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| 論 文 題 目 | Cooperative AI-driven Communication Framework for Wireless Multihop Networks |
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論文の内容の要旨

The continuous evolution from fifth-generation (5G) toward Beyond 5G (B5G) and sixth-generation (6G) systems introduces stringent performance requirements in terms of network capacity, end-to-end latency, and energy efficiency under dynamic and densely deployed wireless environments. Multi-server and multihop network architectures, together with the emergence of artificial intelligence (AI) and multi-access edge computing, provide opportunities for adaptive and scalable communication. However, they also create challenges involving interference-coupled throughput degradation, latency escalation caused by load fluctuations, and inefficient transmit power usage.

To address these challenges, this dissertation proposes a cooperative AI-driven communication (CORE) framework for wireless multihop networks. The framework enables cross-layer and cooperative optimization through three AI-based schemes that operate progressively according to network conditions. First, the efficient capacity management (eCAP) scheme enhances throughput by integrating factor-graph-assisted topology formation, two-phase Q-learning routing, and compute-and-forward transmission to construct interference-resilient multihop paths. Second, the extreme low latency transmission (eLOW) scheme reduces service latency in multi-server wireless networks by employing a Broad Learning System (BLS) for fast and adaptive server allocation under varying traffic loads and link quality. Third, the unified power management (uPOW) scheme improves energy efficiency and interference resilience in multi-server wireless multihop networks by combining BLS-based server allocation, SINR-driven Q-learning path selection, and Consensus Transmit Power Control.

The proposed framework is evaluated through numerical simulations conducted in Python and MATLAB under diverse density, interference, and traffic conditions. Experimental results demonstrate that:

- The eCAP scheme improves network capacity by up to 1.8 times compared with baseline multihop routing protocols through learning-based topology construction and cooperative

forwarding.

- The eLOW scheme reduces service latency by up to 47% and alleviates congestion effects in multi-server deployments through prediction-driven BLS server allocation.
- The uPOW scheme reduces interference power by approximately 40% and achieves 35% energy savings while maintaining high network capacity via distributed cooperative power coordination.

By integrating distributed learning, cooperative decision-making, and adaptive optimization, the CORE framework establishes a foundation for scalable, energy-efficient, and low-latency communication in B5G and 6G wireless systems. The framework demonstrates the feasibility of AI-native network control and offers a conceptual and algorithmic basis for future autonomous communication architectures.

**Keywords**: Cooperative communication, AI-driven framework, Wireless multihop network, Multi-server edge computing, Capacity optimization, Latency reduction, Power control, 6G.

## 論文審査の結果の要旨

The Examination Committee identifies that the dissertation entitled "Cooperative AI-driven Communication Framework for Wireless Multihop Networks" proposes a comprehensive and well-structured cooperative AI-driven communication (CORE) framework to address fundamental challenges in wireless multihop and multi-server networks toward Beyond 5G systems. The dissertation targets three tightly coupled performance issues of network capacity, latency, and energy efficiency under dynamic and dense wireless environments. The CORE framework integrates cross-layer and cooperative optimization through three AI-based schemes. First, the efficient capacity management (eCAP) scheme enhances network throughput by combining factor-graph-assisted topology formation, reinforcement-learning-based path selection, and compute-and-forward transmission to construct interference-resilient multihop routes. Second, the extreme low latency transmission (eLOW) scheme addresses latency accumulation in multi-server wireless networks by employing a Broad Learning System (BLS) for fast and adaptive server allocation under fluctuating traffic loads and channel conditions. Third, the unified power management (uPOW) scheme improves energy efficiency and interference robustness by jointly applying BLS-based server selection, SINR-driven Q-learning path optimization, and consensus transmit power control in multi-server wireless multihop networks. Besides that, each scheme is clearly motivated, mathematically formulated, and systematically evaluated through extensive numerical simulations conducted under diverse network densities, interference levels, and traffic conditions. The simulation results demonstrate substantial performance improvements over the existing approaches, including significant gains in network capacity, notable reductions in service latency, and marked decreases in interference power and energy consumption. These results validate both the effectiveness and scalability of the CORE framework. Furthermore, the dissertation is well written and logically organized, with appropriate background discussions, up-to-date literature reviews, and clearly defined research objectives. The contributions are explicitly summarized, and the limitations and future research directions are appropriately discussed. The references are consistently cited throughout the dissertation, reflecting strong academic rigor. The research outcomes have been disseminated through multiple international conferences and peer-reviewed journal publications, demonstrating the originality, maturity, and academic impact of the work. During presentations, the candidate showed strong technical understanding and clear communication skills in English.

In conclusion, he has made original contributions to AI-driven wireless multihop networking, providing a solid foundation for intelligent and cooperative Beyond 5G communication systems. Thus, the Examination Committee concludes that he fully satisfies the requirements for the degree of Doctor of Philosophy (Information Science).