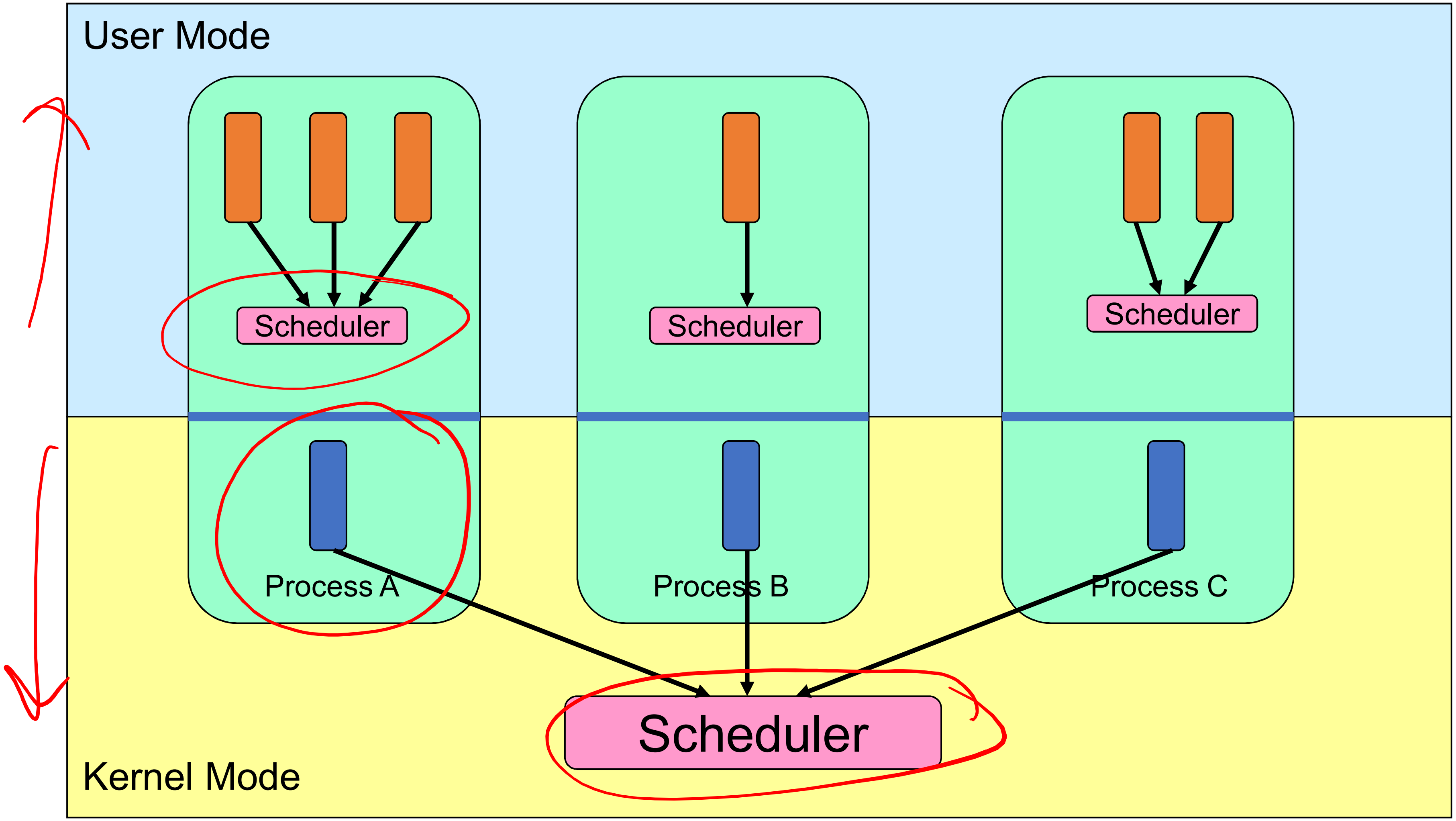
Scheduler Activations

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.

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

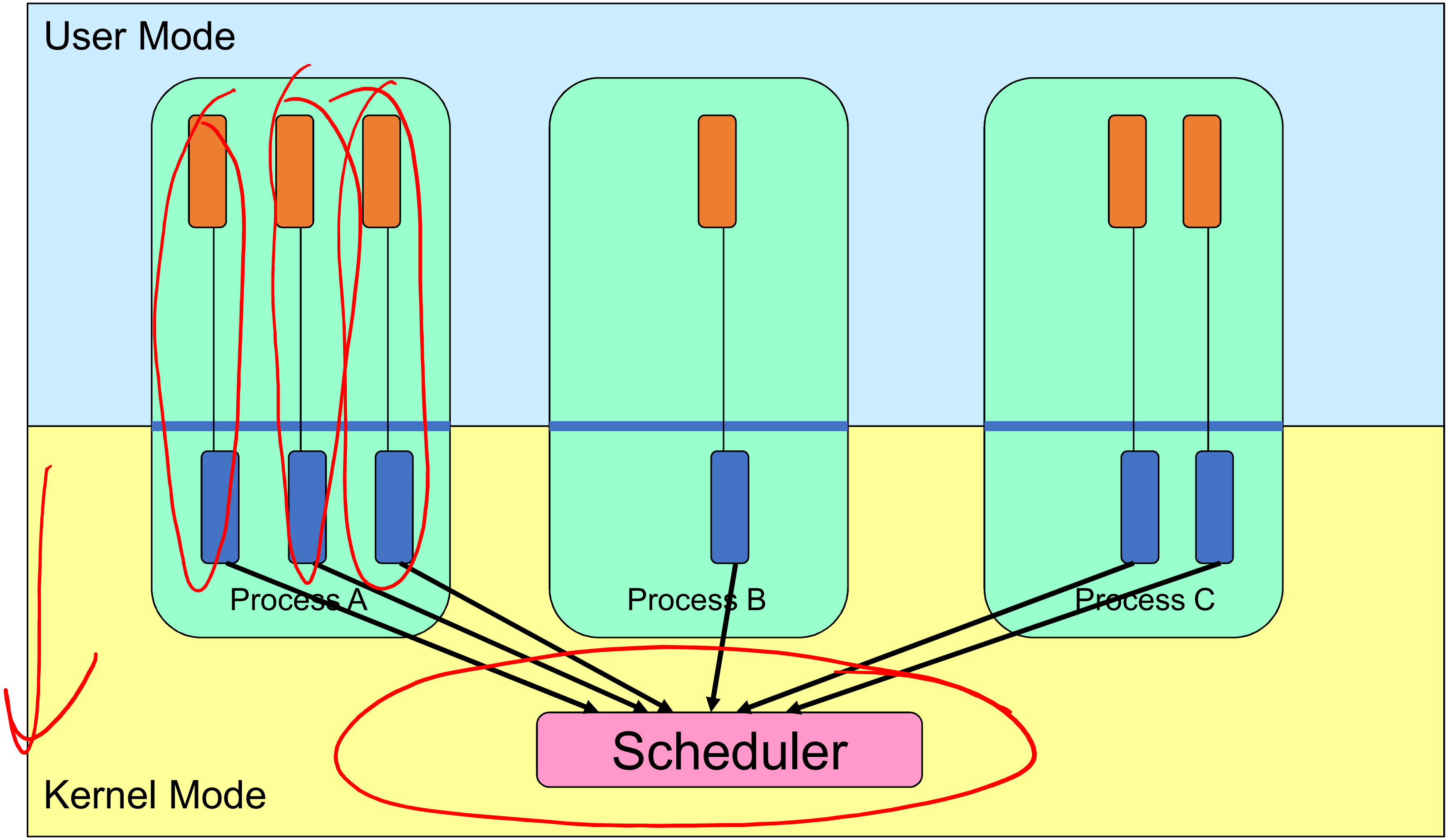
User-level Threads



User-level Threads

- ✓ Fast thread management (creation, deletion, switching, synchronisation…)
- ✗ Blocking blocks all threads in a process
  - Syscalls
  - Page faults
- ✗ No thread-level parallelism on multiprocessor

Kernel-Level Threads



Kernel-level Threads

- ✘ Slow thread management (creation, deletion, switching, synchronisation…)
  - System calls
- ✓ Blocking blocks only the appropriate thread in a process
- ✓ Thread-level parallelism on multiprocessor

Performance

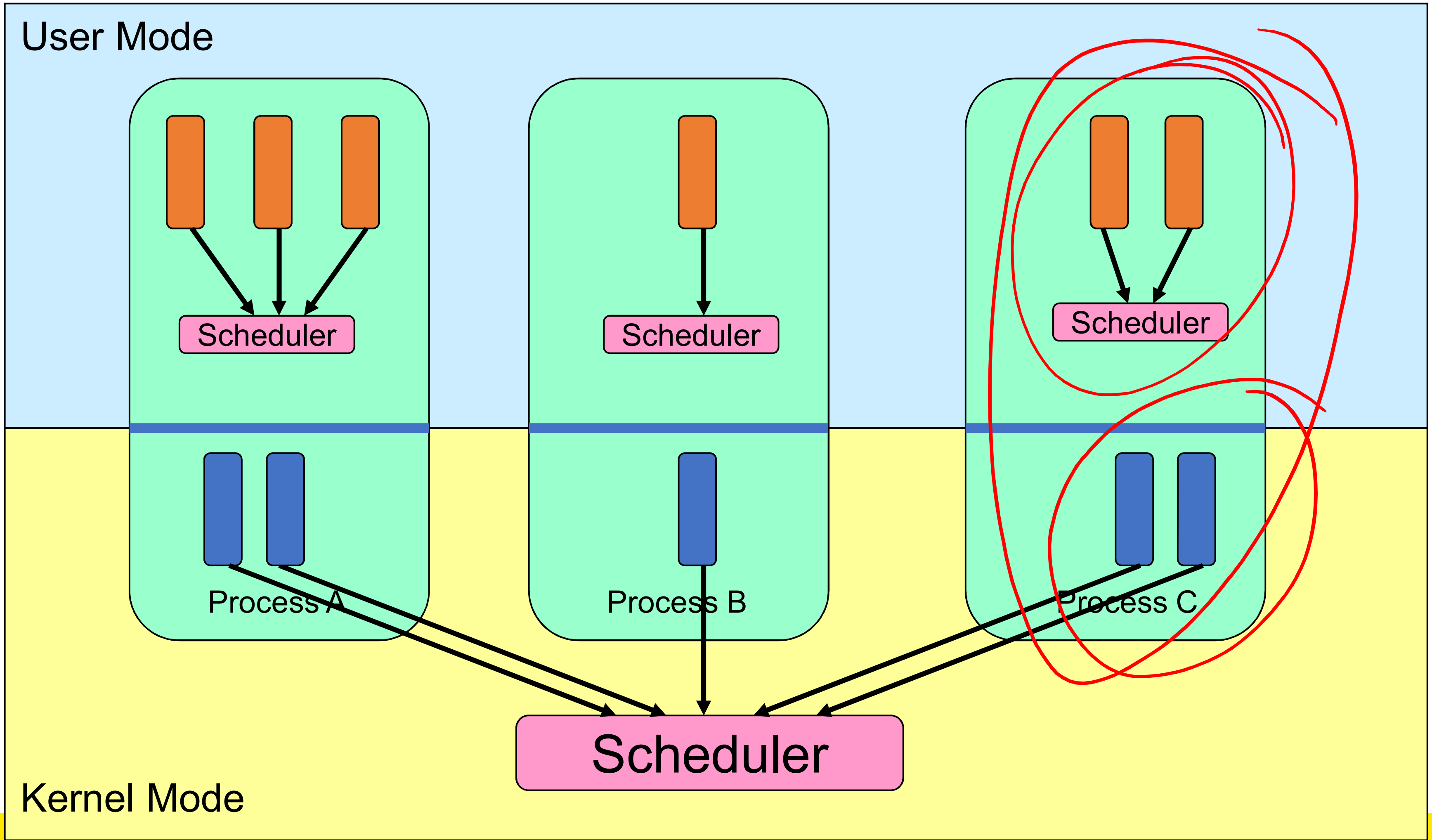
Table I: Thread Operation Latencies (usec.)

Operation	FastThreads	Topaz threads	Ultrix processes
Null Fork	34	948	11300
Signal-Wait	37	441	1840

User-level threads

Kernel-level threads

Hybrid Multithreading



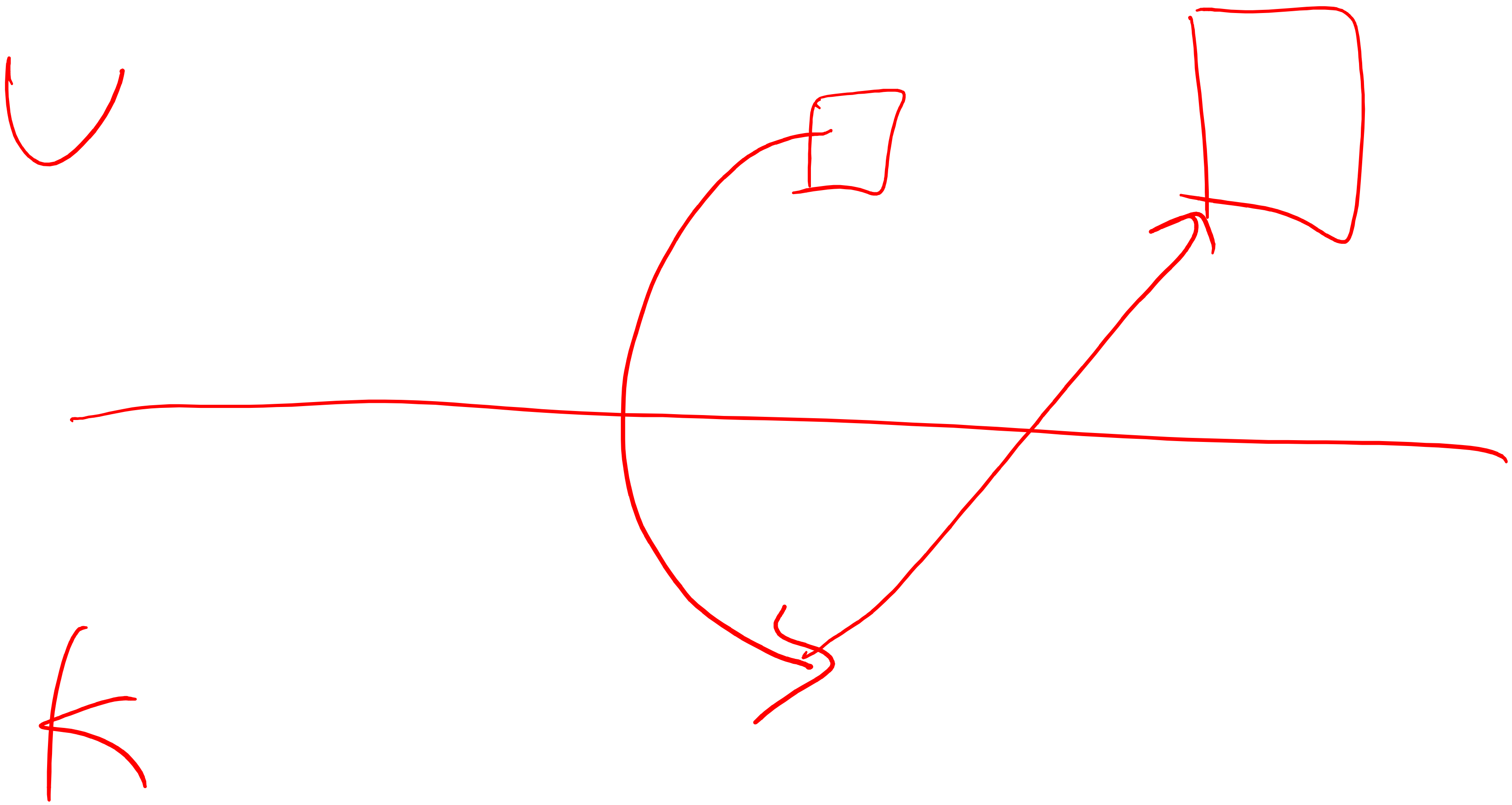
Hybrid Multithreading

- ✓ Can get real thread parallelism on multiprocessor
- ✗ Blocking still a problem!!!

Scheduler Activations

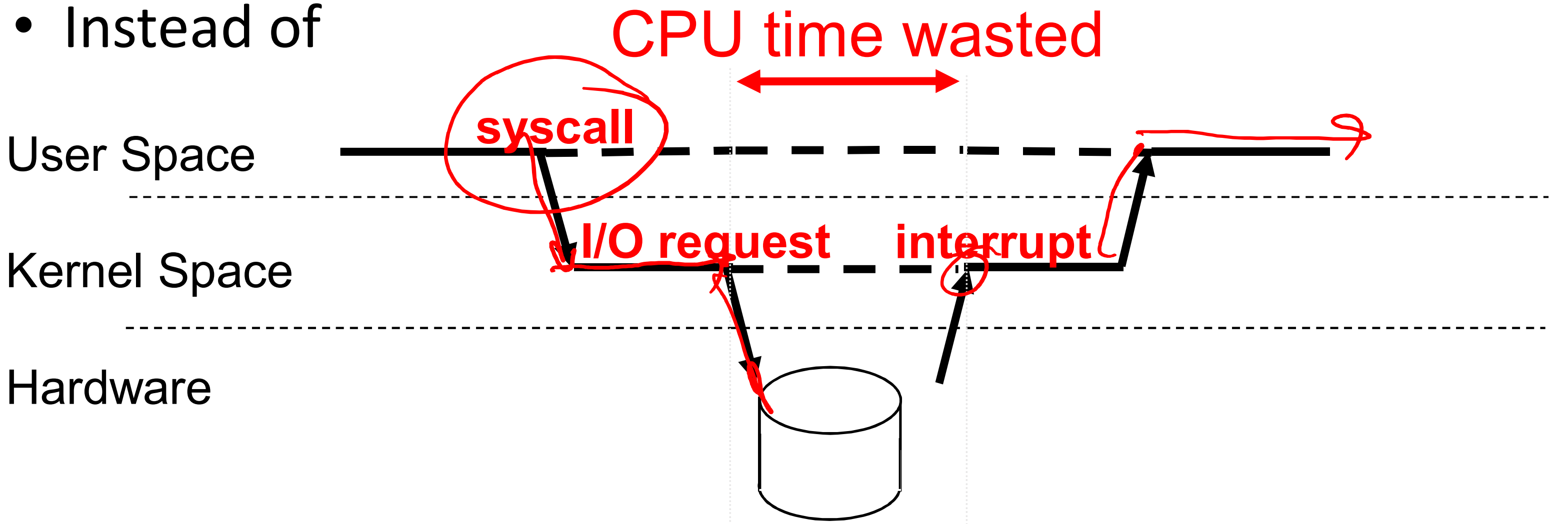
- First proposed by [Anderson et al. 91]
- Idea: Both schedulers co-operate
    - User scheduler uses system calls
    - Kernel scheduler uses upcalls!
- Two important concepts
  - Upcalls
    - Notify the user-level of kernel scheduling events
  - Activations
    - A new structure to support upcalls and execution
      - approximately a kernel thread
    - As many running activations as (allocated) processors
    - Kernel controls activation creation and destruction

Upcalls

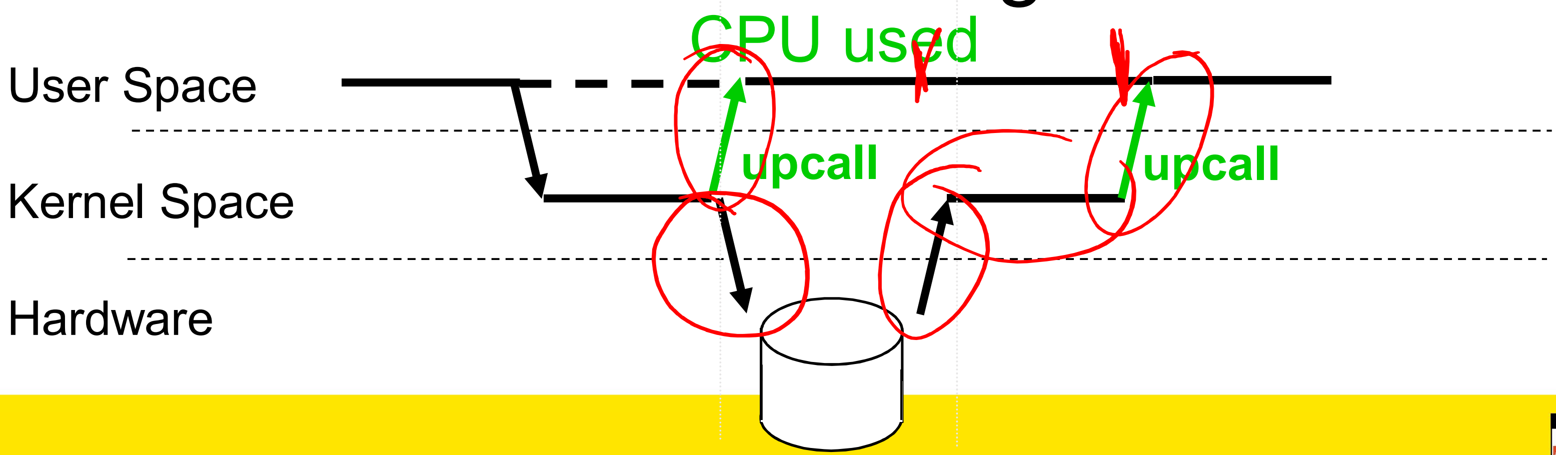


Scheduler Activations

- Instead of



- …rather use the following scheme:

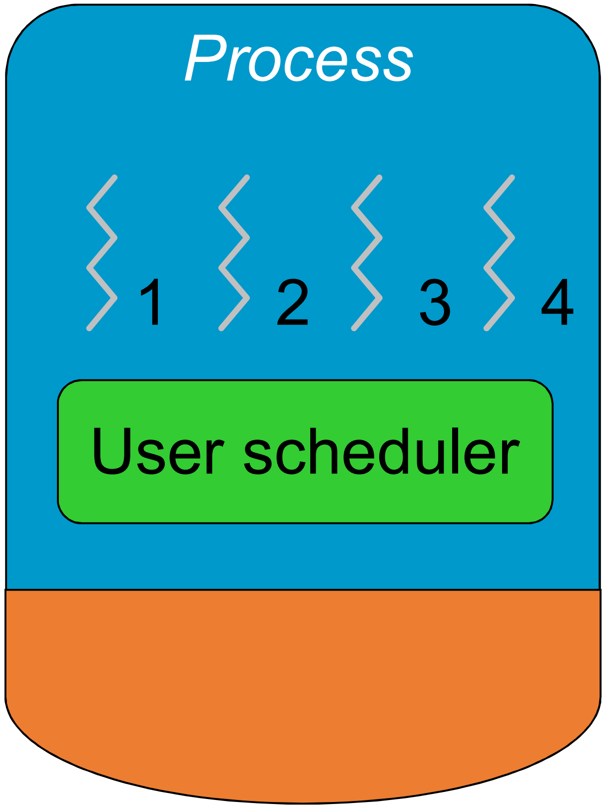


Upcalls to User-level scheduler

- New (processor #)
  - Allocated a new virtual CPU
  - Can schedule a user-level thread
- Preempted (activation # and its machine state)
  - Deallocated a virtual CPU
  - Can schedule one less thread
- Blocked (activation #)
  - Notifies thread has blocked
  - Can schedule another user-level thread
- Unblocked (activation # and its machine state)
  - Notifies a thread has become runnable
  - Must decided to continue current or unblocked thread

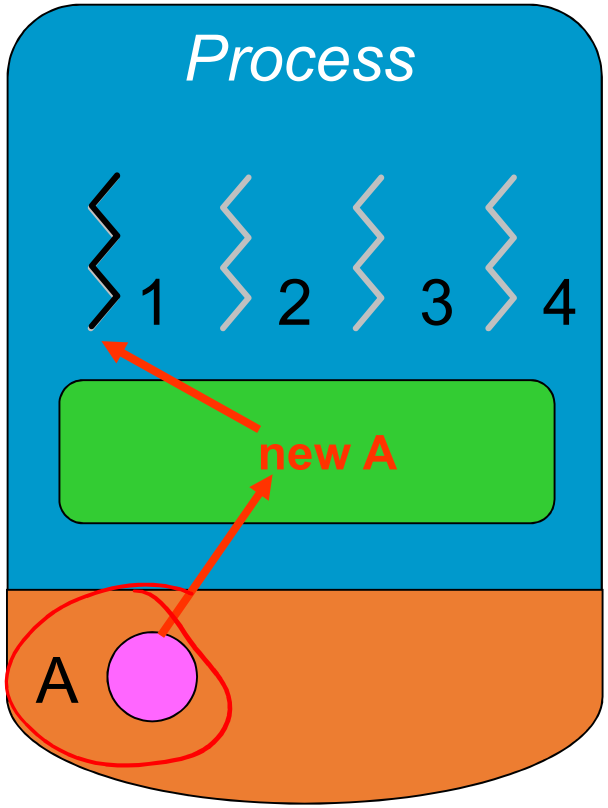
Working principle

- Blocking syscall scenario on 2 processors



Working principle

- Blocking syscall scenario on 2 processors



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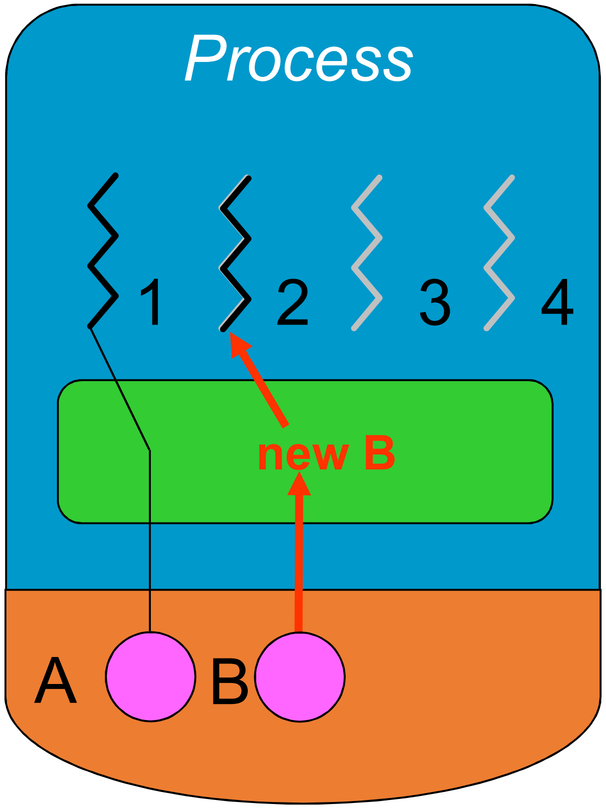

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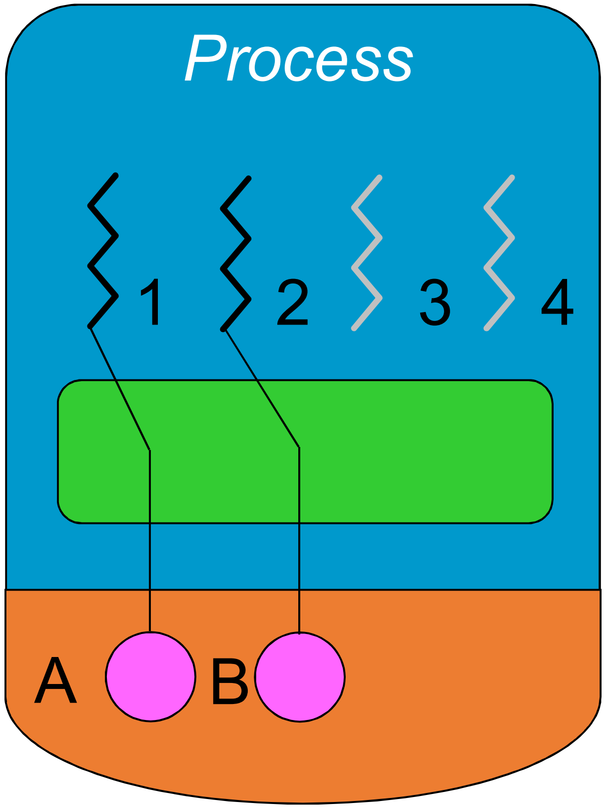

Working principle

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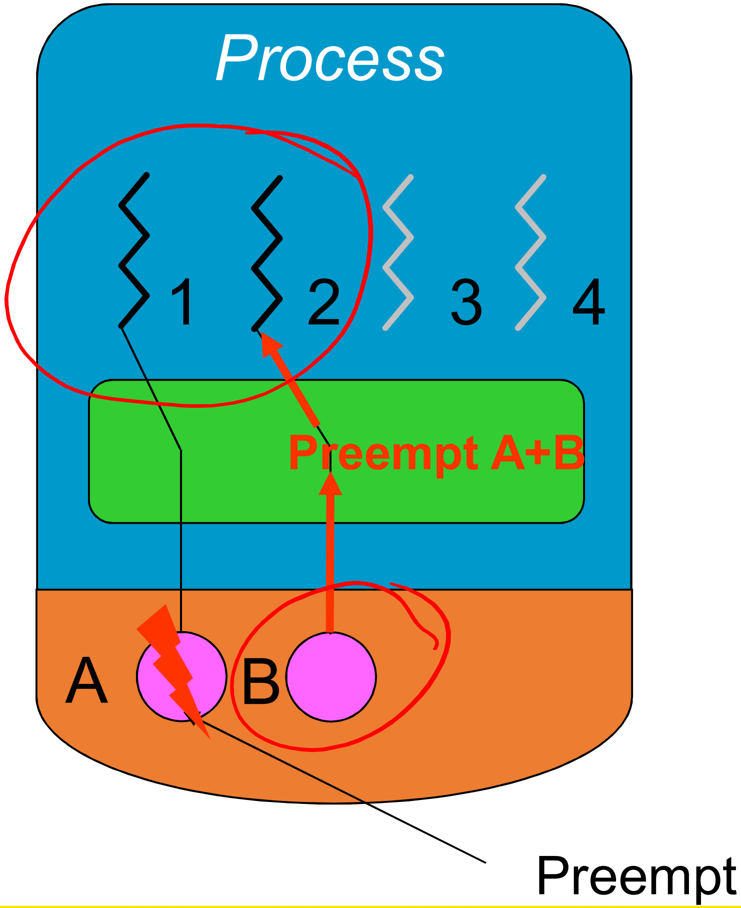

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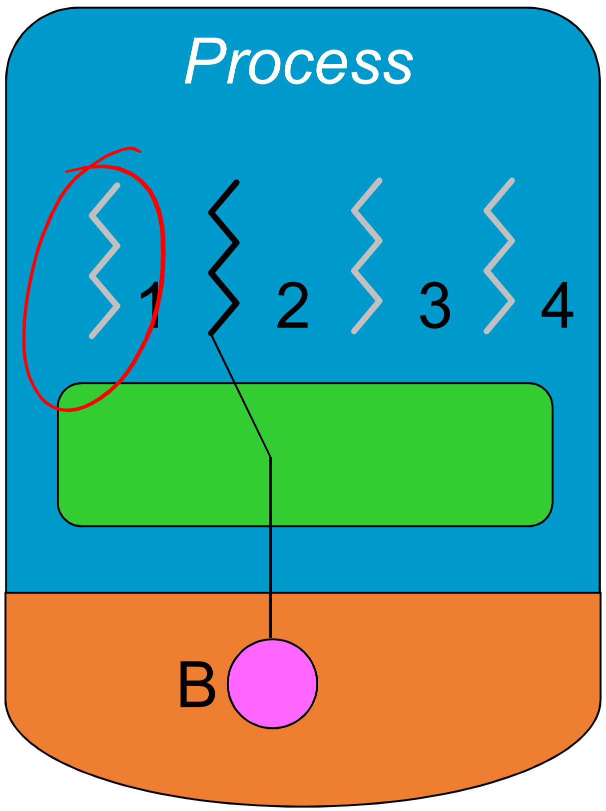

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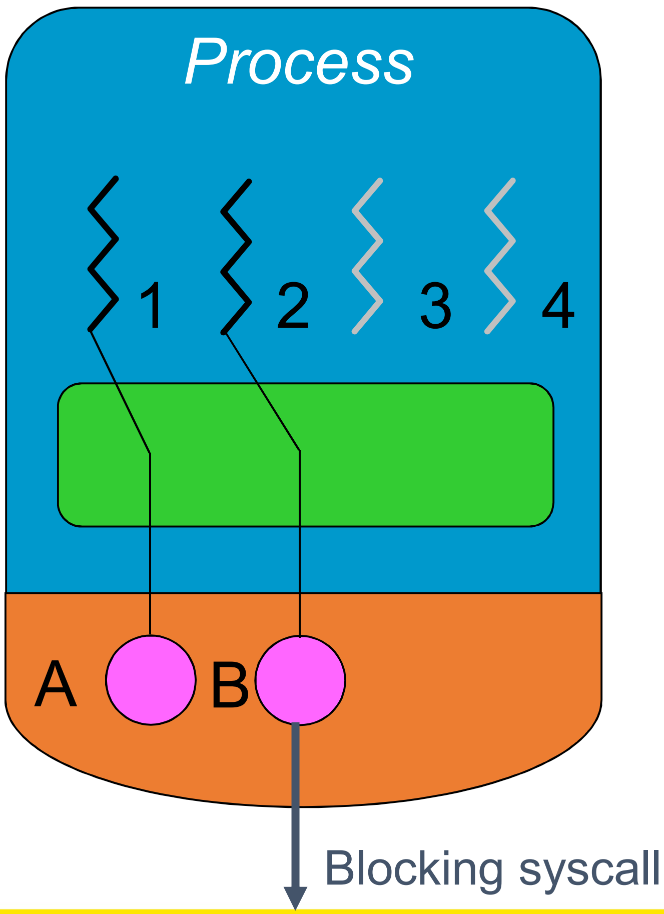
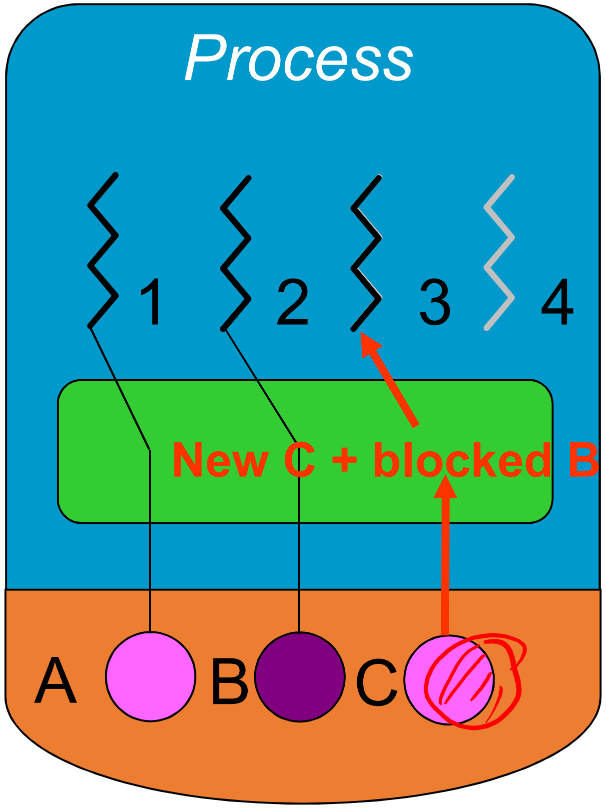


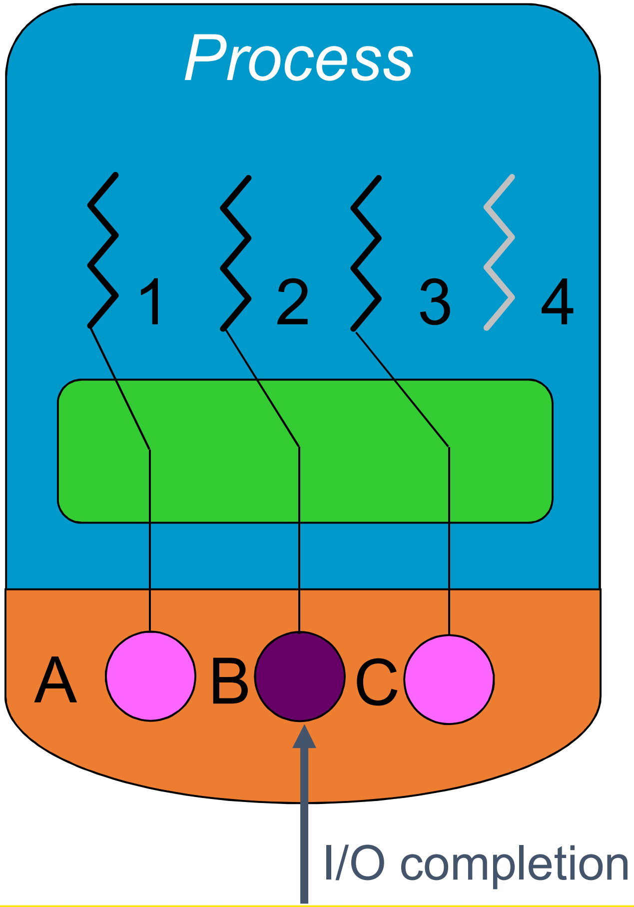
Working principle

- Blocking syscall scenario on 2 processors



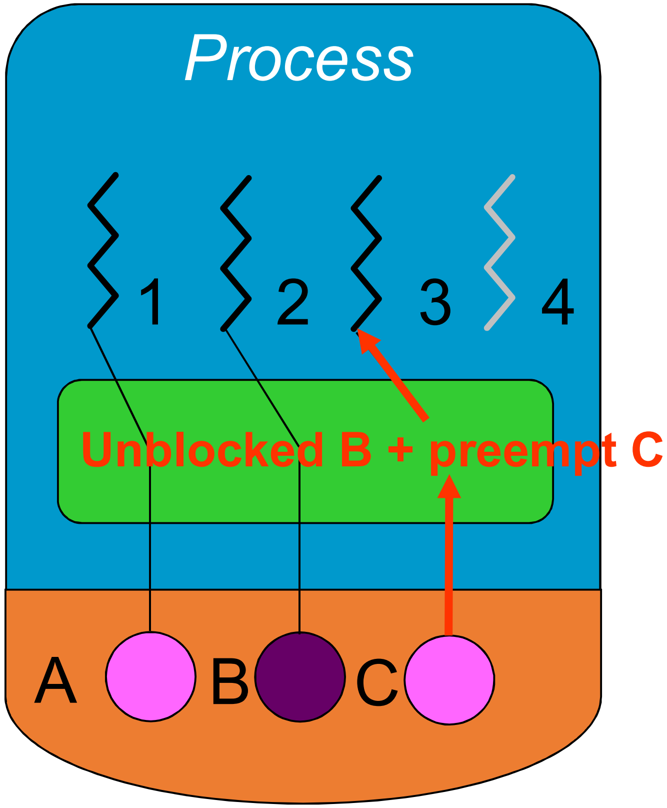
Working principle

- Blocking syscall scenario on 2 processors



Working principle

- Blocking syscall scenario on 2 processors



Working principle

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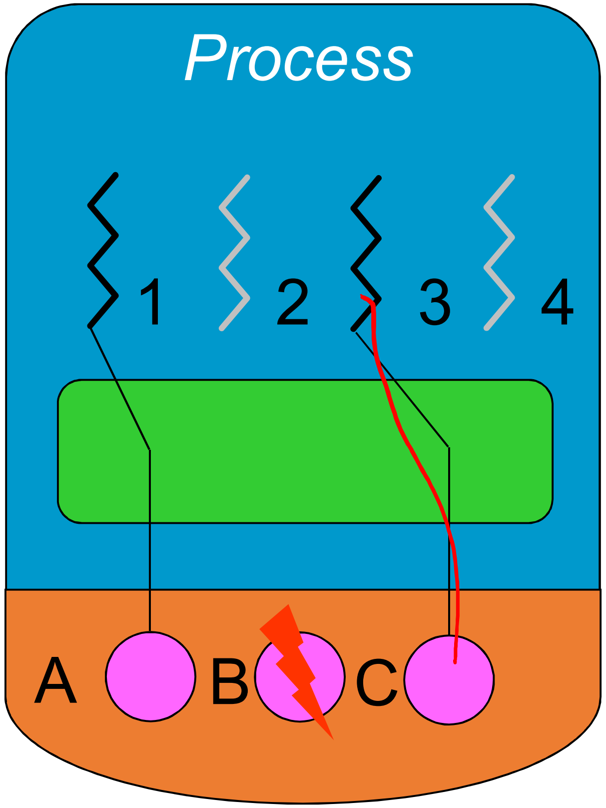

Scheduler Activations

- Thread management at user-level
  - Fast
- Real thread parallelism via activations
  - Number of activations (virtual CPUs) can equal CPUs
- Blocking (syscall or page fault) creates new activation
  - User-level scheduler can pick new runnable thread.
- Fewer stacks in kernel
  - Blocked activations + number of virtual CPUs

Performance

Table IV. Thread Operation Latencies (μsec.)

Operation	FastThreads on Topaz Threads	FastThreads on Scheduler Activations	Topaz threads	Ultrix processes
Null Fork	34	37	948	11300
Signal-Wait	37	42	441	1840

Performance (compute-bound)

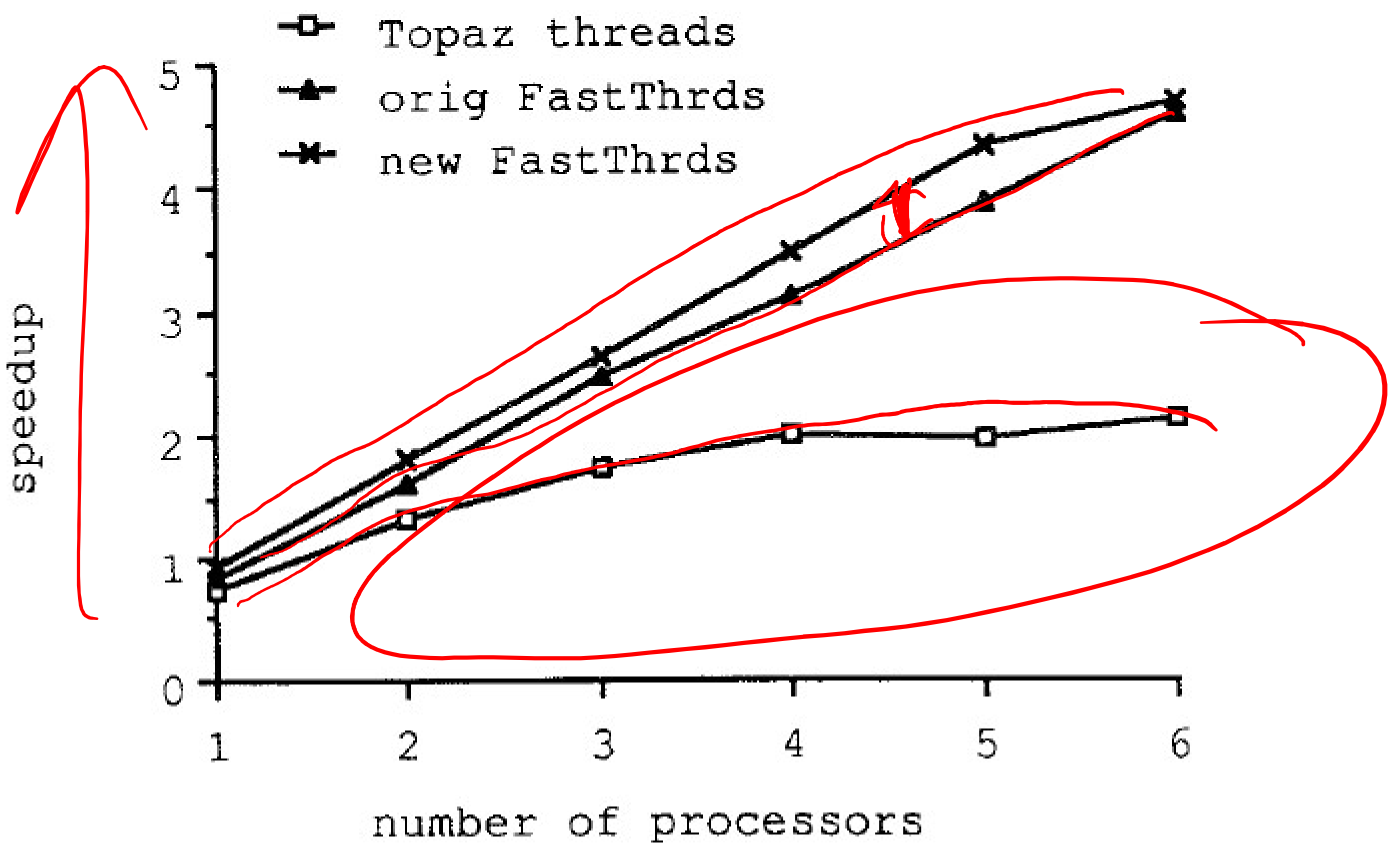

Fig. 2. Speedup of N-Body application versus number of processors, 100% of memory available.

Performance (I/O Bound)

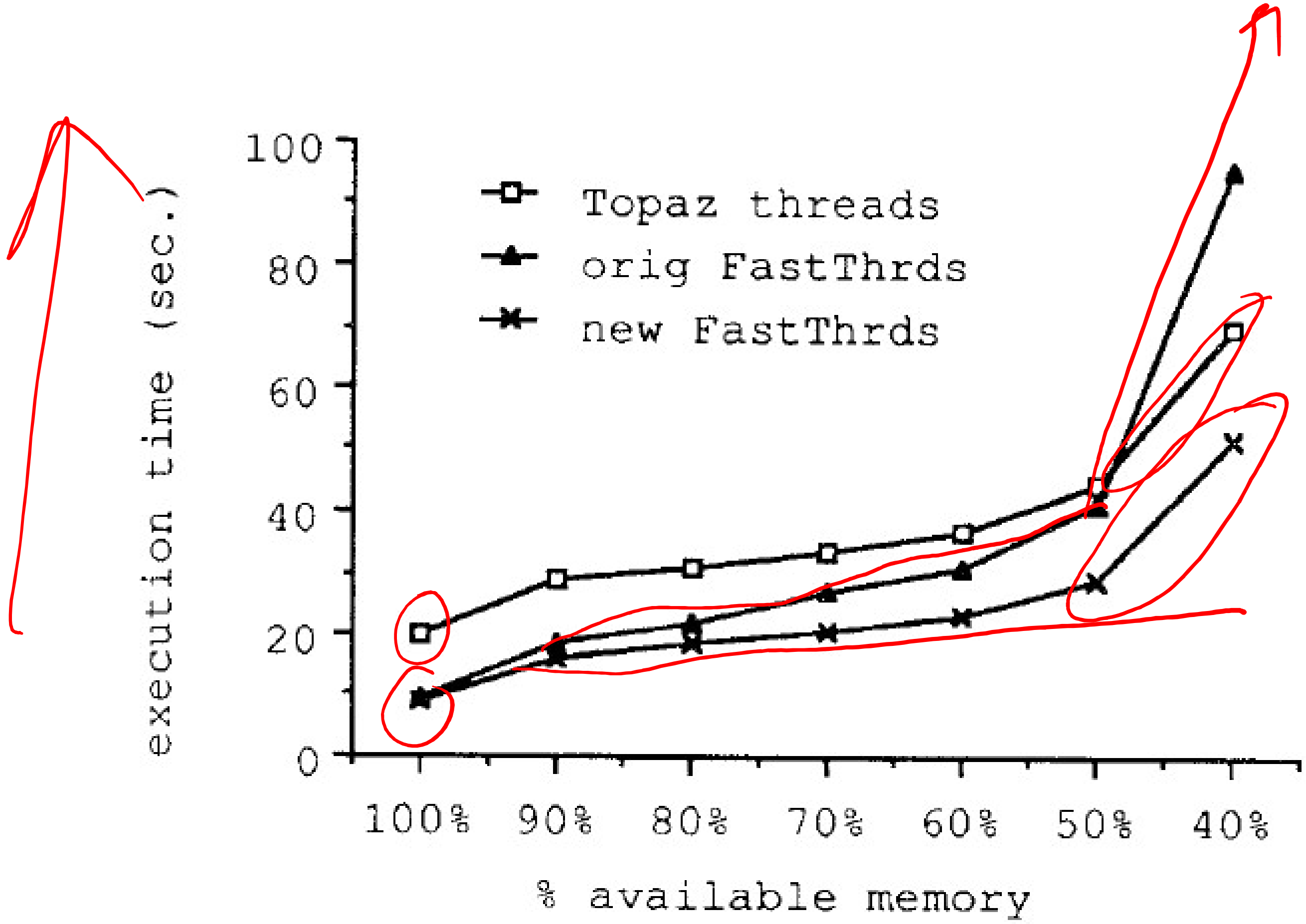

Fig. 3. Execution time of N-Body application versus amount of available memory, 6 processors.

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*
- Linux -> kernel threads

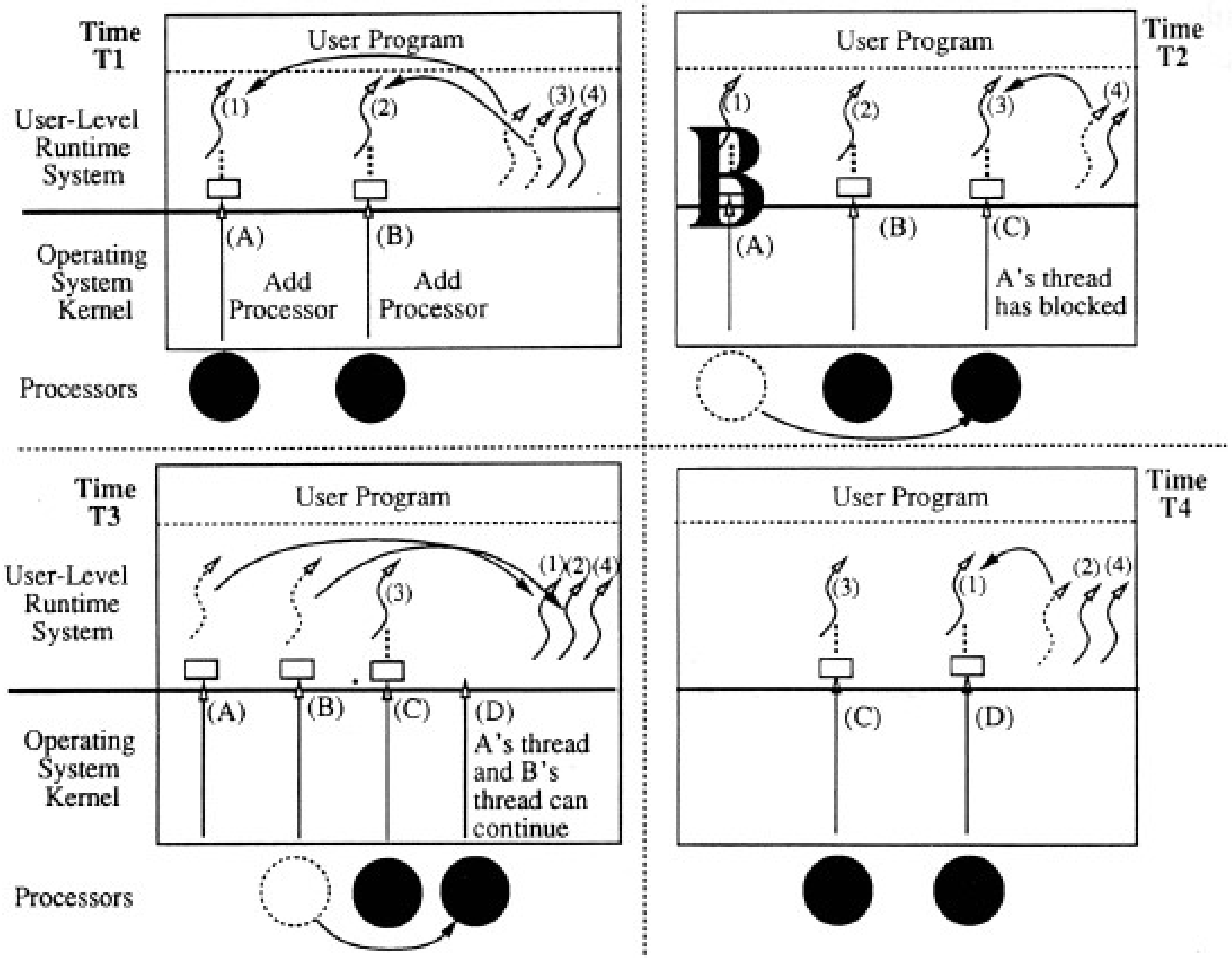

Fig. 1. Example: I/O request/completion.