

A SURVEY ON EDGE COMPUTING AND ITS ROLE IN SHAPING THE FUTURE OF CLOUD COMPUTING

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Abstract:

Cloud computing has evolved into a foundational technology underpinning contemporary digital infrastructure, providing scalable, on-demand, and cost-effective computing services. Nevertheless, with the rapid proliferation of Internet of Things (IoT) devices, real-time applications, and data-intensive systems, traditional cloud computing faces significant challenges, including elevated latency, bandwidth constraints, and prolonged response times. Centralized cloud architectures often fail to satisfy the stringent requirements of latency-sensitive workloads. Edge computing has emerged as a complementary paradigm by processing data in proximity to its source, thereby minimizing communication delays and enhancing overall system performance. This paper presents a comprehensive survey on edge computing and its transformative impact on the future of cloud computing. It explores prevailing industry viewpoints, novel architectural frameworks, and recent technological advances in edge–cloud integration. The study evaluates how hybrid edge–cloud architectures improve performance, scalability, and resource utilization. It further examines critical challenges, such as security vulnerabilities, interoperability issues, and dynamic resource management. Based on this analysis, it becomes evident that edge computing will play a pivotal role in shaping next-generation distributed computing systems by enabling faster, more intelligent, and highly efficient data processing.

Keywords: *Edge Computing, Cloud Computing, Internet of Things (IoT), Low Latency, Distributed Systems*

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Introduction:

Cloud computing has transformed modern information technology by enabling scalable and flexible computing resources over the internet. Enterprises and individuals increasingly depend on cloud platforms for data storage, application hosting, and computational tasks. The on-demand provisioning of resources has significantly reduced capital expenditure and improved operational efficiency across diverse domains.

Despite these benefits, conventional cloud computing architectures exhibit certain limitations. With the exponential growth in connected devices and data volumes—particularly from Internet of Things (IoT) ecosystems—centralized cloud models struggle to meet real-time processing demands. Applications such as autonomous vehicles, smart healthcare systems, and industrial automation require immediate responses, which are often hindered by the physical distance between end users and remote cloud data centers.

Edge computing has emerged as a promising paradigm to mitigate these constraints. By performing computation closer to the data source, edge computing reduces end-to-end latency and enhances responsiveness. Instead of

transmitting all data to centralized servers, edge nodes handle time-critical tasks locally, while the cloud layer manages large-scale storage, batch processing, and advanced analytics.

This paper presents a survey on edge computing and its integration with cloud computing. It aims to examine how this integration is reshaping the future of computing by enhancing performance, scalability, and overall system efficiency.

Background And Concepts:

A. Cloud Computing

Cloud computing denotes the delivery of on-demand computing services—including storage, processing, and networking—over the internet. It offers elasticity, flexibility, and economic efficiency, which has led to its widespread adoption across business, scientific, and social applications.

B. Edge Computing

Edge computing is a distributed computing model that places data processing closer to the point of data generation. By minimizing the distance between devices and processing nodes, it reduces latency, conserves bandwidth, and alleviates the burden on core networks.

C. Edge–Cloud Integration Architecture Fig. 1: Edge–Cloud Integrated Architecture (User → Edge → Orchestration → Cloud)

The architecture comprises multiple layers. End-user devices generate data, edge nodes perform initial processing and filtering, and the core cloud infrastructure handles large-scale analytics and long-term storage.

Explanation:

The integration of edge and cloud computing forms a hybrid model where edge nodes execute latency-sensitive workloads locally, while cloud systems provide centralized computation, orchestration, and storage. This collaboration enhances overall system efficiency, responsiveness, and scalability.

Literature Review:

Numerous studies have investigated the role of edge computing in contemporary computing environments. Research indicates that edge computing significantly reduces latency and improves system responsiveness by performing computation near the data source.

A substantial body of work focuses on IoT-driven applications where real-time processing is critical. These studies demonstrate that processing data at the network edge can enhance performance, lower network congestion, and reduce unnecessary data transmission. Moreover, integrating edge computing with cloud platforms has been shown to improve resource utilization and workload distribution.

Several researchers emphasize the importance of containerization and microservices in enabling flexible deployment across distributed environments. Technologies such as container orchestration frameworks facilitate seamless application management across edge and cloud layers, supporting dynamic scaling and service mobility.

At the same time, existing literature highlights non-trivial challenges, including security threats, data privacy risks, and interoperability issues among heterogeneous devices and platforms. Addressing these concerns is



essential to fully unlock the potential of edge–cloud integration.

Problem Statement:

Traditional cloud computing systems depend on centralized data centers for both computation and storage. While this model offers strong scalability, it introduces propagation delays in processing time-sensitive data. Latency-critical applications require near-instantaneous responses, which are difficult to guarantee with physically distant cloud infrastructures. Furthermore, the persistent transmission of large data volumes over networks leads to increased bandwidth consumption and network congestion. Therefore, it is necessary to explore how edge computing can be integrated with cloud systems to enhance performance, minimize latency, and better support real-time and mission-critical applications.

Objectives:

- To examine the fundamental concepts of edge computing.
- To analyze the role of edge computing in cloud-based environments.
- To investigate prevailing industry trends and future projections.
- To identify key benefits and persistent challenges associated with edge–cloud integration.

Hypotheses:

H1: Edge computing reduces latency in cloud-based environments.

H2: Integration of edge and cloud computing improves overall system performance.

H3: Hybrid edge–cloud architecture enhances scalability and operational efficiency.

Research Methodology:

This study adopts a survey-based research methodology. It involves a systematic review and synthesis of existing peer-reviewed articles, industry whitepapers, and technical documentation related to edge and cloud computing.

The methodology includes:

- Reviewing literature from multiple academic and industrial sources.
- Analyzing emerging technological trends and architectural patterns.

Future Scope:

Future research may concentrate on:

- AI and machine learning integration at the edge for intelligent decision-making.
- Applications in smart cities, including traffic management, environmental monitoring, and public safety.
- Development of autonomous systems in transportation, robotics, and industrial control.
- Advanced security mechanisms such as zero-trust architectures, edge-native encryption, and privacy-preserving computation.

Conclusion:

Edge computing is emerging as an indispensable component of contemporary computing infrastructures. Its integration with cloud computing enhances performance, reduces latency, and improves scalability and resource efficiency.

This study concludes that edge computing will play a central role in shaping the evolution of distributed computing. A hybrid edge–cloud model is expected to become a dominant paradigm, supporting next-generation applications that demand high responsiveness, adaptability, and intelligent data processing.

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