Commentary: Request-Driven Scheduling for NASA's Deep Space Network

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High-level Paper Summary

This paper discusses the efforts to better automate scheduling the resources of NASA's Deep Space Network (DSN) of communication antennas. The authors begin with a description of the DSN, its capabilities and users. The authors also describe why their scheduling process is so complex and time consuming.

After briefly describing several previous automation efforts, the authors explain the motivation of moving to a new request-driven scheduling approach. The authors describe the advantages and disadvantages of request-driven scheduling and the implications in developing the required algorithms. The authors describe how requests are expanded into tracking passes and an overall schedule that minimizes conflicts.

The authors describe their pathfinder graphical user interface (GUI) and web application, which will be used by DSN users for creating and editing schedule requests. These applications have been successfully deployed in a test environment at JPL. The authors conclude with a summary of lessons learned from this preliminary deployment and a description of future work to be done.

Problem Specification

The Deep Space Network is an international network of antennas located at Goldstone, California; Madrid, Spain; and Canberra, Australia. The DSN currently supports about 40 interplanetary spacecraft missions as well as radio and radar astronomy observations and several Earth-orbiting missions. DSN users generally require a final track schedule weeks to months in advance in order to build spacecraft command loads. The DSN scheduling team strives to provide conflict-free schedules 8 weeks in advance of the present. However, many factors impact this delivery schedule (e.g., launch slips, dish hardware problems, etc.). In the future, the authors expect DSN usage to increase significantly, with more NASA and international missions, as well as missions with higher data volumes and greater communication complexities. Therefore, there is a great motivation to increase scheduling automation and reduce manual work.

The current DSN scheduling automation effort is called Service Scheduling Subsystem (or S^3). Now under development by JPL, S^3 will be deployed to all DSN users in approximately 2 years (as a web-based tool). In this paper the authors focus on the DSN Scheduling Engine (DSE) component of S^3, and the conversion to a *request-driven* (rather than activity-oriented) scheduling algorithm.

One of the greatest advantages to request-driven scheduling is that one scheduling request can be used to generate and manage multiple activities. Therefore, one change request can be propagated to all resultant activities. This greatly simplifies the work required to make scheduling changes.

One of the disadvantages of this new strategy, however, is that the request specification language is very complex (Clement *et al.* 2008). Requests often have associated constraints, preferences, priorities and patterns of repetition. As a result, it may be difficult to assess if a particular request is feasible, due to the presence of many interdependent scheduling options. This could lead to scheduling inconsistencies that are not discovered until late in the scheduling process. Since DSN resources are mission-critical (and usually over-constrained), this would not be acceptable.

DSN Scheduling Engine Development & Testing

The DSE is designed to be used by multiple users, each running local instances on their computers. The authors describe the architecture needed to support the client-server interactions.

The DSE expands scheduling requests into actual communications passes (i.e., the times and resources needed for each). The DSE also identifies scheduling conflicts and attempts to find satisfying solutions.

The authors describe the design principles of the DSE and the four algorithms applied to generate feasible scheduling activities from the user requests. Including detailed descriptions of the algorithms in the paper gives the reader good insight into the strategy behind the DSE.

The user is given some control over the scheduling algorithms. For example, some requests can be locked in place so that they are not modified during a future run. This capability is critical for a scheduling system; otherwise, key information could be lost or a manual work would be needed to rework the schedule. In addition, the DSE provides the user with four "relaxation" strategies to help resolve infeasible scheduling requests. Putting this capability directly in the hands of the user will greatly reduce rework time.

The authors describe a pathfinder user interface and web application already being successfully used at JPL on approximately 20 missions. This initial implementation is currently being used only on single-mission, single antenna scenarios. Users can share data via the web application. Users can also obtain immediate feedback when they make changes to their requests, rather than having to wait for a later schedule generation. The authors report that this trial deployment has been very successful, and the teams using it do not want to return to their previous mode of operations.

The authors conclude the paper with a description of work still to be done, including adding multi-antenna scheduling and more complex flexibility options.

Conclusion

The authors present a clear, informative description of a new request-driven scheduling algorithm and the efforts underway to make DSN scheduling easier, more collaborative, and more efficient through S^3.

Despite the challenges associated with moving to a request-driven system, the authors clearly show these improvements will greatly support the ever-increasing demands on the DSN scheduling system. Furthermore, the team plans additional other capabilities to provide more collaboration and reporting tools to all DSN users.

References

Clement, F. J., Johnston, M.D., Tran, D., and Schaffer, S. R. 2008. Experience with a constraint and preference language for DSN communications scheduling. In *ISAIRAS-08*.