Cloud Computing: Survey

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Abstract

Nowadays cloud computing is an area of technology widely used by several businesses and remains a very important means of storing data remotely across several servers spread around the world. Cloud computing came along dissipating several inefficiencies present in pre-cloud systems and solutions. The increase in environmental concerns, the development of virtualization related technology and the growth of ubiquitous computing were at the base for the fast paced growth of this area of technology. The amount of tools and technologies for this purpose is quite significant so it is important to analyze the different kinds of cloud computing, the several cloud services models and the several techniques and tools for building clouds, like virtualization techniques and technology, VM management, programming models and issues/problems with some aspects of cloud computing.

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1 Introduction

Nowadays most IT businesses and organizations have the licenses and tools necessary for building their applications and databases. The deployment and updating of said solutions/applications end up being time consuming and bring several costs to the companies. Thus entering cloud computing, overcoming these issues by reducing the costs, improving how much scalability a company can afford and reducing the overall complexity for these processes.

When talking about the **Cloud**, we're referring to a Network/Internet, and by that, it means that we can say that **Cloud** is something which is placed in a remote location. The cloud can provide several different kinds of services over public or private networks for instance LAN, VPN or WAN.

Cloud computing is an area of technology widely used by several businesses and remains a very important means of storing data remotely across several servers spread around the world. It provides us the means for accessing and creating the applications as utilities over the internet, allows us to create, configure, and customize the companies' business applications online. It dissipated several inefficiencies present in pre-cloud systems and solutions by allowing the manipulation, configuration and access to the hardware and software resources remotely being able to offer online data storage services, infrastructures, and applications. Cloud computing is also taking off problems which are platform related, the software is no longer required to be installed locally, in this way it is making several business applications mobile and collaborative. The increase in environmental concerns, the development of virtualization related technology and the growth of ubiquitous computing were at the base of the fast paced growth of this area of technology.

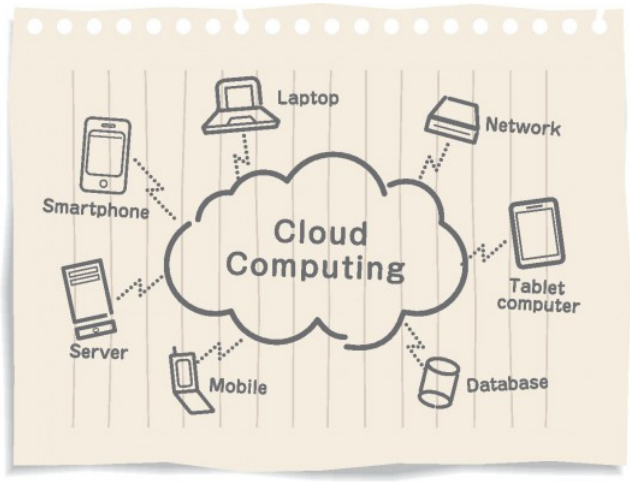

Figure 1: Cloud Computing [3]

Cloud computing has several characteristics which stand out. **Extensive and simpler access to the network**: like it was mentioned before, the functionalities are available and accessible via the web in a multi-platform fashion; **efficient flexibility**: the functionalities may easily be provided and/or removed; **measured service**: the cloud services control and make optimizations automatically on the resources and adjust the fees according to the type of abstraction needed for the service; **self-service on-demand**: a user might obtain computational resources easily without the need to talk to service providers; **resource pooling**: the resources from the service provider are accumulated in order to serve several clients attributing and redistributing resources according to their specific needs; **subscription-based models**: The clients subscribe only to the services that serve their interests, and they pay according to use; **scalability**: The clients have access to a significant number of resources, and they can scale their usage, up or down, according to their needs, allowing the client to create, upload

and install their virtual machine images however they choose in a more dynamic way.

There is "over 1 Exabyte of data estimated to be stored in the cloud at the moment, or 1,073,741,824 gigabytes of data. The Gartner prediction is that at the end of this year (2016), more than 50% of Global 1000 companies will have stored customer-sensitive data in the public cloud". By using the cloud the companies are reducing the staff numbers and costs they need in order to perform complex data analysis, calculations and do the system maintenance.

2 Technologies At The Base of Cloud Computing

Before cloud computing emerged as a usable technology and something that has so many applications and so widely used nowadays other technologies first had to mature so it could later give way to cloud computing. Factors like the increase in internet speed and access and underlying technologies allowing people to have access to systems and data separated from them by miles away thus increasing accessibility, the advances in web technologies, the appearing of many types of data and the need to store and analyse data in a better and more efficient way, virtualization which companies are investing and adopting so that their computational resources can be more efficiently used, the division of functionalities from the already existent and new applications into smaller pieces having a more fine-grained set of components (service-oriented architecture or SOA) which in turn encourages vendors to offer their products as services in order to make the businesses more efficient and agile, the multi tenancy software architecture which allows the businesses to "offer a single instance of one or more of their systems to different tenants (clients)".

3 Cloud Computing Architecture

When we talk about a cloud computing systems it is important to look at the several parts composing their architecture, those parts are the front end and back end which are connected through a network, most of the times through the Internet. The front end is what appears in front of the end user/client whilst the back end is the remotely located so called "cloud" part of the system. In this "cloud" section of the system there are several servers, data storage systems and computers present which constitute the computational resources of the services. Normally each application has its own dedicated server. The front end part holds the end user's computer, or computer network for that matter, and the necessary applications which grant access to the cloud computing system. And different cloud computing systems might have completely different user interfaces.

Besides all of this there is a central server which administrates the cloud computing system in order to make sure that every operation is running smoothly and efficiently, it uses set of protocols in order to ensure the necessary reliability and uses Middleware software which provides services to software applications past the ones available from the operating system, it allows networked computers to communicating with each other easily providing a sort of abstraction regarding the more lower level and hardware specific details.

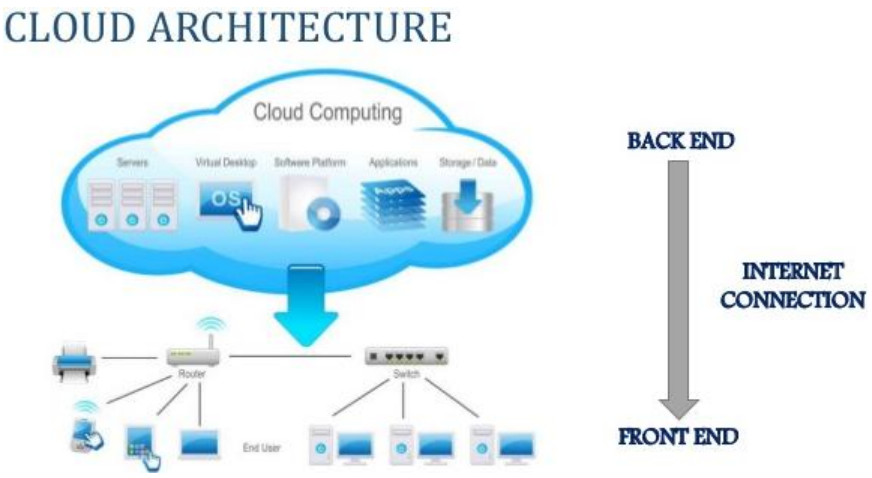

Figure 2: Cloud Computing Architecture [2]

4 Types of Cloud

The kinds of cloud can be identified taking into account either the cloud location or what it offers. Regarding the cloud location there are 4 kinds of clouds: **Public, Private, Community** and **Hybrid**.

A **public cloud** can belong, be managed or used by any public or private entity or by a combination of both kinds of entities, and the whole infrastructure is located within the premises of the cloud computing company offering the service keeping the location separated from the costumer thus having physical control of the infrastructure, although they are very efficient in terms of performance due to the use of shared resources they do lack protection against several kinds of attacks.

Private clouds exist to complement the needs of a certain entity or community, by other words the cloud infrastructure is still located remotely but it is only meant for one entity or organization and is not shared with others. The access to this infrastructure is granted only to members of said entity or community which owns the cloud. The entities/communities can choose to have a private cloud located physically on its premises which might be significantly more expensive but they do hold physical control over said infrastructure. Given this choice of cloud infrastructure the control and security over it is significantly greater than that of a public cloud, but the costs will be higher and the expenses reduction regarding non-cloud solutions might be minimal if they end up investing in an infrastructure located inside the companies' premises.

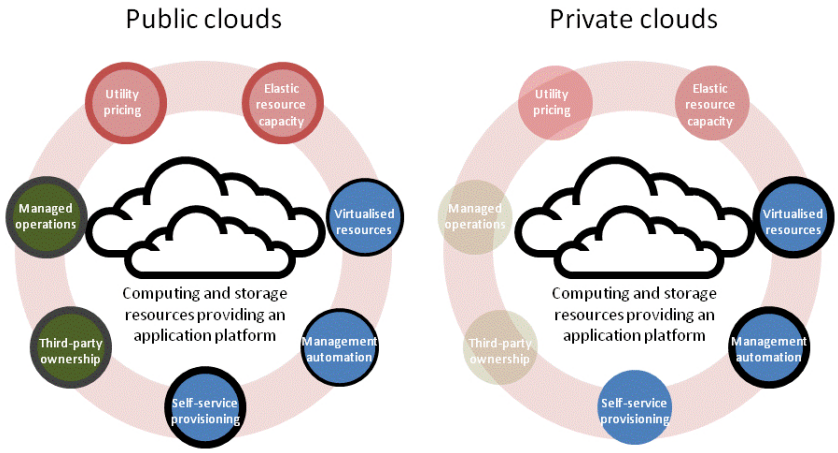

Figure 3: Private vs Public Clouds [64]

A **hybrid cloud**, like the name indicates, is a mix of 2 or more clouds from different types private and public depending on the entities'/communities' purpose, for instance, the entity/-community might want to use a private cloud to hold their more "sensitive" data and have a public cloud in order to interact with the clients.

A **community cloud** is a shared cloud between 2 or more entities that might have shared data and shared data management concerns and have similar need given this kind of computation. This kind of cloud can be used and managed by one or more organizations belonging to the same community, by third parties or by a mix of both. For instance, a community cloud can belong to the government of Portugal but be used by the several entities belonging to the government. These community clouds can also be located both on and/or off the premises.

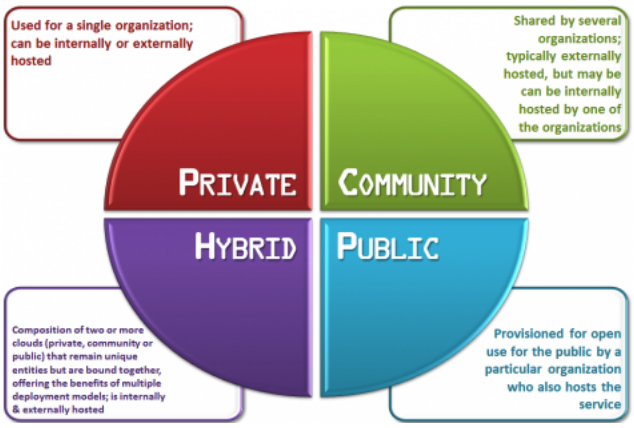

Figure 4: Different types of cloud [11]

5 Cloud Service Models

Regarding what the cloud is offering and what one can do with the data, the most commonly known cloud services are the ones of **infrastructure, platform, software, or storage**. The three main models for cloud computing are **Infrastructure as a service (IaaS), Platform as a service (PaaS)** and **Software as a service (SaaS)**. Each of these models represents a "different part of the cloud computing stack". There are many other service models besides the main ones like **Storage as a service (STaaS), Security as a service (SECaaS), Data as a service (DaaS), Test environment as a service (TEaaS), Desktop as a service (DaaS)** and **API as a service (APIaaS)**.

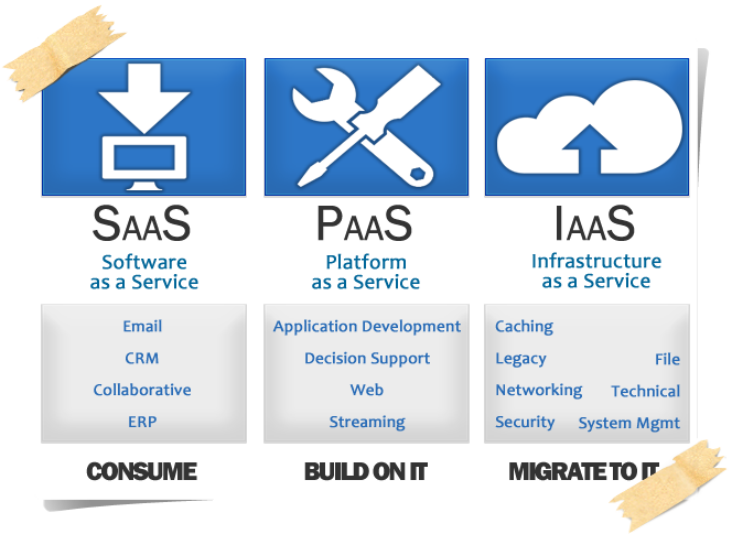

Figure 5: Types of cloud service models [4]

The most common service is the **Infrastructure as a Service (IaaS)** which offers data storage disks and virtual servers, it offers computers, physical or, most of the times, virtual machines, and several other resources. These online services bring a certain level of abstraction to the customer regarding the physical details of the infrastructure like the computational resources needed, data partitioning, scalability issues, security, backups, location, etc. In other words it gives the costumer the basic pillars for cloud IT and provide the much needed access to computers, be it virtual or physically dedicated hardware, data storage space as needed and several networking features. This is the most common service exaclty due to this considerable level of flexibility and control over ones resources resembling some of the existent IT resources that the several IT departments and developers are used to.

Infrastructure as a Service provides you with the highest level of flexibility and management control over ones IT resources and is most similar to existing IT resources that many IT departments and developers are familiar with today. *Amazon Web Services (AWS), Microsoft Azure, Google Compute Engine (GCE), Openstack, CloudSigma, HPCloud, Softlayer* and *Joyent* are some examples of IaaS examples and *Amazon, Rackspace, VMware* and *Flexiscale* are examples of companies that provide this kind of service.

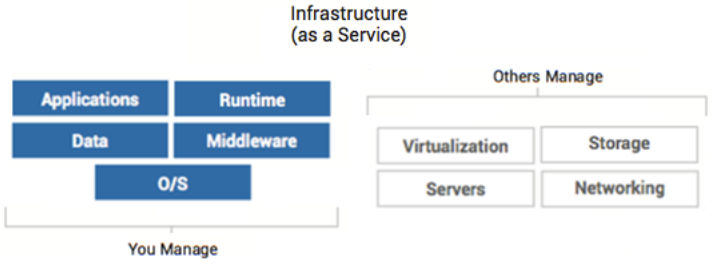

Figure 6: Infrastructure as a service (edited from: [5])

The **Platform as a Service (PaaS)** is another one of the available service models supplying computational platforms to the end user. It offers a development platform which includes programming language execution environments, databases, operating system, and web server. Unlike what happens with the IaaS model, the user holds no control nor does he manage in any way the underlying infrastructure, including storage, operative systems, servers or the network, but he still maintains control over the applications that are implemented and over the data and any configuration settings related to the environment where the applications are implemented. This service model aims to supply to the consumer the possibility to implement created applications within the cloud' infrastructure by using several libraries, services, programming languages and any other service provider supported tools, there are frequent upgrades to the operative system and the services may be obtained from several sources and allows for programming in team work (remotely). Examples of this service model are *Google App Engine, force.com, Red Hat's OpenShift, Heroku* and *Microsoft Azure*.

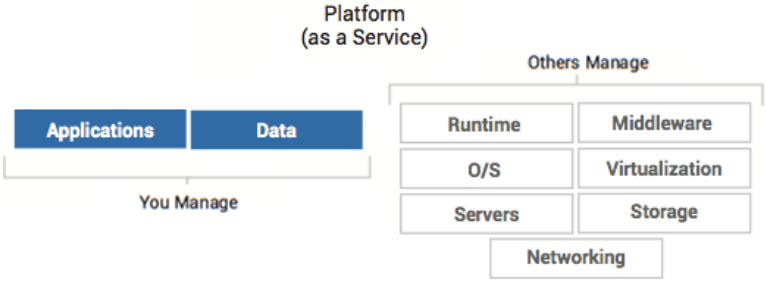

Figure 7: Platform as a service (edited from [5])

Finally, the **Software as a Service (SaaS)** service model allows the user to use apps supplied by the service supplier which are then executed in the infrastructure within the cloud, it means that the users can access several software apps on a pay-per-use basis, instead of spending more money on the expensive closed source licensed programs. These kinds of apps are available through an interface in several kinds of clients and this interface might be web-based or it might have a program that assumes the role of interface. Examples of these services are *GMail, Google Docs, Google Apps, Dropbox, Net Suite, IBM Lotus Live* and *Salesforce*.

Besides these 3 service models there are other service models, Storage as a service (STaaS), Security as a service (SECaaS), Data as a service (DaaS), Test environment as a service (TEaaS), Desktop as a service (DaaS) and API as a service (APIaaS) as said before.

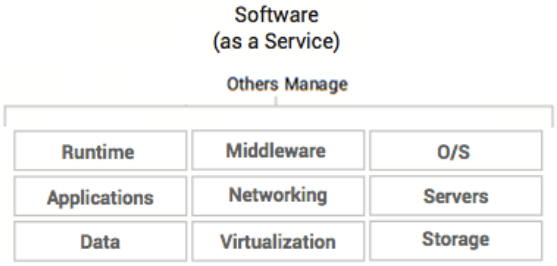

Figure 8: Software as a service (edited from [5])

Storage as a Service (STaaS) is a service model in which a provider rents digital space in their own storage infrastructure to a smaller company or individual, they can implement this as rental of their storage space on a subscription basis. This service provided by the service provider usually solves problems with "offsite" backup. At the corporate level, SaaS service providers are doing secondary storage applications promoting SaaS as a useful way to make, store and manage backups and the main advantage here is the price reduction in the solution be it in physical storage space, software or hardware needed or in labor.

This solution is mostly regarded as a good fit for small or mid sized businesses which hold fewer capital to invest in cloud services or has few personnel to carry out the technical details regarding the implementation of this solution "inhouse". It is also a great way for companies to eliminate the risks associated with disaster recovery, enhance availability and continuity for businesses and provide long-term data retention. *Accelera solutions, Zadara storage, Proact, CGI* are examples of companies which provide this kind of service to their clients.

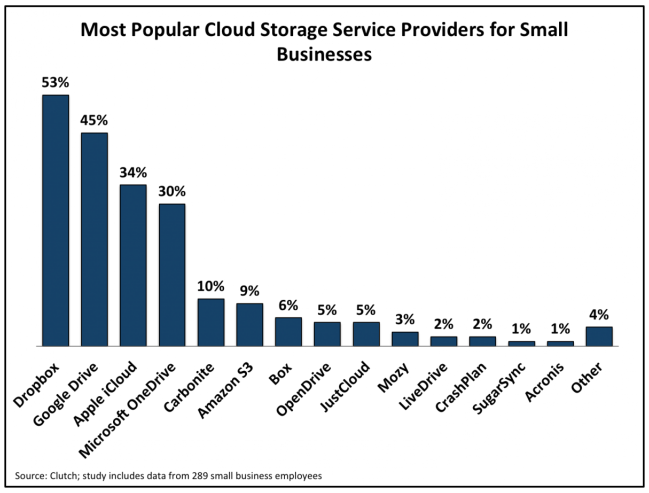

Figure 9: Most Popular Cloud Storage Service Providers for small businesses [9]

Security as a service (SECaaS) is a service model in which the service provider delivers its security services over the internet to a company' infrastructure usually on a subscription

basis proving to be less costly to the company other than providing the security service themselves. This service is a sort of "branch" from the Software as a Service (SaaS) model in which it focuses more on the information security services providing the service in the cloud thus removing the need to have physical hardware on the businesses installations. The security services range from intrusion detection, security events management to anti-virus or anti-malware and anti-spyware solutions, amongst several others.

This service brings great advantages for the businesses allowing them to outsource several administrative tasks, having a greater security expertise than you would expect to have inside the business, constant security updates non-reliant on user compliance and a simple interaction with the task administration and the security activities and environment by having a web interface that allows it more easily. This service can also be provided in-house (physically).

Although it might be a very useful service and might bring some advantages there is still a challenge to overcome in the SECaaS market, which is the creation of a reputation of reliability and superiority taking into account other non-cloud services still which are still being used. Ultimately it is up to the client to determine if it is or not a good fit for their purposes and intents. Services like *CloudFlare, Imperva, Valid, Cloudbric* and *Cisco's* are some examples of this increasingly popular service model.

Figure 10: Valid security as a service [12]

Data as a service (DaaS) is a service that is a branch or "cousin" of Software as a Service (SaaS) in which any business process can access the data independently of the geographic locations of both the service provider and the consumer. This service emerged from the increase in the use of service-oriented architectures which made the infrastructure and platform where the data is being held irrelevant. This is being widely used in all sorts of businesses and organizations due to its advantages. The platform matters less, this means that it can be outsourced given that the data and business processes are solid enough.

The data as a service service model doesn't have to be used solely for outsourcing, it can be used by companies to manage and hold their own data assets. There are service providers which offer master data hubs as a service to ensure data availability to everyone. Given the significant costs associated with data and routine maintenance and with updates/upgrades as the data keeps on changing constantly, this solution becomes a quite attractive one for businesses allowing lesser costs and a more transparent separation between the data related costs and the

specific software platform costs. The disadvantage here is usually the same ones as the ones related to the other kinds of cloud computing, and, for instance, the trust that must be placed in the service provider's ability to deliver a good service by avoiding at all costs server downtime. *Oracle, IBM, zData Solutions, Landmark solutions, Amazon Simple DB, Amazon RDS, Google BigTable, Microsoft SQL Azure Database* are examples of companies that provide this kind of service.

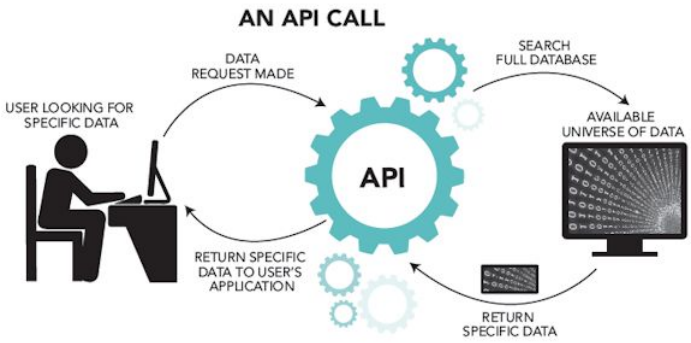

Figure 11: Data as a service usage process (API call) [7]

Test environment as a service (TEaaS), also known as "on-demand test environment" in the cloud provides, as the name indicates, test environments for business and enterprise applications and for testing them in the cloud by using virtual test labs that can be scalable and it implements a multi-platform environment as it is common in cloud service models. It includes several virtualization services infra-structurally speaking, and several other testing services. It enables the clients to easily access "on-demand" test environments without having to worry about the resources needed for such a solution and also carries a minimal cost relative to other more expensive solutions.

The performed tests are often just seen as performance or load tests, but there are several types of tests like stress testing, load testing measuring performance under heavy user traffic, functional testing, compatibility testing, browser performance tests, overall performance and latency tests, etc. Distributed Systems and Parallel Systems are the most common users of this approach for testing due to their complex nature. Some of the examples of companies or solutions that offer/employ TEaaS are *Amazon, Cisco, Advaltis, 3-terra, Skytap, HP, SOASTA, InfoTree solutions, CSC, D-Cloud, CloudTest, SOAtest, HP LoadRunner*, amongst others.

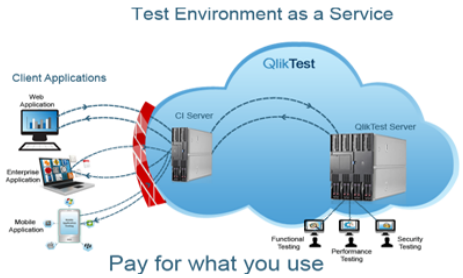

Figure 12: Test Environment as a Service [10]

Desktop as a service (DaaS) is a service model which offers a virtual desktop infrastructure (VDI) back end which is hosted by a cloud service provider and is commonly based in a monthly fee subscription model. It makes the administration easier, reduces the costs and brings greater flexibility to businesses. It has a multi-tenancy architecture, which means it is served to multiple users referred to as "tenants". In this model the service provider manages all of the back end responsibilities regarding data backup, upgrades/updates, security and storage. Usually the customers' data is exchanged with the virtual desktop at the moment of the login/logout processes and the access to the desktop is entirely not platform, location and network dependent. Customers normally manage their own images of the desktop hosted in the cloud and their applications and underlying security, unless the service provider does provide said extra services.

In the end the users, by using this service, can access their data and apps from virtually anywhere with any device, it provides much needed data security, ease of platform migration, greatly improved disaster recovery methods and desktop provisioning in just a couple of minutes instead of taking hours, and greatly reduce their costs by adopting this solution. Examples of companies and solutions that provide this service model are *Cisco, Oracle, Amazon WorkSpaces, NaviSite Managed NaviCloud, Citrix Workspace Cloud, VMware Horizon, Azure RemoteApp, VMware Horizon Air, Citrix XenDesktop,* amongst others.

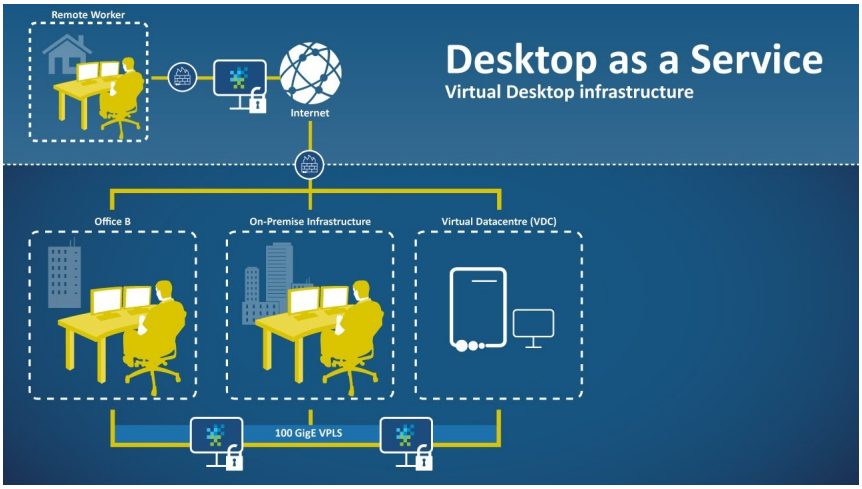

Figure 13: Desktop as a Service [8]

API as a service (APIaaS) is a kind of Software as a Service (SaaS) service model specialized in APIs (application programming interfaces), and it is a fully managed solution that allows the customer to "expose select information assets through web facing APIs". An by fully managed it means that the solution is previously built, hosted and integrated. Companies that focus on API management began using this term for this solution but it didn't quite stick around due to their solutions being based off of API management for APIs hand built, this kinds of solutions, to be more correct, are called API Management as a Service.

The API as a service is sometimes confused with API Hosting as a service which allows for services to expose the "API endpoints as part of an API hosting platform". The API calls can go from XMl web services, TCP/IP to REST or WebSockets. APIaaS is a cheap and interesting solution which works basically out of the box with a reasonable amount of pre-built apps, it provides a managed platform, pre-designed APIs and pre-built integrations. Examples of providers for this service and solutions that make use of it are *Atmosphere, Layer 7 Technologies, 3Scale, Apigee, Mashery, Apiary.io, Microsoft Azure, WSO2*, amongst others.

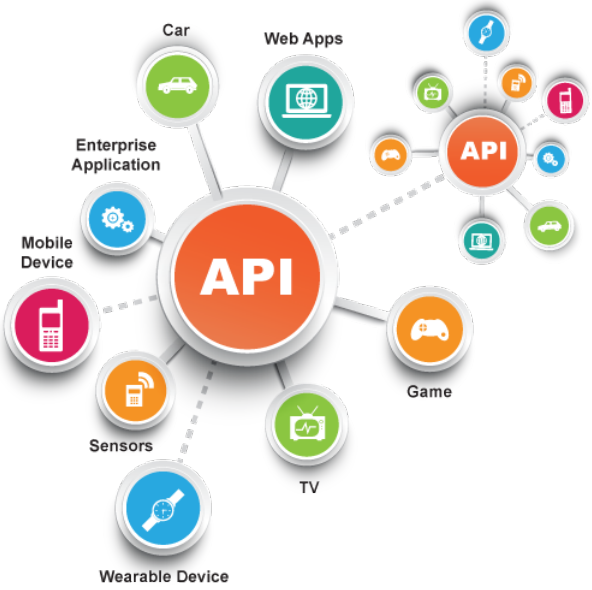

Figure 14: API as a service [1]

6 Security Issues

The pervasiveness of cloud computing and its extensive and varied use led to multiple security issues that not only affect the consumer but the service supplier as well. Data security and confidentiality still are some of the most serious and important problems and concerns, if not the most important ones, regarding cloud storage due to the privacy factor the consumers so greatly value which leads them to spend more money if need be to ensure said privacy and security. Given that the consumer is not always in full control over the environment in which his data is being stored and given that some part of it is sensitive data these confidentiality

and privacy issues are inevitably brought up.

Figure 15: Biggest concerns regarding cloud services and applications providers [6]

Some of the most common and relevant threats to the security of the stored data within cloud storage servers also threaten its confidentiality/privacy whether whilst in transit or whilst at rest within the service providers' servers. Besides these threats, there are also threats related to the security flaws in the used APIs for the client and server communication, threats related to the separation between consumers, related to the cloud legal and regulatory issues, incidents response and the threats to user authentication are significant threats to make this an even bigger risk and issue.

Encryption is usually a good practice in this quest for data privacy and security regarding data sitting in the service provider' cloud storage servers. Maintaining the stored data' privacy is a crucial task most of the times to be handled by teams which are responsible for the security regarding both software and hardware.

A key problem in these systems' moving process to the cloud is usually the lack of confidence and trust in the service providers thus leading to and requiring the enforcement of strict and strong security measures by said service providers in order to ensure the trust of the client. There must be a kind of mutual trust between both parties. According to the **Cloud Security Alliance**, the top three threats in the cloud are "Data Loss and Leakage", "Hardware Failure" and "Insecure Interfaces and API's" which accounted for an average of 21% of all cloud security disruption representing some of the shared technology vulnerabilities.

Data loss is also a security issue related to cloud computing. The possibility of loosing ones data might be catastrophic or at least damaging for the company. A Hacker may well be capable of deleting his targets data or it may be only due to natural causes, like accidents, natural disasters such as earthquakes or fires for instance, or sometimes in cases of encryption keys' loss. It can also lead to legal issues dues to loss of very important data that must be present in order to oblige certain laws.

Insecure interfaces and APIs, sometimes dated APIs can bring huge security flaws as they are fundamental to ensure security and availability of most of the clouds' services. And there are several other issues that pose a threat to the security of these cloud computing systems.

7 Parallel Programming Models

There are several programming models and techniques used to process data on clusters of a considerable size. All of the raw data, structured and unstructured data simply cannot be processed in a single system due to the obvious limitations present in the use of a single local system requiring a considerable amount of computational resources thus bringing the need to spread the data around several computers and clusters in order to process the data in parallel. This is no easy task and there has to be some problems that need to be taken into account like, for instance, fault tolerance in order to detect and correct errors ensuring redundancy in these cases, or how the data is distributed, amongst others.

MapReduce is a very well known parallel programming model and a widely used one for processing and generating huge amounts of data using a distributed algorithm on a cluster. A MapReduce program is composed of Map() and Reduce() procedures, the reduce one executes a summary operation and the map one executes a filtering and sorting of the data. This software framework was introduced by Google in order to process such large amounts of data in distributed and/or parallel computers.

This MapReduce infrastructure marshals the distributed servers to make the processing, runs several tasks in parallel and manages all communications and data transfers between the different parts of the system ensuring fault tolerance and redundancy in this process. Apache Hadoop is an example of an open-source software framework used for distributed storage and processing of considerably large data sets on computer clusters. The processing part of the Hadoop core is the Hadoop MapReduce which is an implementation of the MapReduce parallel programming model, MapReduce is the pillar of Hadoop, it allows for a tremendous scalability across hundreds or thousands of servers in a Hadoop cluster, and the storage part of the core is the Hadoop Distributed File System (HDFS).

There are other models like the Bulk Synchronous Programming (BSP) model or Message Passing Interface (MPI) primitives, and the main difference between them is that the MapReduce one uses a restricted programming model to parallelize the program automatically and to provide a clearer and more efficient fault tolerance system.

8 Applications

The number of applications there are for Cloud Computing are endless to say the least. Given the right conditions and the right software one could execute all of the programs that could otherwise be executed in a regular computer. So basically everything ranging from a generic utility program to any specialized programs that could be used by any company can be integrated into a cloud computing system. As referred before cloud computing can be used as Infrastructure as a service (IaaS) and platform as a service (PaaS), as a private cloud or hybrid cloud, for test and development of ones software, big data analytics, disaster recovery, backup,

file storage, and thousands others more. And there are several reasons why one should hold his programs and data in a remote computer system in the cloud.

9 Pros & Cons

The usage of cloud computing systems brings several advantages both to service providers and to clients. Regarding the **clients**:

- Taking into account small and mid-sized companies, they would have much **lower costs** renting the needed physical resources that would otherwise almost cost a fortune, reducing drastically these prices due to the fact that the data is held on the other end of the cloud computing system taking away the need to have certain specialized hardware. No storage will be necessary due to it being stored away remotely. Besides this, companies can save quite a significant amount of money on **IT support** because there should be less compatibility issues due to the homogeneity in the hardware located remotely.
- **Higher level of scalability** which allows companies to add or remove any number of software/hardware instances needed without effort and they have access to a significant number of resources, being able to scale their usage, up or down, according to their needs, allowing the client to create, upload and install their virtual machine images however they choose in a more dynamic way, granting a greater flexibility in this matter against the on-premises models, and saves the clients from spending money on resources that may not be fully used in the near future and they can easily overcome fluctuations and spikes in their needs due to this flexibility and ease of scalability.
- The **setup time** a client would need to plan, acquire and install all of the required resources to start working and making use of said resources would be considerably longer than what it would take if the client chose a cloud computing system for the same purpose.
- The **mobility and accessibility** part is also quite alluring, because clients can now access their data from virtually anywhere in the world using any kind of device connected to the internet. Data is available everywhere, at any time, without most of the limitations inherent to the confinement to a physical hard drive on the users computer or computer network.
- If the back end part of the cloud computing system is a grid computing system, the clients can take full advantage of this by using its full processing power in order to **execute all sorts of complex tests or calculations** that would otherwise be almost impossible to do as fast in individual computers, the cloud system could process these data and calculations stacking up the computational processing power of its machines thus increasing the speed at which the calculations are executed.
- Cloud computing solutions take away the need for clients to buy so many proprietary software licenses for each program and software, for each employee, they can instead spend less quantities of money on said cloud computing companies in order to have a full coverage of the company by the cloud computing systems which hold all the necessary software.
- Clients can **save lots of space** due to the fact that they wont have to set up servers and all kinds of storage devices in their facilities if they use cloud computing. These companies can avoid this problem by renting physical space located remotely on someone else's physical storage units.

Regarding the **service providers** there are also several advantages for them to provide this kind of services:

- The service provider companies have significantly **higher financial gains and revenue**, new specialties can be created out of the blue, specialties that weren't there before and the ability to lease unused hardware in-house brings an even greater revenue stream to the company which can then be used to improve their infrastructures and hardware.
- Service providers can efficiently **monitor and supervise** their clients' activities, and with these collected bits of information on the clients they can exploit opportunities together with them in order to promote and sell other products they might need which may bring more revenue streams to the service provider company.
- The release management get an improvement, the SaaS service model providers for example are thus free from sending several releases, upgrades/updates and patches to each client in separate, due to the fact that the software applications are being held on the service providers' servers which means that these upgrades/updates and releases can be automatically and promptly applied without further intervention from the client.
- Besides the inherent profit that comes from leasing unused hardware in the service providers' facilities there is another advantage which is a more efficient usage of the hardware, the physical computing resources almost never run at full capacity so in order to mitigate the large initial investments in the hardware they can just simply lease the unused parts to the clients in order to maximize the hardware usage.
- Software vending companies can sell their applications adopting a service oriented approach, using a service oriented architecture they can sell the software by means of providing services to the clients at lower costs, usually in a subscription fee basis, this would in turn mobilize and encourage the clients to make a more prolonged and extended use of their software resulting also in higher revenue streams.

But as there are several advantages, there is also a set of issues related to cloud computing, this being still in its "early years". Some of these issues were already mentioned before like the **dependability, trust, security, privacy and availability factors** which have to be taken into account and mitigated in order to minimize the issues related to this service. Regarding the **legislation** related to some of the cloud computing issues such as providers availability, presented solutions reliability and information privacy and security, as well as the financial right of the service providers is still missing.

10 Conclusion

Cloud computing remains a widely used model for allowing companies to host and run their systems and data on remote servers on the cloud and remains quite an impressive phenomenon, the adopting of this concept of utility computing and services providing model brings lots of advantages not only to the clients but for the service providers as well, the clients can follow a pay as you go model in order to grant them full control, flexibility and scalability over their businesses and resources, there's no longer that immediate need to heavily invest in physical computational resources to accomplish the companies' goals. Besides all the issues that must be solved in the near future in order to advance this technology to even higher levels, it has quite a significant amount of success nowadays with big and growing amounts of either open source or closed source tools so that anyone can develop a solution or work with cloud computing.

References

[1] *API as a Service Image.* http://www.happiestminds.com/pes-solutions/web-scraping-api/img/api-services.png.

[2] *Cloud Architecture Image.* http://image.slidesharecdn.com/13615debidattascloudcomputing-141218120941-conversion-gate02/95/cloud-computing-a-new-trend-4-638.jpg?cb=1418904732.

[3] *Cloud Computing Image.* http://www.camptocamp.com/wp-content/uploads/cloud_computing-527x400.jpg.

[4] *Cloud Computing Service Models Image.* https://mizitechinfo.files.wordpress.com/2013/10/11.png.

[5] *Cloud Computing Service Models Specifics Image.* http://com.kii.community.us-west-2.s3.amazonaws.com/44b3f8ebc259ad9ab01975d4e84f01f25d7d35023.png.

[6] *Cloud Service Providers Concerns Image.* http://cdn.ttgtmedia.com/rms/onlineImages/srchcldprvdr_cloudsurvey_2013_06A.jpg.

[7] *Data as a service usage (API call).* http://www.dnb.com/content/dam/english/image-library/graph/an_api_call.jpg.

[8] *Desktop as a Service Image.* https://i.ytimg.com/vi/Gjqm3jeyM04/maxresdefault.jpg.

[9] *Popular Storage Service Providers Image.* https://static1.clutch.co/sites/default/files/most_popular_cloud_storage_providers_for_smbs_clutch_survey.png.

[10] *Test Environment as a Service Image.* https://www.clictest.com/wp-content/uploads/2014/07/TestEnvironmentasaService.png.

[11] *Types of Cloud Computing: Private, Public and Hybrid Clouds.* https://media.licdn.com/mpr/mpr/shrinknp_800_800/AAEAAQAAAAAAAAUvAAAAJDZlMzM5YTEyLTJiNDMtNGJiNi04MTI0LTlkMzE4YzcyNWMwNQ.png.

[12] *Valid security as a service.* http://image.slidesharecdn.com/valid-securityasaservice-150625073823-lva1-app6892/95/valid-security-as-a-service-7-638.jpg?cb=1435577917.

[13] Amazon. *Types of Cloud Computing.* https://aws.amazon.com/types-of-cloud-computing/.

[14] Nick Antonopoulos and Lee Gillam. *Cloud Computing: Principles, Systems and Applications.* http://www.asecib.ase.ro/cc/carti/Cloud%20Computing_Principles,%20Systems%20and%20Applications%20%5B2010%5D.pdf, 2010.

[15] Cloudbric Blog. *The Newbie's Guide to Security as a Service (SECaaS).* https://www.cloudbric.com/blog/2015/09/the-newbies-guide-to-security-as-a-service-secaas/, 2015.

[16] Alessio Botta, Walter de Donato, Valerio Persico, and Antonio Pescapé. Integration of cloud computing and internet of things: A survey. *Future Generation Computer Systems*, 56:684 – 700, 2016.

[17] J. Peter Bruzzese. *Do you really need VDI? Try desktop as a service instead.* http://www.infoworld.com/article/2975897/desktop-virtualization/do-you-need-vdi-try-daas-desktop-as-a-service.html, 2015.

[18] Christine Burns. *10 useful cloud-management tools.* http://www.computerworld.com/article/2474204/cloud-computing/93685-Top-10-cloud-tools.html#slide2, 2013.

[19] Christine Burns. *Top 10 cloud tools.* http://www.networkworld.com/article/2164791/cloud-computing/top-10-cloud-tools.html, 2013.

[20] Kaushik Chandrasekaran. *Analysis of Different Parallel Programming Models.* http://salsahpc.indiana.edu/b534projects/sites/default/files/public/8_Analysis%20of%20Different%20Parallel%20Programming%20Models_Chandrasekaran,%20Kaushik.pdf.

[21] CloudTweaks. *4 Tools To Help Enable A Successful Cloud Computing Experience.* http://cloudtweaks.com/2013/10/4-tools-successful-cloud-computing-experience/, 2013.

[22] Jill Dyché. *Data-as-a-service, explained and defined.* http://searchdatamanagement.techtarget.com/answer/Data-as-a-service-explained-and-defined, 2007.

[23] Inc Embarcadero Technologies. *Cloud Computing for Technology Tools.* https://www.embarcadero.com/images/dm/technical-papers/cloud-computing-for-technology-tools.pdf, 2010.

[24] Michael Farber and Michael Cameron. *Cloud Computing Technology.* http://www.boozallen.com/media/file/it-cloud-computing-technology-framework-for-application-fs.pdf.

[25] Tynan Ford. *Cloud Computing's Increasing Importance for Businesses.* globaledge.msu.edu/blog/post/13812/cloud-computing's-increasing-importance-for-businesses, 2014.

[26] Trusted Computing Group. *Cloud Computing and Security - A Natural Match.* https://www.trustedcomputinggroup.org/files/resource_files/1F4DEE3D-1A4B-B294-D0AD0742BA449E07/Cloud%20Computing%20and%20Security%20Whitepaper_July29.2010.pdf, 2010.

[27] Qusay F. Hassan. *Demystifying Cloud Computing.* http://static1.1.sqspcdn.com/static/f/702523/10181434/1294788395300/201101-Hassan.pdf?token=81gsnQEtNjibffg40yEB4OaI%2FfQ%3D, 2011.

[28] C.L. Jermain, G.E. Rowlands, R.A. Buhrman, and D.C. Ralph. Gpu-accelerated micromagnetic simulations using cloud computing. *Journal of Magnetism and Magnetic Materials*, 401:320 – 322, 2016.

[29] Kin Lane. *Roundup of 20 API Service Providers in 2012.* http://apievangelist.com/2012/06/15/roundup-of-20-api-service-providers-in-2012/, 2012.

[30] Mingwei Lin, Zhiqiang Yao, and Tianqiang Huang. A hybrid push protocol for resource monitoring in cloud computing platforms. *Optik - International Journal for Light and Electron Optics*, 127(4):2007 – 2011, 2016.

[31] Fang Liu, Jin Tong, Jian Mao, Robert Bohn, John Messina, Lee Badger, and Dawn Leaf. *NIST Cloud Computing Reference Architecture.* http://www.nist.gov/customcf/get_pdf.cfm?pub_id=909505, 2011.

[32] Samara Lynn. *20 Top Cloud Services for Small Businesses.* http://www.pcmag.com/article2/0,2817,2361500,00.asp, 2012.

[33] Ricky M. and Monique L. Magalhaes. *NaaS is the future of networking cloud based.* http://www.cloudcomputingadmin.com/articles-tutorials/naas/naas-future-networking-cloud-based.html, 2014.

[34] Oracle. *Cloud Computing.* https://www.oracle.com/cloud/index.html.

[35] Oracle. *Data as a Service.* https://www.oracle.com/cloud/daas.html.

[36] Oracle. *Infrastructure as a Service.* https://www.oracle.com/cloud/iaas.html.

[37] Oracle. *Managed Cloud.* https://www.oracle.com/cloud/managed-cloud.html.

[38] Oracle. *Platform as a Service.* https://www.oracle.com/cloud/paas.html.

[39] Oracle. *Private Cloud.* https://www.oracle.com/cloud/private-cloud.html.

[40] Oracle. *Software as a Service.* https://www.oracle.com/cloud/saas.html.

[41] Tim Panagos. *API as a Service.* http://point.io/sites/default/files/whitepapers/api_as_a_service.pdf, 2014.

[42] Margaret Rouse. *cloud services definition.* http://searchcloudprovider.techtarget.com/definition/cloud-services, 2011.

[43] Margaret Rouse. *Heroku definition.* http://searchsalesforce.techtarget.com/definition/Heroku, 2012.

[44] Margaret Rouse. *Desktop as a Service (DaaS) definition.* http://searchvirtualdesktop.techtarget.com/definition/desktop-as-a-service-DaaS, 2015.

[45] Sebastian Rupley. *11 Top Open-source Resources for Cloud Computing.* https://gigaom.com/

2009/11/06/10-top-open-source-resources-for-cloud-computing/, 2009.

[46] Technopedia. *Security as a Service (SecaaS or SaaS)*. https://www.techopedia.com/definition/26746/security-as-a-service-secaas-saas.

[47] Bob Violino. *Before the Cloud, IT Was Burdened with Inefficiencies*. http://216.97.230.27/uptime/cloud-it-was-burdened-inefficiencies.

[48] Mike Vizard. *Delivering Network Services via the Cloud*. http://talkincloud.com/cloud-computing/delivering-network-services-cloud, 2015.

[49] Wikipedia. *Apache Hadoop*. https://en.wikipedia.org/wiki/Apache_Hadoop.

[50] Wikipedia. *API as a service*. https://en.wikipedia.org/wiki/API_as_a_service.

[51] Wikipedia. *Cloud-based networking*. https://en.wikipedia.org/wiki/Cloud-based_networking.

[52] Wikipedia. *Cloud computing*. https://en.wikipedia.org/wiki/Cloud_computing.

[53] Wikipedia. *Cloud testing*. https://en.wikipedia.org/wiki/Cloud_testing.

[54] Wikipedia. *Data as a service*. https://en.wikipedia.org/wiki/Data_as_a_service.

[55] Wikipedia. *MapReduce*. https://en.wikipedia.org/wiki/MapReduce.

[56] Wikipedia. *Network as a service*. https://en.wikipedia.org/wiki/Network_as_a_service.

[57] Wikipedia. *Platform as a service*. https://en.wikipedia.org/wiki/Platform_as_a_service.

[58] Wikipedia. *Security as a service*. https://en.wikipedia.org/wiki/Security_as_a_service.

[59] Wikipedia. *Software as a service*. https://en.wikipedia.org/wiki/Software_as_a_service.

[60] Wikipedia. *Storage as a service*. https://en.wikipedia.org/wiki/Storage_as_a_service.

[61] J. Sean Wilson. *Rethinking Testing - Moving to the Cloud: Types of Clouds*. https://www.linkedin.com/pulse/rethinking-testing-moving-cloud-types-clouds-j-sean-wilson-pmp, 2015.

[62] Davey Winder. *Security as a service really has become a no-brainer*. http://www.cloudpro.co.uk/cloud-essentials/cloud-security/3671/security-as-a-service-really-has-become-a-no-brainer, 2014.

[63] William Van Winkle. *Top 3 Desktop as a Service (DaaS) Providers Compared*. http://www.tomsitpro.com/articles/desktop-as-a-service-providers,2-838.html, 2014.

[64] Goran Čandrlić. *Cloud Computing – Types of Cloud*. http://www.globaldots.com/cloud-computing-types-of-cloud/, 2013.

[65] Goran Čandrlić. *How Cloud Computing Works?* http://www.globaldots.com/how-cloud-works/, 2013.