Threads

- Suspending a process
  - suspends all threads of the process since all threads share the same address space
- Termination of a process
  - terminates all threads within the process
Thread States

• States of a thread
  – Spawn
    • when process is spawned
    • thread may spawn other threads
    • each thread has its own:
      – register context, state space, and place in ready queue
  – Block
    • when thread waits for event
      – saves user registers, PC and stack pointer
Thread States

• States of a thread
  – Unblock
    • when blocking event occurs
    • thread is moved to ready queue
  – Finish
    • register context and stack is deallocated
Remote Procedure Call Using Single Thread

What is a RPC?

(a) RPC Using Single Thread
Remote Procedure Call Using Threads

(b) RPC Using One Thread per Server (on a uniprocessor)

- Blocked, waiting for response to RPC
- Blocked, waiting for processor, which is in use by Thread B
- Running

Figure 4.3 Remote Procedure Call (RPC) Using Threads
Multithreading

Figure 4.4  Multithreading Example on a Uniprocessor
Basic questions

• What is the difference between this and multiprocessing?
  – kind of looks the same, or...?

• Is there a need to synchronize threads?
  – e.g. two threads insert an element into a linked structure
User-Level Threads (ULT)

• All thread management is done by the application
  – e.g. using threads library
• The kernel is not aware of the existence of threads
User-Level Threads
Thread 2 is only perceived as running by the thread library.

Thread 2 makes call to I/O that blocks.

Thread 2 is still "running".

Time slice expired and other process is executed. Thread 2 is still "running".

Thread 2 needs action from thread 1 and blocks so thread 1 can execute.

Figure 4.7  Examples of the Relationships Between User-Level Thread States and Process States
Kernel-Level Threads (KLT)

- Often called *lightweight processes*
- Windows is an example of this approach
- Kernel maintains context information for the process and the threads
- Scheduling is done on a thread basis
Kernel-Level Threads

(b) Pure kernel-level
VAX Running UNIX-Like Operating System

<table>
<thead>
<tr>
<th>Operation</th>
<th>User-Level Threads</th>
<th>Kernel-Level Threads</th>
<th>Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null Fork</td>
<td>34</td>
<td>948</td>
<td>11,300</td>
</tr>
<tr>
<td>Signal Wait</td>
<td>37</td>
<td>441</td>
<td>1,840</td>
</tr>
</tbody>
</table>

Table 4.1  Thread and Process Operation Latencies (μs) [ANDE92]
Combined Approaches

- Thread creation is done in user space
- Bulk of scheduling and synchronization of threads done within application

- Example is Solaris
Combined Approaches

(c) Combined
# Relationship Between Threads and Processes

## Table 4.2  Relationship Between Threads and Processes

<table>
<thead>
<tr>
<th>Threads:Processes</th>
<th>Description</th>
<th>Example Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:1</td>
<td>Each thread of execution is a unique process with its own address space and resources.</td>
<td>Traditional UNIX implementations</td>
</tr>
<tr>
<td>M:1</td>
<td>A process defines an address space and dynamic resource ownership. Multiple threads may be created and executed within that process.</td>
<td>Windows NT, Solaris, Linux OS/2, OS/390, MACH</td>
</tr>
<tr>
<td>1:M</td>
<td>A thread may migrate from one process environment to another. This allows a thread to be easily moved among distinct systems.</td>
<td>Ra (Clouds), Emerald</td>
</tr>
<tr>
<td>M:N</td>
<td>Combines attributes of M:1 and 1:M cases.</td>
<td>TRIX</td>
</tr>
</tbody>
</table>
Advantages of ULT over KLT

• thread switching does not require kernel mode privileges
  – saves two mode switches (user-to-kernel and kernel-to-user)

• application specific scheduling
  – applications may prefer their own specific scheduling algorithm

• ULT can run on any OS
Disadvant. of ULT vs KLT

- Many OS system calls are blocking.
  - so if ULT executes such call all threads within its process are blocked
- In pure ULT strategy a multithreaded application cannot take advantage of multiprocessing
  - no concurrency