



Edge Intelligence: Edge Computing for 5G and the Internet of Things

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1. Introduction

In recent years, the field of artificial intelligence has made a revolutionary breakthrough. The remarkable success of deep learning technologies and large language models (LLMs) has fundamentally reshaped industrial processes and societal dynamics, with their transformative impact poised to persist in the foreseeable future. With the continuous advancement of artificial intelligence (AI) technology, edge intelligence has emerged as a new research hotspot. Just as edge computing was developed to provide faster and lower-latency computing and storage services compared to cloud computing, the development of edge intelligence aims to deliver enhanced responsiveness and diversified intelligent services that surpass conventional cloud-based AI implementations. The emergence of edge intelligence not only brings AI closer to users but also provides new technological support for the development and application of 5G and the Internet of things (IoT).

Specifically, edge intelligence will promote innovative development in the fields of 5G and the IoT in at least three areas. First, it will reconstruct the network infrastructure of 5G and the IoT, making networks more efficient and flexible, thereby laying a solid foundation for intelligent network services and applications. Second, it will provide faster and more diverse intelligent service support for end-user applications. While enhancing existing applications with faster and more personalized intelligent services, it will also give rise to numerous innovative intelligent applications, such as augmented reality and virtual reality. Last but not least, edge intelligence offers new solutions to the technical challenges faced in the era of 5G and the IoT, for example, how to efficiently and rapidly utilize large amounts of local data generated by numerous IoT devices in a manner that protects user privacy.

While demonstrating significant potential, edge intelligence remains at a nascent stage of development, requiring in-depth academic research and continuous industrial exploration. To promote the development of edge intelligence, this Special Issue aims to gather recent advances and novel contributions in the areas of edge intelligence and edge computing for 5G and IoT networks, providing opportunities for academic researchers and industry practitioners to exchange creative ideas, with the goal of inspiring further innovation and fostering progress in academia and industry.

2. An Overview of Published Articles

Yushan Li's article (contribution one) proposes a novel edge-based programming framework tailored for real-time and distributed applications in smart transportation systems. It leverages the Elixir programming language, event-driven architecture (EDA), and the MQTT protocol to enhance edge-based vehicular systems. The proposed solution



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enhances system performance, achieving low-latency response times, high-concurrency handling, and fault tolerance, as demonstrated through two case studies: a traffic light system and a cab dispatch prototype. This work not only contributes to the development of more scalable and responsive applications in edge computing but also highlights the potential of Elixir in smart transportation applications, paving the way for future research and practical deployment in edge-based smart transportation systems.

The article by Gulshan Saleem et al. (contribution two) introduces Edge-Enhanced TempoFuseNet, a cutting-edge framework designed to address the challenges of intelligent multiclass video anomaly recognition in low-quality surveillance video analytics within 5G and IoT environments. It tackles issues such as poor lighting and low spatial resolution, which are prevalent in real-world surveillance scenarios. The framework employs a two-stream architecture combining spatial and temporal feature extraction for anomaly classification, enhanced by a super-resolution technique using a pre-trained StyleGAN to improve video quality. This approach significantly outperforms traditional methods, achieving high accuracy and low false positive rates in anomaly classification. The study's significance lies in its ability to enhance the effectiveness of video surveillance systems by improving anomaly detection accuracy, thereby contributing to safer and more efficient monitoring solutions in various applications such as security, traffic monitoring, emergency response, and behavior analysis.

The third article is from Rafael Moreno-Vozmediano et al. (contribution three) and presents a comprehensive study on intelligent resource orchestration for 5G edge infrastructures, addressing the challenges of efficiently managing and optimizing resource allocation in distributed edge environments. The proposed Smart 5G Edge-Cloud Management Architecture integrates predictive intelligence mechanisms for workload forecasting and optimization algorithms to achieve the optimal allocation of virtual resources across multiple edge locations. By leveraging various prediction and optimization mechanisms, such as Bayesian regression for CPU usage prediction and integer linear programming for resource optimization, the study demonstrates significant improvements in managing latency-sensitive and data-intensive applications. This work is significant as it provides a robust framework for intelligent edge orchestration, which is crucial for the deployment of next-generation applications in 5G networks.

The subsequent contribution to this Special Issue, written by Laura Lemmi et al. (contribution four), addresses the challenge of ensuring service continuity for edge computing applications in 5G mobile networks, particularly when workloads need to be migrated between edge nodes due to user mobility. The authors propose an innovative solution that integrates Segment Routing over IPv6 (SRv6) into the 5G core data plane alongside the ETSI multi-access edge computing (MEC) architecture. This approach allows for lossless workload migration by implementing a packet buffer as a virtual network function (VNF) within the SRv6 framework, ensuring that services can follow users without packet loss or significant performance degradation. The solution is evaluated through a small-scale testbed and the results demonstrate higher scalability and flexibility compared to traditional IPv6 routing methods, showcasing the potential of SRv6 for enhancing service continuity in dynamic 5G edge environments.

The article by Daniel Christian Lawo et al. (contribution five) addresses the critical issue of securing Internet Protocol security (IPsec) tunnels against future quantum computing threats by integrating post-quantum cryptography (PQC) algorithms. The authors experimentally demonstrate the first IPsec tunnel secured by PQC algorithms such as Falcon, Dilithium, and Kyber, deploying it in two scenarios: a high-performance data center environment with a 100 Gbit/s line rate throughput and a wireless client-to-cloud connection with a 0.486 Gbit/s throughput. The significance of this work lies in its contribu-

tion to the development of quantum-resistant communication protocols and the adoption of PQC in existing network infrastructures, ensuring data security in the post-quantum era.

In the sixth article, Yi Liu and Leonard Barolli (contribution six) tackle the critical issue of determining driver anxiety levels while driving, which is crucial for improving driving safety and reducing the risk of traffic accidents. The authors propose an intelligent system based on fuzzy logic to decide a driver's anxiety level (DAL) by considering various factors, including driving experience, in-car environment conditions, and driver age. They implement and compare two fuzzy-based models (DALM1 and DALM2), with DALM2 incorporating an additional parameter related to accident anxiety state. The simulation results show that the system can effectively evaluate driver anxiety levels, with DALM2 providing more accurate assessments due to its more comprehensive rule base. The study bridges the gap between psychological and technical approaches in assessing driver anxiety, providing a reliable and explainable method for real-time driver state evaluation in intelligent transportation systems.

The research from Youssef Abadade et al. (contribution seven) delves into the problems faced by diagnosing respiratory diseases, particularly asthma, using lung sound recordings. Traditional diagnostic methods, such as the stethoscope, are limited by their reliance on physician expertise, lack of recording functionality, and inability to filter out noise. Cloud-based deep learning solutions, while effective, often face issues related to latency, Internet dependency, and privacy concerns. To overcome these limitations, the authors developed Tiny Machine Learning (TinyML) models that can be deployed on low-power, cost-effective devices like digital stethoscopes to provide the real-time and accurate diagnosis of respiratory conditions. They trained and compared three models—a custom CNN, an Edge Impulse CNN, and a custom LSTM—using a publicly available lung sound dataset. The custom CNN achieved the highest accuracy while maintaining moderate resource usage. This work highlights the potential of TinyML to enhance healthcare by providing accessible, reliable diagnostic tools, especially in remote and underserved areas.

Sakshi Patni and Joohyung Lee's study (contribution eight) presents EdgeGuard, a novel decentralized architecture that addresses the challenges of data privacy, security, and resource management in Internet of Medical Things (IoMT) networks. It integrates blockchain technology, federated learning, and edge computing to enable secure and efficient medical resource orchestration. The key contributions include a federated learning algorithm optimized for medical data with differential privacy, a lightweight blockchain consensus mechanism tailored for IoMT devices to ensure data integrity and security, and an adaptive edge resource allocation method to enhance system scalability and efficiency. Additionally, it introduces an access control system based on smart contracts and a secure multi-party computing protocol for model updates. EdgeGuard significantly improves computational performance, data value, and privacy protection compared to existing solutions. This work provides a comprehensive and effective framework for secure and efficient medical data management in IoMT ecosystems.

The work from Niroshinie Fernando et al. (contribution nine) proposes a novel three-tier architecture integrating edge, fog, and cloud computing to optimize the distributed processing of IoT data. It addresses the challenges of task allocation across heterogeneous resources, dynamic node availability, and maintaining Quality of Service (QoS) in a cooperative edge–fog–cloud environment. The key contributions include the development of a conceptual architecture for dynamic collaboration among these tiers, the implementation of a real-world prototype, and empirical evaluations demonstrating significant improvements in performance, energy consumption, and cost reduction. The results show speedups of up to 7.5 times and energy savings of up to 80%, highlighting the effectiveness of the proposed architecture in supporting the dynamic computational needs of IoT ecosystems.

The last article published in this Special Issue is from Zhiyuan Wang and Yuezhi Zhou (contribution ten), and it provides an in-depth analysis and evaluation of Intel Software Guard Extension (SGX)-based Trusted Execution Environment (TEE) usage in IoT and edge intelligence scenarios. It identifies and addresses key challenges, such as performance overhead, I/O security issues, and vulnerability to side-channel attacks that arise when applying a TEE in resource-constrained edge environments. The study conducts extensive experiments on different SGX implementations, including those based on SGX SDK and LibOS, revealing significant performance bottlenecks and security limitations. It offers critical insights into the limitations of current SGX solutions and proposes performance optimization strategies, such as optimizing enclave entry and exit, bypassing the kernel for I/O operations, and adopting confidential virtual machine (CVM)-based TEE. These contributions provide valuable benchmarks and practical approaches for improving the integration of TEE in IoT and edge intelligence scenarios.

3. Conclusions and Future Directions

This Special Issue on “Edge Intelligence: Edge Computing for 5G and the Internet of Things” showcases the latest advancements and contributions in leveraging edge computing and edge intelligence to empower 5G and the Internet of Things. The articles published in this Special Issue span a diverse range of topics, including innovative programming frameworks, intelligent resource orchestration, secure communication protocols, and healthcare applications. These studies collectively highlight how edge intelligence can revolutionize network infrastructure, enable innovative applications, and address technical challenges facing 5G and the IoT. Together, they underscore the potential and importance of edge intelligence for the future of 5G and the IoT.

Edge intelligence is expected to transform the way we interact with cloud-based AI by bringing AI closer to the end users, thereby enhancing the capabilities of 5G and the IoT. Here are some key future directions for edge intelligence:

Enhanced AI Models for Edge Intelligence: Future research should focus on developing more efficient and lightweight AI models that can run on resource-constrained edge devices without compromising performance. Techniques like model pruning, quantization, and federated or split learning will be crucial in achieving this goal.

Interoperability and Standardization: As edge intelligence continues to evolve, there will be a growing need for standardized protocols and frameworks to ensure interoperability between different edge devices and platforms. This will facilitate seamless integration and communication across diverse 5G and IoT ecosystems.

Security and Privacy: With the increasing adoption of edge intelligence, ensuring the security and safety of intelligent systems and protecting user data privacy and security will remain critical challenges. Future developments should focus on advanced encryption methods, secure communications, robust authentication mechanisms, and trusted or confidential computing technologies to protect sensitive applications and data at the edge.

Dynamic and Scalable Resource Management: Future edge computing systems must be scalable and capable of dynamically managing resources to handle varying workloads and network conditions. Intelligent orchestration frameworks that can predict and optimize resource allocation in real time will be crucial.

Human-Centric Applications: Developing edge intelligence solutions that prioritize human-centric applications, such as healthcare, smart homes, and smart transportation systems, will be an important direction. These applications should leverage edge intelligence to provide more intuitive, responsive, and user-friendly experiences.

By addressing these future directions, edge intelligence can continue to evolve and play a pivotal role in shaping the next generation of 5G and IoT technologies, ultimately leading to a smarter, more efficient, and secure digital ecosystem.

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