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PROGRESSIVE DEPLOYMENT OF A LEO CONSTELLATION PROVIDING SUPPORT SERVICES TO LEO CLIENT SATELLITES: A TRADE-OFF ANALYSIS

Abstract

Scalability is a key feature in systems and networks designs whenever it is advisable to enable the system or network to handle a growing amount of workload by gradually enlarging its size and capabilities. Some examples of cases in which scalability has been a peculiar factor in the build-up process of an infrastructure include the expansion of coverage of cellular networks, which have naturally grown from large cities, to major transport routes and, subsequently, gradually reached areas with a lower density of population. The physical and logical topology of Internet nodes and links can be mentioned as another example of demand-driven natural growing system. In the same way transportation networks, have had in most cases a spontaneous unplanned development, progressively serving areas in which new needs had originated.

This paper presents a framework intended to assist, during the preliminary phases of the design of a space system's architecture, the decision-making process underlying the identification of an appropriate progressive deployment plan for the conceived infrastructure. Specifically, a constellation of LEO satellites, intended to provide support in communication and on-board processing to other LEO client satellites, has been considered for the purposes of this study.

Traditional approaches in the design of large capacity systems make use of optimization methods for specific design objectives -typically cost and performance- calibrated on a fixed market projection, but lack in contemplating the intrinsic uncertainty characterizing demand. Iridium satellite constellation for mobile communication, with its huge $5 billion investment, is an example of an infrastructure devised without scalability and stiffly sized at its origin on the basis of a given market projection, which failed in paying back its financial effort.

This study proposes a progressive deployment strategy in which the system capacity is increased gradually and design options are evaluated at each step of the deployment process. The proposed method considers different architectural options (such as the number of orbital planes and the number of satellites per plane) and makes use of a multi-objective optimization approach. A life-cycle simulation model has been specifically developed to provide a realistic assessment of system behavior. Different market scenarios with different workload conditions have been considered in order to identify some optimal progressive deployment solutions for the proposed infrastructure. The study aims at proposing a method to assess the value of an added system flexibility, by comparing the life-cycle costs of flexibility-oriented designs with costs deriving from traditional design methods.