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Doctoral Dissertation

Cooperative AI-driven Communication Framework for Wireless Multihop Networks

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Abstract

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.