Chapter 3
Edge Computing Empowering Distributed Computing at the Edge

Yogita Yashveer Raghav
https://orcid.org/0000-0003-0478-8619
K.R. Mangalam University, India

Ramesh Kait
https://orcid.org/0000-0002-3084-7646
Kurukshetra University, India

ABSTRACT

Edge computing is a revolutionary approach that enables processing and decision-making in close proximity to data sources, reducing latency and optimizing bandwidth usage. This paradigm involves various components such as edge devices, servers, and networks, integrating sensors, actuators, and IoT devices with real-time analysis enabled by edge processing units and containerization technologies. Edge networks, facilitated by edge routers and gateways and diverse communication protocols, ensure seamless data flow. Network edge computing (NEC) further minimizes latency and supports critical network functions. In conclusion, edge computing is reshaping the computing landscape, fostering innovation across industries. The chapter also addresses challenges, potential solutions, and promising trends for future research.

INTRODUCTION

Edge computing represents a decentralized computing approach that facilitates data processing and computation in close proximity to the data origin, or the network's "edge," instead of depending exclusively on centralized cloud servers. This approach is a direct reaction to the growing necessity for rapid response times and instantaneous data processing in the contemporary digital environment.. Edge computing is not just a buzzword but a transformative technology with profound implications for data processing and

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storage. Its ability to reduce latency, enhance reliability, optimize bandwidth, and improve data privacy and security positions it as a key enabler of the digital future. By unlocking real-time insights and enabling highly responsive applications, edge computing is poised to revolutionize how we interact with and leverage data in our increasingly connected world (Cao et al., 2019; Meneguette et al., 2021; Ren et al., 2019). In today's digital landscape, where data is generated at an unprecedented rate and applications require real-time responsiveness, edge computing plays a vital role. It enables businesses to harness the full potential of emerging technologies like IoT, AI, and 5G, allowing them to make faster and more informed decisions, enhance user experiences, and improve overall operational efficiency. As a result, edge computing is becoming increasingly important for organizations looking to stay competitive in the digital age (Satishkumar et al., 2023).

Significance of Edge Computing

• Proximity to Data Origins: Within traditional cloud computing, data is transmitted to centralized data centers for processing, leading to potential delays and constraints in bandwidth, especially when dealing with substantial data volumes. Edge computing situates computational resources in closer proximity to where the data originates, diminishing latency and ensuring immediate or near-immediate responses (Chakraborty et al., 2023).

- Reduced Latency: Edge computing substantially lessens the time required for data to travel from the source to the processing unit and back. This is critical for applications necessitating minimal latency, such as autonomous vehicles, industrial automation, and augmented reality.
- Enhanced Bandwidth Efficiency: Processing data at the edge results in less data transmission over the network to centralized data centers, helping to decrease network congestion and conserve bandwidth costs.
- Improved Reliability: Edge computing can bolster system reliability by enabling operations even when connectivity to the cloud is disrupted. This is particularly vital for crucial applications like healthcare, where downtime could lead to severe consequences (Raghav & Vyas, 2019).
- Privacy and Security: Data processed at the edge frequently remains on local devices or within a particular network, lowering the risk of data breaches and ensuring better compliance with data privacy regulations.
- Scalability: Edge computing can be readily expanded by incorporating more edge devices or nodes as necessary, rendering it a flexible solution for managing varying workloads.
- Real-time Data Analysis: For applications such as IoT (Internet of Things), edge computing facilitates immediate data analysis, enabling businesses to make instant decisions based on sensor data.
- Cost-Effective Optimization: By processing data locally and transmitting only pertinent information to the cloud, businesses can streamline cloud computing expenses, potentially requiring fewer resources in the cloud.
- Application Scenarios: Edge computing discovers applications across diverse industries, including healthcare (patient monitoring), manufacturing (predictive maintenance), retail (customer analytics), agriculture (precision farming), and smart cities (traffic management) (Tarnanidis et al., 2023).
- Hybrid Cloud Integration: Edge computing complements cloud computing within a hybrid architecture, where specific processing tasks are executed locally (at the edge) while others are man-