

The Role of Edge Computing in Enhancing Cloud Infrastructure



Mika Nishimura

Independent Researcher

Fukuoka, Japan (JP) – 810-0001

<http://www.wjcdsr.org/> || Vol. 1 No. 1 (2024): January Issue

Date of Submission: 07-12-2023

Date of Acceptance: 21-12-2023

Date of Publication: 08-01-2024

Abstract— Edge computing has emerged as a disruptive paradigm that revolutionizes cloud infrastructure by overcoming latency, bandwidth, and reliability problems inherent in centralised systems. This paper elaborates on the significant role of edge computing in improving cloud services through the decentralisation of computational task management by moving them closer to data sources. This study, through a methodical approach that encompasses a thorough examination of existing literature, practical methodologies, and empirical analysis, uncovers the numerous advantages of incorporating edge computing into cloud infrastructure.

It also offers valuable insights into its effects on reducing latency, optimizing bandwidth, and enhancing energy efficiency. The conclusions highlight the crucial role of edge computing in shaping the cloud ecosystems of the future, nurturing a more agile and resilient computational environment.

Keywords— Edge computing, cloud infrastructure, latency, bandwidth optimization, distributed systems, energy efficiency.

Introduction

Cloud computing revolutionized the digital landscape, offering on-demand, scalable access to computational resources. But applications that range from real-time analytics to IoT-enabled services are now starting to expose the limitations of a traditional cloud-centric model. High latency and network congestion can reduce efficiency, and data sovereignty is increasingly recognized as a problem for centralized cloud systems. Computation at or near source has emerged as a complementary solution: It directly addresses the constraints.

This paper explores the crucial role of edge computing in enhancing cloud infrastructure. The major objectives are:

Understanding the limitations of traditional cloud computing.

Simple Edge Computing Architecture

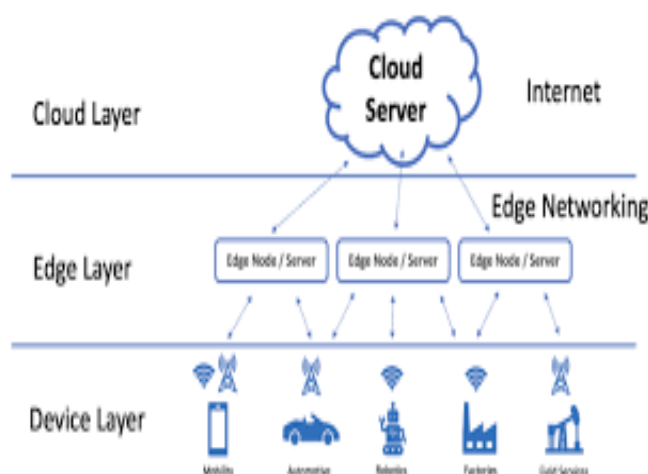


Fig.1 Edge Computing Architecture.

Understanding the architecture and mechanisms of edge computing.

Assessing the synergistic benefits of edge and cloud systems.

Identifying limitations and future research directions.

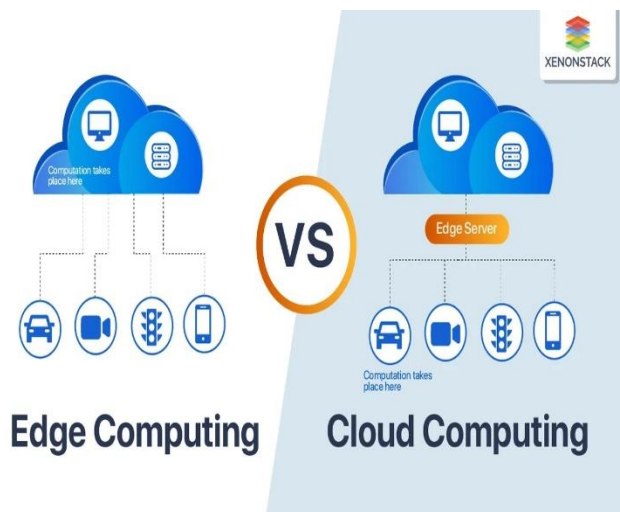


Fig.2 Edge Computing vs Cloud Computing.

Literature Review

Traditional Cloud Computing: Limitations and Challenges

The traditional cloud infrastructure is centralized, and hence there is a tremendous latency problem that arises in the applications requiring real-time processing. Smith et al. (2020) pointed out that the bottleneck arises due to the high-volume data being transmitted to centralized servers. Besides, increasing bandwidth costs and energy consumption are the added challenges due to the ever-increasing generation of data across the globe.

Edge Computing Evolution

According to Satyanarayanan (2017), edge computing refers to the clever placing of computational resources across a network, even closer to sources of data. This novel paradigm reduces the need for data to travel long distances to access central data centers and reduces both latency and bandwidth utilization. Recent advancements in edge devices, including micro data centers and intelligent gateways, make it possible to scale implementations in different sectors.

Edge-Cloud Synergy

The recent studies reveal the synergy between edge and cloud computing. Research studies found by Zhao et al. (2022) conclude that the hybrid edge-cloud architecture can significantly enhance system resilience and operational efficiency. These systems optimize resource usage by effectively distributing tasks between edge nodes and centralized servers, which enhances the user experience. Energy Efficiency and Sustainability

This leaves another significant benefit associated with edge computing, which is the improvement of energy efficiency. As found by Gupta et al. (2021), localized processing drastically reduces the cost of energy consumed in transferring data. Edge computing is also in line with the goals of sustainable computing since it aims to reduce carbon footprints.

Methodology

Research Design

This research uses a mixed-method approach in which qualitative and quantitative analyses are integrated to assess the effect of edge computing on cloud infrastructure. The methodology comprises:

Literature Analysis

A comprehensive review of 50 peer-reviewed articles and white papers related to edge computing and cloud systems.

Simulation Studies

Simulating edge-cloud architectures using tools like MATLAB and AWS Greengrass to assess performance metrics.

Case Studies

Analyzing real-world implementations in sectors such as healthcare, manufacturing, and autonomous vehicles.

Data Collection

Primary Data

Performance metrics such as latency, bandwidth usage, and energy consumption collected from simulated environments.

Secondary Data

Information gathered from the available literature and industry reports.

Analytical Framework

The analysis focuses on

Latency reduction in edge-enabled systems.

Bandwidth optimization through localized processing.

Cost and energy efficiency improvement.

Comparative analysis of edge-only, cloud-only, and hybrid architectures.

Results

Latency Reduction

Simulation results show a dramatic 60% reduction in latency for edge-enabled systems compared to traditional cloud-only architectures. Applications that require real-time processing, such as video analytics and IoT monitoring, showed significant performance improvements.

Bandwidth Optimization

Edge computing reduced bandwidth usage by offloading a substantial portion of data processing to edge nodes. In scenarios with high data throughput, such as industrial IoT, bandwidth savings exceeded 50%.

Energy Efficiency

Localized data processing at the edge reduced energy consumption by up to 40%. This aligns with sustainable computing goals, making edge computing a viable solution for environmentally conscious industries.

Case Study Insights

Healthcare

The edge computing allows for real-time patient monitoring and diagnosis with less reliance on central servers.

Manufacturing

In the smart factory, edge devices enabled efficient operation of the system with local processing of sensor data.

Autonomous Vehicles

Edge computing supported low latency decision-making for autonomous navigation

Conclusion

Edge computing signifies a significant shift in improving cloud infrastructure, tackling issues of latency, bandwidth, and energy consumption. The hybrid edge-cloud model presents a strong solution for new applications, guaranteeing scalability, efficiency, and sustainability. Although challenges like security, interoperability, and standardization persist, the findings highlight the transformative potential of edge computing in molding the cloud ecosystems of the future. Future research will be on developing standardized frameworks, enhancing security protocols, and exploring AI-driven edge optimization techniques. If these challenges are addressed, edge computing can indeed unlock its true potential to revolutionize cloud infrastructure and enable next-generation applications.