School of Computer Science & Engineering

COMP3891/9283 Extended Operating Systems

2025 T2 Week 03

Process Abstractions III: Scheduler Activations

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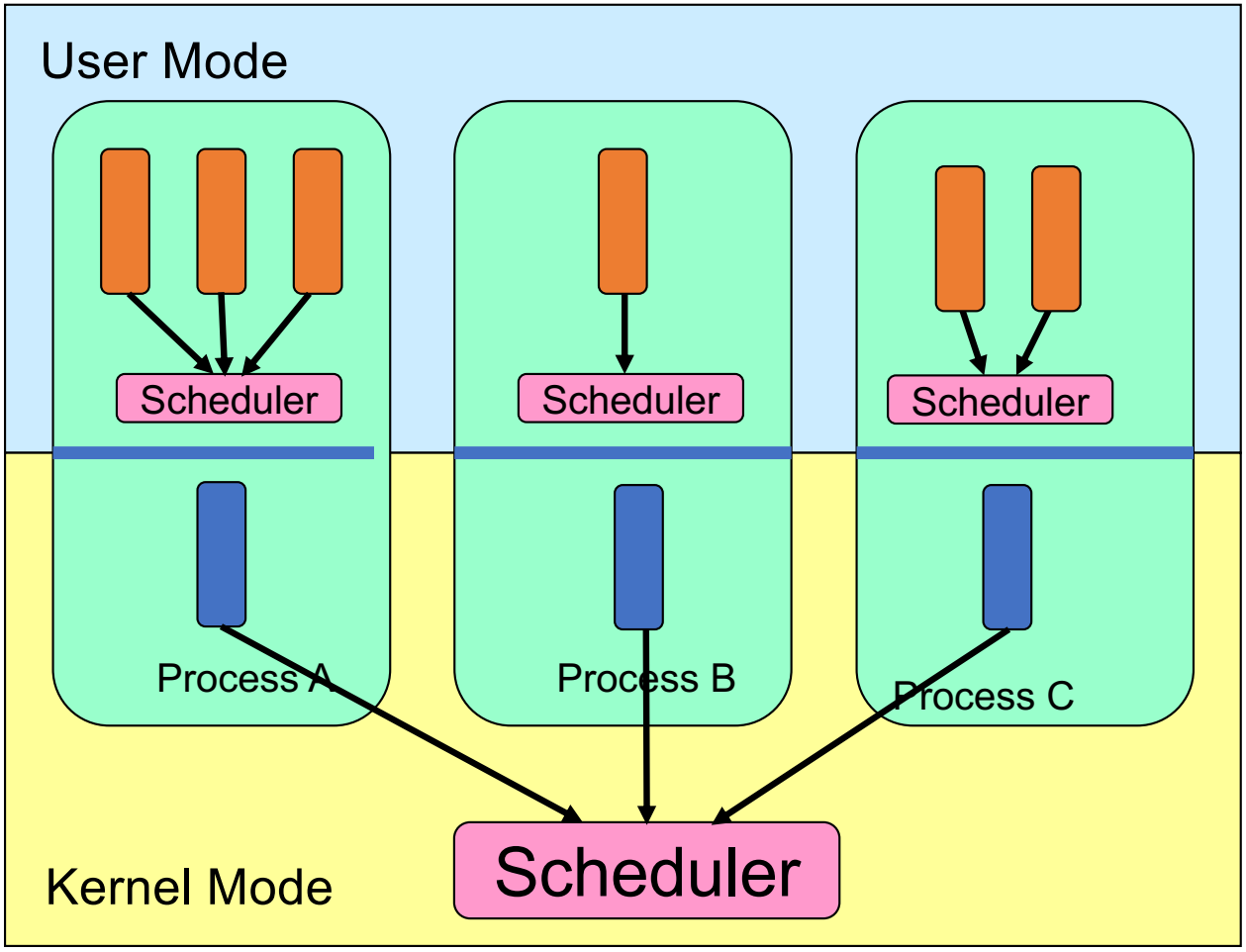
Learning Outcomes

- An understanding of hybrid approaches to thread implementation
- A high-level understanding of scheduler activations, and how they overcome the limitations of user-level and kernel-level threads.

User-level Threads

Thread management cheap
- create, delete, switch, sync

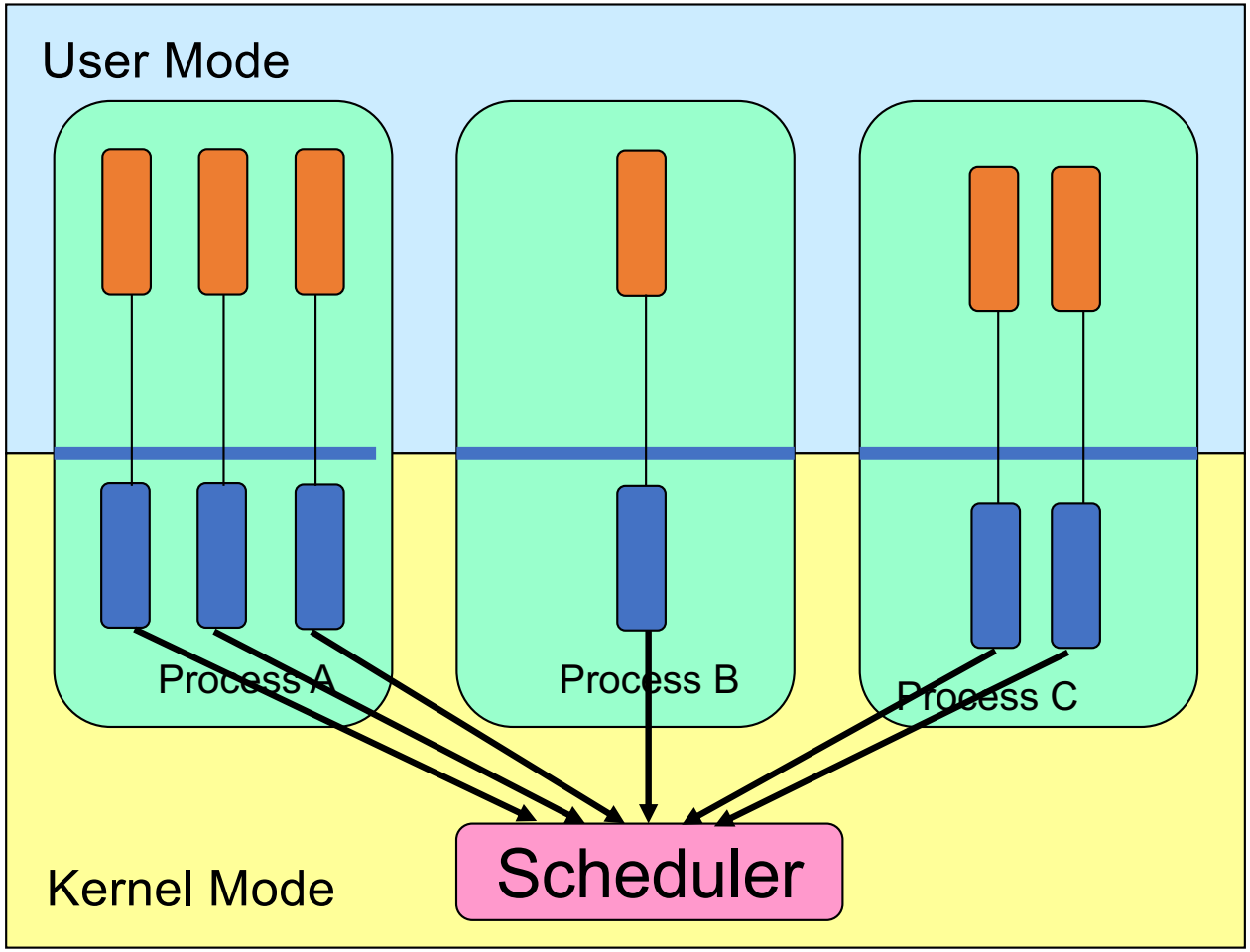


Blocking thread blocks process
- syscalls, page faults

No parallelism on multiprocessor

Kernel-Level Threads

Thread management expensive
- create, delete, switch, sync



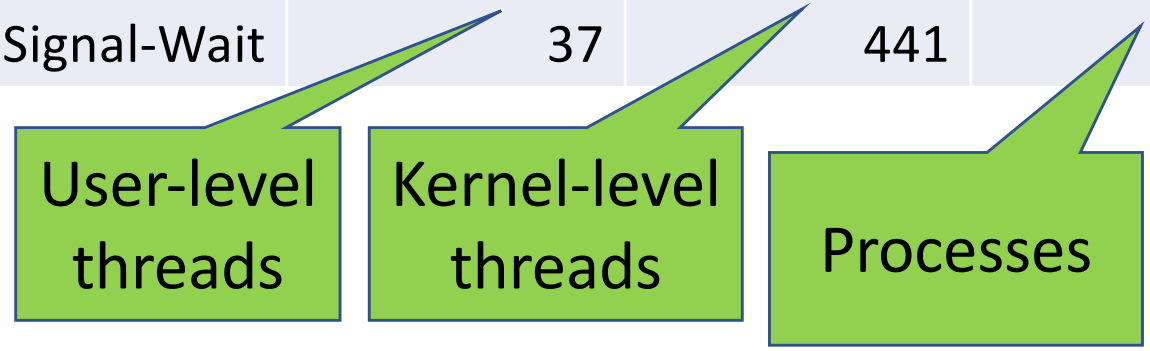
Blocking thread switches to other thread

Parallelism on multiprocessor

Performance

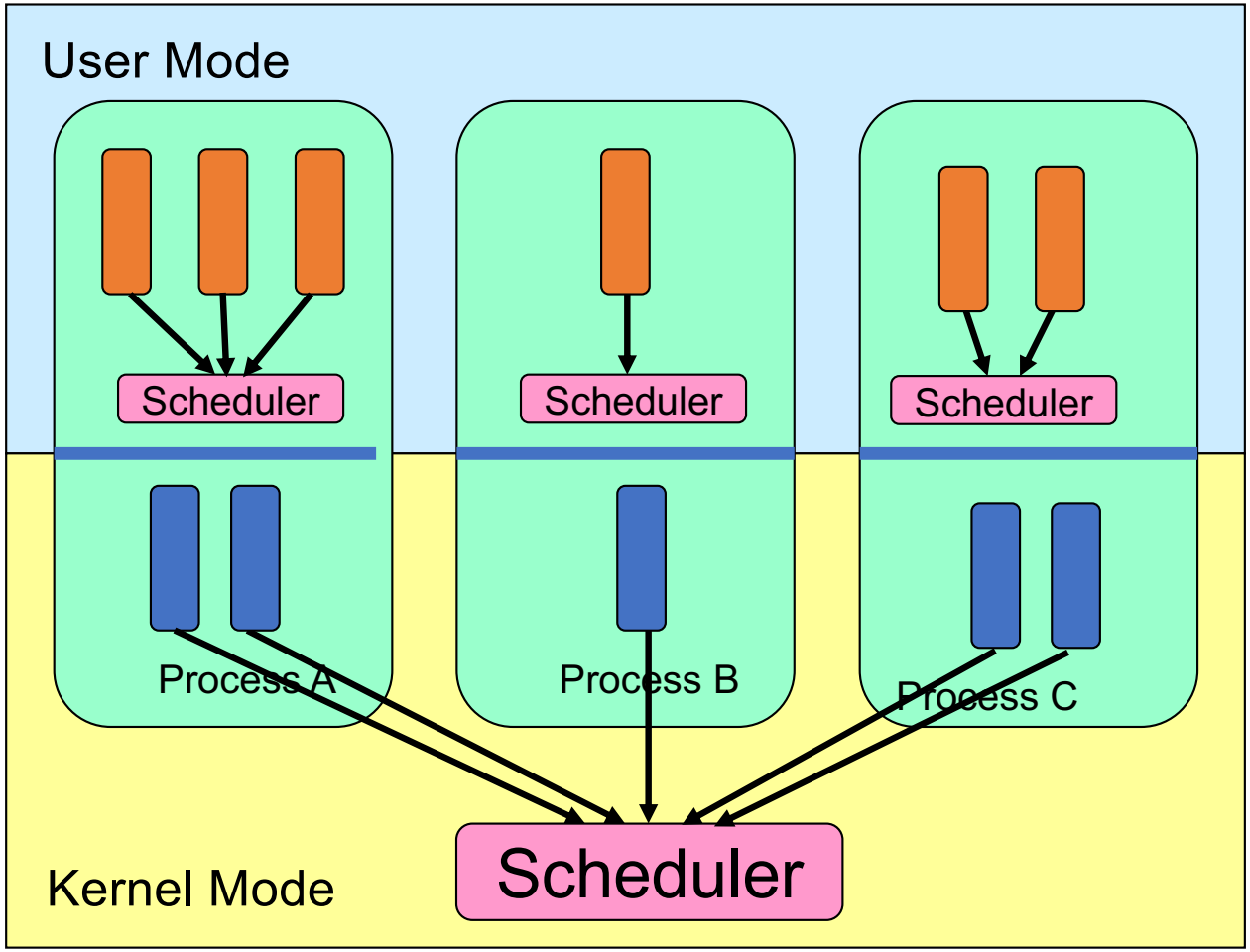
Thread operation latencies (μs) on CVAX.

Operation	FastThreads	Topaz Threads	Ultrix Processes
Null Fork	34	948	11300
Signal-Wait	37	441	1840



Hybrid Multithreading

Thread management cheaper
- create, delete, switch, sync



Blocking can still be a problem!

Parallelism on multiprocessor

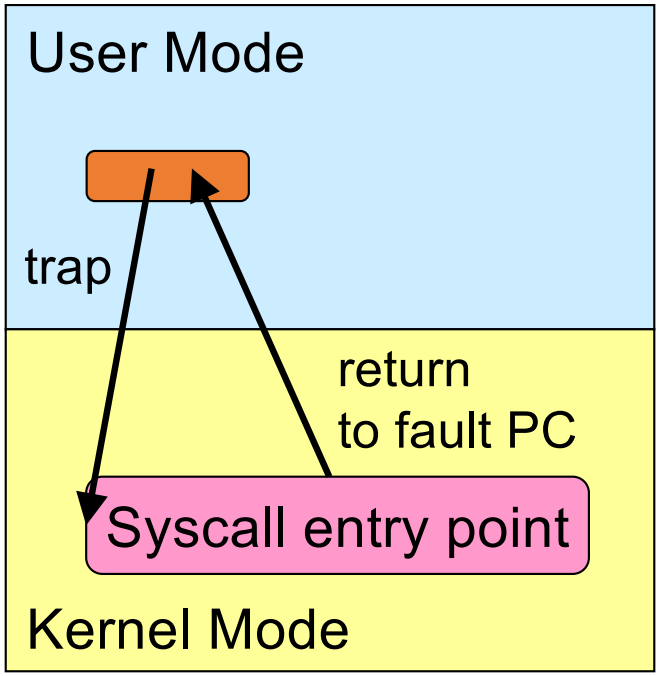
Scheduler Activations

Idea: Both schedulers co-operate

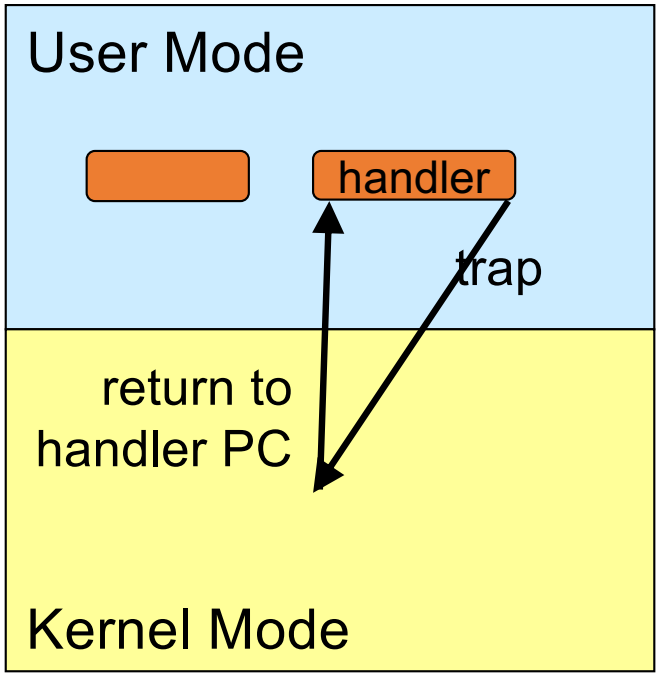
- User scheduler uses system calls
- Kernel scheduler uses upcalls!

First proposed by:
Thomas Anderson, Brian Bershad, Edward Lazowska, and Henry Levy. *Scheduler Activations: Effective Kernel Support for the User-Level management of Parallelism.* ACM Transactions on Computer Systems 10(1), February 1992, pp. 53-79

Syscalls vs Upcalls



System Call
(Downcall)



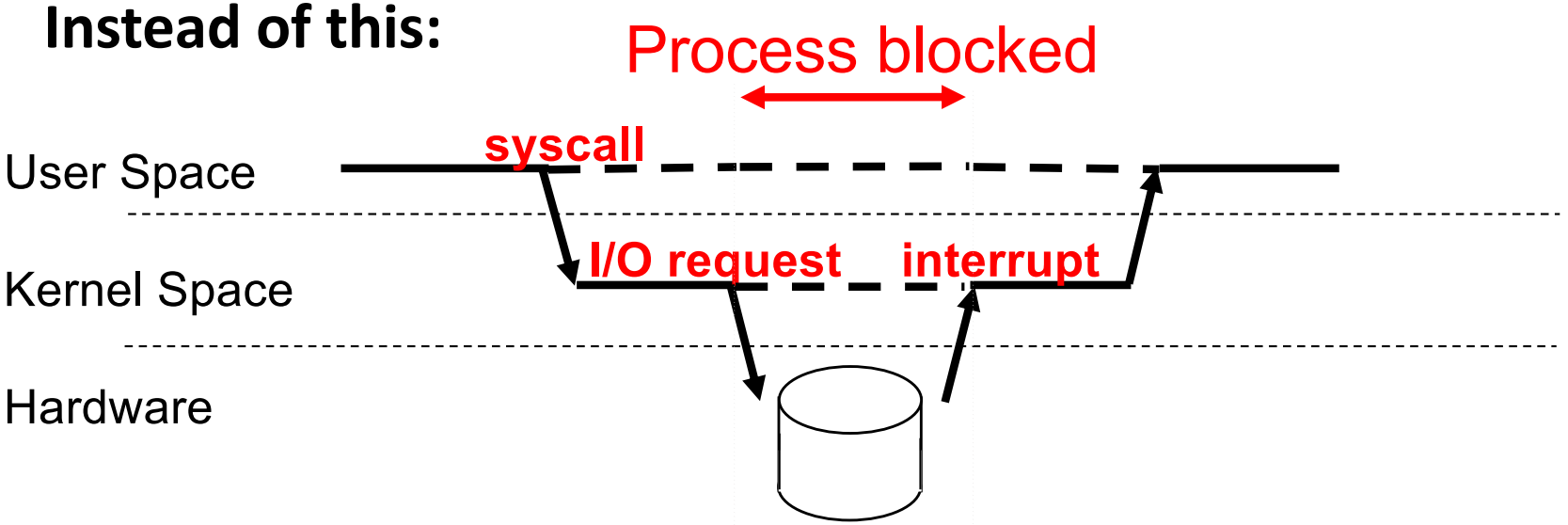
System Call
(Downcall)

Scheduler Activations

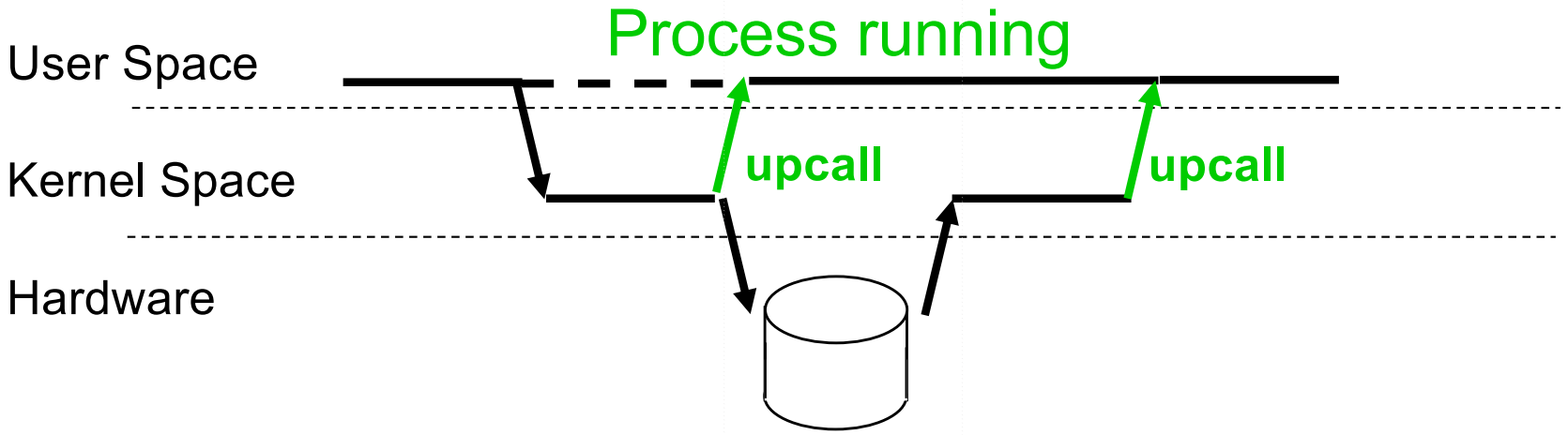
- Idea: Both schedulers co-operate
  - User scheduler uses system calls
  - Kernel scheduler uses upcalls!
- Two important concepts
  - Upcalls
    - Notify user-level of kernel scheduling events
  - Activations
    - A new structure to support upcalls and execution
      - approximately a kernel thread
    - One activations per (allocated) processor
    - Kernel controls activation creation and destruction

Scheduler Activations

Instead of this:



Do this:

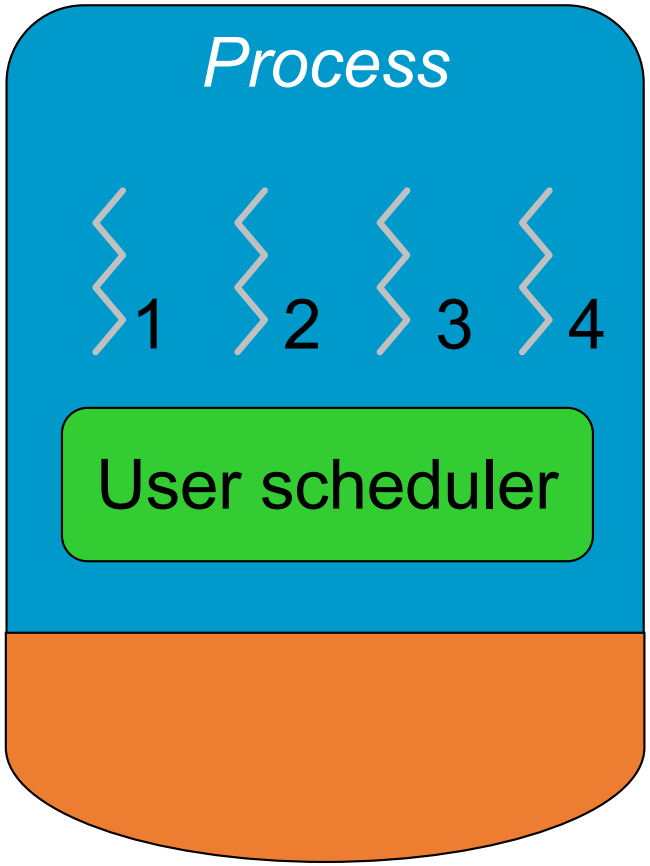


Upcalls to User-level scheduler

- New (processor #)
  - New virtual CPU allocated
  - Can schedule a user-level thread
- Preempted (activation # and its machine state)
  - Virtual CPU deallocated
  - Can schedule one less thread
- Blocked (activation #)
  - Notification of thread blocked
  - Can schedule another user-level thread
- Unblocked (activation # and its machine state)
  - Notification a thread has become runnable
  - Must decide to continue current or unblocked thread

Working principle

Assume 2 processors



Working principle

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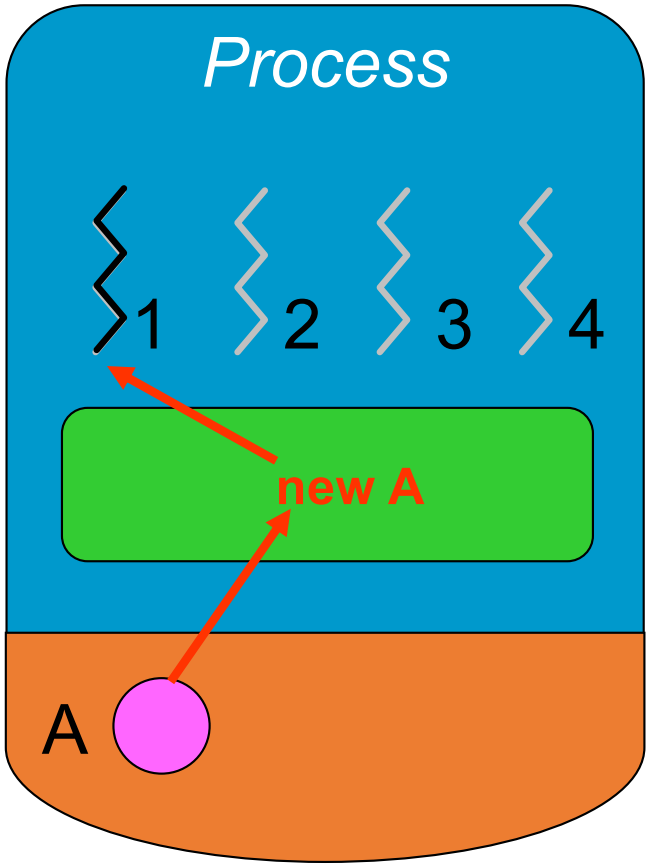

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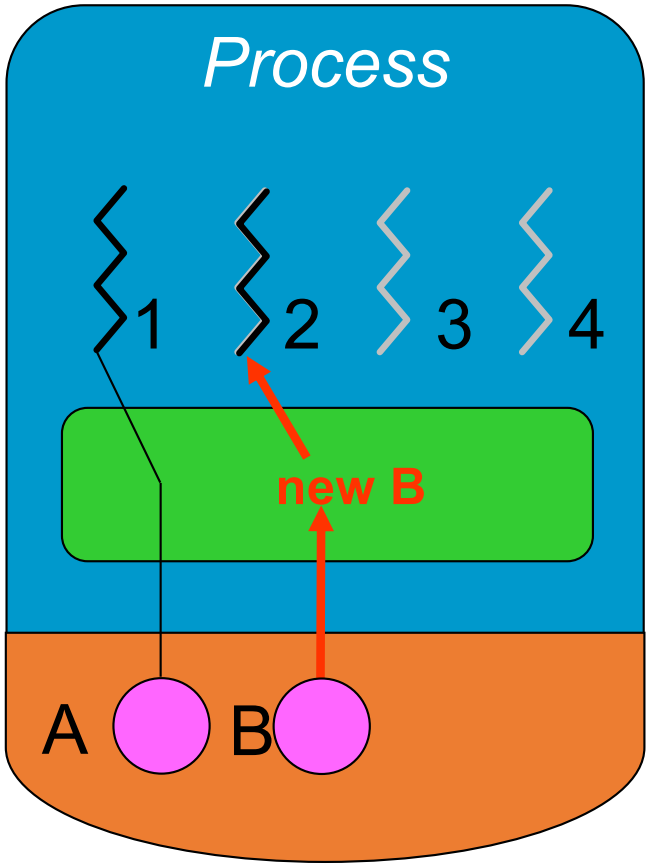
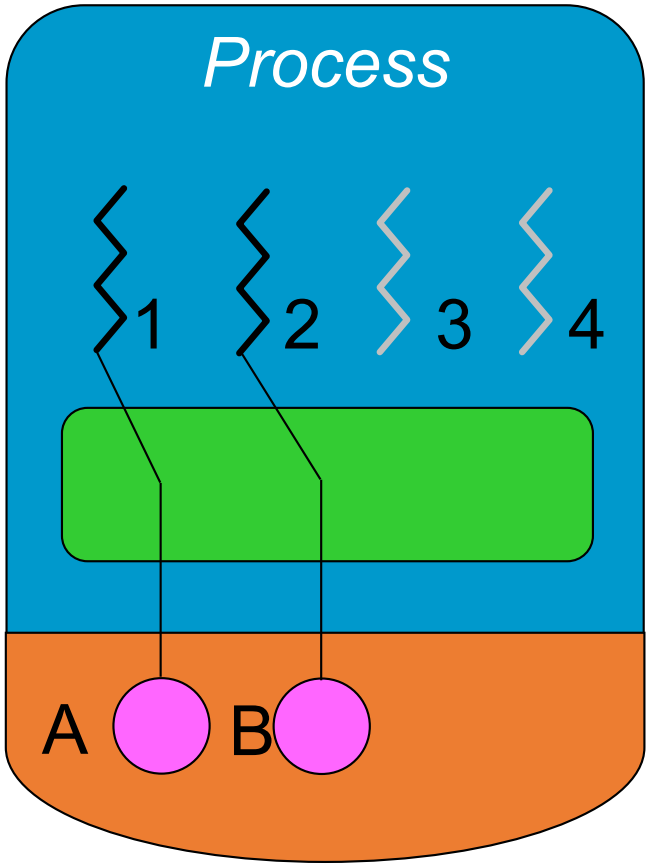


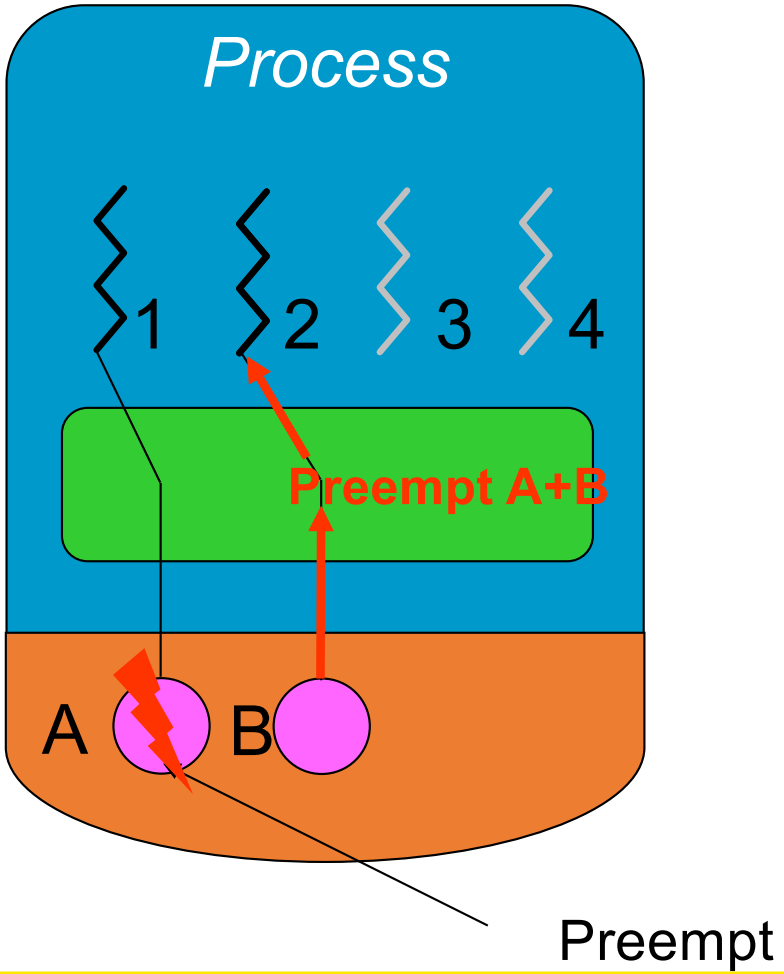
Working principle

Assume 2 processors



Working principle

Preemption scenario on 2 processors



Working principle

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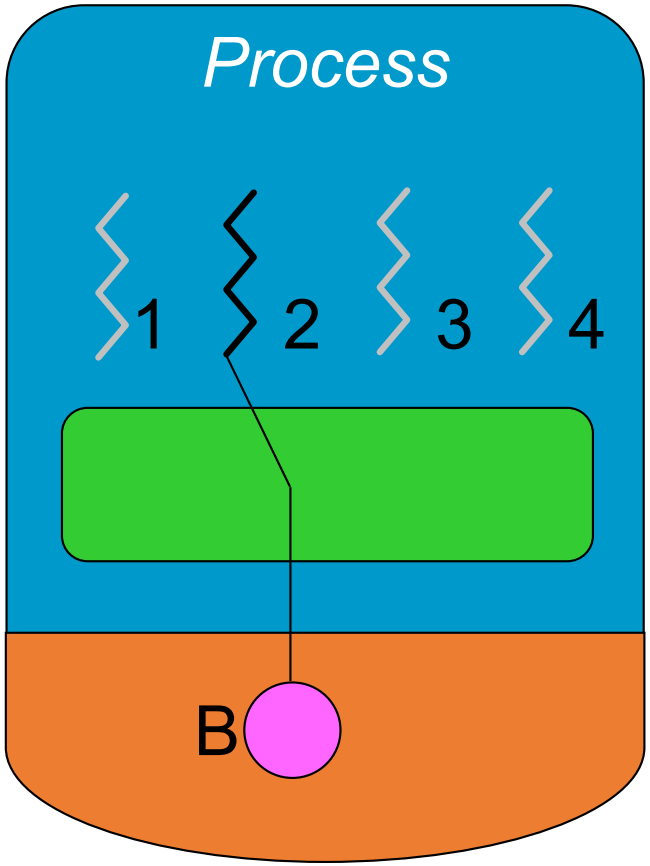
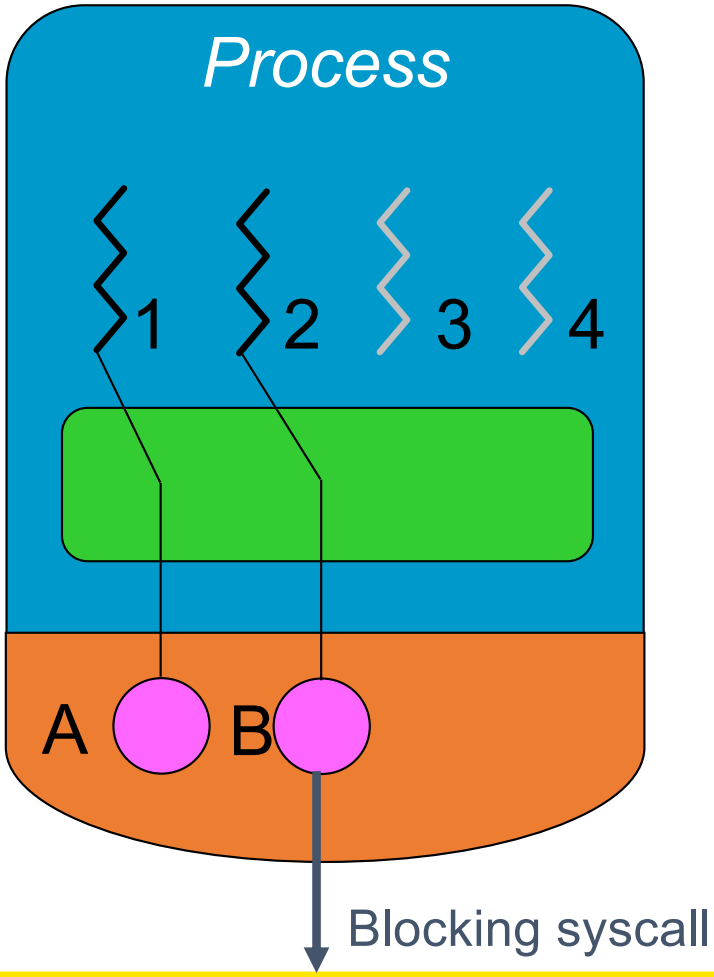


Working principle

Blocking syscall scenario on 2 processors



Working principle

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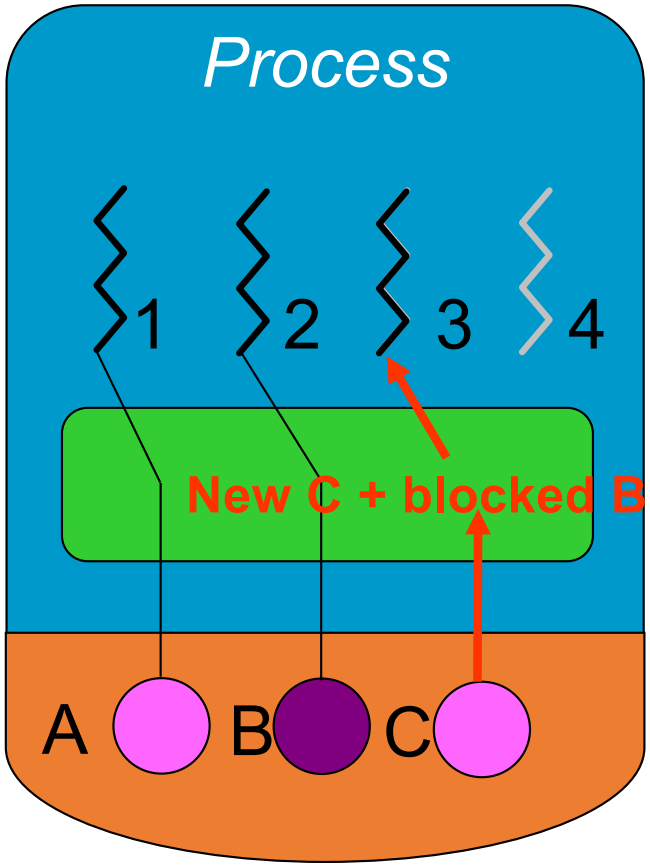

Working principle

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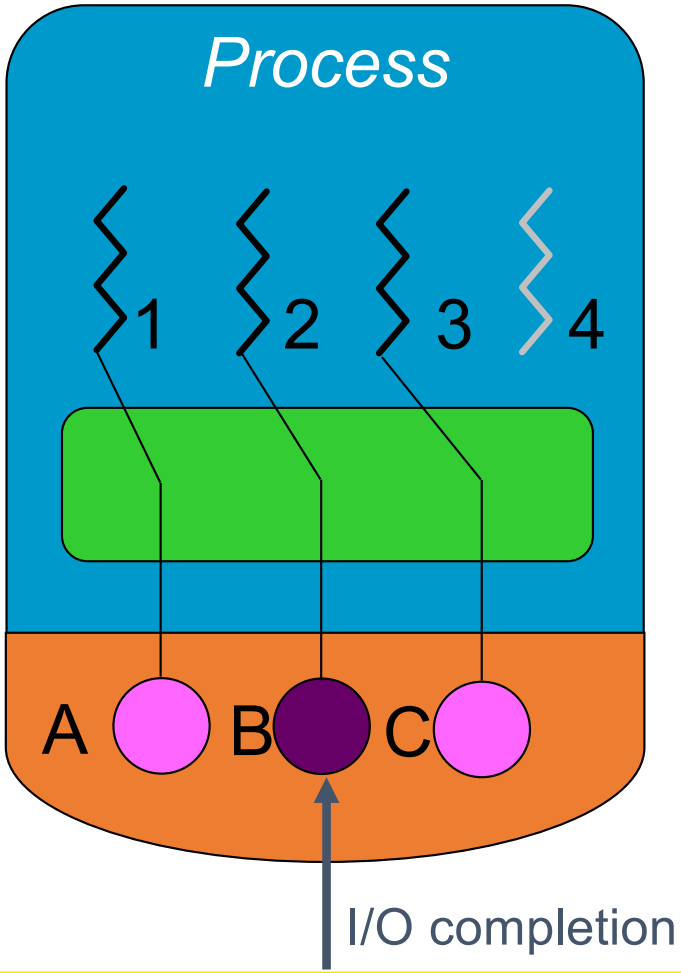

Working principle

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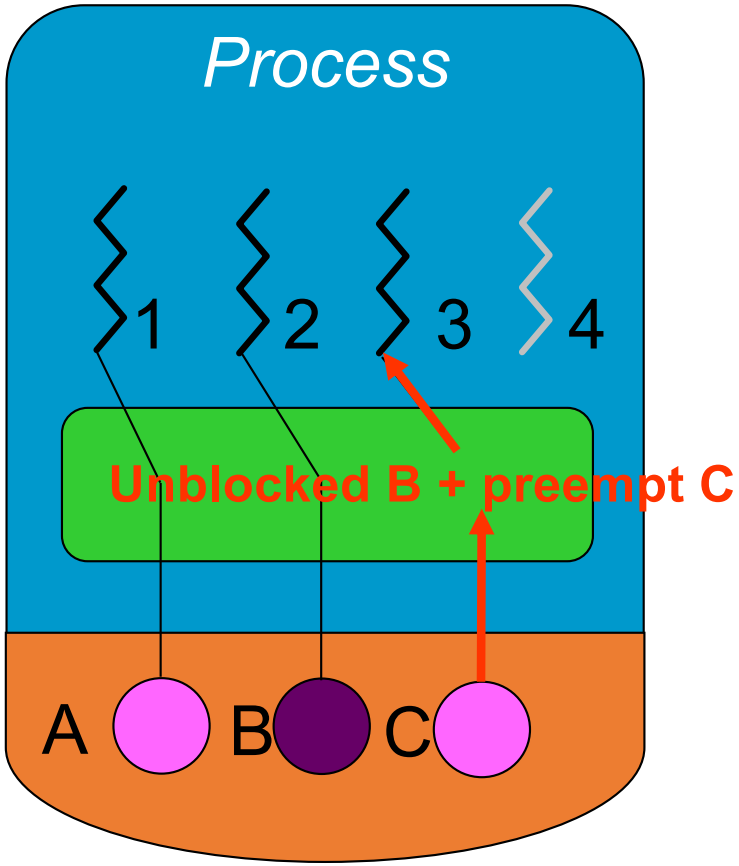

Working principle

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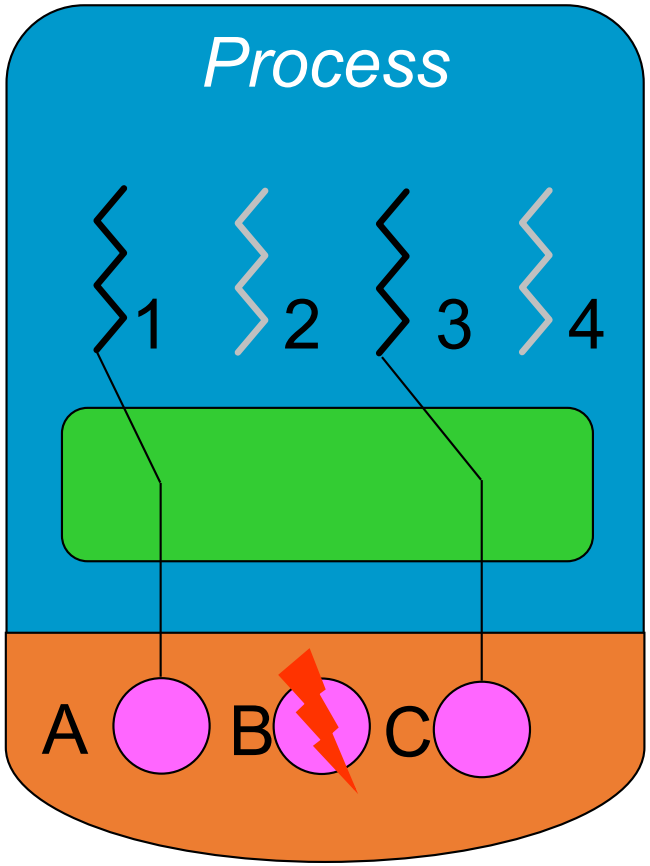
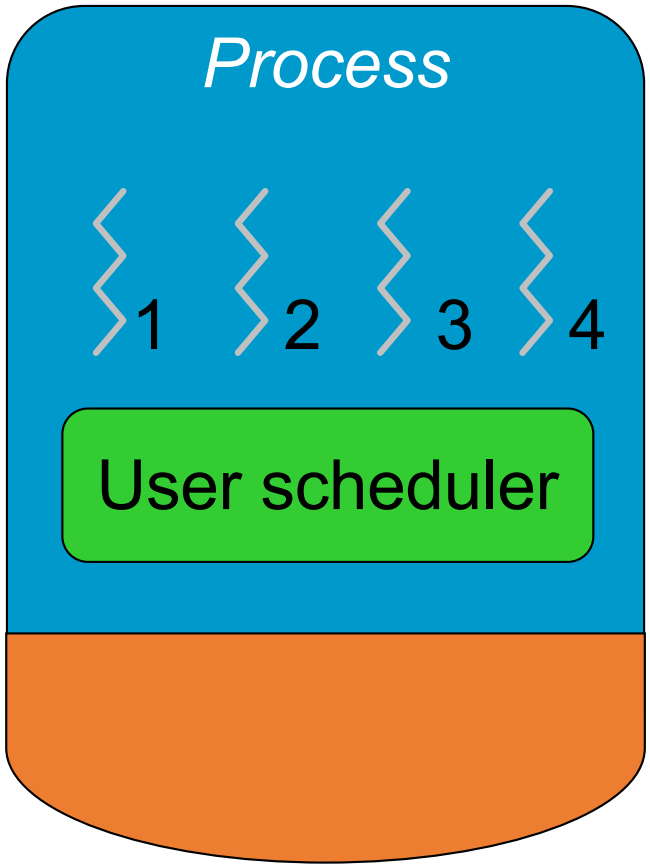


Scheduler Activations

Fast user-level thread management



Blocking creates new activation
- allows user-level scheduler to pick new thread

Real parallelism via activations
- Activations are virtual CPUs
- Can have as many as real CPUs

Performance

Thread operation latencies (μs) on CVAX.

Operation	FastThread on Topaz Threads	FastThread on Sched. Activ.	Topaz Threads	Ultrix Processes
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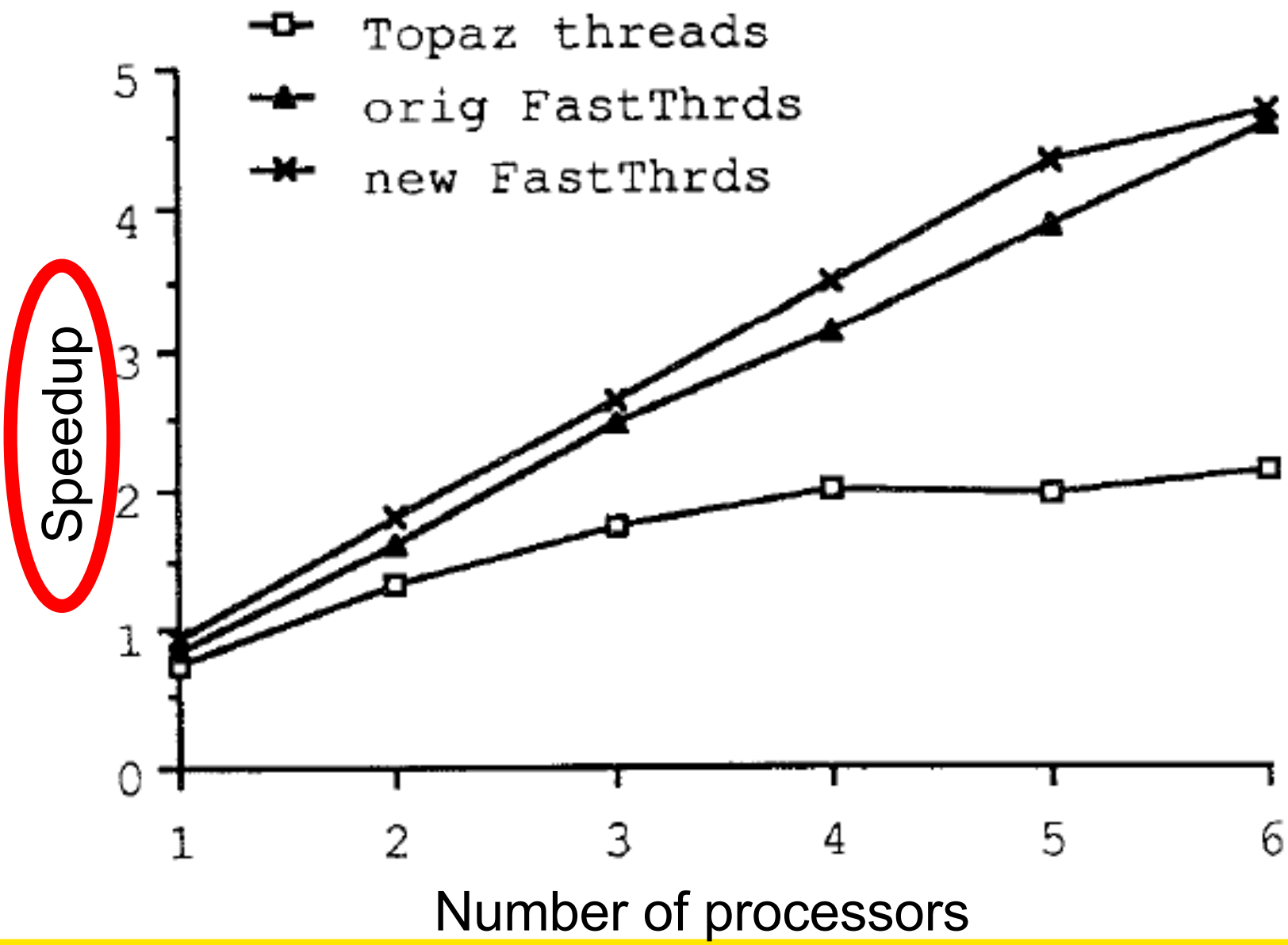
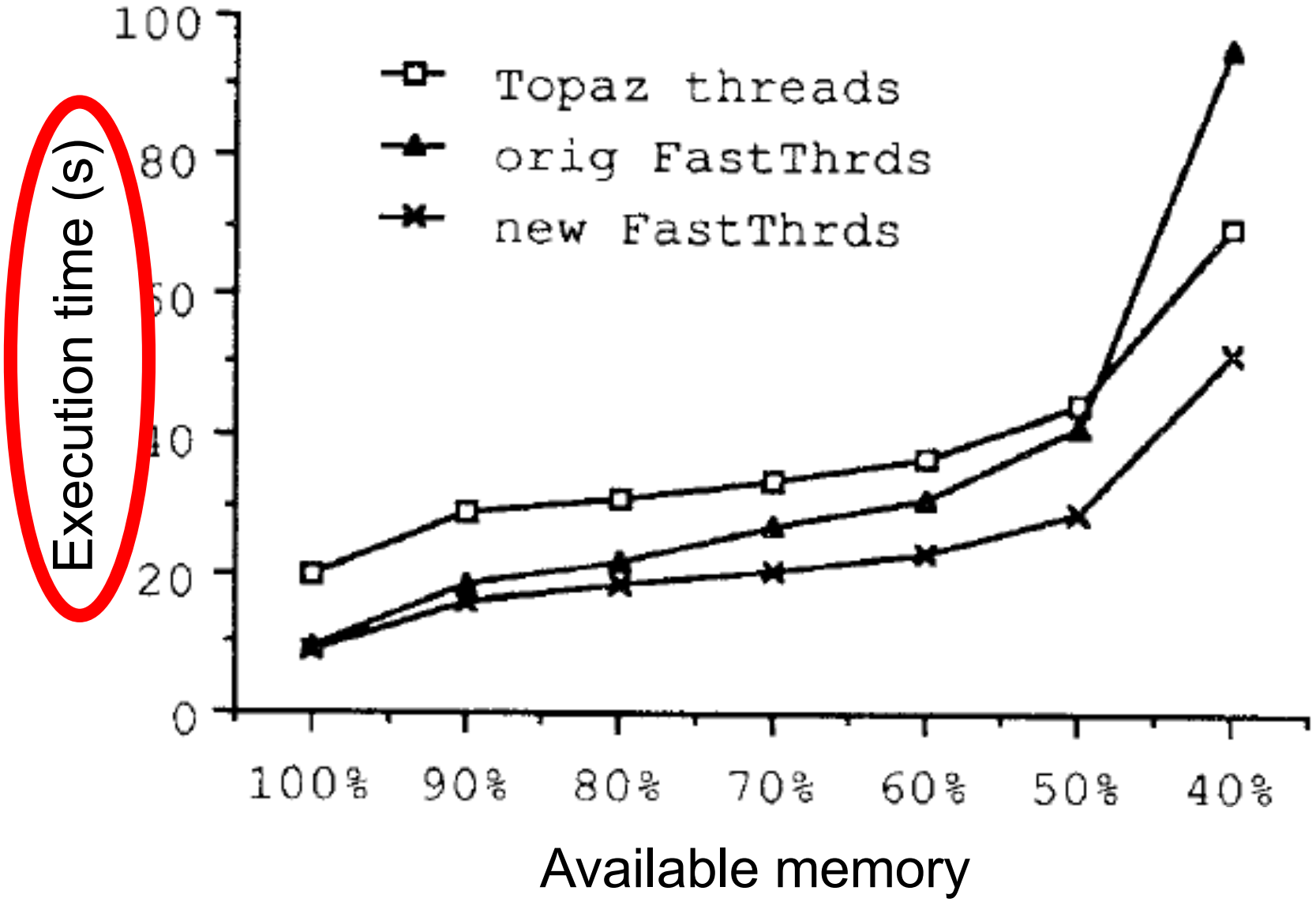
Signal-Wait	37	42	441	1840

Performance: Compute-Bound



Performance: I/O-Bound



Adoption

- Adopters
  - BSD “Kernel Scheduled Entities”
    - Reverted back to kernel threads
  - Variants in Research OSs: K42, Barrelfish
  - Digital UNIX
  - Solaris
  - Mach
  - Windows 64-bit *User-Mode Scheduling*
  - Research OS Composite
  - seL4 MCS timeout exceptions
- Linux -> kernel threads