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Multi-Cloud Computing & Why do we need to Embrace it

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***Abstract*— This study aims to provide a high-level introduction to cloud computing and, more specifically, multi-cloud networks. An introduction to cloud computing's foundational ideas is provided first. Next, we describe several obstacles in the way of cloud computing and talk about how multi-cloud systems, such as multi-clouds, hybrid clouds, federated clouds, and cross-clouds, can help overcome some of these problems. Last but not the least, interesting new developments are possible when multi-cloud systems are employed in tandem with Big Data and machine learning. These are discussed briefly. Our mission is to survey recent developments in multi-cloud computing and to examine outstanding questions in this area. The purpose of this paper is to inform readers about the problems with cloud computing, explain how multi-cloud computing solves some of these problems, and get the community excited about the potential future integration of multi-cloud platforms with other cutting-edge technology.**

Keywords—Cloud computing, Multi Cloud Architecture

I. FOUNDATIONS OF CLOUD COMPUTING

The National Institute of Standards and Technology (NIST) defines cloud computation as a “model for granting users access to a shared pool of configurable computational resources including networks, servers, storage, applications, and services that can be rapidly provisioned (adapted for new services) with little management or service provider interaction” [25]. Cloud computing has been there for a while now and its rather a different approach to use established ones [26]. Computing in the cloud, or "the cloud," is simply a method of gaining access to and controlling hardware and software over the Internet [34]. Third-party cloud networks have made computation the "fifth utility" [6] alongside water, electricity, gas, and telephones, and have been adopted by many enterprises so that they may focus on their core competencies without worrying about the underlying computer infrastructure. Because of the economies of scale, this technology enables for greater efficiency in the use of system resources, leading to faster results. This is demonstrated in [6] by contrasting the price of running one server for 1000 hours with that of running a thousand servers for just one hour. The time required to solve an issue is drastically cut even though the financial costs remain the same when one thousand servers work in unison to do so.

There are five main characteristics of clouds that make them appealing to customers [25]. For starters, a single user can access them from anywhere in the world, anytime, and without the help of any other people (on-demand self-service). Moreover, these networks are accessible from a wide range of endpoints, such as smartphones, notebooks, and desktop PCs (broad network access). Multi-tenant models, in which cloud resources are pooled to serve several tenants, are also commonly used by cloud service providers (resource pooling). Easy provisioning and release of these networks to meet client demand is another benefit of cloud computing (rapid elasticity). And last, cloud systems provide metering features for their services, which may be utilized to give honest feedback to both the service provider and the customer (measured service). These features make cloud computing appealing to startups because no initial capital expenditure is required. By outsourcing the infrastructure to suppliers, they cut down on operational costs, make resources more readily available, and lessen the burden of maintaining company networks, all of which free up time and energy to concentrate on important business issues [26].

SaaS (Software as a Service), PaaS (Platform as a Service), and IaaS (Infrastructure as a Service) are the three most popular cloud computing service models right now (IaaS). Software as a service (SaaS) allows users to access and utilize an application over the provider's cloud infrastructure, most frequently the Internet [25, 26]. PaaS refers to a model of cloud computing in which the service provider facilitates the customer's usage of the cloud infrastructure to run custom software. In IaaS, consumers are given access to virtual servers and data storage.

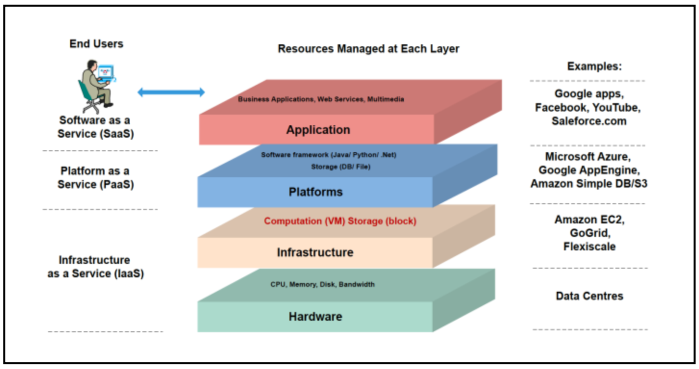

Fig. 1 Cloud Computing Architecture, based on [26]

Figure 1 depicts the four distinct components that make up the Cloud's layered architecture. At the bottom is the Hardware Layer. Physical components like as servers, switches, power, cooling systems, etc. are housed under the Hardware Layer. The Hardware Layer often consists of large facilities housing thousands of servers. The Infrastructure Layer is the next tier up, and it uses virtualization technologies to allocate computing and storage capacity in logical isolation from one another. Operating systems and application frameworks make up the Platforms Layer, and it's mostly utilized to simplify the burden of delivering apps directly into VM containers. Last but not least, the cloud network's infrastructure as a service (IaaS) and platform as a service (PaaS) serve as the foundation for software as a service (SaaS) applications. The applications distributed by Google Play and similar app stores, for instance, often make use of cloud computing to handle some of their functionality. This benefits the user in two ways: it makes it easier to access the app, and it reduces the computational burden the app places on the user's device.

There are four main deployment types to consider when talking about cloud computing. In the private cloud concept, several users belong to a single company that has access to the cloud (e.g. business consumers). The company may run and manage the system in-house, hire an outside party to run it for them, or do a hybrid of the two. Multiple entities may share the burden of cloud provisioning in the community cloud paradigm. Community clouds, like private clouds, can be owned and operated by one or more of the participating organizations, can be outsourced to a third party, or can be a hybrid of the two. However, unlike the private and hybrid clouds, which can be accessed from anywhere with an internet connection, the public cloud can only be accessed on the physical location of the cloud provider (such as a university campus). As a last point, hybrid cloud architectures combine elements from many deployment types while maintaining their own identity. One fundamental technology, however, makes it possible for data applications to be shared between devices [25].

II. ISSUES WITH CLOUD COMPUTING

After going through the fundamentals of cloud computing, we may move on to the challenges that it now faces. Despite of the cloud computing's benefits—such as the elimination of the need for planned provisioning and the facilitation of small businesses' ability to scale computing needs growing in tandem with business requirements—certain problems and difficulties are inherent to cloud systems and could be the subject of future study [26]. Cloud computing's widespread use has allowed many experts and corporations to begin to weigh in on possible difficulties facing the technology.

A. Data Management

Some people may wonder what would happen to the information stored in the cloud if it were completely destroyed. A cloud provider going out of business is one potential threat to data safety. That would be a major issue for corporations that rely heavily on data storage [15, 33].

B. Security

Data security and privacy has been identified as a major issue [6,15,26,27] by numerous authors. Security was identified as a major problem in 66 of the research papers assessed for a study by [15], followed by infrastructure (46) and data management (15). Interviews with practitioners in this study revealed that they had additional worries, but that security was still a practical issue, showing that this is a significant issue for many academics and corporations.

Safety procedures, cloud server monitoring, data confidentiality, and avoiding malicious actions are all subsets of the larger security problem [27]. Data integrity, data confidentiality, data availability, and data privacy are all discussed as they relate to issues with data storage in cloud computing networks. To ensure data integrity, you must guard against unauthorized access to the system and prevent any changes to or creation of existing data. Another problem is that it is difficult to ensure data confidentiality from both internal and external breaches, which reduces the usefulness of cloud networks for storing sensitive data like medical records or government papers [33]. Data availability, or the ease with which lost information can be restored, is another facet of security. Finally, data privacy is defined as the ability to communicate data selectively and discreetly among a subset of the data's intended recipients.

However, [6] contends that with adequate planning, cloud computing has the potential to be even more secure than alternative approaches. Data encryption, virtual local area networking, firewalls, and other technologies are already in use and can be utilized to overcome any problems with cloud computing, as the authors describe.

C. Legal Concerns

While legal concerns are tied to security concerns, they are still separate concerns [15, 27]. Where you live can affect the regulations and policies surrounding data storage [6]. There are now no standards in existence, despite the fact that service level agreements have been negotiated between providers and consumers. Adopting storage standards for cloud computing to match local law may prove difficult in the future and will necessitate meticulous preparation and collaboration when developing such systems.

D. Vendor Lock-in & Interoperability

Data security and trust issues are the primary concerns for cloud computing platforms, with interoperability (the "ability of varied systems and organizations to work together (inter-operate)") coming in a close second. This is significant because it would free customers from the shackles of vendor lock-in, a situation in which they are unable to switch cloud service providers (CSPs) despite having already subscribed to services from those providers. Due to the absence of standardization, it may be challenging to move data between different cloud storage solutions. Several writers have also pointed out the issue of vendor lock-in, in which a client develops an unhealthy dependence on a single service provider and finds it difficult or impossible to switch providers due to high switching prices, legal complications, or technical difficulties. Because there are numerous cloud systems, many of which are incompatible with one another, this problem is related to interoperability as well. According to [21], this is due in large part to the absence of standardization with regard to operating platforms, APIs, SLAs, and cloud semantics, all of which contribute to interoperability problems. Because of this, it's more challenging for businesses to move their resources from one cloud to another, perhaps leading to reliance on a single provider. Some companies have already made the move to the cloud, while others haven't been able to do so because they don't feel they can trust any one particular cloud service provider (CSP). [20]

E. High Latency

High latency, or the delay between an instruction for data transfer and the actual transfer itself, is another difficulty with cloud computing. This occurs in cloud computing because different cloud nodes need to be able to talk to each other. Fog computing and edge computing have emerged as two possible answers to this issue. The term "fog computing" describes a scenario in which "a large number of heterogeneous (wireless and sometimes autonomous) ubiquitous and decentralized devices communicate and potentially cooperate among them and with the network to perform storage and processing tasks without the intervention of third parties." [31]. There is also the definition of fog put forth in [35], which is worth considering. "a geographically distributed computing architecture with a resource pool that comprises of one or more ubiquitously connected heterogeneous devices at the edge of network and not exclusively seamlessly powered by cloud services," as defined by these authors, is what is known as "fog computing." Many customers in close proximity can use elastic compute, storage, and communication thanks to this network's cooperative effort. [17] proposed a fog-based opportunistic spatio-temporal event processing system that anticipates future inquiry region for mobile users as a means of dealing with delay. There are a few different kinds of fog networks, which you should know about. Edge computing is analogous to cloud computing in that both include distributed computing concepts, however with edge computing, computation is mostly performed on devices at the network's periphery (such as smartphones and laptops) rather than in a centralized cloud. The computation is moved to the system's edge.

III. MULTI-CLOUD SOLUTIONS AND ARCHITECTURE

Multi-cloud computing, or cloud systems that make use of many cloud networks and services at once, is the next logical evolution in cloud computing to help cope with some of the challenges [13]. Although there are various subcategories of multi-cloud systems, the main idea is that more than one CSP is used. Systems that operate across various provisioning boundaries are also known as cross-cloud architectures [14]. Although the precise difference between multi-clouds and cross-clouds is lacking (as will be detailed in further detail below), it may be recognized that in multi-clouds, the user or business in question utilizes several cloud services for various applications inside the enterprise. They might use multiple clouds for various tasks; for instance, they might store data in a private cloud, collaborate on documents using the Google Cloud Platform, and do data analysis using a different cloud. Cross-cloud architectures, on the other hand, are made to make it easier to move data and use applications between clouds [14]. Several of the concerns raised up until this point can be mitigated by employing multi-clouds or cross-clouds, which are just two of the many possible justifications for doing so. Some of the 10 major problems that [24] claims multi-cloud computing solves are already addressed above. Individual clients, business customers, and CSPs all have their own unique problems, but it's vital to remember that many of these difficulties are experienced by everyone in the industry. Multi-cloud computing solves the following problems:

1. Use of external, as-needed services and resources for handling demand spikes
2. Prepare for emergencies and periods of idleness by creating backups.
3. Using a variety of service providers because of the unique qualities they offer
4. Improve your own Cloud service/resources offered based on existing partnerships.
5. Optimizing expenditures or enhancing output
6. Adapting to new service offerings as they become available from providers
7. Responding to restraints like new regulations or geographical requirements
8. Constantly providing access to useful tools and services
9. Keeping from having to rely on just one provider

Cross-cloud computing solves the problems of interoperability and vendor lock-in by allowing users to switch between multiple CSPs without committing to any one of them for the foreseeable future. Since cross-cloud platforms rely on inter-cloud communication, they may inspire novel approaches to operability, such as increased system standardization or novel approaches to cloud data sharing. This issue could be mitigated and organizational agility increased by the development of technologies that enable the migration of services to other CSPs [13].

It's important to emphasize, before continuing, that the literature on cloud computing models suffers from a serious lack of clarity. Standardization is problematic, as was previously indicated. More specifically, it concerns the conceptualizations of multi-cloud computing. Multiple clouds in one environment, cloud consolidation, and cloud federation are all examples of cross-cloud computing, according to certain authors (such as [13]). However, [24] distinguishes between multi-clouds and federated cloud frameworks and classifies all the models under the umbrella term "multiple cloud" computing. Hybrid and federated infrastructures have recently been placed within multicloud computing by [32], following the classification of [24]. To prevent any ambiguity, this article will handle hybrid clouds, multi-clouds, and federation clouds as separate approaches.

IV. FUTURE RESEARCH NEEDS AND OPPORTUNITIES

We've seen how multi-cloud computing frameworks can help with problems like data security and avoiding vendor lock-in, which affect cloud computing as a whole, in the sections above. Still, multi-cloud computing networks can be used in a variety of other contexts. Cloud computing, Big Data, and Machine Learning are three hot topics in the research community right now. In what follows, we'll talk about some of the difficulties and ongoing initiatives in these areas.

A. Big Data

Despite the fact that data management has always been a challenge in cloud computing, the prospect of processing enormous amounts of data is one of the most pressing issues in the field at the moment. The financial services industry is the most obvious user of big data because of the requirement to store and process massive amounts of customer and transactional information across expansive cloud computing networks. With the use of digital channels, the transactional information has increased in a massive way, which collect and transmit additional data into the relevant cloud networks while also decentralizing data sources, exacerbates this issue. Since the data will likely come from a wide variety of sources, the IoT, the new interconnectivity of home electronics, smart devices, computers, vehicle monitoring equipment, and any other devices that allow for the collection and exchange of data, presents a significant challenge for data analysis. Traditional analytic approaches are insufficient because of the massive amount of data that already exists and is always being produced [29]. We need effective processing, analysis (both horizontal and vertical), and portability of this data between various cloud environments. Within a nationalized healthcare system, a centralized system, such as those used for medical records, may function successfully. But they should also be able to take into consideration tertiary services, like private practices, that may make use of different cloud infrastructures. These private companies must have some crucial qualities.

B. *Machine Learning*

While machine learning and big data have some similarities, each offers unique difficulties and opportunities when applied to the cloud. There is a wealth of information that may be processed by machine learning algorithms because to the abundance of data saved in clouds (for example, images and movies). Optimization methods for financial services, such as those based on virtual machines, are now being tested and examined, and have shown promise; nevertheless, further testing is required with different diseases to verify consistency [1]. Hybrid cloud storage and machine learning have been investigated in [16] for application in the oil and gas industry, where technical documents containing significant information from disciplines like geology and engineering are stored in a generally unstructured state. To improve data extraction and utilization, the authors propose a machine-learning-enabled platform, consisting of a carefully selected sequence of algorithms, developed as a hybrid cloud container that automatically reads and understands the technical documents with little human supervision. User-generated raw data can be uploaded and kept in a secure local database. The results are in the form of structured data, which is then forwarded to a cloud-based search engine. It facilitates easy identification of the most significant sections of technical documents, automated extraction of relevant data from the documents, meaningful presentation of the data for further study, and easy sharing and portability to other platforms.

Large-scale use of auto-tuners, particularly for the SaaS layer of the Cloud, is a key avenue for future research in machine learning and multi-cloud computing. Moreover, [10] looks forward to the arrival of new automated technologies that will allow cloud users to learn from the experiences of others by utilizing partially automated application builders, automated database sharers, query optimizers, or smart load balancers and service replicators. What this means is that as more data is collected from actual users, the cloud, applications, and interfaces will be refined to be more user-friendly. Novel machine learning approaches may be employed for enhanced security measures in cloud networks, as security has long been a primary concern. Future research could apply to determining what form or foundation these might take.

V. CONCLUSION

The remote computing and storage capabilities offered by the cloud are only two of the many ways in which this rapidly expanding technology is being put to use. Hybrid clouds, multi-clouds, and federation clouds offer users redundancy in the event of maintenance, breaches, or shut-downs, mitigating some of the risks associated with vendor lock-in and cyber security, but each has its own advantages and cons. Multi-clouds and federated clouds are better suitable for enterprises that need numerous activities or services, while hybrid systems can be quickly customized to a certain application but are less transferrable and generally utilized for only one activity. To address the present challenges of cloud computing, such as enhancing security, or to develop novel techniques of analysis, future work should embrace multi-cloud paradigms and mix them with other technologies like machine learning and big data.

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