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.
User-level Threads

User Mode

Kernel Mode

Scheduler

Process A

Scheduler

Process B

Scheduler

Process C

Scheduler
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

User Mode

Kernel Mode

Scheduler

Process A

Process B

Process C
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>
<thead>
<tr>
<th>Operation</th>
<th>FastThreads</th>
<th>Topaz threads</th>
<th>Ultrix processes</th>
</tr>
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<tbody>
<tr>
<td>Null Fork</td>
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**Table I: Thread Operation Latencies (usec.)**
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

 User Space

 Kernel Space

 Hardware

 syscall

 I/O request

 interrupt

 CPU time wasted

• …rather use the following scheme:

 User Space

 Kernel Space

 Hardware

 upcall

 upcall

 CPU used
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 decide to continue current or unblocked thread
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.)

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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.