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Edge Computing For Iot: A Survey On Architectures, Technologies, And Applications

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Abstract

Edge computing has emerged as a transformative paradigm to address the significant challenges associated with the Internet of Things (IoT), such as high latency, bandwidth constraints, and the need for real-time data processing. As IoT devices proliferate, the volume of data generated increases exponentially, necessitating efficient processing solutions to avoid network congestion and ensure timely responses. Edge computing brings computation and data storage closer to the data source, facilitating low-latency communication and reducing the dependency on centralized cloud infrastructure. This survey provides a detailed analysis of edge computing in the context of IoT systems, focusing on three key aspects: architectures, enabling technologies, and applications. The survey begins by exploring the fundamental architectures of edge computing, which are designed to support the distributed processing of data. It delves into the roles of edge devices, edge nodes, gateways, and their interactions with the cloud, offering insights into different architectural models such as fog computing, mist computing, and multi-tier architectures. Then examine the cutting-edge technologies that enable edge computing, including network protocols, data management strategies, virtualization, and containerization. These technologies are crucial for ensuring efficient resource allocation, scalability, and seamless communication between edge devices. Furthermore, the survey highlights a range of IoT applications where edge computing plays a pivotal role, including smart cities, healthcare, industrial automation, autonomous vehicles, and environmental monitoring. In each of these areas, edge computing helps reduce data transfer times, ensures real-time decision-making, and supports intelligent systems by processing data at the edge rather than relying solely on distant cloud servers. Finally, the survey concludes with a discussion on the current challenges in the field, such as security and privacy concerns, resource constraints on edge devices, the need for interoperability across heterogeneous systems, and the scalability of edge computing solutions. The paper also identifies future research directions, including the integration of edge computing with other emerging technologies like artificial intelligence (AI), machine learning (ML), and 5G networks. This survey serves as a comprehensive resource for researchers, engineers, and practitioners seeking to understand and advance edge computing in the context of IoT, providing foundational insights into this rapidly evolving and impactful field. Keywords: Edge Computing, Internet of Things, Architectures, Technologies, Applications, Real-time Data Processing.

Introduction: The rapid expansion of the Internet of Things (IoT) has led to the generation of massive volumes of data, resulting in increased pressure on traditional cloud-based computing systems. The latency, bandwidth limitations, and dependence on centralized cloud resources pose significant challenges in the real-time processing of this data, especially in applications where immediacy is critical. In response to these challenges, edge computing has emerged as a transformative solution, enabling computation and data processing closer to the source of data generation. Edge computing is particularly significant in the context of IoT, where devices and sensors generate data that must be processed and analyzed in real-time to enable intelligent decision-making. This paradigm allows for reduced latency, improved reliability, and lower bandwidth consumption, which are crucial for many IoT applications.

Objectives: The Objective of this study is to examine Edge computing in distributed computing architecture to brings computation and storage closer to the data sources—IoT devices—rather than relying on distant data

centres or cloud infrastructure. This proximity allows for faster processing, reduced latency, and more efficient use of bandwidth, which is especially important in scenarios involving real-time data analytics, smart cities, healthcare, and industrial IoT (IoT) systems.

Methods: This study employs a systematic and structured literature review methodology to examine recent developments, challenges, and future trends in Edge computing for IoT. The methodology involves multiple phases to ensure the accuracy, relevance, and comprehensiveness of the analysis.

Results: One of the key outcomes of this review is a comprehensive classification of edge computing architectures tailored for IoT applications. The study identifies several edge computing models, including fog computing, multi-access edge computing (MEC), and cloud-edge hybrid architectures. These models vary in their ability to handle different IoT applications based on requirements such as latency, processing power, and scalability. This outcome allows researchers and practitioners to select the most suitable architecture for their specific IoT use case, facilitating better performance, real-time decision-making, and resource management. The study identifies a range of key enabling technologies for edge computing in the context of IoT. These include 5G networks, AI and machine learning, blockchain, and software-defined networking (SDN). The integration of 5G with edge computing is emphasized as a game-changer, reducing latency and enabling real-time IoT processing. Additionally, the study highlights the critical role of AI at the edge for enabling autonomous decision-making and intelligent task offloading in IoT networks. These technologies provide a robust foundation for enhancing IoT device efficiency, security, and scalability, driving the next generation of smart devices and systems.

Conclusions: The study outlines several challenges that hinder the widespread adoption of edge computing in IoT, including resource management, task offloading, network congestion, and energy efficiency. Moreover, it identifies critical research gaps, such as the need for AI-driven resource allocation strategies, the development of energy- efficient algorithms, and the optimization of multi-tier edge systems. Future research should focus on enhancing edge-device interoperability, addressing data synchronization issues, and leveraging 5G networks to improve performance and scalability. This outcome provides valuable insights into where the field of edge computing can evolve in the future and directs researchers to focus on critical unsolved problems. The review highlights the emerging trends that are likely to shape the future of edge computing in IoT. 5G technology, artificial intelligence, and blockchain are identified as major drivers that will enable faster data processing, autonomous systems, and secure data exchanges in IoT networks. Moreover, the combination of fog computing with edge computing and cloud integration is expected to create more resilient and scalable IoT systems. These trends not only improve the efficiency and performance of IoT systems but also address key concerns related to data latency, bandwidth limitations, and security risks. These insights are valuable for practitioners looking to implement cutting-edge technologies in IoT solutions.

Keywords: **Edge Computing, Internet of Things, Architectures, Technologies, Applications, Real-time Data Processing.**

1. Introduction

Edge computing refers to the distributed computing architecture that brings computation and storage closer to the data sources—IoT devices—rather than relying on distant data centers or cloud infrastructure. This proximity allows for faster processing, reduced latency, and more efficient use of bandwidth, which is especially important in scenarios involving real-time data analytics, smart cities, healthcare, and industrial IoT (IIoT) systems. Several studies have examined the role of edge computing in improving IoT system performance and enabling new functionalities. For instance, Alsharif et al. (2025) discuss the importance of energy-efficient fog computing techniques and recent advances in improving computational efficiency in distributed systems. Additionally, Tran-Dang and Kim (2025) highlight the integration of digital twin technologies for intelligent offloading in edge computing, emphasizing the critical role of edge nodes in enhancing computation offloading strategies, particularly in the era of 5G and beyond. benefit from edge computing by improving automation, predictive maintenance, and operational efficiency.

2. Objectives

To Investigate and analyze the various edge computing architectures that support IoT systems, including multi- tier, fog computing, and decentralized models, to highlight their effectiveness in reducing latency, enhancing scalability, and improving real-time data processing. Provide an in-depth review of the core technologies that enable edge computing for IoT, such as network protocols, machine learning, virtualization, containerization, and emerging technologies like 5G, blockchain, and digital twins. The objective is to understand how these technologies contribute to the efficiency and performance of edge computing systems.

Identify and analyze the key IoT applications that benefit from edge computing, such as smart cities, healthcare, industrial IoT, autonomous vehicles, and environmental monitoring, emphasizing how edge computing improves system efficiency, reduces latency, and enables real-time decision-making Address the major challenges faced by edge computing in IoT applications, including issues related to security, privacy, resource management, and scalability. The objective is to explore the existing solutions and strategies that mitigate these challenges.

3. Methods

The Mehedology identifies a range of key enabling technologies for edge computing in the context of IoT. These include 5G networks, AI and machine learning, blockchain, and software-defined networking (SDN). The integration of 5G with edge computing is emphasized as a game-changer, reducing latency and enabling real- time IoT processing. Additionally, the study highlights the critical role of AI at the edge for enabling autonomous decision-making and intelligent task offloading in IoT networks. These technologies provide a robust foundation for enhancing IoT device efficiency, security, and scalability, driving the next generation of smart devices and systems. The review outlines a wide variety of IoT applications that benefit from edge computing, such as smart cities, healthcare, industrial automation, autonomous vehicles, and agriculture. For each domain, specific edge computing solutions are discussed. For instance, in healthcare, edge computing enables real-time patient monitoring and on-site data processing, reducing the dependency on centralized cloud systems and improving response times for critical care. Similarly, in industrial IoT, edge computing facilitates predictive maintenance and real-time monitoring, enabling faster decision-making and reducing downtime in manufacturing plants. This section provides insights into the practical benefits of edge computing, showing its potential to revolutionize various industries. A significant outcome of this review is the identification of security and privacy challenges in edge computing for IoT applications. The study categorizes the main security threats such as data breaches, unauthorized access, and malicious attacks in decentralized edge systems. Additionally, the review highlights several security solutions, including encryption techniques, blockchain-based authentication, and secure task offloading algorithms. The integration of AI and machine learning for detecting anomalies and responding to threats in real-time is also discussed as a promising approach. The findings underscore the importance of robust security frameworks for building trust and ensuring the safe deployment of edge-enabled IoT applications.

4. Results

The study outlines several challenges that hinder the widespread adoption of edge computing in IoT, including resource management, task offloading, network congestion, and energy efficiency. Moreover, it identifies critical research gaps, such as the need for AI-driven resource allocation strategies, the development of energy-efficient algorithms, and the optimization of multi-tier edge systems. Future research should focus on enhancing edge-device interoperability, addressing data synchronization issues, and leveraging 5G networks to improve performance and scalability. This outcome provides valuable insights into where the field of edge computing can evolve in the future and directs researchers to focus on critical unsolved problems. The review highlights the emerging trends that are likely to shape the future of edge computing in IoT. 5G technology, artificial intelligence, and blockchain are identified as major drivers that will enable faster data processing, autonomous systems, and secure data exchanges in IoT networks. Moreover, the combination of fog computing with edge computing and cloud integration is expected to create more resilient and scalable IoT systems. These trends not only improve the efficiency and performance of IoT systems but also address key concerns related to data latency, bandwidth limitations, and security risks. These insights are valuable for practitioners looking to implement cutting-edge technologies in IoT solutions. Despite its advantages, edge computing for IoT faces several challenges that require further research and development. Security and privacy are among the most pressing concerns, as the distributed nature of edge computing introduces vulnerabilities at various points in the network. Sheikh et al. (2025) provide a comprehensive survey of the security challenges in edge computing, categorizing threats and proposing mitigation strategies. Other challenges include the management of heterogeneous edge devices, ensuring interoperability across different platforms, and optimizing resource allocation in resource-constrained environments. As edge computing continues to evolve, there is a growing need to integrate it with emerging technologies such as 5G networks, artificial intelligence (AI), and digital twins to enhance its capabilities and support future IoT innovations (Tran-Dang & Kim, 2025; Paje & Teleron, 2025).

5. Discussion

By bringing computation closer to the data source, edge computing significantly enhances the performance and efficiency of IoT systems. However, several challenges remain, particularly in terms of security, resource management, and scalability. Future research directions will likely focus on the integration of edge computing with other technologies to address these challenges and unlock the full potential of IoT applications. The results of this study provide a holistic view of the role of edge computing in enhancing IoT applications, from architectures and technologies to specific use cases and security concerns. The findings not only contribute to the academic understanding of the field but also offer practical guidance to industry professionals on how to leverage edge computing for IoT solutions. The identification of key technologies, challenges, and future research directions establishes a roadmap for further exploration and innovation in this rapidly evolving area. This study thus lays the groundwork for the continued advancement of edge computing in the IoT landscape.

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