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BROADBAND LEO CONSTELLATION DESIGN: STABILIZING PRE-COMPUTED TRAFFIC ROUTING, MULTIPLE PATHS ALLOCATION, AND LINK FAILURE BACKPROPAGATION

Abstract

This study has been conducted as a part of Bureau 1440 LEO constellation preliminary design phase. Bureau 1440 is a private space company that develops a global broadband service provided by its own LEO constellation. The principal objective of the study is to analyze the feasibility of pre-computed routing algorithms for intersatellite communication. The problem has been given much attention lately, however, our state-of-the-art analysis indicates that it does not provide sufficient grounds to make decisions on the level of a commercial project. Most theoretical publications are focused on optimization of end-to-end delays or jitter caused by the dynamic evolution of the intersatellite network topology, which is ascribed to connectivity violations due to hardware malfunctions. However, most intersatellite links break for natural and predictable reasons that can be pre-computed and scheduled, which allows enhancing the stability of traffic routing paths.

We have developed a high-fidelity simulator that allows modeling the orbital motion and attitude regimes of all constellation satellites, configuring each satellite in terms of the lasercom terminals, their position, installation matrix, and other characteristics possibly affecting intersatellite links. The model predicts the link loss because of sun blinding, upper and lower bounds on intersatellite distance, mechanical constraints for each terminal rotation angles, angular speed and acceleration, switching off for scheduled satellite orbit correction maneuvers. The model also takes into account the time required for reestablishing any link. Thus, we obtain a dynamic connectivity graph for which the routing problem can be solved as an optimization problem to minimize the systems latency given the throughput constraints. Priority can be given to the routes with a longer lifetime, thus decreasing the jitter in the system.

Extensive simulations have been run for constellation models comprising different satellite configurations and various connectivity patterns. The talk presents our comparative analysis of a number of routing algorithms we came across during the state-of-the art review and implemented in our simulator. To make the simulations more realistic, we introduced the reliability factor; thus, along with the predicted link loss we account for the occasional laser terminal or complete satellite malfunctions, which further degrade the connectivity graph. On such occasions, we found it instrumental to compute backup routes from each node, and execute the second-choice option when an unexpected failure occurs along the first-choice route. This latter option requires backpropagating the information of the link failure to every node that would normally use the failed link.