IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM (B2)
Advance Higher Throughput Communications and Networks for GEO and LEO satellites (3)

Author: Mr. Andreas Hornig
AerospaceResearch.net, Germany

CLOSING THE FINAL GAP TO A FULLY AGILE, ON-DEMAND SPACE OPTICAL COMMUNICATIONS NETWORK BY MAKING EACH GROUND NODE RESPONSIVE TO INCOMING LASER BEAMS, AS EXPLORED FOR DIRECT-TO-EARTH LEO MISSIONS

Abstract

Space optical communications, whether as inter-satellite links (OISL) or links to optical ground stations (OGS), are now an operational reality and constitute a significant fraction of all data transmission paths in space. From network services like the currently available European Data Relay Satellite (EDRS) service for Earth observation and scientific data, or Starlink/Starshield for public, commercial, and secure data, to single missions with direct-to-Earth (DTE) point-to-point connections to dedicated ground stations, optical communication is a proven and reliable method. However, what is still missing to enable full scalability is a laser-only, on-demand routing capability. In such networks, the satellite would act as the active initiator, requesting a link to any available node serving as an entry-point to the network. The ESA-initiated HyDRON initiative identified this gap, and other "network-of-networks" projects, such as ESA's Moonlight and NASA's Lunanet, will rely on this feature.

Currently, routing is either a direct point-to-point connection between a satellite and a dedicated OGS or a multi-hop transmission through a predefined, pre-planned route to the target. Both routing schemes rely on a brute-force approach to determining valid routes, which are only applicable for a limited time and specific conditions. As the number of satellites increases, the complexity of this approach grows beyond practical brute-force capabilities.

To overcome this limitation, network nodes themselves must be reactive and responsive to incoming laser beams, enabling autonomous link acquisition at each hop until the data reaches its target destination within the agnostic network.

This paper explores the concept of a responsive optical communications network, where each node incorporates a detecting sensor (e.g., the Multi-User Acquisition and Tracking Sensor by Jena-Optronik) and examines its impact on routing efficiency and overall data transfer performance. The study includes examples from the PRINCESS and TALOS projects of the Technical University of Berlin (TUB)—both LEO missions, one in a polar orbit and the other in a 60-inclination orbit, utilizing a DTE scheme with a European-based OGS network comprising up to eight stations. The paper details the challenges posed by local weather conditions at the time of satellite passes and how satellite-driven re-targeting to an alternative OGS upon access request bridges the final gap to a fully agile, on-demand space optical communications network.

These routing model and features are developed in parallel to the PRINCESS and TALOS projects and the paper presents further applications relevant for sat-operators and for the laser-communication-in-space community as a whole.