CS 194:
Distributed Systems
Processes, Threads, Code Migration

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(Based on textbook slides)

Problem

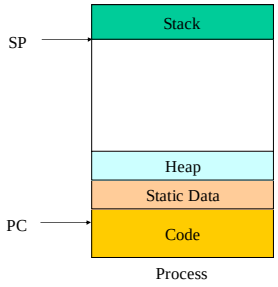
- Escape the curse of blocking!
- A spreadsheet should be able to recompute the values while waiting for user input
- A file server should be able to serve other clients while waiting a disk read to complete
- …

Solutions

- Multi-processing
- Multi-threading
- One process + event driven programming

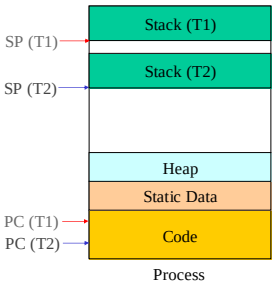
What is a Process?

- Execution context
  - Program counter (PC)
  - Stack pointer (SP)
  - Data registers
- Code
- Data
- Stack



What is a Thread?

- Execution context
  - Program counter (PC)
  - Stack pointer (SP)
  - Data registers

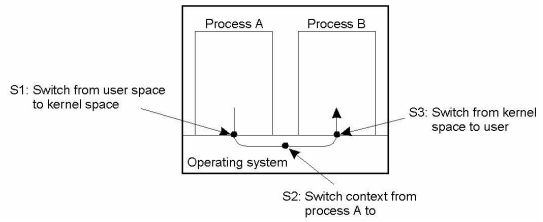


Process vs. Thread (1)

- Process: unit of allocation
  - Resources, privileges, etc
- Thread: unit of execution
  - PC, SP, registers
- Each process has one or more threads
- Each thread belong to one process

Process vs. Thread (2)

- Processes
  - Inter-process communication is expensive: need to context switch
  - Secure: one process cannot corrupt another process



Process vs. Thread (3)

- Threads
  - Inter-thread communication cheap: can use process memory and may not need to context switch
  - Not secure: a thread can write the memory used by another thread

User Level vs. Kernel Level Threads

- User level: use user-level thread package; totally transparent to OS
  - Light-weight
  - If a thread blocks, all threads in the process block
- Kernel level: threads are scheduled by OS
  - A thread blocking won't affect other threads in the same process
  - Can take advantage of multi-processors
  - Still requires context switch, but cheaper than process context switching

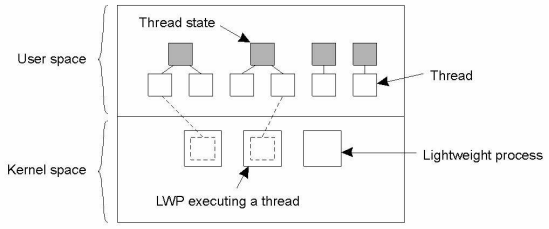
Thread Creation Example (Java)

```
final List list;                        // some sort unsorted list of objects
// A Thread class for sorting a List in the background
class Sorter extends Thread {
   List l;
   public Sorter(List l) { this.l = l; }          // constructor
   public void run() { Collections.sort(l); }     // Thread body
}

// Create a Sorter Thread
Thread sorter new Sorter(list);
// Start running the thread; the new thread starts running the run method above
// while the original thread continues with the next instructions
sorter.start();

System.out.println("I'm the original thread");
```

(Java in a Nutshell, Flanagan)

Thread Implementation

- Combining kernel-level lightweight processes and user-level threads
  - LWPs are transparent to applications
  - A thread package can be shared by multiple LWPs
  - A LWP looks constantly after runnable threads



User-level, Kernel-level and Combined

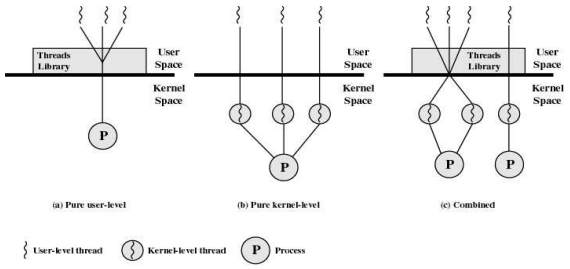
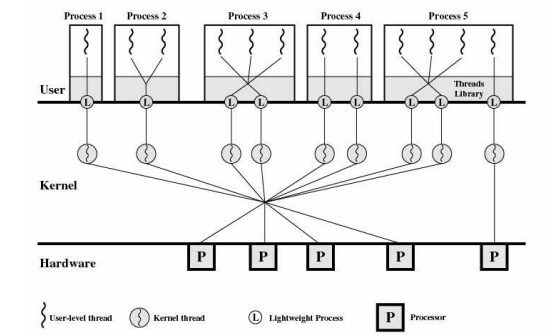


Figure 4.6 User-Level and Kernel-Level Threads

(Operating Systems, Stallings)

Example of Combined Threads

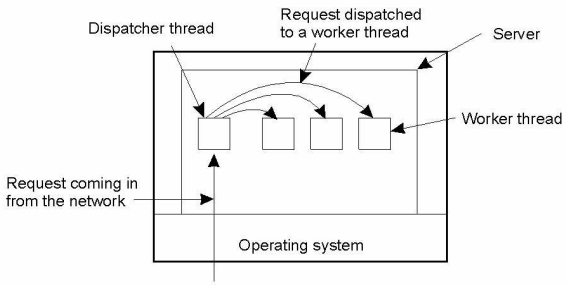


(Operating Systems, Stallings)

Figure 4.15 Solaris Multithreaded Architecture Example

Multithreaded Servers

- A multithreaded server organized in a dispatcher/worker model



Event Driven Programming

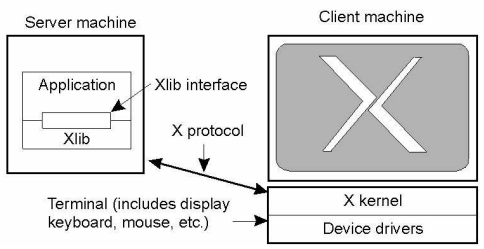
- Organize program as a finite state automaton
- Never call blocking functions
- When a function returns
  - Need a callback mechanism to invoke process, or
  - Process can periodically pool for return values
- Very efficient; zero context switching!
- Hard to program

Trade-offs

Model	Characteristics
Threads	Parallelism, blocking system calls
Single-threaded process	No parallelism, blocking system calls
Event driven (Finite state machine)	Parallelism, nonblocking system calls

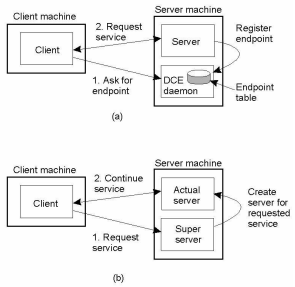
The X-Window System

- The basic organization of the X Window System



Servers: General Design Issues

a) Client-to-server binding using a daemon as in DCE
b) Client-to-server binding using a superserver as in UNIX

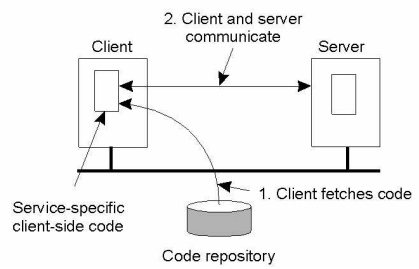


Code Migration: Motivation

- Performance
  - Move code on a faster machine
  - Move code closer to data
- Flexibility
  - Allow to dynamically configure a distributed system

Dynamically Configuring a Client

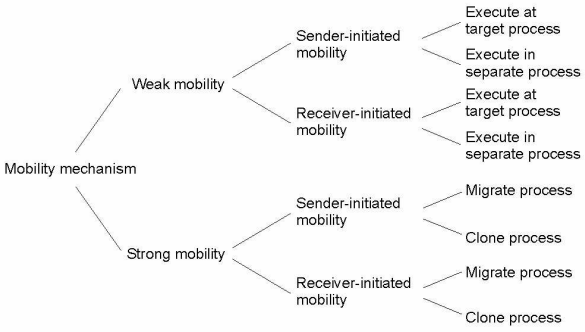
- The client first fetches the necessary software, and then invokes the server



Code Migration Model

- Process model for code migration (Fugetta et al., 98)
  - Code segment: set of instructions that make up the program
  - Resource segment: references to external resources
  - Execution segment: store current execution state
- Type of mobility
  - Weak mobility: migrate only code segment
  - Strong mobility: migrate execution segment and resource segment

Models for Code Migration



Migration and Local Resources

- Types of process-to-resource binding
  - Binding by identifier (e.g., URL, (IPaddr:Port))
  - Binding by value (e.g., standard libraries)
  - Binding by type (e.g., monitor, printer)
- Type of resources
  - Unattached resources: can be easily moved (e.g., data files)
  - Fastened resources: can be used but at a high cost (e.g., local databases, web sites)
  - Fixed resources: cannot be moved (e.g., local devices)

Migration and Local Resources

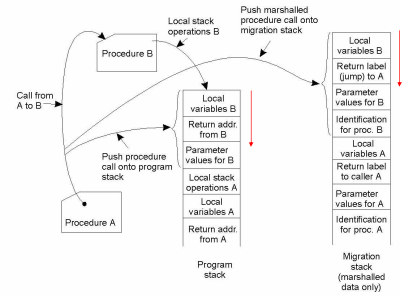
Resource-to machine binding

Process-to-resource binding	Unattached	Fastened	Fixed
By identifier	MV (or GR)	GR (or MV)	GR
By value	CP (or MV, GR)	GR (or CP)	GR
By type	RB (or GR, CP)	RB (or GR, CP)	RB (or GR)

- Actions to be taken with respect to the references to local resources when migrating code
  - GR: establish a global system wide reference
  - MV: move the resource
  - CP: copy the value of resource
  - RB: rebind the process to locally available resource

Migration in Heterogeneous Systems

- Maintain a migration stack in an independent format
- Migrate only at certain points in the program (e.g., before/after calling a procedure)



Weak Mobility in D'Agents (1)

- A Tel agent in D'Agents submitting a script to a remote machine (adapted from [Gray '95])

```
proc factorial n {
   if ($n ≤ 1) { return 1; }                  # fac(1) = 1
   expr $n * [ factorial [expr $n – 1] ]      # fac(n) = n * fac(n – 1)
}
set number …        # tells which factorial to compute
set machine …       # identify the target machine

agent_submit $machine –procs factorial –vars number –script {factorial $number }

agent_receive …     # receive the results (left unspecified for simplicity)
```

Strong Mobility in D'Agents (2)

- A Tel agent in D'Agents migrating to different machines where it executes the UNIX *who* command (adapted from [Gray 95])

```
all_users $machines

proc all_users machines {
   set list ""                    # Create an initially empty list
   foreach m $machines {          # Consider all hosts in the set of given machines
      agent_jump $m               # Jump to each host
      set users [exec who]        # Execute the who command
      append list $users          # Append the results to the list
   }
   return $list                   # Return the complete list when done
}
set machines …                    # Initialize the set of machines to jump to
set this_machine                  # Set to the host that starts the agent

# Create a migrating agent by submitting the script to this machine, from where
# it will jump to all the others in  $machines.
agent_submit  $this_machine –procs all_users
                                  -vars  machines
                                  -script { all_users $machines }
agent_receive …                   #receive the results  (left unspecified for simplicity)
```