The Evolution of Cloud Computing :Past Trends,Current Practices,and Future Directions

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***Abstract*—Cloud computing in recent years has developed into an essential component of modern digital infrastructures, emerging from the concept of shared resources. This document explores the growth of cloud computing from its roots in grid computing, virtualization technology, and modern service based models such as IaaS, PaaS, and SaaS.**

It emphasizes the transformation of cloud computing from an internal IT infrastructure solution to a globally accessible public utility, largely propelled by major technology behemoths like Amazon, Google, and Microsoft. To understand how organizations utilize clouds for agility and rapid horizontal scalability, contemporary practices like serverless architectures, multiclass cloud adoptions, and edge-cloud integration are studied.

Lastly, the paper analyzes the implications of AI on cloud services, green computing projects, evolving security and compliance mandates, and other emerging clouds initiatives to discuss future trends. Studying the history helps illustrate the impact cloud computing has on technology, business, and society in real time.

***Keywords*—Cloud, Iaas,Computing, Paas, Services, Evolution**

I. Introduction

Cloud computing has emerged as one of the most revolutionary technologies of the 21st century, reshaping how computing resources are distributed and used. [1]Cloud computing, which began as grid computing and virtualization, has grown into a highly scalable, service-oriented architecture that supports a wide range of applications, including data storage and web hosting, as well as artificial intelligence and analytics.[2]

The primary idea of cloud computing is effortless yet remarkable: it allows on-demand remote user access through the internet to shared computing resources like servers, storage, and applications with minimal required administrative work.[3] These offered services include use of technology infrastructure (IaaS), Software as a Service (SaaS), and even a computing platform (PaaS) through the commercial internet, which are now essential across consumer and business sectors.[4][5]

Recently, Amazon, Google, Microsoft and other tech companies have greatly improved cloud technologies which are now essential for business processes as well as day-to-day activities.[5]However, other issues such as non-standardized interoperability, security concerns, and lack of safety measures still exist.

In this paper, I will analyze the history of practices and work done in cloud computing technology to understand where it is heading.[6]Additionally, I will propose a classification and discrimination system of cloud services in order to address the restrictions and recommend new advancements.[7]Recognizing this transformations is important to comprehend how the cloud continues to influence the digitization of nearly all sectors.[8]

II. Cloud Computing Overview

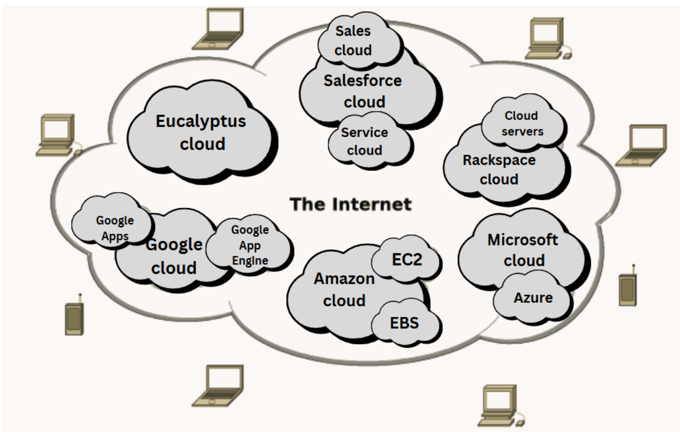

Fig. 1. Cloud computing services

A cloud can be seen as a scalable infrastructure that supports and interconnects several cloud computing services; see Fig. 1. The public cloud itself consists of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s)[9].Clients who are the users of the cloud computing services connect and use their home or work computer or any other Internet-enabled device to connect and use the cloud computing services.The key features that distinguish cloud computing from traditional computing solutions have been recognized in [6,11,8] and broadly comprise the following:

• Underlying infrastructure and software is abstracted and offered as a service.

• Build on a scalable and flexible infrastructure.

• Offers on-demand service provisioning and quality of service (QoS) guarantees.

• Pay for use of computing resources without up-front commitment by cloud users.

• Shared and multitenant.

• Accessible via the Internet by any device.

More over,the main underlying technologies are virtualization technologies to provide flexible and scalable computing platforms, Web ser vices and Service Oriented Architectures (SOA) to manage cloud services, and distributed storage for backup and world-wide data access [11]. The National Institute of Standards and Technology (NIST) proposed the following definition of cloud computing: "Cloud computing is a model for enabling convenient, computing resources (e.g., networks, servers, storage, ap plications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability."[14]. This definition will be used as the basis for distinguishing cloud computing services and traditional Internet services. Next, three service models are currently being differentiated—Software-as-a-Service (SaaS), i.e., online applications, such as web-based email, Platform-as-a-Service (PaaS), which allows customers to deploy their own applications, and Infrastructure-as-a-Service (IaaS), which provides, for example, processing power or storage [14]. Some previous work considers additional service models, such as Service-as-a-Service, and Data-as-a-Service [17, 11] or Storage-as-a-Service, but generally it is possible to group these with the existing three service models. How ever, beyond these service models no further categories are considered in current definitions. Several cloud architectures have been proposed. A reference architecture and implementation of a service-oriented infrastructure (SOI) using open standards and recent virtualization and SOI technologies is the European Union funded RESERVOIR project. The RESERVOIR architecture has been developed jointly with IBM and is described in [19]. Another architecture is Aneka, which is a .NET based PaaS architecture for building.NET applications.

A market-focused deployment of the Aneka architecture has been covered in [20]. IBM has provided in a service-oriented architecture for the construction of a web-based business service platform that is economical, scalable, and secure. In [21] provides a description of each of these architectures and additionally, another service-oriented architecture for cloud computing is introduced.

III. CURRENT CLOUD COMPUTING SERVICES

Differences in cloud computing service models are based in the type of services offered which include: (1) offers of computing resources and storage services, (2) provisioning of software hosting Platforms, or (3) serves software applications accessed through the internet such as web-email and various business analytical tools. Along these lines, NIST has already proposed three primary types of cloud computing services .

Here, I described some cloud computing services from different categories to illustrate the range of services that are available. I have reviewed existing taxonomies [17] and compilation of works to provide an overview of classification of cloud computing services relevant to this context. As additional sources of information the websites of the cloud services have been used to provide more details on the service.

3.1 Infrastructure as a service

Cloud infrastructure services typically offer virtualization platforms, which are an evolution of the virtual private server offerings that are already known for years [17].Clients purchase the resources and are billed for the resources consumed, as opposed to having to set up servers, software and data center space themselves. They deploy their software on the virtual machines and control it. In other instances, they can be rented for as little as an hour, and for as long as required. The amount of instances is scaled dynamically to meet the customer's needs. Billing is based on this unit, the time, and other services used like more storage space. To provide rapid accessibility around the globe, providers usually have data centers in many locations.Web interfaces allow monitoring of the cloud service.

Some providers make it possible to connect the virtual instances to the company's network via VPN (Virtual Private Network), to make the company network seem like one big scalable IT infrastructure. These solutions are called hybrid clouds, as they connect the company's (internal) private cloud with the public cloud of the IaaS provider. A pioneer in virtualization and computing power offerings is Amazon [2]. The Amazon Elastic Compute Cloud (EC2) is one of the most widely used infrastructure platforms [18]. Further popular virtualization services include ServePath's GoGrid and the Rackspace Cloud. Other services are the IBM Smart Business cloud solutions, Oracle Cloud Computing , GigaSpaces , RightScale , and Nimbus . Online storage and backup services fall in the category of IaaS. Like most virtualization platforms, there are several storage solutions intended for corporate use, but there are also special services for private individuals.

Corporate services range from temporal to permanent and from general additional storage space to extend the company's internal capabilities, to storage services aimed at database-structured information.[24] These latter services are billed based not only on the amount of storage space used, but also on the amount of queries on the data. Further, there are specially designed services to extend the storage amount offered with standard virtualization instances. For private individuals more and more cloud storage and backup services are offered. Laptop and netbook manufacturers, as well as, operating system providers advertise for additional web-storage. Files can be stored on the provider's servers as backup or to synchronize multiple workstations and can often be retrieved from different locations, as the services are often accessible also with a web-browser, such as Rackspace's CloudFiles. Rackspace offers online storage for corporate and private use [19]. Another storage provider is Nirvanix . Amazon offers data storage facilities either in combination or separate from their EC2 instances, called Amazon Elastic Block Store (EBS) and Amazon Simple Storage Service (S3), respectively [12]. Amazon also provides special database solutions, such as the Amazon SimpleDB.

3.2 Platform as a service

Every customer can develop and deploy specific applications or services with the help of provided tools, supported environments, or even certain programming languages by the PaaS provider offering a higher level infrastructure as a service. This also includes the use of the underlying infrastructure like servers, network, storage and even operating systems which the customers cannot control as it is abstracted away below the platform [17,20]. Primarily, platform services revolve around the specific domain such as web system application development and are determined by the programming language. There is Self-serviced provisioning wherein customers are given a separate environment to test and develop or to permanently deploy their applications. Advanced Programmers can Do Everything with Google's App Engine which focuses on web application, supporting development in Java or Python . Those who want to host small, not scalable applications can use Google App Engine free of charge. Application development on Microsoft's Azure is possible too, but with the use of .NET libraries [5]. Microsoft uses their cloud offers to promote their own software packages [13]. Specially constructed for development and deployment of cloud applications, Bungee Connect [9]. Another one is Force.com, which is designed with a different domain PaaS, enabling businesses to develop tailored applications contract like how Salesforce.com offers.

3.3 Software as a service

The applications offered with cloud software are usually offered as ready to use products with an application hosted on a cloud infrastructure. One of the most common SaaS services is e-mail which is now offered as web based. Most software as a service (SaaS) solutions run on the web and can be accessed using any client device with a thin client such as a web browser. Customers of these services have no control over the infrastructure or application platform; only limited configuration for specific users is possible. Internet based storage features in standard non-hosted applications are also frequently viewed as part of SaaS offerings. An example of a software cloud service meant for corporate users is Salesforce.com which provides business intelligence and CRM tools. Another example is Appian Anywhere which specializes in offering SAS business process management procedures [4]. Widely known software services designed for personal use include Google Apps such as a calendar, contacts, Google mail and chat, and the Google Docs suite for document, spreadsheet, and presentation access and sharing. Other services include document backup and sharing via Box.net [7]. For video and photo sharing and storage services SmugMug uses Amazon S3 for their hosting services [8].

3.4 Open-source based services

Some cloud service providers employ open-source software, but the underlying systems are usually closed. Still, there are some wholly open-source, as well as applications and tools designed mainly to manage IaaS clouds. These tools enable users to monitor, manage, and control virtual instances. Unfortunately, most open-source cloud computing services are offered at the infrastructure or platform level, and only a handful exist for SaaS applications. Moreover, nearly all open-source platforms run on Linux, restricting the customer base to these operating systems . The Eucalyptus cloud system focuses largely on private clouds [20]. Groundwork is a commercially supported open-source cloud management tool that integrates with Amazon EC2 . OpenNebula is an 'open-source toolkit for building private, public, and hybrid clouds based on standards', and is compatible with Amazon EC2. The Nimbus project also has an open source framework; it is developed by the University of Chicago and was designed for scientific computation .

3.5 New developments

Recent advances include providing fully cloud-hosted computer games. This facilitates portability since the game can be continued from another location [15]. Furthermore, it has less reliance on the user's hardware and is much less susceptible to piracy. An idea that is rather new and not yet commercially offered is providing computational and data storage resources to assist smart phones and other resource straining devices using cloud computing [1, 19]. The limited processing power, storage space, and battery life of mobile phones means that such a provision would enable the operation of more advanced applications and services for smartphone users. These could be provided through Wi–Fi and 3G connections, eventually evolving to 4G and WiMax.

IV. Past Trends

The inception of cloud computing originated from basic grid computing and virtualization technologies which permit multiple machines to share resources and operate as one system. In the early 2000's, there was a surge in internet usage which created further strain on existing IT infrastructure systems to meet the data storage and computing power requirements. To these problems, service providers began using sophisticated software solutions and inexpensive bulk hardware to build elaborate and rigid frameworks which could scale seamlessly. These differences in styles to approach frameworks for cloud computing include: Amazon, Google, and Microsoft, each marked by different resource abstraction technologies.

The first was Amazon, who developed the IaaS model with the launch of Amazon Web Services (AWS) in 2006-2007. It included services (EC2, S3, SimpleDB) which were server virtualized on Xen technology and formed the architectural building blocks of AWS. Flexible Compute resources were offered on rent with unprecedented flexibility allowing users customizable options. A paradigm shift was also experienced with the deployment of IT services.

Google focused on the PaaS model with the launch of Google App Engine (GAE) in 2008.Based on earlier research between 2003 and 2006, Google's cloud strategy used technique-specific sandboxing, enabling developers to deploy applications with built-in scalability.

At that time in October of 2008, Microsoft entered the marketplace with its launch of Microsoft Azure, using WAH (Windows Azure Hypervisor) and .NET for Application development Pre-Azure. Windows Azure offered numerous services which included SQL databases and BLOB storage, thereby marketing itself as a hybrid cloud service solution.

In this period, the virtualization of the server becomes the most preferred model because of its easiness to work with and for its compatibility with pre-existing software's. Although sandbox-based models, which offered reduction of abstraction overhead, were offered programming language constraints. With public cloud platforms being available to a lot of organizations, many also started considering private cloud deployments where principles of cloud were applied to internal infrastructure. This was a huge shift as not only businesses started but governments like the USA, Japan started recognizing cloud computing as a core strategic technological powerhouse. These emerging trend significantly changed the cloud ecosystem we have today and helped transition computers from local individual services to a global ubiquitous service paradigm.

V. Literature Review

Cloud computing are a major trend that are rapidly growing and new challenges and solutions are being published every day. In 2014, a [22] publication gave set procedures to be able to implement big data analytics applications into the cloud. The set of steps are in 6 steps: In the first stage; we create the business use case by figuring how the deep business values will be achieved by moving to cloud and deploying the drivers which will enable this. After this comes alignment with the stakeholder's case in order to get their support which needs to be garnered. Lastly, the case has to be robust through identification of key benefits accompanied by no feasible solutions that are available being provided to the other competing solutions that are available; The second stage is to assess your application workload. In the second stage you will describe your business case and explain the functional requirements in details, The cloud service needs to be able to support the workload and must have the capacity to scale the optimization as new workloads come online rapidly; The third stage is developing a technical approach to the big data platform and this step need to pay attention to both the topologies and data platforms; and The fourth stage is to work on governance, security, privacy, risk and accountability needs.The existing big data platform needs to customize the tools to ensure security of both data and architecture according to the organization’s policies; finally, they have to deploy, integrate, and operationalize the infrastructure. The required data is already provided and can be integrated with the configured cloud platform.

A new paper published in 2014, [20] focuses on the integration of big data and cloud computing technologies, which is of value both from an analytic and performance standpoint. As the data accumulates, it becomes necessary to analyze it in order to extract value from it which is why these cloud services are capable of processing vast quantities of data in milliseconds with real time data manipulation. There are a few integrated cloud environments for big data analytics; Canpass is an environment implemented by Vrije Universiteit Amsterdam, the University of Rennes 1, Zuse-Institut Berlin und XLAB which allows the building of scalable cloud applications without regard to the underlying complexities of these applications. It also offers a number of resources for hosting web applications developed in PHP or java, or for managing various SQL or NoSQL database systems. Additionally, some other environment that include MapReduce which is provided by apache to facilitate parallel compute with distributed file systems and data processing.Cloud computing has the benefits of parallel computing, cost effectiveness, scalability and elasticity. Data security is taken care of by encrypting data using high level encryption secures the data. However, there are other solutions as this causes high processing overheads. With respect to the performance, some challenges which include data transfer restrictions, retention of data, management of isolation and recovery from disasters have to be addressed.

In 2015, [23] published a paper discussing the synergy between the efficiency found in big data in relation to cloud computing and why each technology compliments the other. The coexistence of cloud computing and big data can be observed simultaneously as the two fastest evolving technologies today. It seems that the aggregate computation power of the cloud enables resource to be consolidated and managed as a single system composed of systems and applications, so why is big data better sited on the cloud? The following arguments sufficiently address the question at hand: cost reduction where an organization could adopt a pay per use model as opposed to making a capital investment to set up servers and clusters to manage big data that outdate and require upgrading; reduce overheads by automatically acquiring any new components needed; rapid provisioning/time to market, ability to change the scale of the environments easily based on the processing requirements; flexibility/scalability, environments can be spun up at any point in time at any scale in a few minutes..

D. Malcolm [12] studied the five defining characteristics of cloud computing such as dynamic computing infrastructure, IT service-centric approach, self service based usage model, self or minimally managed platform, and consumption based billing. An application suitable for ‘Cloud computing’ has four main traits such as requiring adaptability, exponential or scalable growth, wishing to operate economically, and independently [13]. D. Amrhein comments saying defining cloud computing has been virtually impossible and proposes five characteristics of a cloud computing solution: shared, virtualized infrastructure, self-service access, elastic resource pools, consumable output, and user based billing [14]. There are various systems of cloud computing with distinguishing features. For example, Amazon EC2 [2] provides infrastructure as a service, while Google App Engine [3] and Microsoft [15] offer their platforms as services. In academia, different cloud computing projects are either under active development or fully operational [16-19].

VI. Conclusion And Future Practices

Industries as a whole have benefitted from the versatile, easily scalable, and affordable solutions that cloud computing provides. The analysis shared within this paper highlights the need to comprehend the models employed within the service of the cloud such as IaaS, PaaS, and more, in order to fully evaluate the merits of using the cloud. Different levels of control, abstraction, and responsibility ranging from ‘tailored’ to ‘fully bespoke’ exist within these frameworks. Their interplay facilitates organizational alignment to a growing technological paradigm. The rationale continued to be strong on adopting cloud computing as collaboration from disparate teams needs to be simplified and the need to deliver vast computing resources efficiently. Furthermore, fog computing centralised IT management structures enabling it to be controlled remotely while streamlining operations. Still, concerns involving data privacy, security, and integrity of sensitive data remain troublesome. Paradoxically, in most working scenarios, the cloud is improving data control and continuity with data storage, replication, and redundancy through intelligent and controlled business processes.

Migrating to a cloud infrastructure has low upfront investment and gives an edge in terms of costs incurred, which are some of the most striking features to businesses. Traditional systems of accessing computers and intense hardware resources coupled with software deployment, a center consumes tremendous energy and demands significant finances.

As posted in the last few years, migrating to cloud infrastructure still has one of the strongest incentives for businesses in terms of capital expenditure on hardware and software interfaces since the cloud model lies in software as a service.

Once again, the emerging and spanning evolutive technologies present challenges in standardization, regulatory compliance, absolute security guarantees, and, most importantly, the complete assurance of security transcend the cloud service itself. The immense growth of these cloud services will force service providers alongside regulatory and end-users to pull these attempts together. Additionally, the taxonomy classification creates practical approaches to outline pre-existing and newly emerging cloud services. As a result of focused comparison, identification, and the sharp integration of set decision trees, businesses can very easily spot features and trade-offs of cloud services as opposed to other conventional methods. However, the constant convergence of service feature similarities at varying levels of classification depicts the need for market deep integration of technology, thus enabling this taxonomy to remain agile at adaptation.

Research in this area needs to change focus on holistic approaches. To begin with, designing and implementing further development on the cloud taxonomy framework will be tremendous in adjusting to the changes of increasingly complex and hybrid cloud services.

Specifically, the taxonomy should incorporate more granular security measures, not only between client and cloud but also within the cloud itself, to reflect the multi-layered nature of cloud security architecture. This will enable organizations to better assess risks and implement appropriate safeguards. Secondly, there is a pressing need for the development and adoption of universal standards for cloud computing. Interoperability between services, platforms, and providers must be improved to allow seamless data and application mobility, reduce vendor lock-in, and support the growing demand for multi-cloud and hybrid-cloud strategies. Various standardization efforts are underway, but active collaboration from all stakeholders—including cloud vendors—is necessary to realize tangible benefits.

In addition to technical enhancements, real-world evaluations of cloud implementations must be pursued more extensively. Case studies and longitudinal analyses of cloud adoption across various industries can offer valuable insights into practical challenges, success factors, and best practices. These learnings will be crucial for organizations currently planning their transition to the cloud or seeking to optimize existing deployments. Furthermore, research into emerging areas such as edge computing, serverless architectures, AI-powered cloud orchestration, and green cloud computing can provide a future-proof perspective and align cloud evolution with broader technological and environmental goals. Lastly, given the dynamic nature of the cloud landscape, continuous monitoring and academic research are required to ensure that cloud computing remains a secure, efficient, and user-centric solution for the digital world.

Overall, while cloud computing has already made a profound impact, it continues to evolve at a rapid pace. The convergence of research, innovation, industry collaboration, and user awareness will shape the trajectory of cloud technologies in the years to come. With the right strategies, tools, and governance models in place, cloud computing has the potential to remain at the forefront of IT innovation—delivering value, scalability, and agility to businesses, governments, and society at large.

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