Abstract— Mars will be conductively explored the decade and beyond by many concurrent spacecrafts. Efficient time periods in the future, these missions are overplanned and potential studies indicate that during such periods resulting deep-space communication infrastructures cannot handle large communication needs. There has been much coordination between various Mars projects and the Deep Space Network to ensure communication resources are efficiently utilized so that valuable scientific data can be accommodated. A robust 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, relay-to-rely communication, either in real-time store-and-forward, can provide network science data return, reduce network utility and direct-to-earth communication demand, and enable communication even when the surface unit is not facing Earth. Our objective is to gain advantage of the relay capability is plan and schedule the communication efficiently subject to operational constraints.

Planning and Scheduling Challenges:

Pre-Qualify Passes:

- Find the best possible start time and end time with each pass as the network (in-event, widget) are maximized without violating the communication constraints.

Operational Constraints (I):

- A qualified pass must be long enough to reach the maximum required communication time
- The max pass capability for each pass must exceed a pre-set performance threshold
- The satellite return data is not stored in the network unless necessary.

Operational Constraints (II):

- Due to the limited network capacity, the data passes for the surface stations may need to be in the network in order to schedule or receive any data.

Operational Constraints (III):

- Nonlinear Constrained Optimization:

Decision Variables:

- \( x_1 \), \( x_2 \), \( x_3 \), \( x_4 \)

Objective Function:

- \( \text{Minimize } C(X) = C_{\text{path}}(X) + C_{\text{comm}}(X) \)

Constraints:

- \( A X \leq B \)
- \( \alpha x_1 \) and \( \alpha x_2 \) are the weights
- \( C_{\text{path}}(X) = \sum_{i=1}^{4} \alpha x_i \cdot s_{\text{path}}(t_i) \)
- \( C_{\text{comm}}(X) = \sum_{i=1}^{4} \alpha x_i \cdot s_{\text{comm}}(t_i) \)

Summary:

Our work in achieving optimal planning and scheduling for the relay communication network includes:

1. Modeling and simulating the overall end-to-end network link capabilities as time-varying resources by incorporating spacecraft dynamics, telecom configurations, and other limiting factors such as plume occultation, weather, etc.
2. Developing mathematical formulations to describe the actual operational constraints such as the relay's local Sun-angle restriction, time for acquisition and calibration, etc.
3. Formulating the objective function by means of maximizing the network throughput and minimizing the total network transmit time.
Abstract—Mars will be continuously explored this decade and beyond by many concurrent spacecraft. 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 as that valuable science and engineering data from Mars orbiters andlanders can be communicated. A possible solution to over the resource allocation for the Mars relay communication network, a network consisting of multiple surface units and stations on Mars and the Deep Space Stations. Unlike direct-to-earth, a relay communication, either in real-time or stored-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 on Earth. Our objective is to take advantage of the relay capability to plan and schedule the network communications efficiently subject to operational constraints.

Operational Constraints (I):

- Operational Constraints (II):

- Operational Constraints (III):

Nonlinear Constrained Optimization:

Considered Mars Relay Communication Network

Summary:

Our work in achieving optimal planning and scheduling for the relay communication network includes:

(i) Modeling and simulating the overall end-to-end network link capabilities as time-varying resources by incorporating spacecraft dynamics, telecentric configurations, and other limiting factors such as planet occultation, weather, etc.,

(ii) Developing mathematical formulations to describe the actual operational constraints such as degree of the Sun angle restriction, time for acquisition and calibration, inter-end communication, return science data volume requirement, on-board storage capacity, network latency, radio frequency interference, mission priority, etc.,

(iii) Formulating the objective function by means of maximizing the network data throughput and minimizing the total network transmission time,

(iv) Building a graphical-user interface tool to animate and visualize the Mars Relay Network, and

(v) Solving the high-dimensional nonlinear constrained optimization problem.