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February 25, 2026

Editor-in-Chief
IEEE Access

Dear Editor,

We are pleased to submit our manuscript entitled "**HMARL-SOC: Hierarchical Multi-Agent Reinforcement Learning for Autonomous Security Operations Center Coordination**" for consideration for publication in *IEEE Access*.

This paper presents a three-tier hierarchical multi-agent reinforcement learning architecture that mirrors the division of labor in real Security Operations Center (SOC) teams. The key contributions include:

1. A Dec-POMDP formalization integrating SIEM, EDR, and SOAR tool APIs with a four-term reward function balancing detection quality, response speed, disruption cost, and false positive penalty.
2. A heterogeneous agent architecture matching each SOC function to its best-suited RL algorithm (PPO, SAC, DQN, MADDPG), connected through a shared replay buffer with attention-based explainability.
3. Formal convergence guarantees via two-timescale stochastic approximation theory.
4. Comprehensive evaluation on a 200-host MITRE ATT&CK simulator with 6 baselines, ablation study with statistical tests, and cross-environment transfer to CybORG CAGE Challenge 4.

HMARL-SOC achieves the lowest false positive rate (0.17%, $p<0.001$ vs. QMIX) and the highest cumulative reward (+6.9) among all evaluated methods, demonstrating that learned hierarchical coordination enables effective and precise SOC automation.

This manuscript is an extended version of our conference paper presented at ITC-CSCC 2026. The journal extension adds approximately 60% new content, including formal convergence analysis, comprehensive ablation studies, expanded related work, and additional experimental evaluation.

This manuscript has not been published elsewhere and is not under consideration by any other journal. All authors have approved the manuscript and agree with its submission to *IEEE Access*.

Code and data are available at: https://github.com/nutthakorn7/HMARL-SOC.

Sincerely,

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