Scheduler Activations

Including some slides modified from Raymond Namyst, U. Bordeaux

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-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>
<thead>
<tr>
<th>Operation</th>
<th>FastThreads</th>
<th>Topaz threads</th>
<th>Ultrix processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null Fork</td>
<td>34</td>
<td>048</td>
<td>11300</td>
</tr>
<tr>
<td>Signal-Wait</td>
<td>37</td>
<td>441</td>
<td>1840</td>
</tr>
</tbody>
</table>

**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
  - 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
Scheduler Activations

- Instead of
  - User Space
  - Kernel Space
  - Hardware
  - syscall
  - CPU time wasted
  - Interrupt

- ...rather use the following scheme:
  - User Space
  - Kernel Space
  - Hardware
  - 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 decided to continue current or unblocked thread

Working principle

- Blocking syscall scenario on 2 processors
  - Process
  - 1 2 3 4
  - User scheduler

- Blocking syscall scenario on 2 processors
  - Process
  - 1 2 3 4
  - A
Working principle
• Blocking syscall scenario on 2 processors

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Working principle
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Working principle

- Blocking syscall scenario on 2 processors

Process 1 2 3 4
A B C

I/O completion

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 (compute-bound)

Table IV: Thread Operation Latencies (usec.)

<table>
<thead>
<tr>
<th>Operation</th>
<th>%Thread on</th>
<th>%Thread on</th>
<th>Scheduler Activations</th>
<th>%Thread on</th>
<th>%Thread on</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Fort</td>
<td>34</td>
<td>37</td>
<td>948</td>
<td>11300</td>
<td></td>
</tr>
<tr>
<td>Signal Wait</td>
<td>37</td>
<td>42</td>
<td>441</td>
<td>1040</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 2: Speed-up of N-Body application versus number of processors, 100% of memory available.
Performance (I/O Bound)

Adoption

- Adopters
  - BSD “Kernel Scheduled Entities”
    - Reverted back to kernel threads
  - Variants in Research OSs: K42, Barrellfish
  - Digital UNIX
  - Solaris
  - Mach
  - Windows 7 64-bit User Mode Scheduling
- Linux -> kernel threads