Satellite Telecommunications Forecasting

Commentary on Paper by D. Joesting & G. Larsson

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Abstract

In an effort to adequately plan for the tracking and communications support of upcoming space missions, a number of methods and tools have been devised to help forecast the loading on existing networks. The need for such accurate forecasting is compounded, given the popularity of proposed mission concepts that call for the placement of entire constellations of satellites in Earth orbit. Joesting and Larson, in their paper, *Forecasting Telecommunications Support Boundaries for Satellite Constellations Using Deterministic Scheduling*, discuss some of the challenges that must be faced, and present some of their recent experience and tools used in tackling the forecasting problem. Capable methods are indeed necessary to establish the nature of the scheduling problems that lie ahead, and to suggest ways of re-designing missions to minimize conflicts. Additionally, new technologies must be developed and widely implemented to automate the station acquisition and telemetry downloading process, if we are to meet the spacecraft telecommunications needs of the future.

The Forecasting Problem

As pointed out by Joesting and Larson, the forecasting of long range telecommunications schedules of low Earth orbiting (LEO) satellites is complicated by imperfect modeling of the forces that perturb spacecraft orbits over time (e.g. variable drag forces that result from solar induced variations in atmospheric density) and the resulting growth in orbital position uncertainty associated with attempts to propagate spacecraft orbits beyond a few weeks. These orbit uncertainties, when coupled with uncertainties in spacecraft true anomaly for pre-launch forecasting, typically require statistical means to derive time-averaged station coverage profiles.

Thus Joesting and Larson describe the use of the Network Planning and Analysis System (NPAS), which relies on a Monte Carlo simulation to generate statistical data concerning spacecraft coverage profiles and station scheduling conflicts. This approach is similar to that implemented in the program LEO4CAST [1] developed by the Jet Propulsion Laboratory (JPL) for station resource allocation studies. Other forecasting methods that have been proposed include a deterministic technique described by M. Lo of JPL, which relies on dynamical systems methods to estimate long-term station view periods [2]. Relative to simulated data gathered from long-duration orbit propagations, Lo's method has been shown to be accurate to within 0.2% for circular orbits and within 15% for low eccentricity orbits ($e < 0.05$). While offering advantages in terms of much lower computational cost, Lo's method, however, does not directly address station conflict assessment between multiple spacecraft.

Another useful software tool described by Joesting and Larson is the Conflict Explanation Utility, which can provide insight into the various factors that influence the availability of station coverage for a spacecraft. When used together, all these tools can help NASA assess the adequacy of its network resources to meet future telecommunications demands. These tools can also suggest changes to a mission's characteristics (e.g. different orbit, antenna size, on-board data storage capacity, station complement, etc.) to improve its chances of obtaining the communications resources it needs.

The potential for such pre-emptive changes to the design of a spacecraft is appealing, in that they could result in a decrease of overall network loading, and lead to a more efficient use of available resources. However, for such changes to be practical, they must occur very early in the design process. As such, it is important that prospective space projects be given access to these forecasting tools and allowed to iterate on their mission design, preferably with occasional access to guidance from NASA scheduling experts. To that end, a web-based tool, accurately configured with an up-to-date station complement and mission set, would be most useful.

The Constellation Challenge

Constellations, consisting of multiple inexpensive spacecraft in orbit, have been advocated lately as a low-cost way of enabling global measurement from space with minimal risk posed to the overall mission as a result of an individual spacecraft failure. While these constellations offer intriguing possibilities, they also have the potential of quickly overwhelming existing communications resources. Aside from adding a large number of spacecraft to future mission sets, constellations composed of inexpensive spacecraft will likely be limited in on-board storage capacity, power, and antenna size --- attributes that exacerbate the scheduling problem.

But beyond the station-scheduling problem, there is also the hurdle of cost for the support of such large numbers of spacecraft. Given traditional operations methods, the resources required to maintain these constellations, in terms of station scheduling, commanding, and data reception, could dampen enthusiasm for such missions. As an example, the cost of operations support for the recent Lunar Prospector mission was largely driven by the need to maintain 24 hr operator support to ensure the nearly continuous tracking requirement for downlink of science telemetry. During a one-month period arbitrarily chosen for study, over 30 data transfer anomalies were counted which involved problems with station acquisition, data transfer, or workstation errors. In most cases, without the active intervention of spacecraft controllers and station personnel, significant amounts of data would have been lost.

The Role of Automation

To help get around the scheduling challenge imposed by the future use of spacecraft constellations, a greater reliance on automation is necessary. Already, spacecraft operators have implemented ground stations that can automatically acquire and track a satellite without operator intervention [3]. Such automation has been easier to implement on missions with a dedicated ground station and a limited number of common spacecraft. For large networks like NASA's GN and SN that support a wide variety of missions, automation has proven to be more challenging, due to the large disparity in tracking requirements and spacecraft characteristics. However, in recent years, there have been some successful demonstrations of "lights out" station operation using NASA's Low Earth Orbit Terminal with a 3-m antenna system, and the Deep Space Terminal with a 34-m antenna [4].

Such progress has indeed been promising; however, further steps will probably be necessary to meet the heavy telecommunication demands of spacecraft constellations. Perhaps the ultimate goal should consist of enabling spacecraft to independently request support from automatic ground stations. Using GPS to establish their position relative to an onboard database of available ground stations, future spacecraft could compute view periods at candidate sites along with their required contact duration, and request service directly from a station. Priority for a given s/c request could be decided by each station, based on the saturation level of a spacecraft's storage capacity, or according to the relative importance of the data collected, as defined by scientists and operators. Of course such a system would not eliminate contention over limited telecommunications resources, and it would require solutions to non-trivial technological hurdles. It may ultimately, however, be the direction of things to come, given the complexity and costs associated with more traditional alternatives.

References

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