A Stack-Based Resource Allocation Policy for Realtime Processes

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Outline

- Abstract & Introduction
- Definitions
- Stack Resource Policy(SRP)
- Schedulability
- Relation to Prority Ceiling Protocol(PCP)
- Implementation Consideration, Conclusions, and Further Research

Abstract & Introduction

- share a single runtime stack
- if Job is preempted it can’t resume until all the jobs that occupy stack space above it have completed
- refinement of the Priority Ceiling Protocol

Abstract & Introduction (contd.)

- SRP offers improvements over the PCP.
  - unifying the treatment of stack, reader-writer, and multiunit resources, and binary semaphores
  - applying directly to some dynamic scheduling policies, including EDF, as well as to static priority policies
  - with EDF scheduling, supporting a stronger schedulability test
  - reducing the maximum number of context switches by a factor of two

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Definitions

- Jobs
  - a finite sequence of instructions to be executed on a single processor
  - pending requests are classified as *waiting*, meaning the job hasn't yet started
  - *active*, meaning the job has started to execute
  - process P_i is an (infinite) sequence of job execution requests $J_{i,1}$, $J_{i,2}$, $J_{i,3}$ ...

Definitions (contd.)

- Resources
  - assume there is a single processor, which is preemptable, and a finite set of nonpreemptable resources R_i,... R_m
  - *(J,R,m) J*: a job, *R*: a nonpreemptable resource, *m*: a mode (read = 1, write = N_R(total # of R))
  - while a job holds an allocation, says *outstanding*
  - LIFO request order, overlap if properly nested

Definitions (contd.)

- Stack Space
  - Shared runtime stack space is a nonpreemptable resource
  - 1. request at least 1 cell before execution, can't relinquish until completes execution, entire execution of each job is a *critical section*
  - 2. it must continue to hold its stack resources while it is blocked for some request
  - 3. request can be granted iff is not yet holding any space or holding the top of the stack
  - 4. only the job at the top may execute(grow up)

Definitions (contd.)

- Direct blocking
  - *(J, R, m)* is blocked directly iff $V_R < m$
  - identifable set of other jobs that are blocking J
  - job *J* is directly blocked iff there's another job *J'* holding the space immediately above the space occupied by *J* on the stack

Definitions (contd.)

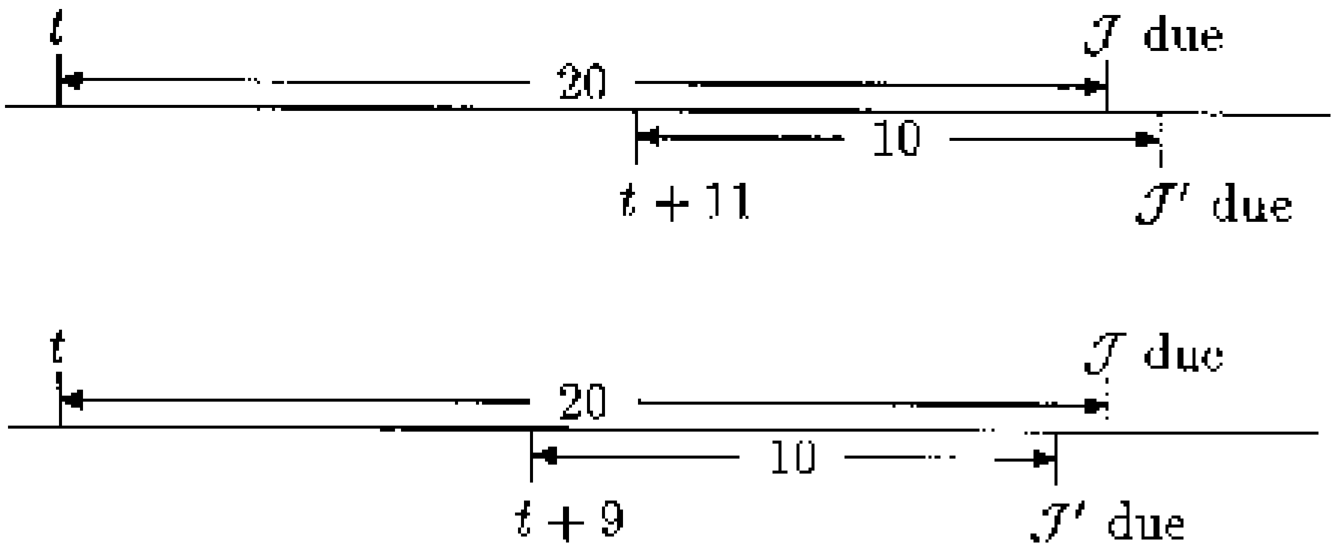
- Priorities
  - *J* has higher priority than *J'* iff *p(J) > p(J')*
  - larger values indicate greater urgency
  - preemptable according to the priorities of requests and FIFO among jobs of equal priority

Definitions (contd.)

- Preemption levels $\pi(J)$
  - statically assigned to jobs
  - J' isn't allowed to preempt another job J unless $\pi(J') > \pi(J)$
  - enable static analysis of potential resource conflicts, even for dynamic priority schme
  - $p(J) < p(J')$ *iff* $t' + D' < t + D$ (by EDF)
  - $\pi(J) < \pi(J')$ *iff* $D(J') < D(J)$
  - J' can never be preempted by J, but this doesn't mean that J' always have higher priority than J

Definitions (contd.)

- Preemption levels (contd.)
  - $\pi(J) < \pi(J')$:
  - $p(J) > p(J')$ or $p(J') > p(J)$ can preempt J



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Stack Resource Policy(SRP)

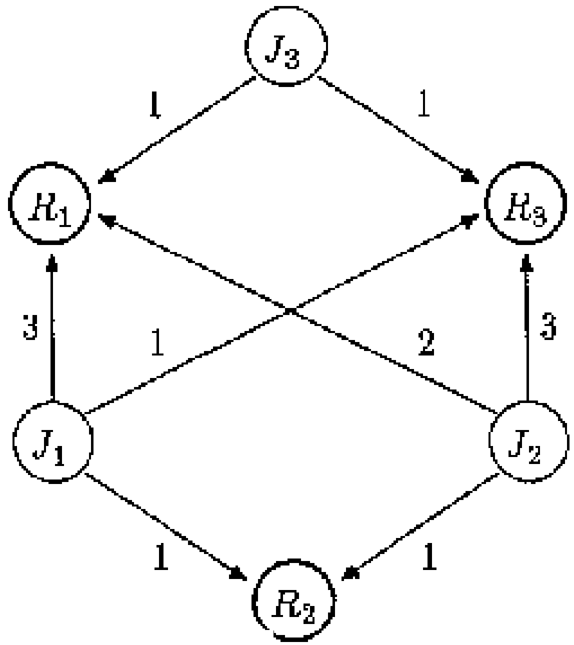
- Unify and extend definition of priority ceiling
  - priorities are replaced by preemption levels. This allows EDF priorities to be handled without requiring to recompute ceilings at run time
  - ceilings are defined for multiunit resources, subsuming both binary semaphores and r/w lock
- Abstract ceilings
  - if J is currently executing or can preempt the currently executing job, and may request an allocation of R that would be blocked directly by the outstanding allocation of R, then $\lceil R \rceil \geq \pi(J)$

Stack Resource Policy(SRP) (contd.)

- Specific ceilings
  - $\lceil R \rceil_{V_R} = \max(\{0\} \cup \{\pi(J) \mid V_R < \mu_R(J)\})$
  - V_R units of *R* available
  - $\mu_R(J)$ is the maximum number of units of *R* that job *J* may need to hold at any one time

Stack Resource Policy(SRP) (contd.)

- Specific ceilings (contd.)



R	N_R	$\mu_R(1)$	$\mu_R(2)$	$\mu_R(3)$	$\lceil R \rceil_0$	$\lceil R \rceil_1$	$\lceil R \rceil_2$	$\lceil R \rceil_3$
R_1	3	3	2	1	3	2	1	0
R_2	1	1	1	0	2	0	0	0
R_3	3	1	3	1	3	2	2	0

Stack Resource Policy(SRP) (contd.)

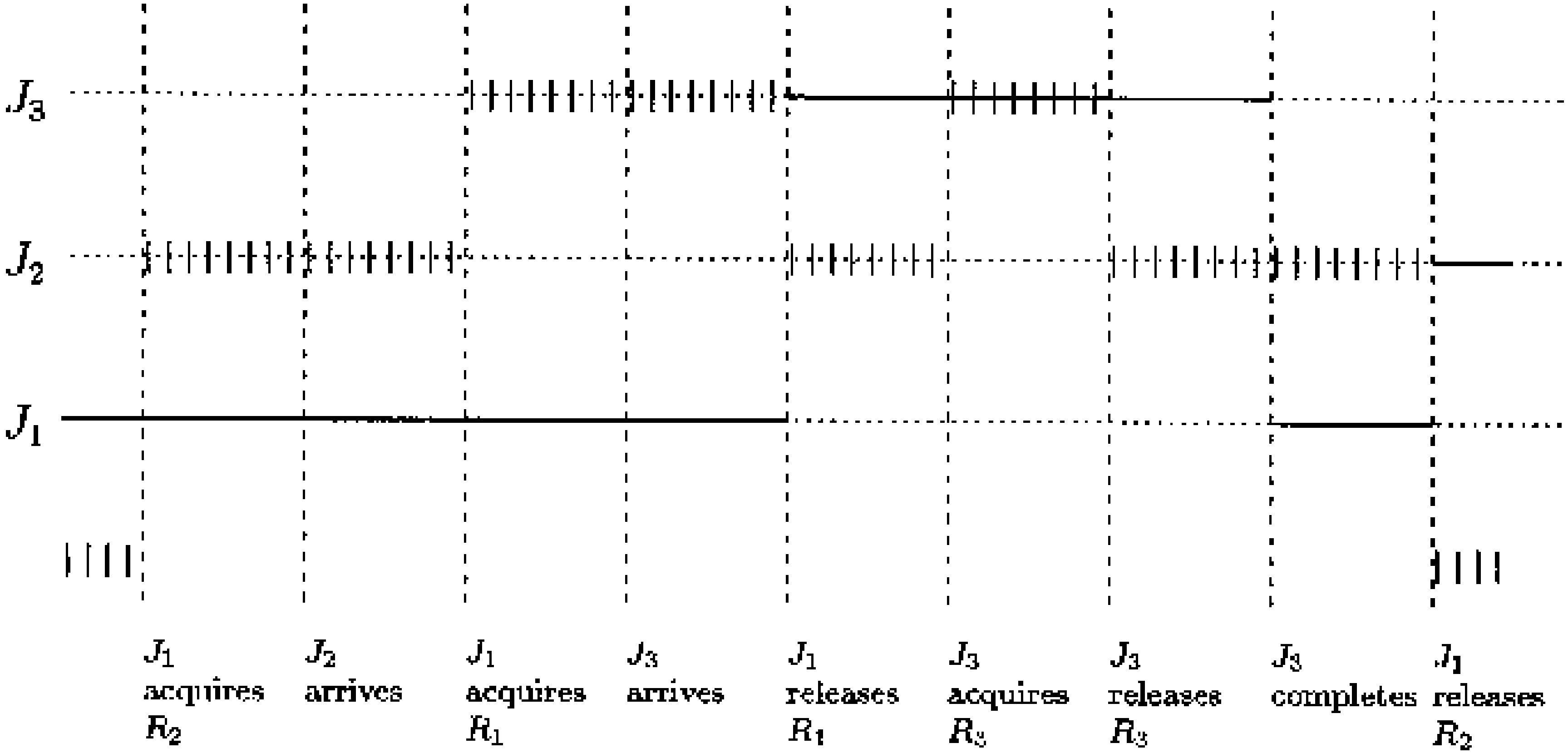
- Current ceiling
  - $\pi' = \max(\{\lceil R_i \rceil \mid i = 1,\ldots,m\} \cup \{\pi(J_c)\})$
  - if there're no jobs currently execute, $\pi' = 0$
- the SRP
  - requires that a job execution request *J* be blocked from starting execution until $\pi' < \pi(J)$
  - once *J* has started execution, all subsequent resource request by *J* are granted immediately
  - doesn't restrict the resource acquiring order, and allocate only when requests.

Stack Resource Policy(SRP) (contd.)

- the SRP (contd.)
  - release resources when they are not need.
  - J_H is free to preempt until J actually requests enough of R to block J_H (without being blocked)
- examples
  - solid horizontal lines indicate job executions
  - barred lines indicate π'
  - ex1: since $\lceil R_2 \rceil_0 = 2$, J_2 is unable to preempt J_1 after it acquire R_2 , J_3 preempts J_1 as soon as J_1 release R_1

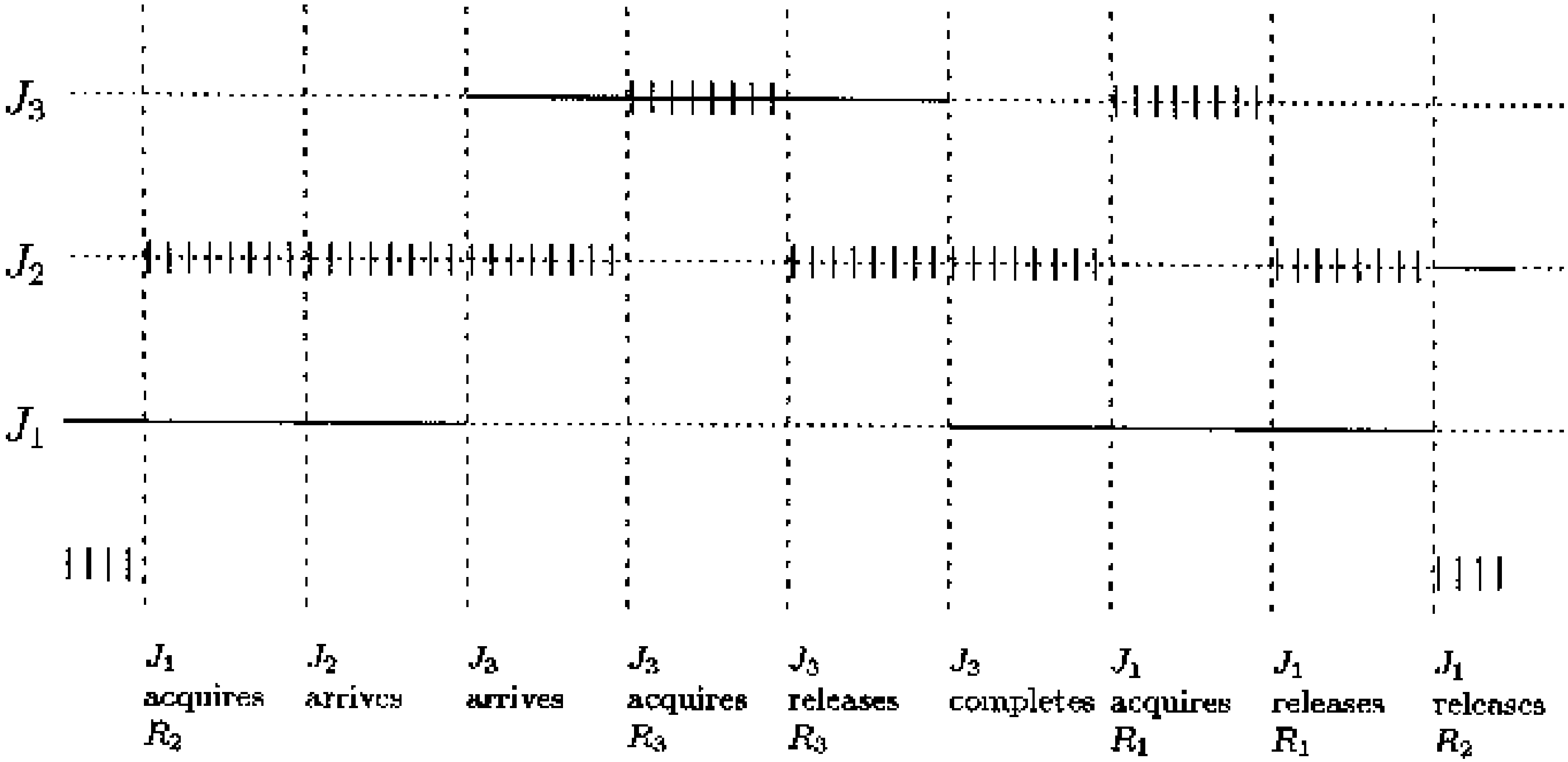
Stack Resource Policy(SRP) (contd.)

- the SRP (contd.)



Stack Resource Policy(SRP) (contd.)

- the SRP (contd.)



Stack Resource Policy(SRP) (contd.)

- Blocking properties of the SRP
- Theorem 1
  - If no job J is permitted to start until $\pi' < \pi(J)$ =>
  - (a) No job can be blocked after it starts
  - (b) There can be no transitive blocking or deadlock
  - (c) If the oldest highest-priority job is blocked, it will become unblocked no later than the first instant that the currently executing job isn't holding any nonpreemptable resources.

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Schedulability

- Theorem 2
  - A set of n (periodic and aperiodic) jobs is schedulable by EDF scheduling if

$$\forall_{k=1,\ldots,n} k \quad \left(\sum_{i=1}^{k} \frac{C_i}{D_i}\right) + \frac{B_k}{D_k} \leq 1.$$

B_i : the execution time of the longest critical section of any job J_k such that $D_i \leq D_k$ and i != k

C_i : max execution time $\qquad$ D_i : relative deadline

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Relation to PCP

- Ceiling are defined in terms of preemption levels, instead of priorities, so that the SRP applies directly to EDF scheduling (without dynamic recomputaion of ceilings)
- Ceilings are defined for multiunit resources.
- Stack sharing is supported
- The blocking test is only applied when a job tries to start execution

Relation to PCP (contd.)

- Resouces requests never block, and hence can't require extra context switches (at most TWO!)
- Because there is no blocking after a job starts executing, a stronger EDF schedulability result can be obtained than with dynamic priority ceilings
- Different jobs of a process may have different priorities

Relation to PCP (contd.)

- Theorem 3
  - The maximum priority-inversion time of any job under the SRP is no longer than under the PCP
- Theorem 4
  - The SRP requires at most two context switches per job execution request
- Theorem 5
  - The PCP, like any other policy that waits to block a job until it makes a resource request, may require four context switches per job execution request, for any job that shares a semaphore with a lower priority job

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Implementation Consideration, Conclusions, and Further Research

- Simple and efficiently, similar to that of PCP, but simpler blocking operation.
- Ceilings $\lceil R \rceil_n$ are static in table
- $\pi' = \lceil R \rceil_{vr}$ iff $\pi' < \lceil R \rceil_{vr}$ when V_R is updated, and the old π' and V_R are pushed on the stack (be restored later and check whether waiting jobs to preempt)
- refinement version of SRP, the Minimal SRP(MSRP) is developed

Thank you