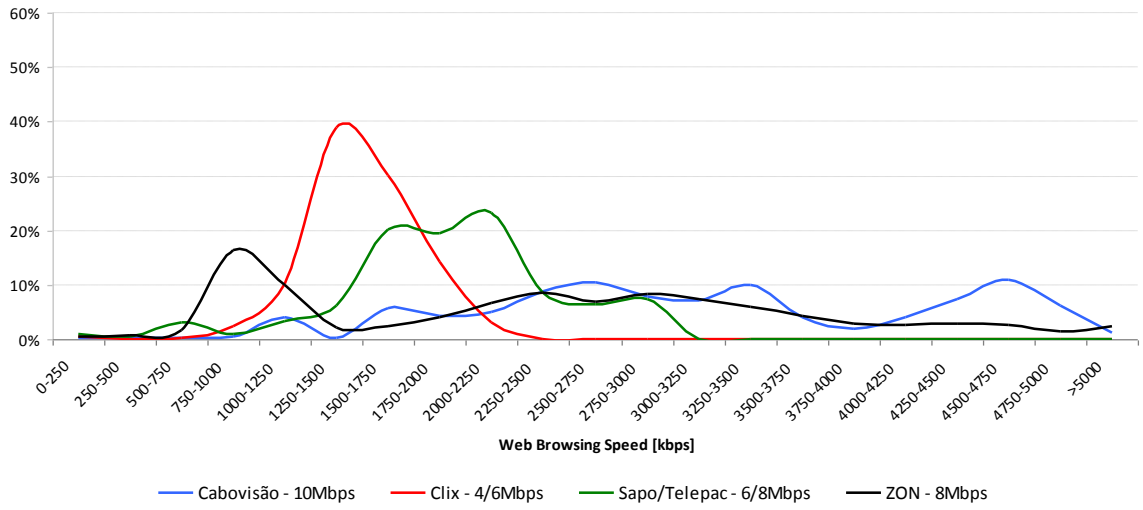


Figure 126 - Frequency distribution per operator and WEB Browsing speed category for the National server

3.4.2.2. Web page Download time during Web Browsing

Considering the download time during Web Browsing, there are no significant differences between fixed operators, varying 0.23 seconds at the most, as with the mobile service, as shown on Figure 120.

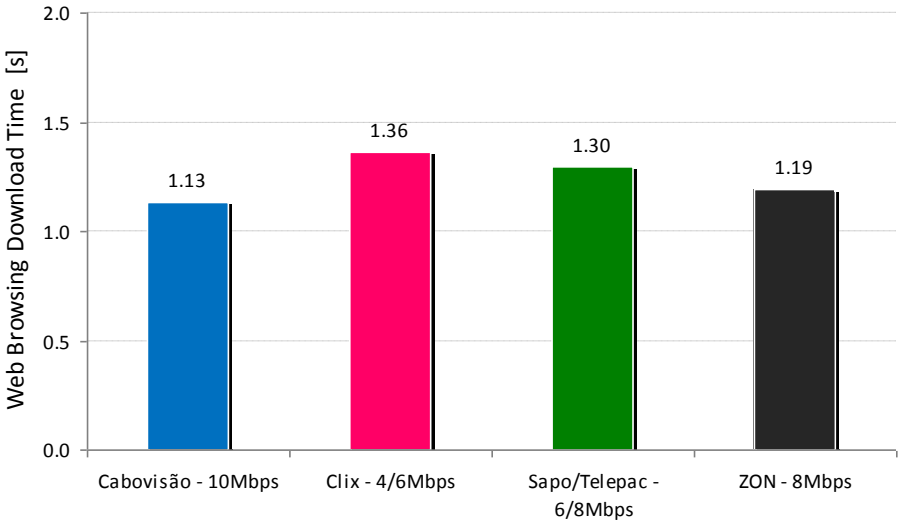


Figure 127 – Average Web page download time during Web Browsing per operator

Analysing the distribution of measurements by duration intervals on Figure 128, it is possible to conclude that about 40% of the measurements, for all operators, are concentrated between 0.5 and 1 second.

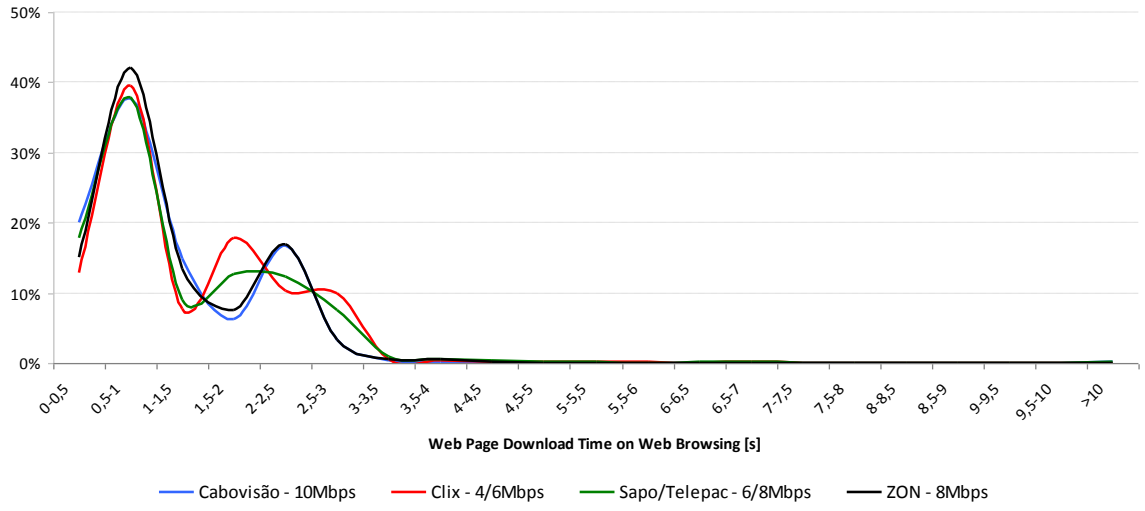


Figure 128 - Frequency distribution per operator and Web page Download time during WEB Browsing

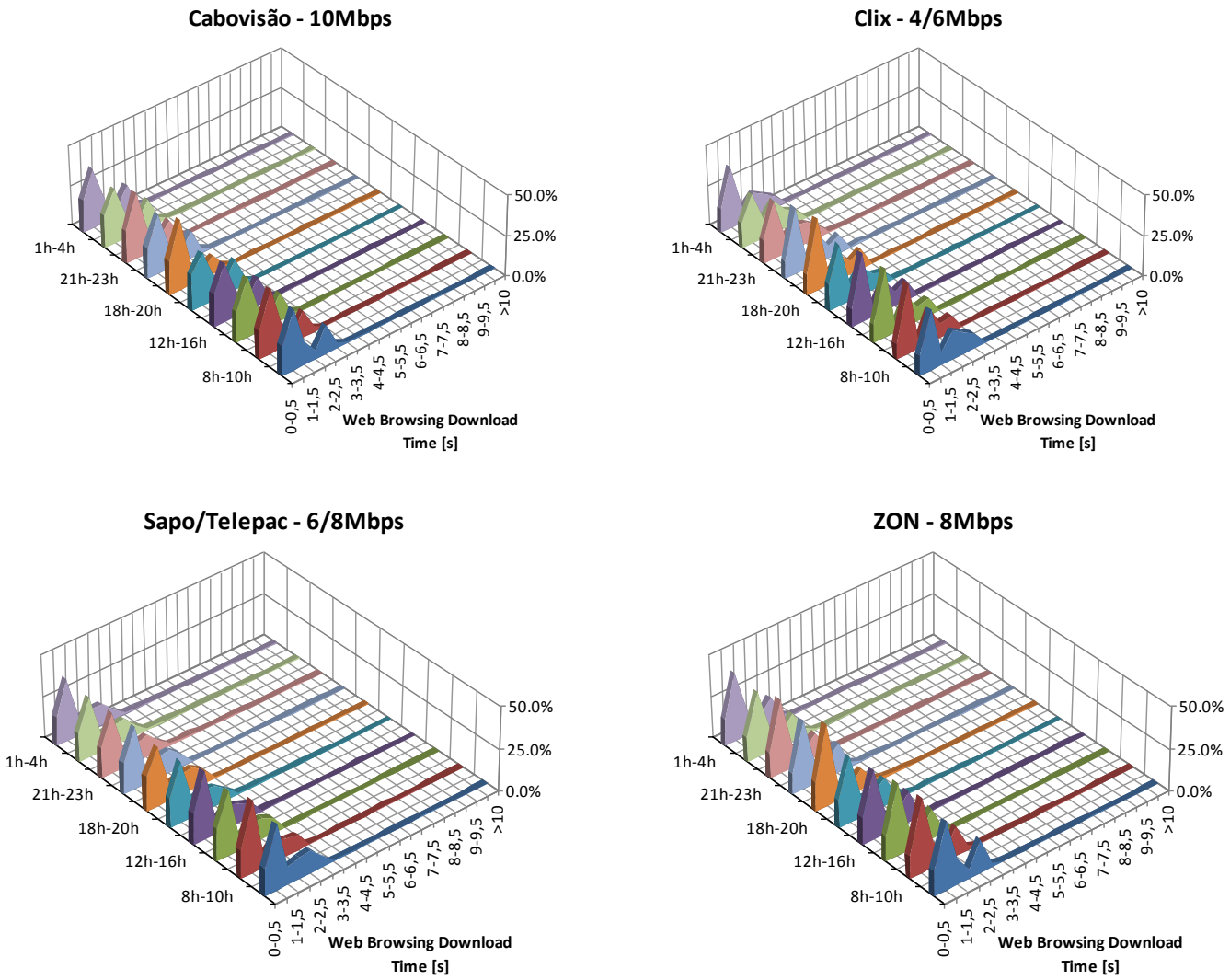


Figure 129 - Frequency distribution per operator, time period and Download Time during Web Browsing

According to Figure 130 and Figure 131, and regarding the behaviour per time period and per weekday, in spite of some variations, absolute differences are not perceived by the user. The maximum variation is 0.2 seconds and occurs in Cabovisão.

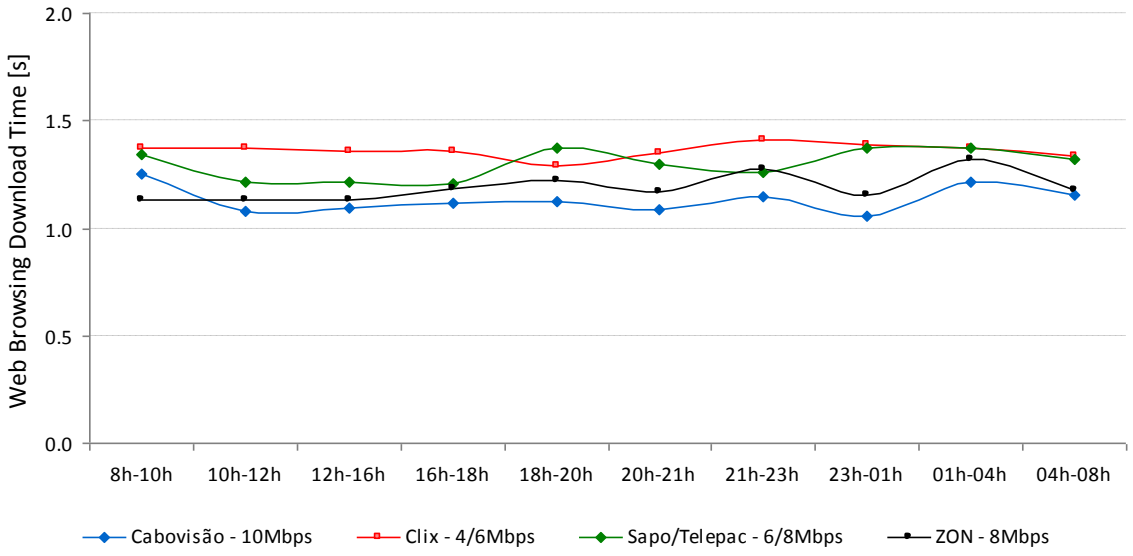


Figure 130 – Average Download Time during Web Browsing per operator and time period

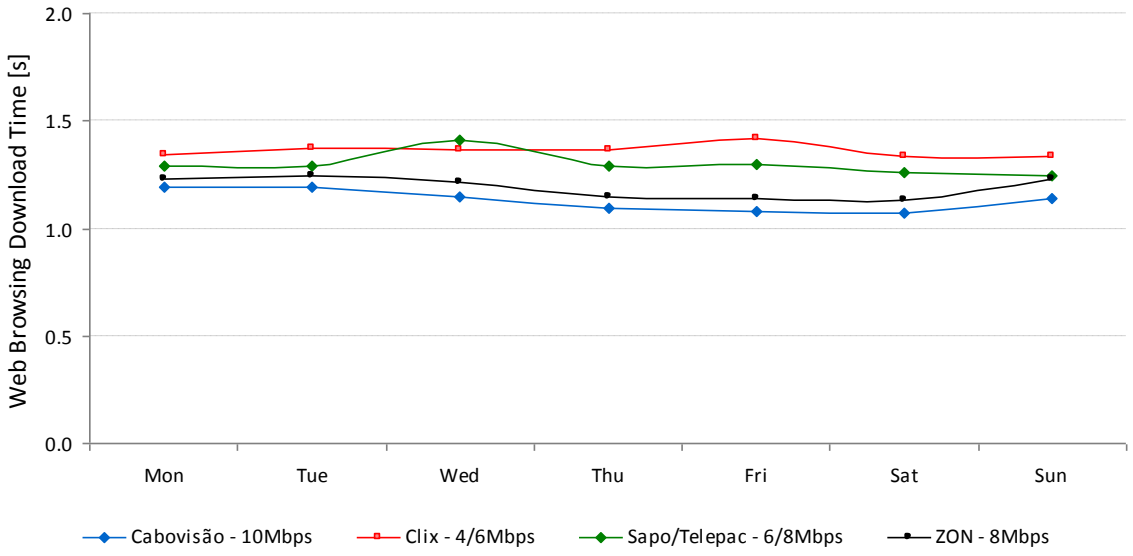


Figure 131 – Average Download time during Web Browsing per operator and weekday

There are considerable differences per server, particularly when compared with the download time of pages located in Portugal with those located the West coast of the United States (USA2), were the duration surpasses 2 seconds.

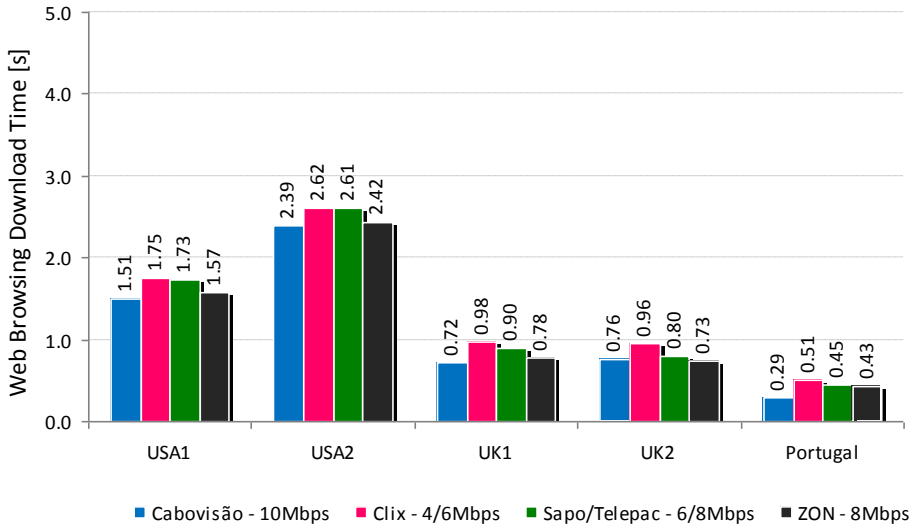


Figure 132 – Average Download time during Web Browsing per operator and server

For the national server, it stands out that most measurements on both cable operators register Web page transfer times below half a second (see Figure 133).

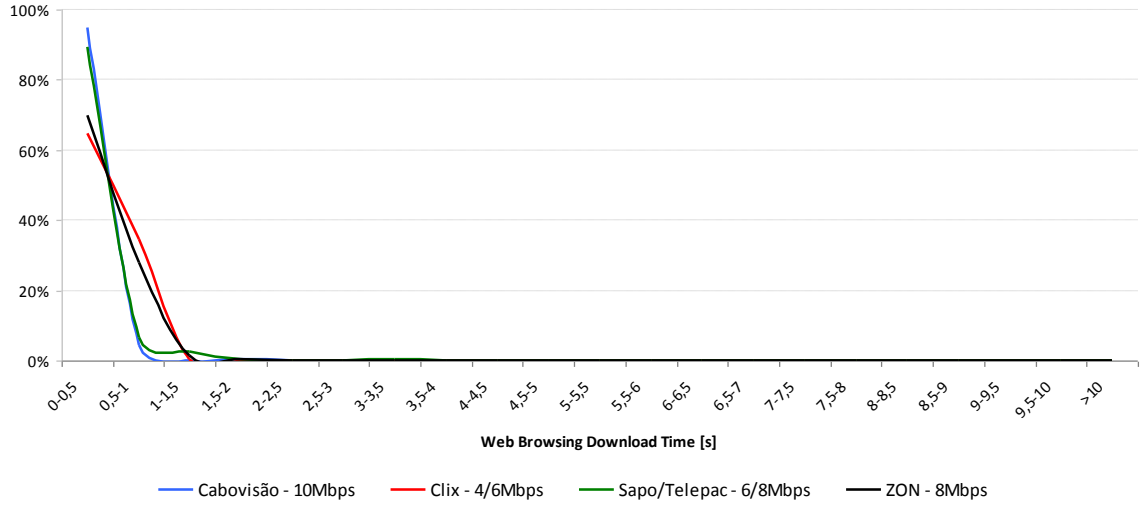


Figure 133 - Frequency distribution per operator and Web page Download time during WEB Browsing for the national server

3.5 User's Perception of Communication Delay / Latency

3.5.1 3G Mobile Accesses

The telecommunications networks' latency indicator counts the time spent on the transmission of the IP packages since the origin to the destination, i.e., from the measurement unit until the target server, on the test and vice-versa. In general, the higher its value is, the lower will be the quality of the provided service.

The latency values recorded for the three operators are within the values expected for the technology under study, in both municipalities.

The highest values for this indicator were recorded by Vodafone in Lisbon, and by Optimus in Porto, registering averages of 109 milliseconds and 106 milliseconds, respectively (Figure 134). TMN registers identical values in both municipalities, around 88 milliseconds.

The latency variations recorded may be due to several reasons, namely to differences on each operator's network architecture, and to the connections to international servers (distances in number of network hops that a data package goes through until reaching its destination).

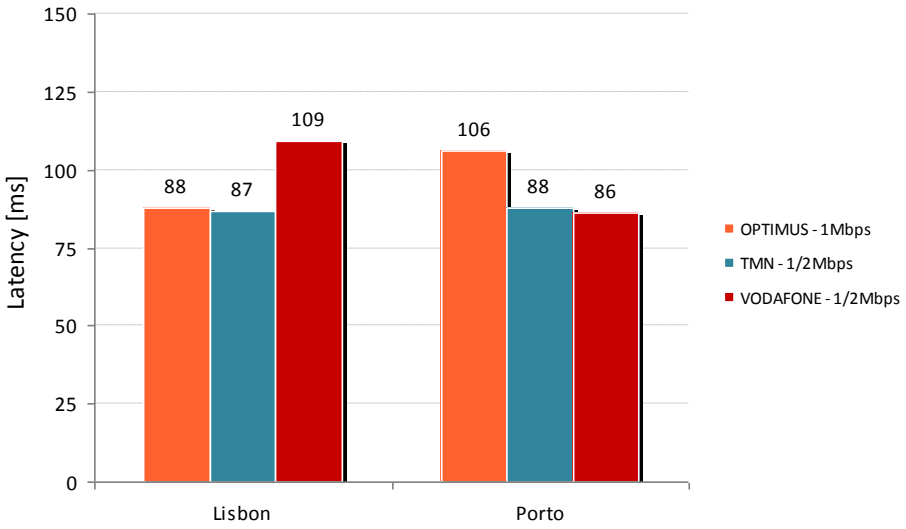


Figure 134 – Average latency per operator and municipality

Latency distributions for Lisbon and Porto represented on Figure 135 and Figure 136 reflect the averages described above for the entire set of servers, showing an accentuated dispersion for all operators in both municipalities, which translates into a reasonably unpredictable indicator.

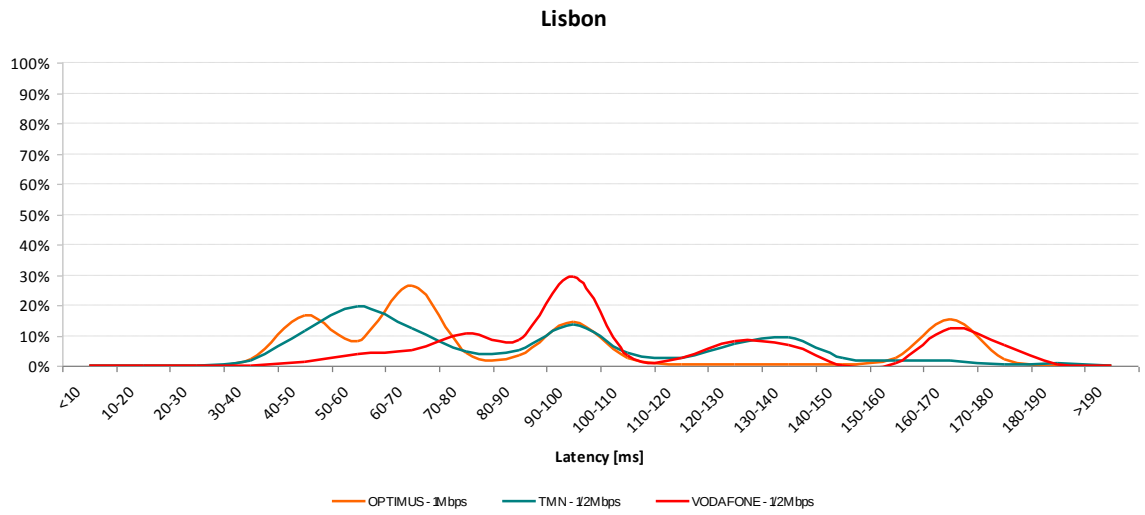


Figure 135 - Frequency distribution per operator and Latency category or the municipality of Lisbon

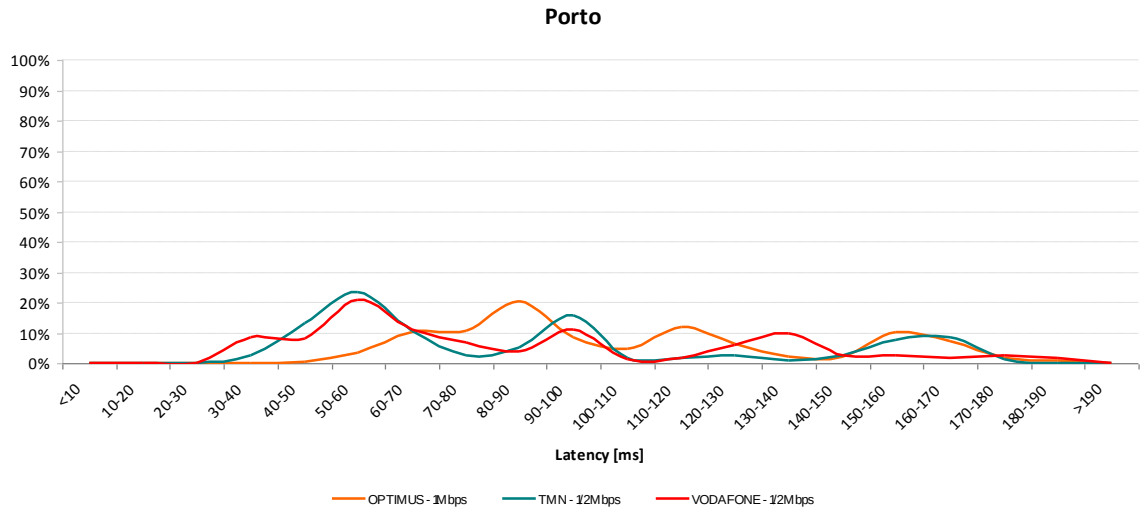


Figure 136 - Frequency distribution per operator and Latency category for the municipality of Porto

Latency distributions along the day and per weekday present small variations for TMN in Lisbon, and for Vodafone in Porto, although with small relevance and a reduced impact on the quality of service (see from Figure 137 to Figure 140).

Lisbon

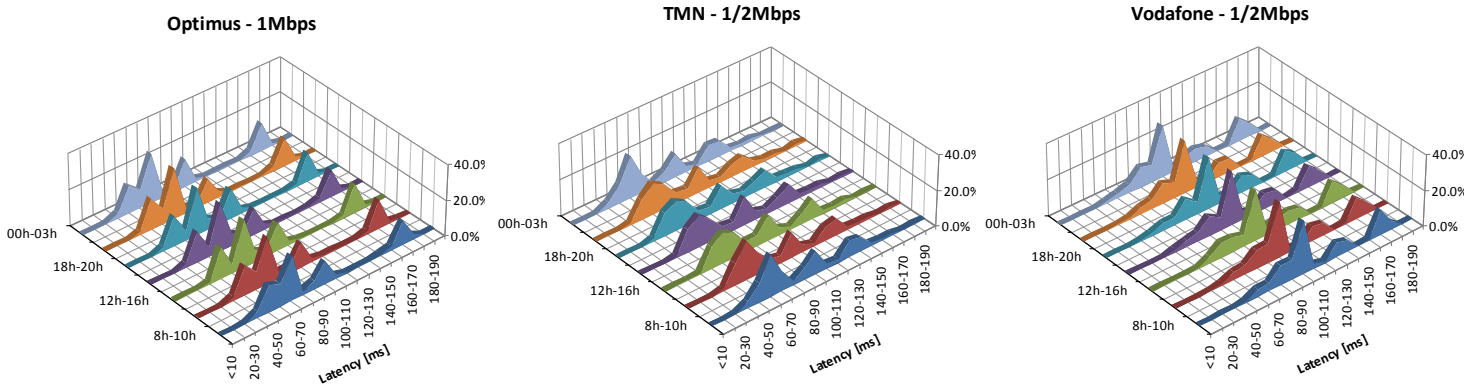


Figure 137 - Frequency distribution per operator, time period and Latency category for the municipality of Lisbon

Porto

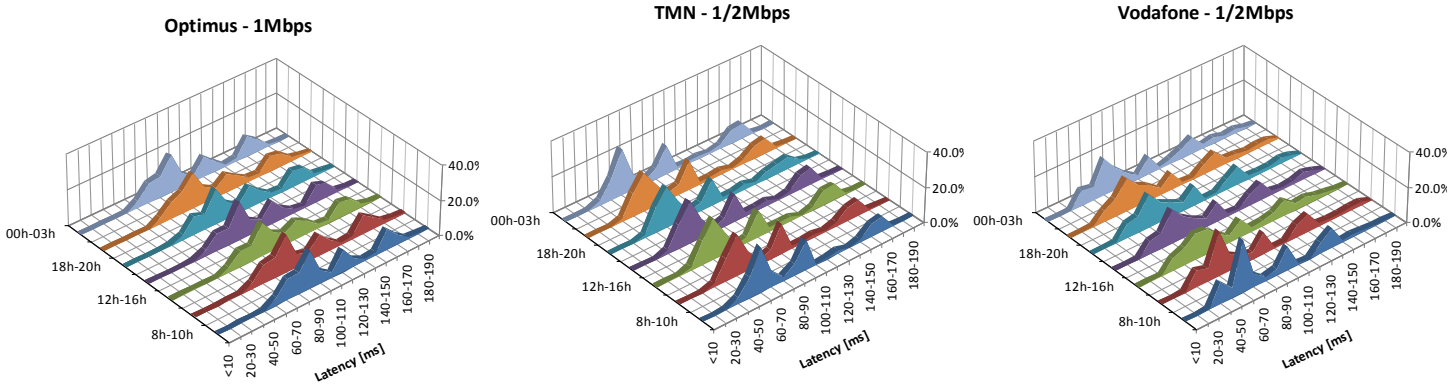


Figure 138 - Frequency distribution per operator, time period and Latency category for the municipality of Porto

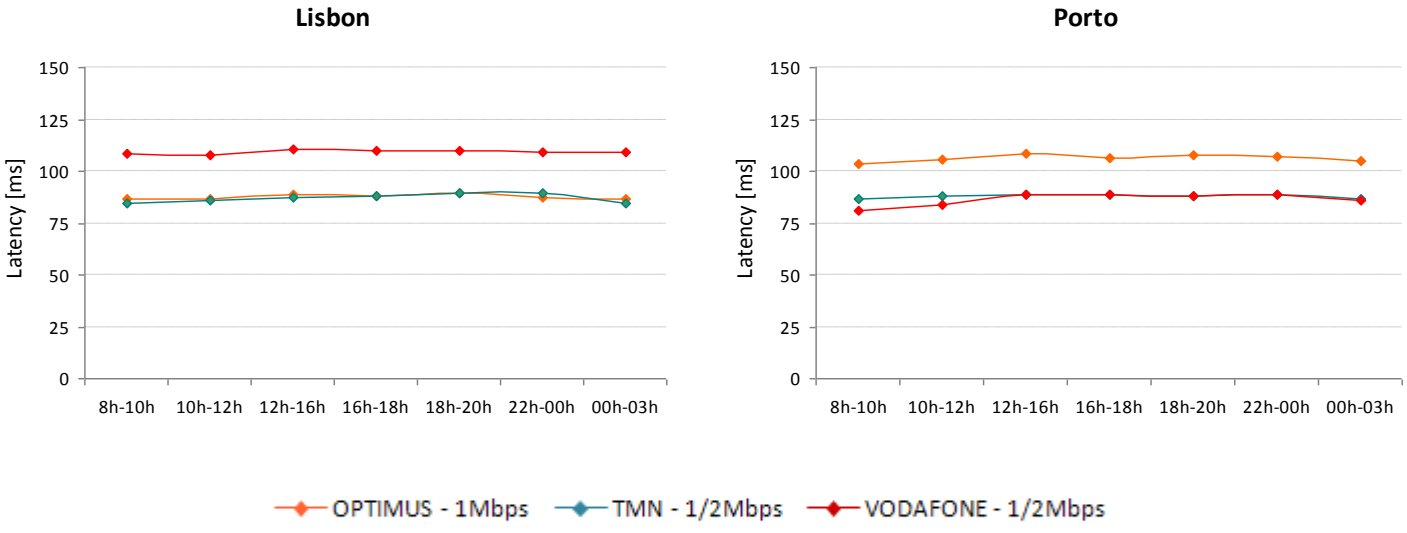


Figure 139 – Average Latency per operator, time period and municipality

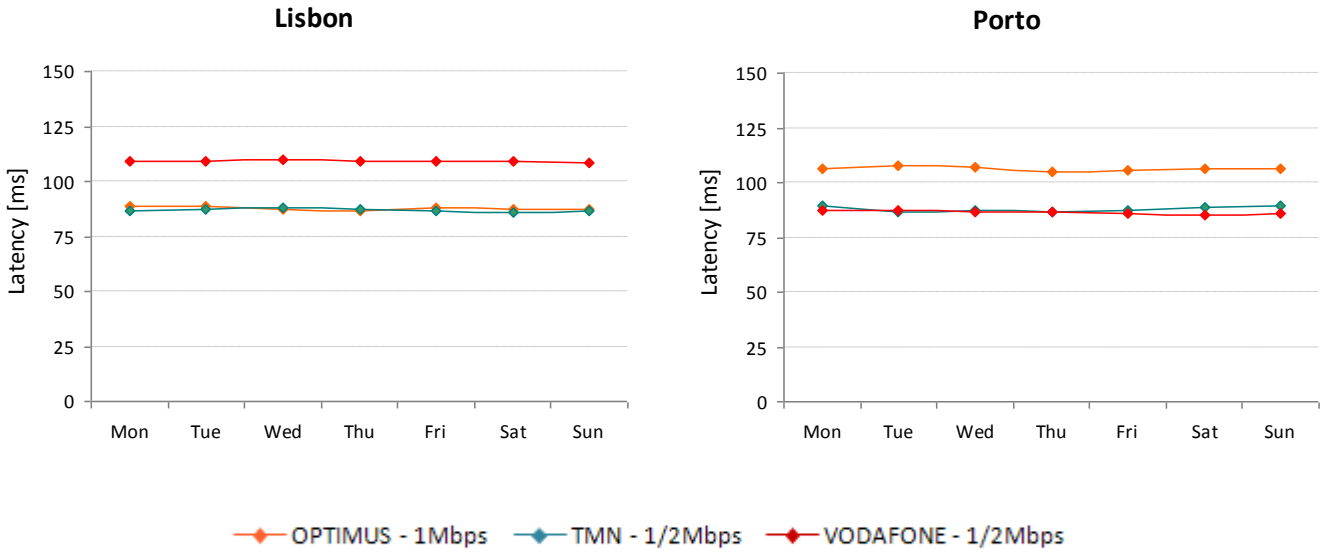


Figure 140 – Average Latency per operator, weekday and municipality

According to Figure 141, latency values are higher for connections made to the servers in the United States. Furthermore, it also shows that these values are greater for the connections made to the server located in the West coast of the United States (Seattle), USA2. This situation results from the higher distance towards this city, thus requiring a larger amount of hops and consequently increasing the time to reach this server.

Latencies recorded for the servers located in the United Kingdom (UK1 and UK2) show no differences between both servers, given their proximity, although being higher for the national server located at FCCN.

As a reference, for online multiplayer games, latency values should stand below 150 ms, a value that is usually surpassed by all operators for server USA2. However, for national servers, the player may expect to have a good experience on the perception of the response to commands/movements and of the interactivity with other players, since the ideal values for operating online multiplayer games usually stands around 50ms.

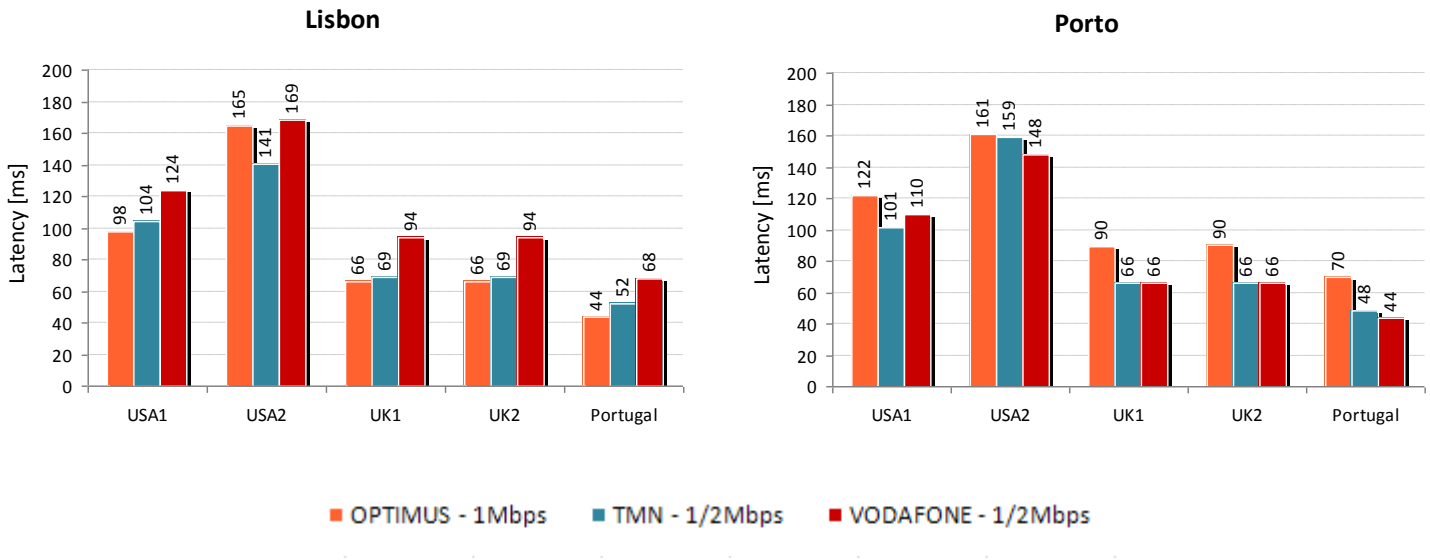


Figure 141 – Average Latency per operator, server and municipality

Isolating the latency dispersions for the national destination (see Figure 142 and Figure 143) from the dispersions for all destinations (Figure 135 and Figure 136), it is possible to observe the distributions around the averages for each municipality. TMN's similar performance in both municipalities stands out, with distributions reaching about 60% of the measurements in the 40-60 milliseconds interval.

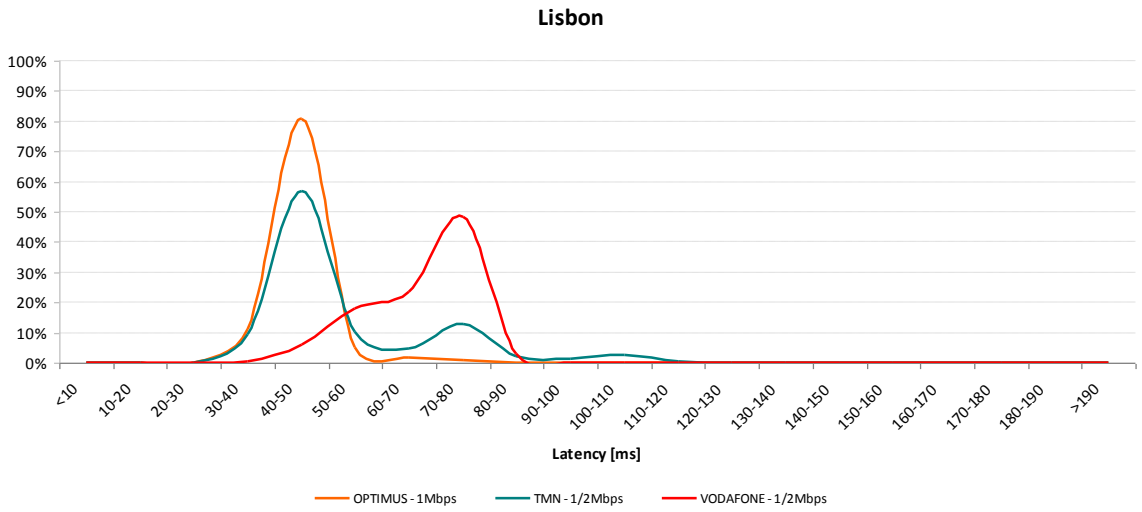


Figure 142 - Frequency distribution per operator and Latency category for the municipality of Lisbon for the National server

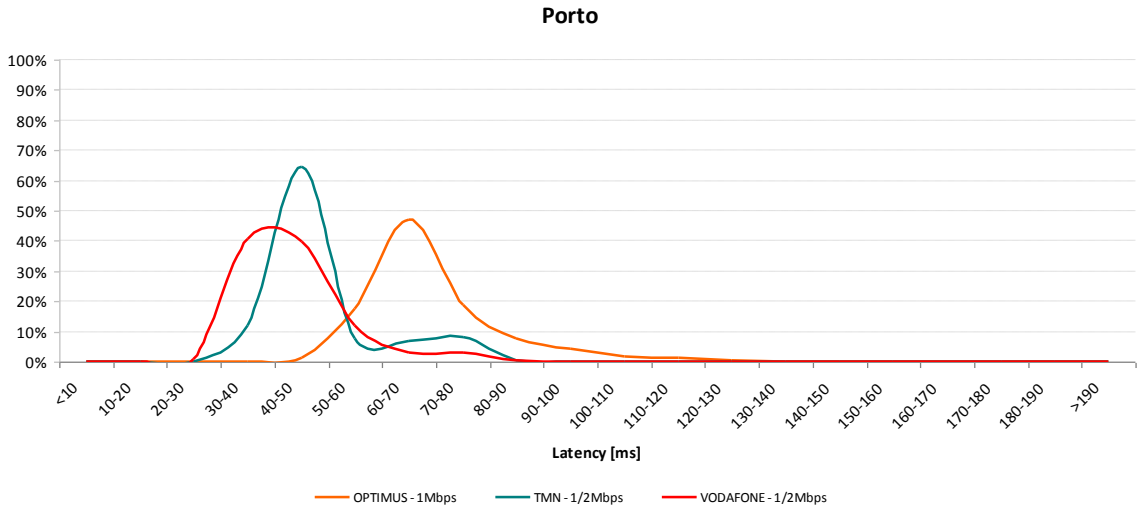


Figure 143 - Frequency distribution per operator and Latency category for the municipality of Porto for the National server

Fixed Accesses

For fixed operators, latency values measured are similar for the four operators, with no major differences according to the tariff scheme. However, Clix presents a slightly lower performance than the remaining operators, concerning this indicator.

Values presented on Figure 144 represent the averages of all servers (National and international).

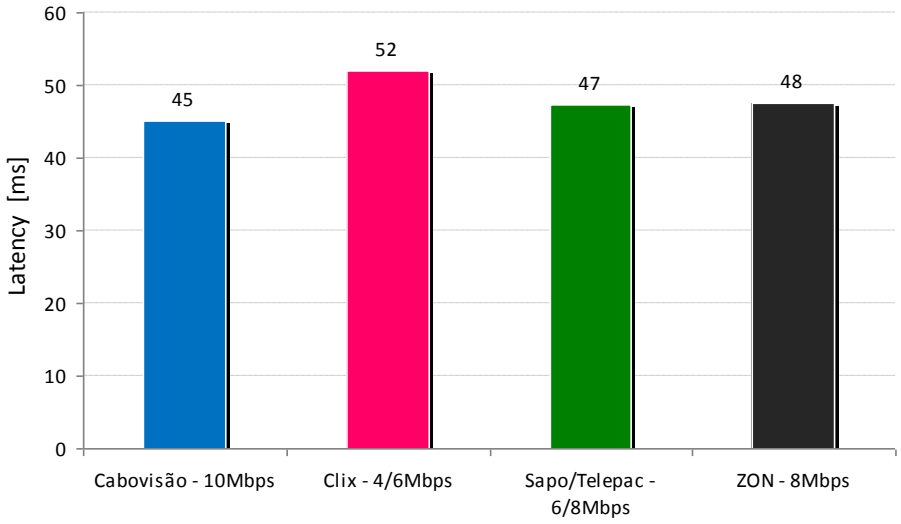


Figure 144 - Average Latency per operator

The frequency distribution per operator and latency category, for all servers (see Figure 145), shows a great variation on the latency values experienced, since it depends on the distance from the servers. Furthermore, there is a predominance of values in the 10-40s range, related to the national and UK servers, in the 50-75s range, related to the server located in the East coast of the United States and, finally, in the 100ms range, due to the server located in the West coast of the United States.

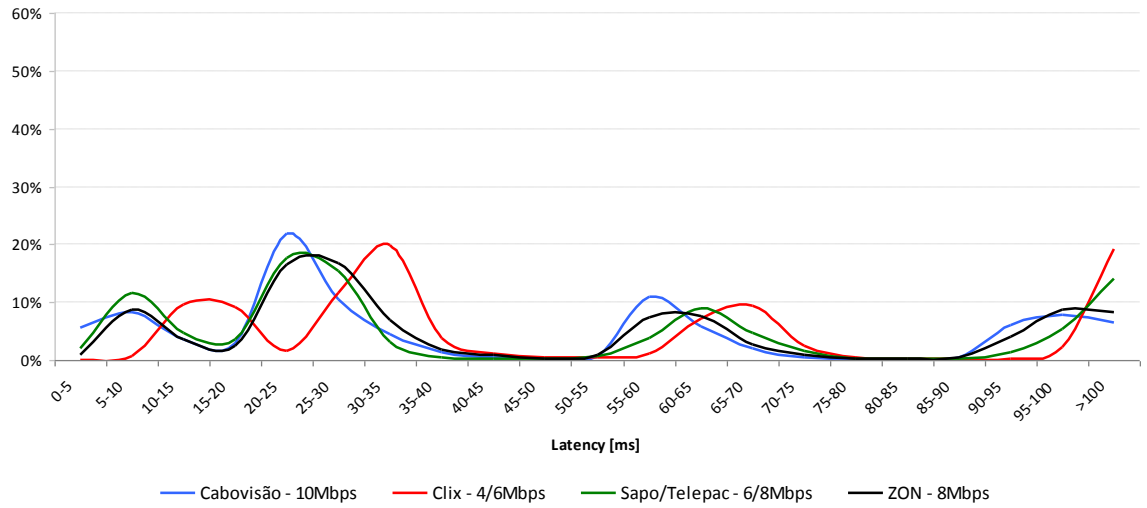
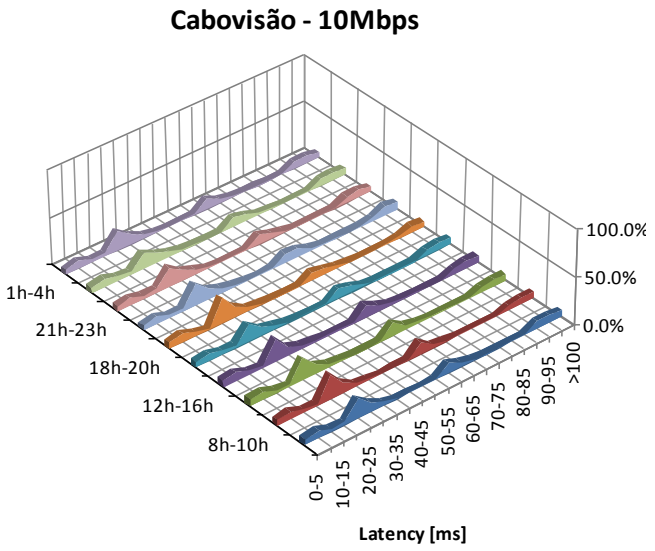
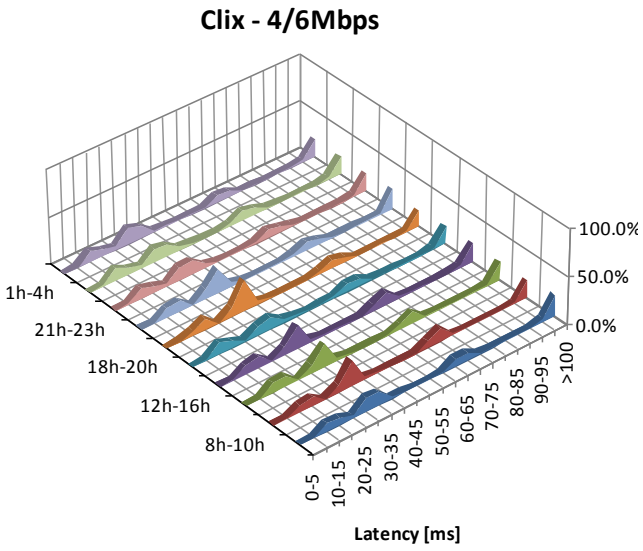


Figure 145 - Frequency distribution per operator and Latency category





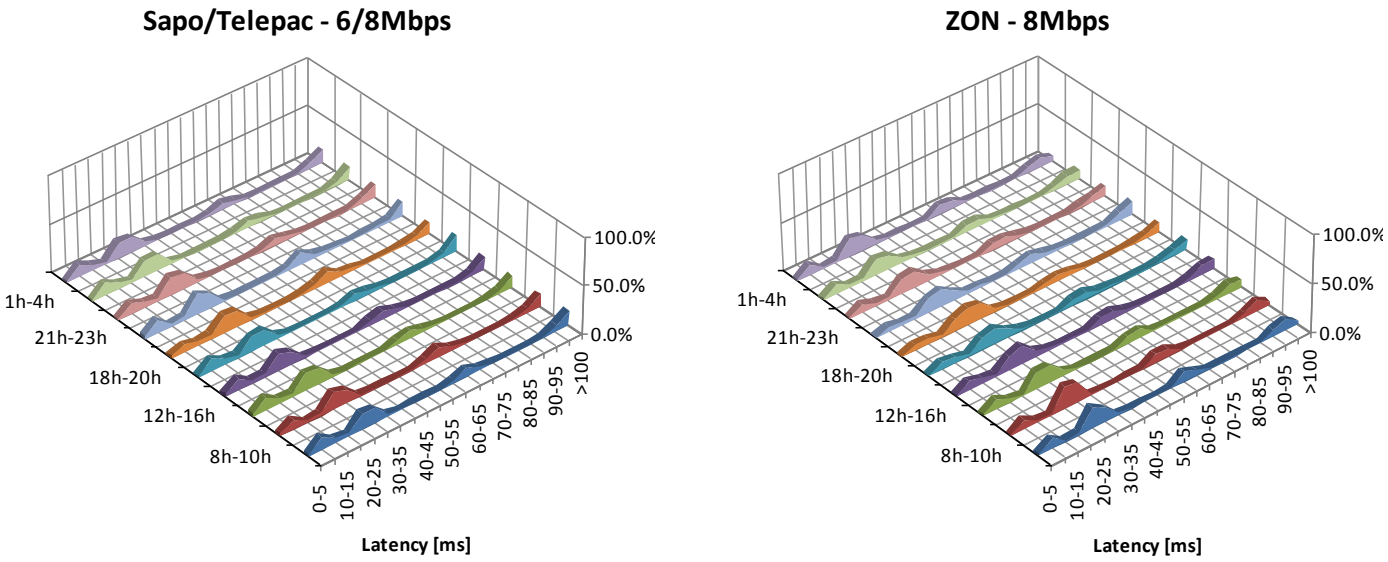


Figure 146 - Frequency distribution per operator, time period and Latency category

Latency values per operator do not present a great variation during the day. However, there is a slightly more accentuated decrease for operators ZON and Cabovisão in the 21h-23h period, probably due to the larger usage rate, as shown on Figure 147.

During the week, average latency values do not vary considerably, for any of the operators (see Figure 148).

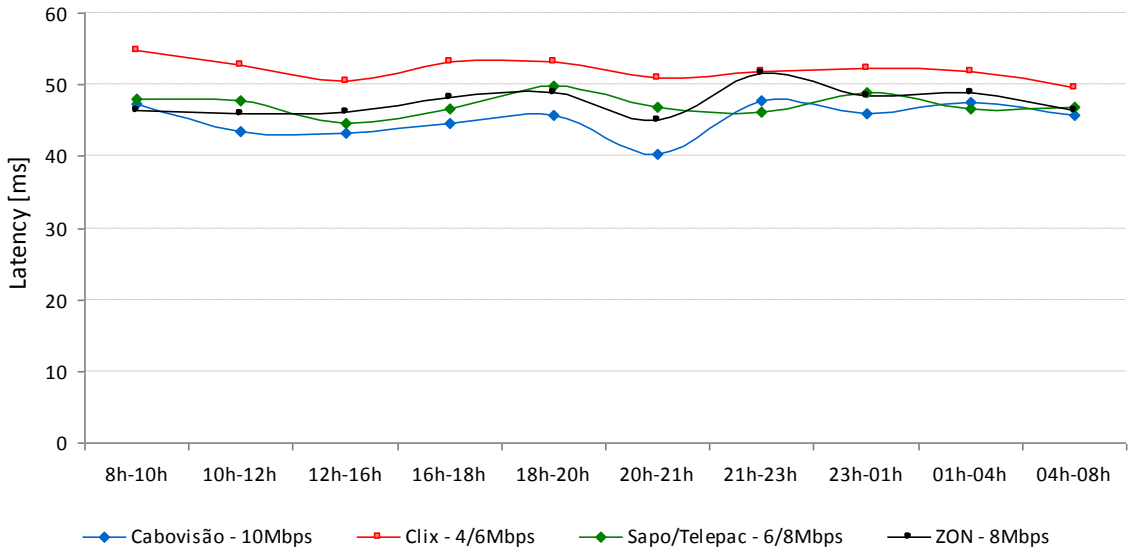


Figure 147 – Average Latency per operator and time period

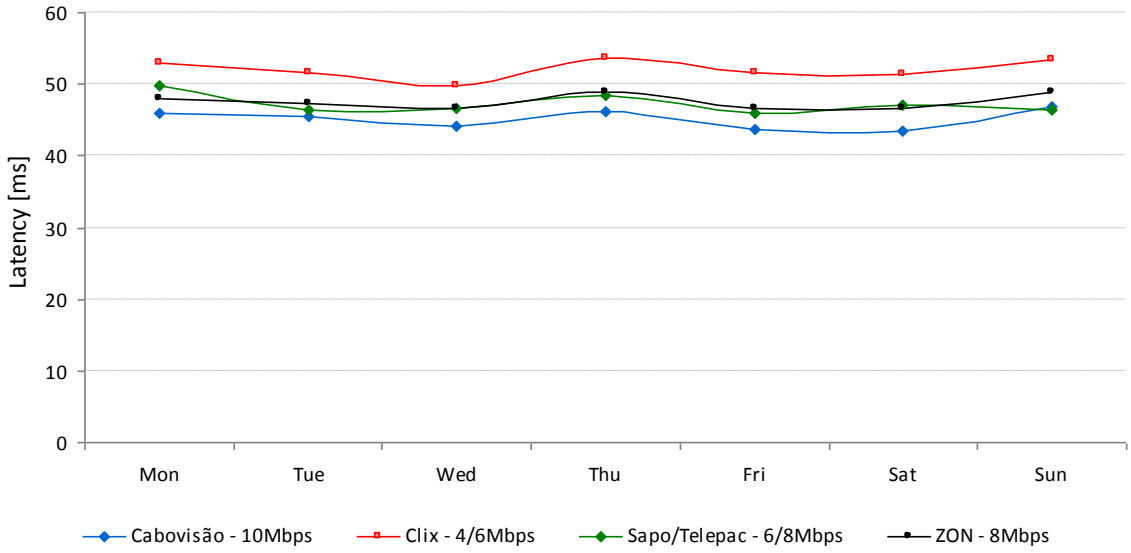


Figure 148 – Average Latency per operator and weekday

Analysing Figure 149, concerning the latency per operator and for each of the test servers, it is without surprise and in line with the mobile operators' results that higher latency values were recorded in the servers located in the United States, particularly for the server located in the West coast of the United States. The values measured for the servers in the UK are about twice the values recorded for the national server.

Performing the analysis per server, similar average latency values were recorded for each operator, as it occurred, in fact, with the overall average.

As it also shows, latency values recorded on fixed operators are quite lower than those for mobile operators. Therefore, given the results obtained, it may be concluded that the fixed broadband network, for the tariff schemes under analysis, provides, for example, an online game user experience with higher interactivity potential between players in Portugal and in the United States, given the average latency values registered for the server Seattle, of around 100 ms.

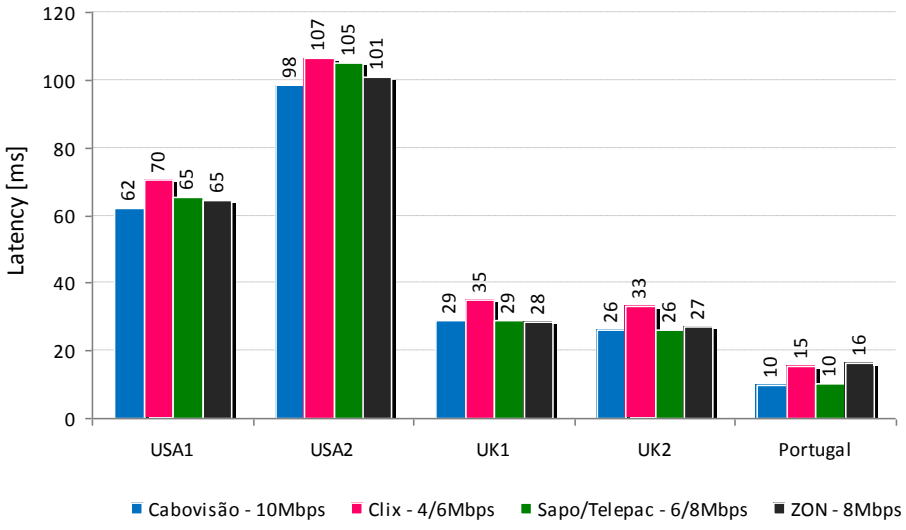


Figure 149 – Average Latency per operator and server

Isolating the latency distribution regarding the national destination (see Figure 141), it shows that the influence of the international destinations, besides being a negative contribution for this indicator's average performance, makes it harder to estimated the expected values.

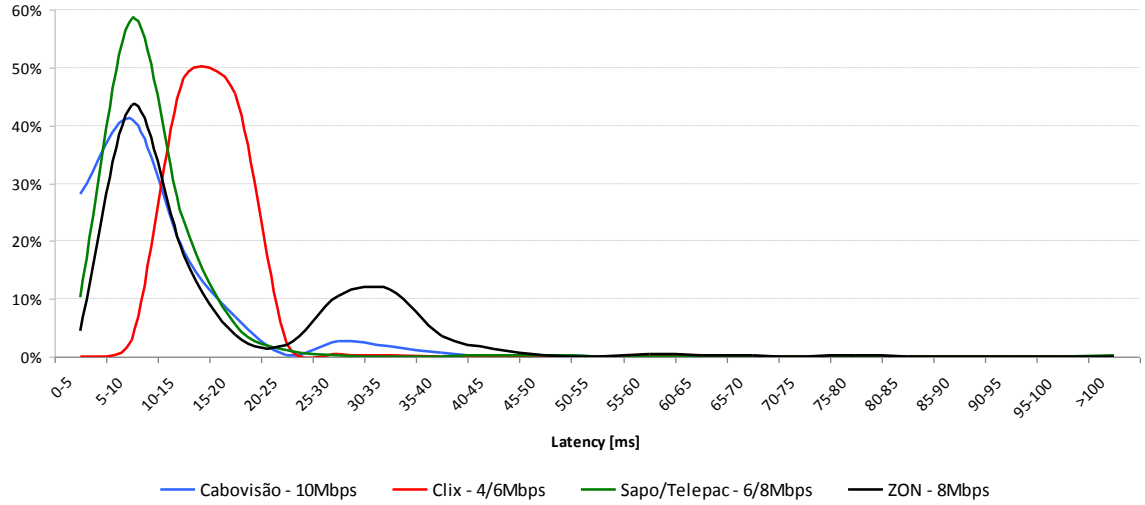


Figure 150 - Frequency distribution per operator and Latency category for the National server

4. ANNEXES

4.1 Error Margin

4.1.1 3G Mobile Accesses

			Absolute Precision (p.p.)		
			OPTIMUS	TMN	Vodafone
LISBON	GLOBAL		0,03	0,23	0,11
	Period	8h-10h	0,05	0,53	0,10
		10h-12h	0,04	0,62	0,13
		12h-16h	0,13	0,75	0,08
		16h-18h	0,05	0,59	0,11
		18h-20h	0,06	0,58	0,15
		22h-00h	0,04	0,70	0,67
		00h-03h	0,05	0,44	0,08
	Weekday	Mon	0,05	0,10	0,09
		Tue	0,14	0,55	0,10
		Wed	0,07	0,59	0,12
		Thu	0,03	0,91	0,11
		Fri	0,06	0,78	0,15
		Sat	0,06	0,45	0,37
		Sun	0,01	0,53	0,59

			Absolute Precision (p.p.)		
			OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		0,12	0,16	0,13
	Period	8h-10h	0,19	0,21	0,23
		10h-12h	0,17	0,34	0,11
		12h-16h	0,58	0,55	0,06
		16h-18h	0,25	0,43	0,17
		18h-20h	0,21	0,60	0,24
		22h-00h	0,23	0,50	0,79
		00h-03h	0,27	0,22	0,18
	Weekday	Mon	0,29	0,91	0,18
		Tue	0,58	0,52	0,31
		Wed	0,18	0,18	0,23
		Thu	0,26	0,18	0,22
		Fri	0,17	0,25	0,10
		Sat	0,25	0,23	0,26
		Sun	0,17	0,24	0,71

Table 1 – Success in the Access to the service

			Absolute Precision			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
LISBON	GLOBAL		0,01	0,01	0,03	0,3%	0,9%	1,1%
	Period	8h-10h	0,02	0,02	0,07	0,7%	2,0%	3,0%
		10h-12h	0,03	0,03	0,03	1,1%	2,6%	1,6%
		12h-16h	0,02	0,02	0,03	0,9%	1,6%	1,5%
		16h-18h	0,02	0,03	0,04	0,6%	2,2%	1,7%
		18h-20h	0,02	0,04	0,04	0,9%	3,1%	1,8%
		22h-00h	0,02	0,03	0,14	0,7%	2,1%	5,5%
		00h-03h	0,02	0,03	0,04	1,0%	2,8%	1,6%
	Weekday	Mon	0,02	0,03	0,04	0,9%	2,8%	1,6%
		Tue	0,03	0,03	0,04	1,2%	2,1%	1,6%
		Wed	0,02	0,03	0,04	0,7%	2,6%	1,7%
		Thu	0,02	0,04	0,04	0,9%	2,9%	1,6%
		Fri	0,02	0,03	0,04	1,0%	2,5%	1,8%
		Sat	0,02	0,02	0,06	0,7%	1,8%	2,9%
		Sun	0,01	0,02	0,14	0,6%	2,0%	5,9%

			Absolute Precision			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		0,01	0,06	0,03	0,4%	2,4%	1,4%
	Period	8h-10h	0,02	0,04	0,01	0,9%	1,8%	0,8%
		10h-12h	0,03	0,10	0,02	1,0%	4,2%	1,2%
		12h-16h	0,03	0,13	0,02	1,1%	5,0%	1,3%
		16h-18h	0,03	0,11	0,05	0,9%	4,5%	2,8%
		18h-20h	0,03	0,33	0,06	1,0%	12,0%	3,7%
		22h-00h	0,03	0,18	0,15	0,9%	6,8%	7,5%
		00h-03h	0,02	0,04	0,02	0,8%	1,7%	1,0%
	Weekday	Mon	0,02	0,41	0,02	0,8%	14,0%	1,4%
		Tue	0,02	0,05	0,03	0,7%	1,9%	2,0%
		Wed	0,02	0,06	0,07	0,7%	2,5%	3,8%
		Thu	0,02	0,06	0,02	0,7%	2,4%	1,1%
		Fri	0,04	0,05	0,02	1,3%	2,1%	0,9%
		Sat	0,04	0,04	0,02	1,3%	1,8%	1,5%
		Sun	0,03	0,04	0,15	1,0%	1,7%	7,8%

Table 2 – Connection Activation / Establishment Time

			Absolute Precision (kbps)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
LISBON	GLOBAL		3,23	2,80	2,25	0,6%	0,6%	0,5%
	Period	8h-10h	9,30	7,66	5,61	1,6%	1,6%	1,2%
		10h-12h	8,73	7,26	6,04	1,6%	1,6%	1,4%
		12h-16h	7,98	6,72	5,66	1,5%	1,5%	1,4%
		16h-18h	8,29	7,36	5,85	1,6%	1,7%	1,4%
		18h-20h	8,49	7,74	6,12	1,7%	1,8%	1,5%
		22h-00h	8,26	7,47	6,05	1,6%	1,7%	1,5%
		00h-03h	8,33	7,43	5,97	1,5%	1,6%	1,4%
	Weekday	Mon	8,71	7,49	5,92	1,6%	1,7%	1,4%
		Tue	8,74	7,44	6,10	1,7%	1,6%	1,5%
		Wed	8,18	7,57	6,10	1,6%	1,7%	1,5%
		Thu	8,60	7,18	5,91	1,6%	1,6%	1,4%
		Fri	8,64	7,34	6,12	1,6%	1,6%	1,4%
		Sat	8,47	7,27	5,79	1,6%	1,6%	1,3%
		Sun	8,47	7,59	5,74	1,6%	1,7%	1,3%
	Server	USA1	2,74	3,25	2,25	0,6%	0,9%	0,6%
		USA2	1,46	2,11	1,73	0,5%	0,8%	0,6%
		UK1	4,34	5,00	3,54	0,7%	1,0%	0,8%
		UK2	4,88	5,52	3,94	0,8%	1,1%	0,9%
		Portugal	6,66	6,21	5,30	0,9%	1,0%	0,9%

			Absolute Precision (kbps)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		1,91	3,10	3,61	0,5%	0,6%	0,7%
	Period	8h-10h	5,23	8,10	9,76	1,2%	1,5%	1,7%
		10h-12h	4,92	8,12	9,90	1,2%	1,5%	1,8%
		12h-16h	4,82	7,94	9,07	1,3%	1,5%	1,7%
		16h-18h	4,95	8,29	9,55	1,3%	1,6%	1,8%
		18h-20h	5,13	8,63	9,59	1,4%	1,7%	1,8%
		22h-00h	5,15	8,24	9,09	1,4%	1,6%	1,8%
		00h-03h	4,71	7,81	9,59	1,2%	1,4%	1,7%
	Weekday	Mon	5,01	7,97	9,57	1,3%	1,5%	1,8%
		Tue	5,29	8,20	9,54	1,4%	1,5%	1,8%
		Wed	4,91	8,26	9,49	1,3%	1,5%	1,8%
		Thu	5,19	8,28	9,45	1,3%	1,6%	1,7%
		Fri	5,02	8,33	9,40	1,3%	1,6%	1,7%
		Sat	4,96	8,12	9,66	1,2%	1,6%	1,7%
		Sun	4,86	8,11	9,70	1,2%	1,5%	1,8%
	Server	USA1	2,40	2,65	2,60	0,7%	0,6%	0,6%
		USA2	1,47	1,71	1,90	0,6%	0,5%	0,7%
		UK1	3,37	4,64	4,67	0,8%	0,8%	0,8%
		UK2	3,75	4,96	5,19	0,9%	0,8%	0,9%
		Portugal	3,96	5,82	7,44	0,8%	0,8%	0,9%

Table 3 - WEB Browsing Speed

			Absolute Precision (seconds)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
LISBON	GLOBAL		0,03	0,03	0,03	2,0%	1,5%	1,6%
	Period	8h-10h	0,04	0,05	0,07	2,9%	2,9%	3,9%
		10h-12h	0,07	0,07	0,08	4,5%	3,8%	4,2%
		12h-16h	0,09	0,07	0,10	4,8%	3,2%	4,3%
		16h-18h	0,08	0,10	0,08	4,8%	4,5%	3,7%
		18h-20h	0,10	0,08	0,09	5,2%	3,8%	4,2%
		22h-00h	0,11	0,11	0,11	5,9%	4,9%	4,5%
		00h-03h	0,10	0,07	0,07	6,3%	3,5%	3,5%
	Weekday	Mon	0,13	0,09	0,08	6,8%	4,2%	4,0%
		Tue	0,10	0,08	0,08	5,6%	4,1%	3,9%
		Wed	0,09	0,10	0,09	5,5%	4,5%	4,3%
		Thu	0,08	0,08	0,09	4,9%	3,9%	4,2%
		Fri	0,08	0,06	0,11	5,0%	3,1%	5,1%
		Sat	0,06	0,07	0,08	4,0%	3,4%	3,9%
		Sun	0,04	0,09	0,06	2,4%	4,1%	3,2%
	Server	USA1	0,05	0,07	0,08	2,8%	3,0%	3,5%
		USA2	0,10	0,06	0,08	3,8%	2,0%	2,7%
		UK1	0,08	0,06	0,07	5,3%	3,4%	3,6%
		UK2	0,06	0,06	0,07	4,4%	3,2%	3,7%
		Portugal	0,06	0,08	0,06	4,8%	5,3%	4,0%

			Absolute Precision (seconds)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		0,02	0,03	0,03	1,0%	1,9%	1,6%
	Period	8h-10h	0,03	0,07	0,04	1,7%	4,6%	3,0%
		10h-12h	0,03	0,07	0,07	1,7%	4,3%	4,3%
		12h-16h	0,06	0,07	0,07	2,6%	3,9%	3,9%
		16h-18h	0,07	0,10	0,08	3,2%	5,7%	4,7%
		18h-20h	0,05	0,09	0,08	2,3%	5,2%	4,7%
		22h-00h	0,05	0,12	0,08	2,5%	6,4%	4,3%
		00h-03h	0,07	0,04	0,05	3,3%	2,5%	3,4%
	Weekday	Mon	0,07	0,09	0,07	3,2%	5,4%	4,3%
		Tue	0,06	0,09	0,07	2,8%	5,5%	4,2%
		Wed	0,04	0,06	0,08	2,0%	3,7%	4,9%
		Thu	0,06	0,07	0,06	2,9%	4,2%	3,4%
		Fri	0,04	0,11	0,04	1,9%	6,4%	2,7%
		Sat	0,06	0,07	0,08	2,9%	4,2%	4,8%
		Sun	0,04	0,07	0,07	2,0%	4,5%	4,1%
	Server	USA1	0,05	0,06	0,06	2,1%	3,4%	3,2%
		USA2	0,05	0,06	0,06	1,7%	2,6%	2,5%
		UK1	0,04	0,06	0,06	2,0%	4,5%	4,0%
		UK2	0,05	0,07	0,05	2,6%	4,8%	3,4%
		Portugal	0,03	0,08	0,04	1,7%	6,3%	4,1%

Table 4 – Web page Download Time during WEB Browsing

			Precisão Absoluta (kbps)			Precisão Relativa		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
LISBOA	GLOBAL		3,12	5,90	9,82	0,3%	0,6%	0,8%
	Período	8h-10h	6,30	14,80	24,41	0,6%	1,3%	1,7%
		10h-12h	7,16	14,89	25,00	0,7%	1,5%	1,9%
		12h-16h	7,51	14,47	23,26	0,8%	1,5%	2,2%
		16h-18h	8,72	15,78	25,77	0,9%	1,6%	2,3%
		18h-20h	9,85	16,76	26,04	1,1%	1,8%	2,3%
		22h-00h	9,67	16,35	27,00	1,1%	1,8%	2,6%
		00h-03h	6,55	14,57	25,30	0,7%	1,4%	2,1%
	Dia da semana	Seg	8,85	16,14	25,72	1,0%	1,6%	2,2%
		Ter	8,93	15,51	26,07	1,0%	1,6%	2,3%
		Qua	8,78	15,82	25,51	0,9%	1,6%	2,2%
		Qui	7,57	14,94	24,84	0,8%	1,5%	2,1%
		Sex	8,08	14,66	26,56	0,8%	1,4%	2,2%
		Sáb	7,56	15,91	26,50	0,8%	1,6%	2,1%
		Dom	8,08	16,07	26,29	0,9%	1,6%	2,2%
	Servidor	USA1	7,68	10,84	15,37	0,8%	1,1%	1,4%
		USA2	6,53	8,23	11,31	0,7%	1,3%	1,4%
		UK1	6,97	12,30	21,02	0,7%	1,1%	1,6%
		UK2	7,62	12,16	21,90	0,8%	1,1%	1,7%
		Portugal	5,60	11,75	28,07	0,6%	1,0%	1,9%

			Precisão Absoluta (kbps)			Precisão Relativa		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		2,79	5,88	9,36	0,3%	0,5%	0,7%
	Período	8h-10h	4,78	13,85	24,35	0,5%	1,2%	1,6%
		10h-12h	5,95	15,50	24,26	0,7%	1,4%	1,7%
		12h-16h	7,89	15,42	23,99	1,0%	1,5%	1,8%
		16h-18h	7,37	15,85	25,25	0,9%	1,5%	1,9%
		18h-20h	8,66	16,87	25,42	1,1%	1,7%	1,9%
		22h-00h	8,49	16,37	24,33	1,0%	1,6%	1,8%
		00h-03h	5,33	13,29	23,93	0,6%	1,1%	1,7%
	Dia da semana	Seg	8,04	15,45	25,18	0,9%	1,4%	1,9%
		Ter	8,71	15,69	24,79	1,0%	1,4%	1,8%
		Qua	7,44	15,12	24,39	0,9%	1,4%	1,7%
		Qui	6,53	15,95	24,54	0,7%	1,5%	1,7%
		Sex	6,65	15,32	24,89	0,8%	1,4%	1,7%
		Sáb	6,87	15,88	24,18	0,8%	1,5%	1,7%
		Dom	7,04	15,45	25,02	0,8%	1,4%	1,8%
	Servidor	USA1	5,95	10,47	11,96	0,7%	1,0%	0,9%
		USA2	5,48	8,54	10,29	0,7%	1,2%	1,2%
		UK1	6,61	11,56	18,31	0,8%	1,0%	1,2%
		UK2	6,91	11,84	19,12	0,8%	1,0%	1,3%
		Portugal	4,85	10,79	24,93	0,5%	0,8%	1,4%

Table 5 – File Transfer Download Speed

			Absolute Precision (seconds)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
LISBON	GLOBAL		0,19	0,22	0,22	1,8%	1,9%	2,0%
	Period	8h-10h	0,20	0,47	0,32	2,3%	4,7%	4,3%
		10h-12h	0,40	0,54	0,49	4,2%	5,0%	5,6%
		12h-16h	0,55	0,59	0,59	5,1%	4,8%	4,6%
		16h-18h	0,42	0,73	0,62	4,0%	5,8%	5,3%
		18h-20h	0,68	0,51	0,60	5,8%	4,2%	5,0%
		22h-00h	0,69	0,63	0,80	5,9%	4,9%	5,2%
		00h-03h	0,30	0,46	0,56	3,2%	4,4%	5,2%
	Weekday	Mon	0,58	0,63	0,67	5,3%	5,2%	5,6%
		Tue	0,58	0,38	0,58	5,3%	3,5%	5,0%
		Wed	0,63	0,71	0,73	5,9%	5,7%	6,0%
		Thu	0,48	0,38	0,53	4,8%	3,5%	4,9%
		Fri	0,49	0,34	0,69	4,9%	3,3%	6,2%
		Sat	0,43	0,73	0,43	4,3%	6,0%	4,2%
		Sun	0,23	0,66	0,48	2,4%	5,4%	4,5%
	Server	USA1	0,37	0,42	0,45	3,4%	3,7%	4,1%
		USA2	0,42	0,59	0,56	4,1%	3,6%	3,8%
		UK1	0,56	0,52	0,54	5,2%	4,8%	5,0%
		UK2	0,33	0,47	0,44	3,3%	4,6%	4,2%
		Portugal	0,39	0,31	0,49	4,0%	3,5%	5,2%

			Absolute Precision (seconds)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		0,12	0,24	0,10	1,1%	2,3%	1,3%
	Period	8h-10h	0,19	0,45	0,14	2,0%	5,1%	2,2%
		10h-12h	0,15	0,69	0,24	1,6%	6,4%	3,4%
		12h-16h	0,30	0,78	0,35	2,6%	6,3%	3,9%
		16h-18h	0,25	0,84	0,32	2,3%	7,2%	3,8%
		18h-20h	0,38	0,58	0,26	3,2%	5,1%	3,1%
		22h-00h	0,49	0,60	0,24	4,1%	5,3%	3,1%
		00h-03h	0,20	0,36	0,20	2,1%	4,2%	2,7%
	Weekday	Mon	0,53	0,64	0,27	4,6%	6,1%	3,2%
		Tue	0,40	0,54	0,25	3,4%	5,3%	3,1%
		Wed	0,24	0,56	0,30	2,3%	5,6%	3,8%
		Thu	0,27	0,81	0,25	2,7%	6,8%	3,2%
		Fri	0,18	0,75	0,18	1,7%	6,7%	2,4%
		Sat	0,17	0,55	0,30	1,7%	5,2%	4,1%
		Sun	0,15	0,57	0,26	1,4%	5,5%	3,3%
	Server	USA1	0,37	0,54	0,23	3,4%	5,0%	3,0%
		USA2	0,24	0,63	0,29	2,1%	4,1%	2,5%
		UK1	0,21	0,57	0,16	1,9%	5,8%	2,4%
		UK2	0,23	0,51	0,19	2,1%	5,4%	2,7%
		Portugal	0,21	0,38	0,14	2,2%	4,7%	2,4%

Table 6 – File Download Time

			Absolute Precision (seconds)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
LISBON	GLOBAL		4,28	0,68	3,10	0,6%	0,2%	0,5%
	Period	8h-10h	11,90	1,85	8,32	1,5%	0,6%	1,3%
		10h-12h	11,49	1,91	8,27	1,5%	0,7%	1,3%
		12h-16h	10,86	1,76	7,80	1,5%	0,6%	1,3%
		16h-18h	11,06	1,55	8,20	1,5%	0,5%	1,4%
		18h-20h	11,13	1,74	8,32	1,5%	0,6%	1,4%
		22h-00h	11,33	1,96	8,19	1,5%	0,7%	1,4%
		00h-03h	11,43	1,72	8,13	1,5%	0,6%	1,3%
	Weekday	Mon	11,47	1,76	8,37	1,5%	0,6%	1,4%
		Tue	11,28	1,72	8,31	1,5%	0,6%	1,4%
		Wed	10,98	1,70	8,01	1,5%	0,6%	1,3%
		Thu	11,28	1,84	8,05	1,5%	0,6%	1,3%
		Fri	11,53	2,29	8,47	1,5%	0,8%	1,4%
		Sat	11,28	1,52	7,95	1,5%	0,5%	1,3%
		Sun	11,37	1,60	8,11	1,5%	0,5%	1,3%
	Server	USA1	3,34	1,45	2,98	0,6%	0,5%	0,6%
		USA2	2,72	1,32	2,06	0,7%	0,5%	0,5%
		UK1	4,94	1,57	5,14	0,6%	0,5%	0,7%
		UK2	5,38	1,57	5,81	0,6%	0,5%	0,8%
		Portugal	6,42	1,57	5,49	0,6%	0,5%	0,7%

			Absolute Precision (seconds)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		1,33	4,26	3,81	0,4%	0,6%	0,6%
	Period	8h-10h	3,45	11,26	10,27	1,1%	1,5%	1,5%
		10h-12h	3,54	11,48	10,18	1,1%	1,6%	1,5%
		12h-16h	3,38	11,01	9,84	1,1%	1,5%	1,5%
		16h-18h	3,56	11,39	10,13	1,1%	1,6%	1,5%
		18h-20h	3,64	11,56	9,96	1,2%	1,6%	1,5%
		22h-00h	3,68	11,07	10,18	1,2%	1,5%	1,5%
		00h-03h	3,31	10,97	9,89	1,1%	1,4%	1,4%
	Weekday	Mon	3,50	11,33	9,82	1,2%	1,5%	1,5%
		Tue	3,57	11,15	9,67	1,2%	1,5%	1,4%
		Wed	3,44	11,30	10,20	1,1%	1,5%	1,5%
		Thu	3,40	11,26	10,31	1,0%	1,5%	1,5%
		Fri	3,51	11,32	10,31	1,1%	1,5%	1,5%
		Sat	3,54	11,25	10,08	1,1%	1,5%	1,5%
		Sun	3,52	11,21	10,08	1,1%	1,5%	1,5%
	Server	USA1	2,92	3,41	4,17	0,9%	0,6%	0,8%
		USA2	2,80	2,20	2,78	1,1%	0,5%	0,7%
		UK1	2,82	6,08	6,05	0,9%	0,7%	0,8%
		UK2	2,81	7,33	6,55	0,9%	0,8%	0,8%
		Portugal	2,66	7,87	7,99	0,8%	0,8%	0,9%

Table 7 – File Transfer Upload Speed

			Absolute Precision (seconds)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
LISBON	GLOBAL		0,12	0,13	0,17	0,9%	0,5%	1,1%
	Period	8h-10h	0,32	0,34	0,41	2,5%	1,2%	2,7%
		10h-12h	0,31	0,36	0,39	2,4%	1,2%	2,6%
		12h-16h	0,36	0,34	0,45	2,6%	1,2%	2,8%
		16h-18h	0,33	0,30	0,40	2,5%	1,0%	2,6%
		18h-20h	0,32	0,39	0,49	2,4%	1,3%	3,1%
		22h-00h	0,36	0,37	0,54	2,7%	1,2%	3,3%
		00h-03h	0,26	0,34	0,51	2,1%	1,2%	3,2%
	Weekday	Mon	0,37	0,39	0,47	2,8%	1,3%	3,0%
		Tue	0,32	0,38	0,47	2,4%	1,3%	2,9%
		Wed	0,35	0,39	0,37	2,6%	1,3%	2,4%
		Thu	0,32	0,35	0,43	2,5%	1,2%	2,7%
		Fri	0,30	0,23	0,66	2,3%	0,8%	3,9%
		Sat	0,32	0,36	0,32	2,4%	1,2%	2,2%
		Sun	0,29	0,32	0,42	2,2%	1,1%	2,8%
	Server	USA1	0,29	0,26	0,32	1,9%	0,9%	1,8%
		USA2	0,31	0,32	0,37	1,4%	1,1%	1,7%
		UK1	0,12	0,32	0,39	1,2%	1,1%	2,9%
		UK2	0,12	0,27	0,38	1,2%	1,0%	2,8%
		Portugal	0,11	0,29	0,37	1,4%	1,0%	3,0%

			Absolute Precision (seconds)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		0,21	0,17	0,16	0,7%	1,3%	1,1%
	Period	8h-10h	0,53	0,38	0,43	1,9%	3,0%	3,0%
		10h-12h	0,49	0,55	0,40	1,7%	3,9%	2,7%
		12h-16h	0,49	0,49	0,45	1,7%	3,5%	2,9%
		16h-18h	0,56	0,42	0,45	1,9%	3,0%	3,0%
		18h-20h	0,68	0,48	0,38	2,3%	3,6%	2,6%
		22h-00h	0,63	0,53	0,52	2,1%	3,8%	3,3%
		00h-03h	0,47	0,30	0,41	1,6%	2,4%	2,8%
	Weekday	Mon	0,52	0,51	0,43	1,7%	3,7%	2,9%
		Tue	0,63	0,45	0,47	2,1%	3,4%	3,1%
		Wed	0,46	0,44	0,43	1,6%	3,3%	2,9%
		Thu	0,56	0,43	0,43	2,0%	3,2%	2,9%
		Fri	0,55	0,45	0,41	1,9%	3,3%	2,7%
		Sat	0,60	0,53	0,40	2,0%	3,8%	2,7%
		Sun	0,56	0,40	0,48	1,9%	3,0%	3,2%
	Server	USA1	0,46	0,34	0,37	1,6%	2,2%	2,2%
		USA2	0,51	0,37	0,35	1,4%	1,8%	1,6%
		UK1	0,46	0,41	0,33	1,7%	3,5%	2,7%
		UK2	0,44	0,39	0,33	1,6%	3,5%	2,7%
		Portugal	0,41	0,29	0,31	1,6%	3,0%	2,7%

Table 8 – File Upload Time

			Absolute Precision (ms)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
LISBON	GLOBAL		0,70	0,58	0,58	0,8%	0,7%	0,5%
	Period	8h-10h	1,89	1,53	1,54	2,2%	1,8%	1,4%
		10h-12h	1,85	1,53	1,52	2,1%	1,8%	1,4%
		12h-16h	1,81	1,48	1,50	2,1%	1,7%	1,4%
		16h-18h	1,83	1,53	1,51	2,1%	1,7%	1,4%
		18h-20h	1,84	1,60	1,54	2,1%	1,8%	1,4%
		22h-00h	1,87	1,59	1,52	2,1%	1,8%	1,4%
		00h-03h	1,87	1,52	1,52	2,2%	1,8%	1,4%
	Weekday	Mon	1,86	1,55	1,52	2,1%	1,8%	1,4%
		Tue	1,88	1,56	1,53	2,1%	1,8%	1,4%
		Wed	1,84	1,54	1,54	2,1%	1,7%	1,4%
		Thu	1,86	1,54	1,50	2,1%	1,8%	1,4%
		Fri	1,88	1,53	1,52	2,1%	1,8%	1,4%
		Sat	1,81	1,52	1,51	2,1%	1,8%	1,4%
		Sun	1,83	1,54	1,52	2,1%	1,8%	1,4%
	Server	USA1	0,46	0,64	0,44	0,5%	0,6%	0,4%
		USA2	0,20	0,60	0,17	0,1%	0,4%	0,1%
		UK1	0,35	0,61	0,26	0,5%	0,9%	0,3%
		UK2	0,35	0,67	0,28	0,5%	1,0%	0,3%
		Portugal	0,30	0,59	0,36	0,7%	1,1%	0,5%

			Absolute Precision (ms)			Relative Precision		
			OPTIMUS	TMN	Vodafone	OPTIMUS	TMN	Vodafone
PORTO	GLOBAL		0,55	0,68	0,65	0,5%	0,8%	0,7%
	Period	8h-10h	1,48	1,79	1,62	1,4%	2,1%	2,0%
		10h-12h	1,46	1,78	1,69	1,4%	2,0%	2,0%
		12h-16h	1,43	1,78	1,67	1,3%	2,0%	1,9%
		16h-18h	1,44	1,81	1,76	1,3%	2,0%	2,0%
		18h-20h	1,45	1,81	1,74	1,3%	2,1%	2,0%
		22h-00h	1,49	1,78	1,78	1,4%	2,0%	2,0%
		00h-03h	1,45	1,78	1,72	1,4%	2,1%	2,0%
	Weekday	Mon	1,47	1,80	1,75	1,4%	2,0%	2,0%
		Tue	1,47	1,80	1,75	1,4%	2,1%	2,0%
		Wed	1,47	1,80	1,72	1,4%	2,1%	2,0%
		Thu	1,47	1,78	1,74	1,4%	2,1%	2,0%
		Fri	1,46	1,79	1,71	1,4%	2,0%	2,0%
		Sat	1,44	1,78	1,65	1,4%	2,0%	1,9%
		Sun	1,43	1,79	1,69	1,3%	2,0%	2,0%
	Server	USA1	0,47	0,51	0,71	0,4%	0,5%	0,6%
		USA2	0,31	0,30	0,69	0,2%	0,2%	0,5%
		UK1	0,46	0,55	0,45	0,5%	0,8%	0,7%
		UK2	0,51	0,57	0,48	0,6%	0,9%	0,7%
		Portugal	0,46	0,41	0,35	0,7%	0,8%	0,8%

Table 9 – User's Perception of Communication Delay

4.1.2 Fixed Accesses

		Absolute Precision (ms)				Relative Precision			
		Cabovisão	Clix	Sapo/Telepac	Zon	Cabovisão	Clix	Sapo/Telepac	Zon
GLOBAL		0.67	0.71	0.87	0.62	1.5%	1.4%	1.9%	1.3%
Period	8h-10h	2.14	1.94	2.12	1.68	4.5%	3.5%	4.4%	3.6%
	10h-12h	1.60	2.83	3.14	1.87	3.7%	5.4%	6.6%	4.1%
	12h-16h	1.53	2.63	2.76	1.80	3.5%	5.2%	6.2%	3.9%
	16h-18h	1.68	2.90	3.12	1.95	3.8%	5.5%	6.7%	4.1%
	18h-20h	1.36	1.84	2.34	1.69	3.0%	3.5%	4.7%	3.5%
	20h-21h	1.83	4.00	3.91	2.30	4.6%	7.9%	8.3%	5.1%
	21h-23h	3.33	3.01	3.11	2.24	7.0%	5.8%	6.7%	4.3%
	23h-01h	2.21	1.80	2.60	2.31	4.8%	3.4%	5.3%	4.8%
	01h-04h	1.79	1.47	1.85	1.64	3.8%	2.8%	4.0%	3.4%
	04h-08	1.85	1.56	1.83	1.53	4.0%	3.1%	3.9%	3.3%
Weekday	Mon	2.85	1.80	2.69	1.57	6.2%	3.4%	5.4%	3.3%
	Tue	1.28	1.88	2.20	1.67	2.8%	3.7%	4.8%	3.5%
	Wed	1.33	1.98	2.17	1.70	3.0%	4.0%	4.7%	3.6%
	Thu	1.36	1.94	2.27	1.77	2.9%	3.6%	4.7%	3.6%
	Fri	1.45	1.79	1.89	1.49	3.3%	3.5%	4.1%	3.2%
	Sat	1.35	1.89	2.70	1.65	3.1%	3.7%	5.7%	3.5%
	Sun	1.83	1.80	2.23	1.43	3.9%	3.4%	4.8%	2.9%
Server	USA1	0.40	0.73	1.78	0.91	0.6%	1.0%	2.7%	1.4%
	USA2	0.29	0.44	0.74	0.45	0.3%	0.4%	0.7%	0.4%
	UK1	2.26	0.66	1.38	0.77	7.8%	1.9%	4.8%	2.7%
	UK2	0.24	0.55	0.46	0.36	0.9%	1.7%	1.7%	1.3%
	Portugal	0.24	0.20	0.34	0.45	2.5%	1.3%	3.4%	2.8%

Table 10 – User's Perception of Latency

		Absolute Precision (kbps)				Relative Precision			
		Cabovisão	Clix	Sapo/Telepac	Zon	Cabovisão	Clix	Sapo/Telepac	Zon
GLOBAL		19.18	9.42	12.72	18.29	1.6%	1.3%	1.4%	1.7%
Period	8h-10h	54.04	24.96	33.22	52.89	4.5%	3.4%	3.8%	4.9%
	10h-12h	67.35	33.15	49.62	61.90	5.5%	4.7%	5.5%	5.6%
	12h-16h	62.78	32.62	48.00	54.96	5.0%	4.5%	5.2%	5.0%
	16h-18h	69.59	34.03	48.97	57.15	5.5%	4.7%	5.3%	5.3%
	18h-20h	54.62	24.12	31.77	49.29	4.4%	3.0%	3.6%	4.9%
	20h-21h	88.84	48.08	72.88	69.45	6.7%	6.3%	7.9%	6.5%
	21h-23h	68.82	34.42	51.55	54.23	5.8%	4.8%	5.7%	5.8%
	23h-01h	53.58	23.18	32.50	52.60	4.3%	3.1%	3.7%	5.0%
	01h-04h	49.38	19.80	27.33	49.32	4.2%	2.6%	3.1%	4.8%
	04h-08	49.02	20.25	28.63	49.99	4.0%	2.6%	3.2%	4.6%
Weekday	Mon	51.40	24.05	35.96	49.44	4.2%	3.2%	4.0%	4.6%
	Tue	48.76	24.82	34.26	50.67	4.1%	3.3%	3.9%	4.9%
	Wed	53.77	25.33	34.40	52.81	4.3%	3.4%	3.8%	4.9%
	Thu	50.45	26.55	34.47	49.73	4.1%	3.6%	3.8%	4.6%
	Fri	52.71	24.03	30.51	46.39	4.3%	3.3%	3.5%	4.4%
	Sat	49.09	24.31	32.59	43.92	3.9%	3.2%	3.6%	4.1%
	Sun	48.43	24.70	32.73	43.43	4.0%	3.3%	3.6%	4.4%
Server	USA1	2.25	2.29	3.46	2.68	0.5%	0.6%	0.8%	0.6%
	USA2	1.36	1.38	2.00	1.54	0.5%	0.5%	0.7%	0.5%
	UK1	9.67	8.50	10.81	9.98	0.9%	1.1%	1.2%	1.0%
	UK2	8.44	8.20	9.78	8.75	0.8%	1.1%	1.0%	0.8%
	Portugal	41.88	13.35	28.10	54.23	1.3%	0.9%	1.5%	2.2%

Table 11 – File Transfer Speed during Web Browsing

		Absolute Precision (s)				Relative Precision			
		Cabovisão	Clix	Sapo/Telepac	Zon	Cabovisão	Clix	Sapo/Telepac	Zon
GLOBAL		0.02	0.02	0.03	0.02	2.0%	1.5%	2.1%	2.0%
Period	8h-10h	0.12	0.05	0.12	0.04	9.2%	3.5%	9.0%	3.6%
	10h-12h	0.04	0.08	0.07	0.05	4.0%	5.7%	5.9%	4.1%
	12h-16h	0.04	0.07	0.07	0.05	3.7%	4.9%	5.4%	4.3%
	16h-18h	0.05	0.07	0.07	0.06	4.7%	5.0%	5.9%	4.9%
	18h-20h	0.04	0.04	0.06	0.04	3.5%	3.4%	4.4%	3.6%
	20h-21h	0.09	0.12	0.13	0.08	8.0%	8.5%	9.7%	7.1%
	21h-23h	0.07	0.08	0.08	0.06	5.8%	5.4%	6.0%	4.7%
	23h-01h	0.05	0.07	0.08	0.09	4.9%	5.1%	5.6%	7.5%
	01h-04h	0.06	0.04	0.06	0.10	4.5%	2.7%	4.1%	7.8%
	04h-08	0.06	0.04	0.05	0.05	4.8%	3.2%	3.7%	4.5%
Weekday	Mon	0.09	0.05	0.09	0.14	7.6%	3.5%	7.3%	11.3%
	Tue	0.10	0.04	0.06	0.04	8.4%	3.3%	4.5%	3.4%
	Wed	0.04	0.06	0.11	0.05	3.3%	4.2%	7.9%	3.9%
	Thu	0.04	0.06	0.07	0.04	3.3%	4.1%	5.4%	3.4%
	Fri	0.04	0.05	0.06	0.04	3.4%	3.8%	4.5%	3.1%
	Sat	0.04	0.06	0.05	0.04	3.9%	4.5%	4.3%	3.2%
	Sun	0.05	0.04	0.06	0.05	4.2%	3.2%	4.9%	4.2%
Server	USA1	0.03	0.02	0.04	0.04	1.8%	1.1%	2.2%	2.7%
	USA2	0.07	0.02	0.05	0.07	3.0%	0.9%	1.7%	2.8%
	UK1	0.04	0.04	0.07	0.05	5.4%	3.9%	8.0%	6.7%
	UK2	0.03	0.02	0.04	0.02	4.3%	2.0%	4.9%	2.8%
	Portugal	0.03	0.05	0.05	0.04	11.6%	9.0%	10.4%	8.4%

Table 12 – File Transfer Speed during Web Browsing

		Absolute Precision (kbps)				Relative Precision			
		Cabovisão	Clix	Sapo/Telepac	Zon	Cabovisão	Clix	Sapo/Telepac	Zon
GLOBAL		54.06	25.38	30.64	44.36	1.2%	1.0%	1.1%	1.2%
Period	8h-10h	145.63	62.44	77.55	116.53	3.2%	2.3%	2.6%	2.8%
	10h-12h	172.27	84.56	111.07	134.05	3.8%	3.5%	3.9%	3.2%
	12h-16h	161.56	79.15	112.83	128.77	3.6%	3.2%	3.9%	3.2%
	16h-18h	181.50	82.70	120.53	139.49	4.1%	3.4%	4.3%	3.6%
	18h-20h	151.58	64.20	78.21	126.88	3.6%	2.6%	2.9%	3.6%
	20h-21h	303.08	138.86	186.30	232.77	6.6%	5.6%	6.3%	5.6%
	21h-23h	258.27	110.72	136.13	187.03	6.8%	4.8%	4.6%	5.6%
	23h-01h	166.44	61.61	74.10	139.86	3.8%	2.4%	2.6%	3.9%
	01h-04h	136.25	54.68	68.73	117.50	3.2%	2.2%	2.4%	3.2%
	04h-08	132.65	54.78	67.02	109.11	2.9%	2.1%	2.3%	2.8%
Weekday	Mon	140.93	64.67	91.56	112.52	3.3%	2.6%	3.2%	3.0%
	Tue	140.87	67.79	81.27	121.37	3.2%	2.7%	2.8%	3.2%
	Wed	144.25	72.81	84.13	120.55	3.1%	2.9%	2.8%	3.1%
	Thu	141.44	70.95	78.25	117.06	3.1%	2.8%	2.7%	2.9%
	Fri	152.17	62.12	69.62	111.07	3.6%	2.5%	2.4%	2.8%
	Sat	139.49	61.21	77.45	108.88	3.1%	2.4%	2.7%	2.7%
	Sun	137.16	70.46	88.19	108.89	3.4%	2.9%	3.2%	3.0%
Server	USA1	66.19	39.19	55.69	58.10	2.1%	1.9%	2.3%	2.1%
	USA2	40.09	29.34	42.07	35.12	2.5%	2.0%	2.5%	2.2%
	UK1	93.76	49.81	61.50	83.12	2.0%	1.8%	2.0%	1.9%
	UK2	89.91	49.08	60.96	84.46	2.1%	1.8%	1.9%	1.9%
	Portugal	81.97	50.09	71.40	78.40	1.0%	1.4%	1.8%	1.3%

Table 13 – File Transfer Download Speed

		Absolute Precision (kbps)				Relative Precision			
		Cabovisão	Clix	Sapo/Telepac	Zon	Cabovisão	Clix	Sapo/Telepac	Zon
GLOBAL		1.66	2.24	2.48	1.74	0.4%	0.7%	0.8%	0.4%
Period	8h-10h	3.94	5.91	6.76	4.79	0.9%	1.9%	2.3%	1.2%
	10h-12h	3.86	9.40	11.91	5.54	0.9%	2.8%	3.8%	1.3%
	12h-16h	3.56	8.68	11.37	5.02	0.8%	2.6%	3.6%	1.2%
	16h-18h	3.85	8.96	11.66	5.36	0.9%	2.6%	3.8%	1.3%
	18h-20h	5.31	5.71	6.35	4.80	1.4%	1.8%	2.2%	1.2%
	20h-21h	11.17	17.53	22.10	9.42	2.9%	5.6%	6.9%	2.4%
	21h-23h	10.34	12.17	16.08	7.35	2.8%	3.7%	4.8%	1.9%
	23h-01h	6.82	5.48	6.08	4.94	1.8%	1.8%	2.1%	1.3%
	01h-04h	4.52	4.65	5.22	4.54	1.1%	1.5%	1.8%	1.2%
	04h-08	3.63	4.76	5.42	4.36	0.8%	1.5%	1.9%	1.1%
Weekday	Mon	4.61	5.77	6.87	4.75	1.1%	1.8%	2.2%	1.2%
	Tue	4.33	5.89	6.03	4.98	1.1%	1.9%	2.0%	1.3%
	Wed	4.76	6.25	6.40	4.89	1.2%	1.9%	2.1%	1.2%
	Thu	4.09	6.07	7.09	4.87	1.0%	1.9%	2.3%	1.2%
	Fri	4.29	5.63	6.22	4.12	1.1%	1.7%	2.0%	1.0%
	Sat	4.18	5.67	5.86	3.85	1.0%	1.8%	2.0%	1.0%
	Sun	4.20	6.03	6.72	4.42	1.0%	1.9%	2.3%	1.2%
Server	USA1	4.09	4.42	4.50	3.45	1.1%	1.6%	1.6%	0.9%
	USA2	1.98	4.37	4.57	3.44	0.5%	1.8%	1.7%	1.0%
	UK1	5.69	4.24	5.97	4.04	1.5%	1.2%	1.9%	1.0%
	UK2	3.84	4.37	5.78	4.02	0.9%	1.2%	1.8%	1.0%
	Portugal	1.19	3.81	6.19	3.82	0.2%	1.0%	1.8%	0.9%

Table 14 – File Transfer Upload Speed