

Beyond the Clouds: Reinventing the Future of Intelligent Computing

Edited by

Sourav Saha
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Swami Vivekananda University

Published by

Penprints
India

*Beyond the Clouds: Reinventing the Future of Intelligent
Computing*

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Published by Penprints

Official Address: P-925, Lake Twon, Block - A, Kolkata-700048,
West Bengal, India.

Phone no-8697875467

Website - www.penprints.in

Copyright - Swami Vivekananda University

Cover - ©PENPRINTS

Price: INR 500 | \$22

First Edition - 2025

ISBN: 978-81-999560-8-7

ISBN 10 : 81-999560-8-9

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Printer: S. P. Communications Pvt. Ltd. 1st Floor, Merlin Marigold, 31B, Raja
Dinendra St, Yogi Para, Garpar, Machuabazar, Kolkata, West Bengal 700009

Acknowledgement

For the successful completion of this edited volume, we are most indebted to the vision of our Hon'ble Chancellor, Dr. Nandan Gupta, the inspiration of our Hon'ble Vice-Chancellor Professor (Dr.) Subrata Kumar Dey, the support of our Chief Operating Officer, Shri Saurabh Adhikari, the guidance of our Chief Executive Director (Academics), Professor (Dr.) Deb Narayan Bandyopadhyay, and the co-operation of our Registrar, Professor (Dr.) Pinak Pani Nath.

We would also like to extend our heartfelt gratitude to all the concerned faculty members of Swami Vivekananda University, the contributors and collaborators, who have played an active part in the realization of this book.

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A New Cloud Computing Solution for Government Hospitals to Better Access Patients' Medical Information

Ranjan Kumar Mondal

Abstract

In this paper, we are proposing a new cloud computing solution for government hospitals of 3rd world countries to better access patient's medical information. Existing system is based on manual paper work and independent standalone applications in some districts'/ small towns' hospitals which results in waste of resources, high construction and maintenance costs and difficult to manage and maintain. The main objective of proposing cloud based solution is to reduce the cost (construction and maintenance), to reduce data loss risk, to gather all the government hospitals on one platform to better access patients' medical information for easy management and maintenance. The proposed cloud computing solution is intended to be used by government hospitals of 3rd world countries; however the solution is generic and can be used by government hospitals of any country and the community based hospitals.

Keywords: Cloud computing, Data access, Hospital Information System, patients' medical information

Introduction

Significant improvement in Science and Technology has changed our lives and our life styles. Cloud computing, Big data, and Data mining are the hottest topics or research areas in the field of Information Technology. Researchers are focusing these areas for better improvement. A simple example of data mining can be predicting student success as given in [1].

In contrast to the above improvement, health care services are improving and hospitals are continually improving their

services. The Government of 3rd world countries is trying to continuously improve healthcare services by computerizing the hospitals' whole system through their Ministry of Health. Nowadays most of the hospitals are managing their operations and medical information through Hospital Information System (HIS).

A typical HIS system can have the following sub systems or modules and can have more:

Information security has always been a big issue as the number of malware/ malicious attacks is increasing regardless the improvement in the area of information security. The network connection (internet) is never thought of and realized as an effective and most safe connection. Due to the lack of proper technology (safe internet) government hospitals has established independent and standalone HIS systems in some districts / small towns. These independent standalone HIS systems require high construction and maintenance cost; hence the information sharing is a big issue. The main objective of the paper is to reduce this high cost and to provide a better way for information sharing between government hospitals of different districts/ towns.

Our research paper is organized as follows: In Section 2 we describe the problematic issues of existing HIS and motivation of our research work. Section 3 is about the background of Cloud computing. A new cloud computing solution is proposed in Section 4. We have concluded our research work in Section 5



Figure 1.1. HIS System

2. Motivation

As described above, the current independent standalone HIS system only serves to the specific hospital of any specific district/small town. These independent HIS systems have raised some major problematic issues that are hard to avoid.

2.1. Data Sharing

Currently, most of the hospitals (either district hospital or town hospital) are maintaining patients' medical information and some staff management operations manually (on papers); however some of the hospitals have their own independent standalone HIS system. This creates a high risk for data loss and the problematic issues in data sharing. The main problematic issue is that the patients could not seek proper treatment in any hospital of the other district or town because of the existing independent information systems due to lack of data sharing.

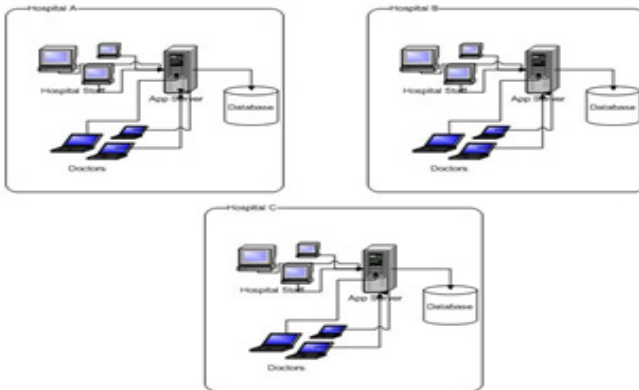


Figure 2.1. Individual HIS systems

2.2. High Construction and Maintenance Cost

A whole information system setup cost usually takes the hardware (equipments including servers and client computers) cost, software development, testing and maintenance cost in account. Current independent standalone HIS systems are very much expensive to setup and just to facilitate specific hospitals of specific districts/towns. Government of all

3rd world countries bears the burden of these independent standalone systems; although this money can be invested on improvement of healthcare services.

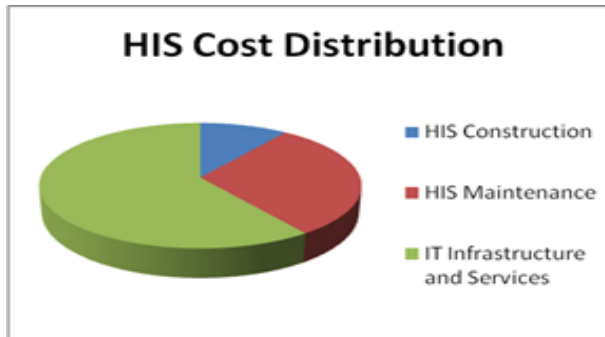


Figure 2.2. HIS Cost Distribution

2.3. Management, Upgrades and Maintenance

Setting up an information system has never been a big issue; however managing, upgrading and maintaining the information system have always been a big concern. Existing independent standalone HIS systems are hard to manage, upgrade and maintain; as for different hospitals in different districts/towns, separate management and maintenance is required.

However, management and maintenance process requires continuous investment including technical skills, proper users and experts. Upgrading the current information system has also been a big issue as the user needs/requirements are changing with time to time. This is same in hospitals as different hospitals produce different individual

needs/requirements for upgrading the current HIS system. The work regarding HIS technical services is carried out in [2].

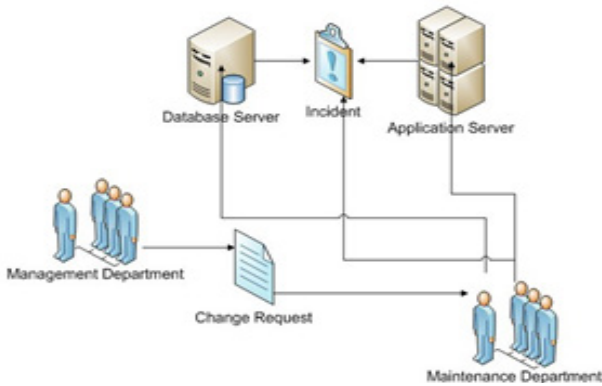


Figure 2.3. Management and maintenance resources

2.4. Resources Wastage

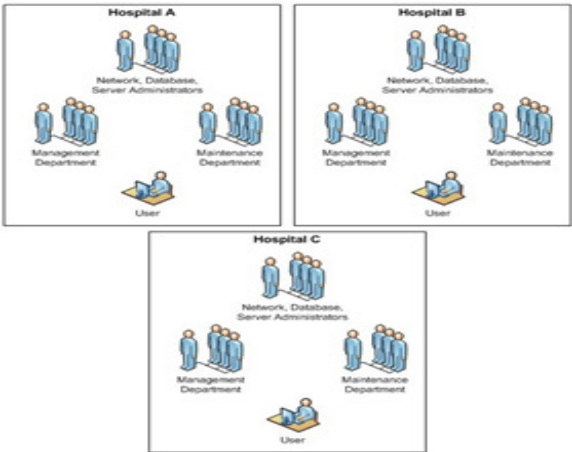


Figure 2.4. Resource wastage

As existing independent standalone HIS systems serve for specific hospitals, there is a lot of wastage of resources.

There is separate management and maintenance department in each hospital including separate network administrators, database administrators and server administrators.

3. Cloud Computing

Cloud computing remains the focusing area since past few years. Cloud computing is basically a network (internet) based innovative model and is referred as platforms, infrastructure and software sold as a service. The main objective or goal of cloud computing is to reduce the infrastructure cost burden from the organizations. In addition to this, it offers organizations better performance, security and less maintenance cost.

Depending on the definition described above, cloud computing has the three types as illustrated in figure.

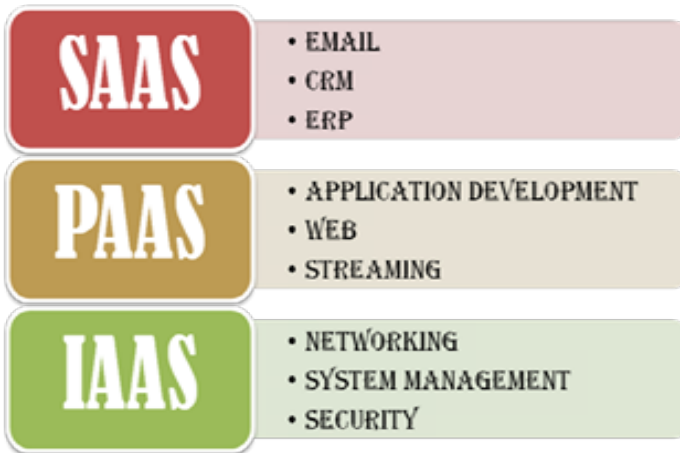


Figure 3.1. Cloud computing types

Cloud computing is being promoted by many of the large companies. In cloud computing a program or application can be run on many computers. Cloud has become the essential necessity to survive in the market, that's the reason for most of the companies to move towards the cloud. In [3,4,5] an extended work is carried out.

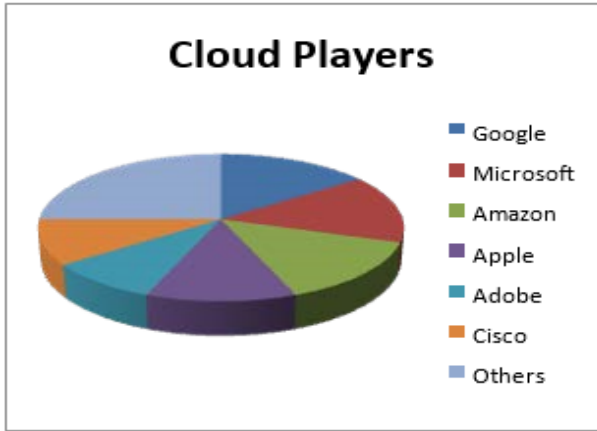


Figure 3.2. The cloud players

3.1. Cloud Computing in Medical Aspects

Cloud computing is growing in almost every field including healthcare services providing a new and better way to incorporate the foregoing problems. Some related research work is as under:

1. In [6], the cloud computing model is proposed to share the critical disease and critical cases information among the doctors of the different countries to improve the treatment.
2. Moreover the work in [7] is related about the cloud computing in medical aspects.

4. Proposed New Cloud Computing Solution

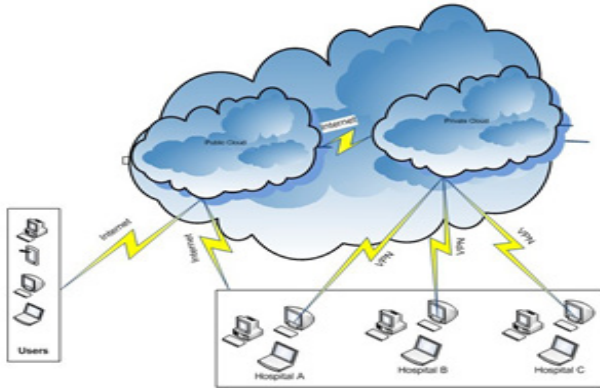


Figure 4.1. Cloud based HIS

Our proposed new cloud computing solution is hybrid cloud deployment model. Hybrid cloud model contains the Private cloud which facilitates the hospitals of the different districts/ towns to manage the important information regarding patient's medical history, laboratory reports, some critical diseases/cases, treatment/ prescription details etc. On the other hand hybrid cloud model also contains public cloud to facilitate some normal management (such as staff) and also facilitates the outside users for appointment and viewing laboratory reports etc.

5. Conclusion

We have proposed a new cloud computing solution for the government hospitals of 3rd world countries to better access patient's medical information. Cloud based HIS facilitates the experienced doctors to better diagnose the patients. Cloud computing solution offers major practical advantages such as reduced construction, maintenance and up gradation cost. The security risk can be removed by deploying hybrid cloud model. The proposed model is for government hospitals of 3rd world countries; however it can also be adopted by community hospitals to save the cost issues and spent that amount of money in improvement of other healthcare services.

Green Computing in Cloud Infrastructures: A Comprehensive Analysis of Environmental Sustainability and Energy Efficiency

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Abstract

This manuscript explores the intersection of cloud computing and environmental sustainability, focusing on the emerging field of green computing. As the demand for cloud services continues to rise, it becomes imperative to assess and enhance the environmental sustainability and energy efficiency of cloud infrastructures. This comprehensive analysis investigates various strategies, technologies, and best practices aimed at mitigating the environmental impact of cloud computing while optimizing energy consumption.

Introduction (Heading 1)

The goals of green computing are similar to green chemistry: reduce the use of hazardous materials, maximize energy efficiency during the product's lifetime, increase the recyclability or biodegradability of defunct products and factory waste. In the intricate landscape of modern technological ecosystems, the concept of green computing emerges as a beacon of sustainable innovation. From the compact confines of handheld devices to the sprawling expanses of colossal data centers, its significance resonates across diverse spectra of systems. Within the hallowed

corridors of corporate IT domains, green computing initiatives stand as stalwart guardians, steadfastly committed to mitigating the environmental ramifications inherent in the operation of digital infrastructures. Indeed, the weight of this environmental imperative looms large, casting a shadow over the collective consciousness of the industry. Statistics paint a stark portrait, revealing the staggering reality that the sector's environmental footprint extends far beyond mere abstraction. A formidable 5-9% of the world's total electricity consumption finds its voracious appetite satiated within the hungry maw of technological infrastructure, while more than 2% of all emissions bear witness to the profound impact of digital prowess. Amidst this labyrinthine tapestry of challenges and imperatives, the clarion call for transformation reverberates with unyielding urgency. Data centers, those hulking behemoths of digital prowess, and the sprawling networks of telecommunications infrastructure must heed the call to arms. The imperative is clear: a paradigm shift towards energy efficiency, the judicious repurposing of waste energy, and a steadfast embrace of renewable energy sources shall serve as the cornerstone of their endeavors.

For in the crucible of competition, where the fires of innovation burn brightest, survival hinges upon adaptability and foresight. The mantle of leadership shall be donned by those who dare to tread the path less traveled, those who dare to reimagine the contours of technological progress through the prism of sustainability. In the relentless march towards a greener tomorrow, the trajectory of progress finds its course charted by the guiding principles of green computing. Some believe they can and should become climate neutral by 2030. In recent years, the rapid proliferation of cloud computing technologies has led to a significant transformation in the way businesses and individual's access and utilize computing resources. While the cloud offers unparalleled flexibility and scalability, the environmental impact and energy consumption associated with large-scale data centers have raised concerns about sustainability. This research journal explores the intersection of green computing, cloud infrastructures, and environmental sustainability, aiming to provide a comprehensive analysis of energy-efficient practices

within cloud computing environments. The overarching goal of this study is to examine the various strategies and technologies implemented in cloud infrastructures to mitigate the environmental footprint and enhance energy efficiency.

With the increasing demand for computing resources and the escalating environmental challenges, understanding and implementing sustainable practices in cloud computing have become imperative. The seminar report on “GREEN COMPUTING IN CLOUD COMPUTING” is outcome of guidance, moral support and devotion bestowed on me throughout my work.

In the realm of content creation, we delve into the intricate dance of perplexity and burstiness, two quintessential pillars shaping the essence of textual expression. Embarking on this voyage, I extend my heartfelt gratitude, an ethereal tapestry woven with threads of appreciation, to all those who’ve served as beacons of inspiration throughout the labyrinthine corridors of seminar preparation. Foremost among these luminaries stands Mr. Ranjan Sir, a paragon of wisdom and custodian of knowledge, whose benevolent guidance and unwavering support have illuminated the path of my seminar endeavor. As lecturer and Head of Department in the hallowed halls of MCA at Swami Vivekananda University, Barrackpore, his eminence radiates across the intellectual landscape, casting shadows of profundity and enlightenment.

Words, however, fail to encapsulate the depth of gratitude that permeates my being, as I find myself entwined in the embrace of Institute’s nurturing bosom. A symphony of appreciation resonates, echoing through the corridors of academia, for the enriching ambiance and the harmonious synergy of the work environment bestowed upon me. Thus, in this tapestry of acknowledgment and appreciation, I find myself humbled by the magnitude of support and care bestowed upon me. With each stroke of gratitude, I traverse the labyrinth of indebtedness, guided by the beacon of communal benevolence and camaraderie.

II. Green Computing

Green computing in cloud computing refers to the practice of designing, using, and managing computing resources in an environmentally friendly and energy-efficient manner. It involves optimizing data centers and cloud infrastructure to minimize energy consumption, reduce electronic waste, and lower the overall environmental impact. Green computing in the context of cloud computing emphasizes the adoption of energy-efficient hardware, virtualization, renewable energy sources, and other sustainable practices to make data processing and storage more eco-friendly.



Figure-1: Green computing model

III. Environmental impact of cloud computing

Cloud computing has become an integral part of our digital infrastructure, offering numerous benefits such as scalability, flexibility, and cost efficiency. However, it also comes with environmental implications. Here are some key factors contributing to the environmental impact of cloud computing:

A. Energy Consumption:

Data centres, which form the backbone of cloud computing, require a significant amount of energy to operate and cool the servers. The energy demand is driven by the massive scale and continuous operation of these facilities.

- The energy mix used by data centres plays a crucial role. If a data center relies heavily on fossil fuels, it can have a higher carbon footprint compared to facilities powered by renewable energy sources.

B. Carbon Emissions:

The energy consumption of data centers contributes to carbon dioxide (CO₂) emissions, which are a major factor in climate change. The carbon intensity depends on the energy sources used by the data centers.

C. E-Waste:

Rapid technological advancements lead to the frequent replacement of hardware in data centers. The disposal of obsolete or damaged equipment contributes to electronic waste (e-waste) if not handled properly. E-waste contains hazardous materials that can harm the environment if not managed responsibly.

D. Resource Extraction

The production of electronic components requires the extraction of raw materials, contributing to habitat destruction, water pollution, and other environmental issues. This includes the mining of metals such as gold, silver, and rare earth elements used in servers and other hardware.

E. Server Utilization and Efficiency

Inefficient use of server resources, such as low server utilization rates, can result in wasted energy. Optimizing resource allocation and improving server efficiency can help reduce the environmental impact.

F. Renewable Energy Adoption

The adoption of renewable energy sources, such as solar or wind power, by cloud providers is a critical factor in mitigating the environmental impact. Many companies are making efforts to increase the share of renewables in their energy mix.

G. Regulatory Compliance and Industry Standards

Adherence to environmental regulations and industry standards can influence the environmental practices of cloud service providers. Governments and organizations are increasingly focusing on sustainability in data center operations.

Efforts are underway within the industry to address these environmental concerns. Cloud providers are investing in more energy-efficient technologies, using renewable energy, and adopting sustainable practices to minimize their environmental footprint. As technology continues to evolve, ongoing efforts to improve efficiency and sustainability will be essential in reducing the environmental impact of cloud computing.

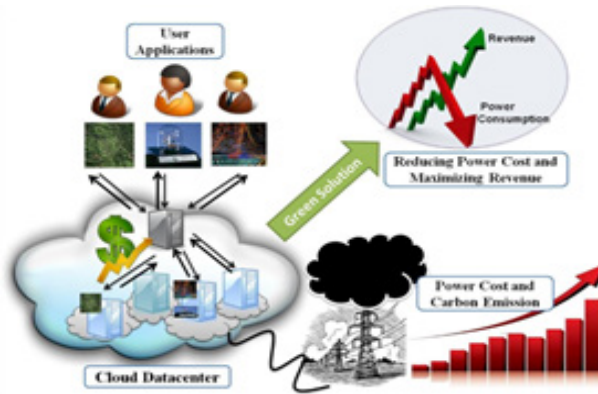


Figure-2: Environments impact

IV. Analysing energy consumption on green cloud computing

Green cloud computing refers to the practice of using computing resources in an environmentally responsible and energy-efficient manner. Analyzing energy consumption in green cloud computing involves assessing various aspects of data centers, hardware, software, and operational practices. Here are key points to consider:

A. Data Center Infrastructure

1. *Energy-Efficient Hardware:* The use of energy-efficient servers, storage, and networking equipment is crucial. Modern hardware designs often focus on optimizing power consumption without compromising performance.
2. *Cooling Systems:* Efficient cooling systems, such as free-air cooling or liquid cooling, can significantly reduce the energy required for maintaining optimal temperatures in data centers.

B. Renewable Energy Sources

Power Supply: Integration of renewable energy sources like solar, wind, or hydropower for powering data centers helps reduce the carbon footprint associated with electricity consumption.

C. Virtualization and Resource Consolidation

1. *Server Virtualization:* Consolidating multiple virtual servers onto a single physical server can reduce the number of active servers, leading to energy savings.
2. *Dynamic Resource Allocation:* Implementing systems that dynamically allocate resources based on demand can optimize energy consumption by adjusting the infrastructure to meet actual needs.

D. Energy-Aware Software

1. *Optimized Algorithms:* Developing and using energy-efficient algorithms can minimize computational requirements and reduce overall energy consumption.
2. *Load Balancing:* Efficient load balancing ensures that workloads are distributed evenly across servers, preventing the unnecessary operation of underutilized hardware. Consumption.

E. Monitoring and Management

1. *Energy Monitoring Tools:* Implementing monitoring tools to track energy consumption in real-time allows data center operators to identify inefficiencies and make informed decisions to optimize resource usage.
2. *Energy Management Policies:* Establishing and enforcing policies that prioritize energy efficiency in the data center's day-to-day operations.

F. Lifecycle Management

End-of-Life Recycling: Proper disposal and recycling of outdated hardware components help minimize environmental impact and promote sustainable practices.

G. Regulatory Compliance and Certification

1. *Compliance*: Adhering to industry standards and regulations related to energy efficiency ensures that cloud providers are accountable for their environmental impact.
2. *Certifications*: Seeking certifications such as ISO 14001 or the U.S. EPA's ENERGY STAR for Data Centers demonstrates a commitment to green practices.

H. User Awareness and Collaboration

1. *User Education*: Educating users on energy-efficient computing practices and encouraging responsible usage can contribute to overall energy savings.
2. *Collaboration*: Collaborating with other cloud providers and industry stakeholders to share best practices and promote green initiatives.

By addressing these aspects, organizations can create a more sustainable and energy-efficient cloud computing infrastructure, reducing the environmental impact associated with digital services.

V. Carbon foot printing

Green computing, also known as sustainable or eco-friendly computing, focuses on reducing the environmental impact of information technology (IT) systems and practices. One important aspect of green computing is addressing the carbon footprint associated with IT operations. The carbon footprint in green computing refers to the total amount of greenhouse gas (GHG) emissions, particularly carbon dioxide (CO₂), produced by the activities and processes related to computing and information technology.

Carbon foot printing in green computing, especially in the context of cloud computing, involves assessing and mitigating the environmental impact of computing activities. The carbon footprint is a measure of the total greenhouse gas (GHG) emissions, primarily carbon dioxide (CO₂), associated with a particular activity, product, or service. In the realm of green computing and cloud computing, the goal is to minimize these emissions and promote sustainability. Here's how carbon foot printing is relevant in this context:

A. Data Centers and Energy Consumption:

- 1) Measurement and Assessment: Carbon footprinting begins with measuring the energy consumption of data centers, which are crucial components of cloud computing infrastructure.
- 2) Renewable Energy Usage: Assessing the carbon footprint involves determining the percentage of energy sourced from renewable resources, such as solar or wind power.

B. Virtualization and Resource Optimization

- 1) Server Consolidation: Virtualization technologies enable running multiple virtual machines on a single physical server, reducing the number of servers needed and, consequently, the energy consumption.
- 2) Dynamic Resource Allocation: Smart resource allocation and de-allocation based on demand contribute to energy efficiency and lower carbon emissions.

C. Energy-Efficient Hardware and Technologies:

- 1) Energy Star Compliance: Choosing energy-efficient hardware, such as Energy Star-rated equipment, can help in reducing power consumption.
- 2) Green IT Practices: Implementing green IT practices, like using low-power processors and energy-efficient cooling systems, can further minimize the carbon footprint.

D. Cloud Service Providers' Initiatives:

- 1) Transparency and Reporting: Cloud service providers can transparently report their energy usage and carbon emissions, allowing users to make informed choices based on environmental impact.
- 2) Use of Renewable Energy: Cloud providers investing in and using renewable energy sources for their data centers contribute to a lower carbon footprint.

E. Carbon Offsetting:

- 1) Offset Programs: Some organizations engage in carbon offset programs, where they invest in projects that reduce or capture an equivalent amount of CO₂ to compensate for their emissions.
- 2) Certifications and Standards: Adhering to recognized standards and certifications, such as the Carbon Trust Standard, indicates a commitment to carbon reduction.

F. Lifecycle Assessment:

- 1) Full Lifecycle Analysis: Considering the entire lifecycle of hardware and software, from manufacturing to disposal, helps in understanding and mitigating environmental impacts.
- 2) E-waste Management: Proper disposal and recycling of electronic waste contribute to reducing the carbon footprint associated with end-of-life equipment.

G. Monitoring and Optimization:

- 1) Continuous Improvement: Regularly monitoring energy usage and optimizing systems based on performance and efficiency data is essential for ongoing carbon footprint reduction.

In conclusion, carbon foot printing in green computing within the realm of cloud computing involves a comprehensive approach, addressing energy consumption, hardware efficiency, renewable energy usage, and responsible end-of-life practices. Organizations and cloud service providers play a vital role in adopting sustainable practices and technologies

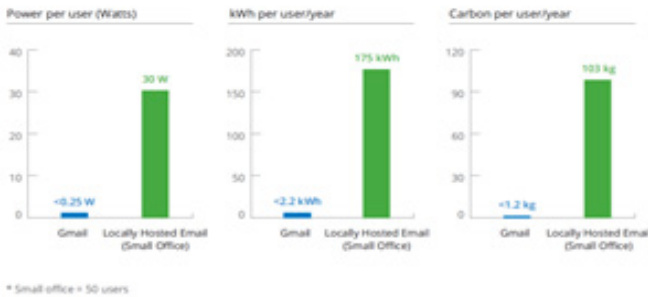


Figure-3: Carbon use per user/year

The Efforts Made By Cloud Service Providers To Adopt Sustainable And Eco-Friendly Practices.

Cloud service providers have been making significant efforts to adopt sustainable and eco-friendly practices in recent years. These efforts are driven by a growing awareness of the environmental impact of data centers and a commitment to reducing carbon footprints. Here are some of the key initiatives and practices implemented by cloud service providers

Cloud service providers have been making significant efforts to adopt sustainable and eco-friendly practices in recent years. These efforts are driven by a growing awareness of the environmental impact of data centers and a commitment to reducing carbon footprints. Here are some of the key initiatives and practices implemented by cloud service providers:

A. Renewable Energy Usage:

- Many cloud providers are investing heavily in renewable energy sources such as solar, wind, and hydroelectric power to meet their energy needs. They are either purchasing renewable energy directly or investing in projects that generate renewable energy.

B. Energy Efficiency Improvements:

- Cloud provider are constantly working to enhance the energy efficiency of their data centers. This includes using more energy-efficient hardware, optimizing cooling systems,

and adopting advanced technologies to reduce overall power consumption.

C. Carbon Offsetting:

- Some cloud service providers are actively involved in carbon offset programs. They invest in projects that capture or reduce the equivalent amount of carbon emissions to offset the emissions produced by their data centers.

D. Green Data Center Design:

- Providers are designing and constructing new data centers with sustainability in mind. This involves utilizing eco-friendly materials, implementing efficient cooling systems, and adopting innovative architectural designs to reduce environmental impact.

E. Circular Economy Initiatives:

- Cloud providers are increasingly exploring the concept of a circular economy by promoting the reuse and recycling of electronic equipment. This involves extending the lifespan of hardware, refurbishing equipment, and responsibly recycling electronic waste.

F. Transparent Reporting:

- Many cloud service providers are committed to transparency regarding their environmental impact. They publish annual sustainability reports that detail their energy consumption, carbon emissions, and progress toward eco-friendly goals.

G. Community Engagement and Advocacy:

- Cloud providers are engaging with local communities and industry stakeholders to promote sustainable practices. They also actively participate in industry groups and initiatives focused on advancing environmental sustainability in the technology sector.

H. Innovation in Green Technologies:

- Cloud providers are investing in and adopting innovative technologies that promote sustainability. This includes exploring new energy storage solutions, more efficient hardware designs, and advanced cooling technologies.

profundity and enlightenment.

Words, however, fail to encapsulate the depth of gratitude that permeates my being, as I find myself entwined in the embrace of Institute's nurturing bosom. A symphony of appreciation resonates, echoing through the corridors of academia, for the enriching ambiance and the harmonious synergy of the work environment bestowed upon me.

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Conclusion

In conclusion, the adoption of green computing principles in cloud infrastructures is imperative for mitigating the environmental impact and ensuring the long-term sustainability of the digital ecosystem. The recommendations provided in this research paper aim to guide stakeholders in implementing environmentally conscious practices, fostering innovation, and creating a more sustainable future for cloud computing.

By prioritizing green computing, the cloud computing industry can contribute significantly to global efforts aimed at reducing carbon emissions and creating a more environmentally sustainable IT infrastructure.

Keywords: *Green Computing, Cloud Computing, Environmental Impact, Energy Efficiency, Sustainability, Green Cloud Services, Renewable Energy, Virtualization, Data Centers*

Future Directions

I. Edge Computing and Green Initiatives

Exploring the integration of edge computing with green computing principles to optimize energy consumption at the edge of the network, reducing the need for centralized cloud data centers.

J. Machine Learning for Energy Optimization

Investigating the use of machine learning algorithms to predict and optimize resource utilization in real-time, enabling dynamic adjustments to energy consumption based on workload characteristics

K. Blockchain for Environmental Accountability

Examining the potential of blockchain technology to provide transparent and verifiable records of energy consumption and carbon emissions, fostering accountability and sustainability in cloud infrastructures.

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An Overview of Cloud Computing Uses in Intelligent Distribution Systems

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Abstract:

In light of the Smart Grid idea, distribution networks will see a significant metamorphosis over the following years to facilitate the development of a more durable, dependable, sustainable, affordable, and efficient system. Modernization can only be accomplished via the widespread application of information and communications technologies to integrate and control this system. In this sense, distributed data storage and parallel processing are two features envisaged as being made practical by cloud computing. This article presents an overview of the key connected works in the field and highlights the possible uses of cloud computing in innovative distribution systems. Along with the basics of cloud computing, it also describes the fundamental advances and technologies underpinning intelligent distribution systems.

1. Overview

The electric power system is the apparatus that produces, transmits, and distributes electricity to final users. Throughout the majority of the 20th century, there has been a steady growth in global energy consumption, necessitating deliberate planning to meet demand. In addition, utilities are attempting to address several issues, such as demand response, energy conservation, more efficient use of renewable energy, and decreased carbon emissions [1-4].

The notion of Smart Grid (SG) emerged to tackle these issues. With further integration of renewable energy sources, the

Smart Grid aims to be a more dependable, secure, affordable, efficient, and sustainable power infrastructure that enables end users to take a more active role in the energy market [5, 6]. Control, automation, and high use of facilities derived from Information and Communications Technologies (ICT) are required to accomplish these aims. In light of these technical advancements, strategic planning

Thus, the efficiency of the distribution system may be enhanced. Comparing the measuring devices—mostly electromechanical and eventually becoming digital—it is easy to see these advancements. These days, many of these gadgets have communication interfaces in addition to being digital. The data exchanged via these communication channels will be saved and examined to enable intelligent decision-making [7, 8].

It's crucial to note, nevertheless, that distribution networks serve as a "bottleneck" for SG, necessitating improvements to customer monitoring devices (which are now primarily electro-mechanical/standalone digital meters in poor nations). The fact that each feeder has many users raises severe concerns since the communication networks will have to send enormous amounts of data, which would result in heavy traffic. It will thus be necessary to store and analyze this massive quantity of data to make historical and decision-making decisions. Therefore, it will be crucial to have a scalable platform that can operate dependably with terabytes of data daily [9]. In this regard, cloud computing has emerged as a promising technology with solid performance [8,10].

Research has been done to identify potential uses cloud computing with the intelligent grid idea [11–16]. Furthermore, several studies aim to anticipate the difficulties associated with managing massive amounts of data, which might potentially be created during the installation of an intelligent grid [17, 18].

Accordingly, this study addresses specific trends and issues by providing an overview of the most essential publications correlating cloud computing with innovative distribution systems.

The purpose of Section 2 is to provide the reader with a better understanding of the Smart Grid idea. The influence of SGs on power distribution systems will be discussed in Section 3, along with the key elements that need to be implemented. An overview of cloud computing is given in Section 4. The main advancements and uses of cloud computing in intelligent distribution systems are covered in Section 5. Lastly, some debates and conclusions about this survey are included in Section 6.

2. GRID FOUNDATIONS SMART

The idea behind the so-called “smart grid” originated from the need to update the electricity system by combining the newest innovations in information technology, instrumentation, control, and communication.

The goal of global energy sector players to modernize electricity networks gave rise to the phrase “smart grid.” With cutting-edge computer and communication resources, this new system should be able to track the growth in energy demand, enhance power quality, decrease losses, and boost operational safety across the system via monitoring, automation, and control [5].

The concept of a “smart grid” is highly inclusive and immediately relates to national interests. As a result, no one definition has been accepted worldwide. For instance, the primary goals in the United States are to revitalize the country’s aging electricity systems, enhance customer satisfaction, provide employment opportunities, support business growth, and boost user involvement. In contrast, the primary goal in Europe is to increase the use of renewable energy sources and lessen reliance on fossil fuels to improve energy security.

“The Smart Grid is a grid system that integrates many varieties of digital computing and communication technologies and services into the power system infrastructure, enabling bidirectional flows of energy and two-way communication and control capabilities,” according to the National Institute of Standards and Technology (NIST) [19].

In the report of the European Smart Grids Task Force Expert Group 1 [20], a smart grid is defined as “an electricity network that can cost-efficiently integrate the behavior and actions of all users connected to it—generators, consumers, and those that do both—to ensure an environmentally efficient, sustainable power system with low losses and high levels of quality, security of supply, and safety.”

The Electric Power Research Institute (EPRI) website provides a shorter definition of an intelligent grid [21]: “A smart grid integrates information and communications technology into all aspects of electricity generation, delivery, and consumption to minimize environmental impact, enhancing markets, improving reliability and service, lowering costs, and increasing efficiency.”

A power grid that integrates ICT and is capable of intelligently connecting all parties involved—generators, customers, markets, service providers, utilities, appliances, etc.—is generally understood to be a “smart grid,” even though the phrase has no one definition [13].

A power grid must have specific characteristics to qualify as intelligent, including [22] allowing for consumer active participation, accommodating all generation and storage equipment, enabling new markets, products, and services, providing power quality, optimizing asset utilization, operating efficiently, anticipating and responding to system

Disruptions (self-healing), withstand the assault and natural calamities with resilience. These qualities will make it possible to reap several advantages, including [19]:

Enhances the quality and dependability of electricity;

Maximizes the use of facilities and prevents the need to build back up (peak load) power plants;

- Expands the capability and effectiveness of current electrical grids

Enhances resistance against assaults and natural catastrophes;

Facilitates anticipatory upkeep and “self-healing.” reactions to disruptions in the system;

- Promotes the increased use of renewable energy sources;
- Supports a variety of energy sources;
- Automates upkeep and functionality;
- Lowers greenhouse gas emissions by making new energy sources and electric/hybrid cars possible; lessens the need for wasteful generating during times of peak use, thereby lowering oil consumption; offers chances to strengthen grid security; Facilitates the shift to plug-in electric cars and introduces novel possibilities for energy storage.
- Gives customers timely and valuable information details on their energy use;
- Expands customer options and makes new goods, services, and markets possible.

To ensure interoperability of Smart Grid devices and systems, the National Institute of Standards and Technology (NIST) in the United States is in charge of coordinating the creation of a framework that comprises protocols and standards for information management. NIST has identified nine priority areas, including network communications, cybersecurity, and seven essential functions, to direct the development of this new power grid architecture [19]. These features, which include the goals suggested by the Federal Energy Regulatory Commission in its policy statement, are essential to developing Smart Grid technologies and services [23]. They are listed in the following order:

Demand Reaction and Energy Efficiency of Consumers;

Broad Area Situational Intelligence;

Resources for Distributed Energy (DER);

- Energy Reserve;
- Electronic Mobility;

AMI stands for Advanced Metering Infrastructure.

- Distribution Grid Administration

Cybersecurity, as well as

- Network correspondence.

These modifications will most impact the distribution system [1], which will be the focus of these services and functions, which will be applied to the power system as a whole.

The distribution system, which serves most users and handles billing, is very complicated by its very nature. It comprises a vast network of substations, cables, poles, and meters, among other things. This system must be completely redesigned to comply with Smart Grid standards. The intelligent distribution system will be able to control the entire grid in real time through automated equipment and smart meters. This will include load balancing, preventing power outages by identifying and isolating faults, reconfiguring and restoring the supply automatically, and managing voltage levels and power flow [24]. A few essential innovative distribution system technologies are covered in the following section.

3. Systems for innovative distribution

Although it makes up most of the power system, the distribution system is presently the least automated. Furthermore, it often contains data from the sub-station feeder and has no discernible intelligence [5].

Many improvements and features are being created to enable the implementation of Smart Grids and improve the system's safety, efficiency, and proactiveness. The following are some of the more notable new technologies: distributed energy resources and peak-shaving, which will allow production to be balanced with demand and improve system reliability; advanced tools and information management, which will enable network situational awareness through system monitoring and control and support planning and optimization tasks through forecasting and simulation procedures; and advanced metering infrastructure and distribution automation, which will enable extensive system monitoring, control, and automated reconfiguration.

3.1. Sophisticated infrastructure for metering

Smart meters, energy management programs, and communication infrastructure are just a few technologies that

make up an advanced metering infrastructure. These systems allow for bidirectional communication between customers and utilities, allowing for real-time power use monitoring [25].

These systems include data management, consumer-associated systems, controllers, software, hardware, and communications [26, 27]. This way, the data-collecting feature of smart meters may be enabled to provide

Some details for service providers and customers [19]. These smart meters will offer real-time power pricing, monitor voltage and current, record waveforms, and remotely connect and disengage customers. However, to provide helpful information, these activities will produce much data that must be handled and analyzed. The data above will be accessible for planning and operation purposes, potentially enhancing asset management and dependability [28]. Furthermore, demand response systems made possible by these meters will allow customers to lower their power energy prices. However, utilities can run their systems, reducing the demand at its peak. The distribution system may be utilized more effectively if peak demand per customer is decreased [29].

3.2. Automation of distribution

The initial stage in the evolution of a distribution grid is distribution automation, which opens up new application possibilities via widespread control and monitoring. The distribution automation idea, for this purpose, refers to a collection of systems that allow the utility to remotely monitor, coordinate, and control the distribution grid components in real-time [30]. Improve effectiveness, dependability, and service quality entails the integration of sensors, bidirectional communication systems, Intelligent Electronic Devices (IEDs), and Supervisory Control and Data Acquisition (SCADA) systems. This system remotely controls circuit breakers, switches, reclosers, capacitor banks, and other equipment to allow Smart Grid functions. It also monitors the voltage and current levels, power demand (active and reactive power flow), equipment, and operational conditions [22].

The system can self-heal based on these monitoring and regulating capabilities, primarily in fault circumstances. As a result, during system restoration, this activity helps the repair teams and control center operators [5]. Thus, distribution automation technologies would enable, among other things, automated reconfiguration, integration of DER, and minimization of both technical and non-technical losses in conjunction with distribution management systems and improved metering infrastructures.

3.3. DER and shaving during peak

Small power sources known as distributed energy resources include microgrids, distributed production from conventional and renewable energy sources,

Energy storage technologies and electric cars [7]. Integrating distributed energy resources (DER) based on renewable energy sources reduces carbon emissions and lessens issues associated with rising consumer demand. Peak-shaving [31] is another advantage of distributed energy resources (DER). This may be accomplished by demand response rules (through load control and intelligent appliances) or by utilizing the energy produced or stored.

As noted, reducing peak demand and improving the demand profile improve system dependability, which lowers capital expenditures. Reducing distribution system losses and using variable power sources more effectively may enhance the grid.

3.3.1. Virtual power plants and distributed generation. Small-scale generation is known as distributed generation. An extensive collection of dispersed generators under the supervision of the system operator, whose aggregate capacity is equivalent to that of a traditional power plant, is referred to as a virtual power plant [8]. The combined output of a virtual power plant may replace a conventional power plant while offering more efficiency and flexibility. Its technical and commercial characteristics are comparable to a central generating unit [32]. However, a massive quantity of data would need to be collected, analyzed, and stored to make this idea feasible.

3.3.2. Tiny grid. A microgrid is a collection of loads and distributed energy resources (DERs) that may provide electricity to a single major consumer or nearby region. As a result, about the grid, a microgrid functions as a single controlled unit. It can also function in grid-connected and island mode by connecting and disengaging from the grid [33].

Different control and power management systems are available for microgrids, which may be configured to operate in a decentralized or centralized way [34, 35]. A microgrid is often not grid-independent [36]. The distributed generators continue to provide electricity to their customers even while the microgrid runs in island mode, negating the utility grid's power requirement. In addition to offering several benefits, the ability to island provides the possibility for superior local dependability than the power system as a whole. For instance, a microgrid may keep going during a power grid interruption. This process may be done by disconnecting the microgrid to execute a load shedding or going into island mode.



Fig. 1. Mental map of the information management system conceptually.

It is crucial to remember that, even while operating in island mode, the microgrid must communicate with the utility to determine the grid's state and whether to rejoin [8].

3.3.3. Electric cars with energy storage. By reducing the peak demand, electricity storage, including electric vehicles, has

several advantages for the distribution system. Energy storage devices may be utilized to make energy accessible when demand grows for variable renewable energy sources (like wind and solar) and sometimes for conventional generating (like thermal, nuclear, and hydroelectric) [7]. Electric cars may function as a stand-alone energy source and support the electrical system. In this manner, energy from electric vehicles' batteries might be transferred to the grid, mostly while parked and linked to it, via vehicle-to-grid technology [37].

3.3.4. Reaction to demand. Demand response refers to a shift in the amount of electricity used (by demand-side resources) in response to price fluctuations (real-time, interval, time-of-use, and critical peak pricing) or to monetary incentives designed to lower peak energy consumption [7, 38]. Customers may take an active role in grid operations by using demand response programs, which enable them to alter their behavior, modify equipment or processes, employ consumer-owned generation (DER distribution), or provide direct control over demand-side appliances and equipment (load management) [33].

3.4. The primary differentiator of intelligent grids is integrated information management systems and enhanced technologies. It is their duty to amalgamate and improve oversight, evaluation, and

Optimization systems facilitate the efficient operation of innovative distribution systems. Therefore, information collection, information processing, and information storage are the three fundamental activities these systems typically include [8,39].

Information collecting involves acquiring data from sensors, smart meters, and IEDs over an adequate communication infrastructure [39–44].

Data modeling, information analysis, integration, and optimization are all connected to information processing. Semantic data representation is the focus of data modeling, which facilitates information sharing across many devices. For device integration, this data must adhere to specific

interoperability standards [19,45,46]. To support new capabilities based on large-scale information management, real-time data analysis, and closed-loop systems, information analysis is used to extract valuable information from the massive amounts of data generated by the widely deployed metering and monitoring systems in Smart Grids [47-50]. Integrating information from several sources with disparate conceptual, contextual, and typographical representations is the goal of information integration [8,45,46]. Information optimization increases information efficiency, lessens communication load, and stores only relevant data [51, 52].

Lastly, information storage is the primary storage for all relevant data collected from various devices via various wired and wireless channels and transit modes. This storage may include additional pertinent processing data [17]. Utilizing cutting-edge methods, the saved data are used for distribution system analysis, planning, and simulation.

Figure 1 shows the conceptual mind map of the information management system described above and its sub-visions and associated problems.

Large-scale information management makes new capabilities based on real-time data analysis and closed-loop systems possible for managing, monitoring, and regulating the intelligent distribution grid [53]. Integrating applications such as electricity management, state estimate, power flow analysis, demand forecasting, outage management, and asset management may achieve a complete distribution management system with high situational awareness [16,54].

The deployment of an information management system necessitates high processing and ample storage space due to the volume of data from the metering infrastructure, which has proven difficult [55]. This premise has led to the concept of cloud computing as a promising technology that may overcome these obstacles and improve information integration while facilitating extension and interoperability [12,56,57]. The features highlighted as benefits of cloud computing in the Smart Grid sector include processing power, storage capacity, scalability, flexibility, cost-effectiveness, real-time response, and interconnection, as mentioned by [58].

The following section will cover the essential terms and ideas of cloud computing technology.

4. COMPUTING IN THE CLOUD

4.1. Definitions

A new computing paradigm known as “cloud computing” allows for the dynamic allocation and scalability of computer resources as services delivered via the Internet. The term “cloud” refers to a metaphor for the Internet, formerly shown in network diagrams as a cloud to abstract the intricacy of its infrastructure [59]. A broad phrase for distant computer resources that are usually accessible via the Internet has emerged: cloud computing. These computer resources are often dispersed throughout the internet and have no fixed physical location. They are typically virtual.

Clouds are vast repositories of readily available and useable virtualized resources, including development platforms, hardware, and services. These resources may be optimally used by dynamically reconfiguring them to suit varying task demands. Cloud computing uses a pay-per-use payment model, where the cloud provider provides service assurances to the customer via personalized Service Level Agreements (SLA) [60].

Even though cloud computing is relatively new, the concept of remotely supplying computer resources on demand goes back to John McCarthy’s early 1960s suggestion that shared computing resources may eventually lead to a world where computing power and

Specific applications, like phone and power services, where each user pays for the utilization capacity, might even be sold as utilities [61].

One of the primary benefits of cloud computing is its capacity to provide on-demand services to customers, relieving them of the expense of purchasing, maintaining, and operating hardware. Because of this, these customers will only pay for what they need and when they need it, saving IT expenses while also providing flexibility and scalability. Cloud computing may dynamically adjust resource utilization

based on demands and available resources without affecting service. The number of allocable resources seems limitless to users. The capacity to provide online services over the Internet or another network resource, enabling service consumption from any location with network access, is another advantage of cloud computing. Because most of the data processing has to be done on the cloud server, cloud computing permits the use of smaller hardware terminals, allowing access to a broader range of hardware platforms.

Another benefit of cloud computing is improved operational security since data and processes are duplicated across numerous servers. Physical cloud servers are often located in several geographical areas. As a result, additional servers may take over if participating servers fail due to natural catastrophes or technical issues, lowering the likelihood of data loss and service outages.

NIST has been defining standards relating to cloud computing since 2010 [62, 63]. The NIST cloud computing definition [64], utilized as a foundational model for the services provided, is generally acknowledged as having significantly contributed to a clear understanding of cloud computing technology and services. Cloud computing, according to NIST, is a model that allows for ubiquitous, easy, and instantaneous network access to a shared pool of reconfigurable computing resources (such as networks, servers, storage, apps, and services), which can be rapidly provisioned and released with little involvement from service providers or management work [65]. This cloud architecture comprises three service models, four deployment methods, and five key features (measured services, resource pooling, broad network access, on-demand self-service, and quick elasticity) [64].

These are the three service models that may be used as a basis for further models:

SaaS, or software as a service, is the highest hierarchical

Layer via which the user may access apps

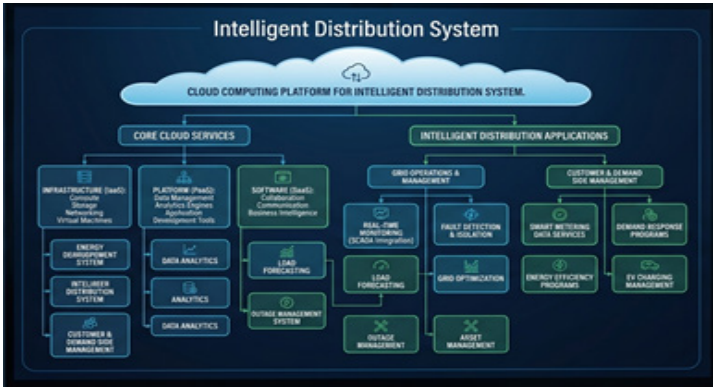


Fig 2. Services Organization Chart

Operating on a cloud infrastructure via a client device (thin client, web browser, program interface, etc.) connected to a network, usually the Internet, the service provider manages and controls the software updates, patches, and underlying infrastructure; the customer is not responsible for these things. PaaS (Platform as a Service): this gives the user the capacity to install, test, and oversee apps that users have obtained or developed on a cloud infrastructure. While the development platform and solution stack are hosted in a cloud environment, the PaaS streamlines the software development process. Although they do not influence the underlying cloud infrastructure (network, servers, operating systems, storage, etc.), users are in charge of the deployed apps and may even be able to modify the application-hosting environment's configuration settings;

● Access to Infrastructure as a Service (IaaS)

Virtual machines, storage accessible via a network, network infrastructure elements, and other essential computing resources allow users to install and execute any software, including operating systems and apps. Disaster recovery and infrastructure upkeep and repair are within the purview of the service provider.

Figure 2 shows these service models may be grouped hierarchically according to the hardware abstraction level. The higher the abstraction level, the less customer engagement with the hardware is required or permitted.

Deployment methods are classified as private, public, communal, or hybrid depending on how exclusive the computing resources are made to a cloud customer. Because of the scale economy, a cloud's services will be more affordable for the more consumers it serves.

A single organization has exclusive usage of the infrastructure in a private cloud. It is usually owned, run, and managed by the company, a different company, or a mix of these parties. In contrast, the infrastructure in a public cloud is made available for anybody to utilize at any time. An operator, manager, and owner might be a service provider. Like a private cloud, a community cloud is used by a collection of organizations with everyday needs and concerns. It may be owned, managed, and run by any of the community's companies, a third party, or a mix. Ultimately, a hybrid cloud comprises two or more separate clouds (private, communal, or public) that continue to exist as separate entities but are connected by proprietary or standardized technology that permits data transfer and applications.

4.2. Framework for cloud computing for intelligent grids
Smart grid data are continuously created and sent as a data stream to the utilities. A stream of data, or a time series, may be seen as an endless series of time-stamped documents. These records must be handled promptly and kept for historical purposes.

Cloud computing is likely the most straightforward and effective method to satisfy large-scale Smart Grid needs because of its scalable and flexible features, cheap cost, redundant design, quick reaction time, and capacity to handle massive volumes of data [12,14,56]. A wide range of technologies may be used when creating a cloud architecture. The fundamental problem is deciding which is best for a given application. As a result, much research [9,49,56,66-78] has been done to create a cloud computing framework that

can handle the enormous data storage, transportation, and communication required by smart grids by offering large-scale real-time computing capabilities.

Dealing with Smart Grids immediately raises the issue of what to store and how to store the data provided by the many available sensors and meters. These data are often gathered across various intervals, from days to microseconds. Different technology and storage techniques are required for such data granularity. For instance, the standard data storage solution based on Relational Database Management System (RDBMS) is not ideal when dealing with a large quantity of data (in the order of terabytes), as it lacks performance in both storage space and speed. Employing NoSQL databases or other

A hybrid approach might help solve this issue [17]. The storage strategy should also consider whether the data will be disseminated across the network or kept locally. While some distributed databases employ third-party Distributed File Systems (DFS), others provide inbuilt DFS. Many ideas have been proposed to complete this storage [66–70, 75, 76, 78, 79].

There are many NoSQL databases with various storage strategies, including time series databases (OpenTSDB), document-oriented databases (Mongo DB, Couch DB, etc.), key-value databases (Riak, Redis, etc.), and column-oriented databases (Cassandra, H base, etc.) [80]. A few well-known time-series databases are compared in [79].

When working with large volumes of data, computing power is necessary to complete calculations and analyses in a reasonable amount of time. Some writers have suggested various approaches to address these high-performance computing needs [50, 72, 75–77]. Many writers have implemented parallel processing and distributed storage using the MapReduce programming paradigm and the Apache Hadoop environment.

The Apache Organization's open-source Hadoop platform makes scalable distributed computing possible. HBase is an open-source distributed NoSQL database that is part of Hadoop. It operates on top of the Hadoop Distributed Filesystem (HDFS) and can handle large datasets with

billions of rows and millions of columns. The MapReduce programming model is supported by the Hadoop framework, which is used by several big websites like Amazon, Facebook, Yahoo, and others to construct and run applications [81]. Google developed the MapReduce programming approach to handle massive amounts of data across computer clusters [82]. When data processing is highly parallelizable—when one process runs independently of the others—Hadoop and MapReduce are meant to be used. In other cases, a more thorough analysis of this solution's suitability would be required. Stream processing, for instance, is preferable when data has to be processed quickly and constantly since it allows data to be examined as it enters the data workflow. However, a hybrid approach could be more appropriate in other circumstances. [71] presents a comparative analysis of several stream processing solutions.

While cloud computing may seem to be a remedy for

Despite the storage and processing difficulties encountered by intelligent grids, not all intelligent grid applications need much processing power or storage. It can still benefit from cloud computing features, however, including on-

Demand measured services, quick elasticity, resource pooling, broad network access, and self-service.

A further worry with cloud computing is assured data delivery and communication time delays, which might be necessary for mission-critical applications. Since most communication occurs online, sending data in real-time with a high delivery probability might be challenging.

A few security and privacy problems must be considered when using cloud computing in intelligent distribution system applications to maintain data integrity and information privacy while transferring data over public networks. To improve data security, network assaults may be prevented by using intrusion detection, trust management, encryption, and authentication security techniques. Many people have spoken about this subject [8,9,13,15,56,83,84].

The cloud deployment methodology is one of the elements that influences security and privacy concerns. When comparing private clouds to public clouds, there are situations where security and compatibility must be traded off against complexity and cost-effectiveness [15,85]. In contrast to public clouds, private clouds are more secure against cyberattacks but lack some benefits, such as non-upfront investment, cheaper operational costs, high scalability, quick access, and fewer business risks and maintenance costs. The actual hardware is often on the utility's property [58]. However, dispersing data among many off-premise cloud providers globally may enhance this data's resilience to disasters.

Therefore, it is improbable that an electric company would use a public cloud for all its information management needs. Implementing a hybrid approach to benefit from the economies of scale provided by public clouds and maintain the security of sensitive data stored in private clouds may be more advantageous.

Notably, the SLA between the utility and the provider considers these three primary risks when outsourcing computing and storage to an external service provider: dependability, performance, and safety. Furthermore, it is relatively uncommon for SLAs to exclude some provisions, such as confidentiality and integrity [84]. The following risks are taken into account while evaluating performance and dependability [13]:

What impact would a fluctuation in performance have?

The business?

What impact will latency and fluctuation have on customers' experiences?

- **What is the acceptable latency?**

Will crucial data be lost in the event of a system failure?

These inquiries would help plan what to outsource and when. Sometimes, when there is a significant demand for computer resources—a phenomenon known as “cloud bursting”—the utility may decide to employ a public cloud.

The proper cloud computing framework can develop many innovative distribution system applications, including demand-side management, demand response, power system monitoring and control, power system analysis, system simulation, state estimation, demand forecast, energy profile analysis, etc. As a result, the primary cloud computing research effort applied to intelligent distribution systems will be presented in the next part.

5. Cloud computing applications in intelligent distribution systems

By combining all utility systems in a cloud environment, cloud computing can increase the degree of information integration in a smart grid, simplifying information system design and lowering operating costs [12, 14].

Most research on cloud computing in intelligent grids involves computing power for data processing and storage in information management [11]. These computer capabilities have been used in other conventional fields, such as power system analysis, reliability analysis, and management systems, in addition to enabling the creation of new fields.

This section provides an overview of the work done in the field to serve as a springboard for future scholars. Table 1 summarizes the critical intelligence.

Applications for distribution systems that use cloud computing technology in their development or implementation, which may be found in the literature up to 2016, are categorized as information management tasks (Section 3.4). These applications vary significantly from one another and have unique needs that call for particular architectures. As is evident, many apps have been created, but there is still room for more. A wide range of research subjects and advancements are possible in the young and rapidly developing field of cloud computing applied to intelligent distribution systems.

Innovative distribution systems mostly use cloud computing for Energy Management System (EMS) applications. In this context, EMS refers to the software package that monitors, manages, and enhances power system performance. The

Supervisory Control and Data Acquisition (SCADA) monitoring and control functions, as well as the “advanced tools” analysis and optimization tools, are a few examples of the software suite that may be included [114]. As mentioned in the ensuing subsections, these programs may include demand response, system modeling and simulation, real-time metering, and several administrative tasks.

5.1. Applications for management and control

Power system monitoring and control [10, 54, 68, 70, 96–99], demand-side management [18, 75, 76, 86–93], micro grid management [18, 94, 95], and other DER management apps [100–103] are the primary energy management applications created in the cloud environment.

The two most crucial roles of the EMS are power distribution system monitoring and control.

They are in charge of gathering, processing, analyzing, and visualizing the data from the smart grid and carrying out certain grid management operations. In this fashion, cloud computing-based system designs were presented by [68] and [70] to analyze and store monitoring data. Their solutions use Apache Hadoop for parallel processing based on the MapReduce programming style and HBase and HDFS for data storage. The creation of a SCADA system using cloud computing was suggested by Alcaraz et al. [96,97] and Goose et al. [10], who also described the specifications for this new architecture and some potential security measures for data sharing. Strategies for controlling and offering service-sensing resources in the cloud were covered by Fazio and Puliafito [98]. To eliminate the equipment from the substations and lower the investment, Bo et al. [54] proposed designing and developing a cloud computing platform to replace the calculating functions of secondary equipment dispersed among several grid substations. Another use case presented by [99] is the creation of Web Services for the cloud computing-based processing of power quality data captured by smart meters or other comparable devices in smart grids.

Demand-side management pertains to adjusting peak loads to accommodate generating capacity by changing customer

demands in response to utility-mandated programs [88, 90], such as demand response initiatives or other tactics that encourage load shifting.

Simmh An et al. [18, 87], Sheikh et al. [88], Lohrmann and Kao [92], and Kim et al. [86] suggested several kinds of cloud-based demand response applications. Mohsenian-Rad et al. [93], Li et al. [91], and Wang et al.

[89] they suggested a few strategies for altering cloud data center energy use to encourage load balancing within the distribution grid. A dynamic load-shifting method based on real-time data was indicated by Rajeev and Ashok [90] to facilitate the integration of renewable energy sources. An energy management system capable of using service-oriented architecture to communicate with appliances and regulate their operation was presented by Yang et al. [75,76].

Applications for microgrid management are in charge of keeping an eye on and controlling the intelligent microgrid's functioning and consumption and handling its related responsibilities. On a smaller scale, microgrid management may also benefit from some intelligent distribution systems management applications, such as those suggested by [18]. Jin et al. [94] and Marchi et al. [95] have put out several methods to leverage multi-

Smart microgrids using agent systems as a distributed control architecture.

Apart from the applications above, additional management applications concerning distributed energy resources (DERs) exist. These applications facilitate utility interface with electric vehicle supply equipment [103] and cloud computing-based monitoring and control of distributed renewable energy resources [100–102].

5.2. Sophisticated instruments

The “advanced tools” are a unique component of the EMS for distribution system analysis and optimization. Using cloud computing, applications for power system analysis [104], cost optimization [105,106], system modeling [107–109], and state estimate [110] have been created.

Using Google App Engine, Huang et al. [104] created a cloud computing-based power system analysis platform offering three primary services: load flow, contingency analysis, and data transformation.

Devie and Kalyani [105], as well as Fang et al. [106], proposed several cloud-based information management models for Smart Grids and provided optimization frameworks for lowering cloud processing and storage costs while using public clouds.

A scalable open-source simulation system that integrates MATPOWER and Grid lab-D as simulation tools was presented by Anderson et al. [107]. The best dispatch schedules for flexible loads and placement optimization for distributed generation have been designed using these technologies. A cloud computing application architecture for power system transition simulation was presented by Lei Jiao et al. [108]. Cloud computing was used by Maheshwari et al. [109] to parallelize and enhance the functionality of a program that helps the utility planner determine if a power system can sufficiently meet the demands of the consumer load.

In their description of a monitoring framework and characterization of a PMU-based state estimation application, Maheshwari et al. [110] explained how the intended system might be integrated into a suggested cloud architecture.

5.3. Data mining and analytics

The science of analyzing unprocessed data to derive conclusions about it is known as data analytics. It is centered on inference, concluding only from the researcher's prior knowledge. In contrast to data analytics, the field of data mining is noted where

Some tools are used to find patterns that haven't been seen before and uncover connections that haven't been seen. Consequently, data mining methods aim to identify trends and information from massive amounts of data [115].

Specific applications in data analytics suggested by Simmhan et al. [18,87], Mayilvaganan and Sabitha [111], and Martin et al. [112] need to be emphasized. They used several demand

forecasting techniques and a cloud-based platform to keep supply and demand in balance.

Nikolopoulos et al. [113] conducted an energy profile study using data mining methods on a cloud computing platform to assist and direct utilities in understanding their customers' consumption habits. Thanks to this study, utilities can provide customized customer plans and services.

As shown, an intelligent distribution system may be used with various cloud computing applications. However, most of the journals and publications in this sector were released less than three years ago, indicating that the discipline is still developing.

6. RESULTS

This essay has discussed smart grids in light of the need to update electrical power infrastructure. By considering associated technologies, applications, and problems, the study focuses on cloud computing applications in innovative distribution systems. Essential definitions and ideas related to cloud computing were presented. The cloud computing infrastructure for intelligent grids was examined regarding storage, processing, security, and dangers to identify the primary research activities, difficulties, and trends.

The study has shown how cloud computing, which offers distributed network storage and parallel processing with large-scale processing capabilities, can handle the enormous amount of data generated by meters and sensors that must be evaluated and saved. It has been determined that NoSQL databases are more suited for storing massive volumes of data than conventional RDBMS. Utilizing MapReduce for parallel processing and the Hadoop environment for distributed storage is the most popular method for handling this data. However, when data has to be handled quickly and constantly, other intriguing alternative methods should not be disregarded. It was said that crucial applications may be impacted by Internet-related communication latency and data supply dependability.

In terms of cybersecurity, intelligent distribution system apps must have security procedures to lower the risks associated with data security to a manageable level. Data outsourcing to a public cloud and its potential effects on the user are significant concerns about cloud use covered in the article.

Lastly, a summary of the primary intelligent distribution system applications that use cloud computing technology in their development and implementation was provided. These applications may be found in the literature. Innovative distribution systems can leverage the processing and storage capabilities of cloud computing to enhance the accuracy and optimization level of power system simulations, power system optimal dispatching, power system optimal planning, real-time monitoring and forecasting systems, and distributed renewable resource management.

Application of Machine Learning Optimization in Cloud Computing Resource Scheduling and Management

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Abstract

Cloud computing has become more prevalent in recent years. Cloud computing is the use of centralized computer resources. Users may utilize these resources to finish calculations, and the cloud computing center will provide the user with the program's processing results. Cloud computing is helpful for both consumer and business users. Users may save computing expenditures by avoiding the need to acquire several PCs by investing in a cloud server. China Economic News Network reports that the country's cloud computing market is worth 209.1 billion yuan. China's more established cloud service providers include Huawei Cloud, Baidu Cloud, Ali Cloud, etc. In light of this, this study suggests a novel method for handling challenging issues related to scheduling and managing cloud computing resources using machine learning optimization approaches. This study provides a comprehensive solution, including optimization techniques like deep learning and genetic algorithms, to improve system performance and efficiency and thus bring breakthroughs and progress in cloud computing resource management. Rational allocation of resources plays a crucial role in cloud computing. The study thoroughly examines issues like low resource utilization and unbalanced load in the cloud environment. Users come in order at the cloud computing center, which has restricted cloud resources for resource allocation. Each user requests a specified quantity of cloud resources to be used by the cloud computing center at a given time.

Keywords: artificial intelligence, cloud computing, resource allocation and machine learning optimization

Introduction

Cloud computing has been employed extensively in recent years. Cloud computing is the use of centralized computer resources. Users may utilize these resources to finish calculations, and the cloud computing center will provide the user with the program's processing results. Cloud computing is helpful for both consumer and business users. Users may save computing expenditures by avoiding the need to acquire several PCs by investing in a cloud server. Cloud service providers may dynamically schedule computing resources based on customers' access needs to optimize computer resource consumption efficiency. China Economic News Network reports that the country's cloud computing market is worth 209.1 billion yuan. China's more established cloud service providers include Huawei Cloud, Baidu Cloud, Ali Cloud, etc.

In cloud computing, rational resource distribution is essential. Users come in order at the cloud computing center, which has restricted cloud resources for resource allocation. Each user requests a specified quantity of cloud resources to be used by the cloud computing center at a given time. The cloud computing service center must decide whether to approve or deny the user's request. Under resource constraints, judicious use of cloud resources may optimize service user quality and boost user happiness. Heuristic algorithms are used by the majority of current resource allocation techniques to allocate resources, but heuristic algorithms struggle to provide accurate outcomes in complex circumstances.

Users' different demands must be considered while allocating cloud computing resources. The resources in the cloud are required differently by various users. Resources must be distributed by the cloud computing center to user demands. Two limitations may be applied to users' demand for cloud resources: hard limits and soft constraints. Problematic limitations are those that need to be adhered to. For instance, a user can ask for many VMS rather than just one VM.

Each virtual machine (VM) must be situated in a distinct fault domain (a server sharing a single point of failure) to guarantee high availability and prevent financial losses from the cloud computing center failing. Soft constraints are either satiable or unsatisfactory, yet satiating a restriction may significantly increase the quality of the service. For instance, placing cloud virtual machines following one another in the network topology helps lower network latency and speed up processing during the neural network training process.

Figure 1. Policy networks using reinforcement learning techniques (Figure: Mao et al. (2016))



Figure 1. Policy networks using reinforcement learning techniques (Figure: Mao et al. (2016))

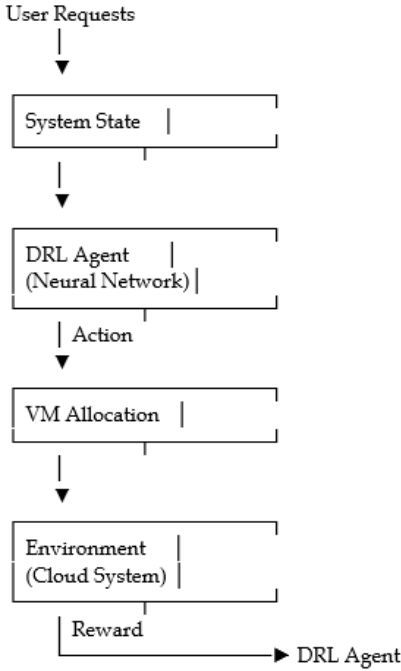
As seen in Figure 1, the action is the neural network's output, while the system's current state serves as its input. The environment will give the appropriate reward once the system accepts the action. System optimization's objective is to.

To increase the user's waiting time, decrease it.

As user requests are processed, VMS that are Being physically near to users may enhance user experience and speed up communication between the cloud computing center and users.

This paper primarily suggests a deep reinforcement learning-based cloud resource allocation strategy that considers user requirements. The primary goal of this research is to enhance customer service quality by allocating users to nearby servers. On the other hand, if users are paired with nearby servers, there's a chance that some of them may be overloaded, leading to lengthy wait times. As a result, this paper examines a deep

reinforcement learning-based approach to cloud resource allocation. With deep reinforcement learning, resources may be dynamically allocated based on the system's present state, optimizing cloud resource consumption and reducing user wait times.



Nearby VM → Lower Latency

Overloaded VM → Higher Waiting Time

Related Works

Deep reinforcement learning for resource scheduling

Mao et al. (2016) investigated resource allocation in cloud computing systems using deep learning techniques. The strategy gradient approach is primarily used in their study to achieve dynamic resource allocation. The strategy gradient method is a reinforcement learning technique that maximizes the intended cumulative reward by optimizing the strategy

for effective resource allocation. This method allows for effective resource use in cloud computing settings that are constantly changing, in addition to adapting to various conditions and needs. Mao et al.'s study offers novel concepts and approaches for resolving resource allocation issues and significant references and inspiration for using deep learning in cloud computing resource management.

Task allocation and unloading under priority restrictions, Optimization Issue To improve computational efficiency, complicated jobs are divided into smaller tasks called task flows, which are then assigned to processors for parallel processing in the cloud computing resource allocation and task scheduling system. Directed acyclic graphs (DAGs) are helpful for modeling and abstracting workflows when jobs have priority restrictions, and some calculations rely on the outcomes of earlier tasks. Nodes in this model represent subtasks, while priority restrictions among subtasks are shown by edges connecting nodes. A tree model of the DAG scheduling issue is given in Literature [4], which considers variables like interconnectivity between processors, processor resource constraints, and communication time between processes. Algebraic Model and Associated Techniques

The restrictions on the order of priority between tasks may be written as follows: for any $i \rightarrow j$, $EST(j) < CT(i)$, where $CT(i)$ is the task's completion time, $i \rightarrow j$ means that task i must be finished before task j , and $EST(j)$ is the earliest time job j can start processing. Regarding the issue of cloud offloading on

CPUs in mobile terminals are capable of handling many jobs at once. A deterministic delay-constrained task segmentation technique based on dynamic programming is introduced in the literature, and its suboptimality is shown. Assuming that processors are limited to one job at a time, the topology of DAG remains unrestricted in light of the deadline limitations. A mixed-integer programming paradigm that considers cooperation between edge computing nodes and distant cloud nodes is presented in the literature [5]. It is a generic allocation issue with NP-hard features for which a polynomial-time optimization technique is unavailable. Books

[6] turns the issue into a convex optimization problem using a relaxed integer programming model with 0-1 variables. A heuristic method is then designed. The literature [7] proposes a mixed-integer programming approach to address the multi-DAG mobile terminal offloading issue. It determines whether to upload work to the cloud and minimize energy usage under deadline limitations.

Heuristic Approaches

Heuristic methods, intelligent algorithms, and hybrid algorithms are the critical optimization techniques for DAG scheduling. List scheduling, clustering, and job replication are the main categories of heuristic methods. List scheduling assigns the highest-priority job from the pending tasks to the relevant processor by arranging the tasks according to priority. Tasks are grouped in clusters until the number of categories and processors is equal. To reduce processing delay, jobs containing important data are replicated across many processors using task replication.

Literature [6] uses forward ranking as the criteria for list scheduling in “cloud-edge-end” systems to minimize computation, communication costs, and latency of cloud and edge computing nodes. In the literature [7], techniques like lower bound estimates are used to calculate nodes for DAG subtasks and assign deadlines while considering cost and deadline. To maximize total time performance, literature [8] assigns virtual machines according to task deadline order, considering the earliest job completion time.

Sensible Algorithms

Intelligent algorithms strive for global optimization performance, as opposed to heuristic guidelines. Genetic algorithms are used in the literature [8] to maximize task-edge node group assignments. Literature [9] uses probability to describe the spatial connection between activities. Following heuristic-based DAG pre-segmentation, the literature

[9] ranks jobs and optimizes edge node energy consumption and total application completion time using bivariate correlation distribution estimation techniques. The Estimation

of Distribution Algorithm (EDA) is used in the literature [10] to minimize overall delay while considering task deadline information. Regarding the assignment issue of task-node, the literature

[10] employs the particle swarm optimization algorithm to maximize the weighted cost and completion time goals. The techniques above are logically linked to the real needs of task scheduling and cloud computing resource allocation.

ACHIEVE DYNAMIC RESOURCE ALLOCATION

One essential component of resource management in cloud computing settings is the dynamic distribution of resources. To do this, several crucial elements and procedures must be taken into account:

Algorithm for Resource Scheduling

Dynamic resource allocation is based on the resource scheduling algorithm. It assesses several variables, including resource availability, kind, and demand, to determine the best scheduling plan. Static allocation, dynamic allocation, and load balancing are standard algorithms. Every algorithm considers specific needs and limitations to guarantee practical resource usage.

Resource Observation

Real-time detection of changes and abnormalities requires resource monitoring. Resources of all kinds need to be regularly observed to track utilization trends and spot problems. By monitoring their resources, organizations may proactively handle variations in demand and adjust their resource allocation methods.

Forecasting Resources

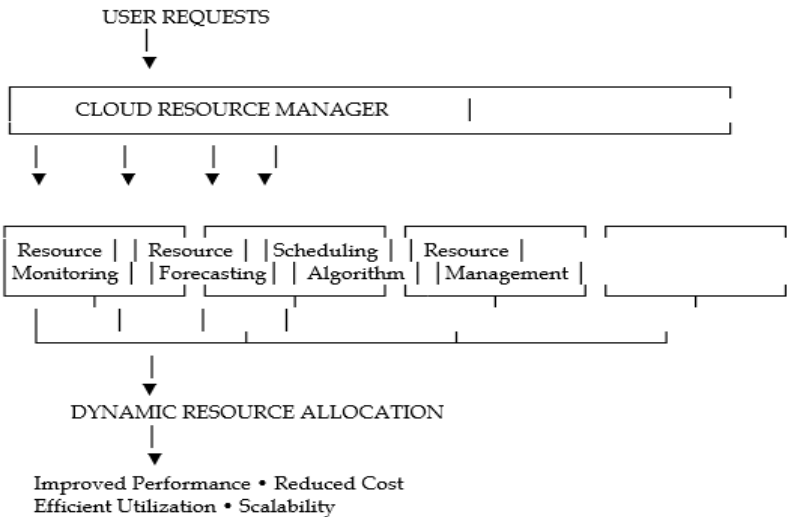
Effective resource allocation depends on predicting future patterns in resource demand and utilization. Future resource needs are expected via prediction tools and historical data analysis. Organizations may avert shortages and maximize efficiency by anticipating resource demands and allocating

resources in advance. This minimizes waste and maximizes usage.

Management of Resources

Enabling dynamic resource allocation requires efficient resource management. Appropriate labeling, classification, and organization of resources are necessary for adequate scheduling and placement. Robust resource management techniques can help organizations maximize performance, optimize resource use, and simplify operations.

Organizations may fully benefit from dynamic resource allocation in cloud computing environments by combining these elements into a unified architecture. This strategy ensures that resources are distributed effectively and flexibly, and by changing needs and circumstances, eventually boosting output and propelling company success.



RESULTS

This research concludes with a thorough strategy for resolving the difficulties associated with resource scheduling and management in cloud computing settings. The suggested approach notably improves system effectiveness and

performance by utilizing machine learning optimization methods, including deep reinforcement learning. It is clear from thorough testing and analysis that the proposed algorithm performs better in terms of time, cost efficiency, service quality, and system resource load than conventional techniques like ant colony optimization and simulated annealing. This highlights its potential to transform resource management in cloud computing and lead to new developments in the industry.

Deep Learning and Cloud Computing Together for Scheduling

Combining deep learning methods with cloud computing scheduling might lead to more intelligent and adaptable resource allocation strategies. This research shows that deep reinforcement learning allows for dynamic resource allocation depending on the system's current state, which maximizes resource usage efficiency and minimizes user waiting times. Deep learning-based methods may provide customized and optimal solutions to complicated scheduling issues in cloud settings by considering system limitations and user demands in an all-encompassing way.

Benefits of Deep Learning for Scheduling in Cloud Computing

Cloud computing scheduling benefits incredibly from deep learning. First, it can adjust to changing cloud settings because of its capacity to extract intricate patterns and correlations from data. Second, deep learning models enable more precise and sophisticated decision-making by handling high-dimensional and non-linear data. Furthermore, deep learning algorithms can learn and grow over time, which may increase scalability and performance for cloud scheduling jobs. Deep learning and cloud computing scheduling integration have much potential to manage contemporary cloud settings' growing complexity and dynamic nature.

Prospects for AI and Cloud Computing Integration in the Future

Significant breakthroughs in several sectors are anticipated due to the confluence of cloud computing with artificial

intelligence (AI). More intelligent and independent features, such as anomaly detection, self-optimizing systems, and predictive resource provisioning, will be available with AI-powered cloud services. Furthermore, companies can make better choices and get a competitive edge thanks to AI-driven insights from massive cloud data volumes. Combining AI technology with cloud computing will bring in a new age of innovation and industry change as these technologies develop.

Clearing the path for digital ecosystems that are more intelligent, effective, and resilient.

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An Examination of Cloud Computing's Impact on Sustainable Development: Its Significance, Research, and Possible Difficulties

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Abstract:

Sustainable development is an approach that considers both short- and long-term needs, such as economic and social justice, environmental preservation, and natural resources. A cloud computing environment is made available to users to facilitate flexible innovation, scalable capabilities, and scale economies. It includes analytics, software, networking, databases, storage, and servers. This study examines many cloud qualities that benefit sustainable development, including resource pooling, simple maintenance, favorable economic effects, and extensive network access. This research also looks at many aspects of modern cloud service providers that support sustainable growth, such as Microsoft Azure, Google Cloud, and Amazon Web Services (AWS). Finally, this study discusses possible issues with cloud sustainability, including lack of knowledge, hidden costs, security, and administration.

Keywords: cloud computing, sustainable development, economic, environmental, and social sustainability; cloud deployment methods; cloud characteristics; cloud service models;

I. OVERVIEW

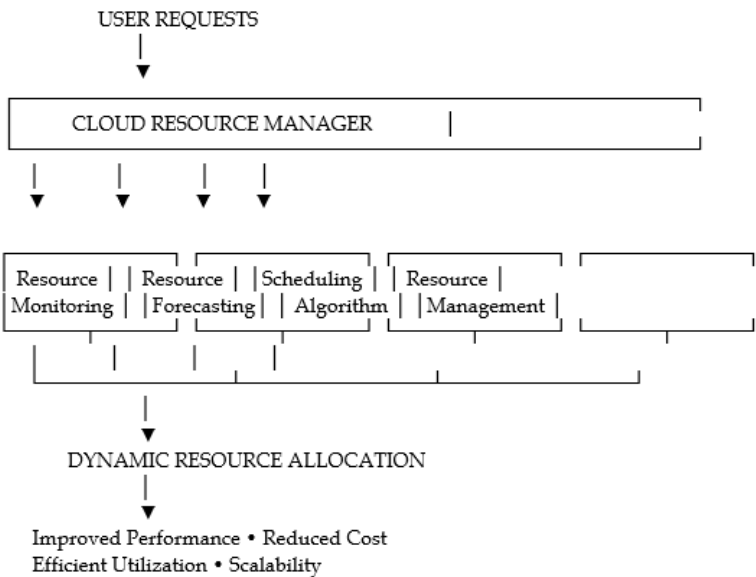
Sustainable development aims to meet current needs without endangering the ability of future generations to meet their own needs [1]. The world faces essential issues related to natural resources and ecosystems, including global

warming, freshwater scarcity, marine resource exploitation, deforestation, pollution, and the struggle to feed billions of people. Sustainability in the environmental context is the management and preservation of Earth's natural resources, biodiversity, climates, and atmosphere to ensure the well-being of current and future populations [2]. Cloud computing provides computing environments, such as servers, analytics, software, networking, databases, and storage, to facilitate scale economies, scalable capabilities, and quicker creative thinking.

Data are required to track and monitor the objectives to ensure the SDGs are reached by 2030. To close the existing information gap supporting the SDGs, a creative and effective technique of gathering and using data must be developed to lower the cost associated with traditional statistical approaches. One of the critical factors influencing innovation nowadays is a sustainable approach and environmental concerns. One of the most influential and environmentally friendly information and communication technologies is cloud computing, which saves businesses more than 200 billion euros and 59 million tons of carbon dioxide annually. These advantages may be attributed to the increasing popularity of on-demand service delivery, dynamic resource allocation, increased error detection, and greater flexibility. Because it is based on a community of cloud computing platforms, it reduces energy consumption and pollutants from traditional server and local application techniques while enabling up to 50% cost reductions.

This article investigates how cloud computing affects sustainable development and promotes innovation, performance, and social, environmental, and economic change. Additionally, the research examined the possible obstacles that cloud computing may pose to sustainable growth. The literature on cloud computing and sustainable development is reviewed in Section II. Cloud service models, such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), are also covered in this area. The modes of cloud deployment—public, private, hybrid, and community—are also covered. This section

examines cloud properties that support sustainable growth, including broad network access, resource pooling, simple maintenance, and sound economic effect. The major cloud providers, such as Amazon Web Service, Google Cloud, and Microsoft Azure that support innovation, performance, and transformation in sustainable development are covered.



II. REVIEW OF LITERATURE:-

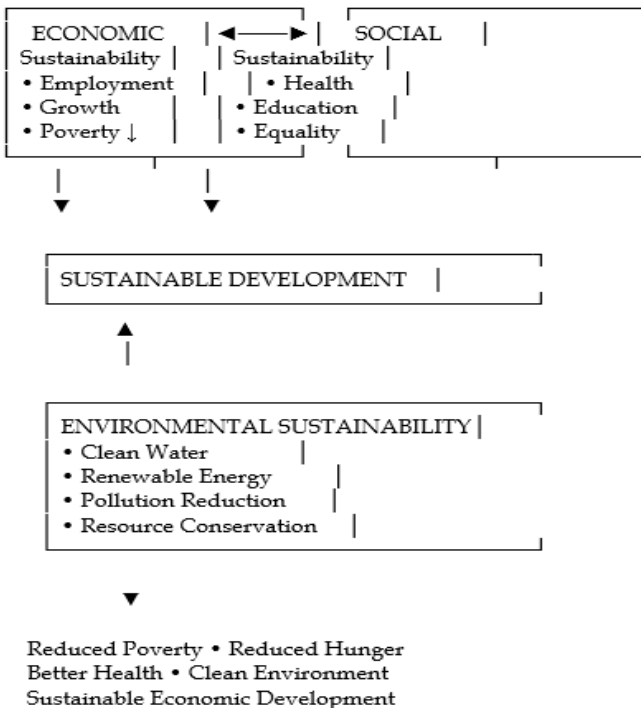
A. Long-Term, Sustainable Growth sustainable development aims to organize civilization in a way that will guarantee its continued existence. This means considering short- and long-term needs, such as natural riches, environmental preservation, or social and economic fairness. The United Nations established the Sustainable Development Goals, a collection of 17 global objectives, as a roadmap for building a more promising and sustainable future for all people [1]. The goal is to balance socio-political stability, economic viability, and ecological stability. By gradually changing how people generate and use innovations, sustainable development constantly inspires people to protect and enhance their assets.

Every country has to provide the necessities of labor, food, electricity, water, and sanitation. Everyone has a right to a safe, secure, and hygienic environment. Reducing unemployment, inequality, and pollution are easy ways to do this.

Among the four goals of sustainable development are:-

- Sustainable financial development ends poverty and hunger and promotes a healthy way of life.
- Protection of natural resources: Ensure that necessities like food, sanitation, and environmental sustainability are fully provided.

LONG-TERM SUSTAINABLE GROWTH



III. Social progress and equity:

Eliminate all forms of prejudice, especially sexual discrimination. Provide opportunities for fair education and fulfilling work to the next generation. Build communities and areas that produce and consume sustainably, resulting in organizational flexibility and strong networks.

Environmental protection includes preventing climate change, preserving agricultural and marine biodiversity, and defending the ecosystem.

The primary international framework for international cooperation in the twenty-first century is the 2030 Agenda for Sustainable Development and its Sustainable Development Goals. The Sustainable Development Goals (SDGs), sometimes called the Global Goals, were adopted by the United Nations in 2015 as a worldwide response to the need to end poverty, protect the environment, and ensure that all nations have peace and stability by 2030. The seventeen Sustainable Development Goals (SDGs) are interrelated because they acknowledge that decisions made in one area will affect outcomes in other places and that social, economic, and environmental sustainability must be managed as a consequence of growth.

Figure 1. The Interconnection Between Environmental, Social, and Economic Sustainability



Figure. 1. The connection between environmental, social, and economic sustainability

Development, administration, intellectual pursuits, and humanitarian aid have all shown great interest in sustainable development. Many public and commercial organizations have accepted it as a practical conceptual framework. Sustainable development requires multi-leveled, integrated efforts considering social, environmental, and economic concerns rather than isolated activity. Detangling the complex relationships between the goals and the objectives will be essential to implementing the SDGs effectively.

Cloud -Based Software

Thanks to cloud computing, consumer devices may access external virtual hosts, databases, and systems online to acquire information and cloud services. High-quality information is necessary to monitor progress toward the Sustainable Development Goals (SDGs), evaluate the effectiveness of legislation, and advise executive management and financial choices. Big data and cloud-based infrastructure have given rise to creative concepts for data collecting that affect both the execution of the activities and the use of reliable data collection methods. To provide insights, data are needed to examine the relationships between several significant topics and social and economic specifics. In addition to national statistical data, there is a need for spatial data that can be split down for vulnerable populations.

The research demonstrates that cloud-based solutions that combine crowdsourcing with open-access EO data sources provide valuable choices for monitoring and following Sustainable Development Goals, particularly for low-income countries. The authors explained that cloud computing may be built for essential topics to monitor, assess, and analyze the advancement of the SDGs, particularly for quick inspections, and to provide real-time support for decision-making. For example, Google has developed a GEE cloud architecture that significantly improves massive data handling and processing capabilities for environmental monitoring. Many businesses are concentrating on cutting carbon emissions to create a long-term plan for environmentally friendly, sustainable growth. Cloud computing offers several benefits for this outcome. The organization shares its equipment to enhance

use rather than having each business on its own. Furthermore, servers are kept in climate-controlled spaces with continuous temperature and humidity monitoring.

The cloud offers several financial benefits, such as cost reductions and increased productivity at work. Moving from on-premises systems to the cloud has many advantages, such as reduced waste, operational expenditures being replaced by capital investments, and flexibility without adding more gear, which lowers hardware costs. Off-site hardware lowers power supply expenses, frees up workspace, and saves money on purchases. When cloud devices are retired, these benefits reduce energy use and ecological harm. Cloud computing lowers electricity costs while simultaneously cutting energy use. Cloud computing dramatically increases economic speed by employing network-connected distant systems instead of local ones. It also reduces operational expenses and provides improved performance and flexibility for business expansion. A virtual conversation framework provided by the cloud may reduce costs and save up to 50% of the time compared to in-person talks [1].

Additionally, employing cloud services may result in considerable savings on staff and service costs. Because cloud computing improves employee productivity and directly reduces labor costs, it may be highly cost-effective for enterprises. Furthermore, the research from [2] also found that companies may move their mission-critical legacy systems to the cloud, a workable alternative environment with better options. According to the research [3], cloud-based solutions are dependable and flexible to help and improve small to medium enterprises (SMEs) for enhanced performance. Additionally, the research of [4] explored how cloud computing and big data can help businesses make better decisions, understand customers, and manage operations.

Additionally, cloud computing may allow educational districts to save money on maintenance, electricity, and infrastructure. Online resource versions are now available to schools, saving money and ensuring students learn from the most recent resources. Cloud computing may lower the costs related to photocopying and printing. Integrating cloud

computing into educational systems will ultimately help institutions realize their goals and guarantee the success of their students. For instance, teachers may save all assignments and class materials in the cloud. Users may link these to other educators and decision-makers over the cloud to receive their feedback. This makes it simpler for instructors to adapt their ideas and enhances class preparation year after year. The data will be stored on the cloud, saving the need to rebuild it if an instructor's equipment malfunctions. Additionally, by using the cloud, administrators, and schools can easily arrange and share important documents and policies with every employee.

Models of Cloud Services

Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) are the three main categories into which cloud services may be separated. These cloud services are helpful in terms of economic, social, and ecological growth. Infrastructure as a Service (IaaS) is an online virtual computer service provider. Under the Infrastructure-as-a-Service (IaaS) model, cloud hosting manages IT assets, such as servers, storage, and networking devices. It provides them to customer businesses via virtual servers available over the internet. Web applications may be distributed as a service using the SaaS approach. By only accessing software over an online platform instead of installing and maintaining it, users may escape the hassles associated with complex program administration. PaaS is a cloud technology strategy in which hardware and software resources are distributed online to customers by a third-party provider. Building programs usually require these resources. The supplier's internal network hosts both the hardware and software. Thus, PaaS removes the need for developers to download their software and hardware to create or run a contemporary service.

IaaS may make operations faster, more accessible, flexible, and affordable regarding sustainable economic growth. IaaS helps to promote sustainable economic development by giving companies the flexibility to choose the services and solutions they need. While the cloud provider manages the infrastructure, businesses can concentrate on downloading, installing, and managing apps and safeguarding their data. It

is also cost-effective as companies only pay for the computing, storage, and networking resources, and IaaS costs are easily anticipated and budgeted for. Additionally, SaaS promotes corporate expansion, which ultimately contributes to economic sustainability. SaaS options provide a unified opportunity for straightforward, distinctive customer addition, feature flexibility, and the newest tailored business solution. SaaS services may significantly reduce operating and maintenance costs, allowing management to finance investments in other areas while maintaining a reliable and secure system. PaaS reduces business costs by providing software foundation facilities. There is no wastage of beneficial money since customers only pay for the resources they utilize.

Energy management is one of the most essential environmental control methods for ecologically sustainable growth. Instead of manually gathering data and entering it into an Excel spreadsheet, more firms are embracing Software as a Service (SaaS) to monitor and manage energy use. One SaaS tool for energy management, called Energy Watch, integrates data insights inside Watch wire to work as a productive partner for risk analysis and energy resources. They work in conjunction with enterprises to determine the optimal length of agreement terms for energy procurement, power supply services, and terms of agreement contracts. SaaS applies to oil and gas management in addition to energy management. Demands on oil and gas companies to demonstrate their efficacious ecological management and sustainability activities are growing. The SaaS system, which shows real-time oil and gas control activities, has dramatically simplified the initial certification process and provided a strong foundation for ongoing safety and risk assessment. It offers an advanced, cost-effective single platform to reduce complexity, boost output, and encourage sound risk management across sustainability, ecological governance, and standard control.

SaaS solutions for legal practice management (LPM) use law practice management software, which contributes to social sustainability. Legal firms use SaaS to help with task administration, accounting, networking, documenting, task delegation, billing, and advertising. Innovation has changed

the legal profession in the same way that it has changed the business sector. Legal practices may save and find client personal information with the help of Law Practice Management Software. It provides the company with a single connection database. It gives a ready store for searches and aids in the upkeep of articles per connection. Generally, the program facilitates the recording of invoices, which may help with managing reports, debtors, costs, timesheets, and customer issues, among other things. Regularly, transactional, or conditional makes monitoring taxable times easier.

Additionally, IaaS is crucial to education under socially sustainable growth. The educational sector has already seen the flexibility of the cloud's operations. They might now use the clouds to support the recently emerging trend of disjointed processes. IT executives and administrators need to understand that Infrastructure as a Service (IaaS) is a valuable tool enabling educators and students to access innovative materials quickly and at a reasonable cost. It is not just a band-aid fix that proved handy during the COVID-19 pandemic. IaaS is a crucial enabler of technological advancements supporting academic teaching and virtual education programs that will allow advanced learning in the next few years. Institutions that integrate Infrastructure as a Service (IaaS) into their computing portfolio will be better prepared to manage staff and student technology needs in the future.

Models for Cloud Deployment

The goal and nature of the cloud, as well as the particular kinds of cloud infrastructure rights of accessibility, scalability, and governance, are all described in the cloud deployment model. Four primary categories of approaches for cloud deployment consist of communal, hybrid, private, and public clouds. The general public may access the public cloud via the internet. The cloud services company controls the technology in this public cloud, not the user. It is a hosting service that makes it simple for users to connect to networks and apps.

Public cloud providers like AWS and Azure have committed to using entirely renewable energy by 2025, playing a part

in ecologically sustainable development. Meanwhile, Google Cloud Platform has declared itself carbon-neutral and plans to use only carbon-free energy by 2030. Moreover, AWS, Azure, and GCP have advanced beyond internal projects like environmentally friendly supply chains, eco-friendly data centers, and advancements in renewable energy. They've all introduced cloud-native technologies, allowing customers to determine their carbon emissions quickly. For instance, using the GCP Carbon Footprint tool, users may track and assess the carbon pollution caused by personal cloud use and the carbon emissions of inactive public clouds.

The phrase “private cloud” describes a computer environment in which every piece of hardware and software is exclusively assigned to and accessible by a single client. Most choose the private cloud over the public cloud because it makes it easier for enterprises to comply with regulatory responsibilities. Private cloud deployments focus on sustainable economics as an alternative to public implementations. Big enterprises are finding the private cloud an increasingly appealing alternative because it offers features similar to public technology inside what they perceive to be a more stable financial structure. Connecting to a cloud network speeds up company data interchange, making joint decision-making simpler and more efficient, ultimately boosting productivity.

A hybrid cloud is an integrated computing, storage, and services platform comprising public cloud services, on-premises infrastructure, and private cloud services. Businesses may use on-premises equipment and data center services while expanding by using the hybrid cloud. In a time when the global community is primarily concerned with sustainable development, hybrid cloud technology gives businesses the power to direct growth and improve their sustainability legally. Additionally, a hybrid cloud platform allows companies to use the services they need when they need them. Hybrid clouds mix limited on-premises system maintenance with infinite public cloud services to promote sustainable growth.

Community cloud computing is a term used to describe a collaborative cloud computing resource platform for a limited

number of enterprises or workers. Another significant factor in socially sustainable development is community clouds. Community clouds are widely used for patient information communication between labs and healthcare institutions. They could use a HIPAA-compliant community cloud to do this without any problems. Pharmaceutical companies who trade data worldwide should also use it. For instance, the worldwide cooperative clinical investigation of the COVID-19 pandemic is presently being made more convenient by the community cloud's deployment. In addition, the community cloud allows instructors and students to share instructional materials to promote cooperative research. This will enable students to get the most recent and up-to-date instructional knowledge.

Features of the Cloud That Encourage Sustainable Development

1) Simple Upkeep

Servers are easily maintained, and there are never any significant disruptions. Services supported by cloud computing undergo several changes regularly to optimize their whole potential. Hardware upgrades are more practical and perform better than previous iterations. Because it saves time and money on maintenance, it is advantageous for sustainable development. One of the characteristics crucial to sustained growth, particularly in the commercial sphere, is the ease of cloud maintenance. Using a cloud-based management system lowers the cost of upgrades. Effective maintenance organizations must often accomplish more with less to reduce service costs. Due to reduced initial costs, this may be a highly tempting option that offers small businesses additional economic opportunities.

2) Advantageous Economic Effect

This particular cloud function helps reduce the IT expenditures of sustainable development organizations. When using cloud computing, the user is responsible for paying the administrator back for the capacity used. There aren't any additional expenses or hidden fees to pay. Some rooms are usually provided for free since the management

is thrifty. Additionally, this characteristic is essential to long-term economic growth. It also enables the IT department to produce more innovative and practical goods. IT inventions increase with business innovation, which creates jobs, and business development increases with more profit. Depending on its Economic Impact Model (EIM), IDC projects that Salesforce customers worldwide might expect a net revenue increase of \$375 billion between 2019 and 2024, with 53 billion coming from Western Europe.

3) Pooling of Resources

A hosting firm may allocate resources among many clients via resource pooling, providing customized features according to their requirements. It is a multi-client technique that may be used for computing, communication, and information storage, among other things. The client's experience is unaffected by the real-time resource allocation management technique [45]. This characteristic is crucial for sustainable growth. For instance, it may support socially sustainable development in the education sector by facilitating more effective lecturer-student sharing of course materials. It allows educators to share instructional materials quickly, administrators to communicate with one other and save money on file storage, and students to do assignments from any location with internet access, all of which contribute to an increase in the standard of education.

4) Broad Network Connection

The consumer may upload data to the cloud and see cloud data from any place with only a device and an internet connection. These features are accessible throughout the form and may be accessible via cloud computing support. Extensive network connectivity promotes paperless practices, which ultimately enhances environmentally friendly development. One advantage of cloud storage is that data may be retrieved anytime and anywhere. Another significant benefit is that data is not lost, unlike what sometimes happens to hard drives in data centers. The extensive network access architecture seeks to utilize less energy while providing clients with efficient services.

III. COMMON CLOUD PROVIDER ASPECTS THAT ASSIST IN ECONOMIC DEVELOPMENT

A. AWS, or Amazon Web Services

One of the critical components of AWS that supports sustainable growth is resource pooling. AWS's infrastructure resources are collected in several data centers worldwide and are distributed according to demand. As we go forward with our plan to run our company entirely on renewable energy by 2025, AWS is committed to sustainability and ongoing development throughout our global network. AWS is committed to helping Amazon achieve carbon neutrality by 2040. Customers may develop sustainability services by collecting, analyzing, and managing sustainability data using AWS services like waste reduction, resource efficiency, and monitoring emissions. AWS provides the broadest and most complete range of capabilities in computing, data analytics, the Internet of Things, machine learning, and artificial intelligence (AI) to assist the business in meeting its sustainability goals. AWS provides the expertise and resources needed for companies of all sizes and sectors to design and implement solutions that support their strategic goals.

In addition, one of the critical components of AWS in sustainable growth is broad network connectivity. The Amazon Sustainability Data Initiative (ASDI), one of the AWS products, may be used to illustrate this characteristic. To accelerate sustainable investment and innovation, ASDI works to lower the cost and duration of obtaining and assessing large datasets on sustainable development. The sophisticated technology, tools, and information needed by researchers and entrepreneurs to promote sustainability are made available by ASDI. Additionally, the AWS Customer Carbon Footprint Tool's functionality, which measures and reports emissions, also helps to provide an overview of carbon emissions. The Greenhouse Gas (GHG) Protocol standards should be followed when utilizing straightforward data visualizations to report pollution from AWS use. As Amazon approaches operating on sustainable electricity, users may also use it to plan and forecast how pollution will change.

B. Google Cloud

One of Google Cloud's products, the Carbon Sense suite, is a crucial component that supports measured and reported sustainable growth. It helps users take action to reduce their carbon footprint and accurately report the greenhouse gas emissions associated with their usage of Google Cloud. With the Carbon Sense package, users may take action towards a better environment by combining features from many Google Cloud products, including Carbon Footprint and Active Assist. By offering scalable services, Google Cloud also offers quick elasticity and scalability. For instance, it helps users of Google Maps make healthier choices. Google Maps lets users choose the route with the least fuel when traveling. This might save over a million metric tons of carbon emissions yearly, equivalent to removing over 200,000 cars off the road.

C. Microsoft Cloud

This cloud solution leverages the depth and breadth of the whole Microsoft cloud to help organizations take control of their environmentally friendly initiatives. It gives enterprises a collection of comprehensive, integrated, and algorithmic information and insight to expedite each stage of their sustainable journey. One of the critical characteristics of Microsoft Azure is flexibility. Users will be able to track their progress in reducing emissions and pinpoint specific sources of pollution. For instance, if an HVAC system is not meeting its designated decarbonization target, managers may be tasked with meeting current system requirements. Using the Vattenfall 24/7 Matching system, Microsoft was the first hyper-scale cloud hosting provider to assess hourly power usage and renewable power matching in a commercial offering. The solution to allow fossil-free existence for generations was developed with the help of Microsoft Azure technologies, including Azure IoT Central and Microsoft Power BI. Businesses may assess the environmental impact of renewable power sources and determine if their commitment to exclusively renewable energy covers every hour of consumption. The best people to explain the hourly need for renewable energy and help with production enhancement to meet demand are energy providers.

IV.POSSIBLE TROUBLES

Because cloud computing provides many benefits for businesses of all kinds, it has become increasingly popular in sustainable development. However, cloud computing has several possible drawbacks for sustainable growth. Security threats are the primary concern when using cloud computing. Sensitive and vital data is stored on cloud servers. Even if the hosting provider promises data integrity, the user is still responsible for user identity and permission, access control, encryption keys, and security mechanisms. Customer trust is eroded by identity theft, data breaches, cyberattacks, and other possible risks associated with the cloud. Income loss and damage to one's reputation and position might arise from this. Furthermore, using cloud computing requires sending and receiving enormous amounts of data rapidly, which increases the risk of security breaches.

Furthermore, even though almost all cloud service providers use a "Pay as you Go" model, which reduces the overall cost of the services used, there are times when a business using cloud computing may incur high costs. When assets are not optimized—for instance, when systems are not used to their full potential—the hidden costs rise. The overall cost goes up if there are unplanned spikes in use or less application monitoring. The underutilization of resources is one of the other main reasons for price increases. The cost will increase without using the resources if the user activates cloud computing and forgets to turn it off. At some point, this affects sustainable development.

Moreover, management is one of the difficulties that might affect sustainable growth. With more options, businesses today depend on many cloud services instead of just one. Most of these companies use several clouds and hybrid cloud solutions. This is sometimes difficult to execute and a hindrance to maintenance management. The process often becomes quite complex for the IT personnel because of the differences between different clouds.

Because cloud computing uses real-time resource allocation, it can handle vast volumes of data flowing to and from computers. This is only possible in the presence of a high-speed network. Even if these tools and data are sent across a network, they might still be vulnerable when insufficient bandwidth or unplanned interruptions exist. Businesses still need to ensure that there are no network outages and that the internet speed is adequate, even if they can lower the equipment cost. For smaller enterprises, maintaining network bandwidth, which comes at a high price, is thus a significant issue.

Lastly, a lack of knowledge about cloud computing affects sustainable growth. Working with it is sometimes lengthy because of the cloud's intricacy and high need for study. Proficiency and in-depth topic knowledge are required. Even if the sector is complete with experts, they must constantly improve their abilities. The cloud computing industry has a massive imbalance between supply and demand, which drives up wages. There are plenty of available jobs, but there aren't enough skilled cloud engineers, developers, and specialists. Therefore, upskilling is required so that these workers can actively understand, manage, and create cloud-based systems with the least amount of downtime and maximum reliability [58].

V. SUMMARY

In conclusion, a thorough discussion of cloud services, cloud deployment models, cloud features, and cloud providers' role in promoting sustainable development that enhances social, economic, and environmental progress was held. In addition, the administration, security, and privacy issues that may arise while using cloud computing for sustainable development have also been examined. Sustainability promotes human and community welfare, a more equal distribution of money, and the health and biodiversity of the environment. It is advised that to avoid identity theft, data breaches, and other possible risks, cloud computing security and privacy management be strengthened in future projects. Implementing a more flexible cost-counting method and controlling hidden expenditures

are also necessary for cloud adoption. Furthermore, additional study is required to enhance cloud management when organizations or businesses use multiple cloud platforms. It will also be essential to continually advance cloud understanding to create cloud-based systems with fewer faults and more dependability.

RECOGNITION

The University of Bahrain gave the authors of this research the chance to present it on the IEEE platform, for which they are grateful. Asia Pacific University of Technology & Innovation (APU) funded this study.

Cloud Computing - Concepts, Architecture and Challenges

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Abstract

The internet has drastically altered the world of computing, from its introduction in the 1990s to its current state of ubiquitous computing. Parallel computing was first introduced, followed by distributed computing, grid computing, and most recently, cloud computing. Even though cloud computing is not a new concept, it is still in its infancy in computer science. Cloud computing may be defined as a computer environment in which a party can outsource its computing requirements to another party and access computing resources, such as databases and emails, over the internet whenever needed. A more recent development in IT is cloud computing, which shifts data and computation from desktop and portable PCs to massive data centers. The primary benefit of cloud computing is that users do not have to pay for equipment, installation, labor costs associated with maintaining such infrastructure, or other related expenses. In this article, we will talk about cloud computing, its architectural design for applications, and how it makes all of this feasible.

Keywords: cloud computing, problems, applications, architecture, and business component

I. OVERVIEW

When service providers started using virtual private network (VPN) services for data communications, the word

“cloud” emerged from the realm of telecommunications [1]. Computation, software, data access, and storage services are all covered by cloud computing, and it’s possible that these services don’t need end users to be aware of the precise location and setup of the system providing them. A more recent development in IT is cloud computing, which shifts data and computing from desktop and portable PCs to massive data centers [2]. Applications can now be delivered as services over the internet thanks to the widespread proliferation of the internet worldwide. The National Institute of Standards and Technology (NIST) defines cloud computing as “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.” This lowers the total cost as a consequence.

The primary objectives of cloud computing are to make greater use of dispersed resources, combine them to produce faster throughput, and address large-scale calculation problems.

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Issues. Cloud computing covers virtualization, scalability, interoperability, quality of service, and the three cloud delivery models – private, public, and hybrid.

II. HISTORY

Cloud computing traces its conceptual origins to the 1960s when John McCarthy proposed that computing resources could eventually be delivered as a public utility, similar to electricity or telephony [4]. This vision laid the foundation for the modern cloud computing paradigm. Subsequently, the characteristics and potential applications of cloud computing were explored in greater detail. One of the earliest comprehensive discussions appeared in Douglas Parkhill’s

book *The Challenge of the Computer Utility* published in 1966, which described the concept of providing computing services on demand [4]. The term “cloud” later emerged from the telecommunications industry, where service providers used virtual private networks (VPNs) to offer flexible and cost-effective network services. Prior to VPN technology, dedicated point-to-point communication lines often resulted in inefficient bandwidth utilization. VPNs enabled providers to optimize network resources through shared infrastructure while maintaining service quality. This concept was subsequently extended beyond networking to encompass servers, storage systems, and computing infrastructure, forming the basis of cloud computing. The commercial adoption of cloud computing accelerated significantly in the early 2000s. In 2006, Amazon Web Services (AWS) introduced a suite of cloud-based services that played a pivotal role in popularizing the cloud computing model. Around the same time, IBM and Google launched major cloud computing research initiatives. Furthermore, Eucalyptus emerged as one of the first open-source platforms for deploying private cloud infrastructures, contributing to the widespread adoption and development of cloud technologies [2], [3].

III. FEATURES OF CLOUD COMPUTING

Cloud computing offers several significant features that have contributed to its widespread adoption across various industries.

- **Accessibility and Ubiquitous Access:** Cloud computing enables users to access data, applications, and services from anywhere in the world through an Internet connection and a web browser, regardless of the device being used. Since the infrastructure is typically provided and managed by third-party vendors, organizations can avoid substantial investments in hardware and software, thereby reducing operational costs [1], [2].

- **Reduced IT Complexity:** The deployment and management of cloud services require less technical expertise compared to traditional on-premises infrastructures. Service providers handle most administrative tasks, including maintenance, updates, and resource allocation [2].

- **Reliability and Disaster Recovery:** Cloud service providers often maintain multiple geographically distributed data centers, which support business continuity and disaster recovery. This distributed architecture enhances service reliability and availability [3]. However, cloud services may still experience outages, and users have limited control during such incidents [4].

- **Resource Sharing and Cost Efficiency:** Cloud computing promotes resource pooling, allowing multiple users to share computing resources and infrastructure. This model improves resource utilization and reduces costs through economies of scale [1].

- **Simplified Maintenance:** Applications hosted in the cloud do not require installation or maintenance on individual user devices. Updates and software patches are managed centrally by the service provider, reducing maintenance efforts and ensuring consistency across users [2].

- **Pay-Per-Use Model:** Cloud services generally follow a usage-based pricing model, where customers pay only for the resources they consume. This enables organizations to monitor and optimize resource usage efficiently [1], [5].

- **Scalability and Elasticity:** One of the key advantages of cloud computing is its ability to scale resources dynamically according to workload demands. Organizations can rapidly increase or decrease computing resources without significant infrastructure modifications [1], [2].

- **Security:** Cloud providers often implement advanced security measures and dedicate substantial resources to protecting data and services. As a result, cloud security can be comparable to or even stronger than that of traditional computing environments. Nevertheless, concerns regarding data privacy, confidentiality, and regulatory compliance remain significant barriers to cloud adoption, particularly for organizations handling sensitive information [6], [7].

IV. CLOUD COMPUTING SYSTEM DESIGN

A cloud computing system consists of two primary components: the front end and the back end, which

communicate through a network, typically the Internet [8]. The front end represents the client side and includes the user's computer, mobile device, or web browser along with the applications required to access cloud services. The back end comprises the cloud infrastructure, including servers, storage systems, databases, and application services that provide computing resources to users.

A central server manages system operations, client requests, traffic monitoring, and resource allocation. It follows predefined protocols and utilizes specialized software known as middleware to facilitate communication between networked computers and cloud services [8]. Middleware acts as an intermediary layer that enables interoperability among distributed applications and computing resources.

A. Cloud Computing Architecture

Cloud computing architecture is generally organized into multiple service layers that provide different levels of abstraction and functionality to users. The three fundamental service models are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) [1].

1) Software as a Service (SaaS)

Software as a Service (SaaS) delivers software applications over the Internet, eliminating the need for users to install and maintain applications on local devices [9]. SaaS applications are centrally managed by service providers and can be accessed through web browsers. Key characteristics of SaaS include centralized administration, remote accessibility, automatic software updates, and reduced maintenance requirements. Major SaaS providers include Salesforce, Microsoft, IBM, Oracle, and NetSuite [10]. Google Workspace is one of the most widely adopted SaaS solutions.

2) Platform as a Service (PaaS)

Platform as a Service (PaaS) provides a complete cloud-based development environment that enables developers to design, test, deploy, and manage applications without purchasing and maintaining underlying hardware and software infrastructure. PaaS offers programming tools, operating

systems, databases, and development frameworks required throughout the software development lifecycle. Examples include Microsoft Azure and Google App Engine (GAE) [10].

3) Infrastructure as a Service (IaaS)

Infrastructure as a Service (IaaS) delivers fundamental computing resources such as virtual machines, storage, networking, and data center facilities as on-demand services. Customers can provision and manage these resources without investing in physical infrastructure. The pay-per-use pricing model allows organizations to reduce capital expenditure while improving flexibility and scalability. Popular IaaS providers include GoGrid, Flexiscale, Joyent, Rackspace, and Amazon Web Services (AWS) [10].

B. Cloud Deployment Models

The deployment model determines how cloud resources are organized and accessed. The four major cloud deployment models are Public Cloud, Private Cloud, Hybrid Cloud, and Community Cloud [11].

1) Public Cloud

A public cloud provides computing resources and services to the general public over the Internet. The infrastructure is owned and managed by a cloud service provider, and users pay based on resource consumption. Public clouds offer high scalability, flexibility, and cost-effectiveness.

2) Private Cloud

A private cloud operates exclusively for a single organization and is typically hosted within an enterprise data center. It provides greater control over data, security, and compliance requirements. Unlike public clouds, the organization manages its own resources and applications, resulting in enhanced privacy and security.

3) Hybrid Cloud

A hybrid cloud combines public and private cloud environments. Organizations can maintain sensitive applications and data within a private cloud while utilizing

public cloud resources for additional computing power and storage when needed. This approach offers a balance between security, flexibility, and cost efficiency.

4) Community Cloud

A community cloud is shared among multiple organizations that have similar operational requirements, security concerns, or regulatory obligations. The infrastructure may be managed by one of the participating organizations or by a third-party provider. Community clouds facilitate resource sharing while maintaining common governance and security policies.

V. PROFITS FROM CLOUD COMPUTING

Cloud computing has gained widespread acceptance due to its ability to provide scalable, cost-effective, and efficient computing services. The major benefits of cloud computing are discussed below.

A. Simplified Administration

Cloud computing significantly reduces the complexity of infrastructure management. Cloud service providers are responsible for maintaining hardware, software, security updates, and system upgrades, thereby reducing the workload on an organization's IT staff. Users can access cloud services through standard web browsers and Internet-connected devices without requiring specialized software installations [1], [2].

B. Cost Reduction

One of the most significant advantages of cloud computing is the reduction of information technology costs, particularly for Small and Medium Enterprises (SMEs). Cloud services follow a pay-as-you-use pricing model, allowing organizations to pay only for the resources they consume. This eliminates the need for substantial capital investments in hardware, software licenses, and maintenance infrastructure [3].

Furthermore, organizations can avoid purchasing expensive computing systems for occasional high-performance workloads. Cloud-based applications such as email, document management, and collaboration tools can be deployed

rapidly with minimal administrative effort. However, public cloud environments may introduce additional security concerns because data and applications are hosted on shared infrastructure. Appropriate security mechanisms, including encryption and access control, are therefore essential [4].

C. High Availability and Service Continuity

Cloud computing providers typically offer highly available services through geographically distributed data centers and redundant infrastructure. This architecture minimizes service interruptions and reduces system downtime. Although occasional service outages have been reported, major cloud providers generally offer higher availability levels than traditional on-premises infrastructures [2], [5].

D. Disaster Recovery and Business Continuity

Cloud computing supports disaster recovery by maintaining data backups in geographically separate locations. Most cloud providers implement comprehensive disaster recovery strategies, ensuring that critical business data can be restored in the event of hardware failures, cyberattacks, or natural disasters. Consequently, cloud storage services play a vital role in ensuring business continuity [1].

E. Green Computing

Cloud computing contributes to environmental sustainability by improving resource utilization and reducing energy consumption. Through virtualization and resource sharing, cloud providers can operate data centers more efficiently than individual organizations. This results in lower power consumption, reduced carbon emissions, and decreased electronic waste (e-waste), thereby supporting green computing initiatives [6].

VI. CHALLENGES OF CLOUD COMPUTING

Despite its numerous advantages, cloud computing faces several challenges that may affect its adoption and implementation.

A. Security Concerns

Security remains one of the primary concerns associated with cloud computing. Organizations often hesitate to store sensitive and confidential information on third-party infrastructures due to concerns regarding unauthorized access, cyberattacks, and data breaches. Cloud service providers continuously invest in advanced security technologies; however, security risks cannot be completely eliminated [7], [8].

B. Privacy Issues

Data privacy is another significant challenge because cloud-based information can be accessed through Internet-connected systems from multiple locations. Improper access control mechanisms may expose sensitive information to unauthorized users. Strong authentication, authorization, encryption, and identity management techniques are therefore essential for protecting user privacy [7].

C. Reliability and Availability

Although cloud providers generally offer highly reliable services, outages can still occur due to hardware failures, software bugs, network disruptions, or cyberattacks. Such failures may temporarily affect service availability and business operations [5].

D. Data Replication and Cost Considerations

Data replication across multiple data centers improves fault tolerance and reliability but may increase storage and operational costs. Organizations must carefully balance performance, availability, and cost when designing cloud-based systems [3].

E. Vendor Dependency

Organizations relying heavily on a particular cloud provider may experience vendor lock-in, making migration to alternative platforms difficult and costly. Standardization and interoperability remain important research challenges in cloud computing environments [2].

VII. CONCLUSION

Cloud computing represents one of the most significant technological advancements in modern information technology. It provides scalable computing resources, flexible service delivery models, high availability, and cost-effective solutions through pay-per-use pricing mechanisms. The technology has transformed the way organizations deploy, manage, and consume computing resources. Despite its many benefits, challenges related to security, privacy, reliability, and vendor dependency continue to influence cloud adoption. Ongoing research and technological advancements are expected to address these concerns and further improve cloud computing infrastructures. As a result, cloud computing is anticipated to remain a key enabling technology for future digital transformation, supporting emerging domains such as big data analytics, artificial intelligence, the Internet of Things (IoT), and Smart Grid systems.

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Cloud Computing and Sustainable Development in Higher Education

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ABSTRACT

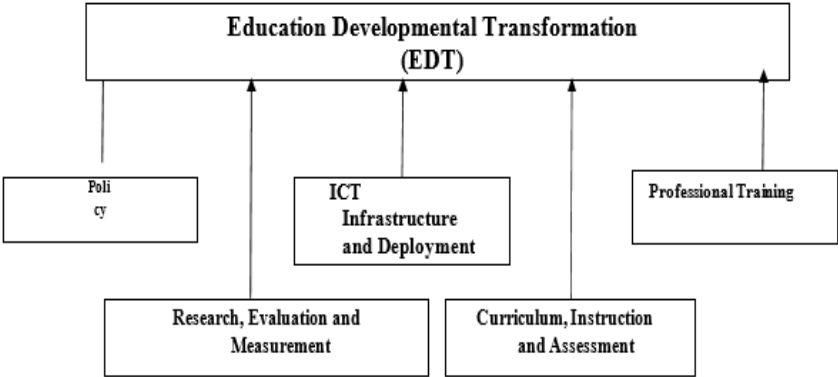
In higher education, sustainable development (SD) is a worldwide process that cuts across social, political, and economic divides. When bolstered by the required information technology (IT) infrastructures, the process of developmental change in higher education will result in long-lasting enhancements that will provide students with the most excellent chance to prosper in the global market. To produce graduates with the abilities necessary to succeed in the twenty-first century, this article discusses the role that cloud computing plays in facilitating and promoting sustainable growth in higher education. Additionally, we offer broad building blocks for a long-term shift in the direction of higher education, using cloud computing as a suitable substitute for existing assistance.

Keywords: *Cloud computing, Sustainable development, Information technology, higher education, virtualization.*

Introduction

Higher education has long been recognized as one of the cornerstones of a rising society hoping for revolutionary advancements in politics, technology, and the economy. There is evidence to support the idea that higher education has advantages for the public and commercial sectors. To change society and the global economy, researchers and students must collaborate with government agencies, businesses, and higher education institutions to produce new ideas

and acquire expertise. Stated differently, universities play a significant role in supplying the human resources needed to create knowledge that strengthens a community (Bulla et al., 2016). Technology and education working together have developed a solid foundation for the growth and improvement of society. Information technology (IT) forms the foundation of education, and education feeds IT. It is clear from this that information technology has significantly influenced the goals, practices, and perceived possibilities of education. When a society achieves sustainable socio-economic growth, it suggests that a sustainable development framework is required to provide education services that maximize benefits while minimizing costs (Kim et al., 2011).



According to Horn, traditional higher education has been disrupted, as stated by [2], particularly in third-world nations, since development is linked to pricey or complex goods that are inappropriate for many consumers because of their cost, complexity of use, or irrelevance to modern demands(*Sensors | Free Full-Text | Smart Learning Services Based on Smart Cloud Computing, i.e.*).

Knowledge is the primary driver of economic growth and progress in today’s information-driven cultures. That information is primarily produced, disseminated, and absorbed by any community through higher education [3]. Higher education thus merits a sustained developing process

for the best outcome, given that it is essential to improving a country's people's ability to generate, assimilate, and use knowledge for sustainable development. A new computing paradigm called "cloud computing" is starting to take shape. It uses the tools and infrastructures already in place in information technology, like virtualization, grid computing, web services, and the Internet, to improve efficiency, save costs, and facilitate the delivery of services and higher education (Kobayashi et al., 2017).

Information Technology in the Development of Higher Education

IT and the deluge of digital data have undoubtedly altered higher education's approaches, goals, and perception of its potential. Without ICT, universities and colleges could not operate. It is essential for communication, administration, research, and information collection, and it is quickly becoming the same for teaching and learning (Wang et al., 2023).

The followings briefly describe how IT has affected Higher Education

Convenience and Availability (Changes to Learning and Teaching)

A large number of universities provide online learning. Additionally, having access to vast information databases improves learning and has trained students to be makers and participants in creating and accessing information discourses. Technology has also changed how instructors educate. With online video conferencing, for example, teachers may now add exciting new elements to their lessons.

Purpose of Education: Information technology has changed the goals of education, from teaching and learning to the creation, preservation, integration, transmission, and application of knowledge for societal advancement.

Potential of Education: Information technology allows educational services to be delivered anywhere, anytime, and

liberates higher education institutions from temporal and spatial limitations.

IT infrastructures have been noted to offer higher education institutions a good platform for conducting fruitful scientific research and carrying out instructional activities [5] and [6].

Cloud Computing and Sustainable Development of Higher Education

As an improved computing paradigm, cloud computing has emerged and offers previously unheard-of, cost-effective ways to supply educational services based on current IT infrastructures. Higher education must adopt a systematic and sustainable developmental strategy to accomplish a functional and goal-oriented delivery of education services. Numerous writers have illustrated in their works how commercial enterprises are already reaping the rewards of this novel computing strategy. So, how does this technology impact the advancement of higher education? How might this 21st-century IT grace help educators, learners, administrators of higher education, and society at large sustainably?

Cloud computing is a reality with several business applications; it is not only a futuristic technological notion with plenty of interesting potential applications. For example, Amazon's Elastic Compute Cloud (EC2) provides various services. A virtual computing environment enables users to launch instances with different operating systems, load them with customized customer application environments, and control access permissions on their networks through Web service interfaces [7].

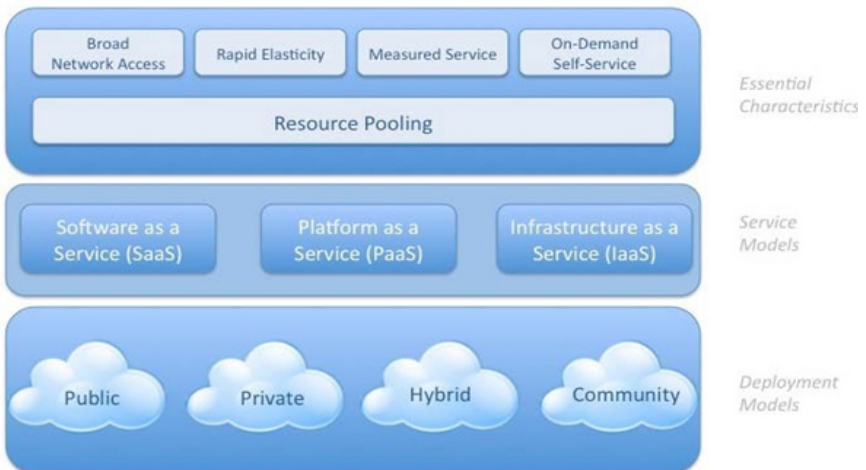
What is the meaning of cloud computing? Cloud computing is a word that is still developing and refers to the many ways that many current computing technologies and techniques have evolved. Application and information resources are isolated in the cloud from their supporting infrastructure and delivery methods. In addition to improving availability, scalability, agility, and collaboration, cloud computing offers cost savings through streamlined and effective processing. In general, cloud-supported assets fall into one of two categories:

Data Applications/Functions/Processes Cloud computing

provides anytime/anywhere services that can be accessed from any device [1]



The architectural framework for Cloud computing was provided by the U.S. National Institute of Standards and Technology (NIST), as illustrated in Figure 3 [8]



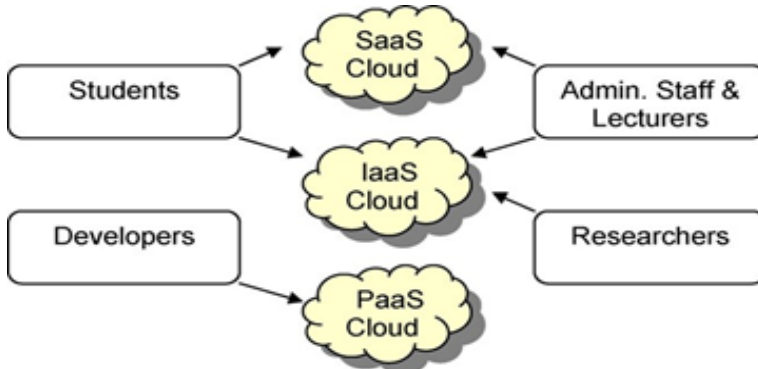


Fig: 4

NIST described cloud computing as consisting of five essential characteristics, three service cloud models, and four cloud development models

Prior research on cloud computing has focused on security concerns as a novel technology, corporate sector cloud computing, and potential future developments. By[13], the methods for modeling Cloud computing as a newly developed application platform for data, computation, and business service sharing were investigated.

[9] Gave a summary of the technical research conducted in HP labs. [10] Built a cloud-based architecture designed for the performance of wide area networks, with features to facilitate data mining applications. Infrastructures for cloud computing have supported many technical advancements and made resources widely accessible for higher education institutions as on-demand services [11]. Gaining a comprehensive comprehension of the many services provided by cloud computing aids in comprehending the essence of this innovative IT methodology. According to Gartner, cloud computing is “a style of computing where massively scalable IT-enabled capabilities are delivered ‘as a service’ to external customers using Internet technologies” [12]. We offer a typology of cloud computing as a service that is distinguished by the attributes listed below:

Infrastructure as a Service (IAAS)

Products or services offered via this mode include the remote delivery, over the Internet, of complete computer infrastructure (e.g., virtual computers, servers, storage devices, etc.);

Platform as a Service (PAAS)

The old computing paradigm, in which each program maintained locally necessary hardware, an operating system, a database, middleware, Web servers, and other applications, must be remembered to comprehend this cloud computing layer. It's also essential to remember that the network, database, and system administration professionals must maintain everything operational. These services are now offered remotely by cloud providers beneath this layer thanks to cloud computing;

Software as a Service (SAAS)

In this layer, you may avoid complicated software and hardware management by only accessing the program via the Internet rather than installing and maintaining it locally. This kind of cloud service provides full application capability, encompassing productivity apps (such as office-type programs) as well as enterprise resource management (ERM) or customer relationship management (CRM) tools. Figure 4 below shows how this may be used in an educational setting.

Fig 4: Cloud computing services in an academic Institution
The evolution of cloud computing as a technology for on-demand infrastructure, application, and support services is vital as a possible means of sustainable development of the transformational higher education framework.

Cloud Computing: Virtualization and Higher Education Services Delivery

The budgets of companies, notably higher education institutions like universities and colleges, will continue to be heavily pressured by the rapidly rising rate of change in IT equipment and products. However, cloud computing is more than a futuristic technology; it already offers business

applications that leverage resources and costs. Elastic Compute Cloud (EC2) from Amazon is one example. It provides a range of services. A virtual computing environment enables users to launch instances with different operating systems, load them with customized customer application environments, and control access permissions on their networks via Web service interfaces. To offer more services, Google also provides Google Apps. Google Apps is a collection of Web-based messaging (e.g., Gmail, Google Talk, and Google Calendar) and productivity and collaboration tools (Google Docs: text files, spreadsheets, and presentations) [7].

One of the main components of cloud computing is virtualization, which is mainly concerned with the technology that makes it possible to create a virtual version of an object rather than an actual one, such as an operating system, server, storage device, or network resource. This idea enables the delivery of a wide range of services via various device types.

A categorization of services available through virtualization in cloud computing is illustrated in Figure5 below.



Fig 5: A categorization of education services [1]

Conclusion and Recommendation

Implementing sustainable developmental reforms in higher education, particularly in light of the global economic crisis, is now possible by utilizing cloud computing's facilities and services. Using cloud computing may decrease costs by

hiring fewer employees, which frees up funds for other uses. Additionally, licensing issues with some institutionally used software are resolved, freeing up funds for other uses. When cloud computing is used, employees and students can use tablets and other portable mobile devices more often than desktop or laptop PCs. Higher education institutions may successfully deploy cloud computing technology services from companies like Google, Postini, Cast Iron, Salesforce, etc.

In conclusion, cloud computing is here to stay. It will continue to play a significant role in transforming higher education, particularly in poor nations that are severely financially strained. Concerns about risk and security related to data and sensitive information held by organizations are being researched.

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Cloud Computing Forensics; Challenges and Future Perspectives

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Abstract

In recent years, cloud computing has grown in popularity and developed into an efficient and economical computing paradigm. It might be among the technologies that have had the most influence in the whole history of computing. Unfortunately, cloud service providers or clients have not yet created significant forensic tools that may help investigate criminal activity in the cloud. Given the difficulty of preventing criminal targeting and cloud vulnerabilities, it is essential to understand the potential procedures for conducting digital forensic investigations into the cloud. This is due to the difficulty in avoiding criminal targeting and cloud vulnerabilities. Within this framework, the present research looks at cloud forensic tools, cloud forensic methodology, and future developments in cloud forensics. The study also examines cloud forensic methodologies, with the aim of providing valuable insights and solutions to the challenges in cloud computing forensics.

Keywords: software as a service, cloud computing, cloud forensics, and forensic tools.

1. Introduction

The cloud has not changed much since it was initially developed, nor has it made notable advancements in several vital areas [1]. The idea of cloud computing is the way of the future and will provide businesses with enormous financial

advantages. Numerous new opportunities have emerged with the advent of cloud computing, some more advantageous than others [2]. Because of this growth, cloud computing has become a new front in the fight against cybercrime, bringing new risks and problems that might endanger enterprises [3]. Users with bad intentions may exploit serious security flaws in the cloud. Most cloud products may be accessed remotely by logging onto virtual computers, carrying out tasks related to those services, and then wiping the virtual machines [4]. This is made feasible because cloud goods don't need physical infrastructure users to own. Cloud criticisms increased as cloud computing became more widespread [5]. When investigating crimes committed in the cloud, the methodology differs somewhat from that used in traditional settings. Many forensics topics, such as trust, network forensics, evidence collection, privacy, and data provenance, emerged throughout the previous ten years of study. When dealing with this kind of computing, investigators specializing in digital forensics have a particular set of difficulties [6]. Furthermore, it emphasizes how important it is to create specialized forensic tools that can be used to collect and examine digital evidence in the digital age—including a range of service models and structural configurations—sometimes even before the evidence is wholly destroyed [7]. These variables have also created new challenges for digital forensic investigators trying to get total access to and control over the distribution of cloud resources. Operating systems that operate on top of another operating system as if running on its hardware are referred to as “virtualization” in computing. Cloud computing emerged as a consequence of virtualization [8, 9]. These and other emerging computer paradigms open the door for new types of cybercrime. Although research efforts in digital forensics for conventional computer paradigms, including virtual environments, have shown better results, these methodologies may not immediately apply in the cloud. When operating in a cloud environment, user data is scattered and often lives in inaccessible places to forensics investigators. The next sections of this article are structured as follows: first, an overview of current and future advancements in cloud forensics is given; second, a review of

tools and techniques for cloud forensics is given; and third, an introduction to cloud incident management is given [10].

Businesses are moving toward migrating their data to the cloud as they become more aware of the advantages of cloud computing. Because of this change, there is an increased danger connected with using cloud resources, which makes cyber criminals more interested in taking advantage of them [11]. The size of an average digital forensic case is growing at a rate of 35 percent per year, which indicates that the number of digital crimes is increasing quickly [12]. Consequently, it is critical to prioritize cloud computer security and cloud computing forensic investigation. It should not be shocking to learn that conversing about either subject requires a basic comprehension of cloud infrastructure and digital forensic investigation [13–17].

The National Institute of Standards and Technology (NIST) of the United States defines cloud computing as “a model for enabling ubiquitous, 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” [18–20]. In the modern world, cloud computing can be divided into three main service categories: platform as a service (PaaS), software as a service (SaaS), and infrastructure as a service (IaaS). Infrastructure as a service (IaaS) provides customers with a virtualized machine, an environment somewhat similar to a physical machine but with some limitations. Platform as a service (PaaS) typically offers customers access to an Application Programming Interface (API) [21–24].

2. A SHORT GUIDE TO CLOUD COMPUTING

The National Institute of Standards and Technology (NIST) describes cloud computing as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of resources.”

Configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be quickly provisioned and released with little management work or

interaction from service providers. Cloud A is the flexibility to scale up or down computational requirements to client requirements. The flexibility to access a network from anywhere at any time is called connectivity. Multi-tenancy refers to the capacity to accommodate multiple tenants on a single set of physical resources, such as shared memory, storage space, and network connections. Visibility is the capacity for customers to fully comprehend and manage the details, use, and costs of their cloud deployments. Measured service allows customers to be charged based on the amount of offered items they utilize [25–30].

The various advantages of cloud computing have contributed significantly to its rapid growth. The main benefit of cloud computing is realizing economies of scale due to the flexible and effective use of available resources and specialization. Cloud computing offers a wide range of deployment and service delivery options. Public cloud deployment is one of the deployment strategies. This method uses the internet to make computer tools and services available to the general populace. A cloud owned and managed by a separate third party and offering cloud services is called a public cloud [12]. A private cloud is a computer environment a firm owns and controls entirely, internally or through a third party. Private clouds are created to support a single tenant and allow more control over all computing resources [31]. As an alternative to private cloud computing, community cloud involves the pooling and sharing data storage and processing capacity across several companies that uphold the same privacy, security, and other legal criteria. A hybrid cloud is a combination of two or more clouds that are connected via standardized or proprietary technologies to enable interoperability. 1. Software-as-a-service (SaaS), infrastructure-as-a-service (IaaS), and platform-as-a-service (PaaS) are three paradigms for cloud services that are widely accepted, according to Jansen and Grance (2011) [32, 33]. Software-as-a-service (SaaS) is a software deployment method in which one or more applications are made available on demand as turnkey services that can be accessed through a thin client with the computing resources necessary to operate them. This strategy aims to reduce the overall cost of creating hardware and software, as well as that

of maintaining and using them. In this paradigm, consumers have limited rights, such as the ability to alter application settings and their data, but CSPs have total authority over the apps and the underlying infrastructure. Platform-as-a-Service, or PaaS for short, is a method of deploying software. The computing platform is made available as an on-demand service and used as the basis for developing and deploying applications [34]. Its main goal is to make acquiring, setting up, and managing the platform's underlying hardware and software components—such as databases, operating systems, and development tools—more straightforward, minimizing costs and complexity. IaaS, or infrastructure-as-a-service, is a software deployment paradigm in which the essential components of a computer system, such as servers, software, and networking hardware, are made available as a service that can be accessed whenever needed. This method enables the construction of a foundation for the development and execution of applications. Because they obtain those resources as virtualized objects that can be managed through a service interface, customers of infrastructure as a service don't need to worry about purchasing, storing, or managing basic hardware and software infrastructure components [35-39].

3. A SUMMARY OF CLOUD FORENSICS

The term “cloud forensics” refers to the application of digital forensics on cloud computing platforms; this field is being explored through interdisciplinary research. The newly established NIST cloud forensic working group defined “cloud computing forensic science” as “the application of scientific principles, technological practices, and derived and proven methods to process past cloud computing events through identification, collection, preservation, examination, and reporting of digital data to facilitate the reconstruction of these events.” The CSPs swapping services further complicates the situation and makes it more difficult to follow the evolution of events; therefore, forensic procedures that would be appropriate in a traditional setting—one that does not involve cloud computing—would not be applicable here.

The technical, organizational, and legal dimensions comprise cloud forensics [41]. The forensic investigation process in the context of cloud computing necessitates the use of specific techniques and tools, which are referred to as the technical dimension as a whole. This includes gathering data, real-time forensics, separating evidence, and preventative actions. On the other hand, the organizational component looks at the forensics aspects of the organization. The participants included CSPs, clients, legal counsel, and issue handlers. It also covers legally binding service level agreements (SLAs), rules, and regulations [41,42]. Last, the legal aspect includes creating rules and agreements to guarantee that forensic activities don't break the laws and regulations in the countries where the data is stored or collected while protecting co-tenants' privacy with the same infrastructure. This is achieved by ensuring that forensic procedures don't violate the rules and laws of the countries where the data is stored or gathered [43].

4. CLOUD FORENSIC STEPS [43–48]

- **Analysis:** The following procedures are used while using cloud forensics to investigate.
- **Identification:** Examiners must determine whether potentially harmful activity or improper behavior has occurred within the cloud-based services. Such activities include suspicious cloud events, individual complaints, anomalies found by intrusion detection systems, and monitoring and profiling resulting from audit trails.
- **Preservation and Collection:** In this stage, data is gathered from all available sources in a way that does not compromise its integrity in compliance with forensic and legal criteria. For the sake of a future investigation, every piece of information and evidence has been stored safely. There is a possibility that the gathering of data may be needed to store vast volumes of data. As a consequence, investigators must consider the laws and regulations that regulate data protection and privacy and the consequences these laws and regulations have for evidence stored in the cloud. When obtaining data from the cloud vendor side, you should always consider the data of

any other users or organizations. An accurate representation of the data stored in the cloud must be gathered before continuing the investigation. An investigator can attempt to get and keep data saved in the cloud by serving the cloud service provider with a court order.

- **Detection: After collecting data:** various strategies and algorithms (such as pattern matching and filtering) are used to find potentially dangerous code or questionable behavioral patterns.

- **Analysis:** Following detection, forensic techniques are used to assess and investigate the data and the crime committed. Law enforcement officials may focus their investigation on a specific organization or person to gather evidence. Following data analysis, the testimony must be shared with law enforcement officials and the victim organization or person.

- **Presentation:** The last phase entails presenting the evidence gathered before a judge or legal authority. This is accomplished using an adequately prepared report, the conclusions of which must be provided by testimonies regarding the research topic.

- **Documentation:** It is difficult to persuade the court that the evidence collected throughout the investigation was accurately recorded and that no modifications were made to it in the first phases of the process.

5. IS CLOUD SIMULATING A LOOMING STORM OR A POSSIBLE RAY OF SUNSHINE?

Software, the computing platform, and the computing infrastructure can all be considered services without considering how or where they are provided because there is no distinction between them. Cloud computing strives to the idea of computers as a utility, providing services like water, gas, electricity, and telephones. It also symbolizes the desire to use computational resources to provide accurate services.

Major industry players have realized the potential of cloud computing, as evidenced by the fact that each of the top five software companies has a sizable cloud product portfolio in

terms of sales revenue. Although there is a lot of material in the community that illustrates the basic concepts, the phrase “cloud computing” is not yet understood by everyone. Several authors have put forth the idea that cloud computing is a development of cluster computing. Cloud computing is called cluster computing with software as a service [49-53]. There are five key characteristics of cloud computing, three delivery options, and four deployment models. This is a concept that is simple to comprehend. As of this writing, perspectives on whether cloud computing might promote or oppose computer forensics investigations are divided. One group thinks cloud computing might support such inquiries, while the other thinks it will hinder them. In the next section, we will analyze the topic’s good and bad elements in more detail after providing a high-level summary of both sides of the argument [54-56]. On the one hand, to accommodate investigations conducted on cloud-based systems, the computer forensic process model would need to be modified, and a new set of procedures would need to be put in place. On the other hand, using the resources and services made available by cloud computing might be advantageous for computer forensic investigations to support the inquiry [57, 58]. The main benefit of cloud computing is its capacity for centralizing data storage; having all of one’s data in one place enhances forensic readiness, leading to a quicker and more well-coordinated response to crises. When IaaS providers can access centralized data, they can build a dedicated forensic server within the cloud. When needed, this server is available for usage. The services and resources that cloud computing platforms may offer, or, more precisely, the scope and power of these services, confer further benefits to the discipline of computer forensics. A huge advantage for the computer forensic investigator is the availability of potentially petabytes of storage and highly available compute-intensive tools. These two elements both influence the research process. During an investigation, a detective may gather many images of hard discs. Infrastructure as a Service, or IaaS, might potentially be used to store these pictures on the cloud. Second, forensic investigators may use the high availability of compute-intensive resources for compute-intensive activities

[59,60]. Forensic investigators, for example, may need to break passwords or encryption keys or review many photos, which may be time-consuming and taxing on a computer's processing power and memory [61, 62]. For instance, an MD5 hash is created when a piece of data is stored in Amazon S3. This indicates that it is no longer necessary to generate the time-consuming MD5 checksums that were previously required. The various log files that might be discovered on a computer can be a useful source of information during a forensic examination. However, logging is occasionally treated as an afterthought, and as a result, insufficient disc space is provided, or no logging occurs at all. Due to the scale at which cloud storage is used, logging may be done and configured to the proper level, and logs can be made available upon request. This is made feasible by the cloud's scalability [62, 63]. A C2 audit trail represents the enhanced logging capabilities of modern operating systems. However, due to worries that it can impede performance and increase log volume, this option is rarely used. Better logging may be achieved with cloud computing, and the granularity of logging can be changed to suit specific needs. Virtualization, which has been considered differently as both a benefit and a drawback, is the final area of concern. As was previously said, in cloud computing settings, virtualization is used to enable several users to use the same resources. Software, platforms, and infrastructure are just a few resources that may all be virtualized. It was also highlighted that a bit-by-bit copy of a disc image must be made using the required software for forensically sound data collection. Recording memory images during live investigations takes extra effort and time because memory must be frozen before the copied host loses power. However, these steps are unnecessary in a virtual environment because administrative tools like snapshots and other functionality make taking photos of the disc and memory easy. However, law enforcement authorities (i.e., the guidelines set by ACPO) have not yet determined the forensic validity of this form of acquisition. Data collecting is cloud computing's worst drawback when considered from a forensic angle. This is the procedure of locating the precise location of data storage and then physically retrieving it. The search

and seizure tactics used in traditional computer forensics are not feasible since the evidence is kept in cloud data centers. These methods are used to gather evidence. Additionally, it is exceedingly difficult, if not impossible, to maintain a chain of custody about collecting the evidence [64]. It is nearly hard for investigators to adhere to the ACPO advice since employing cloud computing makes it difficult, if not impossible, to uphold ACPO standards. Cloud computing is to blame for this [65]. The four guiding principles for the procedures and level of knowledge required for evidence management are laid forth in the ACPO manual. These requirements cannot be met since clouds function as remote data centers, making the ACPO advice unnecessary. Due to this, the validity, integrity, and admissibility of the evidence in a British court process would thus be called into doubt [66]. There is a general loss of control throughout the forensic investigation since the data are stored elsewhere where access is impossible. Overall, this is the situation. Due to a lack of knowledge of where data is held, it is harder to assemble a sequence of events and build a timeline. This, in turn, makes it more difficult to recreate a crime scene. Various other issues discussed further down the page can potentially hinder the study. The gathering of data and the loss of control are two drawbacks. the disposal of important objects, some of which would have served as key pieces of evidence. In cloud data centers, it could be difficult, if not impossible, to access items like registry entries, temporary files, and RAM (often because virtualization is utilized) [67-69]. There is a potential that the metadata will be lost when data is downloaded from the cloud. It is useful for the investigator to access metadata, such as when the file was created, edited, and accessed while performing a forensic investigation. Many investigators still prefer to carry out their authentication rather than depending on the cloud storage service's hash authentication, even though certain cloud storage providers, including Amazon S3, offer a mechanism to confirm data (using MD5 checksums). This occurs as a result of the inconsistency of cloud storage services. Another restriction is the absence of tool support for using cloud data centers. Although computer forensics is still a young subject of study, it has advanced to the point where tools

are suitable for handling typically localized investigations [70-72]. The forensic investigator may utilize instruments like EnCase, Helix, and FTK to help with tasks like initial data gathering, which produces acceptable written evidence in a court environment. Forensic investigators can utilize various instruments to help them with these duties. The last concern results from computer forensics' legal and ethical components. This problem results from the requirement that all digital evidence gathered during an inquiry be presented to a jury, who will

Render a verdict on the matter. In traditional computer forensics, the investigators must present their findings to the jury. Consequently, investigators often find themselves awkward in explaining how evidence was gathered and what it suggests about the case in terms specific to their field. This is especially true when working with conventional, locally based computer systems; cloud data centers, which may be thousands of miles away, run 40,000 virtual machines (VMs) across 512 servers and are accessed by 1000 tenants, of which the accessed is one, present their findings to the jury. This may be too much information for the average juror to process, especially considering they only know how to use a home computer [73-75].

6. The difficulties that cloud forensics faces

As expected, the cloud forensics field presents several unique hurdles. These challenges include technical as well as legal concerns [76]. Some possible problems that may arise while performing a forensic investigation in the cloud include the following:

- **Problems:** Relating to the user's home jurisdiction: Cloud services are frequently hosted in states or countries other than the user's location. While users may occasionally be able to select their preferred location, this is not always the case. For example, Google maintains cloud servers in Australia, Europe, Asia, North America, and South America. This may complicate determining which jurisdiction over the offense [77].

- **Unstable:** In traditional digital forensics investigations, the IT environment is typically “frozen” to prevent disruptions or new problems while investigators finish their work. This ensures that the probe proceeds without a hitch. Still, since public cloud providers may serve millions or even hundreds of thousands of users, this is frequently impossible, leaving the environment dynamic and potentially unstable [78].

- **Physical access:** In some instances, forensics can benefit from physically inspecting a cloud server. However, large cloud providers can find this challenging because they enforce strict security policies to keep unauthorized individuals out of the building. Furthermore, as previously mentioned, the cloud server is not guaranteed to be physically close to the investigator [79].

- **Decentralization:** Cloud organizations often store files across several servers or data centers to increase availability and dependability. This fragmentation and decentralization makes it more challenging to identify the issue and do forensics [80].

- **Data deleted or unavailable:** The information cloud providers give investigators can differ. For example, log files might not always be available. If data is deleted due to criminal activity, it can be challenging to recover it, identify its owner, and utilize it for cloud forensic analysis [81].

7. What’s New In Cloud Forensics And What’s Hot Right Now

Digital forensics, network forensics, and hardware forensics are only a few of the many different forms of forensic investigation that collectively go under the umbrella phrase “cloud forensics” [82]. Various cloud stakeholders (such as cloud providers, cloud customers, cloud brokers, cloud carriers, and cloud auditors) must interact with one another to simplify internal and external investigations. Basic features of cloud computing include a high degree of virtualization, data duplication, jurisdiction, and multi-tenancy. These characteristics increase the complexity of cloud forensics to various degrees [83]. Due to the apparent resources it gives and its low cost, wide availability, and flexibility, cloud

forensics have become widely used in the area of forensics. There are several options for database security, software integration, and application development in cloud forensics, including private, hybrid, and public models [84-86]. Governments and organizations of all sizes may benefit from various advantages thanks to cloud computing, including high scalability, decreased IT expenses, backup, and speedy installation [1]. Similarly, to achieve the objectives of low latency and scalability, cloud-based telecommunications service providers are moving their data centers to a range of various geographic locations. However, the rise in online criminal behavior and the broadening impact of cloud computing pose a more significant threat. Security experts have expressed concern about how challenging cloud forensics are to do. Cybercriminals' primary objective is to exploit the cloud's weaknesses. An example of a potential application in digital forensics is an external inquiry conducted in a cloud-based environment [87,88]. In this area, events in the cloud are processed, and the results are retrieved using academic standards and norms, conventional practices, and cutting-edge technology. Additionally, cloud storage offers a wide range of virtualization, replication, and multi-tenancy capabilities. Additionally, the technique used in cloud forensics depends on how the software platform is installed and operates. There are a lot fewer possibilities for monitoring techniques and services in Platform as a Service (PaaS) and Software as a Service (SaaS) implementations [89-93].

Despite the complexity of cloud forensics, the growth of cloud computing has undoubtedly led to concerns about users' security and privacy. Many currently hired forensics officers have witnessed a significant increase in their engagement in authorization, authentication, and accounting (AAA) due to the advent of cloud technology. This is so that malicious assaults may be looked into and identified using digital proof. It has high precision and contrasts sharply with other forensic techniques that employ the data, making it equivalent to traditional forensic methods for extracting evidence from log data. Legal, organizational, and technological forensics are the three subcategories that comprise cloud forensics. Laws and

agreements have been made to guarantee that digital forensic methods do not violate the rules regulating their usage [94,95]. Instead, a wide range of corporate policy factors is involved in computer forensics organizations [96]. Last, the technological scope describes the procedures and methodologies used to conduct a cloud investigation. Cloud forensics has become a regular procedure in digital forensics. It facilitates the use of forensics as an investigative tool by integrating cloud capabilities like remote analysis, monitoring, and scaling, such as the ability to manage huge workloads. Now, forensics may be employed as a research tool.

Predicted Developments and Changes in Cloud Computing: A Multi-Tenancy Cloud trust model with Quality of Service (QoS) monitoring. This model mainly focuses on the Infrastructure as a Service (IaaS) platform and shows why it.

It is imperative to provide cloud solution users with an avenue to gauge the reliability and caliber of services offered by cloud service providers before committing to such services; the recommended methodology necessitates continuous, real-time service quality monitoring. This builds customer trust and guarantees customers enroll in cloud services meeting predetermined standards and metrics. It also facilitates the assessment of cloud service providers.

Security for Logging Service provided: To undertake investigations that help expose unlawful or fraudulent activities perpetrated by rivals and aid in their prosecution, logs in cloud infrastructures are crucial [97]. Although cloud platforms are advantageous computing models, Zawoad et al. discovered that the computational power and storage resources made available by computer clouds might also tempt dishonest users to carry out attacks via the platforms. This realization came about during the development of their Secure Logging as a Service model. This was brought up as Zawoad et al. developed their Secure Logging as a Service approach [98]. Other researchers point out difficulties with using the Secure Logging as a Service Scheme (SecLaaS) to perform cloud forensics, such as a decreased degree of control when users of cloud services heavily depend on service providers to collect logs from computer clouds [99].

They explore these concerns about the Secure Logging as a Service Scheme (SecLaaS). The results of this study show that relying excessively on cloud service providers might lead to a loss of confidence in their investigators, many of whom are unqualified. They caution that bad actors may manipulate the logs using their power over the created logs if cloud service providers are compromised. Additionally, they warn that cloud service providers can refuse to comply with requests for all required logs if such requests clash with their internal data protection requirements. The main goal of the proposed framework was to overcome the difficulties caused by the lack of logging standards, the erratic nature of logs, and the multi-tenancy feature of cloud platforms. These issues emerge because shared hardware, which could also store the logs of multiple other users, may be used to provide virtualized services. Architecture for the Cloud with Forensic Capabilities Forensic Supported To support a trustworthy digital forensics operation on cloud systems, cloud architecture emphasizes the importance of securely preserving produced logs, proof of data custody, and provenance information in addition to timestamp data [100]. According to Zawoad et al., any data collected should be accessible to cloud users, investigators, and legal authorities [101-103].

Conclusion

One of the most revolutionary innovations in computer history may very well be cloud computing. Both cloud service providers and users have yet to develop suitable forensic tools that may help with cloud-based criminal activity investigations. About crimes using computers, mobile devices, and the Internet, computer forensics is a crucial area of computer science. Computer forensics' primary function is to conduct criminal investigations by examining any evidence discovered in digital forms. Because there have been so many recent reports of cybercrimes, it is now more important than ever to create specialized forensic tools for gathering and analyzing digital evidence in the digital world, sometimes even before it has been lost or erased. Digital forensic investigators now face a more significant barrier in gaining complete access to and control over the dispersed

cloud resources due to the new cloud computing paradigm's distinctive architecture and variety of service models. While the present chapter begins by outlining the significance of digital forensics in general, it concentrates mainly on their function in cybercrime investigations in the digital cloud. This review defines the cloud computing paradigm's fundamental ideas, structures, and service paradigms. The key benefits, drawbacks, difficulties, and strategies for digital forensic processes are then discussed, along with methods for supporting the isolation and preservation of digital evidence. The review article highlights several issues in cloud forensic analysis that require more study.

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Cloud Computing: An Overview Research

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Synopsis: A new computer paradigm known as “cloud computing” attempts to provide end users with dynamic, dependable, and QoS-guaranteed computing environments. This article examines the cloud computing paradigm from several angles, including definitions, distinguishing characteristics, and enabling technologies. This article presents the state-of-the-art in cloud computing technology and provides an overview of cloud computing.

Keywords: distributed computing, cloud computing, grid computing, cyber infrastructure

1. Overview

The term “cloud computing,” first used in late 2007, is becoming increasingly popular because of its capacity to provide dynamic, adaptable IT infrastructures, computing environments that assure quality of service, and adjustable software services.



Figure 1's

Google trends report indicates that cloud computing (the blue Grid computing 8) (the red line) and has already gone beyond it because of virtualization technology (the yellow line).

Several initiatives in both industry and academia have already commenced, such as Amazon Elastic Compute Cloud 13), IBM's Blue Cloud 10, scientific Cloud projects like Stratus 31 and Nimbus 24), and Open Nebula 26. Other examples of ongoing projects include IBM's RESERVOIR project 27. Recently, HP, Intel Corporation, and Yahoo! Inc. announced the establishment of an open-source cloud computing test bed for business, research, and education that spans many data centers globally 3).

Though cloud computing has garnered much attention, no commonly agreed-upon definitions exist. There are many causes for this circumstance:

- Researchers and engineers from various backgrounds, including database management, software engineering, and grid computing, are involved in cloud computing and approach it from many angles.
- Pre-existing computer technologies, such as Web 2.0 and Service-Oriented computers, are continually developing and advancing to allow Cloud computing. However, large-scale implementation and utilization of clouds are still lacking, which would ultimately validate the idea of cloud computing.

We want to provide the definition, functionality, enabling technology, and representative cloud computing applications in this work. This paper's remaining sections are arranged as follows. The idea of cloud computing is covered in Section 2, its functions are presented in Section 3, its unique properties are reviewed in Section 4, and Section 5 lists the enabling technologies for creating computer clouds. Section 6 concludes the work.

2: Cloud Computing

Defined Moving data and apps to a distant location, known as the "Cloud," allows users to access them quickly and widely, making cloud computing one of the newest buzzwords in the IT industry. Once again, there is a use case for central

processing. About fifty years ago, a time-sharing computer server catered to many users in a similar situation. Before the invention of personal computers twenty years ago, most data and applications were housed in local resources. The concept of cloud computing as it exists now does not reflect the past. We were forced to create time-sharing servers because of our inadequate computer resources fifty years ago. The need to develop intricate IT infrastructures has led to the popularity of cloud computing these days. Users are required to oversee the installation, setup, and upgrades of diverse software. Hardware such as computers and other devices has a short lifespan. Thus, outsourcing computing platforms is a wise way for consumers to manage complex IT systems.

Currently, cloud computing is still developing and lacks a well-recognized definition. We provide the following preliminary definition of cloud computing based on our experience:

An electronic a cloud is a collection of network-enabled services that provide easy, ubiquitous access to scalable, QoS-guaranteed, often customized, low-cost computing infrastructures on demand.

3: Utility Features of Cloud Computing

From a conceptual standpoint, users get IT infrastructures or computing platforms from computing clouds, where they execute their applications. Consequently, computing clouds provide customers with the following services to access hardware, software, and data resources, followed by an integrated computing platform as a service:

HaaS, or hardware as a service,

The term “hardware as a service” may have originated around 2006. Thanks to quick advancements in hardware virtualization, IT automation, and metering and pricing, users may purchase IT gear or an entire system.

A pay-as-you-go subscription service for the data center, HaaS is adaptable, scalable, and controllable to suit your demands.

2. Amazon EC2 (13), IBM’s Blue Cloud project (10), Nimbus (24), Eucalyptus (18), and Enomalism (17) are a few examples.

Software as a Service (SaaS) refers to providing software or applications to customers over the Internet as a hosted service. Customers may avoid installing and running the program on their PCs using this option. Because SaaS offers on-demand pricing, it relieves customers of the hassle of maintaining their software and lowers the cost of software purchases. Application Service Provider (ASP) 15 is an instance of SaaS from the beginning. Hosted or distributed online software may be subscribed to using the ASP method. Another illustration may be in Microsoft's "Software Service" (30) section, which depicts the interaction between local software and Internet services. The Chrome browser from Google (version 21) presents an intriguing SaaS scenario: it may provide a new desktop that allows programs to be delivered (locally or remotely) in addition to the standard Web surfing experience.

Data as a Service (DaaS): Users on the network may obtain data via services in various forms and from many sources. For instance, users might manipulate the data remotely like they would on a local drive or access the data semantically over the Internet.

Amazon claims that any quantity of data may be stored and retrieved at any time, from any location on the Web, using its primary Web services interface, Amazon Simple Storage Service (S3) 14. Additionally, the DaaS is available at several well-known IT services, such as Adobe Buzzword 12 and Google Docs 22. A distributed remote storage program called Elastic Drive 16 enables users to mount a distant storage resource, such as Amazon S3, as a local storage device.

In addition, cloud computing may provide consumers with Infrastructure as a Service (IaaS) based on the support of HaaS, SaaS, and DaaS. As a result, users may subscribe on-demand to their preferred computer infrastructures, complete with installation requirements for software, hardware setup, and data access needs. The link between the services is seen in The Google



Figure 2.

One intriguing instance of IaaS is App Engine 20. Using the exact scalable mechanisms that power Google apps, the Google App Engine lets users create Web applications utilizing Google's APIs and SDKs.

4. What Makes Cloud Computing Unique?

The following are some ways that cloud computing differs from previous computing paradigms, such as grid, global, and internet computing:

Interfaces focused on the user.

Cloud services should be accessible and ubiquitous. Utility computing is a notion that cloud computing accepts. Stated differently, consumers may access and use computing platforms inside computing clouds with the same ease that they can utilize a conventional public utility (like power, water, gas, or phone service). To be more specific, the Cloud services have the following

Advantages:

Cloud interfaces do not require users to alter their work surroundings or habits, such as their operating system, compiler, or programming language. Grid users must acquire new Grid commands and APIs to access Grid resources and services, which is how cloud computing differs from grid computing in this regard.

The Cloud client software is lightweight and has to be deployed locally. The Nimbus Cloud kit client, for instance around 15 MB in size.

Certain well-known interfaces, such as the Web services framework and Internet browser, may access cloud interfaces since they are location agnostic.

Supply of services as needed. Computing clouds provide consumers with on-demand resources and services. Since users often have administrative access, they may add more personalization's to their computer environments, such as network settings and program installation.

QoS assurance provided.

The computing environments offered by computing clouds, including hardware performance such as CPU speed, I/O bandwidth, and memory capacity, may guarantee QoS for users.

In general, the computing cloud provides quality of service (QoS) via handling service level agreements (SLAs), agreements between users and the service provider on availability, serviceability, performance, operation, and other aspects of the service, including pricing and penalties for SLA violations, Autonomous System.

Cloud computing is a self-contained system that is openly administered to users. Cloud-based hardware, software, and data may be automatically rearranged, coordinated, and combined to create a unified platform picture that is ultimately shown to consumers.

Flexibility and scalability.

Cloud computing's rise is driven by its scalability and flexibility. The computing platforms and cloud services provided by computing clouds may be scaled across various issues, including hardware performance, software configurations, and geographic locations. Computer systems must be adaptable enough to accommodate many user needs.

5. The Supporting Technologies for Cloud Computing

Cloud computing is made possible by many supporting technologies, including several-

Several cutting-edge methods are included here:

Technology for virtualization .Virtualization technologies provide scalable and adaptable computer systems through hardware partitioning. Virtual machine methods, such as Xen 1) and VMware 34), provide on-demand virtualized IT infrastructures. Advances in virtual networks, like VPN 7, let users access Cloud resources in a tailored network environment. Since virtualization methods provide scalable and adaptable hardware services, they form the foundation of cloud computing.

Coordination of workflow and service flow.

Computing clouds, which may consist of services housed inside the cloud, provide a comprehensive collection of service templates on demand. Thus, computing clouds must be able to automatically coordinate services of all kinds and from many sources to create a service flow or workflow that is visible and dynamic for users.

Service-oriented architecture (SOA) and web services.

Cloud computing services are often made available via Web services that adhere to industry standards like SOAP 28), WSDL 33, and UDDI 25. A service-oriented architecture (SOA) might be used to orchestrate and organize services within the cloud. Additionally, a group of cloud services may be used in an SOA application environment, enabling access to them via the Internet and across several dispersed platforms.

Web 2.0 is a term used to describe the cutting-edge developments in Web design and World Wide Web technology that seek to improve the Web's functionality, information sharing, creativity, and teamwork. Enhancing Web applications' interactivity and connectedness is the primary goal of Web 2.0. Users may now access the Web more effectively and readily thanks to the new paradigm for developing and using Web apps. Web applications that

provide desired computer capabilities on demand are the essence of cloud computing services. Thus, adopting Web 2.0 technology by cloud computing is a logical technological development. Globally distributed storage infrastructure.

A cloud storage strategy must anticipate the following: Users may lease storage capacity from a network storage system supported by dispersed storage providers (such as data centers). The data storage could be moved, combined, and transparently controlled to end users for any data format. Google File System 9) and Amazon S3 14 are two examples. A Web application (Mash up 11) aggregates data from several sources into a unified storage solution. An example of a Mash up is the digital picture-sharing website Smug Mug 29. It supports XML-based RSS and Atom feeds, enables programmers to add new features using a public API, and allows an infinite amount of photographs to be uploaded for all account kinds.

A distributed data system that offers semantically accessible data sources. Instead of using physical locations, users in a vast dispersed system might identify data sources by their logical names. VDS 32, the Virtual Data System, is a valuable resource, Programming model.

Users drive data and apps into the computer cloud. Certain cloud programming paradigms must be presented so users can adjust to the Cloud infrastructure. However, the paradigm shouldn't be too sophisticated or novel for end users to maintain the simplicity and ease of use of Cloud services.

A programming methodology and related implementation for handling and producing massive data sets across Google's global infrastructures is called Map Reduce 4.5. Applying a "map" operation to a collection of key/value pairs in certain data records is the first step in the Map Reduce paradigm. All values that share a key are subjected to a "reduce" action. Including a "merge" process, the Map Reduce-Merge 35) technique expands upon the Map Reduce paradigm. A framework called Hadoop 23) executes programs on significant clusters made of commodity hardware. It offers a distributed file system called the Hadoop Distributed File

System and puts the Map Reduce concept into practice. Yahoo! has just launched a worldwide cloud computing initiative that uses Hadoop and Map Reduce, HP and Intel 3, 19).

Conclusion

This article examines the most recent developments in cloud computing and offers our opinions on its definition, salient characteristics, and supporting technologies. The objective of the prospective study is to aid in developing the cloud computing paradigm.

Cloud Computing: Problems and Difficulties

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Abstract: Many people think that the cloud will revolutionize the ICT sector. Our goal in this research is to identify the problems and obstacles associated with cloud computing. Following a discussion of two related computing paradigms – Service-Oriented Computing and Grid Computing – and how they relate to cloud computing, we list several obstacles to cloud computing adoption. Finally, we will draw attention to the Cloud interoperability problem, which warrants significant further study and development.

Keywords: distributed computing, cloud computing, web services, and service-oriented computing.

I. Introduction

Recently, cloud computing has become a popular term in the field of distributed computing. Many think the cloud will revolutionize and change the IT sector drastically. Describe cloud computing, please. What distinguishes it from Grid computing and service-oriented computing? What are the common problems and difficulties that affect both cloud service providers and users?

By providing answers to these questions, we want to clarify important research topics and outline potential paths and obstacles for cloud computing research in the future. We structure this article using an outside-in method to achieve this. Firstly, we look at many cloud apps that share numerous essential features. Next, we go over how cloud computing, Service-Oriented Computing (SOC), and Grid computing (also known as High-Performance Computing) are related. We provide a comparative analysis of these three computing

paradigms, emphasizing their mutual benefits. Next, we will go into cloud computing deployment and service concepts. We detail a cloud's deployment and service models, which opens the door to discussing several data-related problems and difficulties, including multi-tenancy, security, etc. Lastly, we talk about standards and interoperability problems.

II.CLOUD: SUMMARY

A. Definition

What is the meaning of cloud computing? Even though several formal definitions have been put out in academia and business, the U.S. The following critical common aspects seem to be included by NIST (National Institute of Standards and Technology) [1 and are extensively utilized in the Cloud Computing community:

The cloud computing model allows a shared pool of reconfigurable computing resources (such as networks, servers, storage, apps, and services) to be quickly provisioned and released with little management work or service provider interaction [1].

Security, deployment methodologies, and cloud architectures are all included in this description. Specifically, five fundamental components of cloud computing are explained in detail:

On-demand self-service: Without requiring human interaction with resource providers, a customer with an immediate need at a specific time can automatically (i.e., conveniently, self-serve) obtain computing resources (such as CPU time, network storage, software use, and so forth).

Wide-ranging network access: These computing resources are available to different client applications running on heterogeneous platforms (such as PDAs, laptops, and mobile phones) at the customer's location via a network (like the Internet).

pooling of resources. Using either the multi-tenancy or virtualization paradigm, a cloud service provider's computer resources are "pooled" together in an attempt to serve

numerous customers, “with different physical and virtual resources dynamically assigned and reassigned according to consumer demand” [1]. The establishment of a pool-based computing paradigm is driven by two significant factors: specialization and economies of scale. A pool-based paradigm makes actual computing resources (such as databases and CPUs) “invisible” to users, who often have no control or understanding over these resources’ location, composition, or unique features. Customers, for instance, cannot choose where their data will be kept in the cloud.

quick elasticity. Customers no longer have to worry about upfront contracts or commitments since they can utilize computer resources to scale up and down as needed, and they may release them once they’re done. This makes computing resources instantaneous rather than permanent. Furthermore, they believe resource provisioning is limitless, as consumption may spike to satisfy peak demand at any moment.

Service Measurement. Even though numerous users share and pool computer resources (also known as multi-tenancy), the cloud architecture may make use of the necessary technologies

To use its metering features to determine how these resources are used for every customer.

B. Service Model

The cloud community has widely used the following three service models, in addition to these five fundamental qualities, to categorize cloud services:

Cloud-based software (SaaS). Application users may access cloud-based applications over networks using a variety of clients, such as web browsers and PDAs, when cloud consumers release their apps in a hosting environment. The applications of various cloud consumers are arranged in a single logical environment on the SaaS cloud to achieve economies of scale and optimization in terms of speed, security, availability, disaster recovery, and maintenance. However, cloud consumers have no control over the cloud infrastructure, which frequently uses a multi-tenancy system

architecture. SaaS products include things like Google Docs, Salesforce.com, and Mail.

Software as a Platform (SaaS). Developers may create cloud services and apps (like SaaS) directly on the PaaS cloud thanks to PaaS, a platform for cloud development that supports the whole “Software Lifecycle.” Thus, the distinction between PaaS and SaaS is that the former provides a development platform that houses finished and ongoing cloud applications. At the same time, the latter exclusively hosts finished cloud applications. This means that PaaS has to provide development infrastructure, such as a programming environment, tools, configuration management, and other things, in addition to offering an application hosting environment. Google AppEngine is a PaaS example.

As a Service Infrastructure (IaaS). IT infrastructures (processing, storage, networks, and other essential computer resources) offered by the IaaS cloud are directly used by cloud users. To integrate and disassemble physical resources on demand to accommodate changing resource requirements from cloud users, virtualization is widely used in infrastructure as a service (IaaS) clouds. The fundamental virtualization method creates separate virtual machines (VMs) insulated from one another and the underlying hardware. This approach differs from the multi-tenancy paradigm, which seeks to change the architecture of the application software to enable the operation of numerous instances (from various cloud customers) on a single application (i.e., the same logic machine). EC2 from Amazon is an example of IaaS.

Data-as-a-service (DaaS) data storage. Data storage services are now distinct cloud services, providing virtualized storage on demand. Observe that DaaS may be thought of as a particular kind of IaaS. The driving force is the exorbitant upfront costs associated with dedicated servers, software licenses, post-delivery services, and internal IT maintenance for on-premise business database systems. Instead of paying for a site license covering the whole database, DaaS enables users to pay for their services. Some DaaS offerings offer table-style abstractions that can scale out to store and retrieve massive amounts of data quickly, in addition to traditional

storage interfaces like file systems and RDBMS. These abstractions are frequently too large, costly, or slow for most commercial RDBMS to handle. As an example

Here, indicate which sponsor(s) applies. (Partners)

Examples of this kind of DaaS include Apache HBase, Google BigTable, and Amazon S3.

C.Model of Deployment

The cloud community has recently established our cloud deployment methods:

Private cloud. Whether housed on-site or off-site, the organization or a third party manages and administers the cloud infrastructure. It is only used by one organization. There are several reasons why a company would want to build up a private cloud. Initially, the goal is to use the current internal resources as best as possible. Second, many businesses choose the private cloud due to security concerns about data protection and trust. Third, a significant expense is still associated with data transfer [2] from local IT infrastructure to a public cloud. Fourth, mission-critical operations that take place behind firewalls must always be entirely under the authority of organizations. Finally, academics often create private clouds for use in teaching and research.

Cloud community. The cloud infrastructure is cooperatively built by several enterprises, sharing the same rules, needs, values, and concerns. A certain level of democratic balance and economic scalability is formed within the cloud community. One of the community groups or a third-party provider might host the cloud infrastructure.

Public cloud. This is the deployment model currently in use for cloud computing. Cloud service providers possess all rights to the public cloud, which is utilized by the general public and has its policies, value, profit, pricing, and billing structure. Public clouds include Google AppEngine, Amazon EC2, S3, and Force.com, among many other well-known cloud services.

cloud hybrid. A collection of two or more clouds—private, communal, or public—that are each separate entities but are connected by proprietary or standardized technology that allows data and application mobility (e.g., cloud bursting for load-balancing across clouds) makes up the cloud infrastructure. via the margining out of peripheral business tasks into the cloud and managing critical activities on-premise via the private cloud; organizations use the hybrid cloud model to maximize their resources and improve their core capabilities. A hybrid cloud has brought up the topics of standardization and cloud interoperability, which will be covered in the following parts.

Amazon Web Services (AWS) has introduced an attractive new deployment option: the Virtual Private Cloud (VPC). It is a safe and smooth link between an organization's on-premises IT infrastructure and the Amazon public cloud. This is presented as a hybrid of the public and private clouds. It continues to utilize computational resources that Amazon has pooled for public use, which makes it public. It is, nonetheless, essentially private for two reasons. First, a virtual private network provides security for the link between IT heritage and the cloud, offering the benefit of private cloud security. Even if the cloud resources are on the Public Cloud, all company security standards apply to them.

Secondly, the VPC will get “isolated” resources from AWS. This does not, however, imply that consumers must pay for these exclusive resources in advance. “Pay-per-use” is still an option for users on these remote sites. VPC is the ideal combination of freedom (Public Cloud) and control (Private Cloud).

Observe that the deployment and service models are perpendicular. SaaS, for instance, may be provided on a private or public cloud.

III.GRID, SOC, AND CLOUD

This section delineates the connections between Cloud Computing, Service-Oriented Computing (SOC), and Grid Computing.

A. Service-oriented computing and the cloud

SOC offers significant benefits in encapsulation, componentization, decentralization, and integration: they provide software specifications and architectural guidelines for connecting computers and devices via standardized protocols over the Internet [3]. The idea of the cloud is mainly derived from how SOC—specifically, the SaaS service model—is developing.

SOC developments may help cloud computing in several ways.

This is an explanation of the cloud services' services. Two popular interface languages for describing Web services are Web Services Description Language (WSDL) and the REST protocol. They have been applied to the description of the Cloud API standard.

Cloud Service Service Discovery. Service discovery models may be used for cloud resource selection, discovery, and service-level agreement verification.

Cloud Service Composition Service. Web services are designed to create business applications; therefore, much of this study may be used to integrate, compose, and cooperate with cloud services.

Cloud service management. Research and methods from SOA governance and services administration can be Adapted and reused for cloud infrastructure management.

However, we also need to consider what SOC lacks, particularly for small and medium-sized businesses. From the standpoint of business process and integration, SOC denotes high abstraction. SOC does not, however, provide any applicable computational models for operating services. How can I manage my services for the least amount of money? How to scale up/down my service-oriented architecture-based apps. The strain for SOC developers and the IT department in SMEs is increased by the need to handle these computational aspects on an as-needed basis and in a project-specific way. Furthermore, there is still debate in SOC on integrating services at various levels into a cohesive organizational

unit. For instance, how can I assist my business services by maximizing my IT services' utilization? Thus, we think that there are several significant ways in which cloud computing might advance research in service-oriented computing.

Web service development using the cloud. Under the PaaS service deploy paradigm, cloud computing may support service-oriented development. Distributed computing resources are often needed for SOC development, but they might be difficult for SMEs. For example, Google's AppEngine platform, SDK, and client IDE provide developers with a complete development environment to create and implement Java Web services to develop apps. Furthermore, the Yahoo Pipe platform demonstrates how the cloud can be used as both design and run-time for service composition and mashups.

Cloud for Web Service Testing. To load test and stress test services, web services developers might use the limitless processing power of a public cloud to mimic automated machine requests, and network flows seen in the real world. The difficulty and expense of simulating network traffic for WS testing has hampered the general dependability of the Web. It is now possible to replicate real-world usage of these systems by geographically dispersed users, executing a wide variety of user scenarios at scales previously unachievable in traditional testing environments thanks to the low cost and accessibility of the Cloud's vast computing resources.

They are using the cloud to deploy web services. Web services implementation may be expedited using IaaS. For instance, service providers may distribute their products using the Amazon Machine Image (AMI) in the Amazon EC2 configuration. A service deployment image will be loaded into a designated virtual machine in response to queries to fulfill client demands. When Web services are restarted from the suspended mode, stateful information generated during service interactions may also be persistently maintained on the AMI (e.g., from a long-last transaction).

Cloud for Enacting Service Processes. Service composition and integration are growing issues; cloud environments may bundle solutions for these issues as services. To enable the

reuse of ready-to-use solutions with minimal configuration and composition patterns, a popular strategy is to use the power of the crowd (service users) utilizing a variety of algorithms (e.g., Case-Based Reasoning).

An intriguing subject is how to integrate cloud computing with SOA/SOC. Are they on the same business/technical level? Do they have the same objective in mind? Are they able to work two jobs at once? If so, how? These research issues may be resolved when cloud computing becomes more widely used and developed.

B.Grid and Cloud Computing

A hardware and software framework known as “grid computing” [4] was inspired by actual issues that arose in cutting-edge scientific research. As far as we can tell, the Grid is “middleware” for distributed computing that gives sophisticated computational applications like research and engineering “coordinated cross-organizational resource sharing.” There are many parallels between grid computing and cloud computing. To start with, their shared goal is resource virtualization. They do, nonetheless, vary greatly:

Grid stresses “resource sharing” to establish a virtual organization. Except for community clouds, which are owned by the community, cloud computing is typically owned by a single physical entity that distributes resources across many currently used instances.

Grid uses resource sharing to deliver the most processing power possible for a large operation. Cloud computing seeks to meet as many small-to-medium-sized job needs as feasible in response to consumers’ immediate needs. As a result, the idea of multi-tenancy is crucial to cloud computing.

Grid gives up reusability in favor of high-performance (scientific) computation. Users’ current demands drive cloud computing, driven by different corporate objectives.

A.Safety

The biggest obstacle to cloud computing has been the security problem. Undoubtedly, many people find storing their data

and executing their program on someone else's hard drive and CPU intimidating. Well-known security problems, including data loss, phishing, and botnets—remotely operating networks of machines—pose significant risks to the software and data of a business. Furthermore, new security concerns have been presented by the multi-tenancy model and the pooled computing resources in cloud computing [6], which call for the development of innovative solutions. For instance, since the cloud often offers more dependable infrastructure services at a comparatively lower cost for them to launch an attack, hackers intend to utilize it to create botnets [6].

Q: How would you rank the problems with the “cloud” and on-demand models?

One denotes insignificance, and five have great significance.

Grid wants to do as much computation as possible. On-demand computing is what the cloud is all about: it allows you to scale up and down, in and out, while maximizing your computer's total capacity.

It was designed To provide business application Services. While parallelization has been used in high-performance computing (HPC), it is still challenging to use parallelization computing methodologies for business applications in Cloud computing due to the complex state and data dependencies across multiple business apps. The existing Cloud is not optimized for HPC for several reasons, according to authors in [5]. The first is that it is not yet developed sufficiently for HPC. Second, cloud architecture prioritizes improving overall system performance, unlike cluster computing. Third, HPC uses resources from several organizations to improve a particular scientific application's performance. The main distinction is elasticity, however, since capacity in cluster computing is often set, necessitating significant human intervention to execute HPC applications (e.g., tuning based on a specific cluster with a defined number of homogeneous compute nodes). This is in sharp contrast to cloud computing's “self-service” model, where we often don't know in advance how many physical processors we'll need or have already utilized.

IV.ADOPTION OF CLOUD CHALLENGES

Since cloud computing is still in its early stages of adoption, many obstacles remain.



Figure 1

Illustrates the main barriers enterprises face in adopting Cloud Computing, as identified by an IDC report 2008.

Figure 1. Adoption Difficulties (Source: August 2008 IDC Survey)

The multi-tenancy concept has brought forth at least two additional security risks. First, shared resources on the same physical computer (hard drive, data, virtual machine) attract unanticipated side channels between malicious and normal resources. Furthermore, the problem of “reputation fate-sharing” will seriously harm the standing of several law-abiding Cloud “citizens” who regrettably share computing resources with a fellow tenant who is an infamous user with a criminal past. Any inappropriate behavior will be ascribed to all users because they can have the same network address, making it impossible to distinguish between actual subversives and regular users.

B.Pricing Scheme

Cloud computing users must weigh the integration, connectivity, and processing trade-offs. Although moving to the cloud can significantly reduce infrastructure costs, there

are costs associated with data communication or moving an organization's data to and from public and community clouds [7]. Additionally, the cost of computing resources used per unit, such as a virtual machine (VM), will likely increase. This issue is most noticeable if the customer deploys a hybrid cloud, which divides the company's data between many public and private (in-house IT infrastructure)

cloud communities. Gray's [8] maxim "Put the computation near the data" is still relevant in cloud computing. On-demand computing seems to make sense only for tasks requiring much CPU power. Put differently, transactional apps like ERP/CRM may not be appropriate for cloud computing from a

A pure economic perspective is needed if the cost savings do not cover the additional data transport costs.

Additionally, data integration may be expensive since separate clouds often utilize proprietary protocols and interfaces. To transfer and integrate diverse resources and data assets to and from different clouds (even within a single business), the cloud consumer must create ad-hoc adaptors and use cloud provider-specific APIs to communicate with multiple clouds. For instance, to address the security issue, cloud users (like the Eli Lilly research lab [9]) might need to divide sensitive data (like the medication usage for each patient) into smaller portions and distribute them across multiple clouds to prevent a security compromise in one cloud from causing a catastrophe as a whole. However, dividing and combining data may hurt system performance (i.e., time cost) and add significant financial expense.

C. Model of Charging

In contrast to traditional data centers, which often base their cost calculations on static computer consumptions, cloud providers find that their cost analysis is much more complex due to the elastic resource pool (achieved via virtualization or multi-tenancy). Furthermore, the underlying physical server is no longer the unit of cost analysis—instead, it is an instantiated virtual machine. All of the elements above, as well as VM-related costs like software licensing, virtual network utilization, node and hypervisor administrative overhead,

and so forth, must be included in a solid billing model.

Creating multitenancy inside a SaaS cloud solution may be pretty expensive for providers. These include developing new features that enable extensive customization, improving speed and security for concurrent user access, redesigning and redeveloping the software initially used for single-tenancy, and managing the complications brought on by the modifications above. As a result, SaaS providers must balance the trade-off between offering multitenancy and the cost reductions that come with it, including fewer on-site software licensing, lower overhead from amortization, etc. Thus, SaaS cloud providers' profitability and long-term viability depend on a well-thought-out, workable pricing strategy.

D. Service Level Contract

Once customers have moved their essential business processes onto their trusted cloud, they still need to guarantee these resources' quality, availability, dependability, and performance, even if they have no control over the underlying computer resources. As stated differently, customers must get assurances of the provision of services from suppliers. These are usually supplied via Service Level Agreements (SLAs) arranged between the suppliers and the customers. The first problem is defining SLA specifications with a suitable level of detail, i.e., balancing expressiveness and complexity to meet most customer expectations, and it is reasonably easy for the cloud resource allocation mechanism to weigh, verify, evaluate, and enforce. Furthermore, several cloud services (IaaS, PaaS,

Different SLA meta-specifications will need to be defined for SaaS and DaaS.

For the cloud providers, this also presents several implementation-related issues. Resource managers, for instance, need accurate and up-to-date data on resource use in the cloud at any given moment. When we refer to updated information, we mean that any modifications made to the cloud environment would cause the resource management to subscribe to an event, allowing for real-time assessment and adjustment to fulfill SLAs. To achieve this, resource managers

must use optimization algorithms and quick and accurate decision models. If SLAs are unsatisfied, they could have to deny specific resource requests. Given the promise of “self-service” in cloud computing, all of these must be completed almost entirely automatically. Additionally, user input and customization features must be continuously included in the SLA assessment framework using sophisticated SLA processes.

E. Things to move

The seven IT systems/applications being moved to the cloud are: IT Management Applications (26.2%), Collaborative Applications (25.4%), Personal Applications (25%), Business Applications (23.4%), Applications Development and Deployment (16.8%), Server Capacity (15.6%), and Storage Capacity (15.5%), according to a survey (Sample size = 244) carried out by IDC in 2008. This finding indicates that enterprises still hesitate to move their data to the cloud due to security and privacy concerns. The most accessible IT systems to migrate are peripheral tasks like personal apps and IT management. Compared to SaaS, organizations use IaaS more cautiously. This is partly because core operations are maintained in-house while peripheral duties are often contracted to the cloud. According to the poll, 31.5% of the company plans to shift its storage capacity to the cloud in the next three years. Nonetheless, this figure remains relatively low when contrasted with Collaborative Applications (46.3%) over the same period.

V. INTEROPERABILITY CLOUD ISSUE

The “Hazy Cloud” phenomenon results from the fact that every cloud provider now provides a unique method for cloud clients, apps, and users to interact with the cloud [10]. Vendor lock-in, which prevents customers from selecting from several suppliers or offers simultaneously to maximize resources at various organizational levels, seriously impedes the growth of cloud ecosystems. Integrating cloud services with an organization’s legacy systems—such as an on-premise data center for highly interactive modeling applications in a pharmaceutical company—becomes very

challenging when private cloud APIs are used. Here, the term “interoperability” refers to the connections between several clouds and the internal systems of an organization. Realizing smooth-flowing data between clouds and between cloud and local applications is the main objective of interoperability.

Interoperability is required for cloud computing on many levels. First, to maximize computer resources and IT assets, a business often has to maintain

Internal IT resources and competencies related to their core competencies while contracting out other tasks and services (like the HR system) to the cloud. In this scenario, regular communication between on-premise systems, such as an ERP system, and cloud services, like the HR system, becomes essential to operating a firm. Inadequate interoperability, such as proprietary APIs and excessively intricate or unclear data formats used by an HR cloud SaaS, can significantly worsen integration challenges, placing a challenging position for the IT department. Second, in most cases, a company must outsource several marginal operations to cloud services provided by various suppliers to optimize. For instance, an SME may utilize Salesforce.com for HR services and Gmail for email. This implies that the HR employee directory located in the HR system has to be connected to the various elements (such as the address book, calendar, appointment booking, etc.) in the email system.

A.Middle Layer

Some recent works provide an intermediate layer between cloud users and cloud-specific resources (such as virtual machines) to solve the interoperability problem. For instance, to support different clouds, Sotomayor et al. [11] suggested using Virtual Infrastructure (OpenNebula) Management to replace native VM API interactions.

- private or mixed for a company. Because Open Nebula operates at the virtualization layer, cloud users may access a uniform view and operating interfaces for different underlying virtualization implementations. In contrast to Open sNebula, Harmer et al. [12] created a higher-level abstraction layer. This shields the Heterogeneity of cloud providers and

impedes the creation of cloud-provider-independent apps by offering a standard resource consumption paradigm, user authentication methodology, and API.

B.Normal

Standardization seems to be a reasonable way to deal with the interoperability problem. However, as cloud computing is still starting, most industrial cloud suppliers have not listed the interoperability issue as a top priority. For instance, the Unified Cloud Interface (UCI) Project, which was put out by the Cloud Computing Interoperability Forum (CCIF), is not supported by either Microsoft or Amazon [13]. Moving the standardization process ahead will be tough if these significant actors do not compromise. The Eucalyptus project [14], which replicates the well-known proprietary Amazon EC2 API for cloud operation, is a popular cloud API in academics. While consumers of Eucalyptus IaaS may connect to the EC2 cloud with ease and without requiring significant redevelopment, this does not address the broader interoperability problem that necessitates an open API that is adhered to by many cloud providers.

C.Accessible API

Recently, SUN introduced the Sun Open Cloud Platform.

[15] with permission of the Creative Commons. This platform significantly contributes to its planned (still-in-progress) cloud API. It outlines several distinct and simple-to-understand

Cloud users may develop and manage cloud resources, such as computing, storage, and networking components, in an integrated manner using RESTful Web services interfaces. The open cloud API specifies major resource types: Cloud, Virtual Data Center, Cluster, Virtual Machine, Private Virtual Network, Public Address, Storage Volume, and Volume Snapshot. It uses HTTP as the application protocol and JSON as the resource representation language. There is a resemblance between these constructions and Eucalyptus's interior architecture [14]. The Eucalyptus team is prepared to put in the effort to guarantee that Eucalyptus Clouds and the Sun Cloud API are compatible [15]. This is consistent

with the ongoing research being conducted by DEBII to provide a lightweight PaaS open API that leverages RESTful Web services. It is worth noting that the idea of a Virtual Data Center, which serves as the fundamental unit for implementing the Sun Open Cloud, is similar to the Virtual Private Cloud concept recently established in Amazon EC2 (refer to Section II - C).

D. Interoperability between SaaS and PaaS

Although the methods discussed above primarily address IaaS interoperability issues, not much research has been done on other service deployment models. SaaS interoperability often encompasses many application areas, like CRM, ERP, etc. The data mining research community is one area in which our research group at DEBII is particularly interested. A group of data mining experts discussed creating a cloud-based data mining standard in the recent KDD09 panel discussion [16]. They specifically focused on “the practical use of statistical algorithms, reliable production deployment of models, and the integration of predictive analytics” among various SaaS clouds that use data mining. The Predictive Model Markup Language (PMML), a widely adopted standard that enables users to communicate predictive models between different software applications, is a promising step in this direction.

No significant attempts have been made to provide PaaS compatibility. It would be more challenging to achieve consistency in how users create and deploy cloud applications since PaaS encompasses the whole software development lifecycle on the cloud.

VI. Conclusion

This essay covered the problems and difficulties associated with cloud computing. We explained how cloud computing, grid computing, and service-oriented computing relate. We examined a few obstacles to the adoption of cloud computing. After highlighting the interoperability problem, we covered many solutions for various cloud service deployment methods.

Cloud-Based Technologies

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Abstract:

The next phase of technology is thought to be cloud computing. Users may access software and data stored on distant servers and other high-quality services using this web-based technology. Cloud computing is similar to data outsourcing in that the customer receives storage services from an outside party. It is possible to provide consumers with high-quality results without incurring significant costs for programming and equipment related to information storage. With cloud computing, you may satisfy customer needs and applications without maintaining a hardware and software infrastructure. It may be seen as a whole or partial outsourcing of software and hardware resources. A standard web browser and a quick Internet connection are needed to access cloud apps. It provides scalable, on-demand access to a shared resource pool housed at the provider's premises in a data center.

Keywords: Grid computing, SOA, virtualization, cloud computing, cloud technologies, and utility computing.

1. Introduction

Clouds are networks or the Internet. This suggests that cloud computing can be accessed from a distance. Benefits from the cloud may be gained via systems or the web, whether they are private or public systems. Cloud-based applications like email, online conferencing, and customer relationship management (CRM) remain operational (Boss et al., 2007).

Cloud computing is based on web computing, in which customers may access software infrastructure platforms, devices, and other resources and hosting via virtual shared servers in exchange for payment as they use the services. In this approach, everything data that a digital system has to offer is offered as a service(M. A, n.d.).

Cloud computing offers many benefits to its customers, including access to a wide range of applications without needing a license, purchase, introduction, or download of any of these programs. Because no infrastructure is required, software and machine installation and operating expenses are also lower. Customers must interact with a system (often the Internet) to access data from anywhere.

Clients of cloud computing rent use from a third-party provider rather than owning the actual infrastructure. They pay just for the resources they use, using resources as a service. The majority of distributed computing foundations consist of server-based and regular focus services (D. A, n.d.).

Any modern firm has to start determining where exactly Cloud Computing (CC) is needed in its operations to obtain a competitive edge and stay competitive in its industry. Pay-per-use is a unique feature of cloud computing, where users only pay for the services they utilize.

This document briefly explains cloud computing, outlining its services and deployment techniques while highlighting various.

Characteristics of cloud computing as well as cloud computing technology.

Compared to conventional storage systems, cloud computing provides organizations with more storage. Updates to software are increasingly automated, and fewer highly skilled IT employees are working [2].

Many services and models operate in the background to make cloud computing accessible and valuable for end users. There are primarily two types of distributed computing working models:

Different models and types of services operating in the background make distributed computing feasible and accessible to end users. There are primarily two types of distributed computing working models:

A. Models of Deployment.

B. Service Frameworks.

A. Deployment models describe how the cloud may be accessed or how one finds it. The cloud distinguishes four categories of accessibility: Private, Public, Hybrid, and Community.

1) Public cloud: Any external client may register on the internet and use this cloud, which offers pay-per-use resources for customers. This one is not as secure as a private cloud. Its openness makes it accessible to all internet users. Comparatively speaking, it is less configurable than a private cloud. A sizable Cloud Service Provider (CSP) owns and operates the cloud infrastructure. The cloud provider is responsible for building and maintaining public and IT resources. The external cloud, also known as the open cloud, is where resources are forcefully provided on a self-benefit basis over the internet.

Email, Google App Engine, Windows Azure or Microsoft Azure, and Amazon Elastic Compute Cloud (EC2) are a few examples.

2) Private cloud configured explicitly inside an organization's data center. They manage all cloud resources that belong to the organizations. Unlike an open or hybrid cloud, the private cloud provides better protection. Although private cloud resources are more expensive than public clouds, they provide more productivity. The cloud exists within and beyond the organization's boundaries and is managed by an association that only provides services. A private cloud, often known as an internal or corporate cloud, provides devices enabled to a pre-agreed number of users behind a firewall.

3) Community cloud: A few organizations collaborate to develop and provide a comparable cloud infrastructure, along with regulations, standards, values, and considerations.

The community cloud forms a degree of democratic balance and economic scalability. One of the community groups or a third-party provider might provide the cloud infrastructure. A few firms manage the cloud, which supports a specific community with a similar fascination. Compared to public clouds, community clouds are even more secure.

4) Hybrid cloud: This is a collection of communal, private, and public clouds. Public clouds perform non-essential tasks, while private clouds handle crucial tasks. Hybrid clouds may save money since they are less expensive than private clouds. Since hybrid cloud models rely on internal IT infrastructure, it is critical to ensure excess across data centers.

A cloud client may, for instance, transfer some cloud services—those involving sensitive data—to a private cloud and other, less sensitive cloud services—to a public cloud.

B. Service models: A cloud's capabilities, referred to as services, allow it to interact with a client or application in various ways. The functional models on which cloud computing is built are called service models. Three main service models or sorts of services have arisen over the internet.

1. As a Service Infrastructure (IaaS).
2. Software as a Platform (SaaS).
3. Cloud-based software (SaaS).

1) Infrastructure as a service (IaaS): Cloud computing providers give more capacity for arranging devices, real and virtual computers, etc. Virtual machines are managed by hypervisors grouped into pools and managed by functional networks providing emotional support. Cloud customers are responsible for installing their application programming and operating system images on the virtual machines. IaaS gives the cloud provider a valuable means of publicly locating the infrastructure over the Internet. IaaS resources are made available to rent to customers, including storage, bandwidth, IP addresses, firewalls, virtual machines, monitoring services, and more. The customer's pay depends on how long they can keep the resource.

Examples include Google Compute Engine, Amazon EC2, Windows Azure, and Rackspace.

2) Platform as a service (PaaS): This refers to providing an online application development and deployment platform to developers, enabling them to quickly create, implement, and maintain SaaS applications. Additionally, it provides the deployment and improvement tools needed to develop applications. A point-and-snap tool at the core of PaaS enables non-designers to build web apps. The buyer is not required to acquire pricey power supplies, servers, equipment, or data storage. Therefore, scaling up or down in response to application resource needs is not problematic.

Force.com, Google, Windows Azure, AWS Elastic Beanstalk, Engine, and Apache StratosApp are a few examples.

3) Software as a Service (SaaS): This refers to the delivery of applications (such as CRM or ERP) to end users via browsers on the internet. Cloud service customers may use what is now installed and operational on cloud infrastructure. This way, installing and using the software program on PCs alone is not required. Additionally, there is a decreased requirement for software support and maintenance. Certain SaaS apps, like the Office Suite, are not flexible. SaaS provides an application programming interface (API), allowing developers to create unique applications like Microsoft Office 365 and Google Apps.

2. The features of cloud computing

To satisfy customer or user needs and provide high-quality services, cloud computing has some of the following features.

1) Excellent scalability refers to the capacity to offer resources on a massive scale upon request without needing human interaction with every service provider.

2) High availability and dependability: The infrastructure has fewer opportunities to fail because of the servers' increased and more dependable availability [4].

3) Agility: It operates swiftly and distributes resources among users.

4) Multi-sharing: By sharing the basic infrastructure via distributed computing, different customers and applications operate even more effectively and at a lower cost.

5) Maintenance: Since cloud computing apps don't need to be installed on every device and can be accessed from various locations, maintenance is more straightforward and ultimately less expensive.

6) Low cost: Since the business no longer has to build its infrastructure, it is a cost-effective solution. It pays according to the amount of resources used.

7) Pay-per-use services: Clients are provided with APIs (Application Programming Interfaces) to access cloud services and are charged according to use.

8) On-Demand Self-Service: Cloud computing allows customers to access resources and services for in-person communication with cloud service providers upon request. A website login is available at any time.

Then put them to use. Processing power, storage, and virtual machines are examples of computing resources.

9) Wide network access: Using various devices, including PCs, laptops, mobile phones, and tablets, users may access resources like virtual machines, storage, and computing power over the Internet. Since cloud computing is internet-based, it may be accessible from anywhere at any time [5].

10) Resource Pooling: Many cloud computing users may share a pool of resources, including hardware, software, and a single physical database instance. For example, many virtual machines owned by various people may be hosted on a real server [6].

11) Quick elasticity: Increasing or decreasing resources at any moment is relatively simple. Resources presently allocated to or utilized by clients are automatically tracked, enabling this.

12) Measured Service: A cloud provider that offers measured services oversees and manages every aspect of the cloud service. Capacity planning, resource billing, optimization, and other factors play a role.

3. Technologies For Cloud Computing

The cloud computing platform is being supported by several advancements that are aiming to make it dependable, flexible, and easy to use:

- A. Sophistication
- B. SOA, or service-oriented architecture
- C. Grid-based computing
- D. Practical Computing

1. The process of virtualization

The process of virtualization grants permission for many users or an organization to share a physical instance of a resource or program. This is accomplished by giving a physical resource a logical name and, when needed, supplying a reference to it [7]. The primary use of this technique is to provide cloud customers with standard versions of the apps. For instance, the cloud provider should provide its customers access to the upgraded version of the program whenever it is published. For example, virtualized IT frameworks are available upon request from VMware and Xen. As virtual systems advance, consumers may access cloud resources within a customized network environment thanks to services like Virtual Private Networks (VPNs). Since virtualization methods provide flexible and scalable hardware services, they form the foundation of cloud computing. By delivering virtual disengagement between tenants, the multitenant architecture enables businesses to use and alter the program in the same manner each has its instance running.

Virtualization Types

The kinds of virtualization that follow are:

- 1. Virtualization of Hardware
- 2. Virtualization of operating systems
- 3. Virtualization of Servers
- 4. Virtualization of Storage

1) Hardware virtualization: This refers to installing the Virtual Machine Manager (VMM) or Virtual Machine Software (VMS) directly on the hardware system. Because managing a virtual computer is more straightforward than working on a real server, hardware virtualization is used for the server platform. Virtualization comes in several forms.

2) Operating System Virtualization: This refers to installing the Virtual Machine Manager (VMM) or Virtual Machine Software (VMS) on the host operating system rather than the hardware system directly. Operating System Virtualization has made testing apps across different OS systems easier.

3) Server Virtualization: This refers to installing Virtual Machine Manager (VMM) or Virtual Machine Software (VMS) directly on the server system. Server virtualization is utilized when a single physical server is split into many servers to balance the load on a demand basis.

4) Storage Virtualization: Storage virtualization assembles physical storage from several network storage devices. It seems that a single storage device aggregates many into physical storage. Virtualization of storage is used for recovery and backup.

B. Service-Oriented Architecture (SOA):

In a service-oriented architecture, applications are used as a service for other applications, regardless of the vendor, product, or invention. This makes information sharing between several sellers' uses possible without requiring additional programming or service upgrades. The figure depicts cloud computing Service-Oriented Architecture.

SOA is an application framework that separates typical business applications into distinct

Business processes and functions are known as Services. This aspect of cloud innovation gives associations access to cloud-based registration arrangements with features that can be changed on demand in response to changing business needs. Service-oriented architecture (SOA) transfers the responsibility and costs of web benefit parts' development, deployment, and support to the web services provider,

allowing a web services buyer to access various web services without incurring the overhead associated with traditional IT service delivery methods. SOA is a successful mechanical component of distributed computing because it encourages integrated appropriation and fragment reuse, fundamentally lowering the expense of programming advancement and delivery. Quality of Service (QoS) and Software as a Service (SaaS), two key ideas that are also essential to cloud computing, are introduced and disseminated via service-oriented computing [8]. Software as a Service offers a new application delivery paradigm. Quality of Service specifies a collection of functional and non-functional criteria that may assess a service's behavior from several angles. The realm of Application Service Providers (ASPs) is where it originated.

C. Utilizing grid computing:

Grid computing is a kind of distributed computing in which many computers from various locations are networked to accomplish a shared objective. There are differences in regional distributions in the computer resources. As a result, grid computing divides a big issue into smaller ones, which are then distributed among systems that are part of the grid. The goal of the grid system is resource sharing via large-scale, distributed cluster computing. Grid computing is widely used in e-science, a study where cooperation between data sources, computer services, and massive processing capacity is often needed.

Arranging Grid applications may be a very complex task, especially when managing the flow of information between distributed registration resources. Network work process frameworks are specific work procedure management frameworks designed to develop and carry out a series of work processes, computational or information control procedures, or grid configuration.

Conclusion

More straightforward. An overview of cloud computing, deployment models, service models, cloud computing methodologies, virtualization, SOA, grid computing, and cloud computing utilities is made clear in this article. We

intended to focus on introducing and illustrating the emerging trends in the technology used to provide cloud-based services. Numerous studies have been conducted to give customers on-request advantages and minimize downtime when transferring virtual machine memory from one physical host to the next. Later, we'll try to bring them together to provide a rational framework for describing, locating, forming, and managing.

The cloud comprises network components and computational resources based on the SOA concept. This method will provide the scalability and flexibility required to ensure that the diverse resources forming the cloud and systems work together. We will focus on how systems are created dynamically to shape the cloud and allow "cloud services" to be disclosed, degraded, and executed upon request. Under SOA, these administrations' connections and arrangements will ideally be handled.

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Discovering Cloud Computing Services and Applications

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A cloud computing environment offers more affordability and more flexibility when it comes to computer resources. This new technology ushers in a new age of e-services across several fields. This paper examines cloud computing services and applications. It provides examples of cloud services from popular cloud service providers (CSPs) like Google, Microsoft, Amazon, HP, and Sales Force. It also presents cutting-edge cloud computing applications in e-governance, e-learning, and enterprise resource planning (ERP). Our research aids in the understanding of how cloud computing may provide individualized, dependable, and reasonably priced services to people and companies across a broad range of applications.

Keywords: Pay-Per-Use, SaaS, PaaS, IaaS, Cloud Computing, ERP, e-learning, e-government, Service-Oriented Architecture.

OVERVIEW

Over the last ten years, cloud computing has drawn much interest from people and companies across all disciplines [1-20]. This new ecosystem suggests more flexibility and affordable access to computer resources at various abstraction levels. Cloud service providers, such as Google, Microsoft, and Amazon, rent out cloud computing resources and services to their clients based on a predetermined business model and dynamic consumer demand [7]. Customers may access general services in several application sectors, including business, education, and government, online via a web browser, and data and software are kept on cloud

servers housed in data centers [8]. Figure 1 illustrates how these services are often divided into three groups known as cloud service models. The Service-Oriented Architecture (SOA) used in cloud service models describes cloud services at various degrees of abstraction. These types of models are:

Software as a Service (SaaS): Under this paradigm, CSPs manage the operating system, computer resources, and application software. From the customer's perspective, the Software as a Service (SaaS) paradigm is a web-based application interface that allows services and complete software programs to be accessible using a web browser and supplied over the Internet. Customers may use various client devices, including computers, iPads, and mobile phones, to access hosted apps like Gmail and Google Docs. SaaS has the benefit of not requiring the user to purchase licenses, install, update, maintain, or execute software on their machine, in contrast to conventional software [26]. Additional benefits include multi-tenant efficiency, configurability, and scalability [27]. Zoho, Google Apps, and Salesforce.com are a few SaaS providers.

Platform as a Service (PaaS): In PaaS, a CSP supplies, manages, and keeps up an operating system and other system software. The customer administers and uses the application software under the operating system and on the virtual resources that the CSP provides. In contrast to SaaS, which offers customers fully functional applications, PaaS allows users to design, model, develop, and test applications directly on the cloud, giving them complete control over the software lifecycle [27]. The customer has little control over the operating system and hardware resources [26]. PaaS facilitates cooperative collaboration between project team members. For example, many users in several countries may work together to construct a website using a PaaS cloud service. Aptana Cloud, Google Apps Engine, and Windows Azure are a few PaaS vendors.

Infrastructure as a Service (IaaS): In this approach, a set of virtualized computer resources (such as memory, processing power, storage capacity, and network bandwidth) are made available by the CSP in the cloud. The client manages and

maintains the software applications and operating systems on these virtual resources. To transform physical resources into logical resources that can be dynamically provided and released by clients as required, Infrastructure as a Service (IaaS) leverages virtualization technologies [15–1723. IaaS vendors include Akamai, Amazon EC2, and Drop Box. Table 1 shows how cloud customers and CSPs are assigned to operate and maintain cloud resources under various service models.

CSPs may use several apps to provide cloud consumers with cloud services. This paper examines cloud computing applications and services. It gives examples of cloud services from popular cloud service providers (CSPs) like Google, Microsoft, Amazon, HP, and Sales Force. It also showcases creative uses of cloud computing in e-government, e-learning, and enterprise resource planning (ERP). Our research aims to educate people and companies on how cloud computing may provide them with specialized, dependable, and affordable services across a broad range of applications.

1. CLOUD COMPUTING SYSTEM ANALYSIS

There are four types of cloud computing systems: public, private, community, and hybrid [1,12,19,22,24,28,30,34]. These groups, called deployment models, outline the cloud services available to clients.

- **Public Cloud:** The general public may access the infrastructure and additional cloud services in public clouds over the Internet. A CSP that provides pay-per-use services to customers owns and operates the cloud. Users of public clouds are, by default, seen as unreliable. Therefore, security and privacy are significant issues with this kind of cloud [12]. Public access is available to well-known cloud services, such as Salesforce.com, Google App Engine, and Amazon EC2.

- **Private Cloud:** Only one company operates the computer resources in a private cloud. Either the organization or a CSP may be in charge of managing it. Private clouds are considered more secure because their users are trusted company members than public clouds. Community and hybrid clouds are the

other two deployment options between public and private clouds [12].

- **Community clouds:** Community clouds are comparable to private clouds, but they share computing resources and cloud architecture across several companies with identical goals, rules, and security specifications [24]. The educational cloud, utilized by universities and other institutions worldwide to provide services for research and instruction, is an example of a community cloud.

- **Hybrid Clouds:** The cloud infrastructure of a hybrid cloud combines two or more elements from the public, private, or community cloud. Although the cloud's components are maintained as a unified unit and connected by standardized technologies, each is nonetheless distinct [24, 28]. Organizations may maximize their resources by using hybrid clouds. This means that the private component of the hybrid cloud can manage its essential functions while the public component can do various auxiliary duties. Several cloud deployment approaches are shown in Figure 2 below, and Table 2 contrasts these methods with one another [30].

Cloud computing systems meet intriguing requirements that make them attractive for upcoming IT services and applications. Below are the five crucial qualities that the National Institute of Standards and Technology (NIST) [14] has identified for cloud computing systems [1, 19, 24, 25, 34].

- **On-demand self-service:** Cloud services like web apps, server time, processing power, storage, and networks may be automatically supplied as users require them without human intervention.

- **Broad Network Access (mobility):** Using various platforms, including laptops, PDAs, and mobile phones, users may access cloud resources over the Internet at any time and from any location (ubiquitous).

- **Resource pooling:** the cloud combines virtual and physical computer resources. Since most customers have little control or awareness of their location, these resources are location-independent.

- **Quick Elasticity:** Depending on customer demand, computing resources may be deployed and released quickly and elastically. Customers see these resources as limitless, available for purchase at any moment and in any amount.

- **Measured Services:** Using a pay-per-use business model, the CSPs monitor, manage, and optimize cloud resources and services. Customers similarly use these services to use gas, water, and electricity.

Additional features of cloud computing include [28, 29] Multitenancy, which is the ability of a cloud to serve several users simultaneously. Although each user is isolated inside their virtual application instance, those users share cloud resources at the network, host, and application levels.

- **Scalability:** The cloud computing infrastructure is very scalable. Minor changes to the cloud's architecture and software allow cloud providers to add more nodes and servers.

- In cloud computing, reliability is achieved by using many redundant locations. Due to its high dependability, the cloud is an ideal alternative for disaster recovery and business-critical processes.

- **Economies of scale:** the most significant feasible clouds are deployed to benefit from economies of scale. Additional cost-cutting measures include situating the cloud in cheap real estate and next to inexpensive power plants.

- **Cost-effectiveness:** Clients may lease computing resources and buy IT services that suit their requirements instead of investing in intricate, expensive computer infrastructure and services. As a result, the price of IT services for businesses and consumers would decrease.

- **Customization:** Depending on user needs, a cloud may be reconfigured as an environment with rearranged applications and infrastructure.

- **Effective use of resources:** Resources may be used effectively if provided for the short time required.

- **Maintainability:** CSPs relieve users of the hassle of maintaining their hardware and software.
- **Collaboration:** A platform as a Service (PaaS) enables users to collaborate inside an organization or across companies.
- **Virtualization:** The cloud isolates physical resources at the virtual level, so users needn't worry about them.
- **Green technology:** cloud computing doesn't need massive, power-hungry systems; instead, it divides resources between users.
- **High performance:** Cloud computing technology offers customers a high-performance computing environment because of the cloud infrastructure's enormous storage capacity and potent processing power.

2. COMPUTING CLOUDS SERVICES

This section [32] provides examples of cloud services offered by the most popular CSPs:

A. Services for Google Cloud Computing

Google offers a wide range of services and combines several apps for cloud users [36]. Because of this connection, Google is among the top cloud service providers (CSPs) since it makes cloud clients' jobs easier. It also saves time and money since building and maintaining the software needed to provide these services and apps takes a lot of effort and money. Google Cloud offers the following services, among others [36]:

- **Gmail:** a mobile email service with 25GB of storage, fewer spam, and other features. It has an inbuilt chat widget that saves email exchanges as conversations.
- **Google Docs:** a cloud-based service that lets users create and save word processing, spreadsheets, and PowerPoint presentations. The materials are accessible online, allowing users to view them anytime and anywhere. This makes it easier for team members across borders to collaborate and finish their tasks. Because Google Docs files are protected using cutting-edge encryption technology and can only be read by authorized users, they are safe.

- Google Ad Words and Ad Sense are advertising solutions. Google Analytics is used to track website visitors.
- Picasa: a product display platform that allows users to upload photographs to the cloud.

B. Services for Microsoft Cloud Computing

Microsoft offers a suite of cloud services known as the Windows Azure platform, which is accessible to both consumers and application developers. Every service is hosted in one of Microsoft's global data centers. Among these services are [37]:

- **Windows Azure:** a cloud computing platform built on Windows that allows users to store and execute apps.
- **SQL Azure:** this cloud-based relational database solution uses a specific Microsoft SQL Server version.
- **Windows Azure App Fabric:** offers an internal or external organization-hosted application infrastructure.
- **Windows Azure Marketplace:** an online marketplace where data and application software may be purchased and sold.

C. AWS, or Amazon Web Services

AWS offers a cloud computing platform suitable for all sizes of businesses. Businesses may use AWS to provide adaptable, affordable IT services and infrastructure that can be scaled up or down to their requirements. Companies may choose the platform that best fits their needs and only pay for what they use with the assistance of AWS. Furthermore, AWS utilizes cutting-edge physical security and data privacy strategies to safeguard user information. With security assessments and certifications including SAS 70 Type II, FISMA Moderate, HIPAA, and ISO 27001, AWS is a full-featured cloud service platform that offers a wide range of online services [33, 35]:

One online service that offers cloud computing capabilities that may be customized is Amazon Elastic Compute Cloud, sometimes known as Amazon EC2.

- **Amazon Simple Storage Services (Amazon S3):** This widely used online storage solution is scalable, safe, and dependable and can store and retrieve data of any size.

- **Amazon Virtual Private Cloud (Amazon VPC):** a Virtual Private Network (VPN) links the business's current IT infrastructure to the AWS cloud.

- **Amazon CloudFront:** a web service for content delivery that uses an extensive global network of edge sites to convey client data quickly and efficiently.

A highly accessible and scalable DNS service is Amazon Route 53.

Amazon Relational Database Services (Amazon RDS) is an online service that assists with managing a relational database in the cloud.

- **Amazon Simple DB:** offers the essential database features.

- **Amazon Simple Queue Service (Amazon SQS):** a hosted queue that is scalable and dependable for message storage.

One online service that assists with managing and sending alerts from the cloud is Amazon SNS.

- **Amazon Elastic Map Reduce:** this online solution lets users handle enormous volumes of data in the cloud.

D. Cloud Services from HP

Through its public beta, HP offers several services, which we have listed below [21]:

- **HP Cloud Compute:** offers virtual servers that are elastic, scalable, and adaptable to the user's needs as workloads vary. Customers may save money by only paying for the resources they supply, and they can also avoid wasting time on resource setup. Additionally, it offers an environment with open standards that guarantees portability, avoids vendor lock-in, and facilitates teamwork.

- **HP Cloud Object Storage:** a vast online storage space that enables users to store big data, including music and video files. Its on-demand scalability allows it to adapt to changing storage requirements, and its multi-availability zone replication ensures stability and timely client access to data.

- **HP Cloud CDN:** Also known as Content Delivery Networks, CDN is a web service that uses a global network of servers from HP and Akamai to deliver data from HP Cloud Object Storage to customers worldwide at high speeds. Customers can store data on HP Cloud resources for as long as they need and move it quickly from one computing resource to another.

One online service that offers on-demand access to relational structured databases is HP Cloud Relational Databases for MySQL.

- **HP Cloud Identity Service:** offers a unified identity and authentication management approach for HP cloud users.

E. Cloud Services sales force

Cloud computing technologies like Service Cloud [38] and Sales Cloud [39] are offered by Sales Force:

- **Support Cloud:** an online customer support platform that facilitates hundreds of online chats. It provides many conversational technologies supporting global CRM, including online communities, social networks, phone, email, chat, partners, and search.

- Sales Cloud gives users access to a wide range of easily customizable tools that can be used anywhere, at any time, to get real-time information. These tools include Chatter, Mobile, Files & Libraries, App Exchange, and Marketing & Leads.

3. ADVANCED COMPUTING APPS

We provide a few cloud computing apps in this section:

A. Using Cloud Computing in E-Learning

A recent educational development is e-learning, which aims to maximize information technology (IT) use. Students, professors, and researchers find the atmosphere of cloud computing to be appealing. Cloud computing, an emerging IT, may provide research institutions and universities access to robust and reasonably priced computational infrastructure. Students may use their mobile devices to access university educational services anywhere. Instructors may quickly and conveniently retrieve the necessary course materials in their classrooms. Researchers may discover publications and models on the cloud and conduct tests more rapidly than before [31]. An e-learning cloud's services are shown in Figure 3. Cloud Computing for ERP

There are several drawbacks to conventional enterprise resource planning (ERP) solutions. Different software programs could be required as an organization's operations expand to handle data in various areas, including administration, finance, payroll, and human resources. Acquiring, setting up, and maintaining many different software programs is challenging for expanding businesses. Additionally, the performance, availability of resources, and accessibility for many users are all restricted in conventional ERP systems. ERP cloud [40] is installing ERP systems on cloud infrastructure (servers in data centers, for example) so enterprises can access them from anywhere via a network connection. Thanks to this technology, project managers no longer worry about deploying, updating, and maintaining apps throughout their enterprises. ERP cloud also offers multitenant accessibility, high data and application availability, and reasonably priced scalable resources to enterprises. Leasing resources and services in the cloud instead of buying new hardware and software may help businesses lower their capital costs, increase ROI, and shorten their payback time. This is crucial, particularly for small and medium-sized enterprises with tight finances. An ERP cloud's services are shown in Figure 4.

B. Cloud Processing for Electronic Governance

Conventional e-governance encounters several obstacles, including [41]:

- Resources are not flexible enough to adjust to changing needs. This might lead to duplicate or inadequate resources.
- Time and money must be spent on the regular upgrades and maintenance of SW and HW.
- It is necessary to obtain new SW licenses.
- The system must function around the clock.
- Limited recovery and storing of data
- A secure environment with access control and authentication is required.
- Insufficient responsibility

A government's ability to cooperate with other governments, serve its residents and institutions, and run its operations may all be significantly enhanced by cloud computing technologies. It may assist in overcoming these obstacles by offering an elastic, scalable, personalized, and

accessible setting. Additionally, it frees governments from upgrading, maintaining, and licensing SW, freeing them up to concentrate on their primary duties. In addition, file replication and numerous installations in geographically dispersed places may be used for data recovery during a catastrophe. Scalable and affordable data storage can also be offered. Security methods and procedures may be used in the cloud to stop harmful behavior and safeguard data integrity and confidentiality [6,12,13,19,22,25,28,29,30,34]. The services provided by e-governance Cloud are shown in Figure 5.

CONCLUSIONS AND FUTURE WORK

Cloud computing, a new and developing technology, is anticipated to revolutionize the IT industry in the next few years and shape it for decades. The Cloud offers intriguing and exciting features, making supplying a wide range of services and applications possible. We looked at a few of

these services and used them in this article, and we do not doubt that many more will be implemented soon. Cloud computing technology is not without hazards and worries. Still, cloud services and applications are anticipated to draw many people and organizations from all disciplines, and our research helps them understand the influence of these services on their work. Concerns about security and privacy remain the main obstacles to cloud computing's practical adoption. The many tenancy nature and resource and data outsourcing are the main reasons for the security issues in cloud computing. Organizations and individuals are still concerned about storing and processing sensitive data and critical applications on the cloud. They continue to raise many questions for their CSPs, such as [6, 34, 46, and 47]: Where is their data located and who manages and accesses it, why is their personal information requested and who uses it, and what is the fate of their data in case of disasters or when the CSP went out of business.

Unsurprisingly, much of the future work in cloud computing will focus on developing approaches to address its security issues. Currently, several methods, including those from the CloudSecurityAlliance[42], theJerichoForumSelf-Assessment Scheme [43], the Shared Assessments questionnaires for vendor/service provider assessment [44], the ENISA Cloud Computing Risk Assessment Report [45], and the NIST [14], concentrate on identifying particular cloud security risks in various areas and offering recommendations and guidelines for security and privacy in public cloud computing. In our upcoming research, we aim to examine the security issue with cloud computing and provide a framework and security model that addresses and reduces security threats. This work will motivate businesses and individuals to continue utilizing this technology.

E-Learning Based on Cloud Computing

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Abstract

Modern technology paradigms of learning allow educators the capacity to promote the development of highly professional human resources. For this reason, professors at higher educational institutions find new technology more and more valuable. The rapid adoption of cloud computing into pedagogical practice requires a professional to examine the technical capabilities of cloud-based learning services to pick the best educational solutions among accessible variations. In light of this, the present study gives a theoretical overview of e-learning cloud architectural layers and their implementation models in the education system. To assess the applicability of learning management systems (LMSs) to a collaborative distant learning paradigm, a study among educators of I.M. Sechenov First Moscow State Medical University (Russia), Prydniprovsk State Academy of Civil Engineering and Architecture (Ukraine) and Wuxi Institute of Technology (China) was carried out utilizing the Blackboard Learn LMS as a case study. This research includes 100 persons who tested the Blackboard Learn teaching skills. The performed analysis defined the critical benefits of using computer-based e-learning apps to arrange and support the educational process. Among them are comfortable methods of processing educational information, effective educational process organization, effective instruments for knowledge monitoring, and adequate security and confidentiality systems. The current analysis also sheds light on the advantages of implementing cloud-based e-learning in higher educational institutions as

producers of an integrated educational product. The research verified that integrating cloud computing in education leads to the progress of the training material and may significantly increase students' academic outcomes owing to current learning technologies, ideas, and tools.

Keywords Cloud computing, e-learning, distant education, cloud computing architecture

1 Introduction

In contemporary culture, appropriate education is crucial for business and socio-economic success [1]. The extensive use of different Internet services, particularly social networks, has boosted the digital literacy of the global population. Therefore, modern technology learning paradigms like mobile learning are becoming increasingly popular [2]. Worldwide trends in the growth of the digital economy have resulted in greater technical complexity and the extinction of many old professions due to the automation of human activities and the introduction of new personnel requirements. Now, the virtual world includes many labor relations and even employment sectors. As a result, creating new competencies and reforming the overall education system becomes required [3].

With the tremendous development of the Internet in educational activities, curriculum delivery has migrated from local PCs to online apps. Recent technology breakthroughs have encouraged institutions to create unique instructional techniques. New technologies offer higher education institutions numerous fascinating tools that may be utilized to enhance the educational process [4]. The extensive use of technology, continuously updated information, the necessity for students to access information everywhere, and the customization of education have led to the rise of remote learning, e-learning, and mobile learning. Wireless technology and mobile devices are crucial in popularizing these themes [5].

A key trend in universities has been the development of so-called Learning Management Systems (LMS), which are utilized as a shared platform on which students and professors may communicate digitally [6]. LMS offers

academic institutions good learning tools and facilitates the efficient organizing and exchange of scholarly information [4].

Cloud computing is among the rising technical advancements that may dramatically affect education by employing dynamic scalability and resource efficiency. The cloud-based e-learning model features a scale efficiency mechanism that delegates the responsibility of developing the e-learning system to cloud computing suppliers. This allows suppliers and consumers the chance to create a beneficial connection. For education, such a model becomes a tool that may save a large portion of expenditures for offering an innovative educational process. Partnerships and cost-effectiveness continue to be a privilege of cloud-based e-learning because academic institutions are responsible only for the learning process, content management, and knowledge delivery. At the same time, the vendor deals with the construction, maintenance, development, and management of the educational system. The cloud-based environment may operate on various hardware devices and facilitate the building of next-generation e-learning systems. Modern consumers do not need any specific understanding of cloud computing to connect their PCs or laptops to the server [7].

Various educational organizations are expanding the presence of e-learning in educational activities. Since e-learning typically demands the deliberate use of networked technology in educational processes, cloud computing is a good solution for academic institutions with fewer budgets to host and administer online learning systems. The advantages of cloud computing in education, particularly in e-learning, garner the attention of many developers and software suppliers [12].

Recently, many institutions, universities, and even schools have implemented cloud-based e-learning software in their educational process. However, many of them utilize them as support for their major learning management systems (LMS) [13]. The introduction of cloud computing into higher educational institutions' pedagogical practice generates a professional necessity to research the technical capabilities of cloud services to identify appropriate educational solutions

among analogs. In this respect, the present study aimed to prove the adaptation of cloud computing applications for e-learning and highlight the advantages of employing systems to ensure a quality educational process.

2 Methods

Today, cloud computing has become the primary technology that may present infinite computing for numerous social or economic applications [14]. At the current level of the educational sector's development, cloud computing technologies are cost-effective services that allow the production of learning quality [15]. The E-learning cloud symbolizes a new cloud computing technology transition to the e-learning field, which consequently develops educational infrastructure with all the required hardware and software computer resources [7].

E-learning cloud architecture may be generally separated into various tiers. - The infrastructure layer of e-learning is positioned in the lowest level of cloud service middleware and comprises information infrastructure and instructional materials. Information infrastructure comprises system software, information management systems, and universal software and hardware. Educational resources are generated from training materials developed in the conventional teaching paradigm and are dispersed across the educational system. Using the cloud-based e-learning paradigm, physical servers, storage, and networks create a virtualization group — a pool of physical hosts. The software resource layer is built by the operating system and middleware. Here, various software resources are connected to give a standard interface for e-learning software developers. Specialized apps are produced based on software resources and incorporated into the cloud, making them accessible. The resource management layer is essential for interaction between software and hardware resources. Service layer contains three tiers of cloud computing services designated as SaaS (Software as a Service), PaaS (Platform as a Service), and IaaS (Infrastructure as a Service).

2.1 SaaS (Software as a Service)

SaaS is a software license and delivery mechanism that distributes software goods to clients by request [16]. Its services are hosted by a cloud computing provider and are built of software apps [17]. SaaS offers services such as e-mail, conferencing software, and corporate programs, including enterprise resource planning, customer relationship management, and supply chain management [18]. A single application is executed on the server side and is accessible by one or many runs on the cloud services and various end-users or client companies. The most commonly recognized SaaS examples include salesforce.com, Google Apps, Dropbox, MailChimp, ZenDesk, DocuSign, Slack, and Hubspot [19]. SaaS is also considered a fundamental service paradigm to access the program over the cloud [20]. Artificial intelligence (AI) in SaaS is represented in the form of machine learning (ML), which is engaged in Machine-to-human processes [21]. The presence of AI in SaaS takes the shape of hyper-customization. It represents bespoke instructional material that evolved when the user worked with ML [22].

Cloud computing users do not alter data quality, integrity, and availability. They have to depend on security precautions established by cloud providers [23]. Thus, cloud service vendors' reputation primarily rests on fulfilling the Service Level Agreement they undertake throughout operational operations. To deliver the greatest

Nowadays, big enterprises are inclined to adopt several cloud application services, dubbed the Hazy Cloud process. Due to these measures, cloud service companies must lock their services occasionally, and customers should simultaneously transfer from one service to another. In any event, introducing vendor-user interactions always augments access to services, and both should endeavor to prove mutual security im- [19]. SaaS solutions give a constrained approach at the client end, making the server end considerably resourceful. In such a way, it provides minimum integrated control for service-based capabilities to the client's end-users [24].

2.2 PaaS (Platform as a Service)

PaaS gives the user an electronic environment for constructing cloud infrastructure utilizing platform-level and software-level resources such as operating systems and application platforms. PaaS services are generally employed because of the less optimum solutions or outcomes of IaaS or owing to the requirements included in the network IT applications [25]. In PaaS, AI accelerates connections between the ecosystem and the user [26].

2.3 IaaS (Infrastructure as a Service)

In IaaS, the cloud service provider shares a pay-as-you-go facility to access the numerous characteristics of network servers, computational applications, and storage via the Internet [27]. IaaS is an architecture that balances the quantity of resources given to the service with real users' demands. For this reason, IaaS utilizes a load balancer, PHP, and MySQL servers [28].

In the early phases of establishing a cloud architecture, cloud services were delivered online in three core modalities: SaaS, PaaS, and IaaS. Subsequently, such domain-specific services as BPaaS—business process as a service—arose [29]. In BPaaS, the function of AI is associated with the interaction between Education 4.0 and Cloud-based e-learning [28].

The final one, the application layer, works based on apps that integrate educational resources into the cloud-computing paradigm and assist in building interactive courses and disseminating learning materials. This process comprises content production and delivery, educational goals' construction, and knowledge assessment and management. The distribution of academic resources comprises instructional material and information resources in digital libraries and information centers [7] (Fig. 1).

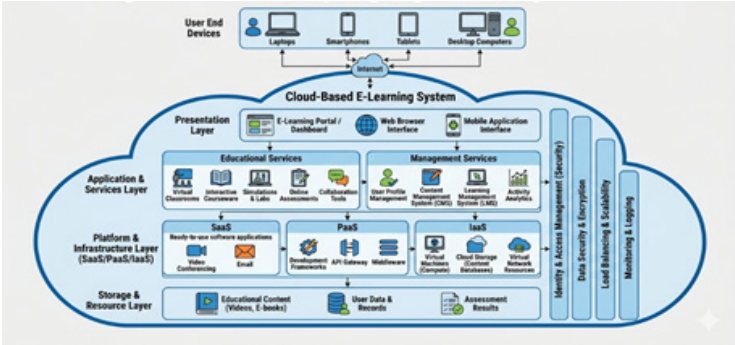


Fig. 1. E-learning cloud architecture

*Developed by the authors based on [7]

There are four typical examples of cloud deployment methods. All of them are illustrated in Fig. 2.

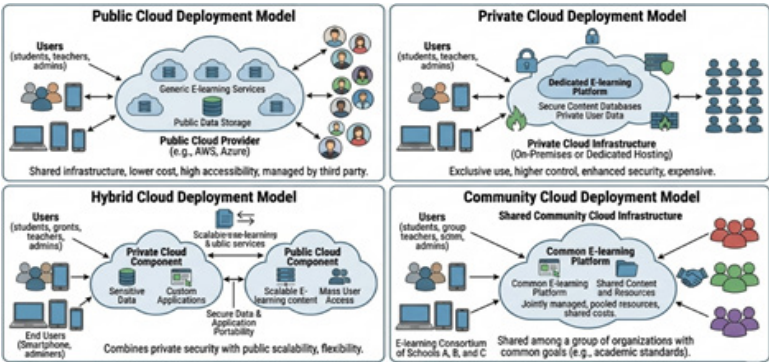


Fig. 2. Cloud deployment models

*Developed by the authors based on [19]

Cloud-based e-learning delivers user-centric adaptive hardware resources, a computing environment, and software services. In the cloud, customers may access digital services transparently at any time and anywhere [9]. Often, e-learning cloud systems consider educational institutions' needs regarding training resources' virtualization, centralized data storage, low operational costs, scalability, flexibility, and availability. Therefore, the cloud-based e-learning

architecture comprises the cloud management system, hardware and software computing resources, and services given by the cloud [22,30].

Most software suppliers deliver their services on cloud platforms. Blackboard Learning is one of the brightest examples of cloud-based LMSs that supply online education services. In a similar spirit, open-source e-learning applications are also hosted on different cloud platforms, such as Moodle Cloud [2].

3 Results and Discussion

Blackboard Learn is an open, cloud-based education platform that improves the learning experience by delivering online training possibilities in synchronous and asynchronous situations. In a synchronous environment, students and instructors are given the option to engage in real-time. A prominent example of synchronous technology is Blackboard Collaborate, where one may schedule study sessions, hold spontaneous conversations, and welcome guest lecturers. In an asynchronous setting, students may use the hourly calendar for reminders about impending activities [31].

Blackboard Learn enables learners to take three courses: online, hybrid, blended, and conventional, with extra web components (Fig. 3).

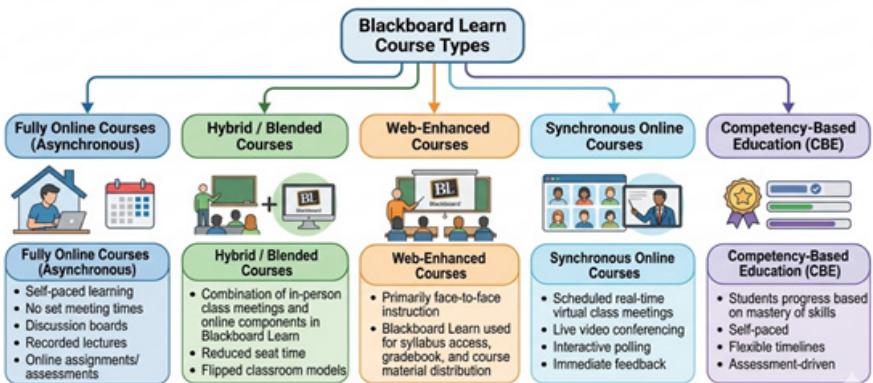


Fig. 3. Types of online courses in Blackboard Learn

Higher educational institutions should embrace digital technology in teaching and learning to allow learners to develop digital competence, which is essential to encourage innovation and employment. The educational process management in universities and colleges should incorporate the utilization of modern interactive teaching techniques based on

Innovative digital software [3]. Adopting a more flexible knowledge management system based on cloud services can enhance education quality. In addition, deploying cloud computing technologies is crucial for achieving the lifelong learning concept [15]. However, with the fast and widespread deployment of next-generation mobile networks (4G, 5G, 6G), the popularity of cloud computing in the educational sector will be boosted.

While e-learning is built on modern digital technology, it will not replace existing teaching techniques. At the same time, it may considerably boost the efficacy of education by deploying sophisticated technologies, concepts, and tools that provide new material, models, and teaching techniques. The key benefits of adopting cloud servers in the educational process are strong computing capabilities, large-capacity data storage, virtualization, and high availability and security of cloud services. The cloud-based e-learning architecture delivers tremendous computing power and ample data storage space by placing the computation and data in many dispersed machines. In the cloud computing paradigm, administrators protect the security of user data and, to the maximum degree feasible, manage unified data, distribute resources, balance load, install the software, and execute dependable real-time monitoring [7].

Due to decreasing enrollment rates and reduced physical presence of students in courses, numerous schools and institutions provide the chance to attend specific courses in a distant mode. Research on the adaptation of cloud-based e-learning in Malaysian institutions has found that the choice to deploy this model is mainly driven by the necessity and perceived utility of the technology. In the meantime, innovation is not significant in implementing cloud-based

e-learning. Cloud computing has become appealing to many educational institutions because it has numerous benefits, particularly geographic distribution and effective cost allocation related to automated systems and open-source software. Systematic communication between learners and instructors in diverse geographic areas enables the creation of vivid and engaging learning platforms, permits active group work, and implements more effective teaching approaches [33].

Despite the increasing emergence of cloud technologies in university teaching practices, there are questions regarding whether these technologies are employed as effective teaching tools or just as a store of electronic papers [6,34]. Results from various studies reveal that while many university personnel throughout the globe utilize LMS to varied degrees, the great majority cannot use the potential pedagogical advantages afforded by the program's full capabilities [6].

The cloud computing paradigm has transformed the computer science horizon and has drawn significant interest from academia, business, and government agencies. Recent technical breakthroughs such as the Internet of Things, Serverless Computing, Software-Defined Networking, and edge processing have opened new prospects for cloud computing and set the framework for expanding the digital economy. However, they have also generated a need for new research methodologies to assess and enhance approaches to scalability, elasticity, dependability, security, and resilience [35].

With the emergence of cloud computing technologies in higher education, many difficulties with security, privacy, poor professionalism, and sluggish Internet connections have developed. According to research conducted in Bangladesh [36], some significant variables that substantially affected the adoption of cloud computing at the University of Dhaka include lack of suitable infrastructure, service availability, and usefulness in education. Studies of the potential for using cloud computing in higher education in Sudan also highlight the problem of privacy and security [37].

Adopting cloud computing into academic practice is tied to technical preparedness and cultural considerations. Research towards a comparison between the Middle East and Europe regarding implementing cloud computing into the educational process has explained that European nations have a higher tendency to adopt advanced technologies. At the same time, the Middle East still prefers traditional ways of learning. As for security difficulties that are still to be handled, Europe already has specific centers for this objective. Middle Eastern nations, particularly Oman and Qatar, are still grappling with security challenges. In addition, cloud-based education in the Middle East is just beginning its first phase, whereas several European institutions are actively adopting modern educational technologies [38]. Numerous primary considerations impact the choice to employ cloud-based e-learning in a specific nation. Among these are perceived usefulness, convenience, trust, security, necessity, and purpose to learn in such a manner [11].

Conclusion

Modern technology paradigms of learning are becoming increasingly popular among instructors of higher educational institutions, whose activities are geared at training highly professional workers of the digital era. Cloud computing considerably influences the teaching and learning environment by utilizing dynamic scalability and resource efficiency, extending the bounds of educational opportunities, and ensuring the availability of educational services. Introducing advanced technology and training standards based on cloud computing provides a new level of remote education organization. The current paper gives a theoretical overview of the architectural layers of the e-learning cloud and its implementation models in the education sector. To investigate the adaptation of LMSs to a collaborative distant learning paradigm in 2019-2020 among instructors of I.M. Sechenov First State Medical University (Russia), Prydniprovsk State Academy of Civil Engineering and Architecture (Ukraine), and Wuxi Institute of Technology (China) experimental study was carried out using the Blackboard Learn application for interactive e-learning, creation of

online communities, and virtual knowledge exchange. This research enrolled 100 educators who were supposed to test the teaching capabilities of the Blackboard LMS. Within the investigation, the main advantages of using Blackboard Learn in organizing and supporting the educational process were outlined: convenient means of processing educational content, effective educational process organization, practical tools for knowledge monitoring, and adequate security and confidentiality system. Furthermore, the current article offers the

Benefits of implementing cloud-based e-learning in higher educational institutions. The study proves that introducing cloud computing into the educational process positively changes academic content quality and can considerably increase training efficiency due to updated learning technologies, concepts, and tools that render new teaching content, models, and methods.

