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MODELLING OPTIMAL END-TO-END DELAY AND BANDWIDTH FOR LASER INTER-SATELLITE COMMUNICATION IN A SPACE SOLAR POWER SATELLITE CONSTELLATION

Abstract

In space exploration and satellite technology, satellite-to-satellite power transmission holds significant promise, particularly when combined with Space Solar Power Satellites (SSPS). SSPS is envisioned as large-scale structures placed in orbit around the Earth to collect solar energy and convert it into electrical power. This power can then be transmitted wirelessly to Earth or other satellites, providing a sustainable and renewable energy source for various applications. Wireless communication has become integral to SSPS missions, facilitating crucial functions such as searching the target location for beaming the power. However, while widely utilized, traditional microwave communication faces significant challenges such as packet loss, retransmissions, and limited transmission rates due to atmospheric and cosmic disturbances. In response to these limitations, laser communication technology has emerged as a promising solution, offering superior transmission rates, reduced end-to-end delays, and enhanced reliability over long distances. This research focuses on applying a reinforcement learning-based Q-routing approach to facilitate laser satellite communication between two intra-orbital satellites: the Energy Satellite (E-Sat) and Space Solar Power Satellites (SSPS), positioned at an altitude of 900km. Laser technology enables the customer satellite to detect and verify power transmission between satellites, addressing the challenge of inter-satellite communication in space. The Laser Inter-Satellite Link (LISL) design between the E-Sat and SSPS involves selecting the most suitable satellite based on laser link budget calculations. This process ensures efficient and reliable communication despite the complexities of space environments. Additionally, the proposed algorithm assists in making routing decisions for precise communication within the E-Sat constellation, known as the Energy Orbit. The implementation of laser communication technology offers several advantages over traditional microwave communication. Lasers exhibit less divergence, allowing for longer-distance transmission with minimal signal degradation, even in atmospheric disturbances. Moreover, laser communication systems have demonstrated higher data transmission rates, enabling faster and more efficient data transfer between satellites and ground stations. The proposed Q-routing algorithm optimizes communication pathways between satellites by leveraging reinforcement learning techniques, enhancing inter-satellite communication systems' overall performance and reliability. Furthermore, laser communication technology reduces the dependence on repeated mission launches to service active satellites in orbit, lowering costs and increasing operational efficiency in space missions. The laser communication technology represents a significant advancement in space communication systems, offering improved performance, reliability, and cost-effectiveness compared to traditional microwave communication methods. The research presented in this paper contributes to the ongoing development and implementation of laser communication systems for future small SSPS constellations.