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OPTIMIZING HETEROGENEOUS SATELLITE CONSTELLATION DESIGN FOR EARTH
OBSERVATION: HARNESSING EMERGENT INTELLIGENCE THROUGH ADAPTIVE
ROLE-SWITCHING

Abstract

In the quest for advanced Earth observation, we propose an innovative satellite constellation framework designed for the continuous and real-time monitoring of earth to tackle emergency response and management during situations like natural disasters or national security threats. This constellation harnesses the power of adaptive role-switching inspired by the self-organizing behavior of ant colonies. Each satellite in the constellation is equipped with a suite of data capture payloads, inter-satellite communication modules, data processing units and transceivers, enabling multifaceted operational capabilities from detection to in-depth analysis of multiple events of interest.

Building upon the contract-network algorithm for task allocation, our framework introduces a dynamic power budgeting and task allocation system that facilitates autonomous role transitions among satellites. These transitions are predicated on a robust scoring mechanism that assesses the utility of each satellite, ensuring optimal balance between collective mission objectives and individual satellite health.

We delineate specific roles within the constellation, ranging from low-power detection, such as smoke identification, to high-power computation tasks, such as monitoring and analyzing fire progression. Satellites autonomously select tasks based on real-time data analysis, available power, onboard memory, and overall system health—quantified by a performance-based scoring system, that utilizes a dynamic epsilon-greedy parameter used to direct the exploration and exploitation of each satellite’s actions in the available state space.

Our approach promises a cohesive and responsive satellite network capable of emergent intelligence and decentralized control. The constellation is designed to self-optimize, tuning the balance between individual satellite utility and collective operational efficiency. This ensures rapid response times, improved data processing, and optimal resource allocation. With full autonomy in tasking and role switching, the constellation stands to revolutionize Earth observation for emergency response and management, reflecting a significant leap forward in low earth orbit satellite constellation technology.