Optimal Planning and Scheduling for a Mars Relay Communication Network

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Abstract: Mars will be continuously explored this decade and beyond by many concurrent spacecrafts. Presently the Mars Global Surveyor and Mars Odyssey 2001 are orbiting and mapping Mars. Future Mars missions within the next few years include Mars Exploration Landers, Mars Express, and Mars Beagle this year, Mars Reconnaissance Orbiter in 2005, Mars Netlanders, Mars Scouts in 2007, and Mars Science Laboratory in 2009. At different time periods in the future, these missions are overlapped and previous studies indicate that during such periods existing deep space communication infrastructure cannot handle all Mars communication needs. There has been much coordination between various Mars projects and the Deep Space Network to ensure communication resources are effectively utilized so that valuable science and engineering data from Mars orbiters and landers can be accommodated. A plausible solution is to perform optimal resource allocation for the Mars relay communication network; a network consisting of multiple surface units and orbiters on Mars and the Deep Space Stations. Unlike direct-to-earth, a relay communication, either in real-time or store-and-forward, can increase network science data return, reduce surface unit's direct-to-earth communication demands, and enable communication even when the surface unit is not facing Earth. It is the objective of this paper to take advantage of the relay operation to efficiently plan and schedule the network communications.

Our work in achieving optimal planning and scheduling for the relay communication network include (i) modeling and simulating the overall end-to-end forward-and-backward network link capabilities as time-varying resources by incorporating spacecraft dynamics, telecom configurations and other limiting factors such as planet occultation, weather, etc.; (ii) developing mathematical formulations to describe the actual operational constraints such as lander's local Sun angle restriction, time for acquisition and calibration, lander and orbiter one-to-one communication, return science data volume requirement, onboard storage capacity, network latency, radio frequency interference, mission priority, orbiter-to-orbiter communication capability, DSN's multiple spacecraft per antenna capability, etc; (iii) formulating the objective function by means of maximizing the network data throughputs and minimizing the total network transmitting times, and finally (iv) solving the resulting high-dimensional nonlinear constrained optimization problem. Detailed mathematical framework for our Mars relay network and numerical simulation and optimization for a Mars relay network consists of Earth stations and multiple landers and orbiters will be presented. The research in this article was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.