

Cloud Nexus: Architecture, Innovation, and the Digital Horizon

Edited by

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Swami Vivekananda University

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Sourav Saha

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The Role of Cloud Computing in Artificial Intelligence

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Introduction

Even though cloud computing has been around longer than artificial intelligence, it has helped artificial intelligence development in a big way. Since cloud computing came along, there has been an enormous push. Some parts of AI that have changed over time are data and data sets, processing power like GPUs, models, algorithms, and talents and abilities. This essay will examine how cloud computing has helped grow artificial intelligence (AI).

Role of Cloud Computing in Artificial Intelligence

Cloud delivery models

With IaaS (Infrastructure as a Service), AI experts can immediately get a fully functional computing environment without waiting for an infrastructure team to set it up (CPU, memory, disc, network, operating system). Recently, cloud service companies have begun to offer GPU hardware.

PaaS makes it easy for AI experts to create new apps by giving users access to AI and data science services like Jupyter Notebooks and data catalog services.

SaaS users can now use AI services inside the app to get the most out of programs like customer relationship management (CRM) and payment processing software (Software as a Service).

Cloud technologies

Thanks to containers, all data scientists can now work in the same place and with the same interface. Data scientists can

still host their containers on that platform, even if a cloud provider runs it with more GPU capabilities.

Using Kubernetes, data scientists could create data science platforms that were easier to scale and were built with containers. Kubernetes allows it to deploy containerized data science applications to several cloud providers without setting up or maintaining the underlying computer infrastructure.

Data is the most crucial part of artificial intelligence, so make sure you use enough of it. You need to be able to access a lot of data to evaluate algorithms and models. The proper knowledge makes storing public and private data in the cloud easy and safe.

Talent/Skills Availability

There are now many undergraduate and graduate degree programs in data science and AI engineering at colleges and universities throughout the United States and worldwide. These programs are available in many fields, such as computer science and mathematics, and higher education institutions often offer this curriculum at undergraduate and graduate levels.

Experts in deep learning, artificial intelligence (AI), machine learning, natural language processing, and natural language comprehension can work together on projects and compete against each other on cloud-based platforms like Kaggle and CrowdANALYTIX.

These platforms make it possible to process information and share data. Anyone who wants to use this service can do so alone. It is easy to get there and only takes a short time. There are several sets of data to choose from. These modern environments are suitable for the growth of intelligent people, and as a result, they are ideal for developing the people who use them.

DevOps

DevOps is a method for running IT operations and making software that uses many of the same languages (Ops). The phrase “for the first time” was used for a conference with the

same name. The DevOps method is not new but has several benefits when used to build a microservices architecture. DevOps doesn't take care of problems during the Data Science life cycle. In 2018, Gartner developed a new idea called "Models." MLOps came before ModelOps (Machine Learning Operations). It was something that DevOps got.

Today, every primary cloud provider, like AWS, Azure, GCP, IBM, Oracle, etc., offers a full range of API services and platforms for data science and machine learning (such as natural language processing, computer vision, and automated machine learning). IBM, SAS, and RapidMiner, three of the biggest companies in their fields, offer cloud-based data science and machine learning solutions. With cloud-native (Kubernetes) infrastructures, the same data science platforms and AI API services can also be used on-premises. Cloud service providers and analytics companies said they would improve their products soon.

The following are some advantages that cloud computing has seen as a result of AI's considerable impact –

Sense of Autonomy

Cloud computing with AI might help businesses become more data-driven and strategic. As a result, people can work more productively. Overall productivity may be increased by using artificial intelligence to automate time-consuming, repetitive tasks and data processing that does not need human participation.

IT teams might use AI to supervise and track essential activities. AI may handle the tiresome work while humans focus on more strategic efforts that add value to the firm.

Cut down on your expenditures.

Cloud computing is more cost-effective than on-premises data centers since it eliminates the need for hardware management and maintenance costs. Although launching an AI effort may be expensive, organizations may acquire the necessary technology through monthly payments to a cloud provider. Research and development costs may be kept to a minimum using this service. AI systems are also capable of data analysis and conclusion-making without human aid.

Minimum effort data management

Critical sectors, including data processing, administration, and organization, have been significantly impacted by AI. By leveraging more reliable real-time data, artificial intelligence may enhance an organization's overall performance. Finally, AI technologies make gathering, organizing, and updating information easier.

Advantages and Applications of AI in Cloud Computing

The rapid evolution of technology has empowered humanity with countless avant-garde tools and solutions. Among these many wondrous technologies and solutions, two names have not only carved quite the niche for themselves but have been deemed proper rockstars in the business world. Artificial Intelligence (AI) and cloud computing have ushered in a new era of technological innovation. Combining the technologies transforms how businesses process data, make decisions, and drive efficiencies. As AI's capabilities expand, its integration with cloud computing creates a synergy that enables organizations to harness the immense power of AI algorithms, data analysis, and machine learning on a scalable and accessible platform.

Now, individually, their benefits and immense potential are known well enough. But what about bringing AI to the mix in cloud computing implementation? This article delves into the dynamic fusion of AI and cloud computing, unveiling the benefits and possibilities with use cases that arise at the intersection of these two groundbreaking technologies.

What is AI in Cloud Computing?

AI in cloud computing refers to the integration of AI technologies and capabilities with cloud computing services. In this union, cloud computing offers on-demand access to computing resources such as storage, servers, networking, software apps, and databases over the Internet. At the same time, AI introduces intelligent systems that can execute tasks that would otherwise require human intelligence and intervention.

AI in Cloud Computing: Benefits

- **Reduced costs:** AI can help to reduce costs in cloud computing in several ways, including through shared resources. Because cloud providers use shared infrastructure, resource use is optimized, and fees for individual users are reduced. Furthermore, most cloud computing platforms use a 'Pay-as-you-go' model, allowing users to pay only for the resources they use. This primarily benefits AI apps that usually need significant computing power and storage.

- **Automation:** Once again, automation is also a multi-faceted benefit of integrating AI in cloud computing. For starters, AI can be incorporated into cloud-based automation tools, automating repetitive and mundane tasks that do not necessarily need human intervention. AI can also be used to analyze data for patterns and trends, thus freeing the IT staff to focus on more strategic aspects of their job. This can also help to improve the efficiency and cost-effectiveness of cloud computing.

- **Data management:** Yet another compelling benefit of combining AI and cloud computing is data management. Cloud providers already have robust security measures to safeguard data from unauthorized access and ensure compliance with data privacy regulations. AI can further fortify these measures by proactively identifying and mitigating security threats.

AI in Cloud Computing: Use Cases

- **Cognitive cloud computing:** A relatively recent type to emerge on the scene, cognitive cloud computing uses AI to deliver user insights and recommendations. It can also be used for tasks like fraud detection, risk management, customer service, etc.

- **Chatbots:** AI-driven chatbots are practically everywhere now! And it is a good thing, too; after all, these mighty tools serve to ameliorate customer service and gather data. Cloud platforms can store and analyze the data collected by chatbots, whereas cloud services can

channel said data to the right apps and services for further processing.

- **Business intelligence:** A crucial application of AI in cloud computing is BI and analytics. In cloud computing, AI enhances data analytics by offering advanced analytics capabilities, such as predictive analytics and data visualization. This means that organizations can leverage AI in the cloud to analyze massive datasets in real-time, glean insights, and make data-driven decisions much more efficiently.

Conclusion

Researchers and tech companies are making predictions about the industries and uses of artificial intelligence that will grow the fastest in the next few years. To get the most out of AI, we must turn it into use cases that take advantage of cloud delivery and processing methods. Edge computing brings the cloud's low latency and ability to work even when the internet is down to a company's servers. This would be especially helpful for businesses with much data and processing power (e.g., video analytics). The progress of quantum computing will help machine learning in particular.

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Enhancing Cloud Computing for E-learning

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Abstract:

This document details the development of an innovative e-learning application that stands out for its unique use of cloud services. This application is designed to create an accessible, scalable, and interactive educational platform, overcoming geographical and temporal barriers. It provides a seamless learning experience from any device with internet access, making it a valuable addition to the e-learning landscape.

Our application is not just about technology; it's about the user. It's designed to offer a flexible, personalized learning experience that caters to individual needs. By leveraging cloud infrastructure, we ensure high availability, real-time collaboration, and secure storage of educational materials. Our key features, including interactive multimedia content, virtual classrooms, AI-driven learning analytics, and adaptive learning paths, are all designed to boost engagement and support diverse learning styles.

The cloud-based architecture we've developed is not just robust; it's highly scalable. It supports various devices and efficiently handles user loads, ensuring a smooth learning experience. Advanced technologies, such as machine learning and data analytics, deliver actionable insights into learner progress and help customize educational experiences.

In summary, this e-learning application represents a significant advancement in digital education. It combines cloud computing with a user-centric approach to enhance learning outcomes and build a global educational community you are a part of. As development progresses, we focus on ensuring an intuitive interface and fostering compelling learning experiences.

Introduction :

In today's rapidly evolving educational landscape, leveraging technology is critical to enhancing the learning experience. We are excited to introduce our innovative application, designed to revolutionize e-learning by integrating cutting-edge cloud services and advanced features. Our platform aims to bridge the gap between traditional education and modern digital solutions, providing a seamless and interactive learning environment.

Welcome to our groundbreaking e-learning application, where innovation meets education! We are excited to introduce a platform designed to transform how you learn and teach. Our application integrates cutting-edge cloud services and advanced features to create a dynamic, interactive learning environment. With seamless access to resources, real-time collaboration tools, and personalized learning paths, we aim to enhance the educational experience for students and educators alike. Whether you're looking to streamline your teaching methods or engage in more effective learning, our application provides the tools and flexibility to support your journey toward success. Join us in revolutionizing education

....

Difficulties of classical E-learning :

- **Technical Issues:** Students often encounter problems with unreliable internet connections, software glitches, or device compatibility, disrupting their learning experience.
- **Lack of Engagement:** Online learning can sometimes lead to reduced student engagement and motivation due to the absence of physical classroom interactions and immediate feedback.

- **Distractions:** The home environment may present numerous distractions, making it challenging for students to focus on their studies.

- **Difficulty in Understanding Content:** Some students may struggle to grasp complex concepts without face-to-face explanations and find it harder to seek help.

- **Time Management:** Managing time effectively can be difficult for students accustomed to structured classroom schedules, leading to issues with keeping up with coursework and deadlines.

- **Reduced Hands-On Experience:** Subjects that require practical, hands-on activities or experiments may be challenging to adapt to an online format, impacting students' learning outcomes.

Limitation of Classroom :

- **Limited Advanced Features:** While Google Classroom excels in basic functionalities, it lacks advanced features in other Learning Management Systems (LMS), such as detailed analytics, complex grading rubrics, and extensive customization options.

- **Storage Limitations:** Google Classroom relies on Google Drive for file storage. This limitation can exist if storage constraints exist or users prefer different cloud storage solutions. So the app will not crash while a massive amount of data is being processed.

- **Customization Limits:** The platform offers limited course structure, design, and user interface customization options. This can be restrictive for institutions or educators with specific needs or preferences.

- **Not Ideal for Complex Courses:** Google Classroom may not offer the depth of functionality needed for courses that require intricate structures, such as those with multiple levels of hierarchy or extensive multimedia content.

Purpose of this Project :

Incorporating new features into e-learning apps is essential

to address the diverse needs of students and enhance their educational experience. Traditional methods often fail to provide personalized support, engaging content, and real-time feedback. By integrating advanced tools such as adaptive learning algorithms, interactive simulations, and gamified elements, we can better cater to individual learning styles and preferences. These innovations not only make learning more interactive and enjoyable but also help in maintaining student motivation and improving retention. Enhanced analytics and progress tracking can offer valuable insights for students and educators, ensuring that learning is more effective and aligned with each student's needs.

Core Services :

- **Enhanced Communication:** Instant messaging, reminders, and feedback loops improve student engagement and support.
- **Integration with Learning Technologies:** AI integrates with VR/AR and simulations, enhancing hands-on learning experiences.
- **AR/VR-Based Classes:** Provide a VR environment where students can interact with teachers and peers in virtual classrooms
- **Predictive Analytics:** Leverage predictive analytics to identify students who might struggle and provide early intervention with personalized resources.
- **Categorized:** IoT sensors or wearables could be used to track student engagement and behavior in physical classrooms.
- **Unlimited Storage Capacity:** Our application provides unlimited cloud storage, enabling seamless access to and storage of vast educational resources.

Provided Features :

AI/ML for Personalization and Automation :

- **Personalized Learning Paths:** AI customizes learning content based on individual student progress.

- ***Automated Grading:*** AI improves grading efficiency for quizzes and assignments and represents their progress report.

- ***Guidance:*** AI provides tailored learning support and suggestions through AI-powered resources, study materials, and virtual guidance.

Adaptive Learning System :

- ***AI-Driven Adaptive Learning:*** Adjusts learning material to match each student's pace.

- ***Predictive Analytics:*** Identifies students at risk and enables early intervention.

- ***Secure Credential Verification:*** Blockchain secures and verifies tamper-proof digital certificates.

Cloud-Based Collaboration :

- ***Real-Time Co-Editing:*** Students and teachers can collaborate on documents in real-time.

- ***Group Projects:*** Provides shared cloud spaces for group collaboration and task management.

- ***Doubt solving:*** AI chatbots offer 24/7 support, assisting with real-time doubt resolution.

Acceptability for students :

- ***Mindfulness and Well-being Modules:*** Integrate mindfulness, meditation, and well-being modules to support students' mental health, reduce stress, and improve focus.

- ***Offline Learning Mode:*** Ensure all lessons, quizzes, and study materials are downloadable and accessible offline.

- ***Parent Portal:*** Develop a dedicated portal for parents to monitor their child's progress, communicate with teachers, and receive recommendations for additional support.

- ***Track Learning Habits:*** Provide tools to track learning habits and patterns, helping students build a consistent study routine and recognize areas needing improvement

Integration of External Educational Resources:

- ***Open Educational Resources (OER):*** Curate and integrate open educational resources from the cloud. Integrate Khan Academy, edX, or Coursera APIs for additional educational material. Cloud-based content aggregation will provide easy access to external resources within the platform.
- ***Cloud-Based Marketplace for Educational Tools:*** Build a marketplace for teachers to access and share educational apps, tools, and templates. Use cloud storage and APIs to provide educators with a seamless app store-like experience.

Conclusion :

The Cloud Computing platform's features are ideal for this learning system's migration, allowing us to fully take advantage of the opportunities presented by developing an effective learning environment that provides personalized content and simple adaptation to the current educational model. The benefits of integrating an e-learning system into the cloud are best described as having good resource flexibility and scalability, including storage, computational demands, and network access; additionally, the cost is reduced due to the pay-per-use billing structure, the avoidance of purchasing new hardware and computers, and the reduction of software licensing fees for educational programs.

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Performance Analysis of Enterprise Cloud Computing: A Review

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Abstract

Cloud computing has quickly established itself as the standard in its industry due to the benefits outlined above. Many firms are transferring their operations to the cloud to decrease the time spent on infrastructure care. Consequently, managing a cloud environment has shown to be incredibly challenging. It is vital to have an effective cloud monitoring system to decrease the effort associated with administration and optimize cloud operation. The cloud monitoring service is advantageous as it can enhance performance and make administration simpler. Managing quality of service (QoS) criteria for cloud-based, virtualized, and physical services and applications is one of the most significant roles in cloud monitoring. Consequently, cloud management software preserves a record of activities and services and performs dynamic configurations of the cloud to boost operational effectiveness. The performance of enterprises and businesses as a whole was explored in this article, as was the effect that cloud-ready programs and tools have on that performance, as well as the benefits of adopting such programs and goods.

Keywords

Enterprises performance; Cloud computing, Cloud monitoring; Types of Cloud; Monitoring tools; IaaS; PaaS; SaaS

Introduction

The use of computers in big organizations for data processing is referred to as “enterprise computing,” which is also commonly referred to as “information management” (IS) or “information technology” (IT). In the 1960s, soon after the advent of mainframe computers, the first extensive use of computers for data processing on a commercial scale was commenced. Because of the emergence of new technology capabilities, there has been a considerable change in the paradigm of business programming. Since the debut of the personal computer in the 1980s, client-server architectures have primarily replaced the enormous mainframes previously in use. The client-server architecture was displaced in the 2000s by web-based commercial systems and e-commerce websites emphasizing the end user. This happened when the internet gained significance in the 1990s [1].

As a consequence of these improvements, the ability of business networks to enable access to the Internet has improved, and they have grown both in size and degree of pervasiveness. Concurrently, both their degree of complexity and, as a consequence, their price have increased: A startling amount of money is spent on information technology (IT) by consumers and corporations all across the globe each year. This involves everything from acquiring new hardware and software to expanding the number of devices joined to the network (in-house or outsourced) [2]. Cloud computing has the potential to transform commercial computing once again, as it will convert computing into a service that can be accessed over the internet rather than physical equipment [3].

Essential aspects of cloud computing include (a) the packaging of computing services as a service and making them available over the internet, (b) the capability of end-users to rapidly provision the resources they require, and (c) a pricing model in which customers pay only for the cloud resources they use. Cloud services may be able to achieve significant economies of scale as a consequence of the aggregation of computing resources; these economies of scale are something that may later be passed on to corporate IT. It is not unexpected that the possibility of cost savings is at the forefront of people’s

thoughts regarding the present enthusiasm for cloud computing. Mining data at previously unfathomable volumes is now viable thanks to the availability of cloud services, which pool together vast amounts of processing power in focused pools. This technique led to a broad range of unique programming models and development procedures called cloud computing. These technical developments make it conceivable to execute calculations on a vast scale and considerably boost the efficacy with which software is built [4].

Cloud computing has experienced a steep surge in importance over the past few years. Consequently, it is dramatically redefining the information technology strategy of several worldwide organizations. The unprecedented benefits that the “as a service” paradigm provides in terms of investment, distribution time, and scalability have led to the wide dissemination of new (mobile) offerings and the introduction of emerging innovations such as big data, the Internet of Things (IoT), and machine learning (ML) [5].

These new improvements are proving the capacity to increase internationally distributed resources, which, in turn, is promoting the continuous growth of the cloud computing company and boosting the prospects open to unique enterprises working in global settings [6].

New computing and network technologies are developed to use global pooled infrastructure to have the most incredible user experience. Due to low latency, A multi-cloud system brings new issues when analyzing end-user service standard of quality (QoS). SLM is vital for significant suppliers because of its expanding prominence in business. The most crucial effect on SMEs’ acceptance of cloud-based services, external circumstances, rather than organizational or technological variables, have a substantial impact on Cloud service adoption, thus summarizing the significance of environmental influences in SMEs’ adoption of innovative technologies in India. Indicates that adequate load and data testing are vital for cloud storage; numerical studies suggest the consequences of the “chilling” process. Identifying approaches to enhance the operability of QS models with queues Using statistics

helps decide what services are necessary to reach the success criteria. Computational capacity is accessible in various data centers globally, with one relying on available power; suppliers often advertise that their charges vary according to the usage [7].

The remainder of this review study is arranged as follows. Section two provides the theoretical notions regarding Enterprise Cloud Computing. The literature review is in part III. Section VI offered the essential discussion and comparison among the evaluated works. Finally, the conclusion stated in section V is followed by the utilized references.

Enterprise Cloud Computing

Cloud Computing

The phrase “cloud computing,” which also refers to “on-demand computing” or “platform computing,” comprises a broad range of resources and applications, including file storage, server and database administration, and device deployment. Other names for this computing include “on-demand computing” and “platform computing.” Because the servers offered by the cloud service provider are machines, it is essential to set up additional infrastructure, which involves both time and resources. The phrase “cloud computing” refers to a paradigm for delivering computer services in which consumers have access to a shared pool of customizable computing resources (such as data storage and processing power) with relatively little involvement from the user. Cloud computing is sometimes known as “utility computing.

Users should store their data online, which can be accessed from any device at any time, rather than locally on a hard drive or backup device, since online storage allows for more flexibility. Cloud computing, or SaaS and IaaS, provides computer resources and applications online. Depending on the network architecture, the cloud environment may be categorized as private, public, or hybrid.

Cloud Computing layers

Carrying Out Your Duties Within the Cloud: The Cloud Consists of Two Layers, Front and Back. A communication

layer exists between the user interface (front end) and the users. This layer facilitates users' access to information kept in the cloud by enabling cloud storage applications [8].

Components such as processing units, routers, central servers, and facilities for storing data are examples of parts included in the back end. The most crucial purpose of this cloud component is to store data safely. It serves as the cloud's skeleton. The central servers, with the assistance of middleware, function as translators between the database and the applications, enabling efficient communication in both directions across the many devices that make use of cloud storage. As may be observed in Fig. 1. [9]

Fig. 1. Cloud Computing layers, front-end and back-end.

Enterprise cloud computing

While enterprise cloud infrastructure provides considerable productivity, efficiency, and cost-cutting benefits, many companies still face significant barriers to cloud adoption. Enterprise cloud computing can be challenging, and the proliferation of social video and streaming media platforms has made it much more difficult. As consumers have an exceedingly high demand for seamless interactions when viewing websites, mobile apps, and digital video content, network congestion makes reliability a problem. Denial-of-service attacks and other advanced threats pose significant security risks for businesses using commercial cloud storage platforms [10].

Monitoring tools and technology are available for companies looking to solve the obstacles to commercial cloud computing. Offering the world's most extensive and most integrated cloud-based infrastructure for delivering and accelerating corporate cloud computing technologies, businesses can expand their network into the cloud and handle traffic around the Internet to provide safe connectivity to sensitive services for staff, collaborators, and clients, making enterprise cloud computing more scalable, efficient, and secure, easier [11].

Comprehensive solutions for corporate cloud computing Web performance technology speeds up websites and web

apps, allowing businesses to provide consumers instant, dependable, and safe access from any platform anytime. Enterprises can offer a flawless viewing experience, quick access to high-definition multimedia content on any device, and the flexibility to expand to meet peak demand using media distribution technologies, such as a live streaming server [12].

Stable websites and data centers with cloud protection technologies reduce the chance of downtime and data stealing. Cloud networking technologies that turn the business network to speed up applications, cut costs, and make cloud infrastructure more available. Network provider solutions that make constructing and operating a service distribution network [13].

Enterprise architecture

Cause and effect: Due to this shift from client-server to the Internet of Things (IoT) to cloud computing, each large corporation must constantly review evolving IT architectures while maintaining reliable business processes to stay operational. With the introduction of emerging technologies, a balancing act is needed to manage the needs of existing business processes [14].

Multiple environments and constantly evolving technological environments necessitated the 'enterprise' feature of IT. [IT Architects] found it advantageous to create an overview of how the enterprise's software fulfills business needs, whether applied architecturally or communicated between the various business applications. It is also necessary to regulate and standardize the options for new technological platforms to ensure that their functionality is met. To explore how major organizations can adopt cloud computing, we must consider the change in the infrastructure model from the viewpoint of business functions [15].

Advantages Of Cloud Computing

Several benefits associated with using cloud computing Since the introduction of cloud computing, the shortcomings of conventional information technology systems have been

progressively more apparent each year. Because their technical environments are not well-equipped to recognize these shifts and put appropriate responses into action, businesses are having a more challenging time adapting to shifts in the market and new technological developments. This makes it more difficult for companies to respond to these changes. Cloud-based solutions provide an IT architecture that is more malleable and effective, and it is created expressly to assist enterprises in thriving and expanding [16].

- **Increased Interoperability:** Because users of various communities and teams may access duplicate files in the cloud, interoperability between these groups is improved, making it more straightforward for them to collaborate. This strategy enhances the efficiency of remote workers accessing data and engaging with management by minimizing the delays inherent in conventional IT models. These delays can hinder remote employees' ability to do their jobs effectively. It streamlines procedures to accomplish more work faster [17].

- **Scalability and Performance:** Market needs are still evolving, so cloud infrastructure is built to be scalable. As businesses expand, more storage and bandwidth are often needed to handle the growing traffic volume. Auto-scaling helps companies manage their cloud resource use to scale up and down as required while maintaining efficiency. In addition to improving website speed, cloud infrastructure minimizes downtime [18].

- **Automatic Software Updates:** Many cloud service providers keep the service up to date to match company demands. Every hour of every day is committed to maintaining the cloud servers, which frees up resources they'd otherwise expend in-house [19].

Cloud-based solutions are also particularly sustainable for companies that practice corporate social responsibility and are concerned with reducing the carbon effect of their operations. In many instances, cloud storage may entirely do away with the demand for hardware, resulting in a significant decrease in the number of essential IT infrastructure components in

the workplace. This may be attributed to the fact that cloud storage can eliminate the need for hardware. Because the price mechanism cloud service providers use is known as “pay as you go,” companies are only required to hand over money when they use the cloud service. As organizations develop and their data requirements rise, they may take advantage of a storage scalability option that is available to them. Employees can now carry out their responsibilities from anywhere as long as they can access the network. This is possible because cloud information is kept remotely on the Internet [20].

Common Cloud Computing Challenges

The most challenging component of cloud storage is, without question, the fear of stability. While cloud storage services offer the most significant security and industry standards, they are still dangerous [21].

Downtime: Any cloud client may admit that downtime outages are their top worry. In rare cases, service businesses can be inundated by their customers daily. If technical difficulties develop, the program or services can be briefly inaccessible.

Internet Connection Dependency: A client cannot view the data without an up-to-date computer and Internet connection. Additionally, utilizing public Wi-Fi for your files may be risky if the necessary precautions are not followed.

Financial Commitment: A pay-as-you-you-go strategy is frequently employed in the cloud sector. However, membership programs commonly involve monthly or yearly fees. They should do this as part of their operational expenses.

Security: Even if your cloud provider claims it is secure, losing your information is just as easy. Dissaving is also becoming an increasingly significant concern as hackers try to access critical corporate data saved in the cloud.

Limited Access: While the cloud service may operate the technology, the customer has little control. Only one person can deal with the front end of the computer; the others will run the infrastructure. Passing critical jobs, such as firmware administration, to the end consumer can be disregarded.

Once a third-party supplier is in the chain, you can never be confident that the data will be safe.

Types Of Cloud Computing

It is possible to categorize cloud computing service providers according to whether or not they provide cloud-based services and use a delivery method based on the cloud. This is one potential method for organizing suppliers of cloud computing services. How clouds are disseminated may determine whether they are public, proprietary, or hybrid. Public clouds are accessible to anybody, whereas private clouds are only accessible to a select few. On the other hand, the service model includes an offering for infrastructure as a service, platform as a service, and software as a service [22].

Types of Cloud Deployment (By Models):

Cloud's categorization depends on the deployment type.

Private Cloud

As an alternative to on-premise implementation, a private cloud offers more limited service than an infrastructure-as-a-service model but is also less expensive. They are currently referred to as “within” or “corporate cloud,” which includes features handled on-premises and inaccessible to the public. A private cloud offers scalability, elasticity, and stability with an extra layer of management controls. Businesses can obtain more protection by creating firewalls while outsourcing to the public cloud. The primary disadvantage of the private cloud is that it can be time- and resource-intensive for the enterprise to use and maintain the servers. Public Cloud

“digital cloud” refers to computer facilities provided over the Internet by third-party providers. Unlike private clouds, public clouds make their capabilities accessible to everyone who wishes to access or buy them. These programs may be offered for free or on a pay-per-use basis, with customers paying only for the CPU cycles, storage, or bandwidth they use. Since the cloud service provider maintains the system, companies may avoid buying, operating, and upgrading on-premises systems. They also have modular RAM and versatile bandwidth, allowing companies to scale their storage requirements more efficiently.

Hybrid Cloud

A public and private cloud blend uses a particular cloud computing technology. The “cloud voodoo” paradigm shifts private and public clouds in response to changing computing needs. As the need for on-premises storage and cloud grows, companies will ramp their networks up to accommodate the additional traffic since it doesn’t originate in the public cloud. In a multi-tenant cloud model, you pay for services. Often, you get the advantages of a decentralized cloud while avoiding the associated security problems.

The Types of Cloud Service Models

Based on the service model, cloud services may be grouped into IaaS (Infrastructure-as-a-Service), PaaS (Platform-as-a-Service), and SaaS (Software-as-a-Service), as shown in Fig 2. [23].

Fig. 2. Types of Cloud Service Models [24].

Infrastructure as a Service (IaaS)

In the context of the “as a service” model that is utilized in computing, the phrase “infrastructure as a service” (sometimes abbreviated as “IaaS”) is the phrase that is most commonly used to describe the delivery of cloud-based server and storage resources, in addition to virtualized network connections. This phrase is the phrase that is most frequently used to describe the delivery of these resources. The client retains control over the servers, operating systems, and applications offered as part of the service even though they are not responsible for administering the cloud resources independently [25].

It is not the client’s obligation to host any of the hardware, software, servers, or data storage for the service; instead, it is the job of a third-party provider to take care of all of these things. The customer is not responsible for any of these things. Hosting the program and making regular backups are the service provider’s responsibilities. Infrastructure-as-a-service (IaaS) is offered by several companies, including Amazon Web Services (AWS) [26].

Platform as a Service (PaaS)

PaaS, which stands for “platform as a service,” is a cloud computing model in which the customer is not responsible for setting or administering the underlying platform. This model is also known as “platform as a service.” Instead, the responsibility for doing so is with the supplier. They are creating a program that can function inside a cloud environment. Customers can have input into the services they get since they are the ones who pay for such services when they are utilizing them.

Users can get the most out of the software they have already paid for by using SaaS, which frees them from worrying about updating or replacing any software. With software as a service (SaaS), consumers can get the most out of the software they have already paid for without being burdened with managing their networks, servers, operating systems, and storage. As a result of this, businesses are in a better position to devote a more significant portion of their time and resources to the development and marketing of new products while also devoting a smaller portion of their time and resources to the routine maintenance of their systems and the development of new software. The Amazon Web Services (AWS) Elastic Beanstalk and the Google App Engine are two of the most well-known examples of the platform as a service (PaaS) [27].

Software as a Service (SaaS)

“software as a service,” more often abbreviated as “SaaS,” refers to a model of delivering computer programs to end users as a subscription service. When users use cloud storage, they are relieved of the responsibility of ensuring that the software installed on their local workstations is kept up to date and do not need to import any new applications. Users can access the software over a distant cloud network using an application programming interface or a web browser (API) [28, 29].

With the software as a service, or SaaS, model, the cloud storage supplier takes full responsibility for everything, including the hardware, middleware, application services, and encryption. SaaS, or software as a service (SaaS), provides

organizations access to hosted applications. This prepares the way for significant gains in administrative efficiency and customer pleasure. Applications like Salesforce, Microsoft Office 365, and G Suite from Google are examples of software as a service. By what can be seen in Fig. [30]

Monitoring Tools

Monitoring is an essential component of management and engineering in the modern, sophisticated infrastructures that support networking. When dealing with novel storage and networking paradigms, such as cloud computing and network virtualization, monitoring becomes significantly more difficult due to the increased variety and changeability of the underlying networks and resources. This is because cloud computing and network virtualization are examples of novel storage and networking paradigms. One of the factors that has contributed to the meteoric rise in popularity of cloud computing over the last few years is this. Getting a consensus on assessing these systems is more challenging since there are currently no industry standards for monitoring cloud infrastructure. Because of this, agreeing on how to evaluate these systems is a difficult task. Understanding the components of cloud services monitoring, which range from the underlying physical and virtual infrastructure to the levels of the end-user and service provider, respectively, can be accomplished most successfully by taking a tiered, top-down approach to the problem at hand. This is the most efficient method available [31]. Each measuring layer incorporates the relevant criteria and metrics for judging.

Fig. 3. Infrastructure with Cloud Computing [24]

performance in dependability, security, SLA compliance, and efficiency, respectively. In addition, the market's most representative cloud service providers are segmented into groups according to the kinds of services that they provide. The management methods associated with each service type are then researched and mapped into the appropriate functional levels [32].

The National Institute of Standards and Technology (NIST) asserts that the architecture of cloud computing makes it

possible to get on-demand access to shared network services that may be made available in a short period with just a minimum amount of administrative work needed. The most notable benefits of using cloud computing are the increased level of productivity, scalability, speed, and accessibility it provides. Cloud computing is also relatively inexpensive. Like any other kind of service, cloud computing does not come in a format that is universally applicable to all circumstances. It is possible to meet the requirements of a broad group of clients by delivering a wide range of service models and different types of solutions. This may be done in several different ways. Using the cloud may be accomplished in various ways in the modern world. Cloud computing may be broken down into three primary service models: infrastructure as a service (IaaS), platform as a service (PaaS), and applications as a service (AaaS). These models are abbreviated as IaaS, PaaS, and AaaS, respectively (SaaS). Because of how they are linked, they make up what is referred to as the “cloud service stack.” The phrase “cloud computing” is gaining popularity due to the growing number of companies and people recognizing this technology’s many advantages. When more individuals use cloud services, a higher volume of data needs to be handled. This increases the difficulty of the task. Because of this, administration and monitoring solutions for the cloud that are at the leading edge of technology are required [33].

- Infrastructure and service monitoring are needed, and automated and manual tools are required to track cloud computing adequately. Managing cloud infrastructures consists of measuring, overseeing, and administering active tasks within that infrastructure. Manual or automated techniques ensure the cloud technology or platform works properly. It’s necessary to cope with cloud-critical resources or scientific calculations. The cloud administration assists with various cloud-related tasks like:

- The accounting and billing cloud includes virtual and physical usage and allocation. The CMP requires sophisticated and precise record-keeping and prohibits fabrication and manipulation to ensure data security.

- Quality of Service (QoS), Price, and penalty provisions in the customer agreement. The Parameter Monitor gathers the CMs and resources and analyzes SLA data to verify services.
- Providing cloud services to meet the workload. The CMT monitors overall resource utilization and service use. This allocation/reallocation assistance may aid in more efficient allocation choices.
- Capacity planning secures the capacity for performing operational activities in the Cloud. The CMT detects resource utilization for various services.
- It is a collection of settings and values that regulates the activities of devices and software. It guarantees cloud services are reconfigured when customers add or remove resources. The CMT supplies the services for configuration.
- The security and privacy of computers are vitally crucial, especially when it comes to leveraging cloud resources and services.
- It is also one of the most essential aspects of operational Cloud regarding reliable and resilient Cloud infrastructure. Proactive management of cloud-driven resources is made possible via monitoring. Shown in Fig 4. [34]

Fig. 3. General design of cloud monitoring Tool[35]

Literature Review

Many companies are choosing to house data in data centers because they need to organize, process, store, and easily access vast volumes of data. A data center has several components, like a space with hard drives, chillers, power supplies, and servers. Data centers run round the clock, seven days a week. IT service companies can own a data center to create an IT enterprise or organization. Most businesses must heavily use apps, utilities, records, and data centers [36]. For this reason, we need a management framework where any administrator can track anything that happens on the network, including all programs, applications, and data. On the face of it, the device

monitoring seems to be done for speed; behind the scenes, though, its objective is to discover disturbances, issues, or dangers. Typical for web servers, the control system is usually mounted on a separate computer and configured to track other computers and software [37]. Today, the network is the only place to access knowledge and records. Many technologies and apps, such as device monitoring, monitoring software, and analytical tools, are already used to monitor network output. We offer some literature reviews on the topic:

D. Chandramohan et al. [38] recognize protection and confidentiality problems in the insurance and finance industries. Concerns for personal freedom under oppressive management facilitating the stealing of third-party services to be aware of and diligent in market continuity/phenomena and protection are critical requirements in the cloud where security and confidentiality are given equal consideration in the new pervasive mobile computing era data in the cloud is very vulnerable Once compromised, the user's trust on cloud services is significant. In the current century, managing and maintaining the flow of knowledge is critical because banking, healthcare, government, and government information are in the cloud, making it difficult to do anything globally.

G. Wenwen et al. [39] presented an innovative approach to punishing malicious ratings focused on three criteria: expense, benefit, and risk. More specifically, they examine each criterion and its contributing factors and propose a coherent model that quantitatively incorporates the three parameters. In theory, work is proposed using on-the-cloud and knowledge-enhanced computer tools. Specifically, it aims to optimize the machining parameters using an event-driven approach. Based on the latest component characteristics, longitude and azimuth parameters that were machined previously are automatically obtained. Finally, the optimization module adapts the movements and cutting parameters to represent the events. Human operators use a sensor network, and human control tracks the data. Research from the mold-making industry validates the proposed structure.

N. Sfondrini et al., [40] IT is being transformed by cloud computing. Many businesses are increasingly investing

money into the Cloud to accelerate IT operations and decrease the time to market with innovative products like IoT and Big Data. However, essential enterprise facilities and confidential data must be moved to the Public Cloud. To survey sixty companies now using the public cloud for their applications. This study looks at enterprise and prospective Cloud strategy options and challenges. For research, cloud service providers (CSPs) are only used for regulation and success management issues. It follows that multinationals would use SLM to gain ownership over their public cloud systems.

A. I. Khan and A. Al-Badi,[41] Today's desktop-based technologies are going from niche to ubiquitous. There are billions of widely distributed software. However, applications are challenging to validate because of the diversity of pervasive hardware. Minimum effort cloud computing is the future. We verify the accuracy of apps. Traditional research methods can't keep pace with the fast-changing technological world. 5G also lowered the network data use requirement; thus, under the presence of 5 G, cloud-based application testing is achievable

S. Afzal and G. Kavitha [42] are concerned about load balancing during the load balancing period. The supplier must carry additional costs when accomplishing a migration that equates to a reduction in profit due to a decline in resources. It is linked to load balancing by the cloud service (CLS). An improved load balancing (IMB) algorithm is developed to lower migration costs. The IMB migration expense indicates that.

F. Zahid et al.,[43] [52] offer a self-adaptive network design to HPC clouds; as a model for lossless interconnection centered on a feedback control system and optimization, we created an HPC network that constantly adapts to the different traffic patterns resource distributions, and policies. Furthermore, we're making a simpler rule-based specification for the framework's service providers. Our self-adaptive built network prototype works using industry-leading applications. The test on a cluster shows the possibilities and outcomes when it comes to meeting the quality of service in HPC clouds.

C. Wu, S. Horiuchi, and K. Tayama [44] also created a novel intent-based cloud resource design (RDF) and successfully tested it in a cloud-based scenario. The well-tailored RDF N mode reached 90.60, 95.44, and 98% in terms of the versions. They additionally proposed an RDF feature (P--mode) to increase user satisfaction. They almost eliminated SLA risk at the cost of a minor quantization error (2.78 percent).

N. Chawla et al., [45] Large businesses are increasingly moving HR, financial, and other vital applications off-premise to the SaaS (Shared Service-Software as a Service) and PaaS (Public-Platform-as-a-Service) ecosystems. As apps are deployed into the public cloud, we see increased potential for designing bespoke performance testing capabilities. Checking the website during migration to the operation under the cloud, he proposed three implementation scenarios and research targets.

W. Hassan, T. S et al., [46] Cloud infrastructure practices and guidelines are a subject that is still being studied and needs to be looked at further. These best practices and policies can help companies understand how to get the most out of cloud infrastructure without putting their businesses at risk. More research also needs to be done on cloud activities and recommendations. These methods and best practices will help organizations use cloud computing to its fullest potential in industry-targeted cloud applications. What is it, hasn't, and will change? Numerically, small numbers of users show the benefits of cloud storage. Capability can be delivered by continuous,- the-the-the-of-the-the-the-moment tracking. All have their head in the cloud. Companies can be helped to appreciate cloud computing by reading this document. Additional analysis is needed to optimize these qualities.

A. Stephens al. [47] to assess the efficiency of IaaS in the cloud service agreement. The measure of real-time analytics is the problem with which to continue computation. In our research contribution, we have taken availability as the main parameter and carried out the study. Some software, such as Manage Engine, display the percentage of being available, whereas others, such as Idea, do not. CPU, network out, and file read and write properties can be seen. The two parties

can understand that it is a compromise without resources. 99.9% uptime in the future, this analysis will be applied to a smaller subset of cloud vendors, and more information will be accessible. The amount of instruments to track can also be expanded, and a calculation for compensation can be constructed mathematically. If these results are applied to all the service suppliers, availability is rated, and the customer can choose a service without a problem.

D. Mourtzis [48] suggests an automated, knowledge-laden system for machining using machine tools. It's an event-driven algorithm that focuses on the machining parameters. Using the characteristics of a new element, it searches for previous component dimensions that have already been successfully machined. Afterward, the optimization module adapts these events to effectively manipulate the step and cutter parameters: a mobile device-based surveillance framework [that] gathers and reports the system.

I. K. Kim et al. [49] propose that NTRU offers a safe and efficient enhancement to DROPs' Confusion and scattering, protecting the confidentiality of the records. The nodes are chosen Using T-sequencing and the NTRU algorithm. Fragmentation also improves efficiency. There is just a user interface for importing and saving data. Additionally, the framework may be further modified to change the settings in the file without impacting output. For distributed data storage and connectivity, TCP over DROP can be employed.

G. Ciccarella, [50] With the introduction of services such as 4K and 8K online, 360-degree virtual reality, and self-enabled vehicles, the ECC has found itself a prominent position in telecommunication networks. This case study describes how ECC can achieve efficiency and total cost savings. It also describes the reasoning behind using ECC to boost KPIs in ultra-wide bar networks by evaluating efficiency and cost on simulation.

O. Pandithurai et al. [51] indicated Enterprise cloud instances in modern data centers operate not only foreground programs such as web and databases but also various background resources (e.g., backup, virus/compliance search, batch) to protect the cloud instances and boost overall resource

efficiency. These context services also experience resource floods, which absorb significant pooled capital on cloud instances. By intervening with the preemption of shared infrastructure, resource storms significantly degrade the output of foreground applications, resulting in repeated SLA breaches. On the other side, Stock OS schedulers are not equipped to manage these conditions, and previous work is inadequate to deal with resource storms in extremely volatile cloud workloads.

M. A. Sharkh, Y. Xu, and E. Leyder, [52] Cloud computing is becoming the standard for companies worldwide. We want to investigate how machine learning algorithms affect cloud device profiling and prediction. While classic machine learning algorithms have been successfully applied in Cloud Computing, cutting-edge methods like deep learning and reinforcement learning have not. Despite having capabilities in image processing and speech recognition, these models (intense neural networks) face problems elsewhere.

W. L. Tsai, [53]. Advancements in cloud computing have also made infrastructure as a service (IaaS) mandatory for businesses. However, evaluation tools in cloud computing remain incomplete. This study uses an improved knowledge framework. Formation perception is used to construct the study framework, updated by transaction cost theory. Experts gauged these metrics using Delphi. The findings show that importance, data security, data integrity, and data retention are critical aspects of cloud computing.

N. S. Kumar et al., [54] AWS Lambda is a compute carrier that allows you to run code without managing or provisioning servers. AWS Lambda executes the code only when required and scales automatically, from a few daily requests to hundreds per second. You pay for the compute time you use; there is no charge when the code is idle. With AWS Lambda, you can run programming for almost every service or backend provider – everything without managing something. AWS Lambda runs the code on a high-availability computing platform that handles all computing resource administration, including application and operating system upkeep, bandwidth provisioning and automatic scaling, and code monitoring and logging.

R. Maeser, [55] It's clear that companies can demonstrate integrity by being straightforward and trustworthy. Be informed, meet and uphold cloud infrastructure and storage requirements, and execute service level agreements trim options focused on cost, user requirements, and tractability to compute private cloud infrastructure. About cases and organizations, these measures will tell them how long to push the related variables to meet their needs. The prototype must address the capacity and security concerns to meet all internal and external needs (i.e., traceability and transparency from expectations to the required investment levels and cloud service capabilities that satisfy requirements). Using this statistical technique, data-driven method (e.g., organizations that are comparing whether to utilize private vs. public vs. hybrid or organizations that are assessing the required investment to their internal private cloud based on required cloud SLA availability levels).

M. M. Khalil et al., [56] the more virtual machines involved, the shorter the overall delay period of the tracking device was. However, the average waiting time for operation was higher than that of fewer devices; thereby, the impact can be offset by including more virtual machines. In AIST's (American Society of Testing) opinion, the organization of cloud service access is needed in every cloud environment. The VM control causes a server delay, which must be accounted for to mitigate. The considered risk model for cloud computing can approximate the time required for service provisioning.

N. Kratzke and R. Siegfried, [57] under the pay-as-you-use cloud computing paradigm, cloud-native platforms are being developed. Add these observations to the simulation. Two significant contributions were proposed: a cloud-native simulation stack and expectable delivery patterns for cloud-native simulation services. Our perspectives are built on case studies of cloud-native technologies, studies of cloud requirements, collaboration with cloud engineers, and action testing with app developers. 2 primary data storage and web applications deployment modules have been made smaller, though horizontally decomposable.

Discussion And Comparison

Benefits to cloud infrastructure include the promise of delivery of service capability. Examples of cloud computing systems include Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS), and Software-as-a-Service (SaaS). This is a cloud storage blog. Each facility is assessed and ranked. SaaS saves consumers time and money by allowing Internet-based program usage and application maintenance. A hosted cloud platform uses virtualization, which ensures enterprise continuity. The service company provides various systems, including APIs, computers, servers, storage, databases, networks, and frameworks. IaaS leases cloud-based resources, including servers, laptops, networking gear, and software. Businesses widely use these to fulfill their IT specifications and redefine emerging cloud infrastructure standards and protocols, including service level agreement (SLA) management and resource provisioning. It will help quantitatively confirm that the different tasks handled in Cloud ecosystems can be viewed from vendors' and customers' viewpoints, as they can be managed independently. To compile this definition, the operating areas of the Cloud produced a taxonomy, and this class serves as a valuable point of reference when testing various control techniques. Emphasized that general monitoring tools and cloud-specific tools had differing functionalities based on their domain; an overemphasis on specific strengths was generally what we had anticipated. Clients also use general monitoring systems that include a client-server model. These tools were built to track conditions where there were no changes in infrastructure. These problems, including scalability, should be discussed when developing new monitoring tools for Clouds. The capabilities of the monitoring tools must be investigated to see if they will improve where needed, as well as to find places that do not have the necessary help described by monitoring tools and their potential to assist cloud management and Performance.

Note in Table 1 that the interest of all research has been focused on strengthening and developing the infrastructure of the cloud, as it saves effort and money for the customers and

users, as well as interest in the aspect of security, especially in the private cloud, to gain the satisfaction of the business and Performance of Enterprise. How cloud TEMP has changed how businesses operate today, John Graham-Cumming, CTO of Cloud Flare, says, "The cloud TEMP has taken what was once costly hardware or software and turned it into services. This first happened with applications (such as Salesforce), then computing and storage (AWS or Google Cloud). It is now happening on the network."

Further commenting on the future of the cloud, he says, "The future of cloud is serverless and infinitely scalable. The next stage is forgetting where and how code runs and has it run everywhere, inside the Internet. This will be the serverless revolution".

In the shadow of rapid technological growth, several companies have rapidly sought to speed up management processes and service delivery to enterprises, companies, and consumers. So, several technologies and tools have evolved in this field, like... The three most advanced firms are. In the shadow of rapid technological growth, several companies have sought to speed up management processes and service delivery rapidly to Enterprise, companies, and consumers, so several technologies and tools have evolved in this field, like Top Cloud Monitoring Tools 2020, Sematext Cloud, AppDynamics, Datadoz, New Relic, Dynatrace, Sumo Logic, CA Unified Infrastructure Monitoring (UIM), Site24x7, Zabbix, Stackify Retrace, Zenoss, BMC TrueSight Pulse, Solarwinds, Amazon CloudWatch, Azure Monitor, etc... The three most advanced firms are Amazon Cloudwatch, Microsoft Cloud Monitoring, and MS Azure on cloud service[65].

Conclusion

Cloud computing is becoming increasingly common. Cloud computing is booming because of infrastructure as a service (IaaS). As a service, cloud services can include virtual servers, raw storage, firewalls, and network equipment. One of the most critical challenges in cloud infrastructure is provisioning. Resource management consists of allocation, provisioning, mapping, and modeling. The following advantages of Cloud

IaaS include scalability, the standard of operation, decreased overhead, increased efficacy, and streamlined GUI; for too many years, network computing has been where it is today. It's the enabling technology of the decade. These traditional structures are commonly clustered. This technique would not scale to millions of artifacts in cloud systems. Scalability approaches that have more excellent dispersed application and monitoring properties are needed. Infrastructure as a Service (IaaS) computing empowers applications to procure or unlock computing services as required. Infrastructure-as-a-Service (IaaS) successes indicate that it will continue to be progressively critical. Although the controversy rages in scholarly and scientific chat rooms, cloud infrastructure does new things for the Performance of Enterprises that they have never been able to get.

IaaS cloud infrastructure employs schemes that provide resource provisioning, allocation, mapping, and reallocation. It's known that there are several considerations when managing cloud resources, including availability, scalability, adaptability, and reusability. Delay, bandwidth overhead, computation overhead, and protection must be factored into the management design of a resource plan. The advantages of the cloud have enabled many Enterprises to solve their problems due to the lack of tools, devices, costly services, storage spaces, and their problems, network performance, and speed in obtaining results anywhere and at any time only with the presence of the Internet or available networks.

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Serverless Computing: Design, Implementation, and Performance

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Abstract

We introduce the architecture of a brand-new, performance-focused serverless computing platform built with .NET, hosted on Microsoft Azure, and using Windows containers for function execution. We detail implementation difficulties, including function scaling, container lifespan, reuse, and discovery. We describe metrics to assess serverless platform execution performance and run experiments on our prototype, AWS Lambda, Azure Functions, Google Cloud Functions, and IBM's Apache OpenWhisk deployment. We analyze the scaling and instance expiration trends in the implementations and find that; at most concurrent levels, the prototype outperforms competing platforms in terms of throughput. We also highlight future research to explore the shortcomings and limits of our existing design and offer potential solutions.

Introduction

Serverless computing is a cloud service that divides application logic into functions and runs in response to events. It was first introduced by AWS Lambda, and other services like Apache OpenWhisk, Azure Functions, Google Cloud Functions, Iron.io IronFunctions, and OpenLambda have followed suit. These events enable developers to quickly assemble applications that are dispersed over several services inside a cloud. Sources outside the cloud platform can trigger them, but they also frequently happen internally between the platform's service offerings.

An event-driven ideal, in which programs are defined by actions and the events that cause them, is partially realized by serverless computing. The event-driven literature has long postulated broad computing systems in which operations are handled reactively to event streams, and this terminology is suggestive of active database systems. These concepts are wholly embraced by serverless function platforms, which extend event-processing logic throughout their clouds and define actions using straightforward function abstractions. The OpenWhisk platform from IBM, now known as Apache OpenWhisk, reflects these ideas strongly by clearly defining functions in terms of event, trigger, and action.

Design conversations go from the event-driven base to software development techniques that utilize function-centric infrastructure and container management. When execution is needed, Iron.io pulls and runs function containers stored in private registries using Docker. An investigation of the scalability benefits of serverless computing and performance analysis of several container transitions are presented via peer work on the OpenLambda platform. Other performance assessments have tested AWS Lambda's potential for embarrassingly parallel high-performance scientific computing, and they have examined the effects of VPC and language runtime on AWS Lambda start times. Serverless computing is a suitable match for Internet of Things applications, which intersects with the edge/fog computing infrastructure discussion. To facilitate the anticipated growth of IoT devices, attempts are being made to include serverless computing in a "hierarchy of data centers." With the launch of their Lambda@Edge product, AWS has entered this market by enabling application developers to install restricted Lambda functions in edge nodes. AWS has also been working on various serverless computing extensions, such as Greengrass, which offers a standard programming paradigm for Lambda and IoT services. By breaking down massive programs into smaller functions, serverless computing enables application developers to scale individual components of the application. However, this creates a new challenge in the cohesive administration of various functions. AWS recently introduced Step Functions, which allows for more accessible organization and visualization of function interaction.

One area of ongoing development is the application of serverless computing. In our earlier research on serverless computing, we deployed monolithic applications on serverless platforms and examined serverless programming paradigms, including function cascades. The design of scalable chatbots on serverless systems has been discussed in other research. Several initiatives aim to increase the capabilities of current serverless technologies. Developers may now efficiently execute shell commands in AWS Lambda containers and explore the Lambda runtime environment thanks to Lambdash. Thanks to other initiatives like Apex and Sparta, users can now deploy functions to AWS Lambda in languages like Go that are not natively supported.

Many works highlight cost-saving opportunities in deploying microservices to serverless platforms rather than developing traditional applications, supporting serverless computing as a cost-saving solution. The points at which serverless or virtual machine deployments become more cost-effective have been attempted to be calculated by others. According to Gartner, “the value of [serverless computing] has been demonstrated, maps naturally to microservice software architecture, and is on a trajectory of increased growth and adoption”; serverless computing is becoming increasingly significant. According to Forrester, serverless computing results from “today’s PaaS investments” and is the next iteration of cloud service abstractions. Several mobile and Internet of Things apps are powered by serverless computing, rapidly spreading across various cloud providers. Ensuring the fundamental performance characteristics of serverless platforms remain solid is crucial as its scope and popularity grow. By describing the deployment of a new serverless platform with an emphasis on performance and contrasting its results with those of current products, we want to contribute to this endeavor.

Prototype Design

To research serverless implementation considerations and offer a standard against which to compare other platforms, we have created a performance-focused serverless computing platform 1. The platform features a modest feature set and a straightforward architecture. It was developed in .NET

and delivered on Microsoft Azure. The message layer and data durability of the prototype rely on Azure Storage. Our implementation comprises two parts besides Azure Storage services: a worker service that runs and maintains function containers and a web service that makes the platform's public REST API accessible. The web application uses the communications layer of many Azure Storage queues to find available workers. Azure Storage tables are used to store function information, while Azure Storage blobs are used to store function code.

Azure Storage was selected because it offers highly scalable, low-latency storage primitives via an easy-to-use API, which is in line with this implementation's objectives. For brevity, these storage entities will be referred to as queues, tables, and blobs, with the understanding that these terminologies relate to the corresponding Azure Storage services in the context of this research.

Function Metadata

- Across the platform, a function is linked to several things, such as its code, operating containers, metadata, and "warm queue." Four fields form function metadata, which is the source of truth for a function's existence:
 - **Function Identifier:** Function identifiers are randomly generated GUIDs issued during function formation to find and uniquely identify function resources.
 - **Language Runtime:** The language used in a function's code is specified by its language runtime. Just
 - Our language of choice, Node.js, is presently supported on all significant serverless computing platforms, so we selected it.

Memory Size:

The maximum amount of memory a function's container can use is determined by size. Currently, 1 GB is the maximum amount of function memory that may be used. A function's memory size determines how many CPU cores are allotted to its container.

Code Blob URI: When a function is created, a zip archive with the function's code is delivered. The URI of the blob that contains this code is added to the function's metadata. The blob is located within the platform's storage account.

we will discuss function containers and warm queues in more depth below. Warm queues are indexed by function identifier and include the running containers accessible for each function.

Function Execution

Our solution only allows manual invocations and offers a minimal style of function programming. Our study focuses on the execution processing of such systems, for which manual execution assistance is sufficient, even if the processing of event sources and the quality of programming constructs are significant factors in serverless offers.

Calling a `"/invoke"` route from function resources on the REST API is how functions are carried out. The functions get the call request bodies from the invocation as inputs, and the function outputs are contained in the response bodies. The web service initiates execution by receiving the invocation calls and obtaining function metadata from table storage. The function information and inputs are included in an execution request object produced by the web service. Next, the web service looks for an available container in the worker service to execute the execution request.

The shared messaging layer controls how the web and worker services interact. More specifically, every platform function has a global `"warm queue"` and a `"cold queue."` These queues carry messages about available containers, which are just URIs with the name of the accessible container and the address of the worker instance. Visible messages in a function's warm queue indicate that the function's containers are not currently handling execution requests. In contrast, messages in the cold queue suggest that a worker has unallocated memory in which it may start a container.

Initially, the web service attempts to dequeue a message from the warm queue of a function. The web service dequeues a

message from the cold queue, which, when forwarded to the worker service, will allocate a new container to the function if no messages are detected. The cold queue will be empty if every worker has a running container assigned to them. Consequently, the web service will return HTTP 503 Service if it cannot locate an available container in the warm or cold queue. Unavailable because the available resources cannot fulfill the execution request. The cold queue is an excellent target for auto-scaling because it represents the available space throughout the platform.

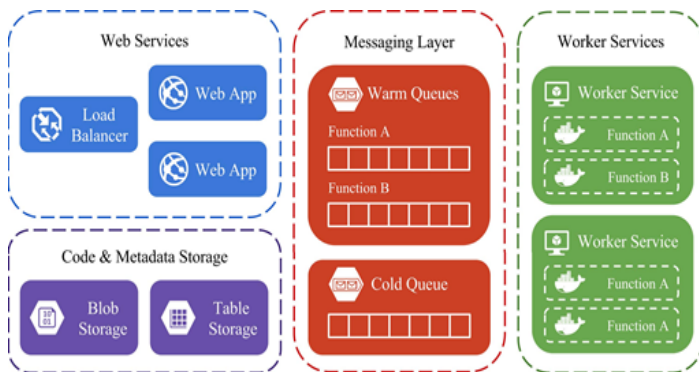


Fig. 1. Overview of prototype components, showing the organization of the web and worker services and code, metadata, and messaging entities in Azure Storage.

After discovering a container allocation message in a queue, the web service uses the message's URI to submit an HTTP request to a worker service. The worker then runs the function and sends its outputs back to the web service, which replies to the call for invocation.

Container Allocation

Every worker has a pool of memory that is not yet allocated, which it may use to allot function containers. A container name, produced when memory is reserved and included in the URI given in container allocation messages, uniquely identifies a container and its memory reservation. As a result, every message in the queues may be individually identified and linked to a particular memory reservation inside a worker

service instance. Worker services presume memory will be used for all functions and is allocated conservatively.

Allocations for containers are not yet allocated to a function when sent to the cold queue. The allocated function is believed to have the maximum function memory size to prevent employees from over-provisioning their memory pool. Then, if the assigned function uses less memory than the maximum size, a worker service reclaims memory upon receiving an execution request for an unassigned allocation. The container allocation message is added to the function's warm queue once the container has been constructed and its function has been used for the first time.

Container Removal

It is possible to delete a container in two ways. First, when a function is removed, the web service also removes its warm queue, which is checked for existence regularly by the worker service instances holding the function's containers. A worker service will eliminate the running containers for a deleted function and recover any memory reservations if it finds evidence of the deleted function queue. Second, our design allows for the removal of a container and the recovery of its memory if it remains idle for a certain amount of time—15 minutes, in our case. If worker services' unused memory surpasses the maximum function memory limit, they will send fresh container allocations to the cold queue whenever memory is reclaimed. Since an expired container might be dequeued from a function's warm queue, container expiration affects the web service. In this instance, the worker service will respond to HTTP 404 Not Found when the web service executes the request. After that, the web service will attempt again after removing the expired message from the queue.

Container Image

The platform runs Windows Nano Server containers with Docker and uses the Docker Engine API to interface with the service. The function runtime (currently limited to Node.js v6.9.5) and an execution handler are included in the container image by design. The lack of any function code in the graphic is noticeable. Instead of creating custom containers for every

platform function, we start the container with a read-only volume that contains the function code. Multiple factors led to the decision to go with a single-image design: managing a single image is more accessible, attaching volumes is a quick process, and Windows Nano Server container images are much bigger than those of lightweight Linux distributions like Alpine Linux, which impacts both startup times and storage expenses. The memory size and CPU percentage of the container are proportionally set based on the memory size of the function, in addition to the read-only volume.

The worker service provides function inputs to the straightforward Node.js server that serves as the container's execution handler. The handler executes the function with the given inputs and returns the function outputs to the worker service after receiving function inputs from the worker service in the request body of an HTTP request. Because containers are added to the default "nat" network—Windows's version of the Linux container "bridge" network—they are addressable on the worker service's local area network (LAN).

Performance Results

We created two tests to gauge the performance of our solution using AWS Lambda, Azure Functions, Google Cloud Functions, and Apache OpenWhisk. To carry out these tests, we created a performance tool that uses the Serverless Framework to distribute a Node.js test function to the various services [28]. We additionally developed a Serverless Framework plugin to allow compatibility with our platform.

This tool uses a simple test function that executes quickly and returns to measure the overhead provided by the platforms. This function is called synchronously via our platform's function invocation route and HTTP events/triggers supported by the different platforms. Since the other services are usually considered development and testing routes, we did not employ manual invocation calls; instead, we felt that a widely used production event or trigger, such as an HTTP endpoint, would more accurately represent current platform performance. Except for Microsoft Azure, which dynamically determines the memory requirements of functions, all systems utilized a 512MB function memory size.

The worker service in the prototype consisted of two DS2 v2 virtual machines running Windows Server 2016, while the web service was an API App in Azure App Service. The prototype was deployed in Microsoft Azure. A single Azure storage account held all platform tables, queues, and blobs.

We conducted our experiments from virtual machines within the same region as our target function, except OpenWhisk, where we measured from Azure's South Central US region and observed single-digit millisecond network latencies to our function endpoint in IBM's US South region. Although our tests did not consider network latencies, we minimized their effects. *Concurrency Test*

The concurrency test, intended to gauge how well serverless systems can efficiently call a function at scale, yields findings in Figure 2. By reissuing each request as soon as the preceding call's answer is received, our tool maintains invocation calls to the test function. In this manner, the test starts with a single invocation call and adds a new concurrent call every 10 seconds for up to 15 simultaneous calls to the test function. The tool counts the number of replies it receives in a second, and when concurrency increases, so should the count. On every platform, this test was run ten times.

The prototype shows almost linear scalability from level 1 to level 14; however, at 15 concurrent requests, performance significantly degrades. Increased latencies from the warm queue, which show that the load is getting close to the scalability limits of a single Azure Storage queue, cause this decline [29]. With 15 simultaneous queries, AWS Lambda has the highest throughput of all the commercial platforms and seems to increase linearly.

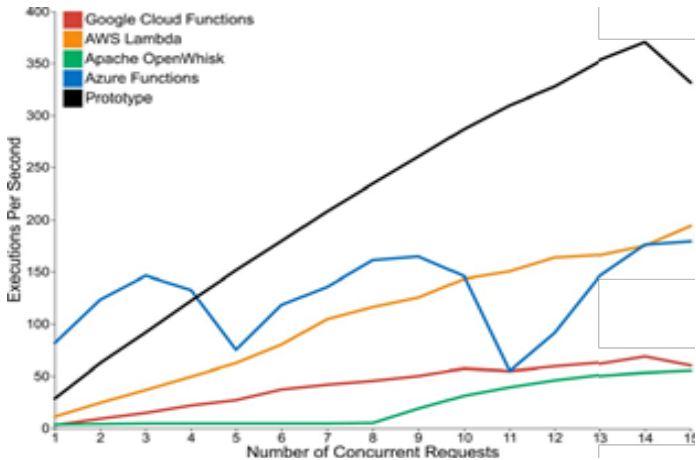


Fig. 2. Concurrency test results, plotting the average number of executions completed per second versus the number of concurrent execution requests to the function.

Sub-linear scaling is seen in Google Cloud Functions, and it seems to taper off when the number of concurrent requests approaches 15. Azure Functions’ performance is inconsistent, even if the recorded throughput is relatively good in some areas and outperforms other platforms at lower concurrent levels. Interestingly, this diversity holds throughout test runs. The peculiar behavior of OpenWhisk’s throughput is evident until eight simultaneous requests, beyond which the function starts to scale sub-linearly. This behavior relies on IBM’s deployment settings, although it might be caused by OpenWhisk’s container pool launching several containers before reusing them.

Figure 3 displays the outcomes of the backoff test, which is intended to investigate function instances’ cold start times and expiry behaviors across the different platforms. For one to thirty minutes, the backoff test sends the test function single execution requests at increasing intervals.

The function containers in the prototype design expire 15 minutes after not being used. This behavior is depicted in Figure 3, and the execution latencies demonstrate

our prototype's cold start performance after 15 minutes. Like our prototype, Azure Functions also has cold start timers and expires function resources after a few minutes. While our prototype and Azure Functions are Windows implementations, it's crucial to remember that their function execution contexts differ significantly since Azure Functions operate in Azure App Service while our prototype utilizes Windows containers. In addition, OpenWhisk offers far shorter cold start times than Azure Functions or our prototype, and it seems to deallocate containers after around ten minutes. Most remarkably, function idling doesn't seem to impact Google Cloud Functions or AWS Lambda. As discussed in the section on Windows containers below, rapid container start times or container preallocation are two possible causes for this phenomenon.

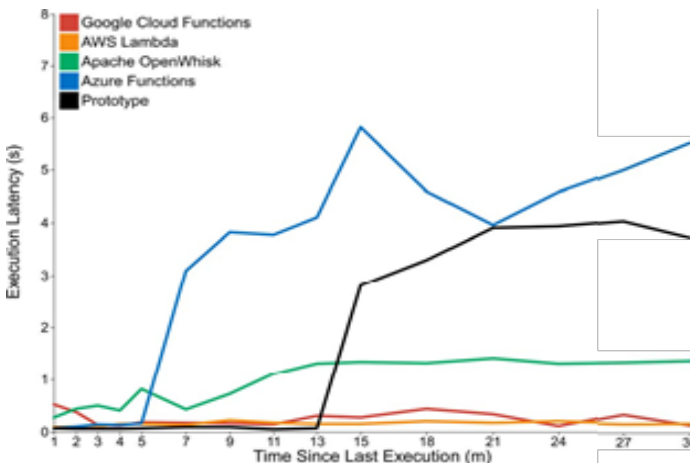


Fig. 3. Backoff test results, plotting the average execution latency of the function versus the time since the function's previous execution.

Limitations And Future Work

Warm Queues

The warm queue is a FIFO queue, so container expiry is an issue. Envision a scenario where a function experiencing high demand is assigned to ten containers for execution. Gradually,

the load is reduced to the point where a single container can manage every function execution. The extra nine containers should ideally expire soon. Still, due to the FIFO queue, all of the containers will be assigned to the function as long as there are ten executions of the function for each container expiration period. The workaround is, of course, to use “warm stacks” rather than “warm queues,” however, LIFO queues are not supported by Azure Storage at this time. This is perhaps the biggest problem with our present setup, although a consistent hashing solution or alternative warm stack storage choices show promise.

Asynchronous Executions

As of right now, the prototype can only handle synchronous calls. Put another way, a request to run a function will return the outcome of that execution rather than just starting and stopping it. Supporting asynchronous executions is straightforward; all that has to be done is for the web service to reply to the invocation call and proceed with processing the execution request as usual. Ensuring at least one execution, as opposed to best-effort execution, is the challenge with asynchronous execution. It’s critical to realize that execution, whether synchronous or asynchronous, is only assured when an invocation request receives a successful status code back. Since a successful status code is only provided after execution, no additional work is required for synchronous execution requests (like in our implementation). Nevertheless, extra logic is needed to guarantee the practical completion of asynchronous executions as they react to clients before executing functions. By keeping track of ongoing executions in a series of queues and adding a third service to oversee the condition of these queue messages, we think the prototype can fulfill this need. When a function is being executed, worker services would continuously update message visibility delays, and the monitoring service would look for visible messages to identify problems. Then, unsuccessful messages could be sent again. Remember that this is about handling platform execution problems rather than exceptions that the function throws while it is being executed, for which you would also want to retry.

Worker Utilization

The warm queue is a FIFO queue, so container expiry is an issue. Envision a scenario where a function experiencing high demand is assigned to ten containers for execution. Gradually, the load is reduced to the point where a single container can manage every function execution. The extra nine containers should ideally expire soon. Still, due to the FIFO queue, all of the containers will be assigned to the function as long as there are ten executions of the function for each container expiration period. The workaround is, of course, to use “warm stacks” rather than “warm queues,” however, LIFO queues are not supported by Azure Storage at this time. This is perhaps the biggest problem with our present setup, although a consistent hashing solution or alternative warm stack storage choices show promise.

Windows Containers

Compared to Linux containers, Windows containers are somewhat more limited. This is mainly because Linux containers were designed to work around Linux cgroups, which provide helpful functions that Windows does not allow. The ability to enable container resource updates and stopping is particularly noteworthy in serverless computing. Implementations of serverless platforms frequently pause containers while inactive to avoid consuming resources and unpause them before execution restarts.

Updating container resources is an additional procedure that may be helpful. It would help cold start performance if we could start containers before they are allocated to a function and then resize the container after an execution request is received. This is because we reserve resources for containers before executions begin. Subsequent research endeavors may examine methods for facilitating these semantics within Windows containers, maybe through resource limitation or updating to the function process alone instead of the container whole. Alternatively, the prototype might compare start-up times and assess the feasibility of container resizing during cold starts by testing Linux containers.

Security

Serverless system security is another unanswered research topic. It is risky to host arbitrary user code in function containers on multi-tenant systems; hence, caution must be exercised while building and utilizing function containers to

Stop weak points. A major practical test of universal container security is this point where container security and remote procedure calls (RPC) meet. Therefore, further research is required to evaluate the attack surface inside function execution contexts, even though serverless platforms can carefully design the function containers and restrict function permissions arbitrarily, increasing the likelihood of secure execution.

Performance Measures

Defining performance metrics and tests for serverless platforms can improve our understanding of their performance. Although the platforms' overhead during single-function execution was the main focus of this work, better management of network latencies and timing considerations should enhance the accuracy of these evaluations. Further research is necessary to understand other elements of platform performance, such as latency changes across language runtimes and function code size, serverless platform system-wide performance, performance variations between event kinds, and CPU allocation scaling.

Conclusion

Powerful, event-driven integrations with several cloud services, straightforward deployment, and programming paradigms, and fine-grained pricing and scale control are all provided by serverless computing. These advantages have led to an increase in the use of serverless applications, which calls for assessing the quality of serverless platforms and creating new methods to realize the promise of the technology. The performance outcomes of our platform are promising, and our examination of the current setup offers several chances for further research and development. We anticipate seeing more academics interested in serverless computing and more

industry executives willing to discuss the broader benefits of serverless technology.

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Smart Campus Energy Management System: Advantages, Architectures, and the Impact of Using Cloud Computing

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A microgrid is a kind of intelligent grid fueled by renewable energy sources. It may function as a standalone electrical or linked system to and from the primary grid. An academic microgrid will address several energy-use issues since universities are significant electricity consumers [1]. The purpose of this work is to discuss the components of microgrids, with a focus on energy management (EMS). In light of its essential function, the study provides several EMS designs and discusses how integrating cloud computing into the Microgrid architecture might increase EMS efficiency. The outcomes of the EMS data collecting utilizing the Kaa IoT platform are presented in the paper's conclusion.

Keywords: Microgrid, Agent, Cloud Computing, Energy Management System, Internet of Things.

Introduction

Given the significance of the electrical grid and the rise in the amount of power used, numerous studies have been conducted.

Aimed at enhancing the electrical system as it is. A smart grid is a pioneering project integrating several information and communication technologies (ICT) elements to monitor and regulate energy generation, transmission, and distribution. It is a cyber-physical system designed to enhance the present power infrastructure. One of the new features of smart grids is using microgrids.

Microgrids are energy systems that operate in linked or islanded modes to and from the primary power grid. They allow the deployment of energy generators at low voltage distribution. The smart grid's goal of supplying electricity using distributed energy resources that are renewable is another innovative feature (DER). Customers may actively participate in the energy generation by installing these DERs at their location. For example, a house is not automatically a microgrid because DER is implemented there. A client must install enough DER to be self-sufficient and run their microgrid independently of the electricity grid under certain circumstances.

An intelligent campus or university campus that uses several DERs is an example of a microgrid. The new Microgrid requires an Energy Management System (EMS) schedule management program to control the DERs so that the intelligent campus can utilize energy effectively since DER power cannot be guaranteed continually [2]. EMS capabilities include economic dispatch algorithms, monitoring, metering, control, protection, stability, and power quality analysis. These features are implemented at various levels depending on the microgrid's timing needs.

It has been suggested that cloud computing may be used to create intelligent grid EMS services. Nevertheless, not much research has been done on how cloud computing affects the implementation of various EMS services. This work aims to analyze the need for a cloud-based EMS on microgrids empirically. The study focuses on

using the Kaa platform to construct its architecture and researching the effects of latency on various cloud-based EMS operations.

Microgrid And Energy Management Systems

What Kind Of Relation?

According to the Consortium for Electric Reliability Technology Solutions (CERTS), a microgrid is a self-sufficient electrical system that can smoothly join and disengage from the primary grid without interfering with its loads. The

microgrid's processor, the Energy Management System (EMS), coordinates the loads, DGs, and DESs to create a dependable, affordable, sustainable, and ecologically friendly energy self-productive system.

Advanced IT Infrastructure: This comprises a system of sensors, meters, and software that gathers and analyzes data in real time so that the user can make choices. For example, the user may switch off the air conditioner when a sensor in the home detects no movement.

A Microgrid and an EMS have a mutually beneficial relationship. This essential computer software will ensure that the Microgrid has the following features: it will schedule generators using forecasting, adjust voltage, meet demand, provide a seamless transition between connected and islanded modes from/to the primary grid, minimize emissions, and maximize Microgrid utilization efficiently[6].

The Architecture of Energy Management Systems: A ANALYZE

The existing electrical system, plagued by several issues, including frequent blackouts that may result in enormous damage, will be entirely transformed by microgrids. For example, the district power supply was harmed by the terrible 9.0 magnitude earthquake that struck Japan in 2011. The Sendai Microgrid managed to provide electricity to hospitals and residents of nursing homes for three days in a row despite the deplorable conditions in the city[7].

Distributed Generators (DSs): These units provide power to microgrids. To continue operating sustainably, a microgrid requires an energy management system to oversee its operations. This system will synchronize the functions of the generators, storage, controls, and coupling points that make up the microgrid. Figure 2 shows an overall example architecture.

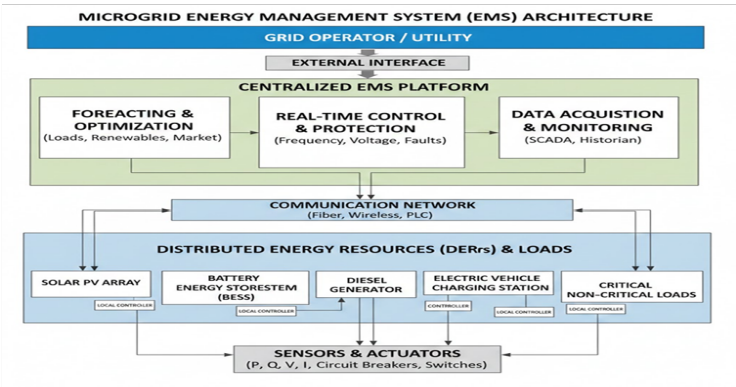


Figure 2: Overall Architecture of a Microgrid Energy Management System (EMS)

- To illustrate how an EMS functions, generators like wind turbines and solar panels are positioned close to the end consumers. To optimize advantages, combined heat and power plants will form the core of the microgrid.
- Distributed electricity Storage (DES): When the primary grid produces electricity at a low cost or when the DSs create an excessive amount of energy, a storage device, such as batteries, is required. The stored energy can be utilized during blackouts and peak periods.
- Controllable Loads: These electrical appliances, like electric cars, can modify how much power they use during peak hours.

Point of Common Coupling (PPC): a hub for electricity production, transmission, and customer-primary utility interface. The EMS is a microgrid processing unit that aggregates forecast data from external sources, analyzes historical and forecast data, optimizes electricity supply and demand, and provides users with interfaces to view, monitor, and control production and consumption. The microgrid will gather real-time data to track its operational condition and respond to system disruptions. MCC will also compile data from various microgrid local controllers connected to distributed energy resources and storage and control loads to make essential choices.

An EMS may oversee and operate the system in either a centralized or decentralized mode[5] to meet the main goals of the microgrid (provide electricity, engage in the energy market, manage critical load, etc.); this can be done by using a hierarchical structure, as shown in figure 3:

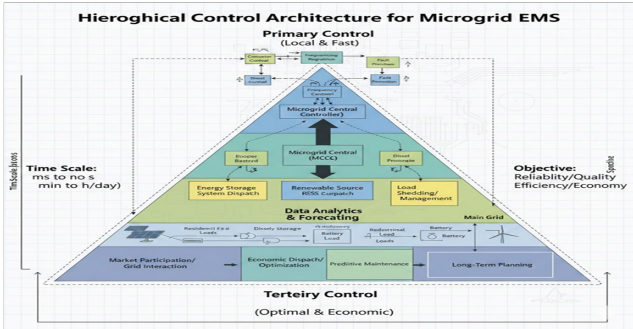


Figure 3: Hierarchical control architecture of a microgrid Energy Management System (EMS)

The components of this three-level hierarchical structure are:

- **Distributed Network Operator (DNO) and Market Operator (MO):** The DNO acts as a management aggregator for instructions and real-time data given by various Microgrids and the primary grid in an area composed of a network of Microgrids. A Microgrid and an electrical market in a particular region will exchange data via the MO system.
- **Microgrid Central Controller (MCC):** a coordinator of local controllers and an interface between DNO/MO and the controllers inside a microgrid.
- **Local Controllers (LCs):** These devices monitor and manage distributed energy supplies and controllable loads like water heaters, depending on whether a centralized or distributed strategy is used.

An Energy Management System should ideally function as a component of the Microgrid Central Controller. To participate in the energy market and communicate vital information like power availability, the latter has a two-

way communication channel with the DNO and MO. MCC will be important Depending on the strategy used; local controllers may display various functions and control types: in a decentralized approach, an LC will make choices locally, while in a centralized approach, an LC will obey directives from an MCC. For example, when the price of electricity on the market rises, the market operator will send information to the MCC, which will use an optimization algorithm to tell distributed energy resources to begin serving, allowing DER local controllers to make decisions in a decentralized manner.

A Microgrid operating in a centralized manner has to be a resilient system that can handle real-time data coming from various DERs, DES, and loads at scheduled intervals [5]. The information flow between MCC and LCs is shown in Figure 4, with two communication infrastructures serving as the means of information sharing. The load LC will transmit a request for demand, and the DER LC will communicate the power production level based on market pricing and DER production level. Using an optimization technique, MCC will utilize this data to tell DER to begin production, show the load distribution, and provide the market rates for the next time slot.

One of the numerous benefits of a centralized method is its simplicity of implementation. However, more information is transferred when more devices are used, which might cause a bottleneck in the processing and communication channels.

A decentralized or distributed strategy, in contrast to the centralized paradigm, seeks to increase the autonomy of the Microgrid DER and LC components. Intelligent controllers capable of making choices independently without receiving instructions from the Microgrid Central are used to accomplish this purpose.

In charge. To improve the operation of the Microgrid and maximize the production of the appropriate units, LCs will also be able to interact with one another and build an intelligent LC network. The Microgrid requires a system of several entities working together to accomplish this aim. The agent-based model is a crucial contender for distributed

control modes and an environment where agents can function regardless of location: grid and microgrid levels. This is because the agent-based approach is designed to divide a main problem into smaller ones and address each more minor problem separately.

One unique feature of using a multi-agent EMS control system over other distributed paradigms is that each agent can anticipate the future move and affect the neighbors of different agents. Agent Communication Language (ACL) allows agents to communicate with one another by exchanging values (e.g., power production level) and by carrying out orders and actions in the next time slot. It will be necessary to convey less information when local neighbors exchange information than when using a centralized strategy. Additionally, the MCC calculations will be performed at the agent level, reducing the strain on the network. It is important to note that an MCC may still be essential under a decentralized model, primarily by taking over an LC in case of a control failure.

Notwithstanding its benefits, such as being modular and flexible in a plug-and-play setting, the decentralized method has some security flows that may be hard to fix due to the architecture's nature. In addition, the information exchange between an EMS and local agents occurs across the communication channel in power systems. This infrastructure must be constructed appropriately to enable nearby agents to communicate information. This is a costly process. The internal Microgrid decentralized EMS control layered architecture is shown in Figure.

Cloud Computing And Energy Management Challenges: What Added Value.

Using a distributed design, the smart grid will provide dependable, economical, and efficient power management to end users. Given that the system is a heterogeneous data source, it is essential to use cutting-edge solutions to prevent technological issues and accomplish this aim, enabling users to access intelligent grid apps anywhere. Cloud computing, an emerging new approach, is an excellent model candidate since it is designed to provide on-demand access to computer resources that can efficiently handle large amounts of data.

Innovative grid applications may benefit from some of the top features and services cloud computing offers. The following categories apply to the primary services:

- Infrastructure as a service (IaaS) refers to an infrastructure that offers consumers scalable resources that may be changed on demand. Such resources include servers, load balancers, virtual machines, storage, and networks.
- Platform as a service (PaaS): A cloud computing service that, often via a web service interface, relieves the user of installing the hardware and software components required to create and execute new applications. Databases, web servers, and programming tools are all included in this service.
- Software as a service (SaaS): a business model where all programs are hosted and made available to users upon request. The primary benefit of using this service is that it removes the need to install and operate software on personal servers, saving money on licensing, installation, hardware installation, maintenance, and support.

Several additional features, including load balancing, dynamic pricing, home energy management systems, and building energy management systems, were introduced to address specific management concerns, given the significance of energy management in smart grids. However, other issues with the existing system might be resolved by using cloud computing technologies to guarantee dependable, economical real-time energy management:

- A Microgrid is a system comprising a dynamic number of sensors delivering massive volumes of data that must be evaluated quickly to fulfill a real-time demand or supply. This is why a scalable platform is necessary. Cloud computing infrastructure is perfect for dynamic and computationally massive data applications requiring scalable resources because of its dynamic elasticity, resource pooling (which will prevent restrictions during peak time), and on-demand self-service (which will allow customers to keep track of energy usage and pricing) features.

- There is a requirement for speedy demand response; thus, offer a new architecture called Cloud-Based Demand Response (CDR), which alters the! Utility-customer representation into utility-smart architecture via controller/agent architecture Home Energy Management System meters. CDR will result in a secure, scalable, dependable demand response through publisher/subscriber, topic-based group, and data-centric communication.

- Intelligent demand management is needed. A system capable of periodically forecasting demand will be created, enabling intelligent demand management to avoid peak time burden[10] through a software-as-a-service cloud-based platform, supporting heterogeneous devices from different layers in the smart grid and dynamic demand response.

- Dynamic Bandwidth Allocation (DBA) is required because peak hours, when demand is high and customers are supplied based on priorities and available resources, are among the issues with the conventional electrical system. Blackouts happen when supply is insufficient to meet demand. A cloud computing scheduling approach that demonstrated the relationship between distributors and customers was presented by X. Li and J. Chung Lo in [16]. The price and peak aware scheduling (PPAS) algorithm is based on dynamic pricing and the dynamic assignment of a peak threshold to prevent energy use above limits throughout the day. The suggested algorithm trials' outcomes demonstrated the energy distributor's and cloud computers' effective energy management.

- To achieve an early warning system and a practical, on-demand, scalable power monitoring service, [17] suggests a monitoring system for intelligent grid users that uses an advanced cloud services solution based on service-oriented architecture and enterprise service bus.

- A requirement to meet customers' energy requirements: By integrating external energy sources and storage devices with internal ones through virtualization in cloud computing applications, it is possible to build an

energy exchange mechanism between various Microgrids and satisfy customers' demands as outlined in the framework.

- a dependable and expandable data analytics platform is necessary to gather, classify (structured, semi-structured, and unstructured), store, model, and forecast solutions for Microgrid customers. An EMS analyzes massive data from several sources, including sensors and weather-predicting agencies. It uses machine learning methods that may be used in an academic microgrid to adjust to users' needs (faculty, staff, and students) and maximize system performance.

The current intelligent grid architecture's master-slave architecture, controlled utility demand response, and bandwidth limitations are just a few of its issues. Numerous research studies have shown that cloud computing applications benefit intelligent grid energy management.

Kaa Cloud-oriented EMS Design

When developing an ideal Campus Microgrid EMS platform, the following research challenges should be carefully considered: how much it will cost to implement the platform, how customizable the services can be, how scalable it is for other campuses, and finally, how well the platform performs in terms of delay[20].

We conduct studies to measure the reaction time for delay-sensitive intelligent grid applications using Kaa, a free and open-source cloud-based IoT platform. The

This platform was selected based on several capabilities listed in [22]. In short, it is a fully functional cloud-based middleware platform for the Internet of Things that can be deployed as a single node, cluster node, or sandbox. Initially, we used the architecture shown in Figure 6 and considered Kaa a single Linux node. Nevertheless, we chose Kaa Sandbox, a ready-made solution that includes every Kaa component in a simulated setting.

Conclusion

Scientists from several fields of study have shown interest in the large field of intelligent grid research. To comprehend the smart grid from a computer science viewpoint, it is essential to consider the study of wireless sensors, the Internet of Things, cloud computing, and big data analytics. This paper's primary goal is to demonstrate the value of an energy management system (EMS) in microgrids and how cloud computing may enhance EMS performance. We measured the delay for some grid delay-sensitive applications using an IoT platform hosted in the Kaa cloud. Our next effort will be to install a genuine IoT test bed with the Kaa platform as a cluster of Linux nodes.

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Smart E-Learning System Architecture Based on Cloud Computing

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With the emergence of new technologies, corporations, and academic institutions are attempting to keep pace with the progress in Information and Communication Technologies and to simplify the approach to managing or improving their IT resources. Cloud Computing presents an alternate method to attain these goals within budget. A lot of colleges and universities all around the globe are embracing cloud infrastructure to minimize IT operating costs and enhance the efficacy and convenience of educational services. Cloud computing may play an essential role in the education industry by offering ubiquitous access (anytime, anywhere, irrespective of the device) to learning content. This technique gives a new way to design and manage IT resources effectively by enhancing the user's productivity and hardware utilization and cutting infrastructure costs via virtualization. This research proposes an intelligent e-learning system based on a cloud platform for delivering and sharing e-learning content. The authors also examine the characteristics of the intelligent E-Learning system over the conventional system and suggest the design of an innovative e-learning system for educational institutions.

Keywords: Smart E-learning system, Smart Education, Virtualization, Cloud Computing.

Introduction

Cloud computing is vital in information technology, with its potential advantages in providing flexibility, accessibility, scalability, high performance, dependability, and cost

reduction. As a consequence, firms all over the globe are adopting cloud computing to manage and develop their operations while cutting IT-related operational expenses. Cloud computing has received much interest in education to provide better educational services within a constrained IT budget. As we know, the number of schools and educational institutions is expanding; embracing cloud computing would enable institutions to minimize their IT expenditures and help them deliver effective and easy educational services. Several learning management systems, such as Moodle, Blackboard, etc. Moreover, it enables cloud-based educational services. (Jyoti Bora & Ahmed, 2013).

Problems Statement

Education, like sleeping and eating, has been vital to human existence. It has been generated for generations and continues to do so in our current state. Technology has consequently modified many new items and how they digest knowledge. As you can see, digital tools are increasingly replacing conventional instructional techniques such as computers, audio, visual, and computers. (Siddiqui et al., 2019).

In developed countries, traditional teaching methods are utilized in educational organizations. In the conventional teaching style, the lecturers explain every idea to the students using the blackboard and chalk. Therefore, every vital issue is printed on the blackboard so students may have written notes. By the way, pupils in traditional instruction aim to pass the tests exclusively. (Al-Rousan et al., 2020).

In conventional education, the classroom settings are lecture-centered, wherein the lecturer frequently speaks to the students instead of encouraging them to ask questions, engage, and help the students learn the lesson properly. Most classrooms entail regular learning; most students rely on remembering things without comprehensive knowledge of the contents to pass the tests. Long dictations and lectures at the school frequently leave the student with less interest and attention. In a regular class, time constraints inhibit the pupils from collaborating. Also, it leads to skipping courses and missing lectures. Furthermore, conventional classes cannot

communicate with their professors and classmates outside the class contact hours(Riahi, 2015).

Weak focus on critical thinking: Conventional teaching techniques are weak in encouraging pupils to think critically and use the abilities learned via reasoning and experience. Traditional teaching approaches lack student-oriented learning, which is the function of a lecturer as a facilitator. This learning style does not give pupils higher levels of comprehension required for lifetime learning and complicated ideas.(El Mhouti et al., 2019).

In poor process-oriented learning, old methods concentrate on passing tests, regardless of whether students underanalyze subjects. The learning process is undervalued, and students are not encouraged to grasp the approaches, skills, and strategies required to discover answers. Constructivist learning believes the process is as significant as the outcome because it stimulates essential skills long after education. Advances in technology and internationalization are robust education systems for evolution to create a flexible education environment that provides learners. (Selviandro & Hasibuan, 2013).

The quality function spans formal, nonformal, and formal education. From this point, there is a complete approach to integrating IT into education, better learning in the present and future, and ensuring the students and instructors effectively use the latest technologies, such as the learning management system. Joining the quality of the information from traditional methods with practical learning and using learning Management system tools in lectures time holds promise as the progressive standard that becomes a wide range of learning skills and will contract the attention of all students from the digital generation and fast-paced.(Romero & Ventura, 2010).

Literature Review

Nowadays, cloud computing is the primary key to innovation in the computer sector. It depends on a network, so it is essentially on the Internet. This ensures that users are supplied with simple usage of computer resources on demand. Cloud

computing has high scalability and establishes virtualized resources that can be provided to consumers. Therefore, cloud computing is a remarkable technology that has a meaningful influence on the learning environment and teaching [2].

Additionally, cloud computing is defined as an on-demand supply of computing power, apps, IT resources, and database storage via cloud services platforms via the internet with the pay-as-you-go price (Amazon,2017). Cloud computing has three basic types: Private, Public, and Hybrid cloud.

A private cloud implies that the firm handles all applications and cloud resources, comparable to intranet functionality. The private cloud supplier delivers scalable resources and virtual applications, which cloud customers can utilize and share. In addition, it is more secure owing to set internal exposure. Only the designee and firm may access the operation in the private cloud.

The Public Cloud is where resources are constantly offered in fine-grained, self-services over the Internet via web services or web applications by third-party offers that share resources and charge the user according to their utilization. On the other hand, the public cloud is less secure than the private cloud owing to the extra weight of ensuring that each application and data accessible in the public cloud are protected from harmful assaults.

Hybrid Cloud is a blend of private and public clouds. It delivers the scalability and cost efficiency of the public Cloud coupled with the performance and security of the private Cloud. Firms do not need to update their fundamental IT architecture [3].

The provided below comparison illustrates the advantages of cloud computing over conventional computing.

Traditional E-Learning to Smart E-Learning Traditional e-learning involves internet-based learning. Using E-Learning via the Internet enhances the efficiency of educational services as it offers many advantages, such as variety, flexibility, openness, control, and more. Figure 2 depicts the architecture of a simple E-Learning system.

Figure 2: Architecture of a basic E-Learning system [2]

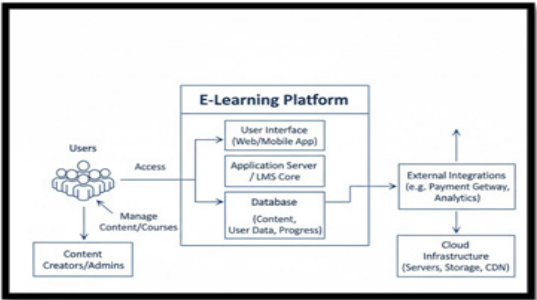


Figure 2: Architecture of a basic E-Learning system

Proposed System

The suggested system offers a technique to provide and exchange educational content using an intelligent e-learning system employing a private cloud. The suggested system leverages the private cloud environment to control cloud services entirely on the institution’s premises. As noted before, it may minimize IT expenditures and boost the scalability, flexibility, availability, and security of the intelligent e-learning system. It permits institutions to develop and distribute multiple formats of learning materials that are accessible on their learning management system over the cloud platform. (Mihye Kim,2013). Figure

3 illustrates the Smart E-Learning System Architecture.

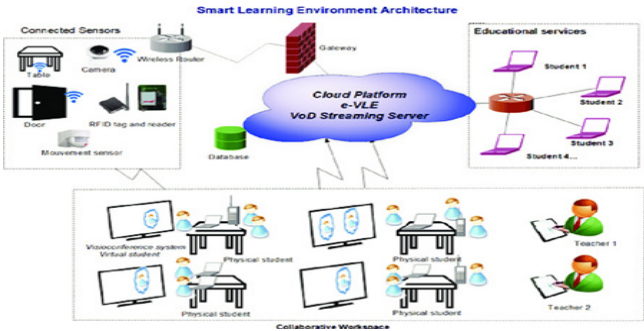


Figure 3: Smart E-Learning System Architecture

Features of the suggested system

The suggested system includes the advantages of the private cloud: it provides superior educational services by integrating with current IT technologies: virtualization, data synchronization, multi-sharing, and services provisioning. Moreover, particular software and applications are required to deliver better educational service in academic institutions employing private cloud and may utilize multiple cloud computing service models (SaaS et al.).

Implementing a private cloud allows educational institutions to benefit from cloud security to the utmost degree, securing their IT resources by only providing access to legitimate users. Automation in the cloud allows for the recovery of a failing node without disrupting the cloud's operation.

System. The suggested innovative e-learning system delivers security, availability, robustness, data preservation, and dependability.

Cloud Computing Architecture

The Smart E-learning System is not replacing lectures; it enables lecturers to exploit the progress in technology, tools, and ideas and upload new material, models, and techniques for teaching. Hence, the lecturer's roles are challenging to replace. The lecturer will still be the leader of duties and, at the same time, will mark and develop the bright e-learning system cloud. The learning approach must produce an educational act. Furthermore, the virtual cooperation and engaging material ensure a high retention factor. On the other hand, an intelligent learning cloud is the immigration of cloud computing technology in the scope of e-learning; it is the future of intelligent e-learning infrastructure, consisting of all essential software and hardware resources engaged in e-learning. After virtualizing computer resources, they provide a service for education organizations, companies, and students to rent computing resources.

Figure 4: Smart E-learning Cloud Architecture [2]

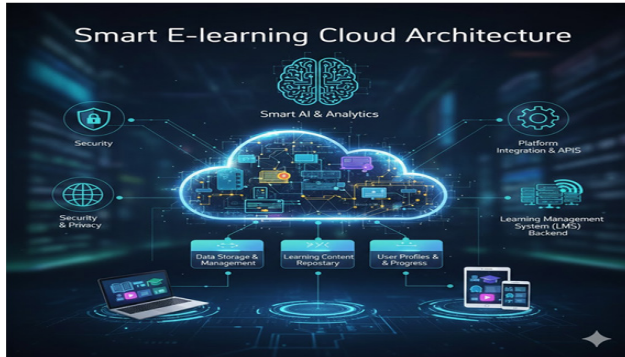


Figure 4: Smart E-learning Cloud Architecture

The architecture of intelligent e-learning utilizing the cloud consists of five layers:

- An infrastructure layer that offers a dynamic and scalable pool of physical resources
- Software layer that gives a user-friendly interface to the learner.
- Resources management layer that is responsible for managing hardware and software resources.
- Service layer that delivers software, platform, or infrastructure as a service.
- Application layer.

Infrastructure: The layer is gathered between instructional materials and information infrastructure; it comprises an intranet/Internet, information management system, system software, and specific standard hardware and software. Teaching resources are classic teaching paradigms provided in numerous departments and domains. This layer is positioned in the lowest level of the cloud service middleware, the primary processing power like physical memory and CPU. By employing virtualization technology, storage, physical server, and network, create a virtualization group to deliver named by the higher software platform. The physical host

pool is dynamic and scalable; a new physical host enables cloud middleware services to boost physical computing capacity.

Middleware and the operating system integrate the software resource layer. Via middleware technology, the selection of software resources is integrated to provide a uniform interface to the software designer; therefore, it is simple to construct many applications based on software resources and embed them in the cloud, and they are accessible to cloud computing users.

The Resource management layer is crucial for ensuring loose coupling of hardware and software resources by integrating cloud computing and virtualization scheduling techniques.

The server layer contains three services: (Software as a service, Platform as a service, and Infrastructure as a service). In SaaS, cloud computing services are supplied solely to consumers. As it differs from conventional software, users can use it online without buying hardware or programs. Moreover, there is no need for upgrading and maintenance; you can pay a monthly price.

The application layer is the definitive application of integrating teaching resources in cloud computing architecture, which is comprised of sharing teaching materials and interactive courses. Sharing teaching resources comprises material resources of education, information resources, for instance, information centers, digital

Libraries and complete exchange of human resources. This layer includes education goals, content development, evaluation and management components, and content distribution technology.

Expected Benefits of the Proposed Architecture

The targeted advantages envisaged from the proposed brilliant learning architecture are:

Expected Benefits of the Proposed Architecture

The targeted advantages envisaged from the proposed brilliant learning architecture are:

High Security: The private cloud can manage the resources more effectively, balance the load, and enable network administrators to regulate user data security and monitor real-time resources.

Virtualization: It enables the institutions to:

- Reduce power usage and data center space
- Increase hardware usage
- Lower upfront expenses, including license fees
- Simplify application and desktop lifecycle management
- Lower operational costs for both maintenance and training

High Availability: One key advantage of cloud computing is automation, which provides a high-quality service. In case of any failure node, the cloud system may automatically identify and remove/replace it, therefore not impacting the functioning of the cloud.

Ubiquitous Access: Users can access the system anywhere, anytime, and from any device.

Students may collaborate using the suggested innovative e-learning system. The proposed system may play a vital role in fully leveraging the institutions' current IT resources and improving the quality of the learning and teaching process.

Conclusion

Innovative E-Learning optimizes the efficiency and quality of the teaching and learning process. An innovative e-learning system gives an alternative answer to institutions attempting to keep pace with improving information and communication technologies and simplifying the techniques used to manage or enhance their IT resources. It minimizes IT operating expenses and offers more affordable, secure, and trustworthy education services. The study article analyzed the conventional e-learning system and presented an intelligent e-learning system based on a cloud platform for delivering and sharing e-learning materials. The authors reviewed the characteristics of the intelligent E-Learning system over the conventional

system and recommended designing an innovative learning system for educational institutions.

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Sustainable development in cloud computing: An analysis

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This research study aims to investigate how cloud computing may support sustainable development. Emerging as a game-changer, cloud computing (cloud computing) can lessen enterprises' and organizations' environmental footprint while promoting social and economic advancement. The advantages of cloud computing for the environment are examined in this research, including improved energy efficiency, lower carbon emissions, and the possibility of integrating renewable energy sources. It also looks at the financial and societal advantages of cloud computing, such as lower costs, more output, and easier cloud computing to technology. In its conclusion, the article highlights the benefits and possible problems of using cloud computing for sustainable development and proposes essential topics for further study and policymaking. The paper's overall thesis is that further research and legislative action must fulfill cloud computing's promise of aiding sustainable development.

Introduction

Using a cloud computing concept, users may rapidly and easily cloud computing these services without maintaining the underlying infrastructure. Infrastructure services, which include renting virtualized computing resources like servers, storage, and networks from the provider, are one of the several service types that cloud computing providers often provide. Platform services provide users with cloud computing, a platform to create, test, and implement their requests. Software services include the supplier's internet-based delivery of software programs to customers. Users do not need to maintain or invest in their physical infrastructure since they can quickly scale their computer capacity up or

down. As a result, firms may react to shifting opportunities and needs more quickly and affordably. Cloud computing makes increased collaboration and distant work capabilities possible. Furthermore, since cloud computing sources store data in several places and routinely maintain backups, they naturally provide high security and dependability. Besides the advantages mentioned earlier, cloud computing facilitates optimal resource usage by enabling different users to share identical computer resources, decreasing waste and enhancing efficiency. Additionally, this democratizes cloud computing to technology by allowing smaller businesses to use the same computer capacity as bigger ones. Because of the elimination of the need for significant upfront infrastructure expenditures, it is now more affordable for companies of all sizes.

Another benefit is that the ease of cloud computing enables disaster recovery and data backup. The risk of records destruction is reduced since providers usually provide many backup solutions and distribute data across several places. Data can be swiftly recovered from backups in a catastrophe or outage, reducing downtime and guaranteeing company continuity. However, there are a few possible disadvantages to cloud computing. Security is a worry as information in the cloud might be subject to hacker attacks or data breaches. Furthermore, depending only on one supplier might result in the vendor.

Lock-in, in which transferring data and apps would be expensive and complicated, making it challenging to move providers. It is expected to grow and change in the following years, becoming an essential component of contemporary technology.

Cloud Computing's Sustainable Development

Sustainable development is crucial because it guarantees that resources are utilized in a manner that is socially, ecologically, and economically responsible. Companies may reduce the need for on-site data centers, which have the potential to be very energy-intensive and carbon-emitting. Furthermore, cloud computing may aid sustainable development by

facilitating distant work and collaboration. Another benefit of cloud-based collaboration solutions is reducing paper waste and other resource usage. Please see below for further information on how cloud computing may support sustainable development.

- **energy efficiency:** Because cloud data centers may use economies of scale to optimize their energy consumption, they are generally more energy-efficient than on-premises data centers.

- **resource sharing:** Cloud computing lowers the required hardware by allowing several users to share resources. This may lessen the quantity of e-waste produced and the carbon emissions brought on by the manufacture and disposal of hardware.

- **Scalability:** Scalability may aid in waste reduction and resource optimization. Businesses in the retail or hospitality sectors, for example, with varying computing requirements, may find this very helpful (Oke, 2021).

- **business continuity and disaster recovery:** Cloud computing can make it easier and more affordable for companies to develop business continuity and catastrophe recovery strategies. By keeping data and apps on the cloud, businesses may ensure they have cloud computing for vital resources even in the case of a catastrophe.

- **green certifications:** Many cloud service companies have certificates from independent agencies attesting to their environmental sustainability. These certifications may assist companies in locating cloud service providers that share their commitment to resource responsibility and environmental sustainability.

- **Data center efficiency:** Cloud providers are constantly innovating and enhancing their data center efficiency through programs like modular data center architecture, cutting-edge cooling technologies, and energy-efficient hardware.

- **big data analytics:** Cloud computing helps companies identify resource and sustainable consumption

optimization opportunities. Big data analytics may enhance supply chain efficiency and find possibilities for buildings to save energy and waste.

As a result, cloud computing offers several advantages for sustainable growth, such as big data analytics, virtualization, efficiency, and green certifications. Industries and organizations may use these advantages to create a more ecological future.

various multinational groups' perspectives on sustainable cloud computing

The UN states that cloud computing may support sustainable development in several ways.

- **energy efficiency:** Cloud computing may dramatically cut energy usage and greenhouse gas emissions compared to conventional on-premise data centers. Cloud service companies may maximize energy consumption and boost infrastructure efficiency using economies of scale (Nara et al., 2021).
- **Less hardware waste:** Businesses may use cloud computing to reduce the physical hardware they need to manage their IT infrastructure. This may significantly lessen e-waste, benefiting the environment (Oke, 2021).
- **Better cloud computing for technology:** By offering a more flexible and economical means of obtaining computer resources, cloud computing may contribute to better cloud computing for technology in poor nations (Yu & Chiou, 2022).
- **Distanced work:** During the COVID-19 outbreak, cloud computing facilitated distance work. This may lessen the need for commuting and the transportation sector's carbon emissions (Issa et al., 2010a).
- **Sustainable business practices:** Cloud computing may help firms implement more sustainable business practices by promoting cooperation and communication, reducing paper waste, and maximizing resource use (ion & Gheorghe, 2014).

indian government on the sustainable growth of cloud computing

Additionally, the Indian government has launched campaigns to encourage the sustainable use of cloud computing. According to Ciocan and Ivascu (2014) and Dogo et al. (2019), India has recognized cloud computing as a critical technology for achieving its sustainability objectives, including lowering carbon emissions and fostering resource efficiency. These are a few programs and directives that the Indian government has introduced.

- **The National Cloud Initiative:** Established in 2013, the National Cloud Initiative seeks to advance the creation of a national cloud infrastructure for businesses in both the public and commercial sectors. The program promotes adopting energy-efficient technology and creating green cloud services, emphasizing sustainability and energy efficiency (Nowicki, 2014).

- **The India Smart Cities mission:** Established in 2015, the mission seeks to advance sustainable urban development in India. One objective is to use technology, especially cloud computing, to increase productivity and lessen the city's environmental effects (Alam, 2022).

- **The National Green Roadways Mission:** Established in 2015, this mission seeks to promote environmentally friendly construction along Indian roadways. The goal of the mission is to use technology, particularly cloud computing, to enhance productivity and lessen the environmental effect of transportation infrastructure (wang, 2022).

The Indian government has taken action to encourage the use of cloud computing in a sustainable and energy-efficient way after realizing its potential to support sustainable development (Zhu & Li, 2021).

the relevance of environmentally friendly growth in cloud computing

Sustainability may be very helpful in enhancing resource efficiency and concurrently lowering environmental impact

in cloud computing (qi, 2021). Here are a few ways that cloud computing may include sustainability.

- **energy efficiency:** Cloud computing providers may employ energy-efficient practices and technologies like dynamic resource allocation and server virtualization to lower energy use and carbon emissions. Compared to conventional IT infrastructure, cloud computing may be more energy-efficient by combining computing resources into data centers and maximizing their utilization (Amendola et al., 2023).

- **decreased resource consumption:** Cloud computing may lessen the loss of tangible resources like hardware, software, and office space by using shared resources and minimizing overprovisioning. This may result in significant financial savings and environmental advantages (Goswami, 2022).

- **Scalability and flexibility:** Cloud computing may assist businesses in reducing waste and needless resource use (Oke, 2021).

- **Telecommuting and remote work:** Cloud computing can facilitate these practices, which will lessen the need for employees to go to work and thus cut down on carbon emissions associated with transportation (Dogo et al., 2019; Goswami, 2020).

Cloud computing may support sustainable development by enhancing resource efficiency, lowering environmental effects, and promoting sustainable corporate practices. By using cloud computing sustainably, organizations may contribute to a more ecological future and lessen their environmental impact.

goals for this project

These are a few potential goals for the current study on sustainable cloud computing.

- to evaluate cloud computing's effects on the environment and its capacity to advance sustainable development.

- to assess cloud computing's energy and resource efficiency and contribution to decreasing resource consumption and carbon emissions.
- to list the obstacles and difficulties in sustainably implementing cloud computing and provide ways to get beyond them.
- to investigate the possibilities for cloud computing providers' pricing and business structures to promote waste reduction and resource efficiency.
- to examine how cloud computing may help eco-friendly activities like telecommuting, remote work, and online meetings.
- to assess how cloud computing affects data security and privacy and suggest ways to improve those aspects.
- investigate how cloud computing may help people and organizations collaborate and share information to promote sustainability and creativity.
- to bring out a framework for evaluating the viability of cloud computing solutions and assisting businesses in using cloud computing in an environmentally friendly way.

Therefore, the particular research questions and study goals would determine the objectives of a research paper on the sustainable development of cloud computing. Nonetheless, the goals mentioned earlier might serve as a basis for creating a research proposal and defining the study's parameters.

Cloud computing's sustainable sources

Concerns about cloud computing's environmental effect have grown in importance as its usage keeps expanding. Cloud computing has a large carbon footprint because it needs much energy to run and cool the servers that handle and store data. In order to tackle this issue, cloud service providers have been looking for sustainable cloud computing sources that may lower their energy use and encourage sustainability. Furthermore, server consolidation, energy management systems, virtualization, energy-efficient hardware, and server

consolidation may all contribute to lowering energy use and increasing efficacy (li et al., 2012). In addition, cloud providers may use sustainable measures like carbon offsetting to offset their carbon emissions and video conferencing in place of travel. In light of this, it is critical to comprehend the origins of sustainable cloud computing and how to use them best to advance sustainability within the sector. Sustainable cloud computing comes from a variety of sources.

- **renewable energy sources:** Cloud companies may draw energy from geothermal, hydro, wind, or solar to power their data centers. This may support sustainability by lowering their carbon footprint (wang, 2022).
- **energy-efficient hardware:** To reduce energy consumption and increase efficacy, cloud providers may use energy-efficient networking gear, storage systems, and servers (Dougherty et al., 2012; Zhu & li, 2021).
- **energy management systems:** These systems assist cloud providers in tracking and controlling their energy use, which helps them find opportunities for energy conservation and waste reduction (li et al., 2022; Popović, 2020).
- **sustainable practices:** Cloud providers may use energy-efficient equipment, encourage consumers to embrace sustainable behaviors, and use video conferencing in place of travel (Jia & wu, 2022; Nara et al., 2021).

Energy-efficient technology, renewable energy sources, virtualization, server consolidation, energy management systems, sustainable behaviors, and carbon offsetting are all necessary to promote sustainable cloud computing. Cloud providers may lessen their environmental effects and encourage sustainability using these measures.

Possible dangers associated with sustainable cloud computing

Although environmentally friendly cloud computing has a lot to offer and may help save energy use, there are certain risks involved as well. Among these dangers are a few of them.

- **reliance on renewable energy sources:** Should there be a deficiency or disruption in the supply of renewable energy, it may impact cloud service performance and availability (zhu & li, 2021; Dougherty et al., 2012).

- **Data security and privacy:** As cloud providers adopt more environmentally friendly procedures, including server consolidation, there may be a higher chance of cyberattacks or data breaches. Because data is consolidated onto fewer servers, more data might be exposed in a single breach (Lee & Zomaya, 2012).

- **Environmental dangers:** Despite the perception that renewable energy sources are better for the environment, there are some environmental risks associated with them. For instance, hydroelectric electricity may impact fish populations, while wind turbines may harm birds and bats (Chandra et al., 2023).

- **greenwashing:** While claiming sustainability, certain cloud service companies may not follow sustainable practices. This may mislead customers, eroding their confidence in sustainable cloud computing (Markovic et al., 2013).

- **Depletion of natural resources:** Although renewable energy sources are more environmentally friendly than non-renewable ones, they still need natural resources like minerals, water, and land. Depletion and environmental harm may result from the overuse of these resources (Amendola et al., 2023; Harmony et al., 2022).

- **ethical issues:** Certain renewable energy sources, like hydroelectric electricity, may have unethical or detrimental effects on society. Large-scale hydropower projects, for instance, have the potential to affect indigenous rights and force populations to relocate (zhu & li, 2021).

- **Effect on local economies:** The move towards sustainable cloud computing may particularly affect communities that depend on conventional energy sources. For instance, a decline in the market for coal may affect communities that mine coal (Park et al., 2023).

- **cost and complexity:** Implementing sustainable cloud computing strategies may be expensive and time-consuming. Certain cloud providers may find it prohibitive to make the significant investments necessary in new infrastructure, technology, and training (Baliga, 2010).

While sustainable cloud computing has many advantages, it has some possible risks. By tackling these issues, the cloud computing sector may minimize adverse environmental and societal effects while promoting sustainability.

A step-by-step guide to help reduce cloud computing risk

There are ways to support sustainable cloud computing, which may help save expenses, minimize energy use, and lessen the environmental effects of carbon emissions (Dougherty et al., 2012; Zhu & Li, 2021). Energy-efficient hardware adoption, virtualization, and server consolidation, the use of renewable energy sources, the implementation of energy management systems, carbon offsetting, the promotion of sustainable practices, the adoption of a circular economy approach, stakeholder collaboration, and research and development expenditures are some of the strategies to mitigate the risk associated with carbon capture (Berl et al., 2010). Cloud providers may lessen their environmental effects, encourage sustainability, and help create a more sustainable future using these solutions. This is a methodical approach to encourage sustainable cloud computing.

- **Perform an energy audit:** Assessing your data center's energy needs is the first step in encouraging sustainable cloud computing. This may assist in determining the regions where energy-saving objectives should be established (Oliveira et al., 2014).
- **Use energy-efficient hardware:** It is critical to select hardware that runs efficiently and with minimal energy consumption (Lee & Zomaya, 2012; Baliga, 2010).
- **Use renewable energy sources:** Cloud companies may power their data centers with energy from geothermal, hydro, solar, and wind sources. This may decrease carbon emissions and enhance sustainability (Dougherty et al., 2012; Zhu and Li, 202).

- **Use energy management systems:** These tools may minimize energy waste and improve energy use. They can monitor energy use, spot inefficiencies, and automate energy-saving measures (Park et al., 2023; Jing et al., 2013).

- **Encourage sustainable activities:** Cloud service providers should encourage sustainable habits, such as telecommuting, reducing paper use, and using video conferencing rather than travel (Zhu & Li, 2021).

Collecting and disclosing sustainability data is essential to maintaining openness with consumers and tracking progress toward sustainability objectives (Goswami, 2022).

- **constantly enhance sustainability practices:** Sustainable cloud computing calls for ongoing development and adaptation to new methods and technology. Cloud computing According to Zhu and Li (2021), cloud providers must periodically assess their sustainability protocols and seek methods to enhance efficacy and mitigate ecological consequences.

- **create a sustainability plan:** A thorough sustainability strategy may help direct environmentally friendly company actions and guarantee that they align with organizational objectives. The plan should include objectives, measurements, and deadlines to cut carbon emissions and advance sustainability (Lee & zomaya, 2012; Baek et al., 2014).

- **encourage clients to embrace eco-friendly practices:** Cloud service providers may maintain energy-efficient offerings, encourage remote work and virtual meetings, and offer incentives for eco-friendly conduct (popović, 2020).

- **Implement a circular economy:** This strategy calls for resource recovery, reuse, and recycling, in addition to waste reduction. Cloud providers may adopt a circular economy strategy by using sustainable materials, recycling or repurposing hardware, and reducing waste (Oliveira et al., 2014).

- **work with stakeholders:** Working with suppliers, customers, and governmental organizations may promote sustainable cloud computing practices. A cloud computing ring to Bag and Pretorius (2022) might include exchanging best practices, working together on sustainability projects, and lobbying for legislative reforms that support sustainability.

- **make research and development investments:** By creating new, more cost-effective, sustainable, and energy-efficient technologies and practices, R&D promotes sustainable cloud computing (baek et al., 2014).

To promote sustainable cloud computing, an all-encompassing strategy that incorporates carbon offsetting, renewable energy sources, energy efficiency, and sustainable activities is needed.

Sustainability's contribution to the promotion of sustainable cloud computing

Sustainability is essential for promoting sustainable cloud computing (Yu et al., 2022). Here are a few ways that cloud computing may become more sustainable.

cutting down on energy use

One of the most important aspects of encouraging sustainable cloud computing is lowering energy use. These are a few strategies for encouraging energy efficiency in cloud computing.

- **make use energy-efficient hardware:** To reduce energy use, cloud providers may choose hardware that satisfies Energy Star requirements and energy efficiency rating (eer) (Bag & Pretorius, 2022; Berl et al., 2010).

- **Implement energy management systems (ems).** These may help data centers use energy more efficiently. To reduce energy use, these systems may improve cooling systems, regulate and automate power distribution, and monitor energy use (Lee & Zomaya, 2012).

- **Use intelligent workload management:** This entails dynamically distributing computer resources using cloud

computing to the workload of each program. Optimizing the use of resources may assist lower energy use (Walter Busch et al., 2015; Chou & Chou, 2011).

- **Use renewable energy sources:** Cloud companies may power data centers with energy from hydro, solar, wind, and geothermal sources. This may help enhance sustainability and cut carbon emissions dramatically (Bressanelli et al., 2022; Valentini et al., 2013).

Promoting sustainable cloud computing requires reducing energy usage (Bag & Pretorius, 2022). Cloud providers can drastically reduce energy usage and encourage sustainability by utilizing energy-efficient hardware, virtualization and server consolidation, energy management systems, free cooling methods, intelligent workload management, renewable energy sources, and power monitoring.

Making Research And Development Investments

Research and development expenditures may be used to find novel and creative strategies to lessen the environmental effect of

Cloud computing. According to Walter-Busch et al. (2015), computing may include creating new technologies, increasing productivity, and streamlining data center operations. Research and development for sustainable carbon capture must be funded to progress in sustainability. Several tactics to encourage these investments include.

- investments from the private sector may be made in startups and other growing businesses creating sustainable cloud computing solutions or directed to internal research and development teams (Bag & Pretorius, 2022).

- **Collaborative research:** To find fresh approaches to sustainable cloud computing and encourage joint research initiatives with business, academia, and other stakeholders. This may include establishing collaborations on research, holding seminars and conferences, and encouraging the exchange of information across various industries (Bayramusta & Nasir, 2016; Valentini et al., 2013).

- **Innovation incentives:** Offer rewards for creative solutions in sustainable cloud computing. Promoting innovation may include setting up award and recognition programs or providing financial incentives to businesses that create new sustainable technology (Hamdaqa & Tahsildar, 2012).
- **open-source software development:** encourage the creation of open-source software programs for environmentally friendly

Cloud computing. This may include starting new initiatives or contributing to existing ones to create sustainable cloud computing technologies (hamdaqa & tahvildari, 2012).

putting green construction principles into practice

The environmental effect of cloud computing may be considerably decreased by using green construction techniques, such as creating energy-efficient data centers, employing sustainable building materials, and implementing green infrastructure. Since data centers consume a lot of energy, green construction methods are essential for sustainable cloud computing (hamdaqa & tahvildari, 2012). These are a few tactics for putting green construction principles into reality for sustainable cloud computing.

- **energy-efficient design:** To reduce energy usage, use techniques such as passive cooling, optimizing the building's orientation, and building envelope technologies that lower the requirement for cooling (Valentini et al., 2013; Di Salvo et al., 2017).
- **efficient cooling systems:** To maximize cooling systems, use liquid cooling or air-side economizers, high-efficiency HVAC systems, or hot and cold aisle confinement techniques (Park et al., 2023; Baek et al., 2014).
- **efficient power use:** Energy-efficient lighting and intelligent building technologies manage and minimize energy consumption in areas not in use or low demand (Hamdaqa & Tahsildar, 2012).

- **sustainable materials:** When constructing a structure, use sustainable materials, such as recycled or low-carbon materials (park et al., 2023; Bayramusta & Nasir, 2016).
- **green landscaping:** Include low-maintenance native plants in your design, and take advantage of the natural cooling properties of your surroundings (bayramusta & Nasir, 2016; Park et al., 2023).
- **Frequent reporting and monitoring:** Inform stakeholders on the transition status to sustainable building techniques and regularly evaluate water and energy use (Park et al., 2023).

Implementing green construction techniques for sustainable cloud computing requires dedication to the environment and a readiness to invest in sustainable solutions (basmadjian, 2019). These techniques may help achieve sustainable cloud computing by lowering energy use and minimizing the adverse effects of data centers on the environment.

Training both staff and clients

This may include educating staff members about sustainable processes, encouraging sustainable conduct, and informing clients about the company's sustainability objectives and programs. Promoting sustainable cloud computing requires educating staff and clients (Hamdaqa & Tahsildar, 2012; Bressanelli et al., 2022). These are some methods for efficiently teaching staff and clients about sustainable cloud computing.

- **Internal training initiatives:** Provide staff with internal training to raise awareness and encourage sustainable practices. This might include educating people about energy-efficient computing techniques, supporting the purchase of environmentally friendly IT equipment, and motivating staff members to adopt eco-friendly habits (Ferrer et al., 2012; di salvo et al., 2017).
- **Educating customers:** This might include offering advice on using energy-efficient computing techniques, reducing energy use, and choosing cloud service providers that prioritize sustainability (Ferrer et al., 2012).

- **Encourage sustainable behavior:** By encouraging the use of teleconferencing in place of travel, cutting down on paper use, recycling, and energy consumption, you may encourage staff members and clients to embrace sustainable behavior (Duan. 2020; di salvo et al., 2017; Baek et al., 2014).

- **Work together:** Develop cooperative educational initiatives and materials that support sustainable practices and collaborate with partners in the cloud computing sector (Zhu & Li, 2021).

- **Track and report progress:** Track and update stakeholders on your progress toward sustainable cloud computing objectives. This might include implementing sustainable practices, tracking energy usage, and cutting greenhouse gas emissions (Bharany et al., 2022).

Teaching staff members and clients about sustainable cloud computing can foster a culture of sustainability and more environmentally conscious and efficient cloud computing practices.

Consequences

There are several real-world consequences of sustainable cloud computing that people, companies, and society at large should think about. The following are some applications for sustainable cloud computing.

- **cost savings:** Organizations may see cost reductions as a consequence of sustainable cloud computing. Energy consumption and operating expenses may be decreased using energy-efficient procedures, adequate hardware, and maximized server usage. These savings might be used to finance sustainability projects or research and development.

- **reputation:** Sustainable cloud computing may improve an organization's reputation by showcasing its dedication to sustainability and social responsibility. Businesses that embrace sustainable practices may make a lasting impression on customers and investors looking for environmentally conscientious enterprises to do business with.

- **compliance:** Sustainable cloud computing may assist businesses in adhering to environmental rules and guidelines. As environmental requirements become more rigorous, businesses must implement sustainable practices to avoid fines, penalties, and other legal problems.

- **innovation:** Sustainable cloud computing may stimulate innovation by encouraging actions that lessen their adverse environmental effects. This invention may result in lower expenses, more efficiency, and new business prospects.

- **Cooperation:** To ensure sustainable climate change, stakeholders from the public and business sectors, as well as people and NGOs, must collaborate. By cooperating, stakeholders may advance sustainability projects and create best practices.

- **education:** To implement sustainable cloud computing, staff and clients must be aware of sustainable practices. Organizations may foster a culture of sustainability to encourage sustainable habits and lessen their environmental impact. Customers may be encouraged to adopt sustainable behaviors by being educated on sustainable practices, which will help create a more sustainable future.

- **research and development:** Research and development expenditures are necessary for sustainable carbon capture. Over time, this investment may result in more breakthroughs, productivity, and lower expenses.

By considering these practical consequences, organizations and people may implement sustainable practices that lessen the environmental effect of carbon capture and promote sustainability. They can save expenses, improve their standing, adhere to rules, foster innovation, encourage teamwork and learning, and help build a more sustainable future.

Restrictions

Cloud computing has limitations for sustainable development despite its numerous benefits. These are a few illustrations of some of the challenges of implementing sustainable development.

- **restricted scope:** A study on sustainable cloud computing could only cover a small portion of sustainability or a small subset of cloud computing technology. This may limit how far the study's conclusions can be applied and prevent a thorough grasp of sustainable cloud computing.

- **bias and confounding issues:** Studies focusing on sustainable cloud computing may be influenced by bias and confounding factors, such as the influence of funding sources or the impact of outside variables not considered during research design. This may reduce the validity and reliability of the study's conclusions.

By reviewing these limits in a research article, researchers may gain a more thorough grasp of the difficulties and constraints of sustainable cloud computing research. Furthermore, recognizing these constraints may support advancing more reliable and consistent approaches for researching the environmental effects of carbon capture (cloud computing) and direct future research in sustainable cloud computing.

Prospective range

The following are some of the many areas where we might focus our efforts in the future on sustainable growth in cloud computing.

- **adopting the tenets of the circular economy:** to reduce waste and advance sustainability, the circular economy places a strong emphasis on resource reuse, refurbishing, and recycling. Subsequent investigations may use circular economy concepts in cloud computing, such as repurposing outdated servers and other hardware elements.

- **education and awareness:** An essential part of sustainable cloud computing is educating staff members and clients about environmentally friendly behaviors. Future research may concentrate on creating and executing efficient education and awareness campaigns to encourage sustainable habits and practices.

By describing these future possibilities in a study paper, researchers may be able to identify potential areas of focus for

future studies in sustainable cloud computing. These future scopes may also help firms implement sustainable cloud computing practices by encouraging sustainability across the industry.

In summary

To build a more sustainable future, sustainable cloud computing is crucial. In the modern digital age, cloud computing is becoming more common, and its environmental effects are irreversible. Thus, sustainable methods must be promoted to reduce cloud computing's detrimental environmental effects. Using energy-efficient architecture, renewable energy, cooling system optimization, sustainable material use, water conservation, and green landscaping are some tactics to attain sustainable cloud computing. Achieving sustainable cloud computing may also be significantly aided by investing in research and development, working with stakeholders, training staff and clients, and integrating sustainability into corporate strategy. It provides several advantages, including less energy use, cheaper expenses, increased efficiency, and better reputation. Additionally, it makes it possible for businesses to achieve their sustainability objectives, abide by rules, and carry out their social obligations. Therefore, businesses must embrace the above-discussed methods to achieve sustainable cloud computing. Moreover, people and organizations must practice sustainable cloud computing. By selecting cloud providers that value sustainability, cutting down on energy use, and using energy-efficient equipment, individuals may contribute to promoting sustainable cloud computing. This may help lessen cloud computing's overall adverse environmental effects. It is important to remember that the topic of sustainable cloud computing is developing fast, with new methods and technology regularly appearing. As a result, both people and businesses need to stay current on emerging trends and consistently innovate and enhance their sustainability practices. Ultimately, cooperation between all parties involved—government agencies, non-governmental groups, the commercial sector, and individuals—is needed to achieve sustainable cloud computing. Together, we can build a more robust and sustainable future where cloud computing

can keep its vital role in advancing the digital economy and raising living standards.

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Task Scheduling in Cloud Computing: Review

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Abstract

Task scheduling plays a crucial role in cloud computer networks. Task scheduling is governed by several guidelines and agreements that we may refer to as a contract between cloud service providers and consumers rather than a single set of criteria. This agreement represents the level of service quality that the user expects from the providers. Delivering high-quality services to consumers by the deal is crucial since providers simultaneously manage several other responsibilities.

Finding or exploring the best mapping or assignment of a collection of subtasks of various tasks across the available set of resources (processors/computer machines) to accomplish the intended objectives for functions may be seen as a task scheduling issue. In this work, we conduct a comparative analysis of several algorithms to determine their applicability, practicality, and adaptability in a cloud situation. We then attempt to suggest a hybrid strategy that may be used to improve the current platform further and enable cloud providers to provide higher-quality services.

Keywords: GA, PSO, Task Scheduling, Scheduling Types, Cloud Computing, Cloud Architecture

Overview

Although there isn't a precise definition for the term "cloud," we may use many approaches and methods to describe it. Cloud computing is a supercomputing method linked to the Internet. It is a shared infrastructure that only uses

distributed computing, virtualization, and other techniques to join the massive system pools. Users may upload data and access processing power using their computers. The cloud computing environment over the Internet provides them with a range of networking, storage, and computing resources (Kaur & Verma, 2012).

“Cloud is a parallel and distributed computing system that consists of a collection of interconnected and virtualized computers that are provisioned dynamically and presented as one or more unified computing resources based on service-level agreement (SLA) established through negotiation between the cloud service providers and users,” according to R. Buyya’s definition of the term (Kaur & Verma, 2012).

Cloud computing is a distributed computing architecture that operates on a vast scale and is dependent on the economic size of an abstract, virtualized, dynamic cloud operator. Its primary function is managing storage, processing power, and other platforms and services.

They are given on demand over the Internet to outside consumers. Cloud computing is a rapidly developing computational paradigm that aims to relieve cloud users of the maintenance of hardware, software, networks, and data resources and assign these responsibilities to cloud service providers (Gu et al., 2012).

Numerous resources are available via clouds, such as computing platforms, data centers, storage, networks, firewalls, and software in the form of services. Additionally, it offers methods for controlling these resources so that cloud users may use them without experiencing any performance-related issues.

Based on the amount of abstraction and the service model used by the providers, cloud computing services are classified into three classes: (1) Infrastructure as a Service,

Software as a Service, Platform as a Service, and (3) Both.

The three fundamental components of cloud computing are virtualization, elasticity, and distribution. Virtualization is one of the critical components of the cloud. The majority of

hardware and software support virtualization. Numerous components, including operating systems, storage, software, and hardware, may be virtualized and managed on cloud platforms.

Related Work

One of the task scheduling issues that has been researched in the past is the NP-hard [3] problem. Due to scheduling's NP-hardness, it is mainly controlled by various well-known heuristic approaches that only partially solve problem cases. A heuristic algorithm guarantees an approximation of the optimum solution finding in a time less than that of a polynomial. To find a route within the specified solution space, it disregards and eliminates any other choices that look reasonable. The following categories also apply to heuristic-based algorithms: 1. Organizing within groups 2. using lists for scheduling.

Clustering techniques [5, 6, 7] assume that many processors are available to do the job for the subtasks. They utilize as many processors as feasible to shorten the creates schedules' makespan since they believe many processors are available for work.

The list scheduling class includes the majority of heuristics. There are two stages to the list scheduling algorithm's searching process: in the first, each subtask is assigned a priority based on a set of criteria, and after establishing.

When a job reaches a lower priority, it is added to the list of tasks that must wait for its turn. In the second phase, the highest priority subtask is chosen from the list and given to the most appropriate processor when the various processors become available to handle new tasks. Therefore, using additional greedy heuristics, the search is constrained to smaller areas of the solution space, improving the makespan. Its inability to provide consistent outcomes for diverse computer systems is a downside.

Meta-heuristics-based algorithms use a combinatorics procedure and these heuristic-based methods to locate the answer. These algorithms have shown optimal performance

across many scheduling problems. However, they need an adequate sample of solutions inside the specified search space. It has proven possible to use Particle Swarm Optimization [8], Simulated Annealing [9], Genetic Algorithms [10], and Ant Colony Optimization [11] for a variety of scheduling issues efficiently and successfully. The main disadvantage of these algorithms over heuristic-based ones is that they are less effective and have more considerable computing costs.

The Cloud Architecture

The front and back end are the two most important parts of cloud computing's architecture. The portion of the cloud users can see is called the front end. This covers the software and hardware users use to reach the cloud. All that remains of cloud computing's back end is the cloud itself, mostly made up of computers and storage devices.

A cloud environment consists of software programs that may be accessed online and used as services whenever needed. Cloud-based applications are designed so that the underlying computing infrastructure is only used when necessary, drawing resources only when requested, carrying out specific tasks, then giving up unnecessary resources and frequently disposing of them once the task is finished. The applications dynamically scale up or down in response to resource requirements while they are in use.

Cloud architectures tackle significant challenges primarily associated with handling massive volumes of data. In

When using a conventional data processing method, acquiring the number of computers required for an application to run well might be challenging. Obtaining machines when one wants them is one of the hardest things to do. It is difficult to distribute and coordinate a large-scale job over many computers, run processes on them, and set up a backup system if one fails during the operation. Additionally, it is difficult to scale up and down in response to shifting workloads automatically. Getting rid of all that equipment is not easy when the work is done.

Applications developed using cloud architectures operate in the cloud, where cloud providers choose where the

infrastructure is physically located. They profit from the straightforward APIs of web-based services that may grow on demand. In contrast, the intricate logic behind their dependability and scalability is executed and concealed within the massive cloud.

Figure 2. Cloud Service Layers

IaaS, or infrastructure as a service, is the lowest tier of cloud computing systems. It essentially offers virtualized resources, such as storage, communication, and processing power, that are accessible whenever needed. PaaS facilitates simple cloud programmability. One word for the software delivery paradigm is SaaS.

Synopsis: Work Scheduling

Cloud computing comprises many resources that vary in a few ways. Because cloud computing services depend on these resources, scheduling tasks in the cloud differs from traditional scheduling methods because cloud computing tasks are more expensive to complete using cloud computing resources.

To increase the adaptability and dependability of cloud systems, task scheduling is essential. The primary motivation for allocating tasks to the resources in compliance with the time limit is determining the most efficient and comprehensive order in which different activities may be completed to provide the user with the most optimal and gratifying outcome. On cloud

Computers and resources (such as networks, firewalls, and cups) are always dynamically assigned according to the order and specifications of the job and its subtasks. Work scheduling in the cloud becomes a dynamic challenge, meaning no previously established sequence may be helpful when processing the work. The unpredictable task flow motivates the dynamic scheduling approach, leading to uncertain execution routes. Additionally, several tasks sharing resources concurrently create uncertainty about available resources.

Task scheduling in the cloud refers to selecting the most appropriate resource for the job at hand or allocating computers to projects in a way that minimizes the amount of time needed to complete them. In scheduling algorithms, a list of tasks is generated by assigning a priority to each job individually. The parameters used to determine the priority of each work might vary. Then, based on their priority, tasks are selected and allocated to processors and computers that meet predetermined target functions as they become available [12].

Scheduling Categories

Static scheduling: This method arranges work in a predetermined context, meaning it already knows about the task structure, resource mapping before execution, and task execution/running time estimations.

When making scheduling decisions, dynamic scheduling must consider the status of computer systems and the tasks submitted to the cloud environment.

Cloud computing leverages virtualization techniques to execute user tasks and map cloud resources to the virtual machine layer. As a result, task scheduling in the cloud computing environment is accomplished at both the applications and virtual resource layers. Scheduling entails mapping activities and resources per specific rules to achieve a particular objective. The cloud computing paradigm makes it easier to connect tasks to resources. Since the necessary resources are all virtual machines (VMs), finding the right resource package is as easy as looking through the different VMs.

Analyzation Of Current Work Scheduling Algorithms

Cost-Time Optimization Algorithm based on Budget Distribution and Deadline [13]

This method considered two limitations: money and the job completion date. This study introduced the (DBD-CTO) scheduling method to plan jobs in a cloud computing environment. This method completes jobs ahead of schedule to meet its objective while minimizing computing costs incurred during operation.

Enhanced job scheduling in cloud computing environments using a cost-based algorithm[14]

The paper's author suggested the method known as the enhanced cost-based scheduling algorithm. His work's primary goal is to arrange tasks on cloud computing platforms with resources that vary in computation speed and cost. When jobs are grouped, communication between jobs and resources maximizes the computation/communication ratio. The computing performance and resource cost were assessed using this algorithm. Combining several tasks during execution also enhanced the ratio of task execution to data transmission across tasks. Combining tasks is often done after evaluating the processing and capabilities of various available resources. The simulation was run using CloudSim, and its inputs were the tasks' average MI, the tasks' granularity size, the total number of tasks, and the task overhead time. The outcome of his study demonstrates that, for this specific method, the time required to finish tasks after grouping is much shorter than the time needed to complete tasks without grouping.

A PSO-based Heuristic for Cloud Computing Environment Workflow Application Scheduling [15]

The study introduces us to an approach based on particle swarm optimization. Here, the cost of calculation and data transfer are considered while scheduling jobs. The author's primary goal is to reduce the overall cost of running the apps on cloud service providers' resources. The work completed for this article is split into two sections: 1. creation of a task-resource mapping model to reduce execution costs overall. 2. creating a heuristic based on the model above that solves task-resource mappings using PSO. The suggested method considers telecommunication costs for Every job, considering the different connections among them. In light of this, the PSO-based algorithm outperformed the "Best Resource Selection" (BRS) method in terms of cost savings, saving three times as much money and achieving a better workload allocation across resources. By increasing the particle size and resource quantity, the algorithms suggested in this study may be used for a wide range of jobs.

Particle Swarm Optimization for Multi-Objective Task Assignment in Cloud Computing [16]

The author of this article schedules jobs here to lower the overall cost of transferring and executing and the overall time required for transmitting and executing. The task scheduling issue in this work is allocating all task data to all resources in a cloud computing environment to minimize overall processing and communication costs. Task scheduling may be the mapping that associates each task with a Directed Acyclic Graph (DAG) $G(V, E)$. Every node has a weight, which primarily indicates how much data needs to be processed by a job on a particular node. The weights assigned to each edge indicate how much information is transferred from one activity that has to be handled to another. This algorithm's goal is not the only one; it also considers the cost, time, and expense of processing and sending data. The experiment's outcome demonstrates how effectively this algorithm reduces all costs and times in a cloud computing environment.

Particle Swarm Optimization Workflow Scheduling Algorithm for Cloud (BPSO): A Bi-Criteria Priority Approach [17]

This article presents a method for allocating workflow tasks to cloud resources to minimize execution time and cost within the specified deadline and budget. The workflow activities in BPSO are carried out according to their priority, determined by utilizing the bottom level, which is the same as what is specified in HEFT [20]. The PSO is then initialized using the provided priority. Following the priority assignment, the tasks are arranged in decreasing order of importance.

Degree. Afterward, the tasks are sent to various processors according to how they should be completed to finish the workflow application. The author created Java simulation software with a data center that included six resources with varying processing speeds for the experiment. The results of the experiment indicate that this method performs comparably to PSO.

Genetic algorithm-based scheduling of independent jobs [18]

The author of this work presents GA in task scheduling to accommodate memory limitations and demands for high performance in cloud environments. The author assumed several things about the tasks: 1. Tasks come in waves. 2. Work is not preemptive. 3. There are two methods for a process unit to access a task: shared and exclusive. The central scheduling technique is also assumed in this study [21, 22]. The method created in this research takes time consumption and resource use into account synthetically, yielding satisfactory results.

Task Scheduling Using Genetic Simulated Annealing Algorithm [19]

The study created an algorithm while considering the benefits of both genetic algorithms and simulated annealing. The algorithm considered the QOS needs of various job types based on the kinds of tasks users do in the cloud. QOS is only a measure of how satisfied customers are with the services. This study argues that since the parameters have multiple orders of magnitude and different dimensions, it is necessary to treat the parameters dimensionless when evaluating how activities are implemented in cloud resources. Various weights of factors might be assigned based on the kind of task to identify resources that meet the requirements and the quality of the work. The algorithm initially executes the GA steps, and then annealing occurs, enhancing the GA's local search capability. This method effectively concludes the cloud computing resource search and allocation procedure.

Future Scope

Since task scheduling is one of the most well-known issues in cloud computing, there is always a possibility that work in this specific area that has already been accomplished may be modified. The researchers carried out their work by their area of expertise, and eventually, other individuals completed their jobs. They had considered several approaches and applied limitations when scheduling, but they could not capture every aspect simultaneously because cloud computing is so large. However, they did note that there is a possibility that

algorithms will change and that part of the system may need to be modified.

Conclusion

Task scheduling remains a fundamental and challenging problem in cloud computing due to the heterogeneous, dynamic, and large-scale nature of cloud resources. This review has examined various scheduling strategies, ranging from traditional heuristic and list-based approaches to advanced meta-heuristic techniques such as Genetic Algorithms, Particle Swarm Optimization, Simulated Annealing, and their hybrids. The analysis shows that while heuristic methods offer lower computational overhead and faster decision-making, they often lack adaptability and optimality in diverse cloud environments. In contrast, meta-heuristic and hybrid algorithms demonstrate superior performance in optimizing key objectives such as execution time, cost, resource utilization, and Quality of Service, albeit at the expense of higher computational complexity. Therefore, no single scheduling algorithm is universally optimal for all cloud scenarios. Future task scheduling solutions should focus on hybrid, adaptive, and multi-objective approaches that can dynamically respond to changing workloads, resource availability, and user constraints, enabling cloud service providers to deliver more efficient, reliable, and cost-effective services.

The Application of Cloud Computing in Education Informatization

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Abstract

This essay mainly focuses on research on the application of cloud computing to education information. Firstly, traditional computer technologies, including virtualization, network storage technology, distributed computing, parallel computing technology, network technology automation techniques, etc., have significantly developed. Google and IBM jointly proposed the concept of cloud computing in 2007. Secondly, cloud computing is of significant importance in adapting to the development of information technology in education. Furthermore, it plays a vital role in creating a flexible, unified, and open platform for educational information, sharing educational resources, and alleviating the information gap between different areas of education. Finally, this paper discusses cloud computing applications in education informatization after analyzing the educational information technology in today's China by studying the basic concepts of cloud computing technology, core technology, and system architecture.

Keywords: cloud computing; virtualization; education informatization; saas;

Introduction

With the fast growth of computer networks since the turn of the twenty-first century, information technologies have been more integrated into our everyday lives, heralding the arrival of the electronic age. The main characters are knowledge

development, the abundance of information, the regular updating of information, and the intense rivalry for skilled employees. Though education is a unique sector, higher education should be seen as one that needs to grow. The quality of their items has to pass the social practice test. Without considering the societal necessities, we cannot examine the composition and caliber of the talent development method. The degree of IT-based education is a crucial indicator of how modernized a nation or region's educational system is.

However, due to China's extensive territory and population, there is a significant disparity in the informationalization of education across different regions, urban and rural areas, and schools. In addition, some public education, resource allocation, and utilization are also deficient in effective monitoring. "information island" and "useless system" are essential issues in the education information system. These issues may be resolved by creating a single, adaptable, and open platform for educational material, raising the bar for academic content. To investigate cloud computing as a means of advancing educational information, we examined the notions of cloud computing and the traits and state of scholarly information.

A Synopsis And Description Of Cloud Computing

The idea behind cloud computing

Many common-sense conclusions have been reached despite disagreement and a lack of consensus regarding what constitutes cloud computing. For example, Google defines cloud computing as network computing and data storage services based on open standards that are Internet-centric, safe, quick, and easy to use. For every netizen, the Internet serves as their data and computer center. However, IBM sees cloud computing as a new IT resource or a virtual pool of computer resources.

It is easy to understand that cloud computing is a hyper Internet-based computer architecture, even with many differing definitions. In the distant data center, thousands of terminals and servers are linked to computer clouds. As a result, cloud computing—which combines many reasonably

priced calculating entities into one robust system over the web—is the ideal example of a system with significant processing capacity. Then, this potent processing capacity was delivered to end users with sophisticated business models like SAAS, PAAS, IAAS, MSP, etc. Users can access the data center via computers, mobile phones, and other terminal modes based on their own needs by simply increasing the “cloud” of processing power, which reduces the processing burden on the user terminal and eventually simplifies it into a simple input and output device.

The way cloud computing functions

Distributed processing, parallel processing, grid computing research, and commercial applications of these computer science ideas are all included in cloud computing. The fundamental building block of the cloud computing architecture comprises several computer servers arranged in a “cloud,” which combines all the resources into one sizable hub for processing and data storage. Meanwhile, a

A range of configuration tools on the servers facilitates the “cloud” aspect of data processing, gathering, and software administration. The servers process the data and deliver search results based on the client’s data requests. According to the categorization of services, the goal is to accomplish monitoring and measurement, guarantee service quality, allocate resources sensibly, and maximize resource efficiency. Super-massive computer and data storage capacity will finally be realized.

By then, we only needed a computer with an internet connection—we didn’t need to worry about storage or figuring out which “cloud” was best for us. However, in a crisis, we may quickly access resources and use cloud services from any place, on any device, including computers, smartphones, and other gadgets.

The benefits of cloud computing

With a solid understanding of the concept and features of cloud computing, we can recognize its benefits:

Security: Cloud computing offers the most dependable and secure data storage facility. Users don't need to be concerned about viruses, data loss, or other issues. An expert staff oversees information management in the "cloud." Furthermore, a firm rights management policy might facilitate data sharing.

Convenience: The users' terminal equipment needs to be minimal. Additionally, using it is simple and easy. Downloading data and software or performing dynamic upgrades on the "cloud" side is unnecessary. All you need is a computer with an Internet connection to access cloud services from anywhere at any time.

Economic productivity. For cloud computing, equipment leasing is required rather than purchasing costly gear. After that, setting up the educational platform would be simple. It is possible to maximize both software and hardware efficiency. Furthermore, we may construct clouds by using the hardware and software resources that are now accessible.

Abundant processing power. Cloud services employ a super server of thousands of machines to give consumers sophisticated computing and data processing capabilities. They are realizing that a home computer is complex.

The kind of technology used in cloud computing applications for education and digitization

Software as a service, or SAAS, is cloud computing that makes a single software program available to thousands of users via a web browser. From the user's standpoint, this means that they don't need permission in advance to buy server hardware or software; for service providers, this means that, compared to traditional software, the price of an application should be much less. Chinese people may save a lot of money using this instructional knowledge, and many software programs are available for free download over the network.

Tech related to virtualization (b). One of the most crucial aspects of cloud computing is virtualization. Typically, it refers to the computation of items based on virtual rather than actual data on execution. Through virtualization technologies, hardware capacity may be increased, making

software re-configuration easier. By enabling a platform to host numerous operating systems and programs that may function independently of one another and affect each other's space, CPU virtualization technology can simulate multi-CPU simultaneous operations on a single CPU, significantly increasing equipment efficiency. With the use of information technology in the classroom, we can address some server overload. Notwithstanding some server idle issues, optimize the effective utilization of instructional materials.

Technology for security. The most sophisticated data center in the world is located in the cloud, and it has a capable technical management staff to assist you in managing your programs and data. With the help of information technology, we can devote more time to designing courses for students and less time to maintaining data throughout the educational process.

Present State Of Information In Education

After years of work, We have made significant progress in developing information technology in education. Based on statistical data, the total investment in IT in China's education in 2006 was 30.48 billion yuan, which accounted for 68% of hardware investment. The China Education and Research Network, which covered 31 provinces, municipalities, and autonomous regions of over 200 cities, networked more than 1,800 teaching and research institution units, more than 2000 users, elected school curricula, credit recognition, and resource-sharing. Additionally, although many colleges and universities have established their campus networks, digital libraries, and other cutting-edge educational information infrastructure, the "School Link" initiative will raise the bar for fundamental education by providing information at the elementary and secondary school levels. Although the primary building of educational information has been achieved so far, it can still not fulfill the demands of China's academic growth, where specific issues persist.

While Infrastructure Moves Quickly, Applications Take Longer.

The primary source of conflict in the present growth of information technology in education is the high investment

in low-output hardware environments and the impact of applying modern instructional material. The field is still in its early stages of development. Although the campus network is built, a significant portion remains idle and is not fully utilized for good. It can be applied to hardware integration and information technology courses, but its impact on education has fallen far beyond expectations. Most of the technology is still in the early stages of exploration and is primarily used as a presentation tool.

Insufficient and unbalanced availability of learning materials

Education and information resources include various items, such as media materials, case studies, books, exams, courseware, and electronic audio-visual assets.

However, the design of China's educational software often focuses on a single topic and one function; as a consequence, subjects cannot be merged across functions, creating operational challenges and the issue of incompatible resources. In addition, there is no efficient management system in place, and many excellent course materials, resources, and other materials are dispersed among numerous prestigious schools, the hands of well-known instructors, and additional local institutions. As a result of poor input, the equipment is outdated, and there are insufficient resources, among other issues. Knowledge gained via education is increasingly closing the gap.

updated sporadically and with little sharing

Information technology has placed a lot of pressure on education due to the rapid development of various technologies, fierce competition for jobs, and the need for schools to provide students with new labs, computer equipment, and related courses to improve students' skills and prepare them for the new environment. However, because of the current network speed, Internet access fees, and other factors, resource sharing between schools cannot keep up with the rapid growth of the Internet, online learning, and distance learning modes. As a result, new challenges related to resource sharing between schools have been raised.

How Cloud Computing Is Used In Information In Education

The future of education's information technology infrastructure will be cloud computing applications, which will contain the educational data needed to create software and hardware environments for resources. Cloud computing integration of these resources will be able to meet the enormous demand for high-speed data processing to alleviate the pressures of the current information age "information explosion" and meet the rapid changes in information technology and software as a service (SaaS) trend in education; significantly improve the types of educational resource utilization, reduce costs, meet the demand for green energy; and ultimately enhance information security. To build academic cooperation projects in China and jointly increase the popularity of cloud computing, Google has announced the commencement of the cloud of academic collaboration programs with Chinese institutions. China has now begun the cloud computing education program. As the first colleges and institutions on the Chinese mainland to participate in this initiative, Tsinghua University and Google collaborated to create "large-scale data processing" courses. As part of this collaboration, Google will provide Tsinghua University's completed professor course materials. Tsinghua University will supply lab supplies and help with resource calculations in the current developing cloud computing research environment. Google engineers actively explain the cutting edge of Google technology while teaching classes at Tsinghua University. Thus, as cloud computing is booming, we should take advantage of the chance to thoroughly examine and use this new technology, the advancement of information technology for educational services.

Learning in a networked setting

According to contemporary conceptions of education, students, who make up most of the teaching staff, should be proactive rather than passive. It will be a trend in contemporary instructional strategies. People have not discovered the optimal, tailored learning strategy in the typical classroom setting. Depending on the sort of cloud services, the student may choose their learning techniques and information at any time while in the cloud. Web 2.0 tools are widely

available on the Internet nowadays. Examples include Sakai Management Network courses, Diigo bookmarks for creating a personalized taste and using iGoogle to customize one's online environment. These Web 2.0 applications fall under the category of cloud services. Control and administration of cloud services may support the fundamental components of virtual learning environments, including text, audio, video, training, and so forth. To provide a customized learning environment for virtual classrooms on-site, instructors and students may interact anytime, anywhere over the network by just connecting via a browser. The learning environment construction barrier is significantly reduced since complicated software operations are not required to be mastered – excellent application of tailored education, perfect for customized training.

Using SAAS in the ITization of education

One kind of cloud service is Software as a Service (SAAS), which Google Apps and Zoho Office provide. Schools may now use these cloud computing services without paying much for commercial software licenses or bear the expense of ongoing maintenance and updates. Some widely used programs, like the Office series, are available on the cloud, have affordable prices, and some are even free. Combining data centers, network centers, libraries, and other data resources with the environment, school reference, and this approach's introduction will be handled through the cloud computing model. The client's local computer only needs to run the graphical interface of the Linux operating system and the Firefox browser to enjoy the cloud; you don't need to worry about whether the application software is up to date, which significantly lowers the costs associated with maintaining and upgrading schools' operating systems and application software. Firefox and Linux are open-source programs for which you may get a free license. One example is the Google Apps cloud computing service, which offers word processing, spreadsheets, PowerPoint presentations, web development, email, and other applications to individual users at no cost. Many educational institutions prefer using Google apps on computers over open-source software designs

due to their convenience and simplicity. It isn't easy to use this open-source software.

Building a net-teaching database among the cloud computing environment's trends

Cloud computing has made a contemporary network of educational resource libraries possible for many people to access. How to create online content in the cloud computing environment of the future

We must consider the current state of affairs in the instructional resource library. Building a library is a long-term endeavor. Thus, planning is also necessary. To promote sustainable and healthy development. The final goal should be providing teaching materials to assist research and teaching; construction should adhere to the general planning process, divide labor, and apply the fundamentals of mechanism innovation while using the most available resources. Reasonably classify, arrange, and assimilate the most recent developments and the outstanding outcomes of external sources, with cloud computing services offering concepts and services to IT architecture, innovation, the building of high-caliber scientific materials, and a practical and suitable library of instructional resources. The first three qualities of the cloud computing environment teaching resource library are stability and speed. Stable, possessing strong, practical, quick search and query skills; second, data storage parameters and categories are apparent. Standardization, user edit and usage, and categorization standards. Favorable to enhance the repository's sustainability. The third is the safe sky's resources. All data and information are stored locally on clouds, eliminating the need for backups or retention. The user-friendly resource-based platform comes in fourth. The resources and related functions are rapidly and readily accessible to all user kinds and levels, and cloud and treatment management is simple – resources for education to maximize transparency and collaboration.

Utilizing cloud computing in a variety of instructional technologies

Information technology is constantly evolving, and as a result, new applications in education have both positive and negative effects on our way of life. Numerous issues emerged as more and more, including the diversity of individual learning, the diversification of teaching styles, the diversity of teaching objectives and levels, the diversified needs for information and expression vectors, the multidisciplinary needs of the construction of information resources, and the inevitable emergence of a wide range of educational information. As a result, information technology in education services must also move in the direction of diversification. The cloud computing platform meets these needs. Google and Microsoft have each released their cloud computing platforms. A great example of using Google Cloud services is the geography curriculum many schools now use, taught via Google Earth Community. Naturally, in keeping with the current state of information technology in education, we can also rent network space and build our network platform, eliminating the need to buy a lot of hardware devices and the hassle of maintaining the system. This has also helped to diversify the development of educational information.

Summary

As cloud computing advances, more personal and educational information processing will be moved to the “cloud” since it is affordable and practical. Cloud infrastructure offers information services to educators, students, and academic institutions. Based on the study above, using cloud computing in education reform will undoubtedly aid in resolving issues with unequal access to learning materials, sluggish updates, and low-speed sharing. Ultimately, there will be a significant improvement in the level of education digitization.

Conclusion

Task scheduling in cloud computing plays a critical role in achieving efficient resource utilization, improved system performance, and enhanced Quality of Service (QoS). By intelligently allocating tasks to available virtualized resources, effective scheduling algorithms help minimize execution time, reduce operational costs, balance

workloads, and ensure scalability in dynamic cloud environments. Although traditional scheduling techniques provide a foundation, the growing complexity of cloud infrastructures demands adaptive, energy-aware, and QoS-driven scheduling approaches. Continued research in this area, incorporating machine learning and optimization techniques, will further enhance the reliability and efficiency of cloud systems, making task scheduling a key enabler for the future growth and sustainability of cloud computing.

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The Effect of Cloud Computing Adoption on the Sustainability of E-Government Services: A Review

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Abstract

The setting in which government agencies operate has evolved. Technology innovation, environmental demands, and changing demographics have all presented severe obstacles to the day-to-day operations of public institutions. As a result, public organizations must embrace sustainable business practices and develop creative ways to deal with the current business climate. Scalable and interoperable technology platforms are necessary for sustainable governance to facilitate the analysis, integration, sharing, and monitoring of various data sets and sustainability metrics. One such platform to assist sustainable governance is cloud computing. Businesses benefit from its agility and the platform it offers for sustainable operations with better services, a cleaner environment, and better resource management. This study goes over the relevant ideas again and analyzes other studies to find the gaps in using cloud computing as a platform for creating long-lasting e-services. The findings indicate that there is still a shortage of studies on how cloud computing may help ensure the supply of long-term e-government services. Research on the difficulties government initiatives face and creating more resilient e-government services through the choice and implementation of suitable cloud models is lacking.

Keywords: Cloud Computing; Sustainable E-services; Survey.

Introduction

E-government services are increasingly essential to people's

lives, enterprises, and governmental institutions. Governments must thus develop and deploy efficient e-services to provide better services. These services are fueled by public pressure, ICT advancements, and government power to reduce obstacles to social inclusion, the environment, and economic growth in the direction of sustainable development. The use of ICT to help governments improve the effectiveness of their internal operations, procedures, and infrastructures with an emphasis on sustainable development is known as sustainable e-government development. Accessible services may be provided using ICT at the lowest possible environmental cost. Increased engagement in governmental policy and decision-making processes is another benefit of ICT [1]. Sustainable e-government, according to Estevez and Janowski [2], may enhance public services, citizen contact, citizen involvement in decision-making, and social promotion while safeguarding natural resources for future generations.

Generations. In addition to protecting the environment, sustainable e-government services can generate economic value, adapt to technological advancements, foster fair access and information sharing among all stakeholders, and promote social sustainability [3]. Though the sustainable development and e-government areas have advanced separately, little is known about the efforts to define and construct sustainable e-government services and investigate how technological innovation may assist these services [2]. A sustainable e-government system may be realized using cloud computing by leveraging several resource-sharing methods. Data, pictures, and shared application infrastructure for e-government systems can be accommodated through cloud computing data centers independent of higher-tier ICT resources. A well-designed e-government system that leverages cloud computing and pre-existing telco infrastructure can establish a robust e-services infrastructure that can benefit developing nations and emerging economies in numerous ways, such as affordability, scalability, resources, integration, expertise, upkeep, and sustainability [4]. An overview of previous studies on the effect of cloud computing adoption on the long-term viability of e-government services is given in this report. To determine the possibility of more

studies evaluating the influence of cloud computing on sustainable e-government services, the relevant papers are investigated and analyzed.

The study is organized to introduce the concept of cloud-based e-government services. Then, state of the art in the sustainability of e-government services is explored and analyzed. Next, a summary of the studies, the applied methodology, and the results are presented. Finally, a discussion and conclusion are provided.

Cloud Based E-Government Services

The benefits of cloud computing have prompted governments worldwide to embrace this technology to provide dependable and long-lasting e-services. Alonso et al. [5] state that using cloud computing to construct reliable, integrated back-end processes while considering the right amounts of data portability, interoperability, and security would enable the successful delivery and maintenance of e-services. Numerous examples demonstrated how cloud computing has evolved into a significant global government initiative. It has already been used to put multiple e-government services into action. Through their research and analysis of several instances from various nations, Mohammed and Ibrahim [6] found that governments use cloud platforms to improve services and save ICT costs. While some businesses have used cloud computing to save costs and improve scalability, availability, and accessibility, others have done so to address actual ICT-related issues. It has also been used to boost openness and public engagement while enhancing the effectiveness and quality of e-services [6]. Cloud-based government solutions enable partner organizations to share ICT resources, systems, and business processes, which lowers operating costs for each organization [7]. A cloud-based government system significantly enhanced resource use [8, 9]. High-capacity storage space is made available via cloud computing, allowing for more data processing and assisting the government in making more informed choices [10]. Additionally, cloud services provide more integrated and fast feedback on various public services by providing more straightforward access and ubiquitous service supply, independent of time and

place [7, 11]. Furthermore, the deployment and updating of applications become more rapid and agile as resources may be automatically managed and dispersed on the cloud based on the business requirements[7,12].

State-of-the-Art: Sustainability of Cloud-based E-Services

Because e-services are becoming increasingly essential to daily living, corporate operations, and governmental duties, sustainability is more important than ever. The capacity to continue offering high-quality services while maintaining client happiness is known as e-service sustainability. According to Brundtland et al. [13], sustainability is defined as development that guarantees addressing the demands of the present generation while considering future generations' needs [14].

According to [14], a viable method for determining the feasibility of cloud computing technology is to apply sustainability assessment to every firm considering adoption. Before deciding whether to migrate to the cloud, sustainability concerns (economic, environmental, social, and technological) should be considered. The cost of cloud migration, including maintenance, consulting, and training expenses, is supposed to be an economic component. Concerns about the use of energy and resources are addressed by taking environmental practices into account. When choosing to migrate to the cloud, social and technical factors are also extensively considered [14].

Walterbusch et al. [15] presented a decision-making approach to assess and choose suitable cloud computing services while considering social, environmental, and economic sustainability factors. A mixed-method approach highlighted the key features of cloud computing and its effects on the economy, environment, and society. Experts validated the model and the findings of a statistical analysis and scenario-based simulation research. The results show that the characteristics of sustainable systems should be considered when assessing and choosing cloud computing services.

Yoo and Kim [16] analyzed technical, organizational, and environmental aspects, other decision-making elements,

and cloud computing qualities using the Delphi method and AHP (Analytic Hierarchy Process). The research recommended that compatibility, competitive pressure, and top management support be considered when using cloud computing services. Furthermore, from the standpoint of the demander, compatibility and competitive pressure were highlighted as high-priority variables; from the supplier's perspective, relative advantage and top management support were regarded as high-priority factors.

Truong and Dustdar [17] investigated the potential of cloud computing to satisfy new demands for the sustainability of public services. After studying academic studies and industrial platforms, they determined the fundamental components and shared traits of cloud computing for sustainability. After careful consideration, they determined that cloud computing may help sustainability by offering several strategies that enable many stakeholders and intricate analysis.

From the standpoint of internal users, Stamenkov and Dika [18] presented a model for sustained quality of services in the e-banking sector. The capacity of a business to supply e-services with sustainable quality while controlling and preserving customer happiness and loyalty was termed sustainable quality of service. A qualitative investigation using interviews was carried out to create a theoretical model. The specified characteristics were the quality of e-service, IT and infrastructure capabilities, quality management system, business/ICT alignment, and ICT service environment. The suggested model was experimentally investigated using structural equation modeling and exploratory factor analysis. Findings confirmed the impact of IT, business/ICT alignment, quality management systems, and

Infrastructure capacity, the ICT service environment, and the quality of the e-services affect the long-term sustainability of e-services that forecast customer pleasure and loyalty.

Chou [19] offered a value-creation model after analyzing the benefits and risks of cloud computing. Several components were determined to assist enterprises in assessing the benefits of cloud computing. Additionally, an analysis was conducted on the impacts of cloud computing adoption on businesses.

To achieve sustainable computing, the suggested cloud computing value creation paradigm had four primary stages: awareness, translation, understanding, and cloud computing value creation.

Estevez et al. [20] examined ten examples of active e-government projects with clear goals for sustainable development. The findings demonstrated how e-government helps achieve a range of sustainability objectives. The most often addressed sustainability challenges are social (empowerment), economic (enterprise possibilities), environmental (artificial activities), and institutional (capacity development). Furthermore, it was shown that industrialized and developing nations' use of e-government for sustainable development differed significantly.

Estevez and Janowski first presented the notion of electronic governance for sustainable development (EGOV4SD) [2]. Initially, a conceptual framework known as EGOV4SD was introduced, aiding in defining the parameters and aspects of both Sustainable Development (SD) and E-Government (EGOV). Next, a conceptual framework-based analysis method for EGOV4SD was established. Using this method, the state of EGOV4SD research was presented, drawing on an analysis of relevant literature.

E-services aren't sustainable until they're built with sustainability factors in mind, according to Razavian et al. [3]. It takes skill to create sustainable e-services, and it takes skill to communicate and evaluate sustainability. A conceptual model was put out by Razavian et al. [3] to determine the fundamental components of sustainable e-services. The goal was to improve stakeholders' awareness of sustainability and to provide a mechanism for sustainability assessments. An actual case study was used to demonstrate the usefulness of the suggested paradigm.

In e-government research, Larsson and Grönlund [21] looked into sustainability. A literature review revealed that the sustainability theory is used arbitrarily and superficially in contemporary e-government research. Furthermore, few studies include and integrate all four aspects of sustainability;

instead, relevant studies mainly concentrate on a subset of the sustainability dimensions (social, economic, environmental, and technological). Most studies focused on the social element of sustainability, with little attention paid to other factors. There was a narrow understanding of what constituted sustainability. Trust, engagement, and economy were among the broad and relevant public sector characteristics that received less attention than project or e-service sustainability.

Discussion and Conclusion

To create and execute efficient e-services, governments must address environmental, social inclusion, and economic growth issues to promote sustainable development. Governments may use cloud computing to improve internal operations efficiency by implementing cutting-edge ICT strategies, procedures, and infrastructures that prioritize sustainable growth. Thanks to cloud computing, small businesses may benefit from affordable, readily available services. Additionally, cloud computing benefits the environment and the economy. The inclination to decrease overall infrastructure, boost productivity, optimize server usage, and enhance data center efficiency propels these effects. Related research has shown that cloud computing improves e-service performance, scalability, and dependability. The associated study used various approaches to look into the possibilities of cloud computing and put forward models and frameworks to determine what elements impact it. However, the variety of cloud models makes it difficult to decide which service model best suits a particular organization's needs and which model to use for deployment. Additionally, choosing a cloud service architecture and deployment strategy that meets the company's goals may increase the e-services' sustainability. Because of this, choosing to migrate to the cloud is a difficult option. It depends on several variables, including shifting governmental regulations, financial constraints, the applicability of the cloud environment for certain services, and the development of new technologies.

Few studies provide decision-making models to assist in choosing the best cloud model to satisfy the unique needs of e-services and increase sustainability. Therefore, by selecting

and implementing the best cloud model utilizing Multi-Criteria Decision-Making Models, research can be done to solve the issues with government projects and produce more sustainable e-government services.

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The Fundamentals of Cloud Computing

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What is a cloud?

Publications and users alike, from private citizens to the US government, are paying much attention to cloud computing. However, it's not always certain.¹ A subscription-based cloud computing service allows you to access computer resources and networked storage. Thinking about cloud computing may be compared to your email experience. Your email client—Hotmail, Gmail, Yahoo!, and so forth—stores every gear and software required to run your email account. Launch your web browser, go to the email client, and log in to view your email. The most crucial component of the equation is having access to the internet. Your email is accessible from anywhere in the world via an internet connection, not only from your physical computer. As long as you have a connection to the internet, you can check your email whether you are traveling, at work, or just buying coffee down the street. Software installed on your computer, such as word processing software, differs from email. Unless you physically relocate it, a document created using word processing software remains on the device from which it was made. A cloud computing environment is similar to that of an email client. You may choose which data you can access inside the cloud instead of just having access to your email.

How is the cloud used?

Thanks to the cloud, you can access your data anytime, from any location. The cloud eliminates the need for you to

be in the same place as your data storage device, which is a requirement of a typical computer setup. You no longer need to be in the same physical area as the hardware that saves your data because of the cloud. Applications for your home or company might be run on hardware and software that your cloud provider owns and houses.

Businesses that cannot afford the same hardware and storage space as a giant corporation will find this highly beneficial. Small businesses may avoid the expense of buying and keeping memory devices by putting their data in the cloud. Furthermore, because you only have to pay for the storage space you use, a company may expand or downsize its membership as needed or as its storage space needs change.

Among the prerequisites for using the cloud is having an internet connection. This implies that you need to connect to the internet via a wireless, cable, or mobile broadband connection before seeing a particular document you have stored in the cloud. One advantage is using any internet-connected device to view the same document anywhere. These gadgets may be a phone, tablet, laptop, or desktop computer. Because everyone with an internet connection and access to your cloud can work on papers, use software, and save data, this may also help your organization run more smoothly.

Instead of visiting the office to print or upload a document to your laptop, imagine being able to download it to your smartphone and examine it. This is the flexibility you or your company can have using the cloud.

varieties of clouds

Depending on your requirements, you may subscribe to various cloud services. Public cloud services are probably something you will utilize as a home user or small business owner.

Public Cloud : Anyone with an internet connection and access to cloud space can use a public cloud.

Private Cloud :A private cloud is created for a specific group or company, and access is restricted to that group alone.

Community Cloud : Two or more businesses share a community cloud with comparable cloud computing needs.

Hybrid Cloud: A hybrid cloud is a blend of public, private, and community clouds consisting of at least two.

Selecting a cloud service provider

Depending on the kind, each provider fulfills a purpose and offers consumers varying degrees of control over their cloud. Make sure the cloud services provided meet your requirements before selecting a supplier. Your requirements may change depending on how you use the cloud's space and resources. You will want a different cloud type and provider if you use it for personal home usage rather than corporate purposes. Remember that your cloud provider will be pay-as-you-go, so you may acquire more storage space (or less, for that matter) from them at any time if your technology demands alter.

You may sign up for subscriptions to three different kinds of cloud providers: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). There are differences between these three categories in terms of how much control you have over your information and, on the other hand, how much you can rely on your provider to handle. Here are some brief expectations for each kind.

Apps and resources are made available to subscribers by Software as a Service (SaaS) providers. SaaS eliminates installing software on your devices using a physical copy. By enabling cloud access, SaaS also simplifies the process of having the same software on all your devices simultaneously. You have the least control over the cloud when you have a SaaS arrangement.

Platform as a Service (PaaS): This technology surpasses software-as-a-service configurations. Subscriptions to a PaaS provider provide users access to the necessary components for creating and managing web applications.

Infrastructure as a Service (IaaS): As the name implies, an IaaS agreement focuses primarily on computing infrastructure. Under an IaaS arrangement, the subscriber fully outsources

the storage and resources—hardware and software, for example—that they need.

As you go down the list from number one to number three, the subscriber has greater control over what they can do within the cloud. In contrast to a SaaS arrangement, the cloud provider has less control over an IaaS system.

What does this imply for someone wishing to use the cloud at home or for a business? It means you can choose the services you want from a cloud provider and the degree of control you wish to have over your data. Consider the scenario where you are launching a small company of your own. It is beyond your means to buy and keep all the gear and software required to keep your business at the forefront. You could sustain your new firm with the same computing capacity as a more significant, more established corporation by subscribing to an Infrastructure-as-a-service cloud, and you would only pay for the storage space and bandwidth you use.

On the other hand, this method could require you to dedicate more resources to app creation and maintenance. As you can see, before committing to a cloud provider, you should assess your present computing resources, the degree of control you want, your financial status, and the direction you want to take your organization.

However, if you're a home user, you'll probably be more interested in free or inexpensive cloud services (like web-based email) and less concerned with many more sophisticated cloud options.

After you've made a thorough inventory of where you are and where you want to go, you'll know more about each cloud provider and whether they're a good fit for you.

Safety

Those with evil intentions often see the data stored in the cloud as applicable. People keep many private and perhaps sensitive data on their computers, which is increasingly being moved to the cloud. Because of this, it's crucial that you comprehend the security protocols that your cloud provider has in place and that you take personal security safeguards to protect your data.

It would be best to start by investigating your cloud provider's security precautions. These differ among the different kinds of clouds and from one supplier to another. Which encryption techniques are used by the providers? What security measures are in place for the hardware that will be used to store your data? Will my data be backed up with them? Have they configured firewalls? What safeguards are in place to keep your data private from other businesses if you have a community cloud? The standard terms and conditions offered by many cloud providers may address these concerns; however, the home user's cloud contract will likely have little space for modification. When discussing the terms of their contract with the provider, a small business user could have a little more leeway and be allowed to ask these kinds of questions. While you have a lot of questions, it's critical to choose a cloud provider that places a high priority on data security.

You will be ceding some control to an external source when you subscribe to the cloud, regardless of your cautiousness with your personal information. There is a barrier because of this distance between you and the actual location of your data. Additionally, it can make more room for a third party to access your data. It would be best to voluntarily give up direct control over your data to profit from the cloud. Conversely, remember that most cloud service providers will be knowledgeable about safeguarding your data. To protect their computers and networks, providers probably have more resources and experience than the typical user.

In conclusion

In conclusion, both big and small enterprises and the average computer user have a lot of possibilities thanks to the cloud. Enabling access via any internet connection expands the realm of computer applications and improves usability. However, there are disadvantages associated with this added convenience. You have little to no idea where your information is kept and less control over who may access it. The security hazards associated with storing data in the cloud must also be understood. The cloud has potential drawbacks since it may be accessed via an unprotected internet connection, making it a prime target for malevolent actors.

If you are considering using the cloud, determine what data you will be storing there, who will have access to it, and what you need to ensure its security. Before you sign up, make sure you understand your alternatives about the kind of cloud that will work best for you, the type of provider that will be most helpful, and the reputation and obligations of the providers you are considering.

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A Review of Resource Allocation Techniques in Cloud Computing

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Abstract

Cloud Computing is a type of computing which can be considered as a new era of computing. Cloud can be considered as a rapidly emerging new paradigm for delivering computing as a utility. In cloud computing various cloud consumers demand variety of services as per their dynamically changing needs. So it is the job of cloud computing to avail all the demanded services to the cloud consumers. But due to the availability of finite resources it is very difficult for cloud providers to provide all the demanded services. From the cloud providers' perspective cloud resources must be allocated in a fair manner. So, it's a vital issue to meet cloud consumers' QoS requirements and satisfaction. This paper mainly addresses key performance issues, challenges and techniques for resource allocation in cloud computing. It also focuses on the key issues related to these existing resource allocation techniques and summarizes them.

keyword Cloud Computing, Resource Allocation, Service Level Agreement, Virtualization.

Introduction

Because of the advancement in Information and Communication Technology (ICT) over past few years, Computing has been considered as a utility like water, electricity, gas and telephony. These utilities are available at any time to the consumers based on their requirement. Consumers pay service providers based on their usage [2] [3]. Like all the other existing utilities, Computing utility is the basic computing service that meets the day to day needs of the general

community. To deliver this vision, a number of computing paradigms have been proposed, of which the latest one is known as Cloud Computing. Cloud is nothing but large pool of easily accessible and usable virtual resources [2] [3]. **Dr. Rajkumar Buyya** says “A Cloud is a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resource(s) based on service-level agreements established through negotiation between the service provider and consumers.” [3] Cloud computing is composed of three kind of services [1] [5] [6] [9].

Cloud Software as a Service (SaaS)

In this service model, instead of using locally run applications the cloud consumer uses the cloud provider's software services running on a cloud infrastructure. It is the job of cloud provider to maintain and manage the software services that are used by the cloud consumer. The cloud provider may charge according to quantity of software and using time. SaaS is the best way to use advanced technology. Salesforce.com and Customer Relationship Management (CRM) are the examples of such service model [1] [4] [5] [6] [7] [10].

Cloud Platform as a Service (PaaS)

In this service model, the cloud platform offers an environment on which developers create and deploy applications. It provides platform where applications and services can run. The consumers do not need to take care of underlying cloud infrastructure including network, servers, operating system or storage but has a control over deployed application. Google Application Engine, Microsoft Azure and RightScale are the example of such model [1] [4] [5] [6] [10].

Cloud Infrastructure as a Service (IaaS)

In this service model, cloud providers manage large set of computing resources such as storing and processing capability. Cloud consumer can control operating system; storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls).

Sometimes it is also called as a **Hardware as a Service (HaaS)**. The cost of the Hardware can be greatly reduced here. Amazon Web Services, Open Stack, Eucalyptus, GoGrid and Flexiscale offers IaaS [1] [4] [5] [6] [10]. In cloud computing various deployment models have been adopted based on their variation in physical location and distribution. Regardless of the services, clouds can be classified among four models as mentioned below.

Private Cloud

It is private to the organization. All the cloud services are managed by the organization people themselves or any third party vendors as well as services are not provided to the general public. Private cloud may exist on premise or off premise [1] [5] [6] [8].

Public or Hosted Cloud

All the cloud services managed by the organization are made available as in pay as you go manner to the general public. The business people can adopt such cloud to save their hardware and/or software cost. Public cloud may raise number of issues like data security, data management, performance, level of control etc [1] [5] [6] [8].

Community Cloud

Here cloud is available to specific group of people or community. All the cloud services are shared by all these community people. Community cloud may exist on premise or off premise [1] [5] [6].

Hybrid Cloud

It is a combination of two or more clouds (Private Cloud, Public Cloud, and Community Cloud) [1] [5] [6]. The rest of the paper is organized as follows: Section II presents issues and motivation related to resource allocation in cloud computing. Section III discusses various cloud computing resource allocation techniques proposed by researchers'. Section IV gives summary of all these existing resource allocation techniques with their used tools and possible improvements. Section V presents conclusion and discussion on resource allocation techniques.

Motivation

In cloud computing various cloud consumers demand variety of services as per their dynamically changing needs. So it is the job of cloud computing to avail all the demanded services to the cloud consumers. But due to the availability of finite resources it is very difficult for cloud providers to provide all the demanded services in time. From the cloud providers' perspective cloud resources must be allocated in a fair manner. So, it's a vital issue to meet cloud consumers' QoS requirements and satisfaction. Traditional resource allocation techniques are not adequate for cloud computing as it is based on virtualization technology with distributed nature. Cloud computing introduces new challenges for manageable and flexible resource allocation due to heterogeneity in hardware capabilities, workload estimation and characteristics in order to meet Service Level Objectives of the cloud consumers' applications. The ultimate goal of resource allocation in cloud computing is to maximize the profit for cloud providers and to minimize the cost for cloud consumers.

Literature Survey And Related Work

Qiang Li, Qinfen Hao, Limin Xiao and Zhoujun Li [11] proposed VM-base architecture for adaptive management of virtualized resources in cloud computing. Authors also designed a resource controller named Adaptive Manager that dynamically adjusts multiple virtualized resource utilization to achieve application Service Level Objective (SLO) using feedback control theory. Adaptive Manager is a multi-input, multi-output (MIMO) resource controller which controls CPU scheduler, memory manager and I/O manager based on feedback mechanism. To periodically measure application performance each Virtual Machine has sensor module which transmits information to the adaptive manager. Authors adopted Kernel based Virtual Machine (KVM) as a tool for infrastructure of virtual machine. **Mayank Mishra, Anwesha Das, Purushottam Kulkarni and Anirudha Sahoo** [12] discussed that live virtual machine migration plays a vital role in dynamic resource management of cloud computing. Authors mainly focused on efficient resource utilization in non peak periods to minimize wastage of resources. In order

to achieve goals like server consolidation, load balancing and hotspot mitigation, authors discussed three components – when to migrate, which VM to migrate and where to migrate – and approaches followed by different heuristics to apply migration techniques. Authors also discussed virtual machine migration over LAN and WAN with their challenges. **T. R. Gopalkrishnan Nair** and **Vaidehi M** [13] presented a model, named as Ruled Based Resource Allocation (RBRAM) which deals with the efficient resource utilization in M-P-S (Memory-Processor-Storage) Matrix Model. Authors say that resource allocation rate should be greater than resource request rate. Major components of the system are: cloud priority manager, cloud resource allocation, virtualization system manager and end result collection. To analyse the performance of the cloud system authors considered the Cloud Efficiency Factor. However, authors also identified other parameters of Cloud System for future work. **Rosy Aoun, Elias A. Doumith** and **Maurice Gagnairein** [14] proposed a model named as Mixed Integer Linear Program (MILP) for resource provisioning for enriched services in cloud environment. Authors stated that several basic services offered at IaaS level can be arranged together by the cloud providers for providing sophisticated services to the cloud consumers. Two original services, distributed data storage and multicast data transfer are jointly considered in addition to the traditional computing, centralized storage and point to point data transfer services. However, authors have considered the impact of four types of services: computing, storage, point to point data transfer and point to multipoint data transfer. The numerical results were given by considering 18-node backbone network.

Justin Y. Shi, Moussa Taifi and **Abdallah Khreishah** [15] explored a simple quantitative Timing Model method for cloud resource planning. For the same they considered the estimated resource usage times in steady state. Authors had calculated Speed up for Parallel Resource Planning based on Parallel Matrix Multiplication. To investigate multiple important dimensions of a program's scalability, authors proposed quantitative application dependent instrumentation method instead of qualitative performance models. Authors had mainly focused on application inter

dependencies for cost effective processing. **Chenn-Jung Huang, Chih-Tai Guan, Heng-Ming Chen, Yu-Wu Wang, Shun-Chih Chang, Ching-Yu Li and Chuan Hsiang Weng** [16] proposed resource allocation mechanism based on Support Vector Regression (SVR) and Genetic Algorithm (GA). Authors designed Application service prediction module with Support Vector Regression (SVR) to estimate the number of resource utilization according to the Service Level Agreement (SLA) of each process. Then authors designed global resource allocation module with Genetic Algorithm (GA) to redistribute the resources to the cloud consumers. **Zhen Xiao, Weijia Song and Qi Chen** [17] aimed to achieve two goals - overload avoidance and green computing - for dynamic resource allocation through virtualization technologies. Based on dynamically changing need of the cloud consumers the designed and implemented system multiplexes virtual to physical resources adaptively. The multiplexing is done through Usher Framework. Authors designed a load prediction algorithm to predict future resource utilization without seeing into virtual machines. Authors had used "skewness" metric to measure uneven utilization of server. For the same they defined concept of "Hot Spots" and "Cold Spots" servers. In order to evaluate the performance of the algorithm designed authors used trace driven simulations. **Amit Nathani, Sanjay Chaudhary and Gaurav Somani** [18] proposed an algorithm in a scheduler named Haizea for resource allocation policies like immediate, best effort, advanced reservation and deadline sensitive. Haizea is a resource lease manager that uses resource leases as resource allocation abstraction and implements these leases by allocating Virtual Machines (VMs). Authors main goal was to minimize resource rejection rate and reshuffle cost in order to provide all the above mentioned resource allocation policies for IaaS cloud. Authors also used two concepts named swapping and backfilling for deadline sensitive resource allocation policy. Authors mainly considered four lease parameters for their experiments: start time, duration, deadline and number of nodes. **Weiwei Lina, James Z. Wangb, Chen Liangc and Deyu Qia** [19] proposed a threshold based dynamic resource allocation scheme for cloud computing. Authors mainly

focused on application level resource allocation instead of mapping between physical resources and virtual resources for better utilization of resources. A threshold is used to optimize the decision of resource reallocation. The proposed algorithm consists of two procedures: **Datacenter**-resides at the datacenters central computer and **Broker**-runs on user's machine with the application. Both procedures interact with each other for dynamic resource allocation. The proposed algorithm is implemented by using CloudSim Toolkit. **Yichao Yang, Yanbo Zhou, Lei Liang, Dan He and Zhili Sun** [20] focused on efficient data and network (combined) resource utilization for data intensive applications like IPTV. Authors proposed Cloud Infrastructure Service Framework (CISF) to achieve QoS requirements of cloud consumers. They introduced a Service-oriented Resource Broker (SRB) for guaranteed data transmission in cloud computing to discovery, select, reserve and assign data and network resources. Firstly the collected user requirements are given to Resource Requirement Interpreter to produce abstract resource requirement information. This information is then passed to the Resource Discovery Unit to produce list of resource combination which is passed to Resource Combination Ranker to assign priority. Finally Resource Reservation Unit makes coordinated resource reservation to resource gatekeepers through reservation interface. **Kejiang Ye, Xiaohong Jiang, Dawei Huang, Jianhai Chen and Bei Wang** [21] proposed resource reservation based live migration framework of multiple virtual machines. The target machine in the framework holds four virtual machines: Migration Decision Maker, Migration Controller, Resource Reservation Controller and Resource Monitor. Authors focused on improving the migration efficiency through live migration of virtual machines and proposed three optimization methods: optimization in the source machine, parallel migration of multiple virtual machines and workloadaware migration strategy. To improve the migration efficiency authors had considered parameters like downtime, total migration time and workload performance overheads. Authors claimed that resource reservation strategy is required at source machine and target machine. **Congfeng Jiang, Xianghua Xu, Jilin**

Zhang, Yunfa Li and Jian Wan [22] raised the effective resource allocation problem based on real time knowledge of workload and performance feedback of running services. Authors had proposed stochastic model of resources in virtualized environments. Authors had also proposed resource allocation and scheduling heuristics algorithms with service level agreement constraints. To improve the effectiveness of the future incoming dynamic workload, the performance of the targeted machine had been considered as a performance feedback mechanism to the source. This feedback mechanism improves the resource allocation method proposed by authors themselves. **GuiyiWei, Athanasios V. Vasilakos, Yao Zheng and Naixue Xiong** [23] proposed game-theoretic method for fair resource allocation in cloud computing. Authors used Game Theory for QoS constrained resource allocation problem. Firstly, authors considered optimization problem for cloud services for which Binary Integer Programming method was proposed for initial optimization. Based on the initial result, an evolutionary mechanism was designed to achieve the final optimal and fair solution. In summary, authors focused on the sophisticated parallel computing problem on unrelated machines connected across the Internet.

Baomin Xu, Chunyan Zhao, Enzhao Hu and Bin Hu [24] proposed job scheduling algorithm based on Berger Model with dual fairness constraints. Authors had mainly concentrated on fairness of resource allocation and cloud consumers' satisfaction to the provided services. Based on parameters like completion time and bandwidth, cloud consumers' tasks had been classified. According to the characteristics and preferences of tasks, resources were assigned to the cloud consumers. Authors implemented their algorithm on CloudSim toolkit and compared with optimal completion time algorithm. Results show that algorithm based on Berger Model is better. **Linlin Wu, Saurabh Kumar Garg and Rajkumar Buyya** [25] proposed resource allocation algorithm for SaaS providers who can minimize infrastructure costs and SLA violations and for SaaS consumers to assure service satisfaction. Authors had considered consumers Quality of Service parameters such as response time and infrastructure level parameters such as server initiation time.

Authors implemented three cost driven algorithms from both consumers and SaaS providers perspective. The first algorithm is a base algorithm which maximizes the profit by minimizing the number of SLA violations. The second algorithm maximizes the profit by minimizing the cost by reusing VMs, which have maximum available space. The third algorithm maximizes the profit by minimizing the cost by reusing VMs, which have minimum available space. The second and third are proposed by authors which were simulated on CloudSim environment. **Borja Sotomayor, Ruben Santiago Montero Ignacio Martin Llorente and Ian Foster** [26] presented a lease suspension/resumption time model for prediction of various run time overheads involved in using virtual machines through which advanced reservations can be made. Authors used Haizea, open source lease management architecture for advance reservation leases, best effort leases and immediate leases. As Haizea cannot operate on physical hardware resources, authors integrated Haizea with OpenNebula virtual infrastructure manager. Experiments were done on Xen Virtual Machine.

Conclusion And Discussion

Cloud Computing is the new era of computing for delivering computing as a resource. The success and beauty behind cloud computing is due to the cloud services provided with the cloud. Due to the availability of finite resources, it is very important for cloud providers to manage and assign all the resources in time to cloud consumers as their requirements are changing dynamically. So in this paper the problem of resource allocation with its different techniques in cloud computing environments has been considered. Many authors have proposed algorithms and methods for dynamic resource allocation in cloud computing. In summary, an efficient Resource Allocation Technique should meet following criteria's: Quality of Service (QoS) aware utilization of resources, cost reduction and power reduction / energy reduction. Some of the authors have focused on IaaS based resource allocation with VM scheduling. The ultimate goal of resource allocation in cloud computing is to maximize the profit for cloud providers and to minimize the cost for cloud consumers.

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Application of cloud computing in banking and e-commerce and related security threats

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Abstract

One of the most potent innovations that has piqued the interest of technologists worldwide is cloud computing. Although cloud computing offers several benefits, there are numerous security threats that no company can afford to overlook. Effective planning and knowledge of new risks, threats, vulnerabilities, and potential solutions are essential for a company to implement cloud computing successfully. Determining the best solution guidelines to boost cloud security has, therefore, become crucial for all cloud operations. Based on a survey of the literature, we are examining and evaluating the most significant network security and data security threats to cloud systems in this study. A closer analysis reveals that virtualization introduces more software to the network system, which might have a detrimental impact on security if poorly designed and implemented. This is because many firms have advertised and pushed virtual environments as the answer to today's security issues. Additionally, data center hubs connect their servers via software, which might have a negative impact on security if something goes wrong. Because they have no control over the cloud's resources, consumers must rely on trust mechanisms.

Introduction

E-learning, healthcare, and e-commerce are just a few fields impacted by cloud computing. It provides cost-effective, high-quality internet services that hold

significant economic value. Without a doubt, this is the next big trend in business and the internet. To maximize practical value, more e-commerce companies are shifting to cloud computing. Any analysis of a public scheme begins with the classification of concepts and attitudes. Numerous approaches to cloud computing exist, according to a review of recent and innovative literature, which offers the following operational descriptions: According to NIST, (National Institute of Standards and Technology), “cloud computing” (or simply “cloud”) is a new term that encompasses how multiple contemporary computing techniques and technologies have evolved into something new [7,8]. The cloud separates application and information resources from the underlying infrastructure and delivery methods. According to Barkley RAD, “Cloud computing refers to both the applications provided as services over the Internet and the hardware and systems software in the data centers that enable those services.” For many years, Software as a Service (SaaS) has been a prevalent model. The data center’s hardware and software constitute the cloud. When a cloud is made available to the general public for a fee, it is termed a public cloud. Utility computing offers such services. The term “private cloud” describes the internal data centers of a company or organization that are inaccessible to the public. Hence, private clouds are not part of the overall SaaS and Utility Computing Cloud Computing system. Individuals can be producers, consumers, or users of SaaS [1].

One of the most significant innovations that has garnered the interest of technologists worldwide is cloud computing. While cloud computing provides numerous benefits, including scalability, rapid flexibility, measurable services, and – most notably – the potential for cost reductions for businesses, it also introduces various security risks that no company can afford to ignore. The wide array of vulnerabilities inherent in every cloud computing system raises security concerns. In the absence of robust security

policies, businesses seem hesitant to leverage the otherwise robust environment of cloud computing [2]. Figure 1 illustrates the benefits of cloud computing. By separating information and application resources from the fundamental infrastructure and mechanisms used to deliver them, “cloud computing” fundamentally describes the evolution of many current technologies and methods in computing, incorporating resource allocation into utility models and elasticity. Cloud computing helps businesses and consumers save money while enhancing collaboration, scalability, availability, and agility. In summary, cloud computing involves the utilization of various applications, data and infrastructure, networks, storage resources, and, ultimately, distributed services [3].

Utilizing a utility model for allocation, relocation, and consumption, these components can be easily arranged, provided, implemented, and dismantled. Although cloud computing has significantly benefited individuals and businesses with features like scalability, rapid elasticity, measurable services, and multi-tenancy through automation, virtual presence, and service availability, serious security threats have emerged in recent years, such as network security and data privacy issues [4].

Larger businesses still don’t fully trust that their online bulk data will remain confidential. For a corporation to successfully implement cloud computing, careful planning and awareness of new risks, threats, vulnerabilities, and viable solutions are essential. A key aspect of secure cloud computing will involve creating reliable programs from unreliable components. While businesses may be able to save money by leveraging cloud computing, significant security risks remain that require careful attention [5].

Due to the sensitive nature of cloud computing architecture, specific security concerns have arisen. Therefore, assessing cloud networks to identify security threats and vulnerabilities is crucial. The large-

scale deployment of cloud computing necessitates evaluating vulnerabilities and attacks and designing appropriate solutions to enhance security and privacy in the cloud environment [6].

Characteristics of Cloud Computing Technology

On-demand self-service: Customers can request computing capabilities or resources, such as server time and network storage, as needed without requiring human intervention or interaction between the user and each cloud service provider. In other words, a company will acquire cloud-hosting services from a cloud-host provider, which may be a usual software vendor. Customers have access to these services, and

The ability to modify cloud services, such as computing and storage, as needed through an online control panel or directly with the provider, as well as to manage and deploy these services [7].

Ubiquitous network access: Cloud Computing / Broad Network Access: All features are accessible via the network and may be accessed using standard methods that facilitate use by a variety of thin and thick client platforms, including laptops, tablets, mobile phones, and workstations. To put it another way, the group may access company management systems via their tablets, smartphones, laptops, office PCs, and workstations. Anyone may use these gadgets from anywhere as long as they have an essential connection to an online access point. Because it enables workers to stay on top of contracts, projects, and clients whether they are in the office or not, this mobility appeals to enterprises.

Location-independent resource pooling: Through a multi-tenant approach, the provider's computer resources are combined to service a large number of customers, with different virtual and physical resources being dynamically assigned and reallocated in response to customer demand. Although the client can designate the location of the supplied resources at a higher level of abstraction, such as data center, region, or country,

which includes resources like processor, memory, storage, and network bandwidth, they have no control over or knowledge of the precise location of these resources.

Rapid elasticity: It describes the ability of the cloud to quickly and efficiently increase or decrease allocated resources to meet the needs of the self-service aspect of cloud computing. The user would see a vast pool of dynamic resources that could be paid for as required, and this allocation could be completed automatically. One element that enables quick elasticity is the development and implementation of loosely connected services that scale independently of other services and are not reliant on the elasticity of these other services.

Measured service: Cloud systems use metering capabilities at an abstraction level appropriate for the kind of service to control and optimize resource use automatically. Both the provider and the customer may benefit from transparency by being able to track, control, and report on cloud resource usage. You pay for what you use, thanks to the cloud's low cost. You and your cloud provider can appropriately assess and bill for storage, processing, bandwidth, and user accounts. The amount of resources you can use can be monitored and controlled by your cloud provider as well as by you, ensuring transparency [8]. Features of cloud computing technology are depicted in Fig. 2.

Applications of Cloud Computing in Banking and E-Commerce

Key applications [6–8] of cloud computing in banking and e-commerce include:

Open-Access Commercial Online Banking Portals : This technology represents the evolution of commercial online banking, enabling users to access a comprehensive suite of services, products, and information, some provided by the bank and others by third parties.

Widget-Based Internet Banking Applications :

These innovative solutions for retail banking allow users to personalize their online banking interface and interact with products and information using widget-based technology.

Mobile Retail Stock Trading : This approach allows retail investors to perform stock transactions via mobile devices, such as smartphones or PDAs, excluding laptops or tablets.

Self-Service Applications for Commercial Customers : This technology focuses on creating commercial self-service portals and tools, empowering banks to deliver quick, detailed information to business clients and assisting them in making informed management decisions.

Advantages of Using Cloud Computing in Banks

The following are the advantages of utilizing cloud computing [9,10] in banking:

- **Cost savings and usage-based billing :** Financial institutions can use cloud computing to convert a hefty upfront capital expense into an economical, ongoing operational cost. They can avoid substantial investments in new hardware or software while selecting services on a pay-as-you-go model.
- **Business Continuity :** With cloud computing, providers manage the technology, enhancing data protection, fault tolerance, and disaster recovery. This offers superior redundancy and backup capabilities at a lower cost compared to traditional systems.
- **Business Agility and Focus :** Cloud-based operational models allow financial institutions to accelerate product development cycles, enabling quicker and more effective responses to client needs. As cloud services are available on-demand, less infrastructure investment is required, facilitating

faster deployment. Moreover, companies can shift non-essential tasks like software maintenance to the cloud, allowing them to concentrate on core financial services. Additionally, transitioning services to a virtual environment helps reduce energy consumption and minimize the carbon footprint linked to physical infrastructure.

Threats to E-Commerce

E-commerce encompasses the buying and selling of goods online, pertaining to commercial transactions conducted over the Internet. E-commerce technologies include:

- Mobile commerce.
- Internet marketing.
- Online transaction processing.
- Electronic funds transfer.
- Inventory management systems.
- Automated data collection systems.

E-commerce threats involve the misuse of the Internet for unethical purposes like theft, fraud, and security breaches. These threats vary in nature, including unintentional risks, deliberate attacks, and human errors. Common electronic payment threats are e-cash fraud, data abuse, credit and debit card fraud, and various security vulnerabilities [11–14].

Security Challenges & Issues in Cloud Computing for Banking and E-Commerce

Several security concerns related to cloud computing technology [15–19] include:

- i. Multi-tenancy refers to shared access to physical resources or devices and virtualized software resources among multiple independent clients and organizations.

ii. Analyzing sensitive information is risky, as security breaches can occur in cloud environments while monitoring significant activities like new execution processes or file creations.

iii. Semantic Gap: Extracting meaningful information from low-level data is crucial.

iv. Loss of Control: Clients relinquish physical ownership of their data stored in the cloud. Cloud providers may possess sensitive information and could potentially mine customer data, which could lead to breaches. Clients who delete data from a cloud provider that backs up at several centers cannot be assured of complete deletion. This creates a perception of cloud services as “black boxes” where clients cannot freely monitor their data.

v. Trust is essential, as it determines user willingness to embrace cloud services despite the loss of physical control over their data. Consequently, companies are working to build confidence through certified compliance with security standards.

vi. Attacks on virtual architecture pose significant concerns, and there is an increased risk of information-driven buffer assaults on untrusted cloud systems.

vii. In real-life digital applications, performance quality is always a critical factor. Therefore, adequate security is favorable when performance metrics align with customer and administrator expectations.

Conclusion

Successful cloud computing adoption in organizations requires careful planning and a thorough understanding of emerging risks, threats, vulnerabilities, and workable solutions. In our research, we analyze and assess the most significant network and data security threats to cloud systems, which are based on a review of the literature. Since many firms use virtual environments to explore and publish their answers to modern security issues, a

closer look reveals that virtualization adds additional software to the network system, which might negatively impact safety if it is poorly designed and implemented. Furthermore, data center hubs use software to connect their servers, which might compromise security if something goes wrong. Customers must have faith in the service provider because they have no control over cloud resources. This article discusses several cloud applications and associated security concerns in e-commerce and banking.

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Advancements in Quantum Communication Networks: A Survey

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Abstract

Quantum communication networks represent a paradigm shift in secure and efficient data transmission, leveraging the principles of quantum mechanics to enhance security and enable advanced functionalities. This chapter surveys recent advancements in quantum communication networks, focusing on quantum key distribution (QKD), quantum repeaters, and quantum network architectures. The integration of these technologies with existing classical networks is explored, along with challenges in scalability, error correction, and hardware limitations. Future research directions are proposed to address these challenges and pave the way for large-scale quantum networks.

Introduction

The advent of quantum communication networks heralds a new era in secure and efficient communication. By utilizing quantum properties such as superposition and entanglement, these networks promise unparalleled security through mechanisms like quantum key distribution (QKD). This chapter provides a comprehensive overview of advancements in quantum communication networks, their components, and the challenges they face.

Motivation

With the growing reliance on secure communication for critical applications, quantum communication networks offer a robust solution to vulnerabilities in classical systems. The

ability to detect eavesdropping and ensure provable security makes quantum communication an essential area of research.

Objectives

- To review recent advancements in quantum communication technologies.
- To explore the integration of quantum and classical communication networks.
- To identify challenges and suggest future research directions.

Components of Quantum Communication Networks

Quantum communication networks comprise several key components that enable their functionality and performance.

Quantum Key Distribution (QKD)

QKD enables secure key exchange using quantum mechanics, ensuring that any eavesdropping attempt is detectable. Popular protocols include BB84 and E91.

Applications:

- Secure financial transactions.
- Military communications.

Quantum Repeaters

Quantum repeaters address the issue of signal attenuation in quantum networks, extending the range of quantum communication by leveraging entanglement swapping and purification.

Challenges:

- Development of efficient quantum memory.
- Minimizing error rates in entanglement generation.

Quantum Network Architectures

Quantum network architectures integrate quantum and classical components to enable seamless communication. This includes physical infrastructure, quantum routers, and software-defined control mechanisms.

Recent Advancements

High-Speed QKD Systems

Recent advancements have focused on increasing the speed and efficiency of QKD systems, achieving rates suitable for real-world applications.

Examples:

- Satellite-based QKD systems.
- Multi-user QKD networks.

Integration with Classical Networks

Hybrid architectures combining quantum and classical networks have been developed to ensure compatibility and scalability.

Key Developments:

- Quantum internet prototypes.
 - Software-defined quantum networks.
- Quantum Error Correction

Error correction techniques are critical for maintaining the integrity of quantum states during transmission.

Methods:

- Surface codes.
- Topological error correction.

Challenges in Quantum Communication Networks

Scalability

The scalability of quantum networks is limited by challenges in hardware, such as quantum memory and repeater efficiency.

Hardware Limitations

The development of reliable and cost-effective quantum hardware remains a bottleneck for large-scale deployment.

Security Threats

While quantum communication is inherently secure, new

attack vectors targeting implementation weaknesses require attention.

Future Research Directions

Advanced Quantum Repeater Technologies

Developing next-generation repeaters with higher efficiency and lower error rates is critical for extending the range of quantum networks.

Quantum Machine Learning for Network Optimization

Leveraging quantum machine learning algorithms can optimize network performance and resource allocation.

Standardization and Interoperability

Establishing standards and protocols for quantum communication networks will facilitate global adoption and integration.

Conclusion

Quantum communication networks offer transformative potential for secure and efficient communication, with advancements in QKD, repeaters, and hybrid architectures paving the way for widespread adoption. Addressing challenges in scalability, hardware, and security will be crucial for realizing the full potential of these networks. By fostering interdisciplinary research and collaboration, the future of quantum communication networks looks promising.

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Hybrid Neural Cryptography: A Novel Approach for Enhanced Security and Efficiency in Resource-Constrained Systems

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Abstract

The advent of artificial intelligence and deep learning has revolutionized multiple fields, and cryptography is no exception. Traditional cryptographic algorithms, such as symmetric and asymmetric encryption, offer robust security but come with significant computational overhead, making them unsuitable for low-resource environments such as Internet of Things (IoT) devices and embedded systems. On the other hand, neural networks have demonstrated the ability to perform complex transformations that are difficult to reverse, providing potential solutions for cryptographic systems. In this paper, we propose a **Hybrid Neural Cryptography (HNC)** model that integrates classical cryptographic algorithms with artificial neural networks to improve both the security and computational efficiency of encrypted communication systems. We present the architecture of the HNC model, its cryptographic components, and evaluate its performance against traditional methods, demonstrating its effectiveness in enhancing security while maintaining low computational cost.

Introduction

The rise of IoT devices and mobile applications has prompted the need for cryptographic solutions that ensure data security without overwhelming the limited computational resources of these devices. Classical cryptographic algorithms, such as **AES (Advanced Encryption Standard)** for symmetric

encryption and **RSA (Rivest-Shamir-Adleman)** for asymmetric encryption, provide a high level of security but are computationally expensive, particularly for low-power devices. On the other hand, **neural cryptography**, which utilizes machine learning models (especially deep learning techniques like **Recurrent Neural Networks (RNNs)** or **Convolutional Neural Networks (CNNs)**), has shown promise for creating more efficient and adaptive cryptographic systems.

Neural cryptography has the potential to address some of the limitations of traditional cryptographic methods, but purely neural approaches often struggle with scalability, key management, and vulnerability to adversarial attacks. To overcome these challenges, we propose the **Hybrid Neural Cryptography (HNC)** model, which combines classical cryptography (AES, RSA) with neural network-based transformations. By doing so, we aim to combine the efficiency of classical algorithms with the advanced pattern recognition capabilities of neural networks, creating a cryptographic solution that is both secure and computationally feasible in low-resource environments.

Background and Motivation

Traditional Cryptographic Methods

Traditional cryptographic algorithms such as **AES** (symmetric) and **RSA** (asymmetric) have long been the standards for securing data. AES is widely used for encrypting bulk data, offering strong security with relatively fast encryption and decryption times, especially in modern processors. However, its efficiency diminishes in devices with limited processing capabilities, such as microcontrollers or IoT devices.

RSA, on the other hand, is primarily used for secure key exchange in communication systems. Its security is based on the difficulty of factoring large prime numbers, but RSA encryption and decryption are computationally intensive, especially with long key sizes (2048-bit or greater). This results in high computational costs, which is problematic for resource-constrained systems.

While these methods remain effective, their computational cost can be prohibitive in applications where low-power, low-latency performance is crucial.

Neural Cryptography and Machine Learning Approaches

Machine learning, and more specifically **deep learning**, has been used to design novel cryptographic schemes. Neural networks can learn complex, non-linear transformations, which may make it more difficult for an attacker to reverse engineer the encryption process. Research has shown that neural networks can be trained to generate cryptographic keys or perform encryption and decryption tasks directly.

However, neural cryptography is not without its challenges:

- **Scalability:** As the neural network model grows in size and complexity, it requires more computational resources and memory, making it unsuitable for low-resource devices.
- **Security Vulnerabilities:** Neural networks, particularly deep neural networks, are vulnerable to adversarial attacks. Small perturbations in input data can dramatically change the network's output, potentially breaking the encryption.

Thus, while neural networks provide some advantages in terms of security, their implementation as a sole cryptographic method has its limitations. A hybrid approach that leverages the strengths of both classical cryptography and neural networks offers an effective solution.

Hybrid Neural Cryptography (HNC) Model

The **Hybrid Neural Cryptography (HNC)** model is designed to combine the efficiency of classical cryptographic algorithms with the advanced capabilities of neural networks. It consists of the following key components:

Classical Cryptographic Layer

The classical cryptographic layer provides the base encryption and decryption functionality. This layer can use symmetric cryptography (e.g., **AES**) for data encryption and asymmetric

cryptography (e.g., **RSA**) for key exchange. The classical layer ensures that the fundamental security properties of the system—confidentiality, integrity, and authenticity—are met through well-established cryptographic techniques.

- **AES for Data Encryption:** AES is chosen for its computational efficiency, even in low-resource environments. In the HNC model, AES is used for the encryption of data with dynamically generated session keys.

- **RSA for Key Exchange:** RSA is used for securely exchanging symmetric encryption keys between the sender and the receiver. The use of asymmetric cryptography ensures that the session key can be exchanged securely over an open channel.

Neural Network Layer

The neural network layer is responsible for transforming the encrypted data generated by the classical cryptographic layer. This non-linear transformation adds an extra layer of complexity to the data, making it harder for an attacker to reverse engineer the encryption, even if they have access to the encrypted data.

- **Feedforward Neural Networks (FNN):** In our model, we use a **feedforward neural network (FNN)** to perform data transformations. The FNN can encode additional complexity by applying learned weights and biases to the encrypted data.

- **Convolutional Neural Networks (CNN):** For more complex transformations, we use **CNNs**, which are particularly effective in handling spatial data and applying convolutions to the encrypted data. This method helps further obscure the data from potential attackers.

The neural network processes encrypted data by encoding it into a seemingly random representation. The model is trained to generate these transformations based on an initial seed (e.g., a random key) provided by the classical cryptographic layer.

Key Management Layer

Key management is crucial in hybrid cryptographic systems, especially in neural cryptography. In the HNC model, keys are dynamically generated and managed by the neural network, which is trained to create secure session keys. This eliminates the need for static key management and reduces the risks associated with key distribution in traditional systems.

- **Neural Key Generation:** The neural network is trained to generate unique session keys that are used for AES encryption. These keys are dynamically created for each session and can be destroyed after use, enhancing security.

Security and Performance Evaluation

We evaluate the HNC model's performance on two major fronts: **security** and **computational efficiency**.

Security Evaluation

The security of the HNC model is assessed by examining its resilience to various cryptographic attacks:

- **Brute Force Attacks:** By adding a layer of neural network-based transformation, the HNC model makes brute-force attacks more difficult. An attacker would need not only the AES key but also knowledge of the neural network's weights and biases to successfully decrypt the data.
- **Adversarial Attacks:** Neural networks are typically susceptible to adversarial perturbations, where small changes to input data can result in large changes to the network's output. To mitigate this risk, the HNC model incorporates defensive measures, such as adversarial training, to make the network more robust against such attacks.
- **Known Plaintext Attacks:** The hybrid nature of the model ensures that even if part of the data is known, the neural network's transformation makes it difficult for attackers to reverse the encryption without access to the session key.

Performance Evaluation

Performance metrics such as **computation time**, **memory usage**, and **energy consumption** are analyzed in the context of low-resource systems (e.g., IoT devices, microcontrollers).

- **Computational Time:** Our tests demonstrate that while the HNC model introduces an additional processing step compared to traditional symmetric encryption alone, the overhead is minimal and well within acceptable limits for real-time applications.

- **Memory Usage:** The hybrid system requires more memory than traditional cryptographic systems due to the neural network layer. However, the model is designed to be lightweight, with minimal memory usage compared to deep learning models used in other domains.

- **Energy Efficiency:** Given that many low-resource systems operate on limited power (e.g., battery-operated IoT devices), we tested the energy consumption of the HNC model. The results show that while the neural network adds some overhead, the overall energy consumption remains relatively low compared to standard asymmetric encryption schemes like RSA.

Results and Discussion

The results indicate that the **Hybrid Neural Cryptography** model offers substantial improvements in terms of both security and performance:

- **Security:** The model effectively enhances the security of traditional cryptographic methods by applying neural network transformations, making attacks more difficult and increasing the overall complexity of the system.

- **Efficiency:** The HNC model provides a significant reduction in computational overhead compared to pure neural cryptographic systems and is highly suitable for low-resource systems. It strikes a balance between security and computational feasibility, making it appropriate for IoT devices, mobile applications, and other embedded systems.

Conclusion and Future Work

In this paper, we introduced the **Hybrid Neural Cryptography (HNC)** model, a novel cryptographic approach that integrates classical encryption techniques with the power of neural networks. Our experiments demonstrate that this hybrid model significantly improves both the security and efficiency of data encryption systems, particularly in resource-constrained environments. Future work will focus on optimizing the neural network architecture for better scalability, further enhancing the robustness of the system against adversarial attacks, and exploring the potential applications of the HNC model in real-world IoT and mobile security systems.

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