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Into the Clouds and Beyond: Evolution of Cloud Technologies

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Abstract: *Cloud computing is a transformative paradigm in the realm of computing and technology, offering scalable and on-demand access to computing resources over the internet. This paper provides an insightful exploration into cloud computing, covering its architecture, service models, deployment models, security considerations, and scalability. Furthermore, the paper delves into contemporary technologies, emerging trends, and real-world applications, presenting a holistic understanding of this dynamic and evolving domain. Understanding and harnessing the potential of cloud computing is vital for organizations seeking efficiency, agility, and innovation in the digital age. Understanding and harnessing the potential of cloud computing is imperative for organizations striving for enhanced efficiency, agility, and innovation in the ever-evolving digital landscape.*

Keywords: *Cloud computing*

I. INTRODUCTION

Cloud computing has emerged as a transformative and pervasive technology that is fundamentally altering the landscape of modern information technology and business operations. It represents a paradigm shift in how computing resources are accessed, provisioned, and utilized. The term "cloud" metaphorically refers to a vast and interconnected network of computers, servers, and data centers accessible over the internet, providing a diverse range of services and capabilities to users and organizations. At its core, cloud computing offers a dynamic and scalable model for delivering computing services, including computing power, storage, and applications, as services over the internet.

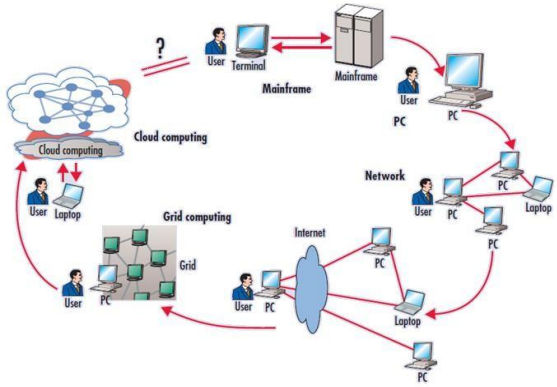

Figure 1. Evolution of Various Computing Models

II. EVOLUTION OF COMPUTING MODELS

In early 1950s, programmers were having limitation in the form of batch files, in which complete jobs were submitted on the punch cards and operators were supposed to run it on a complex computer hardware consisting of power consuming mechanical relays, transistors, vacuum electronic I/O devices. Multi-programmed, batched systems were introduced to effectively utilize various system resources which then extended into time sharing systems in which CPU executes multiple jobs for several users switching among them. In time sharing system, now group of people, mainly

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programmers, could interact with computer, so it was significant milestone in interactive use of computer. In Time sharing systems, programmers were interacting with the computer using the terminals attached to the mainframes using a command line interface. Command line interface is the mechanism by which one can interact with computer system to operating system software on computer, by typing a textual command. A predefined set of instructions or commands are defined. One has to type there commands to perform specific tasks. Once the command is entered, its validity is checked and the corresponding task gets executed. The programmer could now collaborate with the computer in a more reactive and spontaneous manner within the limits of command language, increasing the information processing throughput and programmer's productivity. Mainframe computers are large, powerful computers that are usually used in big organizational settings. The application of mainframe computers include the processing of voluminous data as required for resource planning, census statistics, industry and consumer statistics and large financial transactions. The mainframes we use today date back to April 7, 1964, with the announcement of the IBM System/360™. System/360 was a revolutionary step in the development of the computer for many reasons, including the following:

- System/360 could do both numerically intensive scientific computing and input/output intensive commercial computing.
- System/360 was a line of upwardly compatible computers that allowed installations to move to more powerful computers without having to rewrite their programs.
- System/360 utilized dedicated computers that managed the input/output operations, which allowed the central processing unit to focus its resources on the application.
- These systems were short on memory and did not run nearly as fast as modern computers. For example, some models of the System/360 were run with 32K (K, as in 1,024 bytes) of RAM, which had to accommodate both the application and the operating system. Hardware and software had to be optimized to make the best use of limited resources.

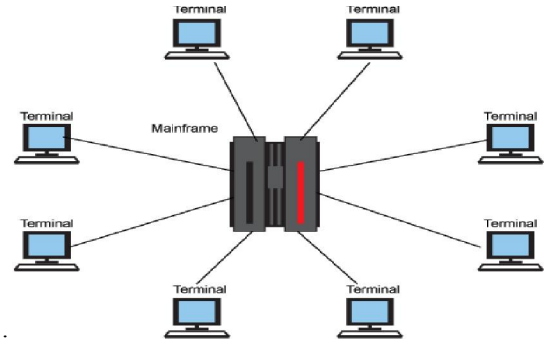

Figure 2. Mainframe Architecture

Personal Computing (PC)

Personal Computing systems considerably smaller and less expense then Mainframe Systems and more suitable for typical office environments and necessary for every personal executive. Traditionally executively were used to setting on a desk performing several tasks by using a set of tools spread on the top of the desk. Soon a personal computer starting occupying an important place on an executive's desk and all other tools on the desk including the time-clock become the part of the desktop interface of the PC. In Personal Computing, interaction focused on addressing the single user engaged in a dialog with the computer in order to carry out a series of tasks. Humans are by nature multitasking as they can think about more than one think at a time. They can effortlessly switch between tasks and have ability to carry out the task irrespective of series of external interrupts. The rise of the personal home computer has driven the need for employers to keep up and provide personal computers in the work place too.

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Figure 3. PC Computing from Desktop to Tablet PC

Network Computing

In the world of computers, networking is the practice of linking two or more computing devices together for the purpose of sharing data. Networks are built with a mix of computer hardware and computer software. Networks can be categorized in several different ways. One approach defines the type of network according to the geographic area it spans. Local area networks (LANs), for example, typically reach across a single home, whereas wide area networks (WANs), reach across cities, states, or even across the world. The Internet is the world's largest public WAN. Computer networks also differ in their design. The two types of high-level network design are called client-server and peer-to-peer. Client-server networks feature centralized server computers that store email, Web pages, files and or applications. On a peer-to-peer network, conversely, all computers tend to support the same functions. Client-server networks are much more common in business and peer-to-peer networks much more common in homes. Another way to classify computer networks is by the set of protocols they support. Network Protocols are the communication language used by computer devices. Networks often implement multiple protocols to support specific applications. Popular protocols include TCP/IP, the most common protocol found on the Internet and in home networks

Client-Server

As personal computers and laptops become cheaper, organizations started to replace their mainframe terminals with PCs linked together in a network. At the heart of the network of PCs (clients) is a server (which might be a mainframe or a powerful PC) which stores some of the data, applications software and other instructions that the network users need in order to communicate and process transactions on the network. There are different types of servers. A web server provides web pages to users, an application server assigns specific tasks to other servers to enable a faster more efficient response to client requests than a single mainframe trying to do everything.

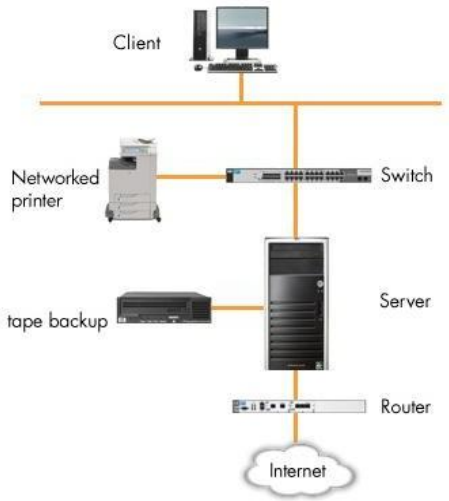

Figure 4. High level view of client server Model

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Large organizations use a multi-tiered client/server architecture that has several different levels of servers. Client/server computing systems are comprised of two logical parts: a server that provides services and a client that requests services of the server. Together, the two form a complete computing system with a distinct division of responsibility. Clients serve as the consumers in a client/server system. That is, they make requests to servers for services or information and then use the response to carry out their own purpose. The server plays the role of the producer, filling data or service requests made by clients. Client/server computing has gained popularity in the recent years due to the proliferation of low-cost hardware and the increasingly apparent truth of the theory that a model relying on monolithic applications fails when the number of users accessing a system grows too high or when too many features are integrated into a single system.

Internet Computing

The Internet is the massive network of networks connects millions of computers together worldwide, forming a network in which any computer can communicate with any other computer provided that they are both connected to the Internet. The World Wide Web (WWW), or simply Web, is a way of accessing information over the medium of the Internet. WWW consists of billions of web pages, spread across thousands and thousands of servers all over the world. It is an information-sharing model that is built on top of the Internet. The most well-known example of a distributed system is the collection of web servers. Hypertext is a document containing words that bond to other documents in the Web. These words are known as links and are selectable by the user. A single hypertext document can hold links to many documents.

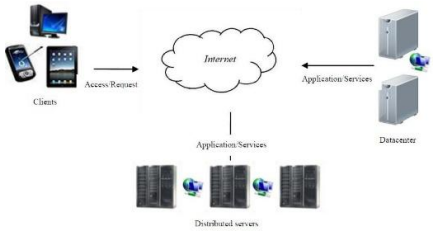

Figure 5. High Level Architecture of Internet Computing

Grid Computing

The aim of Grid computing is to enable coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations. An infinite number of computing devices ranging from high performance systems such as supercomputers and clusters, to specialized systems such as visualization devices, storage systems, and scientific instruments, are logically coupled together in a Grid and presented as a single unified resource to the user.

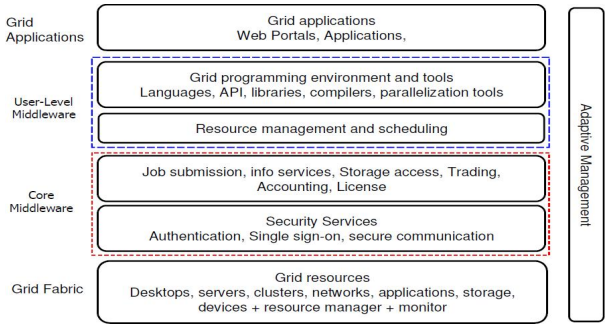

Figure 6. Grid Computing Architecture

Figure 3 shows that a Grid user can easily use these globally distributed Grid resources by interacting with a Grid resource broker. Basically, a Grid user perceives the Grid as a single huge virtual computer that provides immense computing capabilities, identical to an Internet user who views the World Wide Web as a unified source of content.

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III. CLOUD COMPUTING

There are a number of service offerings and implementation models under the cloud computing umbrella. The NIST definition of cloud computing defines three delivery models

- Software-as-a-Service (SaaS)
- Platform-as-a-Service (PaaS)
- Infrastructure-as-a-Service (IaaS)

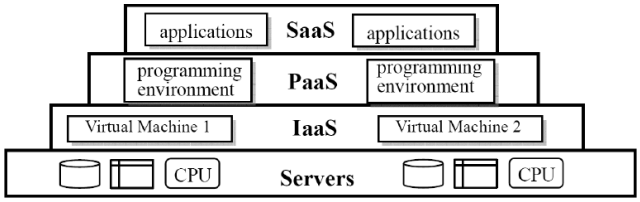

Figure 7. Different Layers of Cloud Computing

Delivery Models for Cloud Computing

- Cloud computing providers can offer services at different layers of the resource stack, simulating the functions performed by applications, operating systems, or physical hardware.
- Software as a Service (SaaS): It offers finished applications that end users can access through a thin client (typically, but not necessarily, a web browser). Prominent examples of SaaS include Gmail, Google Docs, and Salesforce.com. The end user does not exercise any control over the design of the application (aside from some minor customization and configuration options), servers, networking, and storage infrastructure.
- Platform as a Service (PaaS): It offers an operating system as well as suites of programming languages and software development tools that customers can use to develop their own applications. Prominent examples include Microsoft Windows Azure and Google App Engine. PaaS gives end users control over application design, but does not give them control over the physical infrastructure.
- Infrastructure as a Service (IaaS): It offers end users direct access to processing, storage and other computing resources and allows them to configure those resources and run operating systems and software on them as they see fit. Examples of IaaS include Amazon Elastic Compute Cloud (EC2), Rackspace, and IBM Computing on Demand..

IV. CLOUD COMPUTING ENABLING TECHNOLOGIES

- Virtualization
- Web 2.0
- World-wide distributed storage system
- Distributed Computing
- Grid Computing
- Utility Computing
- Network Bandwidth & Latency
- Fault - Tolerant Systems
- Programming Models

A number of enabling technologies contribute to Cloud computing which are described below in details here

Virtualization technology: Virtualization technologies partition hardware and thus provide flexible and scalable computing platforms. Virtual machine techniques, such as VMware and Xen offer virtualized IT-infrastructures on demand. Virtual network advances, such as VPN support users with a customized network environment to access Cloud resources. Virtualization techniques are the bases of the Cloud computing, since they render flexible and scalable hardware services. Hardware virtualization is a technology that organizations are widely adopting to enable better

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utilization for available computing resources. Virtualization is accomplished by offices/departments. Implementers will need to learn how to use resources and services of selected provider(s).

Web 2.0: Web 2.0 is an emerging technology describing the innovative trends of using World Wide Web technology and Web design that aims to enhance creativity, information sharing, collaboration and functionality. The essential idea behind Web 2.0 is to improve the interconnectivity and interactivity of Web applications. The new paradigm to develop and access Web applications enables users access the Web more easily and efficiently. Cloud computing services in nature are Web applications which render desirable computing services on demand. It is thus a natural technical evolution that the Cloud computing adopts the Web 2.0 technique.

Web service and SOA: Computing Cloud services are normally exposed as Web services, which follow the industry standards such as WSDL,33, SOAP28) and UDDI.26). The services organization and orchestration inside Clouds could be managed in a Service Oriented Architecture (SOA). A set of Cloud services furthermore could be used in a SOA application environment, thus making them available on various distributed platforms and could be further accessed across the Internet.

The idea of SOA is to turn functionalities of both existing and new applications into a set of granular components. SOA has encouraged software vendors to offer their products as services that clients can use/reuse and compose together to fulfill business requirements in an agile manner. This agility applies to cloud computing as well making it easier to access available hardware and software resources

Distributed Computing: A distributed data system which provides data sources accessed in a semantic way. Users could locate data sources in a large distributed environment by the logical name instead of physical locations. Virtual Data System (VDS) is good reference.

Grid Computing: A distributed computing model that tends to gather underutilized computing resources available in organizations to process computing-intensive tasks faster. This model has given organizations like Amazon the idea to lease unused resources (both processing units and storage) to clients in need of them.

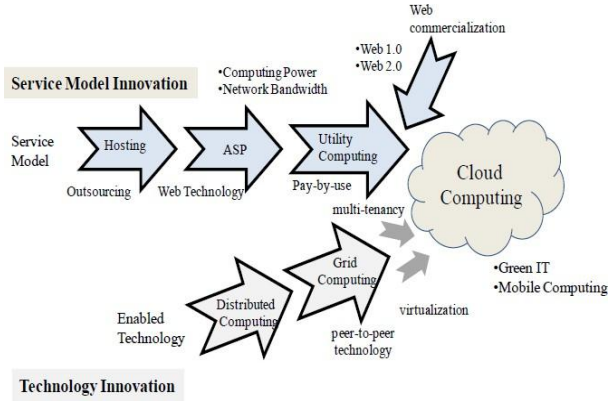

Figure 08. Evolution of Cloud Computing

Utility Computing:

Utility computing represents the desire to have it acquired, delivered, used, paid for, and managed in a manner similar to how we use other commoditized utilities such as electricity, telephone service, cable television, etc. The principal appeal of utility computing lies in the systematized framework it could create for the interaction between providers and consumers of it resources. One of the foundational features of a utility is accounting the ability of both the provider and the consumer to accurately measure the usage of the commodity being exchanged. Accurate resource accounting is desirable for a variety of important reasons, ranging from billing and auditing to effective resource allocation, anomaly detection and resolution.

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Network Bandwidth & Latency:

Bandwidth, sometimes known as throughput, is often defined as the rate at which data is transmitted over a network. It is described in bits per second and represents the capacity of the connection. The higher the capacity, the better the performance subject to other factors such as latency. Cloud computing service providers calculate customer bandwidth requirements by taking into account the amount of available bandwidth and the average bandwidth utilization required by different kinds of applications. They also take into consideration latencies in transmission while computing the time it will take to upload the initial backup and all subsequent backups. Online backup and cloud service providers try to optimize Internet bandwidth in a number of ways.

Fault - Tolerant Systems:

A fault-tolerant system may be able to tolerate one or more fault-types including transient, intermittent or permanent hardware faults, software and hardware design errors, operator errors, or externally induced upsets or physical damage. An extensive methodology has been developed in this field over the past thirty years, and a number of fault-tolerant machines have been developed and most dealing with random hardware faults, while a smaller number deal with software, design and operator faults to varying degrees. Fault tolerance is a major concern to guarantee availability and reliability of critical services as well as application execution. In order to minimize failure impact on the system and application execution, failures should be anticipated and proactively handled. Fault tolerance techniques are used to predict these failures and take an appropriate action before failures actually occur.

Programming models:

Users drive into the computing Cloud with data and applications. Some Cloud programming models should be proposed for users to adapt to the Cloud infrastructure. For the simplicity and easy access of Cloud services, the Cloud programming model, however, should not be too complex or too innovative for end users. The MapReduce is a programming model and an associated implementation for processing and generating large data sets across the Google worldwide infrastructures. The MapReduce model firstly involves applying a ―map‖ operation to some data records – a set of key/value pairs, and then processes a ―reduce‖ operation to all the values that shared the same key. The Map-Reduce- Merge35) method evolves the MapReduce paradigm by adding a ―merge‖ operation. Hadoop25) is a framework for running applications on large clusters built of commodity hardware. It implements the MapReduce paradigm and provides a distributed file system – the Hadoop Distributed File System. The MapReduce and the Hadoop are adopted by recently created international Cloud computing project of Yahoo!, Intel and HP.

V. CONCLUSION

The version of this template is V2. Most of the formatting instructions in this document have been compiled by Causal Productions from the IEEE LaTeX style files. Causal Productions offers both A4 templates and US Letter templates for LaTeX and Microsoft Word. The LaTeX templates depend on the officialIEEEtran.cls and IEEEtran.bst files, whereas the Microsoft Word templatesare self-contained.

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