Applying Autonomy to Distributed Satellite Systems

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Abstract

The need for autonomy in several fields of aerospace engineering has become apparent and widely accepted during the last decade. Autonomy promises to improve the systems' performances, their robustness and tolerance to failures, reduce operational costs and, ultimately increase the intelligence of the system. Many are the researchers that have tackled the design and implementation of autonomy technologies for system-specific purposes: from the control of a UAV fleet or the coordination of a team of robots, to the implementation of spacecraft FDIR techniques. In the area of satellite missions, autonomous systems may drastically reduce their response times when in the presence of internal perturbations (e.g. subsystem failures), or external changes (i.e. changes in the environment) and may allow new monitoring approaches such as the on-board identification of interesting targets (e.g. autonomous detection of natural disasters, crop and forest change detection, etc.)

Autonomy has been deemed essential in the design and deployment of several distributed satellite architectures, especially for Earth Observation applications. The latter systems, grounded on small spacecraft technologies, potentially present node heterogeneity at the functional level as well as in terms of computational and communication capabilities. This, combined with some of their network characteristics (which are dynamic and are affected by the node's orbital properties) and architectural aspects (potentially hierarchically structured and composed of a massive number of spacecraft), enforces the need of autonomous operations. Finally, the absence of autonomy in Distributed Satellite Systems (DSS) architectures, not only could compromise their controllability but could complicate the operational requirements unnecessarily.

This presentation is aimed at gathering the design, functional and execution aspects of autonomous mission planning software for DSS architectures and to identifying open issues that still need to be solved. In the context of distributed satellite architectures, autonomy may be translated as the capability of the system to plan its own activities and observational requests with minimum human intervention. Mission Planning and scheduling Systems (MPS) have been exhaustively explored to provide this capability to the system. Their design, modelling and execution characteristics, however, are particular to the missions for which they were developed and are usually not targeted for new and complex functions that next-generation architectures are aimed to address (e.g. multi-point observations, synchronization of nodes, exchange and management of infrastructure resources, on-board generation of observational requests, self-healing properties, etc.) Some authors have scrupulously identified the commonalities of MPS for monolithic satellite missions, but their characteristics and requirements for DSS are still unexplored. Because of that, this presentation will emphasize their characteristics in that specific context.

Leveraging from the commonalities found in several MPS designs, this presentation will summarize: (a) their fundamental design approaches, ranging from the implementation of negotiation protocols, or multi-agent paradigms to bio-inspired and self-organizing applications; (b) their problem, resource and task modelling, including common algorithms and optimization schemes; and (c) their runtime characteristics (i.e. reactive or deliberative, centralized or distributed). From there, the presentation will conclude discussing the open questions and unsolved features with a focus on small-satellite limitations, network issues and collaborative task requirements, and will propose a roadmap for their resolution.

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