Paper ID: 90645
student

IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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A FEDERATED, SELF-SCALING ARCHITECTURE FOR THE LUNAR INTERNET OF SATELLITES

Abstract

With the expected ramp up in activity on and around the moon over the next decade, the need for a communication infrastructure to supersede legacy one-off solutions has become evident. This need is already being addressed through initiatives such as NASA's Lunanet and ESA's Moonlight initiatives, but the physical implementation of this infrastructure remains relatively conservative through the use of dedicated relay spacecraft communicating over radio and relying on the Deep Space Network. As the number and diversity of users around the Moon rapidly grows, this paradigm may become insufficient for addressing demand. To address this, we propose to leverage idle throughput capacity in user spacecraft via the satellite federation concept.

The principle behind the federated network is to enable users of the network to act as relay nodes for other users' data when their communications system is sitting idle, creating a so-called "Internet of Satellites". The proposed system also provides positioning information, thanks to the ability of a user to crowd-source position data from nearby nodes and a limited number of reference points. By implementing standard protocols as well as non-terrestrial 5G/6G network technology, users of the network act together to create a dense web of nodes which scales organically with demand. This decentralized solution bypasses the need for dedicated hub spacecraft for Moon-to-Moon communication. As an extension to this system, optical communication payloads on board hosts such as the Lunar Gateway or dedicated small spacecraft can act as high-throughput bridges between the lunar network and Earth.

In this paper, we demonstrate the feasibility of such a federated network for the Moon, and determine the conditions needed for a successful implementation of the concept. We evaluate the number and distribution of users needed to successfully run such a network, as well as sizing of communication devices that would need to be carried by users. We particularly consider the ramp-up phase which poses a unique challenge, as the network can only be operational once a critical density of participating nodes joins the federation. To address this, we outline the design of solutions such as low-cost microsatellites to be used as supplementary nodes in the early days of the network.