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Author: Dr. wentao he
Research Center of Satellite Technology, Harbin Institute of Technology, China, wentao_he@yeah.net

Prof. huayi li
Research Center of Satellite Technology, Harbin Institute of Technology, China, lihuayi@hit.edu.cn
Prof. shi qiu
Research Center of Satellite Technology, Harbin Institute of Technology, China, qiushi_rcst@hit.edu.cn

RESEARCH ON INTELLIGENT ROUTING FOR INTEGRATED SATELLITE-TERRESTRIAL NETWORKS THROUGH AUTONOMOUS MULTI-AGENT COLLABORATION

Abstract

In recent years, construction plans for large low Earth orbit (LEO) satellite constellations, such as Starlink, have been gaining increasing attention. These constellations are expected to play a pivotal role in the integrated satellite-terrestrial networks that will form the backbone of the forthcoming 6G network. However, challenges to ensuring network Quality of Service (QoS) performance have arisen due to the high dynamic variability of inter-satellite and satellite-to-ground links and the non-uniform distribution of ground service requests. Current research largely focuses on inter-satellite routing with single optimization goals, which does not fully meet the requirements of integrated satellite-terrestrial networks. Addressing these challenges, this study models the integrated network routing as a problem of satellite-to-ground link selection under constraints and a multi-hop Markov decision process for inter-satellite links. It also establishes predictive models for both satellite-to-ground and inter-satellite link channels and states, as well as a node congestion model that takes into account the distribution of service requests. A routing framework for the integrated satellite-terrestrial network has been designed, based on an autonomous multi-agent collaboration system, along with an improved reward strategy derived from cooperative game theory. In this framework, each satellite node acts as an agent, making forwarding decisions through actor-critic deep reinforcement learning(AC-DRL) and dynamically adjusting rewards based on the network state to optimize decision-making for data forwarding. The results show that, while the performance of this research in terms of path length is comparable to classic routing methods like shortest path search, it significantly improves the network's QoS performance in aspects such as latency, jitter, packet loss rate, and bandwidth.