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NIOA: A Neuro-Inspired Multi-Objective Optimization Framework for Energy-Efficient Clustering in 3D Wireless Sensor Networks

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ABSTRACT

Energy-efficient clustering remains a critical challenge in wireless sensor networks (WSNs), particularly in three-dimensional deployments where existing approaches fail to balance energy efficiency, network lifetime, and throughput. Current clustering algorithms exhibit significant limitations, including static configurations, inability to adapt to heterogeneous nodes, and vulnerability to network dynamics such as obstacles and node mobility. This paper introduces a Neuro-Inspired Optimization Algorithm (NIOA) for WSN clustering that addresses these gaps through an integrated approach combining artificial neural networks, reinforcement learning, and adaptive mechanisms. Our multi-objective framework dynamically balances energy conservation, network lifetime extension, and throughput optimization through a comprehensive fitness function and self-adaptive parameter tuning. Extensive simulations across diverse operational scenarios demonstrate NIOA's superior performance over existing approaches, with substantial improvements in network lifetime, energy efficiency, and packet delivery ratios. The algorithm exhibits remarkable resilience to node failures, environmental obstacles, and security threats while effectively integrating with energy harvesting technologies. These findings indicate that neural-inspired approaches with reinforcement learning can significantly enhance WSN performance in dynamic environments, suggesting promising directions for future intelligent network management systems.

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