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INTERNET PROTOCOL STACK IN DEEP SPACE: ARCHITECTURE AND SIMULATION RESULTS

Abstract

As deep space exploration advances, robust and efficient communication architectures are essential for supporting scientific missions, autonomous operations, and interplanetary networking. Traditional space communication protocols were designed for constrained environments but lack the flexibility and extensibility of modern Internet protocols. Up to now, communications in space has been implemented without the concept of a layer 3 network. Missions and Service Providers(SP) are planning to use the Internet Protocol(IP) stack on celestial bodies such as Moon and Mars as well as from Earth to those. This paper describes the key characteristics of space communications related to networking, the use cases and the architecture of using IP networking in space. It also describes the adaptation to the QUIC transport protocol to handle extreme latencies and intermittent connectivity. Advantages and tradeoffs are presented. Network simulation results for Moon and Mars will be shown. For Mars, the simulation uses real communication windows data provided by JPL with the actual Mars topology of rovers and orbiters, showing the possible use of IP in deep space. The results show that IP-based networking can extend to interplanetary networking uses, beyond the ranges that have historically been considered within the "protocol radius" for Internet suite network and transport layer protocols. Key considerations for using IP applications and protocols are described, enabling mission engineering to properly design applications and networks for deep space. Finally, since the Internet Engineering Task Force (IETF) has chartered a new working group in order to tackle the use of IP-based networking technology for interplanetary use cases, a summary of the current work is provided.