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An Insight into the Future of Cloud Computing: Design, Trends, New Prospects and Challenges

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Abstract: *Cloud Computing provides computing services like servers, databases, storage, software, networking and so on from anywhere over internet. Here, cloud means the internet. The main purpose of cloud is to provide services on demand. Cloud providers such as Amazon Web Services (AWS), Microsoft Azure or Google Cloud platform (GCP) provides cloud services. Cloud computing allows organizations to quickly and easily adjust their IT resources by scaling them up or down as needed without investing in expensive hardware upgrades or it provides no upfront hardware investment. The main purpose of this paper is to provide knowledge about cloud computing by considering its evolution and earlier research work. The design of cloud computing is considered in detailed which helps to understand the working of cloud. It also covers the current trends or methodology of cloud by which the emerging opportunities and possibilities are known. And the future trends or methodology and challenges of clouds are considered which helps to know why clouds are becoming popular and obstacles that need to be faced and overcome.*

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Introduction

In recent years cloud computing is been embedded into our daily digital lives from backing photos on a smart phone to managing large scale corporate applications. Cloud computing is referred as delivery of IT resources. Most striking feature of it is that it eliminates the local servers with efficient digital operations and scalability. Cloud computing has brought change in the field of information technology by providing excellent computing power, storage and networking through internet with the concept of pay as you go pricing model. A particular physical structure is not required to manage and access data by the users and the organization. The basic model of cloud computing is given in Fig. 1 in which three layers are present cloud layer (top layer), server layer (middle layer) and client layer (bottom layer).

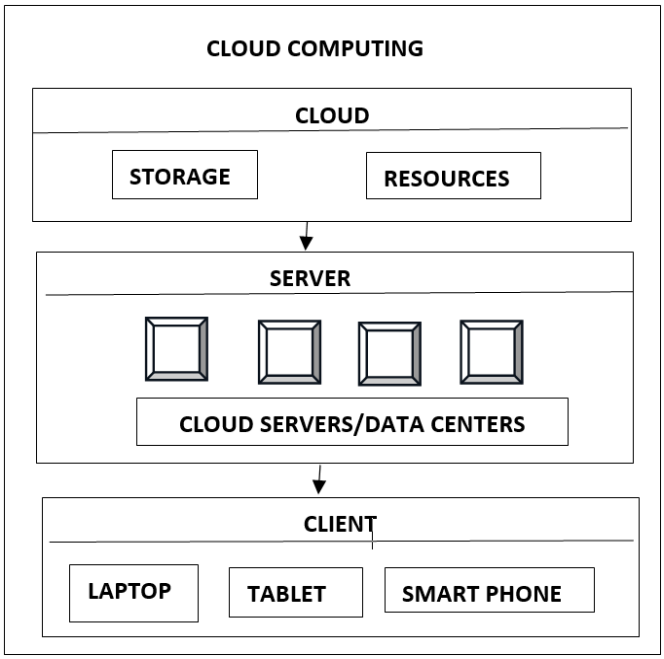

Fig. 1: Basic Model of Cloud Computing

History of Cloud Computing

Cloud computing has evolved through several decades by advancing in distributed computing, networking and virtualization. In 1960s the concept of Cloud computing began with the idea of time sharing system which allows many users at a time to access the computing resources through a central mainframe. During this period John McCarthy**,** a computer scientist marked a comment that someday the computation will be like public utility. Later, in 1990s the virtualization and internet came into existence. By virtualization multiple operating systems runs on one machine and by using internet it became easier to delivering of service remotely. In year 1999, first major Software-as-a-Service (SaaS) was launched by Salesforce which marked as a beginning of cloud computing through which delivering of software (CRM) started. The year 2006 was considered as modern cloud computing era in which Infrastructure-as-a-Service (IaaS) started and Amazon introduced AWS, it offered storage (S3) and compute (EC2) services. In 2010s, as cloud computing was growing quickly the actual competition started and companies like Microsoft (Azure)**,** Google (Google Cloud)**,** IBM, and Oracle entered the market**.** Cloud stretched itself by introducing Platform-as-a-Service (PaaS) with more complex analytical and AI tools. In 2020s to reduce latency the Edge computing, hybrid (mix) and multi cloud strategies were added.

Characteristics of Cloud Computing

The following Table 1 in detail explains about characteristics [1-2] of cloud computing.

Table 1: Characteristics of Cloud Computing

Characteristic	Description
On-Demand Self-Service	Resources are accessed as needed.
Broad Network Access	Usability from any device or location is provided.
Resource Pooling	Efficiently sharing of resources is been provided.
Rapid Elasticity	Scalability of resources up or down easily and quickly.
Measured Service	Pay only for what you use.
Scalability	Easily grow or reduce resource capacity.
High Availability	Continuous service with minimal downtime is provided.
Security	Authorized access and data protection is provided.
Multi-Tenancy	Shared platform and isolated data access is provided.

Types of Clouds

There are mainly four types of cloud computing deployment models which are shown in Fig. 2 and each provides different purpose and needs for organization.

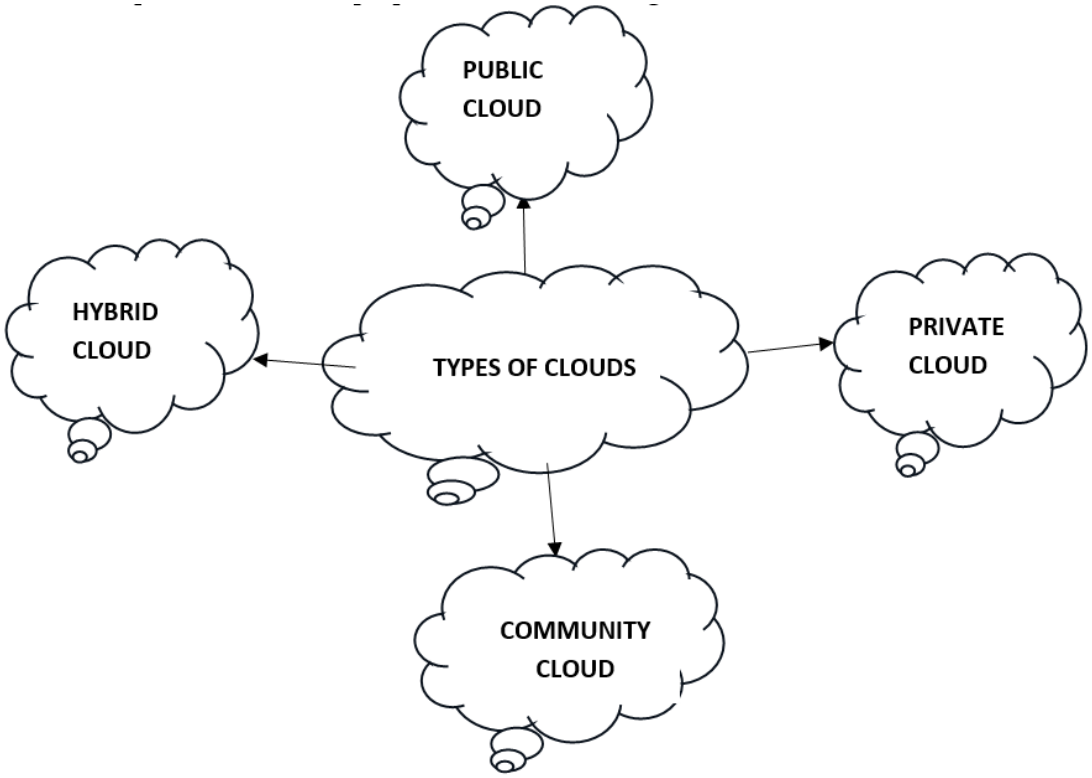

Fig. 2: Types of Clouds

- **Public Cloud:** Over the public internet, the public cloud services are been provided and the services are shared among multiple organizations [3]. Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform (GCP) are example for public clouds. Public clouds are scalable, easy to access and cost effective. The use cases of public clouds are hosting websites, development and testing environments and storage.
- **Private Cloud:** It is exclusively used by one organization only and managed either by a third party or internally. VMware Private Cloud and OpenStack come under the private cloud type. It provides good control, customization and high security. The applications or use cases of private clouds are in government agencies, financial organizations and large enterprises holding sensitive data.
- **Hybrid Cloud:** Here, both public and private clouds are combined and allows data and applications to be shared in between them. Hybrid clouds are more flexible, scalable, cost effective and with control for sensitive data. It is been used where the workloads matter with secure storage, public access and disaster recovery.
- **Community Cloud:** This type of cloud is shared by several organization having with common goals. Universities, research groups and healthcare sectors are example for it. Community cloud provides policy alignment, collaboration and sharing of cost.

Cloud Computing Services

Cloud provides scalability, reliability, accessibility, cost effective and secure services. There are mainly three types[4] of cloud computing services which are mentioned below.

- **Infrastructure as a Service (IaaS):** It provides virtual computing resources facilities like virtual machines, networking and storage. Amazon Web Services (AWS) EC2, Microsoft Azure Virtual Machines and Google Compute Engine provides IaaS.
- **Platform as a Service (PaaS):** It provides a platform for customers to develop, manage and run program or application without worrying about present architecture. Google App Engine, Microsoft Azure App Service and Heroku provide PaaS.
- **Software as a Service (SaaS):** On subscription basis software application over internet are delivered. Google Workspace, Microsoft 365 and Salesforce provides SaaS.
- **Other Computing Services:** Function as a Service (FaaS) or Serverless Computing, Storage as a Service (STaaS),Big-Data-as-a-Service (BDaaS), Hadoop-as-a-Service (HaaS),Data-Analytics-as-a-Service(DAaaS)[5],Information-as-a-Service (INaaS)[6],Business-Process-as-a-Service(BPaaS),Integration-as-a-Service (INaaS),Security-as-a-Service (SECaaS) [7], Testing-as-a-Service (TaaS), Anything-as-a-Service (XaaS) and Database as a Service (DBaaS).

Literature Survey

Cloud Computing is a new model for providing services over internet. Many researchers had worked on it and below Table 2. mentions earlier research work with their title of the paper, year, advantages and disadvantages [8].

Table 2: Literature Survey

S. No.	Title of the Paper	Year	Advantages	Disadvantages
1	Edge Cloud Computing for Internet of Things: A Review [9].	2024	Compares between edge and cloud for Internet of Things and reviews hybrid structure like fog.	Does not introduce new frameworks.
2	Systematic Literature Review on Cloud Computing Security: Threats and Mitigation Strategies [10].	2024	Latest security, mitigation strategies and AI and server less combination are considered.	Insights are basic.
3	Edge AI: A Taxonomy, Systematic Review and Future Directions [11].	2024	Presented a clear classification of Edge AI. The important conditions, security measures and upcoming research needs are identified.	It was found poor in peer reviewed examination.
4	The Future of Cloud Computing: Benefits and Challenges [12].	2023	Scalability of IT resources, pay only for use and AI and ML techniques using cloud are considered.	Performance overhead, complex architecture and challenges not implemented.
5	AI Augmented Edge and Fog Computing: Trends and Challenges [13]	2022	A survey on edge, Fog and cloud.	Detailed comparison is not done.
6	Edge-Cloud Polarization and Collaboration: A Comprehensive Survey for AI[14].	2021	Edge Cloud collaboration with AI is presented along with GNNs and reinforcement learning.	No implementation and performance evaluation.
7	A Study on Cloud Computing: A Review [15].	2021	Provider Comparison and Comprehensive Coverage.	Common insight and no depth.

Cloud Computing System Design

To make a system scalable, reliable, secure, cost-effective and rapidly deployable cloud computing design needs be understood. Cloud architecture is given in the Fig.3 which is basically divided into two parts front end and back end[16-17].

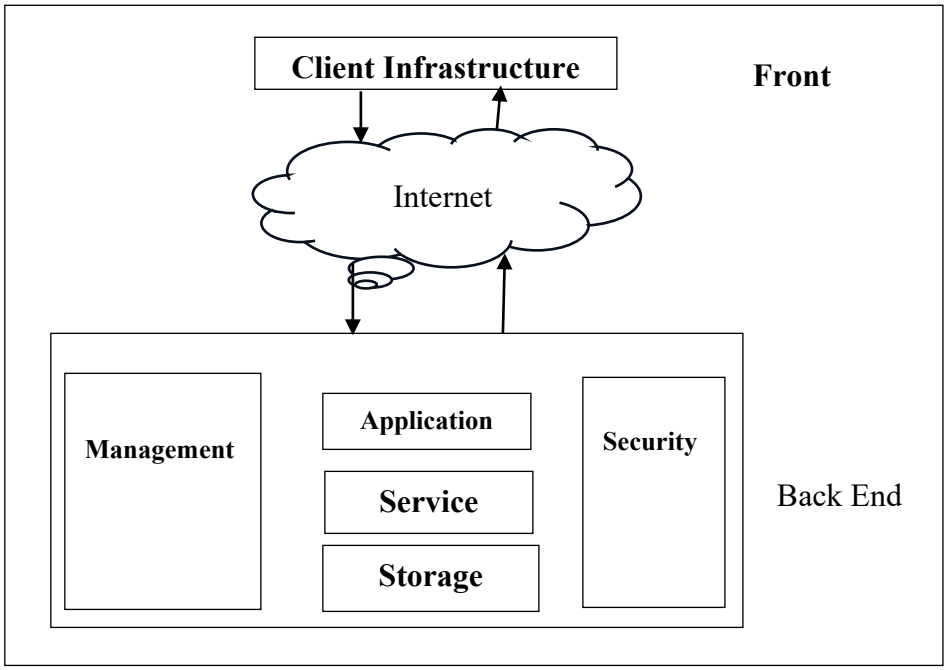

Fig. 3: Cloud Computing Architecture

- **Front End:** The client infrastructure is referred as front end of cloud architecture. Mainly client will be using it. It consists of all applications and user interfaces that client needed to access the cloud resources. Through web browser GUI client access the cloud resources.
- **Back End:** Cloud used by the service provider is known as back end. It includes management techniques, security methods and other resources which are explained below.
- **Application:** It may be any software which user wants to use.
- **Service:** Based on the client needs the relevant service is been accessed.
- **Storage:** Cloud provides large amount of storage for computing.
- **Management:** It manages and coordinates all back end resources of cloud.
- **Security:** By using security mechanism, it provides security.
- **Internet:** It provides interface to the front end and back end. It also acts as connectivity between front end and back end.

Trends or Methodologies in Cloud Computing

Now a day's cloud computing trends are thriving by providing more services to individuals and organization or business. Many cloud service providers like Google, Microsoft, Amazon so on are working on latest trends which helps to provide customers or users with more efficiency. The following are the current trends of clod computing.

- **AI and ML Driven Cloud Services:** By integrating AI and ML technology with cloud the scalability, high computational power and efficiency increases. Many cloud service providers like Amazon, IBM, Google, etc. are upgrading and investing towards AI and MLtechnology. AWS DeepLens camera and Google Lens are two ML driven technology used by Amazon.
- **Enhanced Cloud Security:** Among all services security lies on the top priority[18-19]. Many cloud service providers are opting Zero or never trust security tool for authentication which enhanced the security. Encryption techniques like homomorphic encryption on data are used to provide the privacy. Azure, Google cloud, IBM cloud, AWS implements enhanced cloud security.

- **Multi and Hybrid Cloud techniques:** Many big organizations like bank, insurance companies etc. are using multi and hybrid cloud techniques. By implementing hybrid clouds both public and private data storage are been provided. The work load and multi point failure is efficiently balanced by using the multi cloud. AWS, Google, Microsoft Azure, Oracle cloud implements them.
- **Edge Computing:** Due to increase in IoT devices and 5G network the edge computing is playing more predominant role. Edge computing provides the feature of storing, computing and data analytics at the source place. By which the latency reduces, security and privacy increases and high rate of data transmission is provided. Many IT organizations for real time applications are deploying edge computing. AWS, Microsoft Azure, Google Cloud provides it.
- **Environmental Sustainability Cloud Innovations:** Environmental Sustainability is most predominant trend. Most of the cloud providers like AWS, Microsoft Azure, and Google Cloud are practicing towards carbon neutral operations.
- **Quantum Computing Accessibility:** Organizations complex problems are solved using large computing power. IBM, Google, Microsoft, and Amazon are implementing Quantum Computing.
- **Serverless Architectures:** Developers need to concentrate only on coding part no need to manage the server. Servers are managed by cloud service providers.
- **Kubernetes and Docker:** Kubernetes and Docker plays an important role in cloud deployment. Both are opensource platforms. Kubernetes are used to provide automation for cloud users and Docker provides the facility to pack all required applications and deploy them anywhere. Google cloud, AWS, and Microsoft Azure.
- **Private Cloud Utilization:** Data sovereignty is forcing many organizations to private cloud utilization.
- **Low Code and No Code Cloud Solutions:** Figma and Zoho tools helps to develop website, apps and services in low code or no code cloud solution.
- **Disaster Recovery and Backup:** Clouds provides disaster recovery and backup of data which helps and save many organizations from huge loss.

Exploring New Prospects or Methodologies of Cloud Computing

Future of cloud computing is bright as more IT organizations are using cloud to provide services to their client or users[20-22].

- **Autonomous Cloud Operations Powered by AI:** Smart AI clouds have to be developed with minimum human involvement. Smart clouds must be able to predict faults and diagnosis, self scalability, enhanced security and automatically resource optimization must be done. Overall, AI must act as a cloud operating system.
- **Mixed Quantum and Classical Cloud Infrastructure:** The quantum and classical cloud features must be combined. Mixed quantum and classical cloud must offer quantum computing for cryptography, optimization and research purpose.
- **Distributed Computing Continuum: From Edge to Cloud:** The gap between edge and cloud has to be vanished and provide continuous and unbroken progression with low latency services for IoT, smart cities, Augmented Reality and Virtual Reality. AI must be integrated with cloud so that distributed computing will be closer to the user.
- **Confidential Cloud Security with Zero Trust Assurance:** Sensitive applications like finance, public sectors and health care must be provided with zero trust and confidential cloud security using hardware trust zones.
- **Serverless Powered Composable Architectures:** Automate development by using serverless and composable architectures.
- **Green Cloud Infrastructure with Carbon Intelligent Management:** Cloud must practice Carbon Intelligent Management by carbon tracking, modular hardware, by using energy efficient data centers and AI driven power.

- **Industry Focused Cloud Ecosystems:** Industry clouds must be expanded by providing pre built environments. Prebuilt environment can be integrated with data sharing tools. Prebuilt environment are helpful for finance, public sector and health care.
- **Domain Specific Hardware with Arm Based Architecture:** Cloud to have high performance and to deliver energy efficient a domain specific hardware with arm based architecture, AI accelerators and GPU equipped servers are required.
- **Decentralized Cloud with Blockchain Integration:** By integrating decentralized cloud and block chain technology enables cloud with more resilient, low cost and private.
- **Edge Computing Powered by 5G and going Beyond:** Edge computing powered by 5G and 6G will reshape the architecture of cloud in many ways like intelligence at edge, low latency, distributed, seamless edge security, efficiency and privacy.

Upcoming Challenges for New Prospects

Future or new prospects of clouds have to face lot of upcoming critical challenges despite of many improvements and advantages. First, scalability and resilience must aid bursting AI driven requirement. Server workload in the form of rack now supports 40–100 kW each which requires advanced cooling system, dynamic power control and scaling modular data centers must be practice. Second, environmental sustainability is crucial. IT data centers already utilizeup to 1–2 % of global electricity and which gives rise to water use, greenhouse gases are generated, and lot of electronic waste is generated. To overcome it renewable energy with neutral carbon must be adopted, efficient hardware must be used and minimize the waste and maximize the resource usage. Third, vendor lockin and interoperability creates problems. Trapping of the data and tracing workflows, changing costs and reducing the flexibility can be performed by proprietary holders. So, to overcome it open standards and hybrid system must be adopted. Fourth, as sharing models are used the protection against virtual layer attacks and cross border data must be consider for that security, privacy, and regulation related latest and advanced strategies must be implemented. Finally, the rise of explosive edge computing data is increasingly processed closer to users which create challenge for new latency, data bandwidth and distributed management.

Conclusion and Future Work

Now a day's cloud computing is not an option its compulsory. Cloud computing is a new model for providing online services through internet. The present IT companies are looking ahead towards cloud computing implementations with latest trends. In coming up future IT companies will integrate with cloud computing implementation and have a bright future which provides scalability and efficiency. Not only the IT companies but individuals are also looking towards cloud computing implementation in their daily work activities. Selecting of best or appropriate cloud setup is most crucial task. To select appropriate cloud service and to avail its benefits we have to know about cloud services and providers, design, trends, new prospects and challenges. The cloud services allow us to know the different type of services (IaaS, PaaS, SaaS) which are available to us by different cloud service providers (Google, Microsoft, Amazon so on). The cloud design helps to understand the complete structure and working of cloud. Cloud trends help to know the current technologies available in cloud. The new prospects and challenges of clouds lets to know the coming up future trends and challenges of clouds. The mentioned new prospects or methodologies must be practice or implement by cloud to get more benefits.

In future the detailed study of new methodologies or prospects have to be done and its accuracy must be calculated and must compare with previous trends.

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