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ENHANCING GROUND COMMUNICATION OF DISTRIBUTED SPACE SYSTEMS

Abstract

The functionality of a distributed system can be significantly enhanced by exploring non-traditional approaches that leverage on inherent aspects of distributed systems in space. Till now, the benefit of distributed systems in space has been limited to enhancing coverage, multipoint sensing, creating virtual baselines (e.g. interferometry) or to enhance redundancy. The list of benefits can be further expanded by understanding the behavior of distributed systems in space and by productively incorporating it into mission and spacecraft design. For example, prior knowledge of the spatial evolution of such systems can lead to innovative communication architectures for these distributed systems. In this paper, different communication scenario are investigated that can enhance the communication link between the distributed system and ground.

The increasing trend towards highly miniaturized spacecraft (nano to femto-satellites) and proposals to launch hundreds or even thousands of them in massively distributed space missions have expanded the interest in distributed systems in space. The basic concept is that a large number of small, power and mass limited spacecraft can together achieve a performance that can match the performance of traditional spacecraft, while simultaneously adding additional benefits of distributed systems. A typical spacecraft has several functionalities and previous studies have qualitatively identified which of these functionalities scale with the number of spacecraft in the system. In this paper we focus on the communication capability and identify strategies that will exploit the virtue of distributed systems in space to enhance the capability of the communication link between the space segment and earth.

As an example, the concept of forming a dynamic phased array in space with the elements of a distributed space system in low-earth orbit has been investigated. At the ground receiver, the signals from different satellites forming the array should not differ in phase by more than one-third the transmission wavelength. Realizing such a phased array places strict accuracy requirements on time synchronization and knowledge of relative separation between the satellites with respect to the ground receiver. The relative motion between the satellites, which can be modeled and predicted, can be exploited to effectuate the phased array in space. The performance, requirements and constraints of the various communication scenarios are identified and quantified and a design options tree is developed that outlines all the trade-off involved in selecting the appropriate communication strategy.