CLEAR: A Congestion-Limited, Event-Aware Reinforcement Learning Solution for Preventing Cooperation Collapse in Multi-Agent Systems

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Multi-agent AI systems are increasingly prevalent in various fields ranging from autonomous drone systems to healthcare assistant robots. Achieving success in complex environments requires effective communication protocols for AI agents. This project investigates the non-monotonic relationship between cooperation and utility maximization while proposing a novel congestion-limited, event-aware (CLEAR) solution for communication failure. Cooperation collapse in multi-agent reinforcement learning (MARL) occurs when constraints including limited bandwidth, transmission costs, congestion, and receiver overload impair communication protocols. A novel MARL pipeline that incorporates a receiver-aware speaker agent, stochastic delivery channel, mid-episode goal switch, and belief latch is developed. Proximal policy optimization is implemented to update each agent's parameters. By modeling real-world constraints and using these parameters to probabilistically adjust learned protocols, communication is controlled through a gating policy. The multi-agent system is trained in 300 training episodes at 10 different seeds for each experimental configuration. Experimental results demonstrate non-monotonic behavior with larger budgets in real-world settings, validating the cooperation collapse phenomena proposed by this project. When testing the novel CLEAR algorithm against baseline solutions, CLEAR demonstrates statistically significant improvement in the success per message rate by an average of 53.6%, emphasizing the role of the new algorithm for the future of multi-agent reinforcement learning.

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