

# Future and Advancements in Cloud Computing

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**Abstract-** Cloud computing has transformed information and communication technology, offering flexible resource access through a pay-as-you-use model. However, the proliferation of large-scale server farms raises concerns about energy consumption and the environment. Researchers focus on energy-saving methods like workload scheduling and virtual machine allocation. Emerging trends like on demand mini-clouds, mixed infrastructure environments, distributed computing with shared resources, event driven cloud execution and programmatic infrastructure control. Green computing aims to reduce carbon emissions through measures like virtualization. Edge computing enhances IoT service reliability and security. AI optimizes resource allocation and anomaly detection. Blockchain integration enhances trust in cloud transactions.

**Keywords-** Cloud Computing, Server Farms, Virtual Machine Allocations, Software Defined Computing, Green Computing, Artificial Intelligence, Blockchain Integration, Access Control, Cloud Transaction, Decentralization.

## I. INTRODUCTION

The paradigm of cloud computing has undeniably transformed the landscape of information and communication technology, offering on-demand access to flexible resources—ranging from infrastructure and platforms to software—as services, all based on a pay-as-you-use model. The escalating demand for cloud computing services has led to the establishment of large-scale server farms, housing intricate servers that consume significant amounts of electrical energy and contribute to environmental concerns by emitting CO<sub>2</sub>. [1] In this context, energy conservation in data centers has become a pivotal focus, with literature highlighting two critical aspects: computing and cooling.

The Next Generation of Cloud Computing entails addressing the substantial costs associated with these data centers, particularly in the realms of computing operations and cooling systems. Power consumption is substantial in both operating servers and the subsequent cooling processes. The imperative to curtail energy bills and reduce the carbon footprint has spurred research endeavors aimed at devising methods to diminish energy requirements in cloud computing environments. [1][2] The escalating power consumption, coupled with the high pressing density of servers, has led to a notable increase in heat dissipation and temperature within server farms, impacting reliability and system performance.

This paper delves into a succinct exploration of energy-saving

methodologies in cloud computing, recognizing the crucial role of workload scheduling and virtual machine allocation in conserving energy. The study emphasizes the significance of minimizing the number of hosts for task allocation to achieve energy efficiency. Additionally, it highlights the wastage associated with virtual machine migration, a critical factor contributing to the overall energy consumption in cloud computing. As the utilization of cloud server farms continues to burgeon in both quantity and scale, the energy consumption of these data centers has become a pressing environmental concern. This research aims to contribute to the discourse on energy utilization in cloud computing, recognizing its indispensable role in addressing environmental impacts and fostering sustainable practices in the ever-expanding domain of cloud technology.

## CURRENT SCENARIO

This section explores the historical advancements in cloud computing's energy efficiency, examining how existing strategies have been improved and new techniques incorporated to minimize power consumption. The focus is on how these efforts have balanced improvements in Quality of Service (QoS) with the specific areas of study (FoS) addressed in the referenced research ([1, 3]). The development of numerous Energy-Efficient Algorithms (EEAs) has played a key role in optimizing the cloud environment, leading to better resource utilization, responsiveness, performance, and other QoS factors.



Fig. 1. Energy Efficiency Evolution

To minimize energy consumption, cloud providers focus on several key areas: servers, storage, memory, network infrastructure, and cooling systems. Since servers are major energy consumers, techniques like Dynamic Voltage Frequency Scaling (DVFS), server consolidation, and virtualization are employed to optimize their power usage [2]. Networking strategies involve

powering down idle components and directing virtual network traffic through fewer active devices. Cooling remains a critical aspect, with raised floors offering an efficient solution by capturing warm air and converting it to cool air before expelling it outside the data center.

### 1) New Trends and Directions

Traditionally, cloud services rely on dedicated computing power and storage housed within centralized data centers. While leveraging a single provider's data center can offer a streamlined experience with clear benefits for cloud application hosting, this approach also presents limitations. To address potential failures in the cloud, strategies involve deploying redundant compute systems, creating multiple zones, and establishing backup data centers.[2]

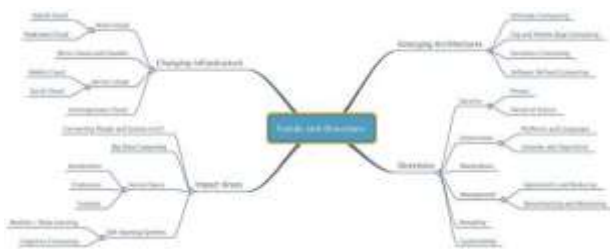


Fig. 2. Trends and Direction

Recent years have witnessed the proposal of alternative cloud infrastructure models, moving away from the reliance on a single provider's data centers. While the adoption of multi-clouds is on the rise, certain obstacles need addressing. A key challenge lies in creating standardized interfaces (APIs) that enable seamless multi-cloud deployments. These APIs need to be flexible enough to accommodate the vast range of resources offered by different cloud providers.[2] These hurdle underscores the need for standardized interfaces capable of handling the variability in resources across different cloud providers, ensuring seamless integration and efficient operation in a multi-cloud environment.

### A) Micro Cloud

*Micro-Clouds play a crucial role in minimizing application latency and reducing the frequency of communication between user devices and data centers. Devices like O-droid boards and Raspberry Pi's are commonly utilized for micro-cloud development, showcasing their potential benefits.[1][2] However, integrating micro-clouds into the existing computing ecosystem poses challenges, and ongoing efforts are dedicated to overcoming these challenges.*

*A significant challenge is the development of efficient runtime application scheduling that can effectively combine micro-clouds with traditional data centers. This requires splitting applications and their data strategically between high-performance processors in data centers and low-power processors in micro-clouds. The goal is to optimize overall performance based on user-defined priorities.*

*In a decentralized cloud computing approach, tasks of applications need to be offloaded from both data centers and user devices onto micro clouds. A critical challenge in this context is effectively utilizing micro clouds, which may not always be available, while managing network abstraction between the cloud and the edge without relying on specific underlying hardware.[2] This underscores the need for adaptable solutions that can seamlessly integrate micro clouds into the broader computing.*

### B) Heterogeneous Cloud

*Cloud computing embraces heterogeneity in two key ways. At the high level, multi-cloud platforms that manage services and infrastructure from multiple providers inherently exhibit heterogeneity. This stems from the use of various hypervisors and software suites from different vendors [1, 2, 3]. On the other hand, heterogeneity can also exist at the infrastructure level, where different types of processors are combined to create virtual machines offering diverse computing capabilities. This approach contrasts with supercomputers, which increasingly leverage specialized accelerators like NVIDIA GPUs or Intel Xeon Phis, while cloud data centers typically favor homogeneous architectures.*

*Second perspective involves Heterogeneous compute pool, where diverse processors are amalgamated to provide Virtual Machines (VMs) with varied compute resources.[1][2][3] In this context, we term it as heterogeneous clouds. Unlike supercomputers, which increasingly incorporate accelerators like Intel Xeon Phis or NVIDIA GPUs, cloud based data centers predominantly rely on homogeneous architectures.*



Fig. 3. Abstraction Layers

*Distinguishing between these two forms of heterogeneity provides a nuanced understanding of the varied facets of cloud computing. Multi-clouds introduce diversity through the integration of infrastructure and services from multiple providers, while heterogeneous clouds at the infrastructure level leverage different processor types to offer VMs with diverse computing capabilities.[1] This differentiation is crucial for navigating the complexities of cloud computing architectures and optimizing performance based on specific requirements and objectives.*

### 2) Green Computing

Cloud computing, despite concerns about increased energy usage, presents a promising avenue for reducing carbon emissions through various efficiency measures. Cloud providers employ technologies such as virtualization to achieve

better utilization of resources compared to traditional computing, leading to lower energy consumption.

Virtualization, a key technology driving energy-efficient clouds, allows for the consolidation of underutilized servers by hosting multiple virtual machines (VMs) on the same physical server.[1][3] This consolidation leads to savings in space, management, and energy.

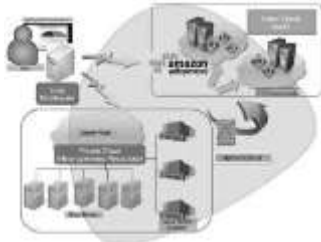


Fig. 4. Deployment Models in cloud

Dynamic provisioning is another factor contributing to energy savings in cloud computing. Unlike traditional setups, where infrastructure is maintained to meet worst-case demand scenarios, cloud data centers dynamically allocate resources based on current demand. This approach reduces over-provisioning and lowers energy consumption.

Multi-tenancy, where multiple tenants share the same infrastructure and software, is also instrumental in reducing energy usage.[1] By serving multiple companies on the same infrastructure, cloud providers achieve higher efficiency compared to deploying separate infrastructure for each tenant.

Efforts to improve server utilization further contribute to energy savings. Through virtualization technologies, multiple applications can run on the same server, increasing utilization levels and reducing the number of active servers required. Although higher server utilization may result in increased power consumption, the overall workload processed per unit of power remains more efficient.

Data center efficiency plays a crucial role in reducing energy consumption. Cloud providers employ energy-efficient technologies and designs, such as modular containers, advanced cooling systems, and optimized power management, to achieve high levels of efficiency.[1][3] Additionally, cloud computing enables workload migration between data centers, allowing services to run in facilities with better energy efficiency metrics.

Overall, the adoption of cloud computing can lead to significant reductions in carbon emissions for organizations. By leveraging the efficiency of large-scale cloud data centers, organizations can achieve savings of up to 30% per user by migrating their applications to the cloud.

### 3) Edge Computing Integration

Edge computing pushes processing power to the network's fringes. This technology enables devices at the edge to handle tasks like processing data for cloud services and managing data streams for Internet of Things (IoT) applications.

Edge devices are no longer passive consumers. They can both request and receive data and services from the cloud, while also performing local computations. This includes functions like offloading complex calculations, storing data locally, caching frequently accessed information, and processing data closer to its source. Additionally, edge devices play a role in distributing requests and delivering content from the cloud to users.[4] Given these diverse responsibilities within the network, the design of the edge itself is crucial to efficiently meet requirements in terms of reliability, security, and privacy protection.

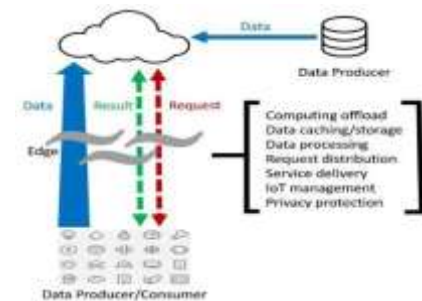


Fig. 5. Edge Computing Paradigm

### 4) Artificial Intelligence usage in Cloud Computing

**AI-Driven Resource Allocation:** Efficient resource allocation is critical for optimal cloud application performance. AI, particularly machine learning and deep learning, analyzes historical data to predict resource usage patterns and dynamically adjust allocations based on real-time demand. This proactive approach ensures smooth application operation while minimizing resource waste. Traditionally, resource allocation relied on static configurations or manual adjustments, leading to inconsistent performance.[1][5] AI transforms this paradigm by enabling data-driven decision-making and real-time adjustments, enhancing performance and reducing operational costs.

**Predictive Scaling:** Scaling applications to meet varying workloads is a challenge in cloud computing. AI-driven predictive scaling uses historical usage patterns to forecast future demands and adjust resources proactively. By analyzing past trends and behavior, AI ensures applications operate optimally even during peak usage periods. This proactive approach eliminates under- or over-provisioning scenarios, enhancing user satisfaction and operational efficiency.

**Anomaly Detection and Performance Monitoring:** Maintaining consistent performance in cloud applications is crucial but challenging due to their complexity. AI-based anomaly detection continuously monitors system metrics, promptly



identifying deviations from normal behavior.[5] This proactive approach allows for timely intervention, minimizing downtime and optimizing performance. By analyzing various parameters, AI algorithms detect anomalies and enable corrective actions, safeguarding application integrity and enhancing operational efficiency.

##### 5) Blockchain and Cloud Integration

It examines two foundational elements: verifying user identities and access rights (through authentication/access control) and monitoring user behavior for adherence to trust principles. In parallel, it investigates a blockchain-enhanced framework with modules for secure cloud transactions, optimized resource allocation, and trust-enabled virtualization. Additionally, it explores data management aspects like access control, data provenance (tracking data origin and history), and secure storage within this blockchain framework. This combined approach aims to establish a secure and transparent cloud environment in the context of a blockchain-based basic trust framework, traditional trust frameworks often rely on a centralized model, where the central node bears a substantial burden of computing and processing overhead. This centralized approach can lead to potential failures, including single-point failures and malicious fraud, and may not adapt well to real-time application scenarios.[1][6] Furthermore, as trust evidence is typically visible only to the central node, trust evaluations might not receive full recognition.

The inherent decentralization feature of blockchain addresses these issues by distributing the process of trust authentication. This decentralization mitigates problems associated with centralization, offering a more robust and adaptable solution. The blockchain-based basic trust framework leverages the decentralized nature of blockchain to enhance trust authentication, promoting a more resilient and transparent trust evaluation system.

##### A) Identity and Authentication

Identity management is critical for building trust in the cloud. Authentication verifies the legitimacy of both service providers and customers participating in cloud marketplaces. However, traditional methods often depend on a central authority, raising concerns about potential security vulnerabilities like a single point of failure and excessive control by the certification body. [6, 10]

In the context of distributed systems, an alternative approach is identity federation, aiming to address trust and security challenges across multiple domains. However, this introduces complexities in system design operations.

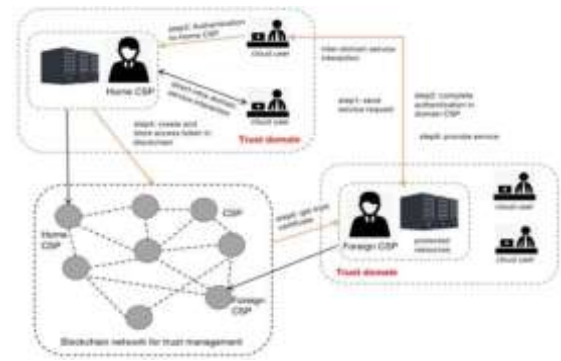


Fig. 6. Blockchain as an Identity Platform

##### B) Blockchain Cloud Transaction

Cloud computing operates as a business model providing IT services, with service transactions serving as its core activities. Security is paramount in such an environment to ensure safe transactions. The Cleanroom Security Service Protocol (CSSP) stands out for its focus on securing Software as a Service (SaaS) environments. This bilateral agreement leverages a consortium blockchain framework, offering a unique approach within the cloud security landscape. [1][6][9].

This detection platform offers several advantages: it acts as a two-way security measure protecting both providers and users, utilizes a consortium blockchain to reduce processing burdens, and leverages smart contracts for faster software deployment and automated responses to malicious activity. However, it's important to acknowledge that the platform's scope, as presented in the literature, is somewhat limited as it focuses on traditional network models without integrating trust and security mechanisms.

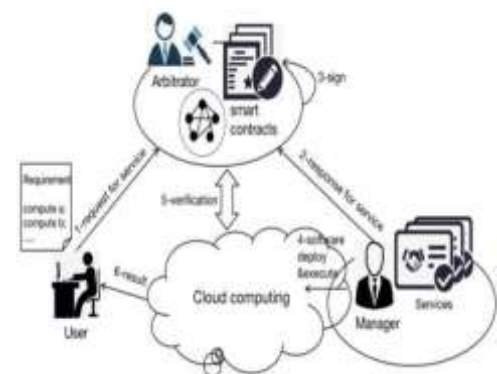


Fig. 7. Main Process in CSSP

## II. CASE STUDIES

### A) Smart Home

The integration of IoT technology holds significant potential for enhancing the home environment. While basic smart home devices like connected light bulbs and TVs exist, simply adding Wi-Fi to appliances isn't enough. A truly smart home goes beyond mere connectivity. It utilizes a network of affordable wireless sensors and controllers to create a more intelligent and responsive environment. [1][3] These sensors should be strategically placed in rooms, pipes, floors, and walls. They generate a substantial amount of data, and to address concerns related to data transportation pressure and privacy protection, it is imperative to primarily utilize and process this data within the confines of the home. This approach ensures efficient data management while safeguarding privacy considerations.

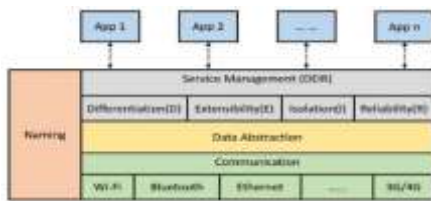


Fig. 8. OS Structure For Smart Home

### B) Collaborative Edge

The potential for collaboration among various stakeholders is often constrained, given the existing limitations. The concept of edge computing, essentially mini data centers bridging the gap between the cloud and users with on-site processing power, can be further expanded. Researchers have proposed the idea of a Collaborative Edge, where geographically dispersed edges operated by different stakeholders can interconnect despite their physical separation and network variations. [3] These interconnected edges function similarly to ad-hoc networks, enabling stakeholders to share and collaborate on data seamlessly.



Fig. 9. Collaborative Edge Uses

The rise of geographically distributed healthcare applications, where data processing needs to occur closer to the source, highlights the need for collaboration and data exchange across different healthcare organizations. **Collaborative Edge presents a potential solution** by facilitating the seamless integration of geographically dispersed healthcare data through... (insert the rest of your sentence about how Collaborative Edge creates this solution).

. Collaborative Edge addresses this challenge by creating virtual shared data views. These anonymized data representations are accessible to authorized users via predefined service interfaces. Healthcare applications can then utilize these interfaces to develop complex services for patients and medical professionals. Importantly, computations occur entirely within each participant's data facility, ensuring data privacy and integrity. This secure and collaborative environment empowers healthcare organizations to leverage geographically dispersed data for improved patient care.

## CONCLUSION

In conclusion, the current state of cloud computing witnesses a dynamic evolution in energy efficiency strategies, focusing on servers, storage, memory, network, and cooling, facilitated by the adoption of Energy-Efficient Algorithms (EEAs) to optimize Quality of Service (QoS) parameters. Emerging trends such as micro-clouds, heterogeneous architectures, serverless computing, and Software Defined Computing (SDC) address challenges like application latency, resource diversity, and dynamic network management, reflecting the industry's response to evolving cloud service demands. Green computing initiatives underscore the potential of cloud technologies to reduce carbon emissions through efficiency measures like virtualization and dynamic provisioning. Integration of edge computing addresses IoT requirements, enhancing reliability and security, while AI-driven approaches optimize resource allocation and monitoring. Blockchain integration introduces trust frameworks, fostering transparency and resilience in cloud transactions. These advancements promise more efficient, sustainable, and secure cloud ecosystems, shaping the future of computing.

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