



# Secure and Scalable Edge Computing through Blockchain Integration: A Systematic Review

Prof. Navneet kaur<sup>1</sup>, Sukhraj kaur<sup>2</sup>

<sup>1</sup>Assistant Professor, Department of Computer Applications , Global Group of Institutes

<sup>2</sup> MCA Student, Department of Computer Applications, Global Group of institutes

## Abstract

The rapid growth of Internet of Things (IoT) devices and decentralized applications has increased the demand for secure and low-latency computing systems. Blockchain technology provides transparency, trust, and decentralized security, while edge computing improves performance by processing data closer to the source. This paper presents a systematic review of blockchain-enabled edge computing systems and discusses their applications, advantages, and implementation challenges. The paper highlights scalability, latency reduction, and secure communication in distributed environments. A valid contribution of this study is the presentation of a simplified integrated framework that supports secure communication between edge devices using blockchain mechanisms. The study also explains the role of Ethereum smart contracts in edge environments and identifies future research opportunities for lightweight and scalable architectures.

Keywords— Blockchain, Edge Computing, IoT, Data Security, Scalability, Distributed Systems

## INTRODUCTION

Modern computing systems generate large amounts of data through IoT devices, sensors, and smart applications. Traditional cloud computing architectures often experience problems such as high latency, bandwidth consumption, and centralized dependency. To overcome these limitations, edge computing has emerged as an advanced computing model that processes data closer to the source. Edge computing improves response time and supports real-time communication.

At the same time, blockchain technology has become an important solution for secure and decentralized data management. Blockchain stores information in a distributed ledger secured by cryptographic algorithms. This structure prevents unauthorized modifications and improves transparency.

The integration of blockchain and edge computing provides a reliable environment for smart healthcare systems, industrial automation, intelligent transportation, and smart cities. Blockchain enhances trust and security, while edge computing reduces latency and improves operational efficiency.

## **BLOCKCHAIN OVERVIEW**

Blockchain is a decentralized ledger technology where transaction records are distributed across multiple nodes instead of being stored on a centralized server. Each block contains encrypted data linked with previous blocks through cryptographic hashing techniques. This architecture makes blockchain secure and tamper-resistant.

Consensus mechanisms such as Proof of Work (PoW) and Proof of Stake (PoS) are used to validate transactions before adding them to the blockchain network. Ethereum is one of the most widely used blockchain platforms because it supports smart contracts. Smart contracts automatically execute predefined operations without requiring intermediaries.

Blockchain technology is widely applied in banking systems, digital payments, cybersecurity, healthcare, and supply chain management because of its ability to provide secure and transparent communication.

## **EDGE COMPUTING OVERVIEW**

Edge computing is a distributed computing approach where data processing occurs near the source instead of relying completely on cloud servers. This method reduces communication delays and improves system responsiveness.

Edge computing is especially useful for applications requiring real-time decision-making, including autonomous vehicles, healthcare monitoring systems, industrial IoT devices, and smart surveillance systems. By processing data locally, edge computing minimizes bandwidth usage and improves system efficiency. Cloud computing still plays an important role by supporting large-scale analytics and storage operations, while edge nodes handle immediate processing tasks.

## **INTEGRATION OF BLOCKCHAIN AND EDGE COMPUTING**

The integration of blockchain and edge computing creates a secure and scalable distributed environment. Blockchain ensures secure communication, authentication, and transparent data sharing among edge devices, while edge computing improves processing speed and reduces latency.

This integration removes dependency on centralized infrastructure and eliminates single points of failure. Organizations can use blockchain-enabled edge systems to improve security and efficiency in IoT networks, smart healthcare systems, and industrial automation.

The proposed contribution of this paper is a simplified integrated framework where edge devices locally validate transactions using blockchain mechanisms before transferring information to cloud systems. This approach improves data privacy, reduces communication overhead, and supports efficient decentralized processing.

## **CHALLENGES AND LIMITATIONS**

Despite the benefits of blockchain-enabled edge computing, several technical challenges still exist. Blockchain systems often face scalability problems because transaction validation requires high computational resources. Large transaction volumes may reduce system performance.

Edge devices also have limited storage capacity and processing power, making blockchain implementation difficult in resource-constrained environments. Security vulnerabilities may occur if edge nodes become compromised.

In addition, decentralized network management increases operational complexity and requires advanced monitoring mechanisms. Energy consumption and interoperability between different blockchain platforms are also major concerns for researchers.

## ETHEREUM IN EDGE ENVIRONMENTS

Ethereum plays an important role in blockchain-enabled edge systems due to its smart contract functionality. Smart contracts support automatic execution of predefined tasks and improve trust between distributed devices.

In edge environments, Ethereum can securely validate and record transactions among nearby devices. Local transaction validation reduces latency and enhances system reliability. This decentralized architecture supports scalable IoT applications and secure distributed communication.

Ethereum-based edge systems can also reduce dependence on centralized cloud infrastructure while maintaining data integrity and transparency.

### FUTURE RESEARCH DIRECTIONS

Future research should focus on developing lightweight blockchain algorithms suitable for edge devices with limited resources. Researchers should also design scalable architectures capable of handling high transaction volumes with lower energy consumption.

Artificial intelligence and machine learning techniques can improve security, predictive analytics, and traffic management in blockchain-enabled edge environments. Advanced privacy-preserving methods are also required to strengthen secure communication in decentralized systems.

### CONCLUSION

The integration of blockchain and edge computing represents a major advancement in modern distributed computing systems. Blockchain provides transparency, trust, and secure communication, while edge computing improves response time and operational efficiency.

Together, these technologies support smart applications such as IoT systems, healthcare, industrial automation, and intelligent transportation. Although challenges related to scalability and resource limitations still exist, future developments in lightweight architectures and secure consensus mechanisms can further enhance performance and reliability in blockchain-enabled edge systems.

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