AUTOMATING THE CONFLICT RESOLUTION PROCESS

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INTRODUCTION

Schedule conflicts occur when the demand for a resource exceeds the availability of that resource. When a conflict occurs in a constraint relaxation domain, such as the Space Network (SN), an action must be taken to resolve the conflict. Providing alternative times, alternative resources, or a combination of the two, are methods of resolving a conflict. These alternatives are then submitted to the requestor. If no alternative is acceptable, the request will be declined. This process is called conflict resolution.

The purpose of this paper is to initiate a discussion of how the conflict resolution process at the Network Control Center can be made more efficient. The paper will describe how resource conflicts are currently resolved, describe impacts of automating conflict resolution in the ATDRSS era, present a variety of conflict resolution strategies, and suggest discussion topics related to automated conflict resolution.

CURRENT SPACE NETWORK CONFLICT RESOLUTION

User POCCs transmit Schedule Add Requests (SARs) to the NCC by the beginning of the forecast period week. The forecast period begins fourteen days prior to the week in which services are to be provided. Requests are ordered and placed on the schedule one by one until a conflict occurs. The request causing the conflict is placed in the declined queue. When all requests have either been scheduled or declined, conflict negotiation begins serially, starting with the highest priority rejected request. Current conflict negotiation is a verbal, time consuming process between the Forecast Analyst and the representatives of the user POCCs. Because of security requirements, the user POCCs are not given access to the entire schedule, so they cannot identify their own time and resource alternatives. Because of current system limitations, the Forecast Analyst has little automated information on user POCC requirements, scheduling aids, or Field of View, so it is difficult for the analyst to determine, other than through operational experience, which of the available alternatives will meet the needs of the user.

Current NCC scheduling software, as with many scheduling systems, emphasizes conflict avoidance, rather than conflict resolution. Care is taken to place an event on the schedule in such a way as to avoid potential conflicts. Some of these algorithms include placing the event within tolerance where it will leave the largest gap of remaining unscheduled time, or a look-ahead metric which places the event to avoid conflict with remaining unscheduled events. The problem with this approach is that it looks at the puzzle instead of looking at the piece. In other words, there is no intelligence or knowledge of the applicability or preference of individual user conflict resolution strategies for each of the requests being placed on the schedule. Rather, the focus of scheduling is on the resources, keeping blocks of resource available time open for subsequent requests.

Another difficulty with the current scheduling and conflict resolution process is that current SN service requests do not contain or utilize flexibility. Flexibility can be expressed in a request two ways. A request can include flexibility of start time by specifying a plus or minus tolerance. A request can include flexibility of resource selection by specifying a configuration code which indicates "open selection" for antenna and interface channel. Because of limitations in the scheduling message formats, the NCC software and the POCC scheduling software have caused users not to include time tolerance in their requests. Other network elements requirements have dictated that users specifically request certain resources instead of allowing the NCC to openly select them to avoid conflicts.

In a typical schedule week, in which approximately 480 unclassified event requests were received by the NCC, about twenty percent of these requests resulted in schedule conflicts. Of that twenty percent, around sixty percent were resolved by alternate links, ten percent by slipping the start time, twenty percent by both slipping time and selecting an alternate link, and ten percent were deleted. The fact that ninety percent of the conflicts were resolvable indicates that there is flexibility in the user's requirements which is not expressed in the request to the NCC.

SN CONFLICT RESOLUTION IN THE ATDRSS ERA

Because the number of service requests and ATDRSS users in the ATDRSS era (1997-2012) will increase three to ten fold, the number of resource conflicts will exceed the current ability to manually resolve them. If conflict resolution is performed one request at a time in priority order, the time required to resolve conflicts will be unacceptable. Automating the process will enable scheduling to be done in a more realistic time frame. To perform automated conflict resolution, information on how to resolve conflicts must be available. It can be identified by the user POCC in each specific service request, and/or be embedded in the knowledge of the NCC scheduling system.

Embedding the Knowledge

To perform automated conflict resolution, knowledge of user capabilities, user preferences, and SN resources could be embedded in the scheduling system. User capability data includes ATDRS to USAT and USAT to ATDRS field of view information, sun interference data, antenna patterns, and restrictions such as power availability that would limit antenna substitution. Knowledge about user preferences include mission characteristics affecting both flexibility in request parameters, service alternatives, and a weighted priority scheme for relaxing scheduling constraints. Knowledge of the SN includes resource availability, resource capability, RFI, to include antenna pattern overlap of scheduled USATs, and antenna slew time.

Using the above knowledge, a conflict resolution profile could be created by the NCC for each user POCC service request defining a hierarchy of conflict resolution strategies applicable in each instance to the particular user spacecraft, service parameter tolerances, and dependencies between spacecraft services. The hierarchy would indicate the **types** of strategies to be used to resolve conflicts and the **order** in which they should be used.

The knowledge about the specific user conflict resolution preferences could be input to the NCC scheduling system by the user POCC during service planning similar to a generic scheduling concept, elicited from scheduling experts at the NCC, and/or learned by the system during analyst-in-the-loop conflict negotiation.

User Specifying the Knowledge

An alternative to embedding all the knowledge in the NCC scheduling system is to include the information affecting conflict resolution strategies in the service request from the user POCC. The user could request a specific event (time and link) as the preferred service. The user could also request subsequent ordered choices if the first preference is not available. The user could prioritize request parameters. For example, a specific start time may be prefered over a specific TDRS. In addition, the user could specify in the request that no strategies be used (feast or famine). The information exchange necessary for both automated and manual conflict resolution could be facilitated by implementation of a Space Network User Pocc Interface (SNUPI) workstation in which schedule and service flexibility could be graphically displayed and communicated simultaneously at the NCC and user POCC.

Factors Affecting Conflict Resolution

In addition to user preference, the order and precedence of conflict resolution strategies may be influenced by organizational and operational goals. Candidate organizational goals affecting conflict resolution are:

> NASA established user POCC priority. This places more emphasis on the higher priority users getting their first preference for conflict resolution strategies.
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> Resource utilization schemes. The NCC may wish that certain users be assigned specific ATDRS or ATDRS links. The NCC may wish to avoid scheduling on one satellite, for example, the spare, except when no other conflict resolution strategy will work. The NCC may wish to maximize utilization of single resources, or ensure a leveling of resource utilization across the system. Each of these schemes would impact the application of conflict resolution strategies.
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> Rewarding cooperation. The NCC may use priority in conflict resolution to reward a user POCC for following the SN rules. For example, the POCC that always has requests in on time, has maximum flexibility in each request, or is willing to give up a service during a conflict, may be rewarded in future scheduling by increasing the priority of its conflict resolution strategies.

In an effort to achieve schedule stability, there may be operational limitations that affect the application of conflict resolution strategies.

> Development (forecast) period. All applicable strategies would be used on all requests.
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> Maintenance period. Strategies that go beyond specific request tolerances for scheduled requests would not used, but all applicable strategies would be used for a request added in this period. Within twenty four hours of a service, no strategies would be used on previously scheduled requests.
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> Spacecraft emergencies. All applicable strategies would be used to ensure the emergency is scheduled without conflict.

Schedule Alternatives

If conflict resolution is possible by performing a service in an alternative manner, generated through knowledge embedded in the NCC scheduling system, the alternative must be approved by the user POCC. For example, the user POCC may have requested an

SSA forward service that can be satisfied only by substituting an available SMA forward service. The knowledge in the system indicates that for an SSA conflict, the user satellite is capable of receiving the SMA forward, and the user POCC has accepted the SMA forward alternative in the past, but the service duration must be increased. The system checks Field of View data to determine if the longer duration service is applicable to the user satellite. The knowledge in the system may also indicate whether such a substitution is possible without advanced user confirmation. In either case, the alternative would be communicated to the user for confirmation before or after scheduling.

Manual Conflict Resolution

In spite of automating the conflict resolution process, special circumstances will occur in the ATDRSS era requiring manual conflict resolution by the SN scheduling analyst. Examples include when two user POCCs having the same priority (Space Station and Space Shuttle) have a resource conflict, when spacecraft emergencies conflict with higher priority user POCC schedules, or when a service bumps a lower priority user POCC less than twenty-four hours before the service. The analyst will have the capability to manually move, fix, or delete a service request from the system. Once a service conflict is manually resolved by the analyst, it cannot be moved as part of further automatic conflict resolution until the analyst removes the override.

CONFLICT RESOLUTION STRATEGIES

In order to resolve conflicts, there must be conflict resolution strategies. Potential strategies include:

(1) Priority. The user POCC having the highest priority established by NASA for both spacecraft and mission, will have its service placed on the schedule ahead of a lower priority user service. Goodness of schedule may be determined by how many highest priority user services are placed on the schedule using the highest priority conflict resolution strategy.

(2) Moving a service in time, by moving the request start time forward or backward within a tolerance window.

(3) Moving a service to the previous or next valid view period appropriate for that spacecraft.

(4) Switching to an alternate resource. If the request can be satisfied by a resource not specifically requested, the requested but unavailable resource may be replaced by the alternate, available resource. An example might be an MA forward service replacing an unavailable SSA forward service.

(5) Shrinking a service duration. It may be acceptable to decrease the duration of a service by a few minutes in order to allow it to fit on the schedule, as an alternative to denying the service request. After a service has been shrunk, it may be moved forward or backward within tolerance. This may be particularly applicable to forward services which currently schedule more time than is normally used.

(6) Breaking up a prototype event into individual services, and performing separate conflict resolution strategies on the individual services. Relationships between services, both temporal and logical, must be specified, and considered so that individual conflict resolution does not invalidate the entire requested event.

(7) Breaking up a service into multiple discontinuous services, or gapping. It may be acceptable to break up a requested service into two shorter services separated by a small, conflicting higher priority request. An example of such a service may be a tape playback that can be interrupted and resumed.

(8) Combinations of the above strategies.

(9) Deleting a service from the schedule. A higher priority request may be scheduled by deleting a lower priority request from the schedule, eliminating the conflict.

AUTOMATED CONFLICT RESOLUTION IMPLEMENTATIONS

Some of the automated conflict resolution concepts mentioned here are already implemented in existing scheduling systems.

Plan-IT-2 developed by the Jet Propulsion Laboratory allows the scheduling analyst to explicitly invoke tactical plans for automatic scheduling, or read them in from a script file. The conflict resolution tactics specify what strategies to implement and in what order.

The Experiment Scheduling Program (ESP)2, developed at Marshall Space Flight Center, allows users to specify weighting factors for each of the parameters in a schedule request. In this way, preferences can be specified for order of application, and the "goodness" of the resultant schedule can be quantified by the sum of the weights.

DISCUSSION TOPICS

The following issues relevant to this paper should be discussed during the working session:

What specific conflict resolution strategies are applicable to the user POCCs?
How much would conflict resolution strategies and preferences vary between services of a specific user POCC?
How much would conflict resolution strategies and preferences vary between different user POCCs?
Does a hierarchy of strategy preferences exist?
Under what circumstances should manual conflict resolution be required?
How amenable to automatic conflict resolution are user POCCs?
How much and what type of tolerance could be communicated to the NCC from user POCCs?
How much would tolerances vary between services of a specific user POCC?