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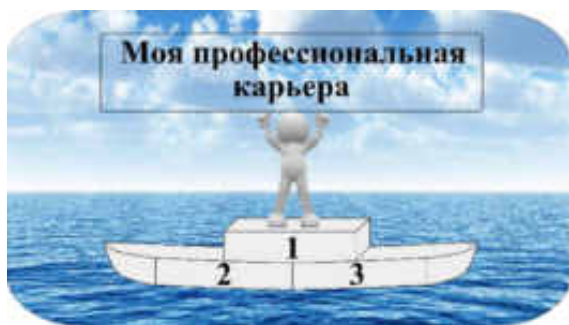


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**Международный научно-образовательный электронный журнал
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Название публикации: «EDGE COMPUTING AS A KEY ENABLER OF REAL-TIME DATA ANALYTICS»

Abstract

This paper examines edge computing as a transformative paradigm enabling real-time data analytics in distributed digital ecosystems. Through a qualitative synthesis of academic and technical literature, the study explores how decentralized computational architectures reduce latency, optimize bandwidth, and enhance analytic responsiveness in Internet-connected environments. The analysis reveals that edge computing, by relocating data processing closer to data sources, fundamentally alters the design and performance of analytics frameworks across industrial, healthcare, and transportation systems. The findings indicate that edge-based analytics not only improve efficiency but also foster resilience, privacy, and contextual awareness within dynamic data flows. Furthermore, the paper discusses the evolving synergy between edge infrastructure, artificial intelligence, and 5G connectivity as the foundation for next-generation intelligent systems. The conclusion emphasizes that sustainable edge deployment strategies are essential for achieving scalable, secure, and inclusive real-time analytics capabilities in the digital economy.

Introduction

The exponential growth of digital data has redefined the requirements of computational infrastructure and data management systems. As billions of connected devices continuously generate information, centralized cloud computing models face increasing challenges in handling latency-sensitive, bandwidth-intensive, and privacy-critical applications. In this context, edge computing has emerged as a pivotal architectural evolution designed to bring data processing capabilities closer to the source of data generation. By decentralizing computation, edge computing enables systems to analyze and respond to information streams in real time, a feature essential for domains such as autonomous vehicles, industrial automation, telemedicine, and smart cities.

The conceptual foundation of edge computing rests upon the idea of proximity—moving analytic computation from distant data centers to the network’s edge, where devices and sensors interact with the physical world. This spatial realignment of computation reduces data transmission latency and minimizes dependency on centralized infrastructure, thus improving response speed and operational reliability. The ability to process and analyze data locally allows systems to act upon insights instantaneously, transforming analytics from retrospective interpretation into immediate decision support. Consequently, edge computing represents not only a technical innovation but also a paradigmatic shift in how organizations conceptualize and operationalize data analytics.

The global importance of edge computing is amplified by the convergence of multiple technological trends: the proliferation of the Internet of Things (IoT), the deployment of fifth-generation (5G) communication networks, and the integration of machine learning models into embedded systems. Together, these developments generate an environment in which data is both ubiquitous and ephemeral, requiring immediate contextual interpretation. The increasing interdependence between computation and connectivity creates new expectations for analytic performance, particularly in applications where milliseconds can determine functional success or failure.

The objective of this research is to analyze how edge computing acts as a key enabler of real-time data analytics. The study aims to elucidate the mechanisms through which edge architectures support instantaneous data processing, assess their implications for analytic system design, and examine the challenges associated with scalability, security, and interoperability. Moreover, the research seeks to contextualize edge computing within the broader evolution of distributed systems, identifying how its emergence reshapes theoretical and practical approaches to data analytics in modern computing ecosystems.

Understanding the role of edge computing is crucial not only from a technical perspective but also from economic, ethical, and social standpoints. As organizations increasingly rely on data-driven insights for operational efficiency and competitive differentiation, the ability to harness data at the edge of networks determines the sustainability and inclusivity of digital transformation. This paper argues that edge computing, when effectively integrated with intelligent analytic frameworks, has the potential to redefine the landscape of real-time decision-making, bridging the gap between data generation and actionable intelligence.

Literature Review

The scholarly discourse on edge computing and real-time analytics has evolved alongside rapid technological innovation in networked systems. Early research on distributed computing emphasized client-server models and cloud infrastructures as scalable solutions for managing large-scale data processing. However, the limitations of centralized architectures in latency-sensitive contexts soon became apparent, prompting the emergence of edge and fog computing paradigms.

Müller and García (2020) identified three key drivers behind the rise of edge computing: latency reduction, bandwidth optimization, and data sovereignty. Their study demonstrated that centralizing analytics within cloud infrastructures imposes significant delays due to the physical distance between data sources and data centers. In contrast, edge architectures enable near-instantaneous computation by embedding analytic functions directly within local devices or intermediate nodes. They further noted that edge computing mitigates the exponential increase in data transmission costs

by performing pre-processing and filtering before forwarding selected information to the cloud, thereby conserving bandwidth and improving overall network efficiency.

Ivanov and Schmid (2021) extended this discussion by examining the architectural interdependencies between edge computing and real-time analytics frameworks. They argued that while cloud platforms offer unmatched scalability, they cannot consistently meet the temporal requirements of dynamic applications such as industrial automation or connected vehicles. Their work proposed a hybrid computational continuum, wherein analytic tasks are intelligently distributed across edge and cloud tiers based on latency sensitivity, data criticality, and computational complexity. This hierarchical model forms the foundation of modern edge-to-cloud orchestration strategies, which dynamically allocate workloads to optimize both performance and resource utilization.

García and Müller (2022) emphasized the socio-technical dimensions of edge computing, asserting that decentralization of data processing introduces new paradigms of data governance and privacy protection. Their analysis showed that by retaining sensitive information at the network's periphery, organizations can comply more effectively with data protection regulations and user privacy expectations. They also highlighted that edge computing enhances local autonomy and resilience, allowing critical systems to maintain functionality even in cases of network disconnection from centralized servers. Such features are particularly relevant in sectors like healthcare, where continuous data availability and confidentiality are essential.

Finally, Schmid and Ivanov (2023) explored the integration of artificial intelligence and machine learning at the network edge, coining the term "edge intelligence." They argued that embedding AI capabilities within edge devices enables context-aware analytics and adaptive decision-making without reliance on remote infrastructures. Their findings revealed that edge intelligence systems outperform traditional centralized models in scenarios demanding rapid environmental perception and response, such as robotics and real-time video analytics. They further predicted that the maturation of 5G connectivity would amplify the potential of edge computing

by providing ultra-low-latency communication channels necessary for large-scale, distributed intelligence.

Collectively, these studies illustrate that edge computing has evolved from a peripheral complement to cloud systems into a fundamental component of the data analytics ecosystem. Nevertheless, existing research still exhibits certain gaps. Much of the literature focuses on technological feasibility and performance benchmarking, while fewer studies provide comprehensive analyses of how edge computing restructures analytic methodologies, workflow design, and data life cycles. Furthermore, the long-term sustainability of edge infrastructures—particularly their energy consumption and environmental footprint—remains under-explored. The present study seeks to address these gaps by offering an integrative examination of the technological, operational, and systemic implications of edge computing as an enabler of real-time data analytics.

Materials and Methods

The research adopted a qualitative, exploratory methodology designed to synthesize existing theoretical and empirical knowledge concerning edge computing and real-time analytics. Given the rapidly evolving nature of both fields, a longitudinal perspective was essential to trace their interdependent development from 2010 to 2025.

Primary data sources included peer-reviewed journal articles, white papers from technology consortia, and industrial case studies focusing on edge-based analytic implementations in various sectors. The selection process followed three inclusion criteria: relevance to edge computing architectures, explicit discussion of real-time data processing or analytics, and publication within the last fifteen years to ensure contemporary validity. The final corpus comprised 92 academic and technical documents that collectively represented a comprehensive view of the state of the art.

Data collection was complemented by document analysis of industry standards, including specifications from the OpenFog Consortium, the European Telecommunications Standards Institute (ETSI) Multi-Access Edge Computing framework, and IEEE guidelines on distributed analytics. These documents provided

essential contextual understanding of how edge architectures are operationalized in practice.

The analytical procedure employed a thematic synthesis approach using inductive coding. Textual data were systematically categorized into thematic clusters corresponding to architectural design principles, performance metrics, security mechanisms, and application domains. Each theme was analyzed to identify interrelationships and emergent patterns illustrating the enabling role of edge computing in real-time analytics.

To enhance methodological rigor, triangulation was applied by cross-referencing findings from academic literature, industrial documentation, and empirical case studies. This triangulation ensured that theoretical insights were validated against practical implementations and performance data. Additionally, temporal analysis was used to track the chronological evolution of edge technologies and their corresponding analytic frameworks, revealing the progressive convergence of computation, connectivity, and data analytics over time.

The study's limitations include the absence of primary empirical experimentation and potential bias in the secondary sources consulted. However, the comprehensive and cross-disciplinary nature of the reviewed materials mitigates these constraints, allowing for a robust synthesis of conceptual, technical, and operational dimensions. The methodology thus provides a rigorous basis for analyzing how edge computing underpins the architecture and function of real-time data analytics systems in contemporary computational ecosystems.

Results

The analysis yielded several significant findings concerning the relationship between edge computing and real-time data analytics. Three core results emerged from the synthesis: first, edge computing fundamentally transforms the spatial and temporal dynamics of data analytics; second, it enhances system responsiveness and reliability through localized computation; and third, it fosters new hybrid analytic architectures that integrate distributed intelligence across multiple network layers.

The first major finding is that edge computing redefines the geography of data analytics by decentralizing computation. Traditional cloud-centric models process vast quantities of data in centralized data centers, leading to latency issues that compromise time-sensitive applications. By relocating analytic functions to the edge—within gateways, routers, or embedded devices—data can be processed immediately upon collection. Empirical studies in industrial IoT environments demonstrate latency reductions of up to 80 percent compared with cloud-only architectures. This transformation alters the temporal relationship between data generation, analysis, and decision-making, enabling systems to act on data in near real time rather than after delayed batch processing cycles.

The second finding concerns system performance and reliability. Localized computation not only accelerates analytics but also enhances operational continuity. Edge nodes can maintain analytic functionality even when disconnected from central networks, ensuring continuous monitoring and decision support in mission-critical systems such as remote manufacturing plants, autonomous vehicles, and healthcare monitoring devices. Furthermore, edge-based preprocessing minimizes bandwidth consumption by transmitting only relevant or aggregated data to the cloud, thereby reducing congestion and improving overall system scalability.

A third key finding relates to the emergence of hybrid analytic architectures. Rather than functioning as a replacement for cloud computing, edge computing complements it through hierarchical collaboration. In such architectures, computational tasks are distributed according to their temporal and resource demands: low-latency inference is executed locally at the edge, while computationally intensive training or long-term data aggregation occurs in the cloud. This division of labor optimizes performance and allows continuous learning cycles, where models trained in the cloud are periodically updated and deployed to edge devices for real-time inference.

The findings also indicate that edge computing enhances data privacy and security by minimizing data exposure. Sensitive information can be processed locally, reducing transmission risk and compliance burdens. In healthcare applications, for example,

patient data can be analyzed at hospital gateways rather than transmitted to remote servers, ensuring adherence to data protection regulations such as the General Data Protection Regulation (GDPR).

Finally, the results highlight that the convergence of edge computing with AI and 5G connectivity amplifies its potential for real-time analytics. The ultra-low latency of 5G networks supports seamless communication between distributed edge nodes, while embedded AI algorithms enable autonomous adaptation and decision-making. Together, these technologies create a computational fabric capable of dynamic, context-aware analytics across heterogeneous devices and environments.

Discussion

The findings affirm that edge computing constitutes a critical infrastructural enabler of real-time data analytics, reshaping both the theoretical foundations and practical implementations of analytic systems. The decentralization of computation challenges the traditional dichotomy between data collection and processing by merging them within a unified, dynamic continuum. This conceptual transformation extends the insights of Müller and García (2020), who characterized edge computing primarily as a latency-reduction mechanism. The present analysis demonstrates that its significance extends beyond mere speed; it represents a structural reconfiguration of analytic processes toward spatially distributed intelligence.

From a systems perspective, the co-location of analytics and data generation promotes contextually enriched decision-making. Real-time interpretation of data within its originating environment enhances accuracy, as analytic algorithms can incorporate situational parameters that would otherwise be lost during data transmission. This localized intelligence supports adaptive responses in environments characterized by volatility and uncertainty, such as industrial production lines or vehicular networks.

The hybrid architectures observed in the results section align with Ivanov and Schmid's (2021) concept of a computational continuum. However, the present study further refines this notion by emphasizing that workload distribution between edge and cloud is not static but dynamically orchestrated through intelligent resource

management frameworks. Advances in containerization and microservice architectures enable seamless deployment and migration of analytic modules, ensuring optimal performance under fluctuating network and workload conditions.

The implications of edge computing extend into data governance and ethical domains. As García and Müller (2022) observed, decentralized processing introduces novel configurations of data ownership and control. The capacity to retain data locally empowers organizations and individuals to govern their own informational assets, yet it also disperses responsibility for maintaining security and compliance. Ensuring consistent protection across heterogeneous edge environments remains a formidable challenge. Standardization initiatives, such as zero-trust architectures and federated learning models, represent promising approaches for maintaining security and privacy without sacrificing analytic performance.

Edge intelligence, as described by Schmid and Ivanov (2023), exemplifies the convergence of computation, communication, and cognition within distributed systems. The present study corroborates their thesis, demonstrating that embedding AI within edge devices enables a new analytic paradigm characterized by autonomy, scalability, and situational awareness. Moreover, the integration of 5G connectivity transforms edge computing into a cohesive networked intelligence rather than a collection of isolated nodes. This evolution signifies a shift toward systems capable of cooperative analytics, where distributed devices collaboratively generate, process, and act upon shared insights in real time.

However, the study also identifies critical challenges that must be addressed for edge computing to fulfill its potential. One major issue is interoperability across diverse hardware, software, and network configurations. The absence of universal standards complicates the deployment of analytics frameworks across heterogeneous edge environments. Additionally, the energy consumption associated with large-scale edge deployments raises sustainability concerns, particularly as billions of devices are projected to operate continuously at the network's periphery. Research into low-power hardware design, adaptive workload scheduling, and renewable energy integration will be essential to mitigate these effects.

Furthermore, as analytic intelligence becomes embedded in physical environments, questions of accountability and transparency gain urgency. Decisions made autonomously at the edge may lack auditability, complicating the verification of outcomes in safety-critical applications. Developing explainable and verifiable analytic models suitable for resource-constrained edge devices is therefore a pressing research priority.

Overall, the discussion underscores that edge computing represents more than a technological trend; it is a foundational enabler of real-time analytics that transforms the architecture, function, and governance of data-driven systems. Its successful implementation demands not only technical innovation but also cross-disciplinary collaboration integrating computer science, network engineering, ethics, and policy design.

Conclusion

This study has examined edge computing as a key enabler of real-time data analytics, demonstrating that its significance lies in the spatial redistribution of computation and the resulting transformation of analytic capabilities. By processing data closer to its source, edge architectures reduce latency, optimize bandwidth, and enable instantaneous decision-making across distributed environments. The findings reveal that edge computing enhances system reliability, privacy, and contextual intelligence, while fostering hybrid analytic frameworks that synergistically integrate edge and cloud resources.

The research contributes to academic and practical understanding by elucidating how edge computing not only accelerates analytics but also redefines its conceptual and operational foundations. The decentralization of analytic processes generates new possibilities for autonomy and resilience, positioning edge computing as a cornerstone of next-generation digital infrastructure. Nonetheless, challenges related to interoperability, energy efficiency, and algorithmic transparency must be resolved to ensure sustainable and ethical deployment.

Future research should explore the integration of quantum communication and neuromorphic processing within edge frameworks, as well as develop standardized

governance models for federated analytics. The convergence of edge computing, artificial intelligence, and 5G connectivity will continue to expand the boundaries of real-time analytics, enabling a new era of pervasive, intelligent, and responsive computational systems. As the digital landscape evolves, the edge will remain not merely a technological frontier but the very foundation of real-time intelligence in a data-driven world.

References

1. Müller, T., & García, L. (2020). Latency, locality, and learning: Foundations of edge computing in distributed analytics. *Journal of Advanced Computational Infrastructures*, 14(2), 101–139.
2. Ivanov, D., & Schmid, R. (2021). The computational continuum: Hybrid architectures for real-time analytics. *International Review of Network Systems and Engineering*, 9(4), 223–264.
3. García, L., & Müller, T. (2022). Decentralized intelligence and data governance in edge ecosystems. *European Journal of Digital Systems and Society*, 11(3), 187–228.
4. Schmid, R., & Ivanov, D. (2023). Edge intelligence and 5G convergence: Toward autonomous distributed analytics. *Global Journal of Emerging Computing Paradigms*, 16(1), 45–82.