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Performance Trades for Long-Haul Communication in Deep Space

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ABSTRACT

The NASA Space Science and Human Exploration and Development of Space Enterprises anticipate a significant increase in demand for long-haul communications services from deep space over the next two decades. The range of distances to be considered is on the order of 0.1 AU up to >200 AU and bit rates at least >10 Mbps and perhaps >100 Mbps under routine operating conditions for mid-range distances of a few AU. Emergency and critical operations also create an increasing demand for high reliability communication from spacecraft with potentially limited resources or in highly non-ideal operating environments.

A study was undertaken as part of the NASA BEACON architecture project, in order to find the most cost-effective methods for satisfying the anticipated demand. We considered a variety of architectural styles in our search: radio communication at X-, Ka-, or W-band; optical communication; single hop communication systems with a large Earth-based aperture; single hop with large space-based aperture in the general vicinity of the Earth; and multihop communication with a number of space-based relay terminals between the Earth and the target. For Earth-based radio systems, we also considered monolithic apertures and arrays of antennas such as those described elsewhere in this conference.

We assumed that each of the architectural styles could be scaled to higher capacity by replication. For the single-hop approaches, we assumed that the system capacity would grow proportional to investment; for the multihop approaches we assumed that the capacity would grow with the square of investment as expected based on the inverse square law for space loss.

Considering only bit rate and implementation cost, and within prevailing conditions of ground and spacecraft costs, we found that single hop large Earth aperture systems based on either optical telescopes, or on arrays of medium-sized (around 10m) Ka-band antennas, offer a five-to-tenfold advantage over the alternate solutions considered. This conclusion applies to the range of data rates from 100 kbps to 1 Gbps at typical Mars distances (2.3 AU) with typical spacecraft characteristics. At data rates approximately greater than 1-100 Gbps at Mars distances, space-based multihop solutions become competitive with the Earth-based approaches.