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CAPACITY ANALYSIS OF SLOTTING ARCHITECTURES FOR SUN-SYNCHRONOUS ORBITS

Abstract

Low Earth Orbit (LEO) is a finite common pool resource shared by all humankind. Within LEO, sun-synchronous orbits have historically been in particularly high demand due to their convenient properties for Earth observation missions. At the same time, only a relatively limited region of suitable orbital volume exists, especially for missions with repeating ground track requirements. This makes sun-synchronous orbits one of the denser orbits already in use. In that respect, prior work has proposed slotting as a mechanism to achieve rational and efficient use of this limited shared resource, with slots carefully phased to avoid conjunctions that could result in potential collisions. The aim of this work is to study this problem in a more general and systematic manner.

This paper assesses the capacity of sun-synchronous orbits by estimating the maximum number of sun-synchronous orbit slots that can be defined at a given altitude. This number provides a measure of the remaining system capacity for future missions and a metric to aid in studies of how to best optimize slot architecture. This work proposes a slot architecture that accommodates the various perturbations experienced by slotted satellites while simultaneously defining a minimally burdensome set of constraints on satellite placement. A constraint is set to ensure that satellites within a given slot will not need to maneuver more frequently than industry standards under a non-slotted system. In addition, the condition that no conjunction will happen under normal operation between the defined slots of the proposed architecture is imposed.

In order to define this slot architecture, this work makes use of the Flower Constellation theory both to define the slot distribution and to study the dynamic of the system, a new strategy not employed by prior sun-synchronous slotting studies. This allows us to assess all potential uniform slotting solutions in an efficient and compact manner. Aspects analyzed using this approach include the minimum separation distances between satellites, the station keeping maneuvers required for slotted satellites to maintain orbits in their assigned slots, and an evaluation of the differences in the slot architecture that occur with changes in the altitude of the orbits.