DIGITAL TWIN-ENABLED SEMANTIC IOV NETWORKS USING QUANTUM DEEP DETERMINISTIC POLICY GRADIENT

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Abstract

The rapid evolution of Intelligent Transportation Systems (ITS) and the Internet of Vehicles (IoV) has introduced unprecedented demands for ultra-reliable, low-latency, and semantically efficient communication. Traditional data-centric vehicular networking approaches transmit raw sensor data, leading to excessive bandwidth consumption, increased latency, and limited scalability. To address these challenges, this study proposes a Quantum Deep Deterministic Policy Gradient (Q-DDPG) framework for Digital Twin–Enabled Semantic IoV Networks, integrating semantic communication, digital twin modeling, and quantum-inspired reinforcement learning for intelligent vehicular control.In the proposed architecture, vehicles continuously sense environmental and contextual information, which is processed through semantic encoding mechanisms to extract task-relevant meaning rather than transmitting complete raw data. A real-time Digital Twin (DT) model mirrors the vehicular network state, including channel conditions, traffic density, semantic importance, and risk levels. The digital twin predicts system dynamics and assists in proactive decision-making. To optimize transmission power allocation, semantic compression ratio, and edge offloading decisions in a continuous action space, a Q-DDPG agent is introduced. The actor–critic architecture incorporates quantum-inspired embedding layers that enhance feature representation through sinusoidal transformations and entanglement-like interactions, improving learning efficiency and stability in high-dimensional, nonlinear IoV environments.