APSEI 2020-21

Assignment 2

Subject: **Analysis of Cloud Computing**

Context: **Group work to be carried out in the framework of APSEI 2020-21 under the supervision of Prof. Manuel de Oliveira Duarte**

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1 Framework

Traditionally people would have to buy and maintain hardware and software equipment *(on-premise infrastructure)*, however, nowadays, with little effort and configuration it is possible to deploy our IT services, using Cloud Services. The utilization of Cloud Services and Cloud Computing has been increasing more and more everyday by startups, small businesses, and many others, driving revenue growth and cost savings while providing on-demand access to powerful and flexible IT resources and tools.

2 Objectives

In the context of the framework above, this assignment aims to do a brief analysis between the Traditional Approach and Cloud Computing. As there are multiple types of services labeled as Cloud Computing - IaaS, PaaS and SaaS - we will do a succinct explanation on their differences and basic concepts, but the focus of the assignment will be on IaaS.

In addition to this, we intend to do a comparison between the most used Cloud Providers (*AWS*, *Microsoft Azure*, and *Google Cloud*), using different types of metrics like CPU, Bandwidth, Storage or TCP Traffic. Another objective that is also intended, consists of the investigation and explanation of the social and economic impacts of Cloud Computing on today's society.

3 Cloud Computing

3.1 Definition

Essentially, cloud computing has enabled the use of a wide range of resources from third parties companies over the internet that can be provided quickly and easily. All the trouble needed to build and manage a static IT infrastructure is thus avoided. Many cloud providers offer different deployment models for such resources: Public Cloud, Private Cloud, and Hybrid Cloud. The private Cloud model is used only by a single organization, while Public Cloud resources are offered to the general public by providers such as Google, IBM, Amazon, Microsoft, and others. Hybrid Cloud models are a combination of Private and Public Cloud resources.

Apart from those models, cloud-based resources are commonly classified into three categories:

- ***Infrastructure as a Service*** (***IaaS***): Offers services, such as Pay as You Go, and allows users to access processing, storage, networks and other fundamental computing resources, to be used for any purpose.
- ***Platform as a Service*** (***PaaS***): Is usually used to create and deploy applications. Resources like servers, and storage can be managed by the enterprise or other 3rd Party Provider, while developers can focus on the management of applications. Examples: *Heroku*, *OpenShift*, etc.
- ***Software as a Service*** (***SaaS***): Allows users to use third-party software that runs on Cloud infrastructure. Frequently it is used when Companies do not want to spend time on installing, managing or upgrading software. Examples: *Dropbox*, *Cisco WebEx*, etc.

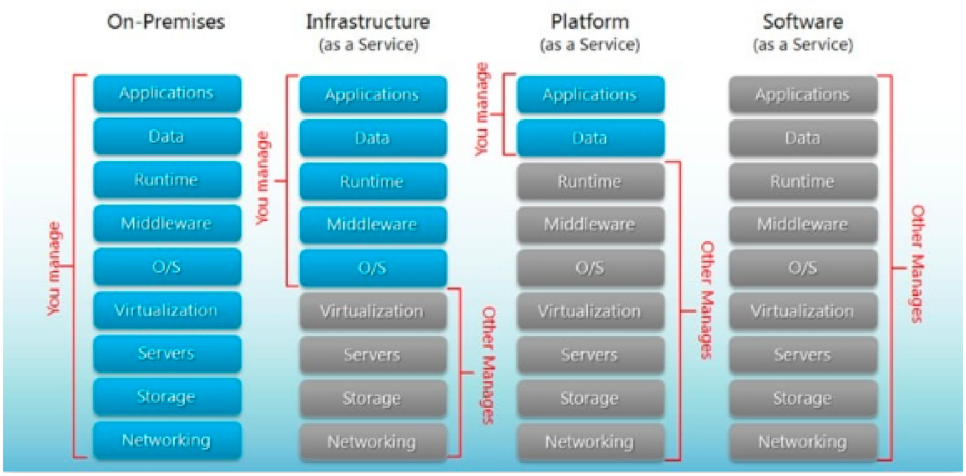


Figure 1: Cloud Computing Types

3.2 Differences between Off-Premise and On-Premise

Cloud Computing can also be referred to as off-premises solutions. As the name suggests, they do not require access via physical hardware. Instead, all servers, software, and networks are hosted in the cloud. This solution came to replace the traditional on-premise setups, which usually had a physical central server and software that required to be installed on each host [1].

The main differences between these two approaches, which can also be seen as the reasons to lean towards cloud providers rather than the traditional on-premise structures, are dissected below.

1. **Resilience and Elasticity**

   When it comes to resilience, cloud computing takes the upper hand, since backups and performance are consistent, sufficient, and automatically managed. The information hosted in the cloud is evenly distributed across their servers, meaning that if one server fails, all the information can be retrieved without downtime. To maintain consistent performance, these systems use what is known as cloud elasticity, which is the provision of resources based on the needs of a machine. This means that they automatically deliver or remove resources to provide the right amount needed, ensuring the concept ”You only pay for what you need”.

   Traditional computing is not so resilient and is limited to a certain maximum server performance, which is conducive to server downtime. What these systems lack the most is automation, like the elasticity provided by the clouds.

2. **Flexibility and Scalability**

   Cloud computing not only provides unlimited storage capacity and server resources, but also allows to scale these resources according to the business needs, allowing for a more flexible and scalable model in comparison to traditional data centres.

   In terms of OS dependency, cloud-based applications are fully independent, as they are not constraint on a system with a specific OS, which is the case of the less flexible traditional applications.

   Traditional IT systems do not require an internet connection to access any data, but this is more a disadvantage than an advantage, as users can not access this data anywhere. Cloud hosting breaks this limitation by providing a fast and reliable internet connection, so it can be scalable to a wider range of people.

3. **Security**

   From a first insight, cloud computing may seem less secure than traditional computing, as it may be accessed by anyone in the world with an internet connection, and this is somewhat true. Cloud platforms are highly targeted by hackers because they store large amounts of sensitive information. However, it might be better to trust the data security needs to a reputable cloud provider, rather than dealing with the security ourselves.

   Traditional platforms give more freedom to choose the security and recovery plans and the devices to deal with threats, but this is not an advantage at all. It just means that we are responsible for dealing with incoming threats and managing these security devices, which is many times neglected due to their costs.

   Besides, the most renowned cloud providers offer other approaches to cloud security to overcome its lack of freedom control. There are plans, like Private Clouds or Hybrid Clouds (previously mentioned), which give more control over data management and security protocols in exchange for a higher cost. [2].

4. **Cost Effectivity**

   With regards to cost-effectiveness, cloud-based services also come first, as people will only pay for what they use. Comparing to on-premise computing, we can avoid the licensing costs and the investments in expensive equipment to operate and maintain the servers. Besides, as off-premise computing can be locally manipulated, the infrastructure costs also decrease.

3.3 Cloud Providers Metrics

Cloud Providers must keep track of some metrics to improve their business, stay competitive with other providers and to show people, as customers, the quality of their services. The principal metrics that should be taken into account are:

1. **System Availability**, which works out as the portion of time that system is available. This portion can be both directly(for example, 8/10 corresponds to 0.8) or in percentage(80%). It is important to consider this metric since it is extremely important that the customer of these kinds of services has a product that is frequently available;

2. **Reliability**, that, usually is the result of the combination between two values, in case of repairable components (like Cloud Services), **MTBF**(*Mean Time Between Failures*) and **MTTR**(*Mean Time To Repair*). While the **MTBF** measures the average total of time that a service is functional before a failure occurs, the **MTTR** has the object to measure the meantime needed to repair a device, after its failure, until it comes back as operational. This is a key metric since it allows to understand better what may be causing a failure, and as a consequence, it allows the Companies to have equipment with more preparation to be fault-tolerant. Besides this, failures of hardware components are expensive, so it is important to see how often those components fail. The following formulas, shows how we may calculate

the Mean Time Between Failures and the Mean Time To Repair:

$$MTBF = \frac{(TotalWorkingTime - TotalBreakdownTime)}{NumberofBreakdowns} \tag{1}$$

$$MTTR = \frac{TotalmaintenanceTime}{NumberofRepairs} \tag{2}$$

3. **Response Time**, tells the time it takes for any request to be made and the time to complete that request. It can be helpful to have this metric to measure the performance and availability of the Cloud service;
4. **Security**, works as a set of policies and measures that are applied to ensure protection over a whole amount of things that are involved in cloud computing, for example, user's private data and applications, the infrastructure, and many others. Security nowadays is a must on IT Systems and technologies, and as Cloud providers need to host their customer's Platforms, Products, and other types of services, these need to be secured to avoid any attacks that may occur (**DDOS**-(*Distributed Denial of Service* Attacks, for example).
5. **Capacity**, is the size of the workload compared to available infrastructure, Cloud providers need to keep track of their capacity to ensure they have enough resources to deliver to a service request, this way they can pay attention to the supply and demand of their services.
6. **Scalability**, evaluates to which degree the service can grow, for example, how many users can the service handle without suffering any failure to any user or any crash because of the exhaustion of the system's resources. This metric is very relevant to the customers since, usually, the capacity of expanding the resources and upgrade the system is one of the main reasons to use Cloud Computing Services;
7. **Throughput**, corresponds to the performance of a certain amount of tasks, during a precise period of time. The type of measurement done in this kind of metric depends a lot on the type of application: for example, in terms of Web Servers the throughput measurement is done by the number of users that it can support, but in other cases like a server that processes audio and video streams, it can be measured as Megabytes per second. To make sure that all applications run with a suitable efficiency, the throughput shows great importance;
8. **Latency**, demonstrates the time interval between submitting a packet and arrival at its destination, it has an immense impact on the usability of the product deployed, especially if the product focus on cloud services communicating with each other, however, this metric can be very hard to keep track;
9. **Service and Helpdesk**, measures the time it took for assistance to be provided to the customers. It can be critical for the assistance crew to improve as it is a way of getting more feedback on their services.
10. **Cost per customer**, shows how much it costs to deploy a service in the cloud for each customer. With this metric, it is possible to measure profitability and make the necessary adjustments to the provider's pricing plans accordingly to the costs and profit made.

3.4 Cloud Providers Pricing

One of the hardest things to calculate when it comes to Cloud Computing is without a doubt, the estimated price we may pay for the service provided. The reasons for this situation are that there are a lot of financial factors that need to be considered, going from the type of service to the computational resources we want to put into our system, and many others. In an article from InfoWorld, it was mentioned a new approach to calculate the costs for our system in the cloud, by using a general formula:

$$CloudOpsCostPerYear = (NW * CW) * COM) + ((NW * CW) * SR) + ((NW * CW) * MR) \tag{3}$$

Where:

- *NW*: Number of workloads under the Cloud
- *CW*: Complexity of workloads (on a scale of 1.01 to 2.0)
- *SR*: Security requirements (on a scale of 100 to 500)
- *MR*: Monitoring requirements (on a scale of 100 to 500)
- *COM*: ”CloudOps” multiplier (on a scale of 1,000 to 10,000), based on resources used, including the cost of cloud services and the cost of people

As we may see, even though the formula provided is considerably simple, it can be too ambiguous which may result in incorrect calculations, especially if we are using it for the first time, due to the fact that it is not trivial to know exactly the scale of security or monitoring requirements, for example, needed in our system. Therefore, this approach should be followed carefully.

3.5 Migration from On-premise data centers to Cloud IaaS

After stating the advantages of cloud-based apps, it would seem reasonable to assume that the best policy for on-premise companies would be to migrate their infrastructure to a cloud service. However, this is not always true, as there can be more drawbacks than benefits. The figure below shows research made on a workload migration of 2,500 virtual machines from an on-premise data center to Amazon Web Services EC2 [4].

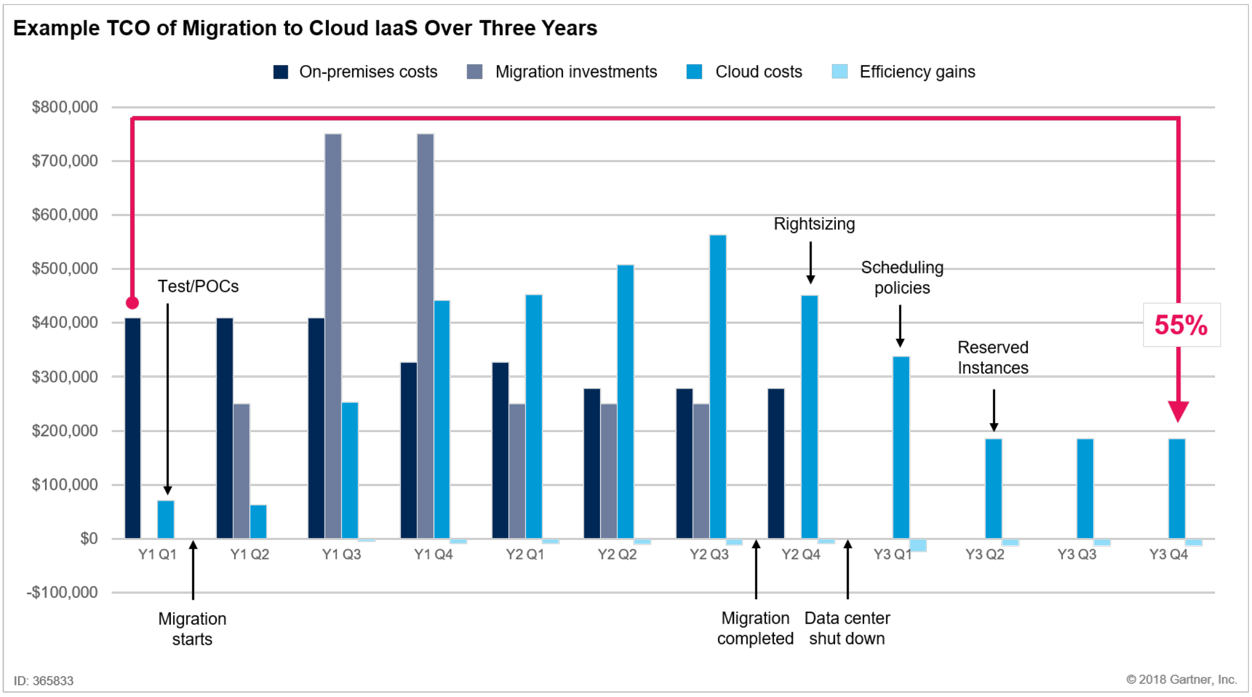


Figure 2: Migration costs to cloud IaaS over 3 years

From this bar chart, the first idea that takes place is the large workload efforts necessary to migrate such an organization, as it took 3 years until reaching a stable and optimized cloud service. The next thing that comes into mind is the 55% decrease of costs from the initial state till the end. So, it is evident that migrating to a cloud service, if well controlled, would become beneficial in the long term, but it is also evident that in the short term, the migration costs would be very discouraging. After all, cloud services can be surprisingly more expensive than on-premises data centers at the start of the migration. With all said, migrating to the cloud should always be a very thoughtful decision, with a planned financial management process.

4 Top Cloud Platform Comparison

4.1 AWS vs Azure vs Google

In order to achieve one of the objectives of this assignment, the comparison between the principal Cloud Providers, we needed to have some important metrics that should be considered such as Networking, *CPU* Performance, and Storage I/O. To make this comparison possible we recurred to data from an external source, CockRoachLabs, since all of the Cloud Providers oblige a registered user to input Credit Card Information, and, in most cases, payments would be involved which steps us back from doing the experiments ourselves.

4.1.1 Network Throughput

A common way to compare and visualize how viable is the Network of each provider is to make tests to the Network Throughput. Network throughput consists of the amount of traffic that is channeled from a source to a target, in a certain time interval. A common mistake that is done is confusing Network throughput with network bandwidth: while bandwidth is nothing more than just a theoretical concept, of how much data may be transferred from the source to the destination, throughput is the real measurement of it. Besides this, another normal misleading idea is the dubiety between throughput and latency, which can be very simple to clarify: Network Throughput measure how many packets may be transferred, meanwhile, latency measures how much time does it take to channel the packets towards the destination. The formula that allows the calculation of the maximum network throughput, for TCP(Transfer Control Protocol) connections (since TCP is one of the most used protocols in network connections) is the following:

$$NetworkThroughput \leq \frac{RWIN}{RTT} \tag{4}$$

Where:

- *RWIN*: the TCP Receive Window, in other words, the ammount of data that a machine may receive without acknowledging the sender for it.
- *RTT*: the Round Trip Time, the amount of time needed to send a packet, the receiver acknowledge it, and sending it back to the original source.

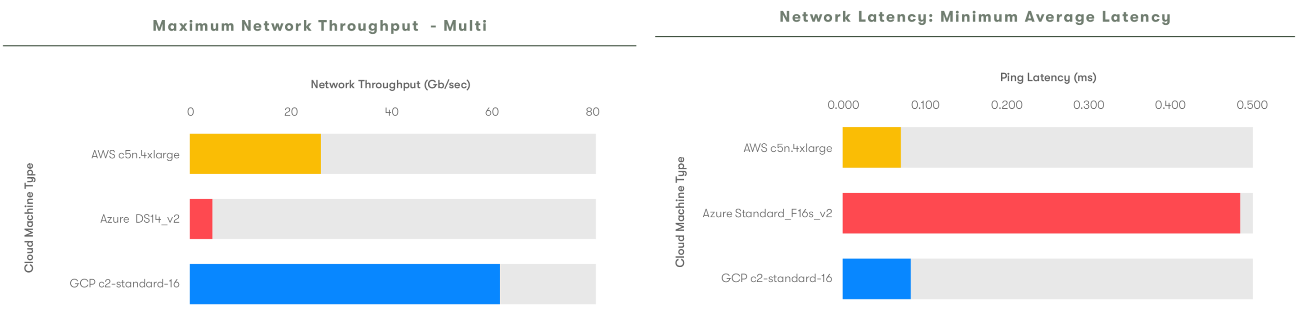
Considering a connection in a network with packet loss, the previous formula should be replaced by the following one, in order to calculate the maximum network throughput:

$$NetworkThroughput \leq \frac{MSS}{RTT\sqrt{Ploss}} \tag{5}$$

Where:

- *MSS*: corresponds to the maximum segment size, which in practice is the same as RWIN, since it is a TCP header that stablishes the greatest amount of data that our destination is able to receive in a single TCP segment.
- *RTT*: the Round Trip Time, the amount of time needed to send a packet, the receiver acknowledge it, and sending it back to the original source.
- *Ploss*: the probability of a packet being lost.

The next picture shows the statistics from Network Throughput in each of the Cloud Providers, previously identified.



(a) Network Throughput

(b) Network Latency

Figure 3: Comparison between Network

As it can be seen, GCP machines, GCP c2-standard-16, beat the competition by a giant margin, with a throughput of over 60 Gb/sec, while the maximum from Azure or AWS was over 25 Gb/sec.

4.1.2 *CPU* Throughput

Bogo Ops (bogus operations/second) is a unit made by Linux for comparing *CPU* speed across machines. It derives from BogoMips, which is more commonly used, meaning "Millions of Instructions Per Second". It is a useful unit, since it diminishes the heterogeneity between machines, easing the comparison between them. However, it is very important to point that this is very unreliable and way too unscientific. It is very difficult to just compare MIPS for different kinds of computers, but, in the need for something alike, people keep abusing the use of this unit, making it the best benchmark available. For curiosity purposes, "Bogo" comes from "bogus", i.e, something which is fake.

System	Rating	Index
Intel 8088	clock × 0.004	0.02
Intel/AMD 386SX	clock × 0.14	0.8
Intel/AMD 386DX	clock × 0.18	1 (definition)
Motorola 68030	clock × 0.25	1.4
Cyrix/IBM 486	clock × 0.34	1.8
	...	

The BogoMips can be calculated by the upper table [8]. Each system has a *CPU* rating compared to the Intel/AMD 386DX, which is the one used as definition. There is not a rating for every existent system, as some systems do not have the *CPU* speed available and other are programmed on other assembler languages, which makes it harder to classify.

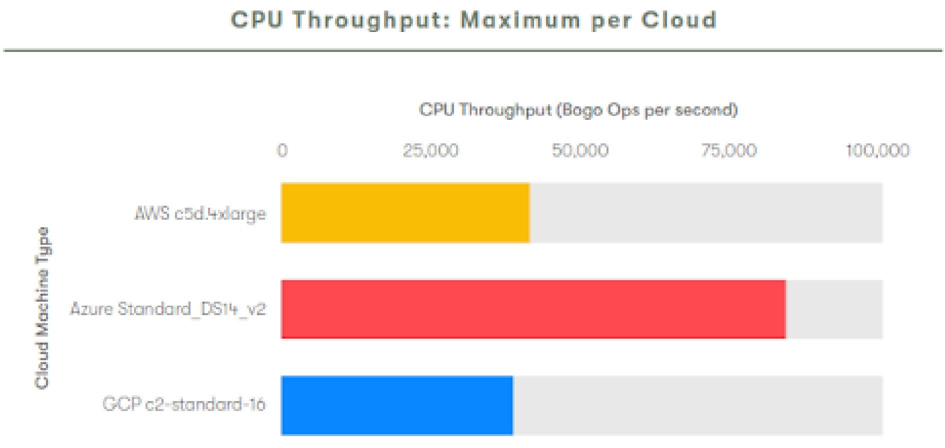


Figure 4: Comparison between *CPU* Throughput

This is the analysis show the best performing machines from each cloud on the *CPU* microbenchmark based on Bogo Ops. Despite all of these controversies, we may say with fairly certainty that the best performing machine is the one from Azure.

4.1.3 Storage I/O

I/O Disk Operations, as we know them today, are slow operations since it involves reading and writing from/to a physical Disk. Many factors may influence the I/O operations performance, depending on the type of the disk (Random Access Disk or Sequential Access Disk). Besides this, depending on the type of the operation, some factors may be more important than others, for example, for use cases considering writing and/or reading large files, the *IOPS (I/O operations per second)* is a great factor to take into account, while with small files reads/writes we would be concerned about the disk throughput. The difference between *IOPS* and Disk Throughput is that *IOPS* measures the number of read and write operations, the Disk Throughput measures the number of bits read/written per second.

There are many approaches to calculate the *IOPS*. It is often measured with an open-source network testing tool called an Iometer, but some find it outdated. This method uses the *RAID* factor to calculate this. RAID stands for Redundant Array of Independent Disks, and combines multiple hard drives together in order to improve efficiency. Since *RAID* has a great impact on this metric (each writes operation results in multiple writes to the storage array), we must take it into account.

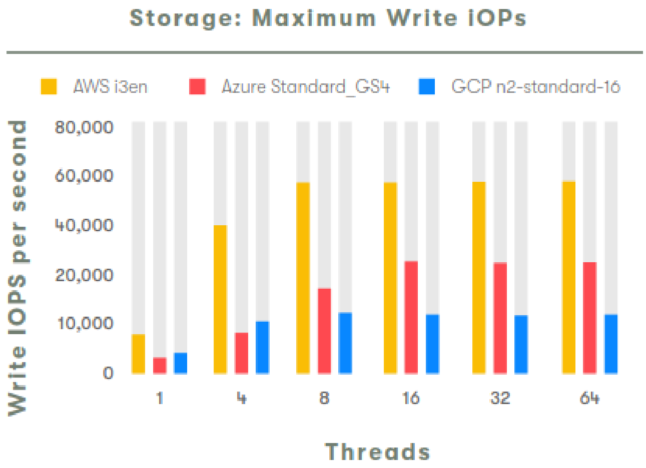
$$\mathit{IOPS} = \frac{NDisks \times Average\ I/O\ Operations\ on\ 1\ disk\ per\ sec}{read\ workload\ \% + (Raid\ Factor \times write\ workload\ \%)} \tag{6}$$

Where:

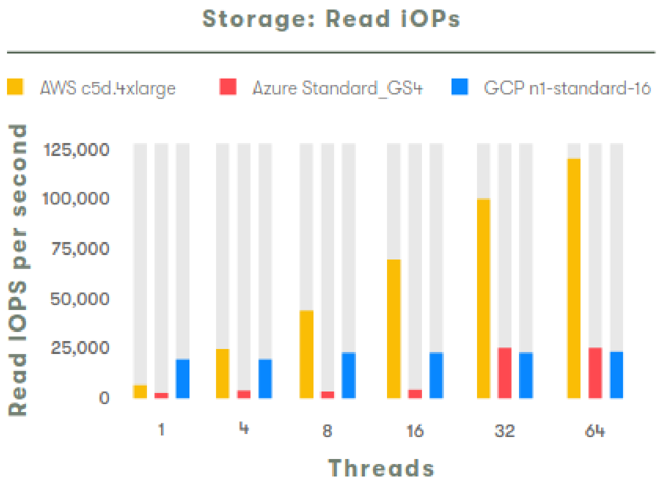
- *NDisks*: Number of disks. If one disk can perform 150 *IOPS*, two disks can perform 300 *IOPS*.
- *Raid Factor*: the RAID efficiency factor (i.e. RAID1, 2, . . .)

However, *IOPS* can also be measured using an online *IOPS* calculator, which determines *IOPS* based on the drive speed, average read seeks time and average write seek time.

Considering now, the analysis of the results of the benchmark towards Write and Read *IOPS*, it can be visualized that AWS seems to have a greater performance both on the number of writes as well as read operations per seconds, with outstanding results in all cases.



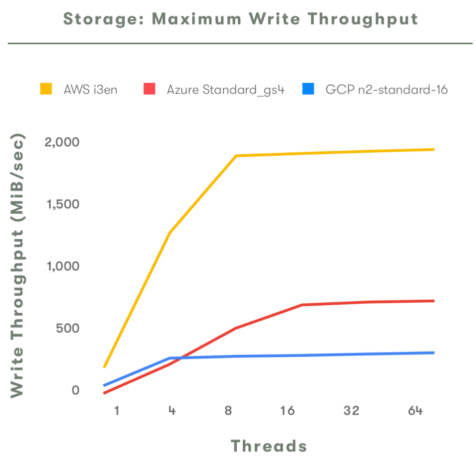
(a) Maximum Write *IOPS*



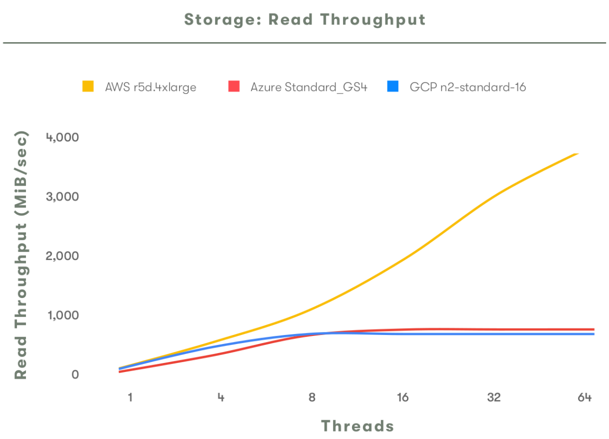
(b) Maximum Read *IOPS*

Figure 5: Comparison between Storage *IOPS*

The impact of AWS on Storage I/O is even greater when we look towards the throughput of both writes as well as read operations. As we may visualize on the charts below, AWS manages to achieve over 1900 MiB/sec of write throughput, and over 4000 MiB/sec of reading throughput, which is much greater than the values achieved by both Azure and GCP.



(a) Maximum Write Throughput



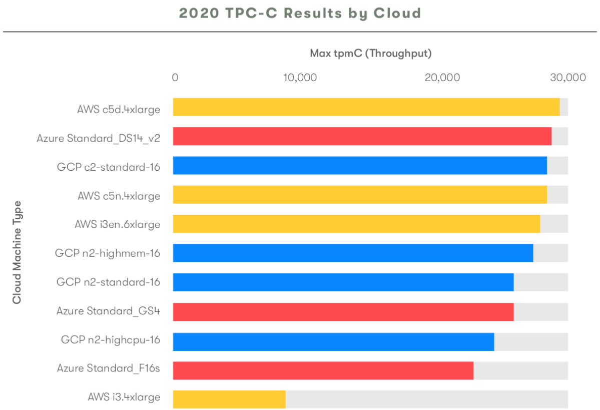
(b) Read Throughput

Figure 6: Comparison between Storage I/O Throughput

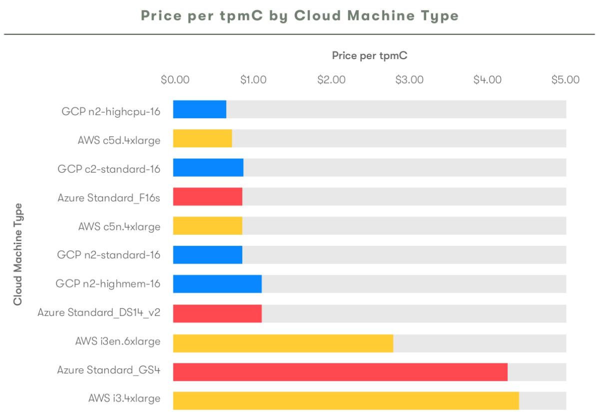
4.1.4 *TPC-C* Performance

To test the overall workload performance between these three cloud providers, we will be using *TPC-C*, which is a popular benchmark tool that can be explained through the above microbenchmarks, meaning that we can take *CPU*, network, and storage I/O into account in one metric. There is no local way to calculate this metric. Instead, we need to look at the *TPC* website to locate the nearest match to the computer model and disks.

TPC-C is measured in two different ways. The way we use is throughput-per-minute type C (tpmC), i.e., the number of orders processed per minute. From this, we present the comparison of max tpmC throughput and price per tpmC across the best cloud machine instances.



(a) Max tpmC Throughput



(b) Price per tpmC

Figure 7: Comparison between *TPC-C*

Notice how machines with higher performance on computing power (Figure 4) and network (Figures 3a-3b) are the same machines which performed the best on the maximum tpmC throughput (Figure 7a). Talking about *AWS c5d.4xlarge* and *GCP c2-standard-16*. However, this does not apply for the storage I/O, which suggests that the storage does not influence the tpmC throughput too much.

For comparing the price per tpmC, it is used the default on-demand pricing available for each cloud, as making a very complex price comparison would be too much of an effort. With that clarified, we may say that Google has the best performance per dollar machines, despite the other two not being too far behind. If price is not a concern, AWS is the best on throughput alone.

4.2 Use Cases Comparison

As it was discussed before, Cloud Providers offer a wide range of services, which can be acquired by their clients taking into account each of their use cases. Therefore, to compare *GCP*, *Azure* and *AWS*, we considered some use cases, which will be detailed on the next subsections.

4.2.1 Video Conferencing System

Nowadays, with the COVID-19 pandemic that our society is going through, video conference systems have been rising in terms of usability and number. These kinds of systems depend on how streams are going to be handled by a media server. They usually choose a Selective Forwarding Architecture, which receives the streams and just routes them to the corresponding users. This approach requires some *CPU* usage, but not too heavy, since it just forwards those streams to the clients, and also requires a very high bandwidth usage to deliver streams with a low latency avoiding conferences with high jitter (video lag, distortions and congestions). Besides this, scalability and availability are important and essential requirements, since it is always desirable to host video conferences with the largest possible number of people, and that the calls do not fail or go down too often.

Given these system requirements, good network latency and throughput, and some *CPU* power, by analysing the Figure 3, we notice that GCP has the best highest network throughput and the least latency, followed by AWS. However AWS has a little bit more *CPU* Throughput than GCP (Figure 4) and, given these statistics, we believe the best options are either Google Cloud or AWS.

Obviously the latencies would be dependent of where the company that wants to host a video conferencing system is from, for example, if they are from France, they would rather go for a cloud provider that has machines hosted near France like Paris.

In terms of pricing, (Figure 7), GCP has a better Price per tpmC, which means that overall it has a lower cost than AWS, however they are fairly similar and depend on the type of machine that is chosen.

All in all, we would suggest to use GCP has a cloud provider for a video conferencing system, but AWS is also worth checking and comparing to see which one fits the user better.

Concluding, GCP has a pay-by-the-second billing in use, which provides a much more transparent and consistent customer experience, as compared to AWS or Azure. From financial and manufacturing giants to small-to-medium businesses, Google Cloud provides the flexibility and performance needed to satisfy the needs for any video conferencing system.

4.2.2 Big Data

Since *"Big Data"* companies require massive amounts of storage and processing power for analytic purposes, lots of them are turning to the cloud for greater amounts of both, plus enhanced security for business records.

Companies like Google, are one example of this use case, since they store giants amounts of data, to provide "in real-time" results. For this reason, and considering the previous analysis done on the Storage I/O comparison, we assume that AWS would be the best option in this use case. However, like was already mentioned, in terms of *CPU* throughput, Azure outstands both GCP and AWS, which makes us conclude that, for this use case, either AWS or Azure is the best option.

While smaller businesses might find AWS functionality overwhelming, larger companies vastly benefit from an ability to meet every aspect of their complex workflows using purpose-built AWS tools.

Besides this, when pondering about Price per tpmC, as it was mentioned, GCP is the best option followed by AWS, which allied to the previous factors referred, makes AWS the optimal solution for this use case.

4.2.3 Hybrid Systems

Azure is commonly used by researchers, who benefit from its integration with connective technologies and ability to perform data analysis at scale. In addition, Azure is the primary choice for all geographically distributed organizations that use the Office productivity suite and Windows Active Directory to support their daily workloads and also, Microsoft's decades-long expertise in developing SQL and NoSQL databases, overpowers AWS and GCP, therefore Azure is usually a natural choice if a company relies heavily on Microsoft products.

Azure is the leader in building hybrid cloud ecosystems to allow their customers from, for example, the healthcare and banking industries, to benefit from combining the security of their on-premise data centers with the computing power of the cloud for their customer-facing interfaces. Healthcare and manufacturing companies benefit the most from Azure's ability to easily integrate smart IoT sensors to collect vast data arrays and organize them for cost-efficient Big Data analytics.

5 Social and Economics Impacts

Accordingly to a study made to measure the level of dependence of enterprises to cloud computing services, in the year 2020, 36% of EU enterprises reported using the cloud, and a relatively high proportion (21% of the total) reported using at least one of the advanced services.

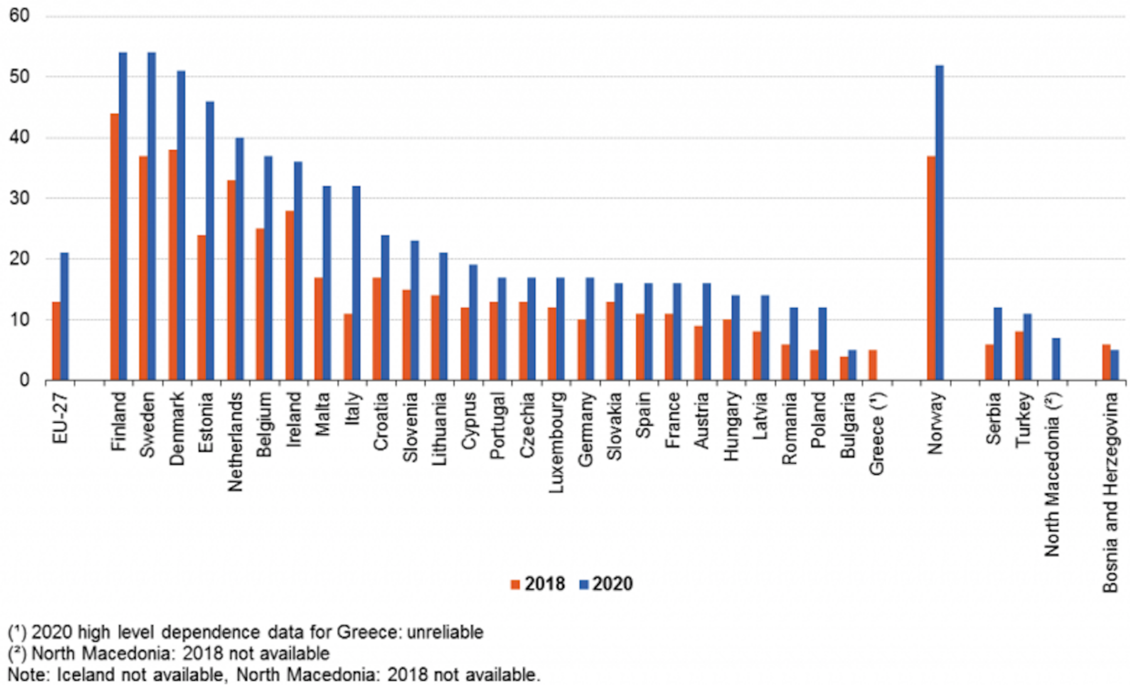


Figure 8: High Level Dependence on Cloud Computing Services, 2018 and 2020 (% of Enterprises) - Source: Eurostat

Compared with 2018, the high-level dependence on cloud computing is higher, having most countries in Europe a significant increase over the course of two years (Figure 8).

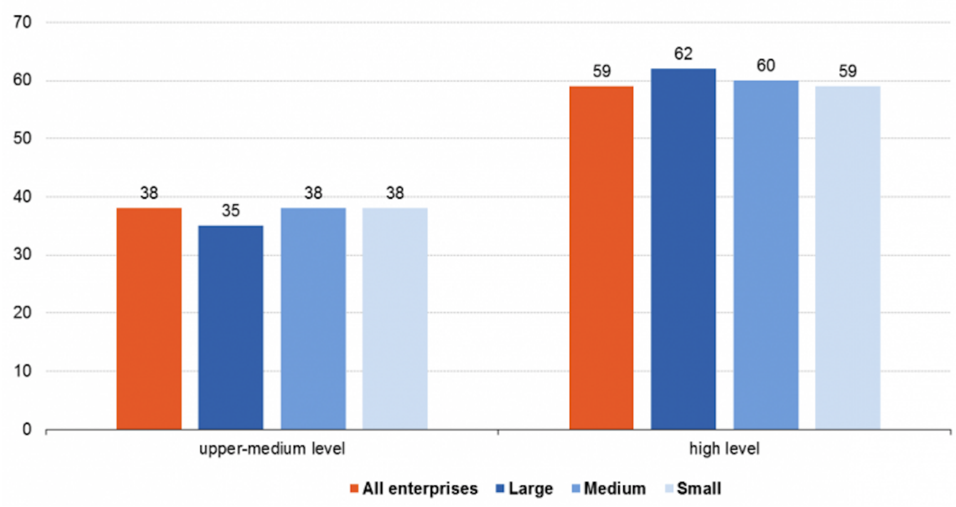


Figure 9: Dependency Level on Cloud Computing Services by Small and Large Enterprises, 2020 (% of Enterprises using the Cloud) - Source: Eurostat

The degree of dependence on cloud computing was almost the same among enterprises using cloud computing regardless of their size. The advanced cloud computing services were used by 62% of large enterprises that used cloud computing services compared to 59% of small enterprises that used cloud computing services (Figure 5).

By looking at the graphs we can confirm that there is indeed a clear growth of the adoption of cloud services. Cloud technology is becoming more and more critical for business growth and cost savings across both small and large companies, providing on-demand access to powerful and flexible IT resources and tools. It is one of the strategic digital technologies considered important enablers for productivity and better services. Enterprises use cloud computing to optimize resource utilization and build business models and market strategies that will enable them to grow, innovate and become more competitive.

The reasons behind this major adoption are many, and a lot of them have been already mentioned previously when comparing to on-premises solutions. It is more efficient, reliable, scalable, faster, safer... All of this allows for companies to have much better productivity levels and expands their revenue and profits, and a reduction of costs. Also, another reason that explains this continuous growth of the usage of cloud services, is that companies need to maintain competitiveness, and since a lot of their competitors might be using cloud solutions, they realize it offers them access to high-level technology while most likely, getting a return in the investment quickly.

Another aspect of cloud services is that they enable companies to innovate their products or services. Whenever companies need to launch new mobile or web applications, develop new types of Cloud-based software, or incorporate technology such as Machine Learning and Big Data, cloud services have several features that enable them and make these innovations a lot easier to implement and commercialize.

Besides all the positive impacts of cloud computing, there are also some negative impacts, with a massive movement to a cloud solution creates a single point of failure on each provider. Since a lot of companies requires continuous delivery of their service, if for some reason the cloud provider fails, and the servers shut down, even if it is for just a minute, it will create a massive negative impact on millions of companies that are using that provider, such as, loss of information, transactions, data leaks, and loss of profits.

If a massive cyber attack were to take out a top cloud service provider like Amazon Web Services for a few days, it could cost the US economy almost $15 billion, according to a report from specialist insurance provider Lloyd's and risk modeler AIR Worldwide. While these numbers are just estimates, they point to the increasingly important role that cloud computing is playing in US commerce.

This isn't something very uncommon, many times cloud providers suffer from service outages, cyber attacks, and power loss, or even human errors, and are forced to shut down for some time. As such, businesses must have a clear disaster recovery plan, as well as a plan for protecting their cloud assets. Smaller and larger companies would feel the effects of such an outage at different levels, some would lose millions or maybe even billions, others would barely feel it. Companies can prepare by, for example, creating countermeasures such as backups, or investments in higher availability services.

It is also worth mentioning that cloud services created a lot of new jobs, such as DevOps that are specialized in each cloud providers, and IT managers for their infrastructures, however, it also caused more traditional jobs to be a loss since a lot of companies that used to have an on-premise infrastructure decided to move to the cloud and therefore their jobs were no longer necessary at that company, even though these kind of jobs are still necessary, but on the infrastructures of the cloud providers.

Beyond business benefits, Cloud services are being used to support social impacts, helping to improve patient outcomes in healthcare and educational results for students. Cloud services may also support the reduction of carbon emissions when compared to on-premise solutions.

- **Healthcare**

  Cloud computing helps to reduce carbon emissions when compared to on-premise solutions due to its big scale. It also could play a role in facilitating data sharing between medical professionals and accelerating the analysis and use of data, while preserving the security of sensitive data. Besides all other impacts mentioned before, Cloud drives enhancements and innovations in healthcare delivery that show some potential to feed through to patient outcomes in terms of better diagnosis and treatment, though many of these initiatives are still at a nascent stage. Example: Allcyte, a company that uses thousands of microscopic images from blood cancer patients to "very quickly predict the clinical effectiveness of large libraries of drug treatments", helping physicians choose adequate courses of treatment. Google Cloud, the provider of Allcyte, has provided the scalability and computing power to enable the rapid screening of more than 150 billion blood cells in total.

  Artificial Intelligence and Machine Learning tools are increasingly being used to create new opportunities for the diagnosis of serious diseases. New initiatives using Cloud to analyze healthcare data to provide new insights are being developed by major global providers, algorithm-based solutions have potential, for example, to identify heart risks from retina photos.

- **Education**

  Students can learn in different and flexible ways with access to a wealth of materials and resources. For example, Kaggle, which is a platform hosted on Google Cloud, that allows users to learn data science techniques and encourages them to compete by producing the best models for predicting and describing datasets. Another aspect is that most cloud providers offer free subscriptions to educational organizations and students can use them to deploy their services, this can increase the engagement and performance of the students and help teachers monitor and manage lessons more efficiently.

- **Environment**

  Cloud Providers have data centers on a big scale, which makes it that overall they have lower energy consumption due to the efficiency gains they get from being massive. By centralizing computing requirements, resources are better coordinated and spread over the infrastructure required, with higher utilization rates and reduced idle time. Cloud is also becoming more efficient over time. Given the increasing service demand, Cloud service providers are making efforts to increase energy efficiency and go green. Of course, these efforts don't mean there aren't negative impacts to the environment, since they have service outages and require a lot of power to keep their servers up all the time and keep the temperature low of their machines, this is somewhat unavoidable since on a traditional on-premise approach it would happen the same, however, one can argue that Cloud providers enable this to happen much easier since anyone can use the Cloud but not anyone could build an infrastructure.

6 Conclusion

For this assignment, a lot of investigation was required to achieve the intended objectives, starting with the definition of cloud computing and services, the reasons for its increasing usage, every year, and what are the advantages/disadvantages of this approach versus the traditional on-premise one. As an addendum, we looked forward to making a comparison between the top platforms that provide cloud services, such as AWS, GCP, and Azure. This comparison was indeed possible since we managed to retrieve information from benchmarks that were made to these services. Unfortunately, it was not viable and practical for us, to make these comparisons ourselves due to the fact it would involve payments to each provider, to obtain their services. However, as a way to understand how these benchmarks are possible, we researched the ways each metric used to compare, can be calculated. Finally, it allowed a good understanding of the positive economic and social impacts that Cloud Computing allowed on today's technological paradigm.

It is important to note that this analysis may be and will be outdated, depending on the amount of time that has passed since the elaboration of this report. The cloud providers' performances change drastically, since, like it was mentioned in this document, each cloud provider needs to improve their services to be more competitive and a greater solution for a wider range of customers' use cases.

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