An Agentic AI-Based RAN Optimization Framework for SINR-Aware CCO Optimization with Physical-Layer Modeling

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Abstract

Coverage and Capacity Optimization (CCO) is a critical function of the Radio Access Network (RAN) in 5G and emerging 6G systems, where network performance is strongly influenced by the signal-to-interference-plus-noise ratio (SINR). However, existing CCO approaches often rely on simplified system-level SINR models and uncoordinated optimization strategies, limiting their effectiveness in dense and interference-limited deployments. This paper proposes SINCAM, an agentic AI-based RAN optimization framework for SINR-aware CCO that integrates physical-layer modeling into the decision loop. In SINCAM (SINR-Aware Coordinated Agent-Based Model), configuration parameters are based on explicit SINR feedback obtained from PHY-accurate simulation, while coordinating decisions through agent-to-agent (A2A) interaction to mitigate inter-cell interference. By grounding CCO decisions in realistic physical-layer behavior, the proposed framework provides a scalable and adaptive foundation for improving SINR stability, coverage reliability, and capacity performance in dynamic multi-cell wireless networks.

Keywords- SINR, SINCAM, CCO, RAN, A2A.

Ⅰ. Introduction

CCO is a fundamental function of the RAN, directly influencing user experience, spectral efficiency, and network reliability in 5G, and emerging 6G systems. The effectiveness of CCO is strongly governed by the SINR, which reflects the combined impact of propagation conditions, interference, and transmission strategies. However, most existing CCO solutions rely on system-level abstractions and simplified SINR estimation models that fail to capture realistic physical-layer effects, particularly in dense and interference limited deployments [1]. In parallel, learning-based CCO approaches have been introduced to improve adaptability, yet many of these methods optimize RAN parameters in a largely uncoordinated manner across cells, limiting their ability to manage inter-cell interference and SINR coupling effectively [2].

SINCAM is proposed to address these limitations by enabling SINR-aware CCO through Agentic-AI based RAN optimization grounded in physical-layer modeling. The proposed approach employs multiple cooperative agents that adapt RAN configuration parameters based on explicit SINR feedback, while coordinating decisions through A2A interaction to mitigate inter-cell interference effects. By integrating physical-layer modeling into the CCO decision loop, SINCAM allows optimization decisions to reflect realistic radio-level behavior rather than abstract performance indicators. This design provides a structured and scalable foundation for coordinated, adaptive, and SINR-driven CCO in next-generation wireless networks.

Ⅱ. Challenges in SINR-Driven CCO

A. Simplified SINR Estimation

Most existing CCO approaches estimate SINR using system-level or path-loss-based models, which do not accurately reflect realistic interference and physical-layer effects. This results in unreliable assessment of coverage and capacity performance [3].

B. Inter-Cell Interference Coupling

CCO parameters are often optimized independently across neighboring cells. Such uncoordinated optimization leads to strong inter-cell interference, causing unstable SINR, particularly for cell-edge users [4].

C. Restricted SINR Generalization

SINR-based CCO strategies are often designed and evaluated under specific deployment assumptions, limiting their ability to generalize across dense, heterogeneous, or interference-limited scenarios with different channel and traffic characteristics.

Ⅲ. SINCAM Model Solution for Coordinated SINR-Driven CCO

The SINCAM framework formulates CCO as a SINR-driven RAN optimization problem, where each gNB is modeled as an autonomous learning agent

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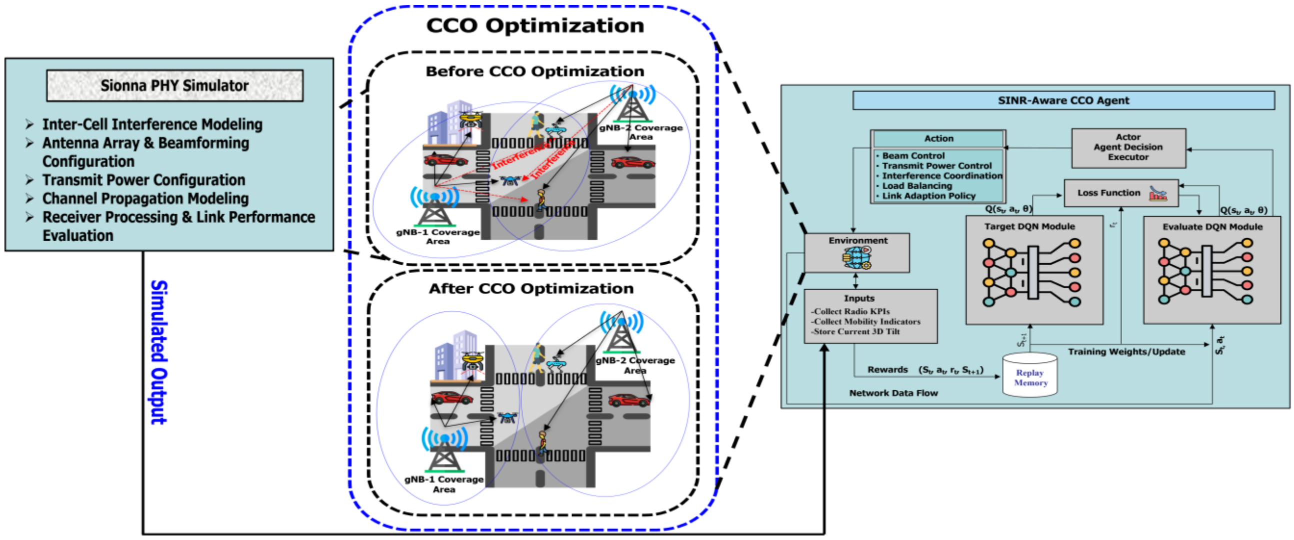

Fig. 1. SINCAM Framework for SINR-Aware CCO

interacting with a shared radio environment. The framework integrates physical-layer modeling to provide explicit SINR feedback under realistic propagation and interference conditions. At each decision interval, PHY-level simulation evaluates inter-cell interference, channel propagation, antenna and beamforming configurations, and transmit power settings, producing per-cell and per UE SINR metrics. These PHY-accurate outputs characterize the RAN state both before and after CCO optimization and enable the agents to observe the direct impact of their actions on SINR distribution, particularly for interference-limited and cell-edge regions. By explicitly exposing PHY-level SINR behavior to the learning process, SINCAM bridges the abstraction gap between radio-level dynamics and high-level RAN optimization decisions.

Based on the observed SINR state, each SINCAM agent performs coordinated decision making through a deep reinforcement learning architecture, where candidate CCO actions, including beam control, transmit power adjustment, interference coordination, load balancing, and link adaptation, are evaluated using a DQN-based policy. Agent-to-agent coordination allows neighboring gNBs to exchange compact SINR and interference indicators, enabling distributed yet cooperative optimization across the RAN. The learning process operates in a closed-loop manner, where selected actions are enforced at the physical layer, updated SINR feedback is collected, and policies are refined through reward-driven updates. Through continuous interaction between PHY-accurate simulation and agentic decision making, SINCAM stabilizes SINR behavior and mitigates inter-cell interference in dynamic multi-cell wireless networks.

IV. Conclusions

This paper proposed SINCAM, an agentic AI-based RAN optimization framework for SINR-aware CCO that integrates physical-layer modeling into the decision loop. By combining PHY-accurate SINR evaluation with coordinated multi-agent learning, SINCAM addresses key limitations of conventional CCO approaches, including simplified SINR estimation and uncoordinated inter-cell optimization. The framework enables adaptive and interference-aware RAN control under dynamic network conditions. Moreover, SINCAM provides a scalable foundation for future PHY-aware AI-native RAN optimization.

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