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DYNAMIC RESOURCE PRICING STRATEGIES ANALYSIS FOR ON-ORBIT CLOUD COMPUTING ENVIRONMENTS

Abstract

Space missions are designed to operate in uncertain environments, and since performance degradation occurs over the lifetime of a mission, engineering margins are required to ensure satisfaction of overall system requirements. Nevertheless, design margins are associated with overheads in spacecraft dry mass, thus resulting in extra marginal development and launch costs for the mission, and in inefficiencies in resource utilization. This amount of resources available in orbit are actually unused at any given time of the lifecycle. Federated Satellite Systems (FSS) have been recently proposed to improve the efficiency of spacecraft resource utilization by means of in-orbit sharing of resources. Such concept is similar to what is done with terrestrial cloud computing environments and smart grids for electrical power distribution and trading. Examples of resources that could be shared in a satellite federation include processing power, data link, and data storage. Trading of such assets can result in a market, where prices are determined by the equilibrium between supply and demand of resources.

This paper addresses the issue of dynamic pricing, i.e. real time pricing, and its impact on the engineering design of federated satellite environments. The goal of the analysis is to identify optimal pricing strategies that maximize the utilization efficiency of the federation, here defined as federation welfare, as well as to identify the most important impacts in the design of spacecraft participating in the federation as either customers or suppliers of on-orbit resources.

The analysis is structured as follows. First, the paper characterizes the cost structure of satellite missions and identifies primary design drivers to be accounted for in the analysis. Once cost drivers are identified, the paper introduces a mathematical model to define, simulate, and quantify, the federation welfare associated with different resource pricing strategies such as fixed price, variable price, and auction-based price, accounting for and modeling uncertainties in the supply and demand of resources. Lastly, the paper derives conclusions from the analysis and discusses the impact of the different pricing strategies identified on the engineering design of federated satellite systems and associated ground and support systems. On-orbit cloud computing environment could leverage an important new space market, supporting multiple space missions and potentially improving the utilization efficiency of future spacecraft developments.