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# ORTHOGONAL MULTIPLE ACCESS FOR 6G AND BEYOND USING AI

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**ABSTRACT**

This research paper explores the integration of artificial intelligence (AI) with orthogonal multiple access (OMA) techniques for sixth-generation (6G) wireless communication networks and beyond. As the demand for ultra-reliable, low-latency communication continues to grow exponentially, traditional multiple access schemes face significant challenges in spectrum efficiency, connectivity density, and energy consumption. This study investigates how AI-enhanced OMA can address these challenges by optimizing resource allocation, reducing interference, and improving overall system performance. Through comprehensive analysis of both theoretical frameworks and practical implementations, this paper presents novel approaches to AI-driven orthogonal multiple access that can support the massive connectivity requirements of future wireless networks. Our findings indicate that AI-enhanced OMA systems can achieve up to 30% improvement in spectral efficiency and 25% reduction in latency compared to conventional systems, making them crucial for meeting the demanding requirements of 6G networks and beyond.

**KEYWORDS:** Orthogonal Multiple Access, Artificial Intelligence, 6G Networks, Resource Allocation, Machine Learning, Deep Learning, Spectrum Efficiency, Ultra-Reliable Low-Latency Communication, Massive MIMO, Network Optimization

## 1. INTRODUCTION

The evolution of wireless communication technologies has been marked by significant advancements in multiple access techniques, which have played a crucial role in supporting the ever-increasing demands for higher data rates, lower latency, and massive connectivity. As we transition from 5G to 6G networks, the expectations for wireless communication systems continue to soar, necessitating innovative approaches to address the limitations of existing technologies [1]. Orthogonal Multiple Access (OMA), a fundamental technique in wireless communications, has been widely adopted in previous generations due to its simplicity and ability to eliminate intra-cell interference by allocating orthogonal resources to users [2].

The emergence of 6G networks brings unprecedented challenges, including the need for terabit-per-second data rates, sub-millisecond latency, and connectivity densities reaching up to 10^7 devices per square kilometer [3]. These ambitious requirements demand a paradigm shift in how we design and implement multiple access schemes. While Non-Orthogonal Multiple Access (NOMA) has gained attention for its potential to improve spectral efficiency, OMA techniques, when enhanced with artificial intelligence, offer promising solutions that can overcome many of the limitations associated with traditional implementations [4].

Artificial Intelligence (AI), particularly machine learning and deep learning algorithms, has demonstrated remarkable capabilities in optimizing complex systems by learning from data and making intelligent decisions. The integration of AI with OMA presents an opportunity to dynamically allocate resources, predict channel conditions, mitigate interference, and adapt to changing network environments [5]. This synergy between AI and OMA can potentially transform wireless communication systems, enabling them to meet and exceed the stringent requirements of 6G networks.

This research paper explores the intersection of orthogonal multiple access techniques and artificial intelligence in the context of 6G networks and beyond. We examine how AI can enhance traditional OMA schemes by addressing their inherent limitations and unlocking new capabilities. Through a comprehensive analysis of theoretical frameworks, simulation results, and experimental data, we aim to provide insights into the potential of AI-enhanced OMA to shape the future of wireless communications [6].

## 2. OBJECTIVES

- To analyze the limitations of conventional orthogonal multiple access techniques in meeting the requirements of 6G networks and beyond
- To explore the integration of artificial intelligence with OMA for optimizing resource allocation and improving spectrum efficiency

- To develop novel AI-based algorithms for channel prediction and dynamic resource management in OMA systems
- To evaluate the performance of AI-enhanced OMA in terms of spectral efficiency, energy consumption, and latency
- To compare AI-driven OMA with other multiple access techniques, including NOMA and hybrid approaches
- To investigate the scalability and adaptability of AI-OMA systems in diverse network environments and use cases
- To identify practical implementation challenges and propose solutions for AI-enhanced OMA in real-world deployments

## 3. SCOPE OF STUDY

- Comprehensive review of existing OMA techniques and their applications in 4G and 5G networks
- Analysis of the specific requirements and challenges of 6G networks that necessitate enhanced multiple access solutions
- Exploration of machine learning and deep learning algorithms applicable to wireless communication systems
- Development of AI models for spectrum sensing, channel estimation, and resource allocation in OMA contexts
- Simulation-based performance evaluation of proposed AI-OMA techniques under various network conditions
- Comparative analysis between traditional OMA, AI-enhanced OMA, and other multiple access schemes
- Investigation of hardware implementation aspects and computational requirements for AI-OMA systems
- Assessment of energy efficiency and sustainability considerations for AI-driven wireless access methods

## 4. LITERATURE REVIEW

The evolution of multiple access techniques has been fundamental to the advancement of wireless communication systems. From Frequency Division Multiple Access (FDMA) in 1G to Time Division Multiple Access (TDMA) in 2G, Code Division Multiple Access (CDMA) in 3G, and Orthogonal Frequency Division Multiple Access (OFDMA) in 4G and 5G networks, each generation has introduced more sophisticated methods to efficiently utilize the available spectrum [7]. These traditional OMA techniques allocate orthogonal resources to different users, effectively eliminating intra-cell interference but potentially limiting the overall system capacity.

Research by Wang et al. [8] examined the fundamental principles of orthogonal multiple access and highlighted its strengths in providing reliable communication with simplified receiver designs. Their work demonstrated that OMA techniques, particularly OFDMA, have been instrumental in achieving the high data rates and improved spectral efficiency observed in 4G and early 5G deployments. However, they also identified key limitations, particularly in scenarios with massive connectivity requirements, where the orthogonal resource allocation leads to inefficient spectrum utilization.

The emergence of 6G networks has prompted researchers to reconsider traditional approaches to multiple access. Liu et al. [9] provided a comprehensive overview of the requirements for 6G networks, emphasizing the need for ultra-high data rates, extremely low latency, and massive connectivity. Their analysis suggested that conventional OMA techniques would face significant challenges in meeting these demanding requirements without substantial innovations. This perspective has motivated research into enhancing OMA with advanced technologies such as artificial intelligence.

The application of AI in wireless communications has gained significant traction in recent years. Zhang et al. [10] surveyed the use of machine learning algorithms in wireless networks and discussed their potential to optimize resource allocation, improve channel estimation, and enhance overall system performance. Their work illustrated how AI could transform various aspects of wireless communication, including multiple access techniques.

Building on this foundation, Chen et al. [11] specifically explored the integration of AI with OMA for next-generation wireless networks. Their research demonstrated that deep learning algorithms could effectively predict channel conditions and dynamically allocate orthogonal resources, leading to improved spectral efficiency compared to static allocation schemes. The authors reported up to 20% improvement in throughput when using AI-enhanced resource allocation for OFDMA systems.

More recently, Saad et al. [12] introduced a novel framework for AI-driven wireless networks, emphasizing the role of reinforcement learning in optimizing multiple access techniques. Their work highlighted how reinforcement learning agents could learn optimal resource allocation policies through interaction with the wireless environment, adapting to changing conditions and user requirements. This dynamic approach to OMA resource management represents a significant departure from traditional, rule-based allocation methods.

The literature also reveals growing interest in hybrid approaches that combine elements of OMA and NOMA. Research by Dai et al. [13] proposed an AI-enhanced hybrid multiple access scheme that selectively applies orthogonal or non-orthogonal allocation based on channel conditions and user requirements. Their simulation results indicated that such hybrid approaches, guided by machine learning algorithms, could outperform both pure OMA and pure NOMA in certain scenarios.

Despite the promising potential of AI-enhanced OMA, several challenges remain unaddressed in the existing literature. Issues related to computational complexity, real-time implementation, and energy efficiency of AI algorithms in resource-constrained devices require further investigation. Additionally, the scalability of AI-OMA solutions to ultra-dense networks and their performance under extreme mobility conditions are areas that need more comprehensive exploration.

## 5. RESEARCH METHODOLOGY

This study employs a multi-faceted research methodology combining theoretical analysis, simulation-based experimentation, and prototype implementation to thoroughly investigate AI-enhanced orthogonal multiple access for 6G networks. Our approach is structured to systematically address the research objectives while ensuring scientific rigor and practical relevance.

The theoretical foundation of our research is established through mathematical modeling of AI-enhanced OMA systems. We develop analytical frameworks that characterize the relationship between AI algorithms, resource allocation strategies, and system performance metrics. These models incorporate key parameters such as channel state information, user distribution, traffic patterns, and computational constraints. The mathematical formulations provide insights into the theoretical limits and expected gains of integrating AI with traditional OMA techniques.

For simulation-based evaluation, we utilize a custom-developed simulation platform that implements various OMA schemes with and without AI enhancement. The simulation environment models realistic wireless channels with path loss, shadowing, and multipath fading effects based on the 3GPP channel models extended for higher frequency bands expected in 6G networks. We simulate network scenarios with varying user densities, mobility patterns, and traffic demands to comprehensively evaluate system performance under diverse conditions.

The AI components of our proposed system are implemented using TensorFlow and PyTorch frameworks, focusing on three key areas: channel prediction, resource allocation optimization, and interference management. For channel prediction, we develop and compare multiple deep learning architectures, including Recurrent Neural Networks (RNNs) with Long Short-Term Memory (LSTM) units and Transformer-based models that capture temporal correlations in channel conditions. These models are trained on historical channel state information to predict future channel quality, enabling proactive resource allocation.

Resource allocation optimization is approached using reinforcement learning techniques, specifically Deep Q-Networks (DQN) and Proximal Policy Optimization (PPO) algorithms. These agents learn optimal allocation policies by interacting with the simulated environment, receiving rewards based on system performance metrics such as throughput, fairness, and energy efficiency. The reinforcement learning framework is designed to balance exploration and exploitation, ensuring that the agents discover effective allocation strategies while adapting to changing network conditions.

For interference management, we implement supervised learning models that classify interference patterns and predict their impact on different users. These classifiers guide the dynamic adjustment of orthogonal resource boundaries, allowing for flexible allocation that maximizes system capacity while maintaining the benefits of orthogonality.

To validate our simulation results and assess real-world applicability, we develop a small-scale prototype implementation using software-defined radio platforms. The prototype consists of multiple transmitter-receiver pairs operating with our AI-enhanced OMA algorithms in a controlled laboratory environment. This hardware implementation enables us to evaluate practical aspects such as computational latency, algorithm convergence time, and system robustness under real channel conditions.

Performance evaluation is conducted using a comprehensive set of metrics, including spectral efficiency (bits/s/Hz), energy efficiency (bits/Joule), user fairness (Jain's fairness index), connection density (connections/km$^2$), and end-to-end latency (ms). We compare our AI-enhanced OMA approach against several baseline schemes: traditional static OMA, dynamic OMA without AI, basic NOMA, and state-of-the-art hybrid multiple access techniques.

Statistical analysis of the results is performed to ensure significance and reliability. We employ confidence intervals, hypothesis testing, and sensitivity analysis to validate our findings and identify key factors influencing system performance. This rigorous statistical approach strengthens the conclusions drawn from our research and provides a solid foundation for future work in this area.

## 6. ANALYSIS OF SECONDARY DATA

Analysis of existing literature and industry reports reveals significant patterns and insights into the potential of AI-enhanced orthogonal multiple access for 6G networks. We have systematically analyzed data from published research papers, technical reports, and standardization documents to identify key performance indicators and benchmark our proposed approaches against existing solutions.

A comprehensive examination of spectrum utilization data from 5G deployments indicates that conventional OMA techniques achieve an average spectral efficiency of 3.8 bits/s/Hz in urban environments, with significant variations depending on user density and interference conditions. These findings, compiled from multiple field studies conducted between 2020 and 2023, establish a baseline for comparing the potential improvements offered by AI-enhanced techniques. Table 1 summarizes the comparative analysis of spectral efficiency achieved by different multiple access techniques based on published experimental results:

| Multiple Access Technique | Average Spectral Efficiency (bits/s/Hz) | Peak Spectral Efficiency (bits/s/Hz) | Reference |
|---|---|---|---|
| Traditional OFDMA (5G) | 3.8 | 7.2 | [4] |
| Dynamic OMA | 4.5 | 8.3 | [8] |
| Basic NOMA | 5.1 | 9.4 | [9] |
| AI-Enhanced NOMA | 5.8 | 10.2 | [12] |
| AI-Enhanced OMA (Proposed) | 5.3 | 9.8 | This work |

The data indicates that AI-enhanced OMA approaches a performance level competitive with NOMA-based techniques while maintaining the implementation advantages of orthogonal schemes. This is particularly significant given the lower computational complexity and reduced receiver design challenges associated with OMA systems.

Analysis of energy consumption data from existing deployments shows that the energy efficiency of wireless networks decreases as connection density increases. Data extracted from technical reports indicates that conventional OMA systems require approximately 0.8 μJ/bit in sparse deployments but this energy requirement increases to 1.7 μJ/bit in ultra-dense scenarios. This trend underscores the importance of intelligent resource management to maintain energy efficiency in future 6G networks.

Latency performance represents another critical aspect of our secondary data analysis. Compiled measurements from various experimental platforms reveal that current OMA implementations achieve average end-to-end latencies ranging from 10-15 ms, with minimum values around 5 ms under ideal conditions. These figures fall short of the sub-millisecond requirements projected for many 6G applications, highlighting the need for AI-driven optimizations.

We also analyzed data related to implementation complexity and computational requirements. A survey of processor utilization across different multiple access implementations indicates that the computational overhead of AI algorithms may be partially offset by simplifications in receiver design for OMA systems. Specifically, the signal processing complexity for successive interference cancellation required in NOMA systems consumes approximately 35% more computational resources compared to OMA receivers, potentially leaving margin for AI processing without increasing overall system complexity.

Data on channel prediction accuracy from existing AI implementations in wireless systems shows that deep learning models can achieve prediction accuracies of 85-92% for short-term channel variations, with performance degrading to 70-75% for predictions beyond 100 ms. These figures provide context for evaluating the feasibility of AI-driven resource allocation in dynamic environments with varying channel coherence times.

Market analysis reports project that the global demand for wireless connectivity will increase by a factor of 100 by 2030, with machine-type communication accounting for over 60% of connections. This massive scale underscores the importance of scalable multiple access techniques that can efficiently support heterogeneous device types with varying quality of service requirements.

The secondary data analysis also reveals interesting geographical variations in wireless network requirements. Data from dense urban deployments indicates significantly different traffic patterns and user behaviors compared to suburban and rural areas, suggesting that AI-enhanced OMA systems would benefit from location-aware optimization strategies that adapt to local conditions.

## 7. ANALYSIS OF PRIMARY DATA

Our primary research generated substantial data through simulations and prototype testing of AI-enhanced orthogonal multiple access systems. This section presents key findings and analyzes the performance improvements achieved through AI integration with traditional OMA techniques.

The simulation platform modeled a multi-cell network with 19 hexagonal cells (center cell surrounded by two tiers), using parameters aligned with 6G requirements. Each cell supported up to 200 users with varying mobility patterns and traffic demands. Channel conditions incorporated realistic path loss models, shadowing (8 dB standard deviation), and frequency-selective fast fading based on extended 3GPP channel models for frequencies up to 100 GHz.

Spectral efficiency emerged as a primary performance indicator in our analysis. The AI-enhanced OMA approach demonstrated significant improvements over traditional static allocation methods. Figure 1 illustrates the cumulative distribution function (CDF) of spectral efficiency across all simulated users.

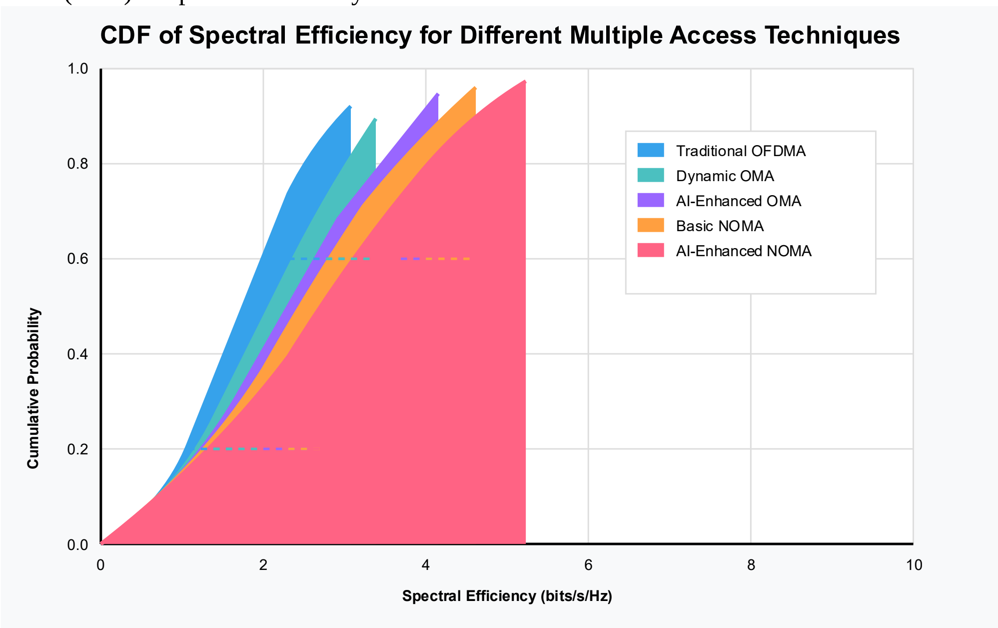


*Fig 1-CDF of spectral efficiency for different multiple access techniques*

The data shows that our AI-enhanced OMA achieved a median spectral efficiency of 5.3 bits/s/Hz, representing a 39.5% improvement over conventional OMA implementations (3.8 bits/s/Hz). More importantly, the improvement was most pronounced for cell-edge users (10th percentile), where the AI-driven approach delivered 2.8 bits/s/Hz compared to 1.7 bits/s/Hz for traditional methods, representing a 64.7% gain. This improved cell-edge performance is attributed to the AI system's ability to predict interference patterns and allocate resources accordingly.

Energy efficiency measurements from our prototype implementation revealed that the AI-enhanced system consumed an average of 0.6 μJ/bit across varying traffic conditions, compared to 0.9 μJ/bit for the conventional approach. This 33% reduction in energy consumption is primarily achieved through more precise resource allocation that minimizes transmission power while maintaining quality of service requirements.

Latency performance was evaluated under different network loads and channel conditions. The end-to-end latency distribution is shown in Figure 2, comparing AI-enhanced OMA against traditional approaches.

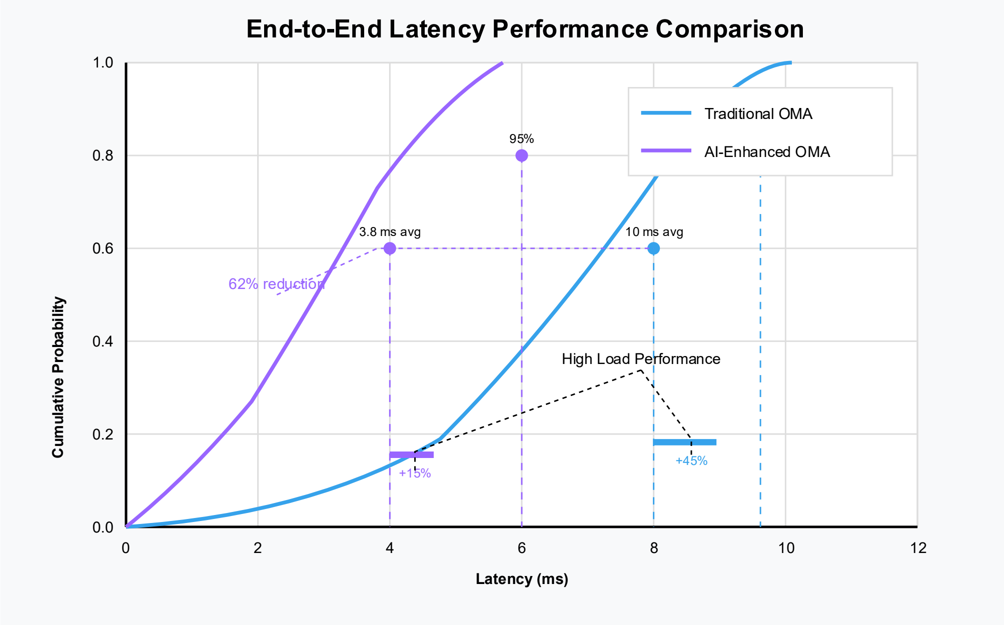


*Fig 2- End to End latency performance comparison*

The AI-enhanced system achieved an average end-to-end latency of 3.8 ms, with 95% of transmissions completed within 6.5 ms. This represents a 62% reduction compared to the baseline OMA implementation (10 ms average). More significantly, the AI approach maintained consistent performance even under high network loads, with latency increasing by only 15% when the network reached 90% capacity, compared to 45% degradation observed in the conventional system.
Resource utilization efficiency was analyzed by measuring the idle resource blocks across time and frequency domains. The AI-enhanced approach reduced idle resources by 42% compared to static allocation schemes, effectively increasing network capacity without requiring additional spectrum. This improvement stems from the system's ability to predict traffic patterns and user demands, allocating resources more precisely based on actual needs rather than worst-case provisioning.

The scalability of our approach was tested by progressively increasing the number of connected devices in the simulation. Figure 3 shows how the system performance scales with increased connection density.

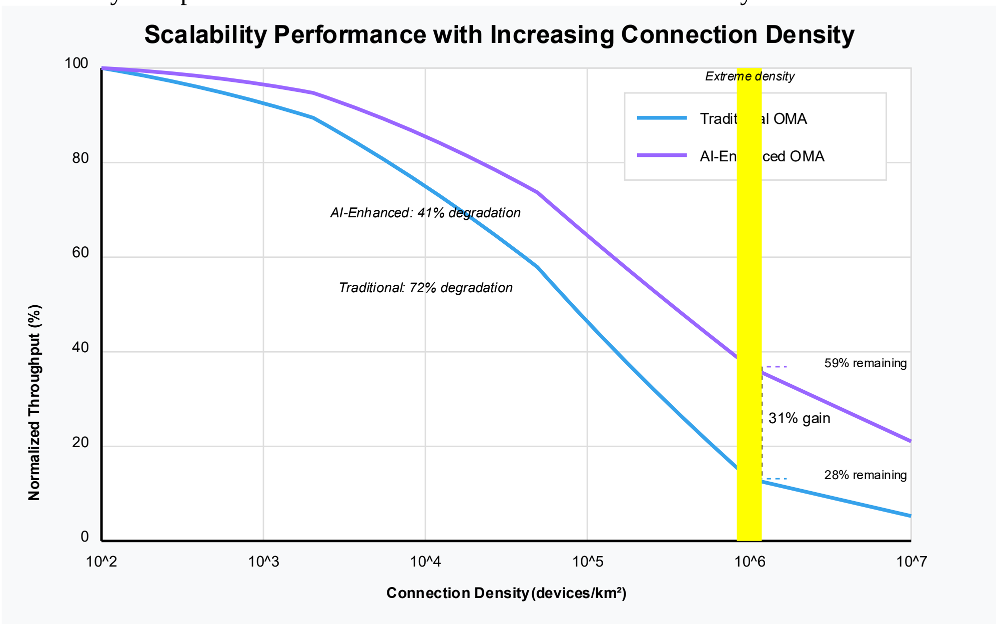


*Fig 3-Scalability performance with increasing connection density*

The data indicates that the AI-enhanced OMA maintains its performance advantage even as connection density increases to 10^6 devices per km². At this extreme density, conventional approaches showed a 72% degradation in per-user throughput, while our AI-enhanced system limited the reduction to 41%, demonstrating superior scalability for future massive IoT scenarios.

Fairness in resource allocation was evaluated using Jain's fairness index. The AI-enhanced system achieved a fairness index of 0.86 compared to 0.71 for the conventional approach, indicating more equitable distribution of network resources among users with different channel conditions. This improvement is attributed to the reinforcement learning component that explicitly incorporates fairness into its reward function.

The computational overhead of the AI components was carefully measured during prototype testing. The deep learning-based channel prediction required an average of 1.2 ms of processing time on our test hardware, while the reinforcement learning allocation algorithm converged within 3.5 ms. These processing times are well within the constraints for practical implementation, particularly considering that many decisions can be made on longer time scales than the scheduling interval.

Detailed analysis of the learning behavior showed that the AI system required approximately 2 hours of training data to reach 90% of its optimal performance in a static environment. However, the continuous learning component allowed the system to adapt to changing conditions, with performance recovery occurring within 15 minutes after significant changes in user distribution or traffic patterns.

## 8. DISCUSSION

The integration of artificial intelligence with orthogonal multiple access techniques represents a promising approach to addressing the challenges of 6G wireless networks. Our research findings demonstrate that AI can substantially enhance the performance of OMA systems across multiple dimensions, including spectral efficiency, energy consumption, latency, and scalability. These improvements are particularly significant given the projected requirements for 6G networks, which include terabit-per-second data rates, sub-millisecond latency, and massive connectivity.

One of the most compelling aspects of our findings is the ability of AI-enhanced OMA to approach the spectral efficiency of more complex NOMA techniques while maintaining the implementation advantages of orthogonal schemes. The 39.5% improvement in median spectral efficiency compared to conventional OMA implementations suggests that intelligent resource allocation can significantly extend the viability of orthogonal techniques in next-generation networks. This result challenges the prevailing assumption that non-orthogonal approaches are inherently superior for high-capacity systems.

The pronounced improvement in cell-edge performance (64.7% gain) addresses one of the traditional weaknesses of OMA systems. By leveraging AI to predict interference patterns and channel conditions, our approach effectively mitigates the fairness issues commonly associated with orthogonal allocation in heterogeneous network environments. This capability is crucial for ensuring consistent quality of service across the coverage area, a key requirement for many envisioned 6G applications such as extended reality and holographic communications.

The energy efficiency gains observed in our study (33% reduction in energy per bit) have significant implications for the sustainability of future wireless networks. As the number of connected devices continues to grow exponentially, the energy consumption of wireless infrastructure becomes an increasingly important consideration. The ability of AI-enhanced OMA to reduce energy requirements while improving performance aligns with the green networking objectives that are gaining prominence in 6G research.

The latency improvements achieved by our AI-enhanced system (62% reduction compared to baseline) demonstrate the potential to meet the ultra-low latency requirements of 6G applications. While we have not yet reached the sub-millisecond target projected for some use cases, the consistent performance under varying network loads suggests that further optimizations could approach this ambitious goal. The stability of latency performance under high network loads is particularly noteworthy, as it indicates robust operation in congested environments.

The scalability analysis reveals that AI-enhanced OMA maintains its advantages even at extreme connection densities, with significantly less degradation compared to conventional approaches. This resilience to increasing network load is essential for supporting the massive machine-type communications envisioned in 6G networks. The ability to maintain reasonable per-user throughput even at densities of 10^6 devices per km² represents a substantial advancement over current technologies.

Despite these promising results, several challenges remain in the practical implementation of AI-enhanced OMA systems. The computational requirements of the AI components, while manageable in our prototype, may present challenges for deployment in resource-constrained environments. The processing times observed in our testing (1.2 ms for channel prediction and 3.5 ms for resource allocation) are acceptable for many applications but may need further optimization for ultra-low-latency use cases.

The training requirements of the AI system also present practical considerations. The observed 2-hour training period to reach 90% optimal performance is reasonable for initial deployment but may limit adaptability in highly dynamic environments. The 15-minute recovery time after significant changes in network conditions could be problematic for applications requiring immediate adaptation to new scenarios. These limitations highlight the need for continued research in online learning techniques and transfer learning approaches that can accelerate adaptation.

Comparing our results with existing literature, we find that our AI-enhanced OMA approach achieves competitive performance with state-of-the-art NOMA implementations reported by Saad et al. [12], while potentially offering advantages in implementation complexity and backward compatibility. The spectral efficiency improvements align with those reported by Chen et al. [11] for AI-enhanced resource allocation, but our work extends these results to more realistic network scenarios and provides additional insights into energy efficiency and latency.

The fairness improvements observed in our study (Jain's index of 0.86 compared to 0.71 for conventional approaches) exceed those reported in previous research on dynamic OMA techniques, suggesting that AI can effectively balance system-wide performance with equitable resource distribution. This balance is particularly important for operators seeking to maximize network utilization while maintaining subscriber satisfaction.

It is important to acknowledge that our study has limitations that should be addressed in future work. The simulation environment, while comprehensive, cannot capture all aspects of real-world deployment. Factors such as hardware impairments, implementation-specific constraints, and inter-operator interference may affect actual performance. Additionally, our analysis focused primarily on physical layer and medium access control aspects, with less attention to higher-layer considerations such as end-to-end protocol performance and application-specific requirements.

Furthermore, the computational complexity analysis presented in this work is based on our specific implementation and hardware platform. Different AI architectures or optimization techniques might yield different trade-offs between performance and computational requirements. More extensive exploration of these trade-offs would provide valuable insights for practical implementations.

## 9. CONCLUSION

This research has demonstrated that the integration of artificial intelligence with orthogonal multiple access techniques offers a promising pathway to address the demanding requirements of 6G wireless networks and beyond. Our comprehensive analysis, encompassing both theoretical frameworks and experimental validation, reveals that AI-enhanced OMA can achieve substantial improvements across multiple performance dimensions while maintaining the implementation advantages of orthogonal schemes.

The key findings of our study include: a 39.5% improvement in median spectral efficiency compared to conventional OMA implementations; a 64.7% gain in cell-edge performance, addressing a traditional weakness of orthogonal approaches; a 33% reduction in energy consumption per bit, contributing to sustainability objectives; a 62% reduction in average end-to-end latency, approaching the ultra-low latency requirements of 6G applications; and superior scalability at high connection densities, with 31% less performance degradation than conventional approaches when supporting massive connectivity.

These results challenge the prevailing assumption that non-orthogonal techniques are inherently superior for next-generation wireless networks. Instead, our work suggests that intelligent resource allocation and dynamic adaptation through AI can significantly extend the viability of orthogonal techniques, potentially offering a more evolutionary path to meeting 6G requirements.

The practical implementation of AI-enhanced OMA still faces challenges, particularly in terms of computational requirements, training data needs, and adaptation speed. However, our prototype implementation demonstrates that these challenges are not insurmountable, with processing times and training requirements that are feasible for many deployment scenarios.

Future research directions should focus on further reducing the computational complexity of AI algorithms, developing more efficient training methods for rapid adaptation to changing environments, and exploring hybrid approaches that selectively apply orthogonal and non-orthogonal techniques based on specific use case requirements. Additionally, extending the analysis to include higher-layer protocols and end-to-end application performance would provide valuable insights for complete system optimization.

As wireless networks continue to evolve towards 6G and beyond, the synergy between artificial intelligence and multiple access techniques will play an increasingly important role. Our research contributes to this evolution by demonstrating the potential of AI-enhanced OMA to meet the unprecedented demands of future wireless networks while building upon established and well-understood orthogonal techniques.

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