Monitoring tool to evaluate portuguese ISP's among public cloud providers

Eduardo Cunha[1[PG45515]], Miguel Peixoto[1[PG45517]], and Isaías Nambissi[1[PG47489]]

University of Minho
{pg45515, pg45517, pg47489}@alunos.uminho.pt

Abstract. The work carried out in this document aims to assess the quality of connection from the main Portuguese ISPs to the largest public cloud providers on the internet. To our knowledge, this is the first work carried out in this area by the academic community. An active monitoring tool was developed to run measurements on personal computers against virtual machines located in the different cloud providers. During one month different metrics were collected and the conclusions shows which ISP and cloud providers has the best metrics results.

Keywords: QoS · monitoring · bandwith · delay · jitter · isp · cloud.

1.0 Introduction

Monitoring mobile network resources or devices can be seen as a solution that helps to evaluate the performance of a particular IT infrastructure, with regard to Internet traffic on an organization's network to optimize the use of resources in a more efficient and safe since in this area there is an exponential growth day after day. It also monitors connected servers and other peripherals continuously, in real time, to predict potential problems and helps identify network abnormalities and takes strategic measures to minimize or prevent any damage.

A mobile communication infrastructure is not always easy to manage and the level of difficulty increases with the size and number of devices present in the same network infrastructure. Monitoring a network is a fundamental process as it prevents and detects possible problems and has several auxiliary tools that allow evaluating the quality of such network resources.

In this context, for this research, we want to use certain cloud platforms, such as Amazon, Alibaba, Azure and Google, to monitor a wide variety of network resources, located at different points or services, such as NOS, Vodafone, and MEO which are the main country's mobile telecommunications organizations. However, the ICMP measurement variables were defined, and for each platform, latency, jitter and loss were evaluated, and in terms of bandwith, the Download and Upload speed were evaluated, then we will show step by step how, each one of these objectives were achieved in the present research.

2.0 Objectives

The main purpose of this work is to measure the quality of service provided by the between Portuguese ISP's to the leading public cloud providers. Through active measurements, the following metrics were evaluated:

- Latency;
- Jitter;
- Packet loss;
- Throughput;

Through the development of a tool that were running on personal computers, the measurements were running during one month. The tool were developed in Python and will use ICMP libraries for latency, jitter and packet loss metrics. Iperf3 will be used to perform throughput measurements.

The developed tool consists of a small application written in Python which measures against virtual machines that have been created in the various clouds. At the end of each measurement, the results are sent to a database that will also be located in a cloud.

3.0 Comparison between Active and Passive Measurement

The main difference between active and passive monitoring is that passive monitoring gathers real user data and analyzes it over a specific period of time. That is, the monitor then studies the analysis and releases the results to the monitor user.

Unlike active monitoring, passive monitors do not inject test data into the network to emulate user behavior. Instead, it extracts real user data from specific points on the network.

So, a passive monitor can collect and generate large amounts of performance data. After all, it does not run as often as active monitors. This data provides a more holistic view of your network performance. Therefore, it can cover a wide spectrum of metrics. Since it gathers real user data, passive monitors inform you about issues that directly affect users. That is, it does not make changes based on live forecasts.

When compared to active monitoring, passive monitoring puts less strain on the network. After all, the interval between tests is much longer. However, passive monitors usually analyze the inflow and outflow of a specific device on the network. As such, it requires specialized hardware to obtain user data.

This work used active measurement, once the developed tool injects traffic as ICMP packets to measure jitter, delay and packet loss. Moreover, the Iperf3 build-in in the tool acts sending as much as packet is possible to measure the max bandwidth possible in certain link/connection.

4.0 Topology

The client server topology is a centralized application topology, that is, in the network there are service providers, called servers, and there are requesters of resources or services, called clients.

The client does not share any of its resources with the server, but nevertheless it requests some function from the server, being the client responsible for initiating communication with the server, while the server waits for incoming requests.

For this context, as shown in the figure below, there are several users requesting services on the network, and there are different virtual machines running on different cloud platforms (Web Servers), and a database, which in turn is a virtual machine as well, these servers have been implemented on various platforms such as Alibaba, Amazon, Azure, Google.

Unfortunately, IBM cloud service is not included on this work due to problems with credit cards to create an account. However, this work still relevant to compare the greatest player in the market.

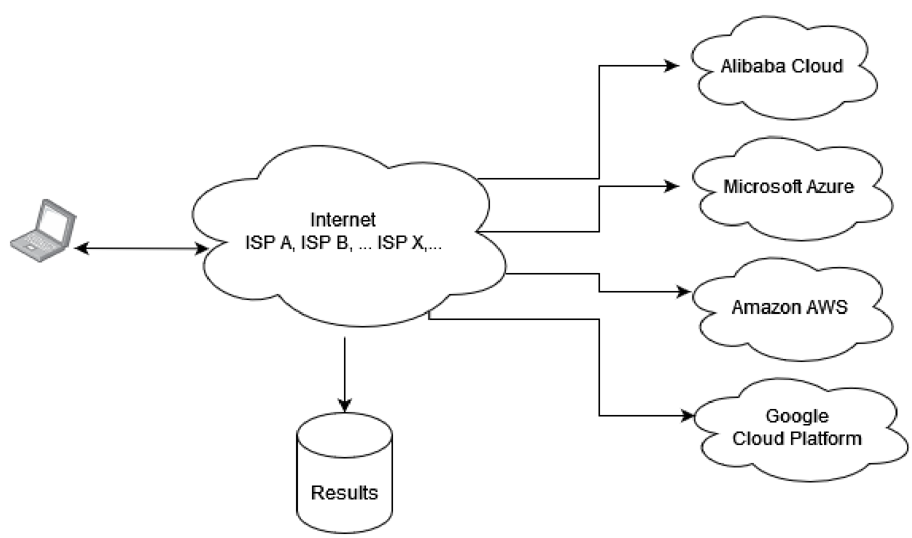


Fig. 1: Client-Server Topology

4.1 Cloud Virtual Machines

A virtual machine (VM) is a digital version of a physical computer. Virtual machine software can run programs and operating systems, store data, connect to networks, and perform other computing functions. In addition, it requires maintenance such as system updates and monitoring. Multiple VMs can be hosted on a single physical machine, typically a server, and managed with virtual machine software. This provides flexibility for compute resources (compute, storage, networking) to be distributed across VMs as needed, increasing overall efficiency. This architecture provides the building blocks for the advanced virtualized capabilities largely used nowadays, including cloud computing.

In the present work, it was necessary to create four VMs clouds, on different platforms; Google, Alibaba, Amazon and Azure. Below is represented the references and specifications of the aforementioned VMs.

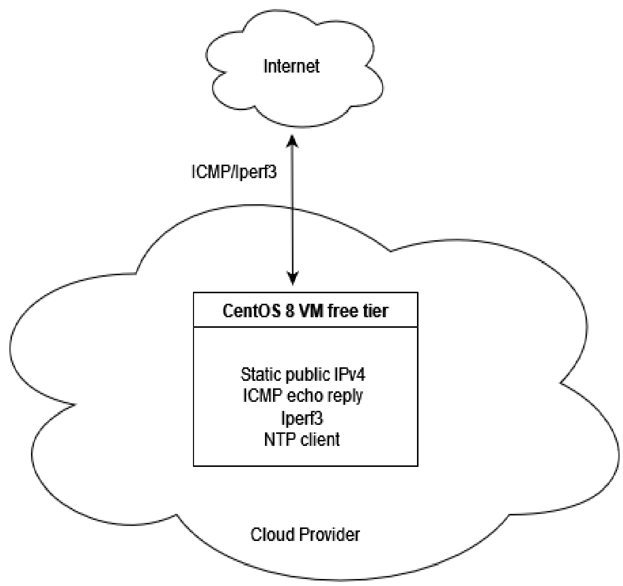


Fig. 2: VMs architecture

Virtual Machines configuration:

- 1GB of memory
- 1 vCPU (except Google - 2 vCPU)
- Region/Location: UK/London
- OS: CentOS8
- Firewall rule: allow ICMP echo reply and TCP port 5201(iperf3)
- Static public IPv4

For all the cloud plataforms used the free tier was used, keeping the comparison among cloud service providers as fair as possible. Google Cloud Platforms offers in its free tier a minimum of 2 vCPU, but it does not impact the final results because our tests do not exhausted the CPU's in any VM.

All the VMs are located at the same region, in UK/London, to make possible compare the results based on time like the delay. The Operational System (OS) chosen was the CentOS8 to all the machines.

To allow the tests to run properly was necessary to add a rule in the firewall in each VM to allow traffic coming from outside - TCP port 5201.

The setup of the virtual machines consisted of:

– Installation and configuration of iperf3 to run as a system service (systemd).
– Reply to ICMP echo requests
– Configuration of a NTP client to automatically adjust clock to Portuguese time to ensure the use of same time on VMs

4.2 Database

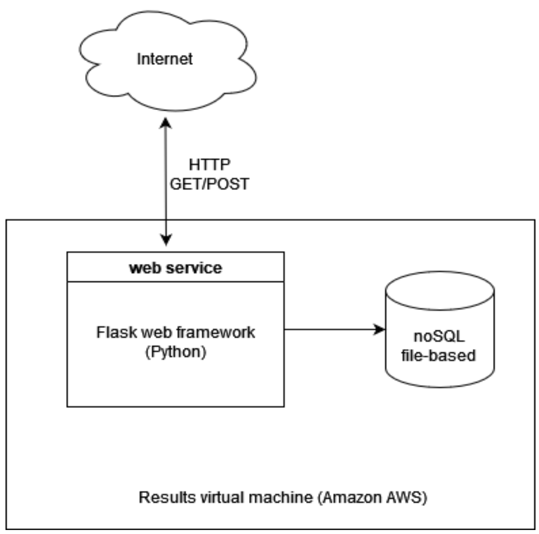


Fig. 3: Results VM architecture

In the present research, we opted for the implementation of a cloud database, which is understood as a database service developed and accessed through a cloud platform. It serves many of the same functions as a traditional database with the added flexibility of cloud computing. The data is accessed via a web service - HTTP GET and POST - to store the measurements data we use HTTP POST and to read the results and the list of targets we use HTTP GET. Cloud databases will allow data storage, collected by different cloud platforms such as Google, Amazon, Azure, and Alibaba. This database virtual machine uses the same NTP configuration as the other VMs and is in charge of record the time of the measurements.

4.3 Code

The tool was totally developed in Python using mainly the **icmplib** and **Iperf3** libraries. The tool and all its dependencies are available on the GitHub repository used to this work.[6] On the repository the project is specified and the necessary steps to run the tool are available as well.The tool was designed to be as simple as possible because of the deadline it was important to start to collect data as soon as possible.

When the tool starts, it gets the IPv4 address that is attributed to each VM in the cloud. Then, the latency, jitter and packet loss tests are firstly run. After, the throughput tests are executed using the Iperf3 tool and then all the results are sent to the Database available in another virtual machine in the cloud. The test is run until all the targets were executed. If an error occurs when the client is trying to contact the cloud, the code raises an exception and the flow of the code is finished.

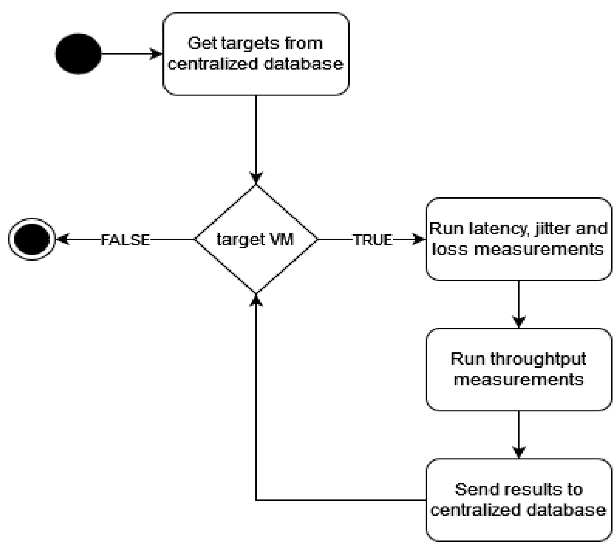


Fig. 4: Code state diagram

```
imac:QoSI-main administrator$ sudo python3 qosi.pyc
Getting data from server...
OK
Getting information from device...
AS15525 MEO - SERVICOS DE COMUNICACOES E MULTIMEDIA S.A.
Darwin
Starting ICMP measurement to alibaba
Latency: 38.13ms
Jitter: 0.126ms
Loss: 0.0%
Starting bandwidth measurement to alibaba
Download: 10.36Mbps
Upload: 10.48Mbps
Sending results to databse...
OK
Starting ICMP measurement to amazon
Latency: 36.907ms
Jitter: 0.095ms
Loss: 0.0%
Starting bandwidth measurement to amazon
Download: 284.71Mbps
Upload: 286.38Mbps
Sending results to databse...
OK
Starting ICMP measurement to azure
Latency: 33.523ms
Jitter: 0.549ms
Loss: 0.0%
Starting bandwidth measurement to azure
Download: 377.43Mbps
Upload: 379.93Mbps
Sending results to databse...
OK
Starting ICMP measurement to google
Latency: 36.567ms
Jitter: 0.262ms
Loss: 0.0%
Starting bandwidth measurement to google
Download: 568.36Mbps
Upload: 571.09Mbps
Sending results to databse...
OK
Measurements finished.
```

Fig. 5: Running the tool

5.0 Results

At this section, the result will be available followed by a critical analysis to each graph and tables. In total, approximately 800 test were run during one month to generate this results. The tests were run in different periods of time to increase the variability.Two types of graphs were generated - by cloud services and by Internet Service Providers (ISPs).

The tables show in a intuitive and direct way the maximum, mean and minimum values to each metric to the pair CSP-ISP. It allows analysed the impact of each ISP to each CSP and vice-versa.

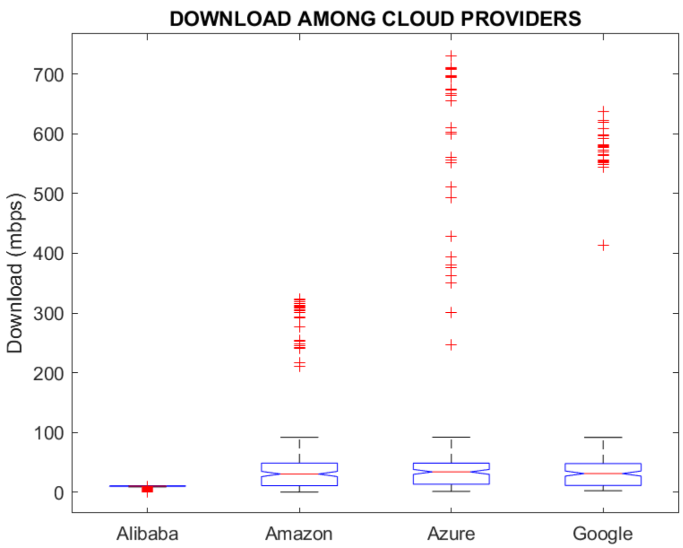
5.1 Graphs

5.1.1 Cloud Service Providers comparison

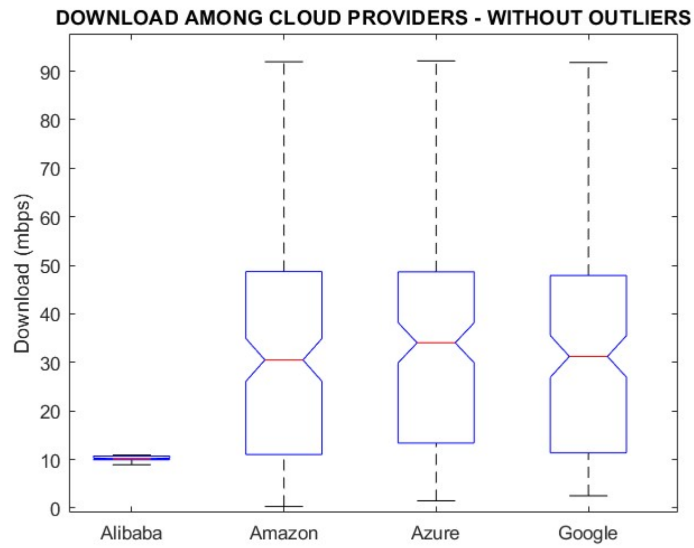
The first one to be analysed, figure 4, is the download. It is evident that Alibaba performs much worst than other services. Otherwise, Amazon, Azure and Google showed similar results with the outliers are ignored.

However, including the outliers, the Azure performs much better, being capable of handle to download rates of almost 700 mbps. The other services can clearly not support such high rates.

Due to the similarity between download and upload graph, only the download graph is represented in this report, but all the graphs are available on GitHub.[6] The similarity between upload and download shows that CSP have symmetrical connectivity.



(a)



(b)

Fig. 6: Download results among CSPs

The next metrics to be analysed are the delay and jitter. Delay is the time needed to a packet do a round-trip between the client and the server - time in the ping test. However, the jitter is the constant variation between delays in a ping test. It is extremely important to analyse both metric before chose a cloud service to host some service because depending on the type of application or service the costumer want to run on the cloud, theses metric can impact directly the QoE of the end-user. Services like VoIP, live video or on-line gaming can be seriously degraded by poor rates of delay and jitter.

Due to the low values to represent both metrics it was adopted a logarithm representation to allow readable graphs. In Figure 5 (a), the latency is represented and all the clouds perfoms similar. It is possible to see the the median of the Microsoft Azure is a little bit lower than the competitors. But at the same time the highest outlier belongs to Azure. However to analyse the delay is more relevant the median or the mean.

For the jitter the median and maximum values of all the CSPs are close to each other. However, Azure and Google have similar minimum values. Amazon and, surprisingly, Alibaba have the same minimum values. At this aspect, all the CSPs show satisfying results.

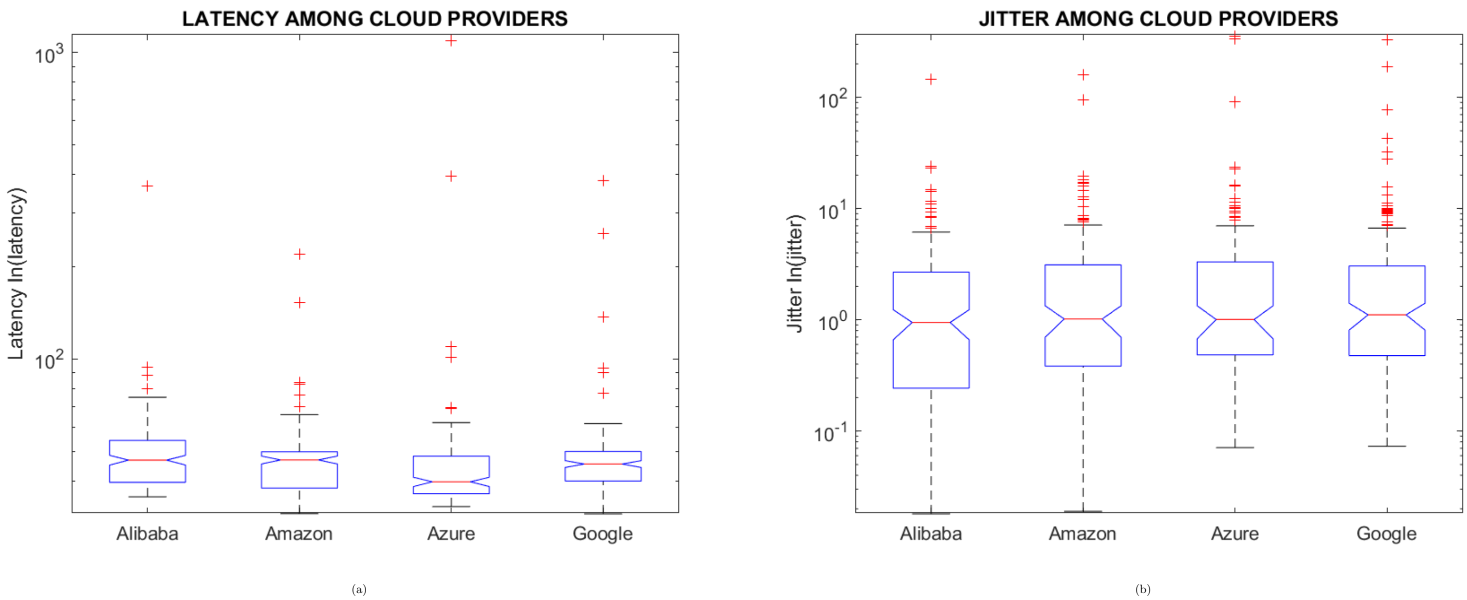


Fig. 7: Latency and Jitter results among CSPs

The last metric to be analysed among CSPs is the packet losses. Sincerely, no significantly packet losses were registered in the results. In general, the links to the cloud services are extremely reliable, even in the rush hours. The highest packet loss were registered in the Azure cloud (0.4%). The other ones, except Amazon, registered losses in some test as well but only 0.2% were loosed and fortunately losses are not common. The losses registered could be have as reason the links of the ISP as well. So this metric with this results could be assumed as not crucial in the decision to choose one CSP.

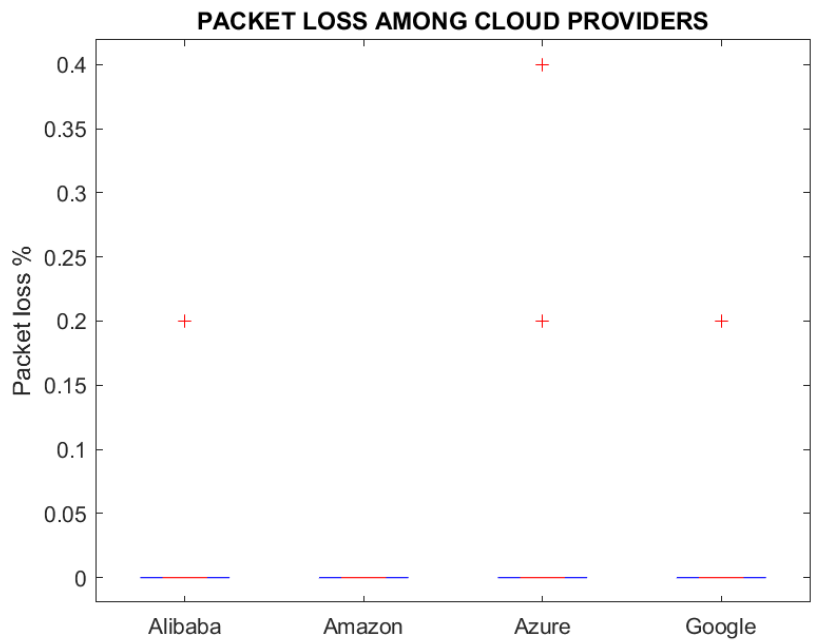


Fig. 8: Packet loss result among CSPs

5.1.2 Internet Service Providers comparison

Until the moment the performance among CSPs were showed. At this part, the performance among ISPs will be evaluated. The download and upload graphs for ISPs are similar as well due to the same reason (symmetrical connectivity) as before.

Over all the ISPs the MEO outstanding the others. However, the Autonomous System (AS) associated with the MEO that showed better performances is reserved only for business. It happened because some tests were run in machines used in business environment.

Keeping the AS15525 out and comparing the others. NOS and MEO (AS3243) showed similar performance. Vodafone is the Internet Provider with worst bandwidth among all the tested ones. Unfortunately, because the test were run in different machines in variable places it is impossible to determine if the worst performance associated with Vodafone is due to the limited in the contract.

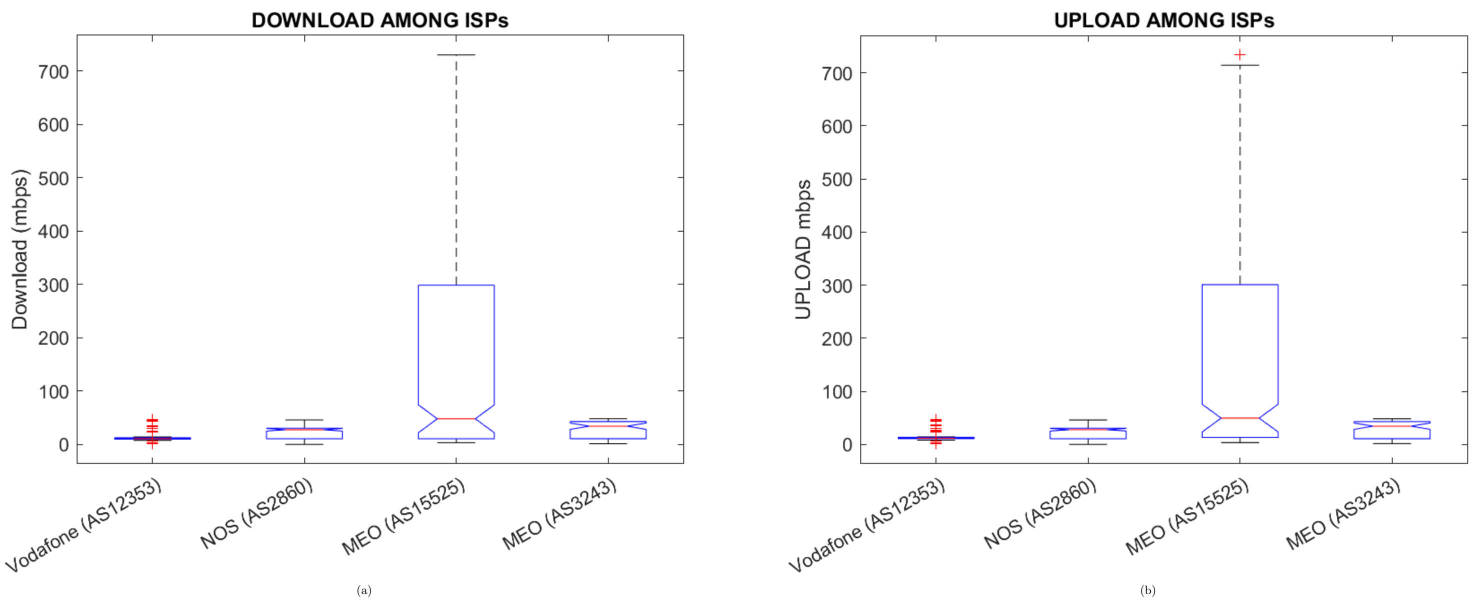


Fig. 9: Download and Upload results among ISPs

Differently from the analysis in the CSPs, in the ISPs the jitter and the latency have significant differences. Once again, the MEO attributed to business - AS15525 - showed better results for both latency and jitter. It can represents that the dedicated links have less congestion or higher priority in the MEO's network.

Although MEO AS3243 has less latency than others, the jitter is the highest one and with the highest variability what is not a good point for MEO personal users. Then NOS has the highest delay among all the ISPs and do not showed satisfying results in the jitter metric as well when compared with others.

Otherwise, Vodafone that showed to be the worst ISP in term of bandwidth, surprisingly showed the best results in terms of jitter. Although the delay is not the best one among the analysed ones still performing well and with low variability in delay and jitter, showing be more reliable on theses two metric.

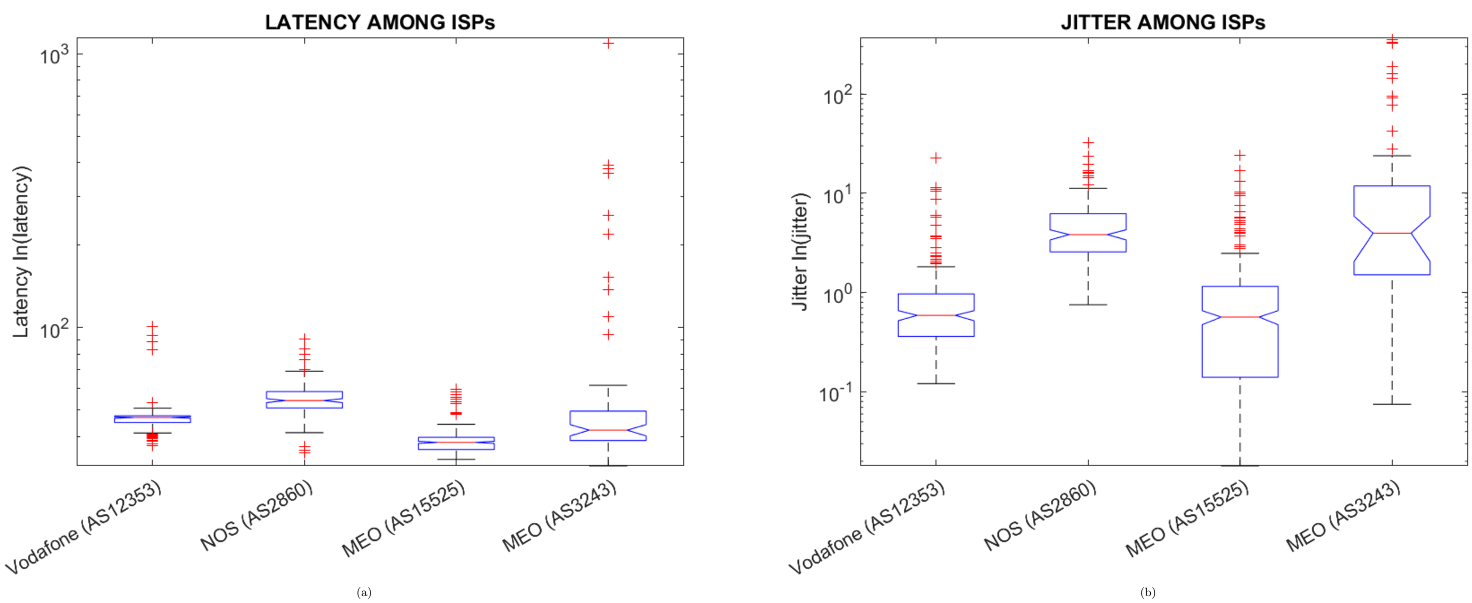


Fig. 10: Download and Upload results among ISPs

In terms of packet loss the analysis is similar with the CSPs. All the ISPs showed to be reliable only some packet losses occurred and the percentage and frequency is insignificantly to affect the QoE and the QoS overall. Only Vodafone do not had losses during all the tests run.

If this metric had showed significant result could be worth a deeper analysis to try to understood were in general the packet loss occurs - ISP or CSP side. However, as the result are irrelevant in the results obtained during the period that the data was collected try to understand were the losses are is totally irrelevant.

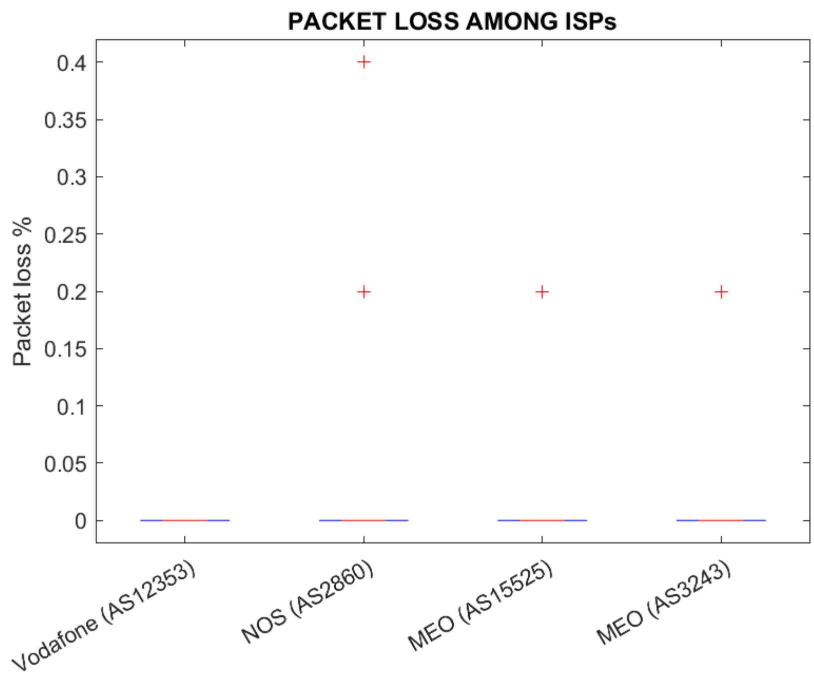


Fig. 11: Packet loss result among ISPs

5.2 Tables

The tables are separated by maximum, mean and minimum values registered to each pair ISP-CSP. The highest value in the download and upload are achieve in the AS15525 MEO with to the Azure. It shows that the Azure is the Cloud Provider that supports more bandwidth through their servers. However, the another AS associated with MEO showed slightly better results to all the cloud providers in the maximum values.

The Alibaba showed to limit the bandwidth in approximately 10 mbps. This limitation could become a problem if the costumer looking for a service needs to transfer great amount of files or data. It is not possible to ensure if the limitation is per connection or per VM in the cloud. It is necessary to run the bandwidth test with Iperf3 from different machines to the Alibaba VM to see if the 10 Mbps is going to be shared or if both clients could achieve 10 Mbps at the same time.

	MAX DOWNLOAD			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	10,9	10,8	10,9	10,77
Amazon	43,09	43,16	45,85	323,85
Azure	46,65	46,01	48,31	730,52
Google	45,76	43,82	45,49	637,09

Table 1: Highest Download in Mbps

Ignoring the AS15525 that is destinated to business, the AS3243 showed that the mean of MEO is significantly higher than competitors. Almost three times better than Vodafone and 30% - 38% higher than NOS.

	MEAN DOWNLOAD			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	9,76	9,43	10,52	10,37
Amazon	12,10	25,62	33,63	146,29
Azure	14,66	27,90	38,01	259,55
Google	11,85	25,86	35,70	238,88

Table 2: Average Download in Mbps

Ironically, AS3243 from MEO that showed the best results to maximum and mean values had the worst results in the minimum values to Azure and Google services. But the worst results are from NOS AS2860 to Alibaba and Amazon, 0.21 and 0.31 Mbps, respectively.

To avoid repetitive analysis the upload table is not represented in the report because those tables are have similar results than download. However, all the tables are available on the GitHub.[6]

	MIN DOWNLOAD			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	2,41	0,21	7,85	8,48
Amazon	1,89	0,31	2,3	10,49
Azure	1,47	2,51	1,57	9,85
Google	2,52	6,81	2,62	3,46

Table 3: Lowest Download in Mbps

Despite MEO shows the best bandwidth, the results to jitter are incredible disappointed even for the AS dedicated to business. The AS3243 showed performance until 30 times worst than Vodafone. This differences in the jitter could impact directly final users, presenting totally different QoE for user from different Internet Providers.

Vodafone shows incredible results to the maximum value of jitter and the best combination overall is Amazon-Vodafone with only 8.65 ms. The ideal value for jitter is below 20 ms and the worst case of Vodafone happend to Azure with 22.55 ms, all the others are half or less than the ideal jitter.

	MAX JITTER			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	11,08	14,84	144,11	24,15
Amazon	8,65	19,52	160,44	17,10
Azure	22,55	23,70	353,70	7,52
Google	10,58	32,25	327,73	13,14

Table 4: Highest Jitter in ms

The average jitter for Vodafone is even more incredible, achieving final results better than the AS of MEO dedicated for business. For jitter is desired values as close to zero as possible and in average to all the from Vodafone to all the CSPs tested the values are approximately 1 ms. It is 5 times compared to NOS and until 40 times less when compared to MEO - AS3243.

	MEAN JITTER			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	1,13	4,52	13,64	1,16
Amazon	0,99	5,23	19,04	1,13
Azure	1,46	6,27	46,49	1,05
Google	1,03	5,14	40,47	1,24

Table 5: Average Jitter in ms

The lowest values to jitter are registered in the MEO AS15525, all the values are less than 0.1 ms. In the best cases - to Alibaba and Amazon - incredible 0.02 ms are achieved. The MEO AS3243 achieved variable values depending on the cloud - worst case to Azure (0.67 ms) and the best to Amazon (0.08 ms). Showing that in fact MEO is not as reliable as Vodafone that apresent persistent results that the minimum values varies from 0.12 ms (Alibaba and Azure) to 0.18 ms (Amazon).

	MIN JITTER			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	0,12	1,26	0,29	0,02
Amazon	0,18	0,78	0,08	0,02
Azure	0,12	0,75	0,67	0,07
Google	0,16	0,84	0,13	0,07

Table 6: Lowest Jitter in ms

The delay/latency is another important metric to be evaluated. In general, people usually cares more about delay than jitter due to lack of knowledge some of them not even know the difference between jitter and delay. However, both metrics must be analysed together to offer a better QoE for end-users.

On this metric, the AS15525 performs much better than other. However is incredible to see that only the difference from business plan or personal plan with the Internet Provider can have such differences. At the same time, the AS of MEO for personal contracts showed the worst performance results. In the worst case the AS3243 registered delays of more than 1 s. Among the AS for personal contracts, the NOS showed the best results, but not outstanding from Vodafone (except to Azure).

	MAX LATENCY			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	88,53	79,79	366,64	58,22
Amazon	82,76	83,59	219,86	56,66
Azure	101,09	69,24	1095,03	55,70
Google	93,36	90,52	380,86	59,56

Table 7: Highest Latency in ms

The average values for delay is the most important to be analysed. Because it shows how the behaviour of the network most of the time. And the AS15525 outstanding the others, but it is not incredible because business plans are more expensive than personal ones, so better performances are expected.

What really shows impressive results is, once again, Vodafone. Until 11 ms in average better than NOS and 80.36 ms better than MEO. MEO for sure is the worst one when the metrics are delay and jitter - AS3243.

	MEAN LATENCY			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	48,35	59,35	63,46	39,78
Amazon	48,33	55,32	57,72	37,80
Azure	42,07	50,93	122,43	35,74
Google	46,76	53,58	80,13	39,38

Table 8: Average Latency in ms

As happened in the jitter, the results for MEO AS3243 to the minimum values achieved in latency is closer from competitors. Whatever, it shows big variances in the delay and jitter metrics to MEO - until 1060.68 ms in the highest difference from maximum to minimum value (Google - AS3243). The minimum values among Vodafone, NOS and MEO AS15525 are close and satisfying.

	MIN LATENCY			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	39,76	36,81	34,35	35,49
Amazon	41,17	34,73	31,28	34,34
Azure	37,07	36,85	34,35	32,99
Google	38,61	35,67	31,23	34,32

Table 9: Lowest Latency in ms

The last table shows the maximum % of packets losses. Vodafone has no packets losses registered to any cloud service, all the others have. Whatever, the percentages are really low and it could not affect the performance overall. But do not register any losses in Vodafone give us the idea that probably the losses of the competitor happened in the Internet Provider infrastructure, but it is impossible to ensure it without a deeper analysis.

	MAX LOSS			
	AS12353 Vodafone	AS2860 NOS	AS3243 MEO	AS15525 MEO
Alibaba	0	0,2	0	0
Amazon	0	0	0	0
Azure	0	0,4	0,2	0,2
Google	0	0	0,2	0

Table 10: Highest Loss %

6.0 Conclusions

During the creation of the monitoring tool a problem to run the tool on Windows machines were faced. It happened due to the incapability of the Python libraries used that only works on Linux and Mac machines. However, this issue were overcome adding in the code the capability to run the Iperf3 through command line when a Windows machine was detected as a host. The Iperf3 offers an option to get the output as JSON. So the values were parsed and the problem was solved easily.

Another problem faced was the lack of automation to run the tool in different machines systematically. All the runs executed were made manually, could had being much easier if machines connected 24h could automatically run the code to us. Sometimes the members of the group forgot to execute the tool or they could not run it because they were at the University and the tool were not able to be executed properly inside the University's network. For security reasons of the institution the connection with the VMs hosted in the CSPs could not be contacted. This issue were overcome with cooperation among the authors, always remembering each other to execute the tool as much as possible in different hours and days. Another solution was to appeal to closer friends to run the tool as well. Acting like that approximately 800 entries in the database were possible. It is not that much but it is enough to analyse the results and come with some conclusions about the perfomance. This approach was necessary because the authors want to not only measure the performance of the CSPs but of the ISPs too. Because the another option was to use a Raspberry to execute the tool in pre-defined hours of the day, every day. However, this structure could give us only the data from one ISP to the CSPs because only one Raspberry was available to be used in this project.

About the performance among CSPs, when the metric bandwidth (download and/or upload) is analysed, the Azure performs better because this specific Cloud Provider is able to handle with high rates in both ways (symmetrical connectivity), the other clouds have limitations. Specially the Alibaba that limits the maximum bandwidth to approximately 10 Mbps. But for normal users that usually hire until 100 mbps or less, the Amazon, Azure and Google perfoms quite similar in terms of bandwidth.

The latency and the jitter among the CSPs were evaluated as well and in general Azure performs better, but the median values are quite the same for all. However, alibaba and Amazon had the highest variation, what is not desired.

The packet losses are not so representative to distinguish the CSPs from each other. However, it is important to emphasises that Amazon do not had any losses during all the tests run. Unfortunately, a deeper analysis were not done to determine if the losses happened in the CSPs or in the ISPs side. But it is not that relevant because losses showed to be quite rare among all the ISPs and CSPs, not affecting services that could be running on the cloud.

The ISPs analysis brought the difference between a business plan and a personal plan with the same operator - MEO in this work. The results of the service given by MEO to business is incredible. It was expected a better service due to the difference of price. However, still impressive to see such difference, specially in the latency and delay.

Although Vodafone presented the worst bandwidth it can be due to the contract hired. However, Vodafone looks to be a really good option after the results. The latency and jitter results are impressive when compared with competitors, sometimes better or really close to values achieved by the MEO AS3243 (for business). It is important to emphasises that Vodafone was the only one to do not have any packet loss. It gives an idea that the losses probably happened in the ISPs side, but it is not possible to confirm that.

Elaborate this work was interesting, specially the analysis part were conclusions about different CSPs and ISPs could be made. Could be more interesting compare only business plans from the main ISPs available in Portugal. But it has costs and is quite difficult to raise the funds for that. With funds could be possible to acquire equipment to run the tool automatically and then could be possible to analyses the result through the hours of the day. Surely that with some support could be possible to have more reliability in the data as well because more data could be captured and analysed.

If we had more time to work on this project, we would introduce more variables for analysis, such as:

- running tests on IPv6 connectivity
- detect whether the connection of the client is wireless or not
- the client IP address to have the perception of how many different measurements were made in a given ISP

The tool developed to elaborate this work is available in a public repository on GitHub[6] and can be accessed for everyone. The script to generate the graphs are available as well so any one in any part of the world could test different CSPs and ISPs. The authors really motivate others to perform tests in your own region. It could be used in a personal or business context to help in the decision making of the best ISP or CSP for a specific case, for example.

7.0 Bibliography

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