Meta-Heuristic Fusion for 5G VANETs: A GWO–PSO–ACO Framework Balancing Latency, Energy and Spectrum

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Abstract— Next-generation vehicular applications such as augmented-reality navigation and cooperative collision avoidance demand sub-second response times, low on-board energy use, and judicious utilisation of the scarce 5 G/DSRC uplink spectrum. We address these conflicting requirements by formulating task-offloading in 5 G-enabled vehicular ad-hoc networks (VANETs) as a multi-objective optimisation that minimises end-to-end latency and vehicular energy consumption while maximising deadline reliability and spectral efficiency. A detailed system model captures variable-size tasks generated by mobile vehicles, bandwidth-constrained LTE/5 G and Wi-Fi channels, finite-capacity edge servers at roadside units (RSUs), and a remote cloud. Soft-deadline penalties are imposed on tasks whose latency exceeds 1 s, and channel-congestion costs discourage excessive simultaneous off-loads.

To solve the resulting NP-hard problem we propose an integrated GWO–PSO–ACO swarm optimiser: Grey-Wolf encircling provides global exploration, Particle-Swarm velocity updates accelerate exploitation, and Ant-Colony pheromone learning refines discrete task-channel assignments. All three sub-swarms share the best candidate each iteration, yielding rapid yet robust convergence.

Extensive simulations with realistic workloads (5 – 50 MB tasks) and fleets of 30, 50, and 100 vehicles demonstrate that the hybrid algorithm outperforms the standalone PSO, ACO, and GWO baselines.