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# A Systematic Review on Cloud Computing

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***Abstract*—** Cloud Computing is the fastest growing technology in the IT world. It is an architecture which combined the concept of Virtualization technology with several computing paradigms such as Distributed computing, Utility computing, Grid computing etc. to achieve the goal of providing unlimited resources and services over the internet. Cloud computing uses the concept of pay as per use basis where users do not need to pay for infrastructure, installation and its maintenance. Anyone can access the desired service from cloud anytime, anywhere in the world on demand basis. This paper presents an overview of cloud computing along with Root of cloud computing, its evolution and a comparative study of Cloud with several other computing paradigm. It also highlights the characteristic, deployment and service model of cloud computing. The various benefits of cloud with its challenges and applications are also addressed in this paper.

***Keywords*—** Cloud Computing, Roots of Cloud computing, Evolution, Benefits, Challenges, Applications.

## I. INTRODUCTION

Cloud Computing is an emerging field of computer science which takes the IT sector to a new level. Cloud Computing is an advancement of various combined technologies such as Distributed computing, Utility computing, virtualization etc. to provide IT resources and services over an internet on pay as per use manner. These services are available to the user on demand basis at very low cost and charged at the time of the release of resources. These services include storage, processing, network, application etc [1]. The contribution of this paper is to discuss the roots of cloud and provide a broad comparison of existing computing technology with cloud computing. Also, highlighted the current challenges of Cloud.

The structure of the remaining paper is organized as. Section II discusses the root of cloud computing. Section III highlight the evolution of cloud computing. Section IV gives an overview of cloud computing, its main characteristics, different service models and deployment models. Section V shows some lights on the benefits of the cloud. Section VI describes various current challenges of cloud computing, which are needed to be tackled to make cloud successful. Section VII describes major applications of cloud computing. And lastly, Section VIII concludes the paper.

## II. ROOTS OF CLOUD COMPUTING

Cloud Computing is the development of various technologies such as Hardware technology, Distributed computing, Internet-based technologies and System management. Most importantly, virtualization which is also known as backbone of Cloud computing is a part of hardware technology which improves the resource utilization. Distributed Computing is another technology which used grid, utility etc. to share resources at very low cost. The advancement in Internet technologies increase the growth of Cloud computing and make them available to user anytime and anywhere. Lastly, System management takes a responsibility of whole cloud setup to avoid any fault and keep them updated with the latest technologies [2].

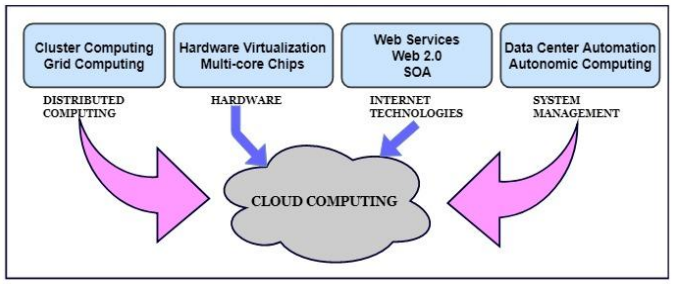


Figure 1. Roots of Cloud Computing

## III. EVOLUTION OF CLOUD COMPUTING

Cloud Computing gaining popularity day by day because of its various qualities. Cloud Computing is not a new paradigm, it is an enhancement of various technologies. Evolution of cloud started from Distributed computing after that advanced to Utility computing and furthermore to grid computing. And then, the universal paradigm Cloud Computing came to deliver these services [3].

 

Distributed computing is a system in which a group of computers works together to achieve common goal. It divides the program into smaller segments and solves each part simultaneously. Distributed computing helps in minimizing the execution time of a program without affecting the complexity of the program [4]. Utility computing used the technique of Distributed computing and provide computing resources and services on demand to users at very low cost [6]. Cluster computing is a bunch of interconnected computers which is used to processed data in a large amount at very high rate for computing purpose. These group of computers present at same physical location which pretend to be a single unit and connected to each other through very high-speed network such as LAN [5].

Table1. Comparative study on Evolution of Cloud paradigm [5] [8-14]

| # | Feature | Distributed Computing (DC) | Utility Computing (UC) | Cluster Computing | Grid Computing (GC) | Cloud Computing (CC) |
|---|---|---|---|---|---|---|
| 1 | **Ownership** | Multiple | Single | Single | Multiple | Single |
| 2 | **Architecture Used** | Service Oriented Architecture (SOA) | SOA | SOA | SOA | User Chosen Architecture |
| 3 | **Computation Service** | Computing | On demand | Computing | Maximum Computing | On demand |
| 4 | **Virtualization** | Yes | Half | Half | Half | Must required |
| 5 | **Multitenancy** | No | No | No | Yes | Yes |
| 6 | **Security** | Conventional login | Conventional login | Conventional login | Security through credential delegations | Security through isolation |
| 7 | **Privacy** | High level | Service level | Medium level of privacy | Limited support for privacy | High privacy is guaranteed |
| 8 | **Service License Agreement (SLA)** | Limited | Limited | Limited | Yes | Yes |
| 9 | **Interoperability** | Yes | Yes | Yes | Yes | No |
| 10 | **Resource Management** | Distributed | Distributed | Centralized | Distributed | Both |
| 11 | **Homogenous / Heterogeneity** | Homogenous | Heterogeneous | Homogenous | Heterogeneous | Heterogeneous |
| 12 | **Reliability** | Half | No | Less | Medium | High |
| 13 | **Scalable** | Yes | Yes | No | Half | Yes |
| 14 | **Self Service** | No | No | No | Yes | Yes |
| 15 | **User friendly** | No | No | No | Half | Yes |
| 16 | **Failure Management** | Limited control over failure management | Limited control over failure management | Limited control over failure management | Limited control over failure management | Strong failure management |
| 17 | **Internet** | Not Required | Not Required | No internet access required | Internet Required | Internet Required |
| 18 | **Interconnection Network/Speed** | High bandwidth | High bandwidth | Low latency with high bandwidth | High latency with low bandwidth | Low latency with high bandwidth |
| 19 | **Location of Nodes** | Need not to be a same physical Location | Need not to be a same physical Location | Physically in the same Location | Distributed all over the globe | Location doesn't matter |
| 20 | **Size of Servers** | 100s or 1000s | 100s | 100s | 1000s | Varies from 100s to 1000s |
| 21 | **Operating System (OS)** | Windows or Linux | Linux through windows and Solaris | Linux, Windows | No restriction is made on the OS. | Multiple OS can run |
| 22 | **Services** | Distributed File Service, Distributed Data Service | N/A | DNA sequence analysis,3D modelling | Intergrids, Intragrids, Extragrids | IaaS, PaaS, SaaS |
| 23 | **Applications** | Geographically dispersed | Business model | HPC, Nuclear simulation | HTC, Collaborative Scientific and | Google Docs, Facebook |
| 24 | **Example** | ATM, WWW, Google Bots | IBM, HP, Microsoft | VAXcluster, Beowulf Cluster | Tera grid, NKN | Amazon EC2 |
| 25 | **Future** | UC, Cluster, GC and CC | GC and CC | GC | CC | Next generation of Computing |

 

Grid Computing in another computing paradigm which inherits the concept of Cluster as well as Utility computing. It uses the clusters of computers from different physical location connected with a network to provide powerful computational resources on demand. In Grid, clusters of computers present at various locations work as single virtual entity to give high computing power [6]. Then, Cloud computing emerges with the advancement of these technologies. Unlike cluster and grid computing which focus on computational power to solve large problems, cloud computing is concerned with the provisioning of services on demand. These services include Infrastructure (IaaS), Development tools (PaaS) and Software applications (SaaS) [7].

## IV. CLOUD COMPUTING

Cloud Computing is an internet-based architecture which creates a computing environment to provide availability, scalability and flexibility of computer infrastructures at different level of abstraction. It can be defined as computing model which offers computing as a utility to meet the requirement of users at very low cost based on pay as per use manner. Cloud computing delivered applications, hardware and software as services on demand [15].

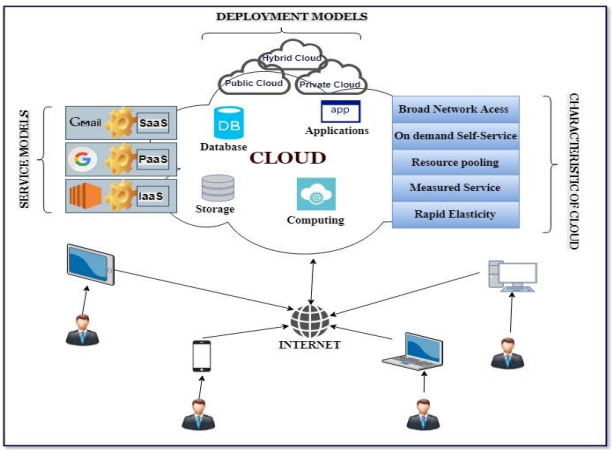


Figure 2. Overview of Cloud Computing

### A. CHARACTERISTICS OF CLOUD COMPUTING

National Institute of Standards and Technology (NIST) recognized five special features of Cloud computing which are given below [16].

1. On-demand Self-service: A cloud's subscriber can access resources such as computing capabilities, storage etc. anytime when needed without a need of service provider.
2. Broad Network Access: Any device such as smartphones, laptop, workstations etc. can be used to access the resources available over the internet.
3. Resource Pooling: Computing resources can be accessed by more than one user at a time using multi-tenant architecture. However, users are not familiar with the exact location of provided resource but in the case of higher level of abstraction such as datacentre location may need to be specified.
4. Measured Service: Cloud systems provides pay as per use service which monitors and control resource usage to provide transparency for both user and service provider.
5. Rapid Elasticity: The services of cloud computing are so elastic that one can add resources when needed and release them once they finish. In addition, resources are accessible to users in unlimited quantity at any time.

### B. SERVICE MODEL OF CLOUD COMPUTING

Cloud computing delivered IT resources and capabilities as a Service. National Institute of Standard Technology (NIST) recognized "three service model" which provide services for cloud computing. They are:

#### a) SaaS (Software as a Services)

Software as a service is the software delivering model used by cloud's customer in a pay-as-per-use manner. It is hosted by a service provider and available to its customer anytime through the internet. It is a multitenant architecture which means that thousands of customers can access it at a time. For example: Gmail is the best example of SaaS in which user only need a browser and internet to access the application [17].

Advantages [18]:

- SaaS provides lots of application to accesses.
- Eliminates the need to install an application
- Support many concurrent users at once.

#### b) PaaS (Platform as a Services)

Platform as a Service is a model which offers deployment of applications by reducing the cost of buying and maintaining hardware and software. It is used by developers for developing new applications. PaaS services include application design, development, testing, deployment and hosting. Example: Google App Engine, which offers clients to run their application on Google's infrastructure [17].

Advantages [18]:

- Pay for use the infrastructure.
- Multitenancy architecture.
- Provide reliability and security.

#### c) IaaS (Infrastructure as a Services)

Infrastructure as a Service is an architecture which provides infrastructure over the internet. It allows accessibility of

 

infrastructure which consists of hardware, network, storage, operating system and storage devices on a pay-per-use basis. Example: Amazon Elastic Compute Cloud (EC2) [17,19].

Advantages:

- Provides resources as a service.
- Pay IaaS services on a usage basis.
- Dynamic scaling is allowed

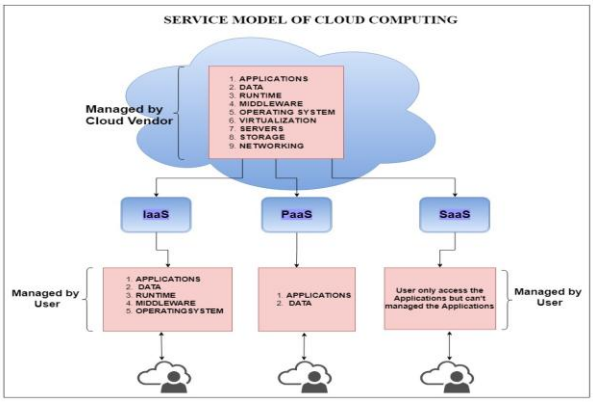


Figure 3.Cloud Service Model

C. DEPLOYMENT MODEL OF CLOUD COMPUTING

According to NIST, there are 4 types of deployment models.

**a) Public Cloud:** This cloud infrastructure such as storage, applications and other services is made available to everyone and users only pay for time duration they use the service i.e. pay-per-use. However public clouds are less secure because all the applications and data are available to all users. Example: Google App Engine, IBM smart cloud [20,21].

Benefits of Public cloud:

- Availability and Reliability
- Pay as per use
- Freedom of Self-Service

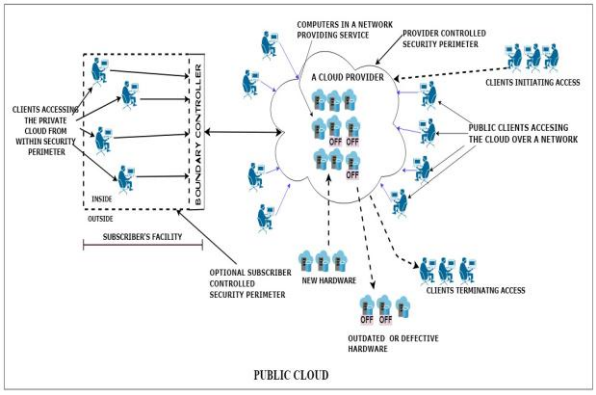


Figure 4.Public Cloud

**b) Private Cloud**: This cloud infrastructure is implemented in a single organisation and available to limited users which are part of that specific organisation. Its resources and applications are controlled by organisation itself. So, it improved the security of the private cloud [18,21]. Example: Amazon PVC, Ubuntu Enterprise Cloud.

Benefits of Private cloud:

- High Level Security
- Utilization of existing resources
- Full control to customize

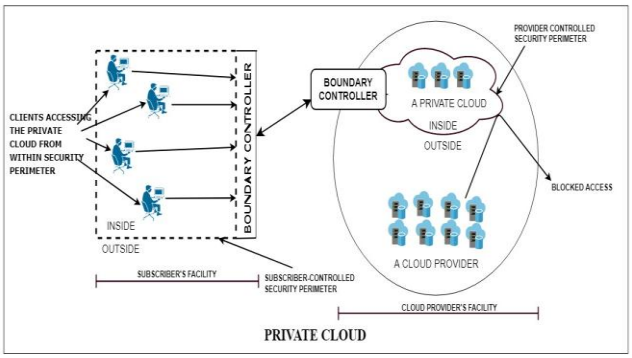


Figure 5.Private Cloud

**c) Hybrid Cloud**: This deployment model is the composition of more than one cloud in which critical data is hosted on the private cloud and less secure data on the public cloud. The merging of these two cloud models uses a concept called Cloud Bursting. The idea of hybrid clouds that extend the use of infrastructure by hiring additional capabilities from public cloud is also known as Cloud Bursting [18,22]. Example: EMC Hybrid Cloud, HP Hybrid Cloud

Benefits of Hybrid cloud:

- Cost reduction
- High availability
- More secure

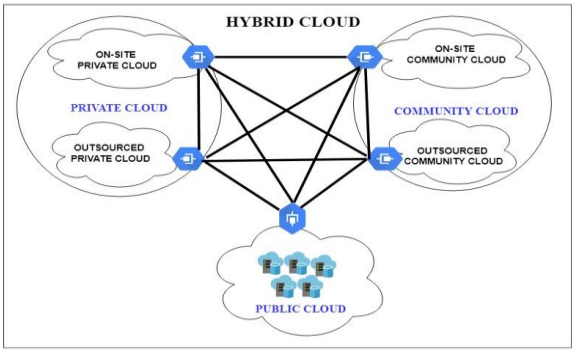


Figure 6. Hybrid Cloud

**d) Community Cloud:** Community cloud involves the distribution of computing infrastructure in between organizations of the same community. The

infrastructure and computational resources of a cloud are exclusive to two or more organizations that have common privacy, security, and regulatory considerations [23]. This may help in reduce the capital costs for its setup as the costs are distributed among the organizations [20]. Example: Google's "Gov Cloud".

Benefits of Community cloud [23]:

- Lower cost than private cloud
- Limited users
- High security

In the figure below, organisation 1 and organization 2 are part of a same community which can access the same cloud i.e. community cloud. Whereas organisation 3 is blocked from accessing the community cloud because it is not a part of a community.

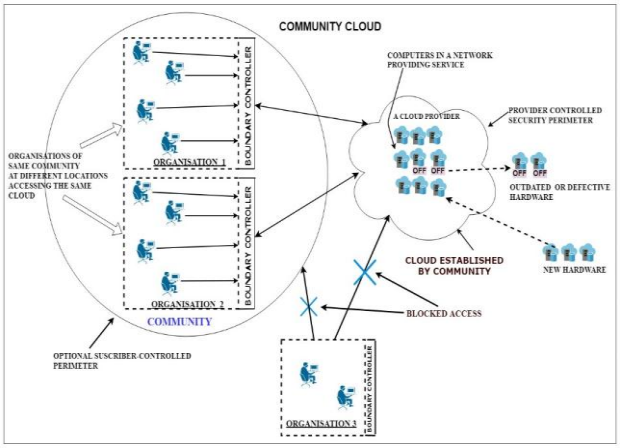


Figure 7.Community Cloud

Table 2. Comparison between Cloud Deployment Models [17] [24] [25]

| Attribute \ Deployment Model | Public Cloud | Private Cloud | Hybrid Cloud | Community Cloud |
|---|---|---|---|---|
| **Ownership** | Owned by customers | Owned by single organization | Partially owned by Service Provider and partially by consumer | Owned by two or more organizations which has common goal |
| **Performance** | Low to medium | Excellent | Good | Very Good |
| **Setup cost of building datacentre** | Low initial cost | High | Medium | Varies from number of organizations |
| **Used by** | Anyone can access | Limited people can access | Medium accessibility | Depend upon number of cooperatives |
| **Security** | Less | Highest | Medium | High |
| **User's control** | Limited control | Full control | Full control over private part and limited at public part | High control but limited by community policies |
| **Maintenance cost** | Lowest | Highest | Moderate | High |
| **Space required** | Very low | Very large | Medium | Depends on number of cooperatives |
| **Workload** | Normal workload with short-spikes in demand | Not suitable for handling large workload | Highly dynamic or changeable | Suitable for handling large workload |
| **Size of Datacentres** | Around 50,000s | Around 50,000s | Less than private cloud | Public cloud>15,000>Private cloud |
| **Virtualization** | Resource utilization is optimized via server virtualization | Resource utilization efficiency gains through server virtualization | Resource utilization is optimized via server virtualization | Resource utilization efficiency gains via server virtualization |
| **Reliability** | Medium | Highest | Medium | High |
| **Cloud Bursting** | Not supported | Not supported | Supported | Not supported |
| **Example** | Amazon EC2 | Microsoft Azure | Rackspace Hybrid cloud | Microsoft government community cloud |

## V. BENEFITS OF CLOUD COMPUTING

Benefits of Cloud Computing can be described easily by dividing it into three parts [17,24].

### A. Non-Functional

- Simplicity: Users only required tiny knowledge to use cloud services.
- Reliability: This property minimizes the chance of any failure and provides speedy recovery if required.
- Quality of Service (QoS): This feature provides best services to satisfy the user's requirement.
- Availability: Resources available 24*7 for users.

 

- Elasticity: Easily accessible and can be modified as required.
- Mobility: Users can access these services anytime in the entire world.

**B. Economical**

- Cost Reduction: It reduces the cost as users don't need to buy and maintain the expensive software.
- Pay as per use: Organizations charges according to the usage of services.
- Green Environment: Efficiently sharing of resources, minimizes the consumption of a large amount of powers which in turns reduces the carbon emission.

**C. Technological**

- Virtualization: Virtualization is the abstraction of IT resources in which single physical resource works as multiple virtual resources. It creates a multiple execution environment of a single physical resource and hide its physical properties from other systems, applications or end users to keep it simple. These physical resources include an operating system (OS), storage device, a network or server [1].
- Multi-tenancy: This property shows that multiple users can access cloud resources at a time.
- Security and Privacy: It secures our data from unauthorized users.
- Data Management: It stores the data of cloud in a large amount and manage it by providing fast access.
- Tools: There are so many tools present, which help in implementing the cloud setup.

## VI. CHALLENGES OF CLOUD COMPUTING

Cloud Computing is growing technology with lots of benefits. However, due to the complex architecture of Cloud, many challenges arriving day by day. Some of the current challenges are:

- Load Balancing: Load balancing is a major factor for raising cloud performance and for entirely utilizing the resources. One of the serious issues in cloud computing is to divide the workload uniformly between all nodes. Workload always required to be shared among all the available nodes of the distributed system to improve the resource utilization and for better efficiency of the cloud computing environment [26]. Load balancing plays an important role in enlightening the performance of the distributed system by shifting of workload among various nodes [27]. The load perhaps memory, CPU capacity, network load or delay loads [28].
- Performance: A major source of the performance issue for cloud users is the communication time between the user's computer and the Web server in the cloud. When users accessing the cloud services increases, the amount of data transferred to and from the cloud increases and it will affect the performance of the Cloud [29].
- Security: Security is one of the important challenges which obstructs the growth of cloud computing [30]. When databases and application software shifted to a large data centre, there may be an issue of security while accessing cloud computing services [31].
- Interoperability/Communication between Clouds: Cloud services providers use their own methods and technology according to their policy, budget, technical skills, etc. So, it is difficult to use more than one cloud resources due to the incompatibilities between them. The combined use of cloud services is a challenge because of the lack of standardized APIs, each provider has its own techniques on how users and applications interact with the cloud infrastructure [32].
- Energy Consumption: Due to the high demand of Cloud resources, data centres are deployed in large amount which needs a high amount of power. But for energy efficient cloud, power consumption must be reduced [33].

## VII. APPLICATIONS OF CLOUD COMPUTING

Cloud computing is one of the most dominant fields for online resources because cloud makes sharing and management of resources very easy. Due to these attractive properties of the cloud, following are the fields where cloud as an active component:

- Cloud Computing in Medical Fields: Cloud computing plays a vital role in the medical field as it provides various infrastructure at a very low cost to give more accurate results. Cloud computing helps in sharing medical information among the various medical professionals who can contact any individual patient directly anytime and anywhere [34].
- Cloud Computing in Education: Cloud computing offers hardware and software infrastructure to an educational environment so that academic institutions remain focused on research and learning instead of buying and maintaining complex IT infrastructures. It allows retrieving information and using resources which are useful for educational purposes. E-Learning provides online test, online course etc [35].

 

- Online Entertainment/Social Area: People also use cloud for entertainment purpose such as online gaming, online media store etc. Online Entertainment can be reached to users by any device such as smartphones, tablet etc. It helps in stay connected with different people around the globe. For example, Facebook, Google etc [36].
- E-Governance: E-governance is the electronic way to share information between government and citizens and between government organizations. E-governance requires resources such as software, hardware, security to work properly and these requirements are fulfilled by cloud computing as it provides these resources as a service [37].
- Cloud Computing in Agriculture Field: Agricultural Field is catching height using Cloud Computing technology. It stores all the relevant information at one place so that users like farmers, consultant etc. can access easily using any device. This information includes various soil related databases, weather related information, different crops data etc [38].

## VIII. CONCLUSION AND FUTURE WORK

The world is rapidly migrating towards the cloud due to its cheap cost and efficient utilization of resources. We studied that Distributed, Utility and Grid computing are the basic building block of cloud computing and virtualization technology is the backbone of the cloud. In this paper, we presented a broad study on cloud computing, their characteristics, service model and deployment model. This paper also provided a detailed comparison of cloud computing with other computing paradigms, followed by the benefits and application of cloud. Additionally, discussed some current challenges which need to be addressed to make cloud successful. This work will be helpful in the future to improve the quality and availability of services which brings the attraction of users towards the adoption of the Cloud.

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## Authors Profile

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