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Cloud Computing Concept, Classifications, Applications and Challenges

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Abstract : Recently, cloud computing has appeared as a modern technology used to host and deliver services over the Internet. Business owners see the cloud as an interesting technology because it abrogates the demand for customers to plan ahead for provisioning. In addition, the cloud simplifies infrastructure planning for new companies starting as small businesses and enables extra resources to be added only if there are many requests for services. Cloud computing can be represented as a technological revolution in the world of the IT industry; however, cloud evolution is presently in its infancy, accompanied by many challenges that should be addressed. In this paper, an inclusive study of cloud computing is presented, highlighting its main concept including its definition and classifications, architecture, famous applications, serious challenges and popularly used simulators. The goal of this study is to offer better comprehension of the cloud computing design issues and to identify significant research trends in this increasingly significant area.

Keywords : Cloud Computing, Cloud Security, Energy Consumption, Load Balancing, Virtualization.

1. INTRODUCTION

Currently, cloud computing system is deemed as one of the hottest topics in the IT field and the fastest-growing computing environment buzzword [1]. It represents an attractive method used to architect and remotely manage computing resources [2]. Cloud computing has many advantages such as reducing hardware requirements, decreasing maintenance cost, high flexibility, effortless worldwide accessibility, automated processes and nearly no software upgrading [3]. These advantages encourage companies and large organization to utilize cloud computing technologies in their businesses; in a competitive business environment, corporations are always seeking for innovative mechanisms to decrease expenses while maximizing quality [4]. To comprehend the cloud significance in the industry and its effect on the future of technologies and information systems, it is significant to address its concept, classifications, advantages, and—conversely—challenges associated, especially regarding security issues [5]. A comprehensive overview of cloud computing is presented in this paper, concentrating on cloud concept, characteristics, components, classifications, architectures, applications, challenges and well-known simulators. Our goal is to help the researchers obtain a deeper view of the cloud design challenges and note the significant cloud research trends.The remainder of this paper is arranged as follows. In Section II, we provide a survey of the cloud concept including its definition, characteristics and components. In Section III, we describe the deployment and service classifications and the architectural design of cloud computing. Applications of cloud are detailed in Section IV. Section V surveys the open issues and challenges faced by cloud computing. In Section VI, well-known cloud simulators are reviewed. Finally, the paper concludes in Section VII.

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2. CLOUD COMPUTING CONCEPT

As technology moves to a new age of investigations, the cloud is considered as one of the most interesting areas of research. The readership interest is obviously still high, although many researchers have previously published special challenges on this topic [6]. However, the number of people who actually realize the real concept of cloud computing in its formal sense is not obvious. Different customers have different thoughts about the cloud, some of which may be true and some of which may be misguided [7]. Generally, the formal concept will be demonstrated in this paper. Characteristics such as the computing infrastructure, deployment environments, software evolution, and charge-per-use or pay-per-use are allowed by cloud computing. Optimized and efficient computing is provided by cloud computing by promoting agility, collaboration, availability, and scalability features [8]. The number of cloud computing clients is noticeably growing. Nonetheless, numerous users do not even realize that they are cloud participants. Thus, understanding the technology that underlies cloud computing is a very serious issue that should be clearly understood. As a result, that understanding will assist people in utilizing a larger set of cloud services and upgrade their personal and work lives, finding the balance between them [9].

2. 1. Cloud Computing Definition

The Many definitions have been proposed by many researchers to elaborate the meaning of cloud technology depending on the nature of the system on which they work [10]. The different existing definitions motivate researchers to group and study these definitions [10], [11], [12], [13], [14]. In addition to their efforts, a comprehensive view of cloud definitions will be elaborated in this section. One early cloud definition was proposed by L. Wang, G. Laszewski [15]. They defined the cloud as a group of scalable network enabled services with guaranteed Quality of Service (QoS) and usually personalized a low-cost computing platforms accessed on demand in a pervasive and simple way [15].I. Foster, Y. Zhao, I. Raicuand S. Luon presented cloud technology as a large-scale distributed computing environment affected by economies of scale using the Internet to deliver a group of abstracted, dynamically scalable, virtualized platforms; directed on demand computing power; services; and storage to numerous customers [16]. According to Janakiram [10] cloud computing is an Internet-based computing network analogous to the electric grid, depending on shared software, information and resources to provide on-demand access to computers and other devices. A common collection of resources can be admitted on request based on the capacity of the technology. Thus, it can be considered as a striking improvement in the delivery of better service under pressure, which is highly attractive for cash-strapped IT departments. Furthermore, G.A Patil and S.B Patil described the cloud as a web-based application that provides computation, devices, platform, infrastructure, software and other resources to customers on a pay-per-use rule. Cloud services can be utilized by the consumers without installation, and their personal files can be accessed from any computer with Internet access. Thus, it offers more effective computing by organizing data processing and storage [17]. Finally, regardless of the real cloud computing definition, it is obviously noted that the cloud concept is still developing with the development of technology.

2. 2. Analogous Systems

Some features of cloud computing are related with other models [18] [19].

- **Autonomic Computing :** Autonomic computing is a computer system that has the ability to manage itself.
- **Client–Server :** This model indicates to any distributed application distinguishing service providers from requesters.
- **Grid Computing :** This computing is a model of distributed and parallel computing consisting of a network of loosely coupled computer clusters working in harmony to implement complicated tasks.
- **Mainframe Computer :** A mainframe computer is a powerful computer utilized by large institutions for massive data processing such as secret intelligence and police services, industry and consumer statics, processing of financial transaction, planning of enterprise resources, and census.

- **Peer-to-peer :** Peer-to-peer is a distributed model that does not require central coordination. The participants of this model can be both, the resource suppliers and consumers.
- **Utility Computing :** Utility computing is used to package computing resources as a metered service including storage and computation resources comparable to a conventional public utility (e.g., electricity).

2.3. Cloud Computing Characteristics

Not only is cloud computing service considered to be the most inexpensive solution, but it also is a much greener means for building and deploying information technology services owing to efficiency and economies of scale. The following aspects are what distinguish cloud computing from other computing models [20] [21] [22] [23]:

- **On-Demand Service :** Resources and services are presented to the customers on demand by cloud computing. Cloud computing environments can later be customized and personalized by users because administrative privileges are usually owned by them.
- **Quality of Services Guaranteed :** Cloud computing provides computing environments that can ensure QoS for customers such as hardware performance consisting of memory size, I/O bandwidth and CPU speed. Generally, QoS is rendered with users by cloud computing by handling a Service Level Agreement (SLA).
- **Autonomous Environment :** Cloud technology can be seen as an autonomous environment that is transparently directed to customers. Software, hardware, and data located in clouds can be automatically consolidated, reconfigured, and/or chest rated; however, a single platform image can be presented and rendered to users.
- **Scalability :** Driving the emergence of cloud computing requires flexible and scalable features, which consider the most substantial characteristics. Computing and services platforms presented by cloud environment can be scaled across different issues such as software configuration, hardware performance, and geographical locations. There are diversified demands of a potentially huge number of customers to which the computing platforms must adapt. Therefore, it should be flexible.
- **Broad Network Access :** Some abilities are owned by the cloud over the network. Cloud utilizes standard mechanisms to access it.
- **Resource Pooling :** Utilizing a multi-tenant environment, providers pool computing resources to serve many users with different dynamically allocated physical and virtual resources, relying on their requests.
- **Rapid Elasticity :** Users can access services easily, elastically and speedily.
- **Measured Service :** Resource utilization can be checked and optimized automatically by cloud computing using a capability service meter such as processing, active user account, bandwidth, and storage.
- **Multi-Tenancy :** Cloud resources—whether virtual or physical—are located such that various tenants including their computations and data are isolated from each other.

2. 4. Cloud Computing Components

Cloud clients, datacenters, and distributed servers are the main components of cloud environment [24].

- **Cloud Clients :** Cloud clients communicate with the cloud to direct information associated with the cloud. Mobile, thick and thin clients are the three cloud clients' categories. The first category is a mobile smart phone such as a Blackberry or iPhone. The second category does not have internal memory and is used only to show information. It does not perform computation work. Computation work is performing by servers. Cherrypal and Zonbu are examples of thin clients. The last category utilizes Web browsers such as Mozilla, Apple Safari, Firefox, and Internet Explorer to connect to various clouds.
- **Datacenter :** Datacenters are groups of servers hosting different applications. The datacenter can offer various applications that can be subscribed by customers.

- **Distributed Servers :** Distributed servers are responsible for actively checking their hosts' services. These servers are part of the cloud, offering different hosting applications throughout the Internet.

3. CLOUD COMPUTING CLASSIFICATION

Cloud computing deployment or cloud computing service models are typically the basis used for classification. Fig. 1 demonstrates cloud paradigms based on NIST definition [25].Private, public, community, and hybrid clouds are the classification of cloud deployment paradigms.

- Whenever an organization owns or rents a cloud, the cloud is called a private cloud, in which all resources of the cloud are dedicated to that organization for its private utilization—*e.g.*, when a venture builds a cloud to run their important business applications.
- If a service provider owns a cloud and sells the resources of this cloud to the public, this cloud will be called a public cloud. In this cloud, some of the resources can be rented by end users, and their resource consumption can be typically scaled up or down to their demands—*e.g.*, Microsoft, Amazon, Salesforce, Rackspace, and Google.
- A community cloud looks comparable to a private environment, but the difference is related to the cloud resources; only closed community members that have the same interest can share these resources—e.g., the media cloud presented for the media industry by Siemens IT services and solutions [26]. As in the Siemens case, it is possible for this type of cloud to be run by a third party or, as in the grid computing environment, be operated and controlled in a collaborative manner. Finally, if two or more cloud deployment models are merged, a hybrid cloud will be the outcome. The major function of this cloud is to offer extra resources when there is a high demand. A good example of a hybrid cloud is shown when some of computation tasks are given the ability to migrate from a private environment to public.

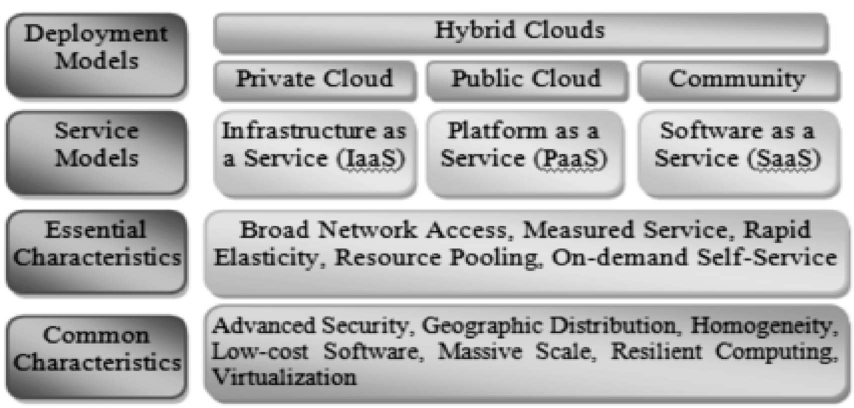

Fig. 1. Cloud framework based on NIST definition [8] .

Another classification can be given is cloud service models, which classify cloud system as Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) [27].

- Using applications that provide services to end users operating on a cloud infrastructure is called cloud SaaS. Moreover, business applications can be delivered by SaaS such as Enterprise Resource Planning (ERP), accounting, and Customer Relationship Management (CRM); however, the underlying infrastructure cannot be controlled by the customers. Salesforce CRM [28] and Google Apps [29] are two models of cloud SaaS.
- The use of tools and resources that provide services to end users operating on a cloud infrastructure is called cloud PaaS. End users can develop and/or acquire the applications on top of the tools offered. As in SaaS, the customers in PaaS do not have the ability to control the operating systems or internal infrastructure; however, he/she has an added ability over SaaS customers with regard to controlling the deployment of individual applications. Microsoft Windows Azure [30] and Google App Engine [31] are cloud PaaS examples.

- The use of resources of fundamental computing such as storage, networks and servers to present services to customers is called cloud IaaS. Arbitrary software can be deployed and run by the end users involving applications and operating systems. In this classification, the underlying infrastructure still cannot be controlled by the customer, but virtual machines with selected operating systems can be typically launched, which are administered by the customer. Amazon EC2 is an example of IaaS [32]. Table (I) epitomizes the essence of cloud categories and mentions several master players in the domain [20].

Table 1. Cloud Computing Services Classification.

Category	Characteristics	Product Type	Vendors & Products
SaaS	Customers are provided with applications that are accessible anytime and anywhere.	Web applications and services (Web 2.0).	SalesForce.com (CRM) GoogledocumentsClarizen.com (Project Management) Google mail (automation)
PaaS	Customers are provided with a platform for developing applications hosted in the Cloud.	Programming APIs and frameworks; Deployment system.	Google AppEngine Microsoft Azure Manjrasoft Aneka.
Iaas/Haas	Customers are provided with virtualized hardware and storage on top of which they can build their infrastructure.	Virtual machines management infrastructure, Storage management.	Amazon EC2 and S3; GoGrid; Nirvanix.

Not only is cloud computing presently being utilized by large companies such as Amazon, Google, Facebook, and Yahoo because it offers many advantages, but cloud is also useful for startups because it conserves startups inceptive investment cost—*e.g.*, Dropbox [33]. As a conclusion, reduced investment and operation expenses and increased business efficiency are the advantages that motivate many companies to move their applications to the cloud [34].

3.1. Cloud Computing Architecture

Fig. 2. Cloud computing architecture [35] .

Fig. 2 describes the cloud platform in its general architecture, which is called a cloud stack [35]. Cloud services can be presented in different shapes from the lower layer to the higher one, building upon hardware facilities (commonly supported by neoteric datacenters). In addition, one service paradigm is represented in the cloud stack by each layer. In the first layer from the bottom where IaaS is presented, resources can be physically assembled and managed such as Emulab or virtually such as Amazon EC2. Services can be presented in forms of network such as Openflow, storage such as GoogleFS, or computational capability such as HadoopMapReduce. Moving to the second layer where PaaS is provided, services are presented as an environment for software execution such as Google App Engine or programming such as Django. In the top level where SaaS is presented, client flexibility can be further confined by a cloud provider by simply providing software applications as a service. Finally, to have the ability to manage large cloud systems, a set of management tools and facilities is maintained by the cloud provider, apart from the service provisioning such as dynamic configuration, billing, metering, and service instance life-cycle management [36].

4. CLOUD APPLICATIONS

The ability of cloud computing to host applications in which cloud services are granted to customers speedily at lower cost has given the cloud huge publicity in the industry environment. The cloud can be used for different ranges of application domains such as science, engineering, education, and social networking [18].

4.1. Scientific Applications

One of the most popular applications of cloud system is in the scientific field. Compared with in-house deployment, smart environment such as cloud has the advantage of prospectively indefinite availability of computing storage and resources at reasonable fees [21]. In the scientific domain, cloud computing can meet the demands of various applications kinds including high performance computing (HPC), data-intensive applications, and high throughput computing (HTC) applications. All that is required for existing applications to take advantage of cloud resources are small modifications, which even further increases the attractiveness of utilizing cloud resources [22]. In addition to PaaS, IaaS could be considered as the most relevant choice offering the best environment to run a group of tasks, applications and workflows. PaaS and IaaS solutions give scientists the ability to develop new programming models to tackle computationally challenging issues. Based on cloud programming application paradigms and platforms, scientific applications have been redesigned and performed to take advantage of the cloud's distinctive abilities [23]. Aneka is an example of platforms that supports MapReduce, besides other models of programming which can be used to solve issues demanded a higher flexibility stage in terms of constructing its computation paradigm [37].

4.2. Education Applications

Cloud computing in the education field fulfills the desired characteristics of e-learning services, particularly if they are computationally intensive such as video streaming, simulators, and virtual worlds or proposed at a high level such as massive open online courses (MOOCs). Students and teachers can be provided with tools by cloud computing to deploy on-demand computing resources for lectures and laboratories depending on their education demands [38]. For example, VMs can be created on demand by teachers using preinstalled software to deploy computing laboratories speedily [39]. Furthermore, the cloud has been used and is still used in some educational institutions to outsource email services, provide students with assistive tools, store data and host institutional virtual learning environments (VLEs) [40]. In addition, new learning scenarios can be produced by cloud computing in which ubiquity, developed online tools and collaboration to originate innovative education opportunities. However, there are some critical issues must be addressed to apply cloud environment in education: privacy and security, reliability and performance, vendor lock-in, licensing and price models, and interoperability issues [38].

4.3. Healthcare Applications

One of the fields that has attempted to derive ultimate benefits from cloud technology is healthcare. Several and varied applications in healthcare have been discovered [40]. In addition to providing support to the business functions and helping health experts improve disease treatments, assisting doctors in finding more efficient diagnostic procedures is considered one of the most significant cloud applications [41]. Cloud technology could be considered as an interesting choice to improve monitoring of health systems owing to the rapid evolution of Internet connectivity and accessibility using different devices types at any time. One of the most convenient and significant example of cloud use in healthcare is ECG data analysis and monitoring. ECG is the technology used to test the contraction activity of the heart muscle. A particular waveform produced by this activity repeated over time represents the heartbeat [42]. Arrhythmias could be identified by analyzing ECG waveform shapes, which is considered to be the most popular method to detect heart disease. A patient's heartbeat data can be monitored remotely by cloud technology, allowing the data to be analyzed quickly, and the first aid personnel and doctor scan be notified as necessary. These data should be able to detect possible at-risk situations. As a result, a patient in danger would not need to go to hospital for ECG analysis but rather could be permanently monitored using cloud technology [43].

4.4. Biology

High computational abilities are frequently in demand in the field of biology for working on large datasets and producing extensive I/O processes. Therefore, supercomputing and cluster computing infrastructures are extensively used in biology applications. Comparable abilities can be available on request, provided cloud technologies in a more dynamic manner and offering extra opportunities for bioinformatics applications [44]. Two examples of biology applications will be explained in this section.

- **Prediction of Protein Structure :** The prediction of protein structure is a computationally complicated process that is essential in various science research fields such as disease treatment by designing new drugs. It is impossible to directly predict a protein geometric structure from its sequence of genes. It can be predicted by sophisticated computations used to identify the structure with minimal demanded energy. This process requires space investigation with an enormous state number, hence generating a huge computations amount for each state [45]. The computational power required to predict a protein structure can currently be gained on demand using cloud technology. Therefore, a company is not required to own a cluster or navigate the bureaucracy to gain access to the facilities of distributed and parallel environments [46].
- **Gene Expression Profiling for Cancer Diagnosis :** The simultaneous expression stages measurement of thousands of genes is called gene expression profiling. Understanding the biological processes caused by medicinal treatment at a cellular stage is the goal of gene expression profiling. Combination of protein structure prediction and gene expression profiling is an essential activity in designing drugs because it assists scientists in detecting the impacts of a particular treatment. Gene expression profiling is also used to diagnose cancer and its treatment [47].

Gene expression profiling is usually suggested with learning classifiers. Learning classifiers produce a condition-action rules population used to direct the classification procedure. For example, in the computer science and bioinformatics fields, the extended classifier system (XCS) has been effectively used to classify large datasets. Moreover, XCS is enhanced by co-evolutionary XCS (CoXCS) for increased efficiency in large datasets. Cloud CoXCS supports Aneka platform to work with the classifying issues in parallel and organize classification results [48].

4.5. Geoscience Applications

Applications of geosciences require gathering, generating, and resolving tremendous amount of geospatial and non-geospatial data. Because technology is progressing and our planet is becoming more instrumented with the spreading of satellites and sensors for observation, the size of data to be analyzed is growing remarkably. Particularly, the main element of geosciences applications is geographic information systems (GIS) [49]. All geographically referenced data types are captured, stored, managed, analyzed, manipulated, and presented by GIS. Geographically referenced data are recently becoming more relevant in different domains of application such as sophisticated farming, civil security and management of natural resources. Thus, significant geo-referenced data amount are uploaded into computer systems for additional analysis and processing tasks. Cloud technology is an interesting choice to execute these tasks and extract significant information to assist experts in making their decisions [50].

4.6. Business and Consumer Applications

One of the domains that derives great advantages from cloud technologies is the business and consumer domain. The capability to convert costs from capital to operational makes clouds a fascinating preference for all IT-centric companies. In addition, the ability cloud offers to access data and services makes it an attractive choice for customers also. Given all of these attractive characteristics, cloud computing has been a favorite technology in vast applications such CRM, ERP, productive applications, and social networks [18].

- **CRM and ERP :** CRM and ERP applications are market segments thriving in cloud environment. ERP are less mature than CRM applications. Small projects and startups find good opportunity in cloud CRM applications. They can utilize fully functional CRM software by paying subscriptions with no considerable up-front payment. Moreover, ERP applications have the potential to contend with well-established in-house applications but are currently less mature. Several enterprise aspects are integrated into ERP applications such as human resources, project management, manufacturing, finance and accounting, and CRM. The target of these applications is to provide regular viewing and access of processes that must be implemented to run large, complicated companies [51]. Salesforce.com may be considered as the most commonly used existing enhanced CRM applications. It is based on the Forc.com cloud platform. Salesforce.com offers customizable CRM promoted by third parties, combined with further features. The cloud platform constitutes a scalable high-performance middleware that implements whole Salesforce.com processes [52]. Another popular CRM application is Microsoft Dynamics CRM. It is an application that can be installed onsite in an organization or served online by monthly payment subscription for each client [53].
- **Productivity and Social Networks :** In the cloud, productivity applications represent some of the most popular tasks used by customers on their desktops such as storing document, automating office and hosting in the cloud full desktop environments. The most significant cloud feature is its availability at anyplace, anytime using any device connected to the Internet. Thus, storing a document represents a normal cloud technology application [18]. Dropbox is considered as the most common application for storing documents online, allowing customers to easily synchronize any file using any device through any platform. Customers are provided by Dropbox with a limited space of free storage, which is accessible by folder abstraction [54]. In addition to Dropbox, iCloud is another attractive cloud based document application. iCloud is released by Apple company for synchronization iOS-based devices via a fully clear method [55]. Other examples of online document storage are Amazon Cloud Drive, Windows Live and CloudMe[56]. The final application regarding productivity is Google Docs. This application is designed to be a SaaS application intended to deliver basic office automation and provide over the Web a cooperative editing. Google Docs is built on top of Google distributed computing infrastructure, allowing the platform to be scaled dynamically depending on the number of customers utilizing the service. Text documents, spreadsheets, forms, drawings and presentations can be created and edited by customers using Google Docs. The aim of Google Docs is replacing computer office applications like Microsoft Office and Open Office by providing a comparable interface and functionality as a cloud service [57]. Recently, applications such as social networking have significantly developed into the most effective websites on the Internet. Facebook and Twitter are popular examples of social networking that utilize cloud computing to handle their traffic and serve millions of customers seamlessly. One of the most interesting characteristics of social networks is their potential to constantly add capacity while systems are running, which continuously enhances their customer base [58].

The final application type mentioned in this section that has received a huge benefit from cloud computing is media applications. Encoding, transcoding, composition, and rendering are video processing operations that are considered as perfect cloud-based environment candidates. These operations are computationally complicated functions offloaded readily to cloud infrastructures. One of the common examples of cloud media applications is Animoto [59].

5. CLOUD COMPUTING CHALLENGES

The approval rating of emerging technologies such as cloud computing has been improved remarkably. Furthermore, many services relating to Paas, IaaS and SaaS are currently offered by numerous cloud computing and storage providers. In spite of all notable benefits gained from cloud computing, the cloud as a new technology has many critical concerns that require attention and new solutions to address them [60]. In general, eight main categories of challenges within cloud computing have been categorized: resource allocation, load balancing, scalability and availability, migration, interoperability, security, energy consumption and traffic analysis [61]. The efficiency and reliability of cloud computing are influenced by each of these challenges [62].

5.1. Resource Allocation

Resource allocation is a significant datacenter principle in cloud computing owing to the huge volume of various used resources in cloud datacenters [63]. Therefore, the management and allocation of resources in cloud computing should achieve network QoS demands, enhance performance without significantly increasing the cost of the service provider, and manage energy consumption [64]. Datacenter processing resources, network resources, storage resources and energy efficiency are the major resource categories included in cloud resource allocation [65].

- **Datacenter Processing Resources :** Datacenter processing resources comprise the combination of physical machines (PMs), each of which includes single or multiple processors, local I/O, network interface, and a memory, together representing the computational cloud environment capacity [64]. Usually, PMs are loaded with virtualization software, which gives them the ability to host several isolated virtual machines (VMs). Each VM runs a different operating system, platform and applications. Some investigators model PMs and VMs as being restricted by their memory availability and processing capacity [64]. VMs share processors, caches, and further micro-architectural resources between them. Current work [66][67] concentrates on the effects of competition among VMs resulting from sharing features, proposing that the resource allocation process may take advantage of more detailed processing resource models.
- **Network Resources :** For resource allocation purposes, processing resources are packaged on PMs into racks within a datacenter and arranged as clusters. Each one contains large number of hosts. The PMs should be connected to a network with a high-bandwidth feature, built on InfiniBand (IB) or Gigabit Ethernet (GbE) techniques. For whole cloud-hosted applications, especially applications realized via parallel computation, the overall performance is constrained by the communication overhead that the datacenter networking protocols and technologies are imposed [68]. There are two types of network resources to be discussed. The earliest is topology of the network, the design of which greatly affects fault tolerance and performance. Existing topologies of datacenter networks are hierarchical comparable to the ones applied in traditional telephony networks. Recently, various alternate topologies have been raised in different projects such as fat trees [69], hyper-cubes [70] and randomized small-world topologies [71]. Regardless of the network topology used, the target is engineering a scalable topology in which the delivered bisection bandwidth is increased linearly by increasing the network ports' number. In a datacenter network, the method used to offer expected latency and bandwidth in a confrontation of changeable traffic patterns is the second aspect of network resources, which is more closely linked to resource allocation [72]. One of the conventionally used methods is network over-provisioning. However, this could be very costly in large-scale datacenters and difficult because of the lack of detailed traffic models. Therefore, some researchers have moved towards investigating service distinction through QoS policies

which used to separate network traffic for performance segregation allowing high-level network traffic engineering. In datacenter networks, virtualization is currently the most interesting extension of the previous method [64]. The use of virtual datacenter networks can assist in deploying custom network to address schemes and networking protocols. Networking protocols have been a source of concern given the issues related to TCP behavior in the datacenter context [73]. There are two serious concerns regarding datacenter networks must be addressed: optimization of virtual network provisioning while maximizing income and selection of the most suitable virtual network with IP regarding the propagation, delay, and flow conversion constant over the cloud-based network [65].

- **Storage Resources :** Various types of persistent storage services are presented by providers of public clouds (*e.g*., Amazon). Service clouds range from virtual disks and databases to object storage. Every service has different levels of guarantees and reliability for data consistency [64]. One challenging storage service concern is accomplishing elasticity to scale the service dynamically with any increase or reduction in the number of customers, data volume, or load. In conventional database systems that are characterized by robust atomicity and data consistency, durability transactional and isolation, scaling is difficult to achieve. Luckily, many cloud-hosted Web applications afford a low consistency level such as eventual consistency such as blogs. In such systems, designers can invest in the tradeoff between consistency and performance represented by response time and availability. This investment has led to evolution of some data storage technologies such as NoSQL. NoSQL is an optimized technology for distinct functional and operational conditions. Documents, columns, triple stores, key values, and graph databases are examples of NoSQL technology [74]. One of the most attractive elastic storage technologies is distributed key-value. It allows retrieval, editing, and insertion of objects specified via keys from a flat name space, exploited by various cloud computing implementations. Usually, these implementations are operated on commodity hardware, built on structured overlays. Models of this technology are Voldemort by LinkedIn [75], Cassandra by Facebook [76], and Dynamo by Amazon [77].

Energy-Efficient Resources : Datacenters occupy a large position in influence in worldwide energy usage and costs. For a large-scale datacenter, Kaur and Chana in [78] calculated the direct energy consumption costs to be 19% of the overall operational costs. In comparison, the power distribution and cooling infrastructure were estimated to be 23% (consumed over 15 years) and 23%, respectively. In a datacenter, power can be consumed by servers, cooling equipments, power distribution and networking tools, and supporting infrastructure such as lighting and others. Usually, datacenters acquire power from different power utility providers. Recently, a new trend has been proposed to exploit storage and local power generation, particularly from renewable energy sources (e.g., wind and solar) [79]. Owing to the substantial costs incurred by powering datacenters, there is a considerable concentration on reducing energy consumption. Four major techniques are proposed to solve the power issue: Enhancing hardware energy efficiency by developing low-power components; developing management mechanisms of energy-aware resource; executing implementations in an inherently energy-efficacious style; and developing effective cooling systems by choosing better geographical locations for datacenters to take advantage of climatic conditions.

5.2. Loud Balancing

Load balancing is a serious cloud computing concern with impacts on storage utilization and system performance. The major goal of load balancing is applying an algorithm that allocates tasks to VMs efficiently regarding to present restrictions such as heterogeneity and high communication delays [80]. Generally, the load balance challenges are divided into four main issues: cloud node spatial distribution, data replication, performance, and failure point [81]. A special distribution of cloud nodes is the method used to manage the load balance process. This method may be exposed to multiple delays. The reason for these delays could be the distance between the cloud customers and the processing nodes, among service nodes or the network connectivity speed [82]. Another concern is data replication, which is the manner by which the data are replicated in different cloud nodes according to the load balancing technique's complexity through partial replication and extra demands to the additional storage in full replication. To avoid performance issues, the proposed algorithm to balance load in the system should be as possible unsophisticated to avert delays and faults in complicated tasks. Finally, the resistance ability of the load balancing algorithm in the face of unusual or unpredictable failures is called point of failure. Utilizing a controller task to reduce and manage system failures due to increasing the proposed algorithm complication used to balance loads is a serious concern in cloud environments which attracts research attention. The major load balancing objectives are given as follows [83]:

1. Avoid overloaded nodes and bottlenecks
2. Enhance overall system performance
3. Optimize resource utilization
4. Reduce response time
5. Provide a backup plan
6. Motivate green computing by reducing energy consumption and carbon emissions.

Clouds contain a massive group of resources. To manage these resources properly, an appropriate plan and analysis scenario are required when the algorithm is first implemented. Load balancing techniques can be categorized as static, dynamic, centralized, distributed and hierarchal [84] [85] [86] [87].

- **Static Load Balancing :** Static load balancing requires prior knowledge of resource information such as capacity and processing power. It is impossible to make any change in the load at runtime. Therefore, it is considered to be an easy technique to implement. Nonetheless, it is unsuitable for different cloud environments, particularly where resources and requirements cannot be fixed.
- **Dynamic Load Balancing :** Dynamic load balancing is appropriate in cases involving heterogeneous resources. It does not require prior knowledge. The system current state can define load provisioning. At runtime, users have the right to change the requirements. Dynamic load balancing is difficult to implement. However, it is more appropriate for the cloud environment.
- **Centralized Load Balancing :** In the centralized technique, the assignment of resources and cancellation of those assignments is carried out by a central node. The central node is called a coordinator. All network knowledge is stored by the coordinator, which it applies an algorithm according to the requirement.
- **Distributed Load Balancing :** This technique does not require a single central node to be in charge of load distribution. Instead, several coordinators in different domains are used to observe the network and control load balancing. In each domain, every node can maintain the local knowledge base and then transfer that knowledge to the coordinator. Hence, a global knowledge base is created to visualize the network status.
- **Hierarchical Load Balancing :** A hierarchical cloud network is partitioned into levels. Each level participates in load balancing. Generally, this technique works in master/slave mode. The status of cloud network in the hierarchical technique can be visualized in the form of a tree structure. In a tree structure, the knowledge base of all children is maintained by the parent, which then passes the knowledge to its own parent. Eventually, the load decision is made depending on the information collected by all parent nodes.

5.3. Scalability and Availability

Another important concern is the possibility of adapting the cloud capacity to provide services on-demand under of different workloads such as static, dynamic, periodic, unpredictable, and once in a lifetime workloads. Cloud performance can be degraded owing to the lack of this ability during peak workloads. Moreover, over sizing can result through the provision of on-demand service during low workloads [88]. One of the most widely used solutions to solve the workload issue in the cloud is elastic resource scaling, which is utilized to make resources provisioning more resilient compared with static scaling. Furthermore, it can reduce the process dependency on workload predictions [89].

5.4. Migration to Clouds and Compatibility

Conventional IT providers are encouraged to migrate and adapt their products such as conventional applications, OSs and middleware to a cloud environment owing to the expeditious development and increasing cloud popularity among customers and companies. However, the success of this process is difficult because of the existent restrictions in conventional IT applications. To improve the migration success rate, five major specifications should the included in a conventional IT network [90]:

- **Modularity:** The computing capability can be scaled up or down according to comparable and duplicated elements on numerous cloud nodes, virtual or physical.
- **Portability :** Components can be implemented in different IaaS infrastructures.
- **Changeability:** Used to adjust IT products with convenient modifications in a cloud environment.
- **Scalability:** Management of numerous workloads.
- **Backward Compatibility :** The possibility of components to have continuous interaction while these components are uncovered in the form of representational state transfer (REST) URLs.

Migration to cloud computing includes four major steps. First, the components are evaluated according to the scalability demands, and dependency rate on persistence-related functionality. Second, system orchestration is investigated to achieve convenient interaction demands among different virtual and physical nodes components. Third, components that cannot achieve adequate scalability demands must be specified and partitioned to smaller parts. Fourth, component adaptation and compatibility against different cloud deployment environments such as public, private, and hybrid need to be taken in consideration, and proper modifications must be made. Migration to cloud environment presents many advantages for customers and companies: improving the work satisfaction rate, offering good opportunities for organizational evolution and new skill growth, and reducing monotonous work. However, it can lead to some critical issues such as rising enterprise dependency on an extrinsic third party, departmental downsizing, insufficient cloud characteristics and structure knowledge, insufficient supporting resources, and distrust in modern technology [91]. Consequently, all possibilities should be taken in to account by organizations and service providers through the migration stage and thereafter.

5.5. Interoperability and Communication among Clouds

The deficiency of interoperability among different service providers is a serious challenge results from different approaches and structures. This may occur in various cloud-based environments levels, such as when an IaaS environment cannot be migrated to any PaaS provider effortlessly, or among providers at the same level such as when Amazon clients cannot effortlessly migrate their resources to Force.com [92]. Interoperability establishment among clouds is categorized into four major levels [93][94]:

- **Agreement :** specific data format and communication protocols are utilized by agreement level.
- **Adaptation :** it enforces the same standards on cloud providers to create their products, so competitive strength is reduced between them.
- **Deployment :** to provide services, vertical or horizontal, interoperability is established at the different or even same deployment stage.
- **Interaction :** concurrent patterns are used while the response period is crucial in real time services or via reducing the interaction among them. Each level features cons that hinder interoperability among cloud environments.

5.6. Security

The assurance of stored resource privacy and security is among the most challenging concerns because it reduces the efficiency and reliability of the cloud [95]. In industry and academic research, the security of cloud environment has been a significant topic and the major hindrance to its evolution [96]. In addition, many cloud customers have fears when depending on cloud service providers to store their sensitive data. They must define data location and people who may have control over their information and guaranteed the important information are not accessed or exploited illegally [97]. Another concern is the ability of the cloud to resist potential attacks or unpredictable events. In the cloud, data protection processes can be enhanced if significant resistance is used by service providers. Hence, the cloud reliability rate is improved. Real-time cryptography algorithms could be the most convenient option to improve cloud resistance against attacks [99]. Some security issues are discussed in this section.

- **System Complexity :** Cloud complexity is much higher than that of a conventional network owing to the extra components required for cloud systems such as VM environment and data storage. Security relies not only on the effectiveness and correctness of the components but also on the intersections between them. The complexity increases with the square of the increasing component number, which increases security issues [100].
- **Outsourcing :** Geographical boundaries of cloud data location is another important security issue because the located data are subject to the laws and regulations of physical boundaries, which may impose unwanted legal liability on the clients. Cloud providers may have subcontracts with other CSPs that lead to additional complexities [101]. Data located in the cloud are influenced by both the countries rules where the service operated and the providers' policies. When users exploit the services presented by the service providers without any information about the real location of the resources (perhaps in other legal domains), customers must present their approval to the "Terms of Service", where this approval grants the cloud providers the prerogative to detect whether users' data is under laws and law enforcement requests [102]. However, when controversy occurs, an issue may arise that is outside the cloud provider's control [103].In conclusion, it is significant to consider the issue of resource location security. This is accomplished by beginning with the cloud providers and the possibility of being trusted to provide authoritative and protected computing and data storage [104].
- **Shared Multi-Tenant Environment :** Multi-tenancy considers as one of the most beneficial features, particularly in the public cloud. Nevertheless, it can reduce cloud security and privacy. Cloud providers can efficiently manage cloud resource utilization because multi-tenancy provides partitioning of a virtualized and shared infrastructure between different users [105]. From the cloud costumer's point of view, utilizing a shared infrastructure can be considered an issue. Nevertheless, a significant difference can be made in terms of the resource sharing level and available protection techniques. For instance, Salesforce utilizes a query rewriter at the database level to isolate multiple tenants' data, whereas in Amazon, hypervisors are used for isolation at the hardware level [106]. Finally, data access policies, data protection and application deployment are all significant issues that should be investigated by cloud providers to provide a secure multi-tenant environment [107].
- **Abuse and Nefarious Utilize of Cloud Environment :** The policies and rules of the cloud have earned respect and gratefulness from their customers, but some users misuse cloud services or utilize it as an attack platform to exploit other remote systems [108]. Cloud providers offer to their customers unlimited data storage space, processing, networking and access. Customers use credit cards to create their accounts in the cloud for registration processes. This can be a problem when cloud providers offer trail time leading to possible security issues by abusive and nefarious cloud resources.
- **Insecure Interfaces and APIs :** A collection of software and APIs are provided to cloud users by the providers to help them manage and interacting with cloud services. These programs and APIs are used to perform system management, provisioning, and monitoring. However, public cloud availability and security depend on these APIs security. From access control and authentication to activity observation and encryption process, the API interfaces should be designed to be protected from incidental and malicious tries to fraud on the policy. Because cloud security relies on API security, increasing complexity in the new API layer leads to more cloud risks because organizations may require their credentials to be relinquished to third parties to use their service [109].

- **Malicious Insiders :** Service abstraction, dynamic scalability and location transparency are all cloud features that lead to applications and different data types in the cloud platform failing to have security boundaries or even a fixed infrastructure. In the case of a security violation, it is difficult to isolate a particular threatened physical resource [110]. Different malicious entities can threat customers' data in the public cloud. Different factors can help create these entities, such as the nature of information technology service and the misapplication of access and viewing privileges. This weakness in the public cloud offers a good opportunity for an attacker to attack the system.
- **Data Loss and Leakage :** Deletion, alternation records, and unauthorized access are examples of data loss in the cloud computing environment. These issues result from the cloud architecture and characteristics. Cloud is a shared environment among its customers. If barriers between customers are violated, data of one customer can be accessed by another, or their applications can interfere with each other. This gives the hackers an opportunity to modify or even delete sensitive information located in the cloud [111].
- **Authentication and Trust of Acquired Information :** Sometimes user information can be modified without their approval because their significant information is assigned in the cloud provider's infrastructure. To make critical decisions, the owners should retrieve the modified date and process it. Data authentication is very significant, and data should be guaranteed. Nonetheless, no common standards exist to guarantee data authentication [112].Agent-based authentication and multifactor processes could be considered as two main suggested solutions to solve authentication issues [98].
- **Access Control and System Monitoring :** Recently, cloud providers have been asked by their clients to provide additional log data and observation for the clients' personnel because most significant business implementations have been moved to the cloud. Regarding results monitoring which can involve sensitive infrastructure information conventionally used internally via cloud providers, many of them are not prepared for sharing portions of their clients' data with third-party examiners or even other clients. Generally in any service convention, the exchange of appropriate observation and log data requires much negotiation between the cloud providers and the clients [113].
- **Cloud Standards :** Not only interoperability among clouds but also increased stabilization and security are significant demands in terms of cloud standards. Thus, developing organizations require various standards. For example, services such as storage provided by a specific provider may be inconsistent with the ones provided by others. Customers could see themselves in a complex position created by service providers who use the sticky services standard when they need to migrate their data from one service provider to other. For example, Amazon's S3 is conflicted with Google storage or IBM's Blue cloud [27]. As a result, if there is a real intention from cloud providers to improve interoperability and data migration between clouds, 'Intercloud' standards are proposed: data format, resource supplying, metering and billing, network architecture, security, service quality, and identity management and privacy.
- **Virtualization Issues :** One of the cloud's strategic components is virtualization, which allows different customers to utilize the same physical resources. Each user can have his own specified VM, which virtually provides him with a full operating machine. In a multi-tenant environment, sundry VMs can be migrated to the same physical resources, creating resource pooling [23].

The module that manages VMs and allows different operating systems to simultaneously work on the same physical system is called the VM monitor (VMM) or hypervisor [114]. However, security issues related to cloud users and infrastructure can result from virtualization [115]. Below are explanations of some of these issues.

- **VM image sharing :** VM image is utilized to instantiate VMs. A VM image can be created by the user of the cloud or utilized from the shared image repository [116].Users are allowed to upload and download images from the repository in services such as Amazon's image repository [116]. In the image repository, VM image sharing is a prevalent practice. However, it can develop into a dangerous threat when it is utilized in a malicious way [117].A malicious user can not only investigate the image code to find a possible attack point but also upload a malware image [117].In the cloud environment, the VM instantiated by an infected VM image could turn into a malware source. Furthermore, it can be utilized to observe the data and activities of other customers, resulting in privacy violations. In addition, users' private information can be exposed if the image is not cleaned properly [118].

- **VM isolation :** On the same PM, VMs should work in isolation from each other. Storage devices, memory and computational hardware all require VM isolation. Logical isolation between various VMs is proposed. However, accessing the same physical resources can lead to data violation and cross-VM attacks [119].
- **VM escape :** When a VM or malicious user escapes from the VMM or hypervisor control, this is called VM escape [120]. All VMs and their access to hardware are managed by the VMM. Attackers can use VM escape to access other VMs, access computing and storage hardware or even bring down the VMM [121]. For example, an affected IaaS service model can affect other service models [121].
- **VM migration :** Transferring a VM from one uploaded or downloaded PM to another is called VM migration [122]. VM migration is carried out for reasons such as load balancing, reduced resources or power consumption, fault tolerance, and maintenance [123]. VM contents are exposed during the migration phase to pass through a network, which might lead to issues such as data privacy and integrity violations [124]. In addition, the VM code also can be vulnerable to attack in the migration phase [125].The migration phase can be exposed by an attacker to migrate the VM to a compromised server or under the compromised VMM's control. VM migration can be considered as a critical phase. Therefore, it should be handled securely. One of the most popular migration phases is live migration, which allows VMs to be migrated without disconnecting the client or application [126]. Live VM migration is utilized to balance workloads, consolidate VMs, maintain online systems, and ensure fault tolerance [126]. The industry is hesitant to adapt live migration to sensitive applications because of the disclosed vulnerabilities that create crucial security concerns [127]. Previous work focused on the advantages of using VM live migration without considering the security risks [127]. Migrating VMs without encrypting its contents, such as the present status of running applications, kernel memory, and critical data such as keys and passwords, is the most significant concern in live migration. Therefore, the migrated data are uncovered and consequently can be accessible to other systems [128] [129].
- **VM rollback :** To provide flexibility to users, virtualization gives the option of VM rollback to some previous state whenever it is needed. Nevertheless, this ability can create some security risks [130]. For instance, VM rollback can enable the security credentials that were previously disabled, expose the VM to a vulnerability that was previously patched, and finally revert the VM to previous security policies and configuration errors [131].
- **Hypervisor issues :** The VMM or hypervisor is the key model of virtualization in charge of managing and isolating VMs and managing and generating virtual resources. The VMM affects the execution of VMs running on the host system [132]. A compromised VMM can expose all VMs and the metadata managed by the victim VMM to attack if the attacker takes control of the VMM. A VMM can provide larger attack vector because of its greater number of entry points and interconnection complexities [133]. There are many reported bugs in a VMM, allowing attackers to take control of it or bypass security restrictions. For instance, vulnerabilities in Xen, Microsoft virtual PC and virtual server can be abused by attackers to gain privileged rights [133].
- **VM Sprawl :** When the number of VMs in a physical system are increasing continuously and most of the already instantiated VMs are in an idle state, this process is called VM sprawl. Resources of physical machines can be wasted on a large scale by VM sprawl [134].

5.7. Energy Consumption

One of the most challenging issues in cloud environment is the improvement of energy efficiency in datacenters [60]. Recently, datacenter energy efficiency has earned key significance owing to its high economic, environmental, and performance effects [135]. Some recent research claimed that the cooling and powering cost accounts for 53% of the total operational expenditure of datacenters. Datacenter energy usage increased by 56% worldwide from 2005 to 2010 [136]. Worldwide, datacenter energy consumption accounted for 1.1–1.5% of total energy consumption in 2010 [137]. Recently, to meet user and business requirements, Microsoft is appending monthly 20,000 servers to their server farms. These servers consume much energy and produce a huge amount of carbon emission [138]. In an average server environment, only 30% of the servers operate in the idle state [3]. The utilization rate is very low, which is approximately 5-10% [3][136]. Hence, service providers are under enormous pressure to minimize energy consumption. The target is to meet environmental standards and government regulations while reducing the energy cost of cloud datacenters [135]. Therefore, the design of energy-efficient datacenters has received significant attention of late. Different directions can be used to approach the energy issue. For instance, the use of energy-efficient hardware architecture to reduce CPU speed and turn partial hardware components off has become familiar [139]. In addition, turning off unused PMs via energy-aware job scheduling [140] and server consolidation [141] are two other methods used to reduce consumed power. Current work has also started to search for energy-efficient network protocols and infrastructures such as MBFD [142], EARH [143] and Tabu [144]. A good tradeoff between energy saving and application performance is a challenging key in all above methods. Therefore, some investigations have lately begun to examine coordinated proposals for performance and power management in a dynamic cloud computing system [60].

5.8. Traffic Management Analysis

For today's datacenters, it is significant to analyze data traffic efficiency and performance. For instance, numerous Web applications can optimize customer experiences via data traffic analysis. In addition, monitoring and analyzing data traffic through the network assists network operators in their management and planning decisions [60]. Nonetheless, the extension to datacenters of existing methods for measuring and analyzing data traffic in Internet service provider (ISP) networks and enterprise comes with many challenges. For example, the worst scenario for the methods in use is the link density of datacenters, which is much higher than that in ISPs or enterprise networks [145]. Moreover, a few hundred end hosts is the average range that most existing techniques can handle to measure their traffic matrices, whereas even a modular datacenter can have thousands of servers. Furthermore, existing analysis techniques in Internet and enterprise networks typically presume some logical flow patterns. However, applications such as MapReduce jobs distributed in datacenters significantly modify the traffic pattern. Finally, it can be noted that there is tighter coupling in application utilization of computing, network, and storage resources than in other settings [146] [147].

6. CLOUD COMPUTING SIMULATIONS

In a cloud system, specified cloud simulators are needed to test the system, reduce complications and split up quality issues. System performance analysts can use simulators to test the behavior of the cloud system by concentrating on quality issues of a particular component in different scenarios. In this section, popularly utilized cloud simulators used to evaluate cloud computing system performance are explained briefly [18] [22].

- **Cloud Sim:** One of the most commonly used cloud simulators is CloudSim. It offers simulation, seamless modeling, besides testing of a cloud environments and their application services, which solves the issue of previously used simulators dedicated to distributed environments inapplicable to the cloud. Users can test particular cloud issues using CloudSim without worrying about the low-level specifics related to cloud-based services and infrastructures [148].
- **Cloud Analyst :** CloudAnalyst is a simulation derived from CloudSim. CloudAnalystis used to test large-scale Internet application behavior in the cloud. In addition, simulation experimentation exercises can be separated from programming exercises by using Cloud Analyst. Furthermore, it gives the modeler an ability to execute simulations iteratively and organize a concatenation of experiments with minimal parameter modification in a speedy and simple way [149].

- **Green Cloud :** To test green cloud computing, the GreenCloud simulator is created, which is an advancement of CloudSim. The motivation to use GreenCloud to test system performance is the insufficiency of detailed simulators and the lack of provisioning systems to test cloud energy efficiency. GreenCloud is a developed packet-level simulator with concentricity on cloud communication. An elaborated fine-grained modeling of the consumed IT datacenter equipment energy such as communication links, network switches, and computing servers can be provided by this simulator. It is considered as a network simulator (NS2) extension [150].
- **EMUSIM :** On cloud platforms, EMUSIM is an integrated architecture suggested to predict the attitude of the cloud services at a higher standard based on CloudSim for simulation and automated emulation framework (AEF) for emulation [151].
- **Network Cloud Sim :** Another CloudSim extension is NetworkCloudSim. Workflow, e-commerce, and high-performance computing are all generalized applications supported by NetworkCloudSimin addition to real cloud datacenter modeling [152].
- **SPECI :** The size of datacenters used to provide services in cloud environment is growing, besides some middleware characteristics administer these datacenters will not linearly scale with the components number. Simulation Program for Elastic Cloud Infrastructures (SPECI) is a simulator program that enables large data centers' behavior to be tested with the middleware size and design policy as inputs. Two packages compose SPECI—datacenter topology and layout and the experiment implementation and measuring components.
- **Ground Sim:** This application is an event-based simulation tool which requires only a single simulation thread for scientific applications in cloud and grid computing systems. GroundSim focuses most on IaaS. However, it can easily extend to applications in other environments such as cloud storage and PaaS. Further investigation was accomplished to enable users to simulate various experimental systems as a similar environment utilized for real applications via integrating GroudSim simulator into ASKALON programming environment [153].
- **DC Sim :** One of the simulators that is specified for virtualized datacenters is Datacenter Simulator (DCSim). DCSim offers IaaS to multiple tenants to assess and improve datacenter management mechanisms [154].

7. CONCLUSION

Recently, cloud computing has been the most attractive model used to manage and deliver different services over the Internet. The domain of information technology has been developed rapidly by the increasing development of cloud computing, in which utility computing is no longer a fantasy but has become a reality. In spite of the considerable advantages of cloud computing, the existing technologies are not sufficiently mature to realize its full potential. Moreover, many serious cloud issues, including resource allocation, load balancing, security, and power consumption, have been only recently considered by the research community. As a result, we are certain that the researchers still have a massive opportunity to propose and work on innovative contributions to the cloud domain, which can significantly affect the development of the industry. In this paper, a fully overviewed of the state-of-the-art of cloud computing are presented, including its essential concept, architectural designs, distinguishing characteristics, common applications, challenging issues and famous simulators. Because cloud technology evolution is still at an early stage, we hope that our survey will help interested researchers achieve a better comprehension of the cloud design challenges, paving the way for further investigations in this domain.

8. ACKNOWLEDGEMENTS

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Table 1. Cloud Computing Services Classification.

Cloud Challenges	*Paper*	*Utilized Technique*	*Advantages*	*Comments*
	[65]	• Integrated energy-aware resource provisioning.	• Predict number of VM request, estimate the required PMs to serve clients and reduce energy consumption	• Improve the workload prediction module based on investigating if the VM requests follow some daily trend.
	[66]	• Prediction technique based on linear number of messages.	• Predict performance interference due to shared processor cache working on current processor architecture and requiring minimal software changes.	• Require the prerun of workloads to acquire necessary parameters of the statistical prediction model
Resource Allocation	[67]	• Heuristic feedback-based controller, Heracles	• Increased overall cost efficiency substantially through increasing utilization compared to power saving techniques alone.	• Concentrate on poor efficiency of isolation mechanism. Require to investigate flexibility, shifting from one service to other robustly at runtime.
	[68]	• Energy-aware OpenNaas, combined of priority-based shortest routing and exclusive flow scheduling.	• Increase network energy efficiency without performance degradation	• Need to improve reliability and fault tolerance at peak time.
	[69]	• Hybrid topologies, *k*-ary *n*-direct *s*-indirect.	• Provided high performance, through-put and latency figures of merit close to indirect and lower hardware cost.	• Need to improve reliability and fault tolerance at peak time
Load Balancing	[82]	• Using genetic algorithm improved by logarithmic least square matrix.	• Improve Load balancing	• Need to combine with other technique to be improved
	[84]	• Hierarchal search optimization technique	• Ensure efficient routing and reduce carbon emission	• Do not address system performance and response time
Migration to Clouds and Compatibility	[91]	• Interview approach based on the-technology-organization-environment (TOE) theory.	• Address system con-figuration (complexity & compatibility), organi-zation fit, and external support	• Require to address the reliability and validity of the explained factors.
Interoperability and Communication among Clouds	[94]	• Discuss latest work (PSIF, CoCoOn, OCCI, UCI, mOSAIC, WSDL-S, OWL-S)	• Provide a cross correlation study of the cloud interoperability & portability approach	• Need to expand the study for more approaches with more factors to address.
Security	[95] [105]	• Survey papers	• Discuss different proposed techniques to provide security for data allocated in the cloud.	• Focus on cloud storage data only. Need to expand for data in transit or data processing in the cloud. Some focus on cryptography techniques only.

Cloud Challenges	*Paper*	*Utilized Technique*	*Advantages*	*Comments*
	[106]	• Authentication, Authorization, Accounting, and Secure Transport (AAAS) protocol	• Guarantee end-to-end multi tenant session and authori-zation messages.	• Prove in theory. Need to test in real system.
	[108] [114] [121]	• Public cloud security • surveys papers	• Discuss different proposed techniques to provide security for data allocated in the cloud.	• All discuss public cloud in general. Require addressing specific cloud environment and issues in-depth.
	[116]	• VIS, VISOR open source distribution system	• Develop the system based on modularity, extensibility, & performance	• Focus on transaction performance more than security of data transferred.
	[117]	• Develop Susceptible-Protected -Infected (SPI) cloud malware propagation model.	• Overcome malware propagation issue with low budget.	• Need to control the propagation malware using some VM scheduling mechanisms.
	[118]	• Security protocol based on symmetric key's component distribution with integrity based confidentiality and self protection technique.	• Test on two attacks: man-in-the-middle-attack and malicious executing environment.	• Require to be applied on real cloud environment & improve performance, processing speed.
	[119]	• Semi-Markov model, Xen virtualization architecture.	• Specified VM isolation and analyzed identifying areas that are most effective on improving isolation security.	• Need to address the fault tolerance of memory corruption and how it can affect on improving the security.
	[120]	• Biometric encryption	• Improve Bio data confidentiality.	• They did not solve security issues nor test the system in malicious environment.
	[122] [124]	• Review papers	• Address VM migration and consolidation, security of VMs.	• Require to address system performance specially after using security mechanisms.
	[125]	• Fuzzy logic based mechanism	• Construct security profiles for VMs.	• Improved in theory only.
	[126]	• Surveys (live VM migrations).	• Addressed different techniques to secure live VM migration	• Did not address the trade-off between security & performance.
	[130]	• WarmCR(Lightweight checkpoint/rollback system for VMs)	• Decreased extra overhead on application execution time.	• Need to address phase change to reduce performance loss.
	[131] [134]	• Surveys	• Addressed threats and proposed security models to protect the hypervisor.	• Did not discuss the trade-off between performance & the proposed security models.
Energy Consumption	[135] [138]	• Surveys	• Addressed Energy consumption issue in Cloud environment	• Did not discussed the recent proposed techniques to tackle the issue

Cloud Challenges	*Paper*	*Utilized Technique*	*Advantages*	*Comments*
	[139]	• Using rate monotonic (RM) algorithm in a hard real-time environment	• Lower power consumption	• Focus only on CPU resources
	[141]	• Server Virtualization and VM Consolidation	• Reduce energy and Improve resource utilization	• Consolidation mechanism lead to various issues such as performance degradation
	[142]	• Adaptive heuristics for dynamic consolidation of VMs based on an analysis of historical data from the resource usage by VMs.	• Reduce energy consumption and high level of service level agreement	• Do not address resource utilization
	[143]	• Energy aware scheduling algorithm EARH using rolling horizon	• Reduce Energy, Improve resource utilization and Reduce VM migration	• Do not consider mobility & network configuration
	[144]	• Tabu search heuristic	• Optimize network performance, CO2 emission, capital & operational expenditure	• Focus on system performance more than energy consumption
Traffic Management	[145]	• Data center network Architecture for traffic Generation and Analysis Purpose	• Analyze utilization of network link and time taken series of the node for transmit and receive packet	• Need to take network efficiency in consider to increase the optimum utilization on network resources. Monitor scalability requirements.
	[146]	• Using Inter-Cloud communication traffic management mechanism (ICC)	• Reduce ISP transit charge	• Need additional evaluation with more and longer traces. Address cloud layer of ICC technique. Combine network load and energy cost to provide further optimization.
	[147]	• Using Hadoop based traffic monitoring System	• Analysis multi-terabytes (IP, HTTP, TCP, Net Flow). Provide scale-out feature for controlling the increasing traffic data.	• Need to address the centralized network design of Hadoop main node and tracker.

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