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POLYNOMIAL OPTIMIZATION TECHNIQUES FOR ACTIVITY SCHEDULING

OPTIMIZATION BASED PROTOTYPE SCHEDULER

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Agenda

- Need and Viability of Polynomial Time Techniques for SNC
- Intrinsic Characteristic of SN Scheduling Problem
- Expected Characteristics of SN Resource Schedules
- Optimization Based Scheduling Approach
- Single Resource Algorithms
- Decomposition of Multiple Resource Problems
- Prototype Capabilities
- Prototype Test Results
- Computational Characteristics
- Prototype Characteristics
- Some Features of Prototyped Algorithms
- Some Related GSFC References

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Need and Viability of Polynomial Time Techniques for SNC

- **Need for Efficient Scheduling Techniques such as Polynomial Time Algorithms**

  Subjective scheduling decisions in an environment such as the SN are necessary. However, producing a good initial schedule based on subjective analysis is very labor intensive, impractical and unnecessary. Initial schedules based on computationally efficient approaches optimizing a general objective such as maximizing requests can be the basis from which a final schedule can be evolved through changes and fine tuning based on subjective analysis and human interaction.

- **Viability of Polynomial Time Algorithms for SNC**

  Recent R & D effort at GSFC has shown that polynomial time algorithms for SN resource scheduling are viable and practical.

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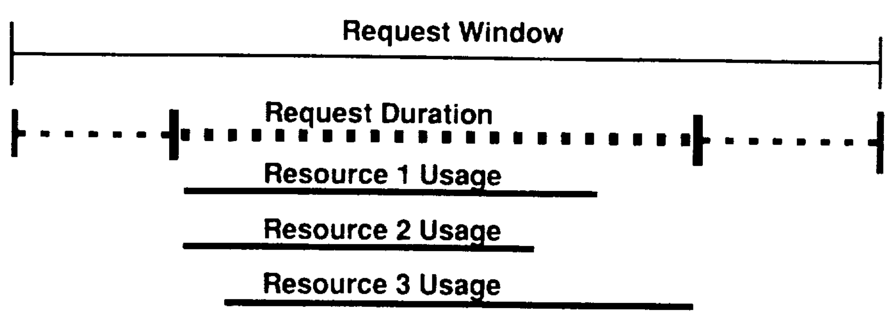
An Intrinsic Characteristic of SN Scheduling Problem

Highly-coupled usage of resources for each request, i.e., Each request uses all resources it requires either simultaneously or in the immediate time frame



Expected Characteristics of the Schedule

Tight coupling of resource usage tends to force schedules with the following characteristics

- General sequence (time-order) of scheduled requests is nearly same for all resources
- Schedule for high-demand resources implicitly control the schedule for resources with low - demand

A multiple resource-usage request which is rejected when attempted to be scheduled independently on a low demand resource type is highly unlikely to be scheduled on a high-demand resource type.

Optimization Based Scheduling Approach

A combination of optimization and heuristic techniques

- Optimal and near optimal single resource scheduling using polynomial time optimization algorithms
- Heuristic reasoning for decomposing multiple resource problems into a series of single resource problems suitable for application of the polynomial time single resource algorithms

Single Resource Algorithms

- **First Algorithm (Does not consider activity priorities)**
  - Maximizes the number of scheduled activities
  - Generates sequence of scheduled activities with reduced windows
  - Developed earlier last FY under SEAS task 20-122
- **Second Algorithm (Considers activity priorities)**
  - Maximizes the priority weighted number of scheduled activities when there are two priorities
  - For problems with > 2 priorities, algorithm is applied to series of two priority problems
  - Generates sequence of scheduled activities with reduced windows

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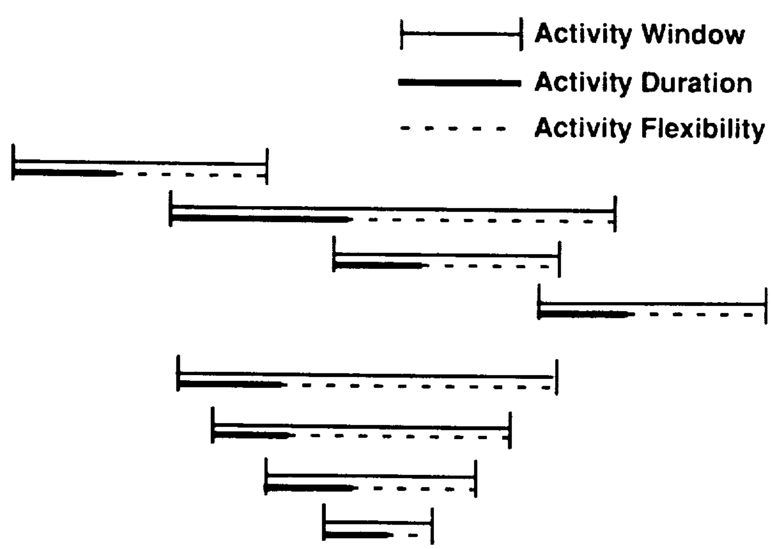
First Single Resource Algorithm

Provides . . .

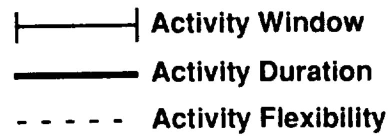
Optimal Solution when windows exhibit (Cascade Structure)

Optimal Solution when windows exhibit (Triangular structure)

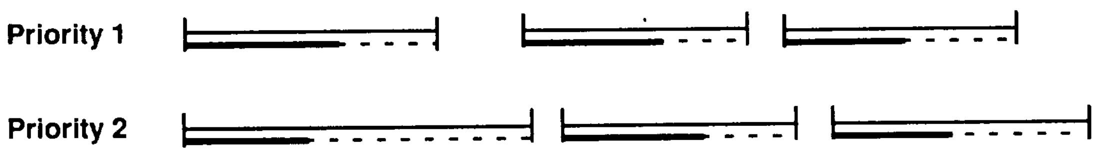


Near Optimal Solution when windows exhibit A general unrestricted structure

Second Single Resource Algorithm



Provides optimal solution for a two priority problem when activity windows within each priority are non-overlapping



Decomposition of Multiple Resource Problems

Schedule resources in increasing order of usability

Reason:

Given: Resources A and B

Activity set S(A) — Schedulable only on A

Activity set S(B) — Schedulable only on B

Activity set S(A or B) — Schedulable on A or B

Scheduling as many of activities in S(A or B) as possible on least usable of A and B tends to maximize the availability of resources for highly resource specific activities

Decomposition of Multiple Resource Problems

(CONTINUED)

Example: S(A) = 100 S(B) = 20 S(A or B) = 20

Scenario 1—Schedule A first and schedule B second

70 of S(A) and 10 of S(A or B) scheduled on A

20 of S(B) and 10 of S(A or B) scheduled on B

Total scheduled: 100

Scenario 2—Schedule B first and schedule A second

20 of S(B) and 19 of S(A or B) scheduled on B

90 of S(A) scheduled on A

Total scheduled: 129

Scenario 2 maximizes the scheduled activities

Prototype Capabilities

Scheduling of Specific and Generic Requests for:

- Tracking and Data Relay Satellites
- Deep Space Network
- Ground Network
- For Combination of Space and Ground Resources

Prototype Test Results

	Total Reqstd Events	Scheduled Events		Upper Bound	Wall Clock Time (Min.)
First Algorithm (Disregard Priorities)	1584	1478	93.3%	98.7%	3 .25
	2960	2415	81.6%	86.%	21.1
Second Algorithm (Consider Priorities)	1594	1499	94.6%	98.7%	18.5

Tested on

- PC/AT running at 12 MHz without a math coprocessor

Computational Characteristics

Analytically determined computational requirements of the prototyped algorithms is a 3rd order polynomial of the number of activities

$t = k * n^3$

For n=1584

$t = 3.25$ implies $k = (1584)^{-3} * (3.25)$

For n = 2960

$t = (1584)^{-3} * (3.25) * (2960)^3 = 21.2$ Min

Prototype Characteristics

- COMPUTER: PC or PC (AT)
- LANGUAGE: MS-FORTRAN
- NUMBER OF LINES OF SOURCE CODE : 2000 Approx.
- EXECUTABLE MODULE: 520 Kbytes
- CAPACITIES: 8 Resource types
  10 Resource Groups (TDRS/Ground Stations)
  12000 Resource Intervals
  3200 Instances

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Some Features of Prototyped Algorithms

Prototyped algorithms can be used for:

- Initial batch scheduling
- Batch rescheduling while limiting changes to any combination of:
  - — restricted deletions for selected instances
  - — restricted non-deletion schedule changes to selected instances
  - — allowable deletion of selected instances

Some Related GSFC References

- Optimization Based Prototype Scheduler
  DSTL-90-024, Available December 1990
- Single Resource Scheduling with Ready and Due Times
  DSTL - 89 - 024, December 1989
- A Study of Optimization Techniques for Activity Scheduling
  DSTL - 89 - 019