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OPTIMIZATION STUDY ON EARTH OBSERVATION AND COMMUNICATION OF SATELLITE CONSTELLATION AND GROUND STATION

Abstract

This paper presents a comprehensive study on optimizing the imaging mission planning and communication scheduling between Earth Observation Satellites (EOS) and ground stations. With the advancement in satellite technology and the increase in the number of satellites and ground stations, there is a growing need for efficient scheduling to maximize the observation of valuable targets and enhance communication reliability. Our study introduces a novel optimization model and algorithm to address the scheduling challenges for a constellation of 40 satellites, 1,000 targets, and 3 ground stations.

We employ Mixed-Integer Linear Programming (MILP) for modeling the complex problem of scheduling observation missions and downlink communications. The objective is to observe as many high-profitable targets as possible within a restricted planning horizon and to optimize the communication schedule, considering the limited memory and power consumption and the Communication Time Window (CTW) between satellite constellation and ground stations. This paper divides the problem into two sub-problems: the target observation problem and the communication problem, each with its unique set of constraints, such as the Visible Time Window (VTW) for targets, the memory capacity of the satellites, and the antenna angle of the ground stations.

To solve these challenges, we develop a Modified Dynamic Programming (MDP) algorithm that significantly reduces computation time while ensuring optimal scheduling. Our approach modifies traditional dynamic programming to better handle the complexities of satellite constellation scheduling and the specific requirements of ground station communication. Through numerical simulations involving a scenario with 40 satellites equipped with Synthetic Aperture Radar (SAR) sensors in a Low Earth Orbit configuration, observing 1,000 targets generated randomly in a specific mission area, and communicating with 3 ground stations, we demonstrate the effectiveness of our optimization model and algorithm. The simulations cover a planning period of 7 days, showcasing the ability to efficiently allocate observation missions to satellites and schedule downlink communications to ground stations.

The results demonstrate a high mission success rate, marked by effective target observations and communication links, surpassing the performance of the Greedy Algorithm in operational efficiency and planning robustness. This study not only highlights the importance of advanced scheduling algorithms in the context of growing satellite constellations and ground station networks but also sets a new benchmark for future research in the field of Earth observation and satellite communication optimization.