A Conceptual View on Cloud Computing Environments

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Abstract: *With the advancement in the IT industry, the cloud computing has arose as a new exemplar. Because the focus of the cloud computing is on providing the flexible, scalable and pay per use services over Internet. Generally the services offered by the cloud computing are provided by a third party called cloud service provider. The characteristics like reduced cost and efficient results make the cloud computing appealing for all type of companies (small/big). But regardless of all the benefits and opportunities that are offered by the cloud computing, there are still some unaddressed issues that need to be dealt with. This paper gives an overview of the cloud computing, along with the revolutions made so far in this field. The main objective of this paper is to provide the insight to the issues and challenges related to the data management in cloud environments and to classify the vital research themes related to this advancing technology.*

I.   Introduction

Cloud Computing has become ubiquitous in the past few decades. It has become a prominent part of our lives, and everybody in this world is using the cloud facilities directly or indirectly, knowingly or unknowingly. It assures the delivery of various types of resources and services through Internet [1]. Cloud provides effective architectures and resources that are suitable for large-scale computations and a variety of applications; these facilities provided by the cloud environments have attracted many small and big organizations [2].

The researchers for carrying out latest researches and experiments can use the combination of various cloud utilities. Moreover, the cloud allows the organizations to focus on their business, and keep them out of the concerns related to resources, infrastructures, data centers etc. [3]. The development of the cloud technologies have influenced the large companies including Amazon, Google, Microsoft etc. to provide platforms based on cloud with more reliability and efficiency. The Cloud offers the IT resources that can be easily accessed via Internet connection through any device. This increases the capability of the cloud in terms of facilities as well as economy. Industries that are moving their business towards the cloud environment include healthcare, education, banking etc.

II.   Cloud Computing: An Outline

Cloud computing is a term that is used to represent a network in which data center, application, network, server, software, operating system etc. exists in the shared environment, this reduces the requirement of the physical resources at the users' site. The cloud offers pay as you go facility that makes it convenient for the end users, as they are only supposed to pay for the resources that is being used. Furthermore, the services of the cloud can be used easily and quickly without concerning about their management. The cloud has been successfully applied in multiple areas including Web Development [4], Enterprise Resource Planning (ERP) [5], Decision Support System [6], Scientific Research [7] etc.

Definition Of Cloud Computing: The CEO of Google Eric Schmidt first used the term "cloud" in 2006 while describing about the services provided by business model over Internet. Ever since, this term became popular and has been used in the market for representing various unique thoughts.
The standard definition of cloud computing given by NIST (National Institute of Standards and Technology) [8] says, "Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction"

Cloud Computing Characteristics: Cloud computing offers several impressive features that makes it attractive for the users [9,10]. Some of its important characteristics are given below:
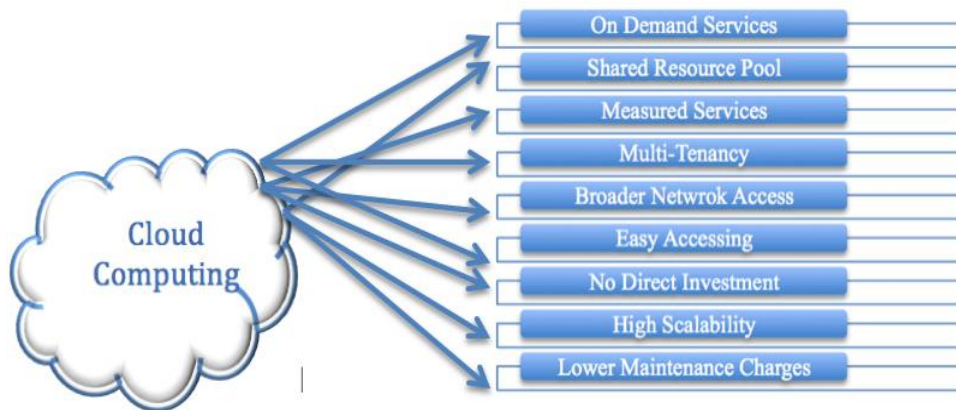

Fig. 1. Cloud Computing Characteristics

Table 1 Brief about Cloud Computing Characteristics

On Demand Services	The cloud computing offers the resources to the users only when they are required. Since the demands of the resources keeps fluctuating, it is not feasible for the companies to keep the highest amount of resources all the time, as it would be a costly affair. Therefore, the cloud offers the facility to scale up and down the resources as per the requirements [11].
Shared Resource Pool	The resources are pooled together and are allocated and de-allocated to the consumers dynamically as per their requirements [12,13]. This is beneficial to both the consumers as well as the providers, because in such environment it becomes easy for the consumers to pick up the resources they need and for providers to keep track on the usage and demand of the resources. It also helps in maintaining the operational cost by leveraging the services.
Measured Services	The services provided by the cloud providers are controlled using meters that helps the users and the providers to keep track of the resources that are being used by monitoring, controlling, and reporting the usage and hence, making the entire system transparent.
Multi-Tenancy	In the cloud computing environments the services offered by the multiple service providers are collected together in a data center and allows multiple number of users to avail these services. This type of model is called multi-tenant model, and the users using the services are called tenants. Moreover, every tenant is isolated and hidden from other tenants.
Broader Network Access	The services provided by the clouds are delivered by the providers and accessed by the users using Internet [43]. However, in order to achieve higher network bandwidth and performance, the data centers are located throughout the globe, and the consumers are unaware of the exact location of the data centers where their data is being stored or from where they are consuming the services.
Easy Accessing	The services hosted by the cloud are usually based on web technologies. These services are accessible by the users easily using devices like mobile, laptop, PC etc. through Internet.
No Direct Investment	As the cloud computing gives the facility of pay per use, the consumers do not have to spend money on buying the entire infrastructure or resources. They can simply rent them as per their needs and pay for them as per their usage.
High Scalability	The cloud infrastructure providers, pools a huge amount of resources together and make them available and accessible to the users. This makes it easier for the providers to scale up the services when there is increase in demands. This model is often referred as surge computing [1].
Low Maintenance Charges	Since the consumers are renting the resources and infrastructures from the cloud providers, they do not have to be concerned about its maintenance, because it is the responsibility of the provider. And at the providers' end there are experts and equipment that are solely dedicated for the maintenance purpose, this cuts the cost down.

Cloud Computing Models: Not all the clouds are of the same type; some of them are dedicated to single organization, while some are available for everyone. Moreover, some considers the lower cost as their priority while some offers security and reliability as their main feature. The different types of clouds and the services offered by the clouds are given in this section.

There are various types of cloud deployment models available according to various requirements. The users can choose whatever suits best for them as per their needs.

Public Cloud: These are the traditional type clouds that provide resources to the customers on pay per use basis. This type of cloud lacks the security and control on data, as the main concern is to provide the general services to the users [14].

Private Cloud:A private cloud is solely dedicated for single organization. The services could be provided and maintained by the service provider or by the organization it-self. It is also called internal cloud, which is designed specifically to meet the requirements of a particular company [15]. Such clouds are highly secure and efficient.

Hybrid Cloud: A hybrid cloud is a combination of private and public cloud; it gives the best of both the worlds. In this model a private cloud is connected to a public cloud. This gives better security and reliability than the public clouds, and wider access than the private clouds [16,40].

Virtual Private Cloud: This type of cloud addresses the problems associated with public and private clouds. It runs on the top of the public cloud and gives the user the right to design their environment including security and network topology on their own.

Federated Cloud: When the services from various cloud providers are bought together, the model is called federated cloud. This provides better portability and interoperability of the resources. It also resolves the vendor lock-in problem as the data could be easily transferred from one cloud to another.

Apart from these clouds, there are some more types of cloud like "micro-cloud", in which the focus is on reducing the power and network consumption, while "cloudlets" focuses on providing quality of service and latency of the system, whereas ad-hoc clouds gives increased connectivity by collecting the spare resources from the systems and making them available for the users.
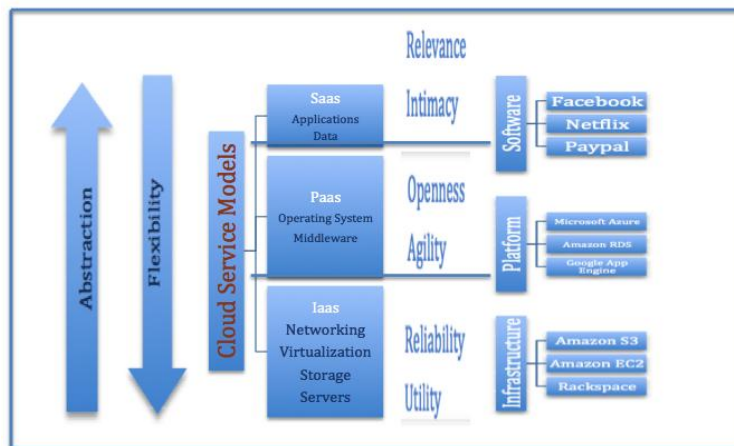

Fig. 2. Cloud Computing Service Model

The Cloud computing offers a layered service model that consists of three layers one above the other. And the layers can use the layers below them as a service as shown in Figure 2. A comparison is also depicted in Figure 3 and Table 1.

Infrastructure as a Service (IaaS): It is the lowest level of the services provided by the cloud. In this the infrastructure is provided to the customers as a service. It includes storage, virtual machines etc.

Platform as a Service (PaaS): This layer offers the platform to the users to develop and deploy the code/application. It offers operating system and software frameworks as a service. It works as middlemen by equipping the user to develop their own program and release it over the Internet.

Software as a Service (SaaS): This layer gives a complete software/application to the user that can be accessed on some device via Internet.

Fig. 3. Comparison of Cloud Service Models

Table 2: Comparison of Cloud Service Models

Service Model	Users	Purpose	Services
SaaS	Business Users/End Users	Complete Business Tasks	E-Mail, Blog, CRM, Virtual Desktop
PaaS	Developer	Deployment and Development of Applications	Application Test, Integration, Deployment and Development
IaaS	IT Expert/System Manager	Creating platforms for Deployment, Development, Integration and Testing	Virtual Machines, Storage, Operating System, Network, CPU

Related Methodologies: Before the cloud-computing era there were few technologies that have some aspects related to the cloud, and they are sometimes compared with respect to the performance and functionalities. Some of them are discussed in this section:
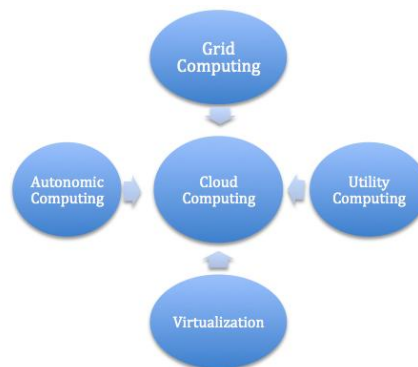

Fig. 4. Technologies related to Cloud

Grid Computing: It is an IT paradigm in which the resources are spread into a distributed network, for achieving a shared goal. The cloud is compared to this technology because of its similarity in terms of distributed network, and its objective of providing resources to the applications. In fact, cloud computing is one step ahead of the grid computing, as it also utilizes the virtual machines and resources.

Utility Computing: It is a type of computing paradigm in which the resources are provided to the customers on demand and the charges are estimated on the basis of usage. Cloud computing uses this strategy and makes the resources available to the customers any time and in a cost effective manner. In other words cloud computing can be recognized as an implementation of utility computing.

Autonomic Computing: Autonomic computing refers to the systems that have the capability of managing themselves i.e. these systems can deal with the internal and external reflexes on their own, without any manual support. The goal is to minimize the management. Cloud computing also shows some automatic management of the resources.

Virtualization: It abstracts the physical hardware from the system, and focuses on providing the virtual resources to the higher-level applications [17]. The virtual machine is the base of cloud computing, it gives the ability to the cloud to pool the resources together and provide them to the users as per their demands. It isolates the applications from physical hardware as well as other virtual machines.

III. Revolutions In Cloud Computing Environments

Cloud computing is an emerging technology, and in the past few decades it has been developing to become more efficient and powerful. This section discusses about the famous cloud architecture, platforms and some popular products available in the market.

Cloud Computing Architectures: Traditional cloud computing infrastructure works on a two-tier architecture, in which the one end is the user and the other one is the resource provided by the cloud. As the number of devices connected to the cloud is increasing, the load on the service providers is also increasing. The challenge is to meet the user requirements along with the maintenance of quality, for which the cloud-computing paradigm is evolving to provide better experience to the users. Few such models are given below:

Volunteer Computing: It can be seen as one of the aspect of ad-hoc clouds. As in ad-hoc clouds the spare resources volunteer themselves for the cloud environment that can help the devices to get closer to the resources. Similarly, in volunteer computing, the owners of the systems donate their spare resources to other systems. All the resources from the systems are collected together to form a huger virtual computer. Usually, most of the computation capacity of the systems is not used, so in order to utilize it efficiently, the resources that are futile are aggregated. In this type of system, the problem is divided into multiple sub tasks, and each one is resolved by different system.

Software Defined Computing: It is a type of computing in which the technologies are shifted towards the virtual infrastructure. The functionalities in the cloud are managed centrally, and consider the resources as single element. With this computing, the number of hardware devices is not pre defined, they can be selected as needed. It provides advantage of flexibility in the infrastructure, which enables the allocation of resources to many consumers at the same time. It provides overall cost saving, better control, improved agility etc.

Fog Computing: In this type of computing, the resources, storage, data is spread at the locations between the cloud and the user that are most efficient. The main objective is to provide better efficiency to the system and reducing the extent of data transportation. The term fog computing was first coined by Cisco, inspired by the natural fog that stays at the edge of the cloud. The devices from where the data generation takes place do not have the capability of computation, for that it needs to be transferred to the cloud, but the transmission takes some time and in order to get the results quickly, fog computing is used, in which the short term analysis are done at the "data hub" or at the "gateways", while the long tem analysis needs to be done on the cloud only. The applications of fog computing are smart cities, software-defined networks, smart grid etc.

Server-less Computing: It provides the backend services on pay per use facility. It gives the infrastructure to the users for the development and deployment of the code. It is also a pay per use facility, and the bandwidth and services are scalable. It is named as server-less computing not because there are no servers, in fact because the users do not need to worry about the servers; the service providers manage all the concerns.

Trending Cloud Platforms: There are several types of cloud platforms available, each one have their own advantages and features and the user can select according to their requirements. Brief information about some of the major platforms available nowadays is given in this section:

Nimbus: It is a cloud platform that provides IaaS [18]. It allows the users to hire the resources and build an environment through virtual machines. It has three components called client supported module that consists of all type of clients, service supported module that provides all the services of the cloud computing, and the background resource management module that manages all types of resources on the cloud.

Eucalyptus: Eucalyptus stands for "Elastic Utility Computing Architecture for Linking Your Programs to Useful Systems" [18]. It is used to develop open source platforms on private cloud. It is used in connecting the user to the programs, and allows them to lease the network for the computations. Client interface acts as the passage through which the users can get the resources both from inside and outside the eucalyptus cloud platform.

Open Nebula: It is also a type of open source cloud platform. It provides virtual machines to the users, to deploy on the physical hardware and allows the data of the user to be adapted flexibly [18]. It can also be used for synchronization of storage and network, and allows the users to dynamically employ the services. It can be used to deploy any type of cloud.

AbiCloud: It is a type of cloud computing platform in which user can build public and clouds in homogeneous settings. It can be used to manage the server, network, and storage, VMs etc. It has a very strong encapsulation and a great user interface that allows the users to simply drag the resources they need. It is the most flexible and

easiest platform that works on very simple command lines. It can be used in implementing hybrid and private cloud.

Famous Cloud Models: The cloud computing offers resources like data centers, virtual machines, networks etc. that allows organizations to rent these resources and pay a fee instead of setting them all up to start their business. A brief introduction of some of the prominent service providers is given in this section.

Rackspace: It is a platform that is offered by the organization called Rackspace. It offers cloud services, platform, and applications as services. It gives the providers the choice to choose for the desired application. The organization has had partnerships with Microsoft, AWS and VMware etc. It supports private, public, and hybrid cloud along with the multi-cloud.

The public cloud platform gives faster and easier access to the resources, and offers great scalability. The private cloud platform provides a single tenant atmosphere, which gives the faster working because of no other tenant; it is also the most secure platform with maximum user control. Such type of platform can either be hosted at the client site or at the providers' site. It also provides hybrid cloud that combines both private and public cloud.

IBM: IBM offers cloud services with the name IBM Cloud. It offers infrastructure, platform and software as a service. It provides the facilities both the cloud and the hardware. It combines the cloud based and hardware based services together into a single platform and gives a complete infrastructure, and provides the access to the servers independently. It offers a product called Bluemix that helps in development of Software. It also provides the facility of customizing the server, and hiring the required features.

AWS: Amazon that provides the on demand cloud services to the organizations and individuals founded it in 2006. It allows the users to build businesses using services like IaaS and Paas. Its products include EC2, Elastic Beanstalk, RDS, S3 etc. The user control provided by the AWS is impressive, the user can access variety of features like encrypting, auditing etc. The infrastructure provided by the AWS is completely customizable, and allows the users to run servers when required. The payment models offered are "pay as you go", Save when you Reserve" and "Pay less using More". The users can select the mode based upon their needs.

Microsoft: Microsoft offers a cloud-computing platform called Microsoft Azure. It allows the users to run services on the cloud and combine them with any other available services. It offers a collection of services appropriate for every company. It offers the on site servers that eliminates the need of physical servers and cuts the overall cost for the organizations. The migration is easy in their environment and has compatibility with Linux.

Google: The cloud services provided by Google is named as Google Cloud Platform. It also offers services like IaaS and PaaS to the users. It provides a secure architecture with multiple layers that secure the users' data on the cloud; their processing is transparent and hence, attracts the users. Their tools include Compute Engine, Big Query, App Engine, and Container Engine etc. It also allows the migration of virtual machines with ease.

IV. Data Management in Cloud Environments

The services offered by the cloud environments have become popular nowadays for performing large-scale computations and a wide range of complex IT functionalities from storing, computing to databases and applications as services. The organizations are adopting the cloud because of their requirement in terms of storage and analysis of huge amount of data [19]. In our previous paper [20], challenges and issues that one might face while adapting cloud computing environments is discussed while in this section of the paper, the challenges and issues particularly related to the management of data in cloud are briefed.

Data Management Challenges: In spite of being such a popular technology in the IT industry, there are still some challenges and issues that are not yet addressed, when it comes to manage the data over cloud. Some of the challenges and issues are given below:

Availability: It means that the services and the resources offered by the system are easily accessible to the authorized users when they need them [22]. They can use the facilities from anywhere and anytime. The availability of the data immediately to the users on request is one of the biggest concerns of the cloud providers.Moreover, it is the duty of the provider to give the quality of service to the users even when the number of user increases [22]. Redundancy and hardening are said to be the two techniques to ensure the availability of the cloud services [22] but these increases the workload on the provider.

Scalability: The cloud provider should be able to handle the increasing demand of the users in convenient manner. The cloud should be able to scale up and down the services according to the user requirements. The database systems on the cloud should also be scalable, as the data to be stored could also increase abruptly. Since, the cloud does not support the traditional DBMS, the NoSQL has become a popular database as it can handle the data on the distributed environment [23], but its maintenance is still very difficult. Moreover, the cloud should be able to add more tenants with minimum effort and no impact on the performance.

Heterogeneity: The variety of data is stored on the cloud environment; this is because of the rapid growth of the users from multiple domains. This variety of data is called heterogeneity. Such data is in multiple formats and exists in improper representation [24]. The users' data could be structured, semi structured and even unstructured, this makes the data storage and handling a complex process [24,25].

Integrity: Maintaining the Integrity of the data in cloud environment is one of the key aspects of the data security. It ensures that any unauthorized user cannot alter the data; this prevents the data from any misuse or mishandling. The cloud offers the data centers to the users to store their important data, so it is necessary for the service providers to maintain the integrity. The cloud should also assure the users by providing them ability to check their data [26].

Quality: Before the emergence of the cloud computing, the data generated was typically from very finite sources and also the data was cleaner and smaller, therefore, the generation of the result was easier and precise [27]. But today, the data sources are huge and the data generated is of poor quality as it contains various data formats and also much irrelevant information. This data quality is becoming a critical challenge for the service providers, as in order to attain quality in the data it requires consistency [28,29].

Privacy: Privacy becomes the concerns of the organizations that store their personal and critical information on the cloud. Because while using the cloud infrastructure the organizations trust the third parties, and this privacy of the data becomes a challenge because the information like bank credentials, location, private information is stored on the cloud, which is prone to stealing [30,31].

Fault Tolerance: The cloud system should be able to recover the data if there happens any fault, without losing any part of the data. This is usually important for the transactional data, because the system cannot afford to lose any transaction because of any type of failure [32,33]. Moreover, it is also important to have a fault tolerant system when there is query processing required, as no query should be missed because of any reason.

Multi-Tenancy: The cloud environment should be capable of supporting multiple tenants at the same time on the same infrastructure. These tenants are independent of each other and also their performance does not affect each other [34]. The cloud should be able to add more tenants with minimal efforts and ensure proper load balancing among the multiple servers and the users.

Regulations: For ensuring the privacy and security of the data in the cloud infrastructure, there are several rules and regulations. These laws are different for every country. So, in order to maintain these laws, the cloud need to offer proper protection of the rights of the user along with providing them with the services.

Governance: The governance incorporates the operation of regulations and laws on the data and provides a transparency among the users and the providers [37]. This maintains the storage of data, retrieval of data, accessing by the users, data streaming etc. The cloud governance policies should be adopted by the organizations for achieving better advantages from service providers in terms of security and privacy of data.

Data Management Issues: There are studies that have tried to address various issues related to data management in the cloud, but the amount of data being generated is increasing exponentially, and the technology for handling the data is improving at a comparatively slower rate. There are few applications that try to solve the issues related processing the queries, but there are still some issues that the customers might face while working on cloud, few important ones are listed below:

Data Analysis: In order to analyze the huge amount of data on the cloud, an appropriate model is required. The timely analysis and delivery of results needs an analysis of the algorithms on the basis of their scalability [30]. Moreover, various tools and technologies are required for proper and accurate analysis of the data [35,36]. The system should be capable of analyzing the data with minimum number of resources and maximum outcome. The analysis of streaming data is very difficult because the speed at which they arrive is quite high and the system needs to match it. Also, the analysis of data from various sources that occurs in heterogeneous form is still a complex process.

Data Security: With every new technology there are some cons and pros, so is with the cloud computing. There are some security issues in the cloud environment that are still unresolved. As with the usage of cloud environment, the customers trust the service providers with their private data, and there are always chances of data theft, data misuse, internal theft, data intrusion etc. Thus, the security of the cloud should be measured on regular basis [38]. Moreover, the service providers should ensure the regulations are met. Cryptography and hashing are traditional techniques for ensuring the security of data [39], but these cannot be efficiently implemented to larger amounts of data.

Data Confidentiality: It prevents the inappropriate exposure of the data. Since the information on the cloud environment is stored on distributed locations remotely. Confidentiality ensures that only the authorized users can access the data [40]. It is quite difficult for the service providers to preserve its confidentiality on the cloud, as there are always chances of attackers to get into the data and if once the data confidentiality is breached, there is no chance of undoing it.

Data Staging: The data needs some processing before the delivery to the user while it is on the cloud. This processing step is called data staging; it includes cleaning, extracting, transforming etc. [41]. But when it comes to huge amount of heterogeneous data, it becomes difficult for the cloud to perform staging because the data occurs in various formats and the transformation, cleaning of such data becomes very complex. However, MapReduce and Hadoop are the two technologies that are available for performing the data processing.

Loss of Control: When the data is shifted to the cloud environment the owner loses the control over the data as it reaches into the hands of a third party [42]. This leads to a fear among the users who wants to move their data/business to the cloud. The reason behind this fear is the control of how the data should be stored, how and when it will be backed up, what mechanism to secure should be applied is all decided by the service provider. However, if the provider somehow develops the trust then also the owner would be hesitant to use the cloud environment because there are always chances of security breach with the data.

V. Conclusions

Cloud computing has recently appeared as an appealing paradigm for hosting, management and delivery of various types of services through Internet. The growth of the cloud environment is moving the entire Information Technology landscape towards the computing that is utility based and cost effective along with efficient performance. Notwithstanding all the benefits provided by the cloud, the computing environment is still not developed enough in terms of fully utilizing the services of the cloud. Therefore, there are huge chances of improvement and researches in various aspects of the cloud computing.

This paper throws light on the outline of the cloud computing, briefly discusses about the technologies that are related to the cloud. It also discusses about the advancements that have occurred in the past few decades in the field of cloud computing, and also provides a gist of some platforms offered by the cloud and popular products that are available in the market. As the cloud technology is still under the development and evolving phase, this paper also provides a better understanding of the challenges and issues related to the management of data in the cloud, that one might face while adapting this technology.

References

[1]. M. Armbrust, A. Fox, R. Griffith, A. D. Joseph, R. Katz, A. Konwinski, G. Lee, D. A. Patterson, A. Rabkin, I. Stoica, M. Zaharia, "A View of Cloud Computing", Commun. ACM. 53. 50-58. 10.1145/1721654.1721672, 2010.
[2]. L. Huan, "Big Data drives Cloud Adoption in Enterprise", IEEE Internet Comput. 17. 68–71. 10.1109/MIC.2013.63
[3]. A. Guiseppe, B. Alessio, D. D. Walter, P. Antonio, "Survey cloud monitoring: a survey". Netw. ACM. 57. 2093-2115.
[4]. L. R. Rewatkar, U. A. Lanjewar. "Article: Implementation of Cloud Computing on Web Application", International Journal of Computer Applications 2(8):28–32, June 2010. Published By Foundation of Computer Science.
[5]. I. Foster, Y. Zhao, I. Raicu, S. Lu, 2008, Cloud Computing and Grid Computing 360-Degree Compared, In: Grid Computing Environments Workshop, 2008. GCE '08, p. 10, 1.
[6]. W.K. Chan, L. Mei, Z. Zhang, "Modeling and testing of cloud applications", to appear in Proceedings of 2009 IEEE Asia-Pacific Services Computing Conference (APSCC 2009), (Singapore, December 7-11, 2009), IEEE Computer Society Press, Los Alamitos, CA, USA, 2009.
[7]. D. Oliveira, E. Ogasawara, "Article: Is Cloud Computing the Solution for Brazilian Researchers?. International Journal of Computer Applications" 6(8):19–23, September 2010.
[8]. NIST Definition of Cloud Computing v15, csrc.nist.gov/groups/SNS/cloud-computing/cloud-def-v15.doc
[9]. Q. Zhang, L. Cheng, R. Boutaba, J Internet Serv Appl 1:7. http://doi.org/10.1007/s13174-010-0007-6
[10]. S. Sakr, A. Liu, D. M. Batista, M. Alomari, "A Survey of Large Scale Data Management Approaches in Cloud Environments," in IEEE Communications Surveys & Tutorials, vol. 13, no. 3, pp. 311-336. doi: 10.1109/SURV.2011.032211.00087
[11]. L.M. Vaquero, L. Rodero-Merino, J. Caceres, M. Lindner, "A break in the clouds: Towards a Cloud Definition", SIGCOMM Comput. Commun. Rev., v. 39, n. 1, p. 50-55
[12]. D. Oliveira, F. Baião, M. Mattoso, "Towards Taxonomy for Cloud Computing from an e-Science Perspective", Cloud Computing: Principles, Systems and Applications (to be published), Heidelberg: Springer-Verlag, 2010.
[13]. H. Kaur, X. Tao, "ICT and Millennium Development Goals: A United Nations Perspective", Springer Publishers, US, pp. 271, 2014.
[14]. A Platform Computing Whitepaper. Enterprise Cloud Computing: Transforming IT. Platform Computing, pp. 6, 2010.
[15]. S. Arnold, "Cloud computing and the issue of privacy". KM World, pp14-22. Available: www.kmworld.com [Aug. 19, 2009].
[16]. Global Netoptex Incorporated. Demystifying the cloud. Important opportunities, crucial choices, pp4-14. Available: http://www.gni.com [Dec. 13, 2009].
[17]. Vmware esx server. www.vmware.com.
[18]. J. J. Peng, X. J. Zhang, Z. Lei, B. F. Zhang, W. Zhang, Q. Li, **"Comparison of Several Cloud Computing Platforms,"** 2009 Second International Symposium on Information Science and Engineering (ISISE '09). IEEE Computer Society, Washington, DC, USA, pp. 23-27, DOI=10.1109/ISISE.2009.94.
[19]. L. Huan, "Big Data Drives Cloud Adoption in Enterprise", IEEE Internet Comput. 17(2013) 68–71.
[20]. R. Jameel, H. Kaur, M. A. Alam, "Technical Aspects and Challenges of Cloud Computing Environments", In Proc. 1st International Conference on ICT for Digital, Smart, and Sustainable Development (ICIDSSD'19), pp. 43-50.
[21]. D. Zissis, D.Lekkas, "Addressing Cloud Computing Security Issues", Futur. Gener. Comput. Syst. 28(2012) 583–592.
[22]. S. Kumar & R. H. Goudar, "Cloud Computing – Research Issues, Challenges, Architecture, Platforms and Applications: A Survey", IJFCC 2012 Vol.1 (4): 356-360 ISSN: 2010-3751 DOI: 10.7763/IJFCC.2012.V1.95
[23]. R.Cattell, "Scalable SQL and NoSQL data stores", ACMSIGMOD Record, 39(4), ACM New York, NY, USA, 2011,12–27.
[24]. D. Che, M.Safran, Z.Peng, "From Big Data to Big Data Mining: Challenges, Issues, and Opportunities", in: B.Hong, X.Meng, L.Chen, W.Winiwarter, W.Song (Eds.), Database Systems for Advanced Applications, Springer,BerlinHeidelberg,2013,pp.1–15.

[25]. S. K. Wasan, V. Bhatnagar, H. Kaur, "TheImpact of Data Mining Techniques in Medical Diagnostics". CODATA DataScience Journal (UNESCO), Vol. 5 (19), pp. 119-126, 2006.

[26]. R. Sravan Kumar, A. Saxena, "Data Integrity Proofs in Cloud Storage", in: Proceedings of the Third International Conference on Communication Systems and Networks (COMSNETS), 2011, pp.1–4.

[27]. T.C. Redman, A. Blanton, "Data Quality for the Information Age", Artech House, Inc., Norwood, MA, USA, 1997.

[28]. K. Weber, G. Rincon, A. Van Eenennaam, B. Golden, J. Medrano, "Differences in Allele Frequency Distribution of Bovine High-Density Genotyping Platforms in Holsteins and Jerseys", Western section American society of Animal science, 2012, p. 70.

[29]. O. Tene, J. Polonetsky,"Privacy in the age of big data: a time for Big Decisions", Stanford Law Review Online 64 (2012) 63.

[30]. D. Talia, "Clouds for Scalable Big Data Analytics", Computer 46 (2013) 98–101.

[31]. R. Chauhan, H. Kaur,"A Spectrum of BigData Applications for Data Analytics". Computational Intelligence forBig Data Analysis, Volume 19 of the series Adaptation, Learning andOptimization, Acharjya et al. (Eds.), Springer, pp 165-179, 2014.

[32]. M. Hasan, M . S. Goraya, "Fault tolerance in cloud computing environment: A systematic survey", Computers in Industry, Vol. 99, August 2018, pp. 156-172.

[33]. P. Kumari, P. Kaur, "A survey on Fault Tolerance in Cloud Computing", Journal of King Saud University-Computer and Information Science, Aug 2018, https://doi.org/10.1016/j.jksuci.2018.09.021

[34]. A. Hussain, A. Abdulaziz, G. Peter, T. Paul, L. Lydia, X. Jie, "Multi-Tenancy in Cloud Computing", Proceedings - IEEE 8th International Symposium on Service Oriented System Engineering, SOSE 2014. 10.1109/SOSE.2014.50.

[35]. R. Baboota, H. Kaur, "Predictive Analysisand Modelling Football Results using Machine Learning approach forEnglish Premier League", International Journal of Forecasting, ElsevierVolume 35, Issue 2, April–June 2019, pp. 741-755.

[36]. H. Kaur, R. Chauhan, M. A. Alam, "Spatial ClusteringAlgorithm using R-tree", Journal of Computing 3 (2), 85-90, 2010.

[37]. M. Al-Ruithe, E. Benkhelifa,K. Hameed,"Data Governance Taxonomy: Cloud versus Non-Cloud. Sustainability" 2018, 10, 95.

[38]. Y. Sun, J. Zhang, Y. Xiong, "Data Security and Privacy in Cloud Computing", International Journal of Distributed Sensor Networks, Vol. 10, Issue 7, 2014.https://doi.org/10.1155/2014/190903

[39]. D. Ramesh, B. Rama, "Cloud Computing–Key Hashing Cryptographic Implication based Algorithm for Service Provider based Encryption and Decryption", International Journal of Computer Trends and Technology. 49. 246-252. 10.14445/22312803/IJCTT-V49P140.

[40]. M. R. Gawande, A. S. Kapse, "Analysis of Data Confidentiality Techniques in Cloud Computing", International Journal of Computer Science and Mobile Computing, Vol.3 Issue.3, March- 2014, pp. 169-175.

[41]. Y. Wang, B. Veeravalli, C. Tham, "On Data Staging Algorithms for Shared Data Accesses in Clouds", in IEEE Transactions on Parallel and Distributed Systems, vol. 24, no. 4, pp. 825-838, April 2013. doi: 10.1109/TPDS.2012.178

[42]. A. Gholami, E. Laure, "Security and Privacy of Sensitive data in Cloud Computing: A Survey of Recent Developments". arXiv:1601.01498

[43]. H. Kaur, E. Lechman, A. Marszk,"Catalyzing Development through ICT Adoption: The Developing WorldExperience", Springer Publishers, Switzerland, pp. 288, 2017.