Process Management

COMP 229 (Section PP) Week 8

Prof. Richard Zanibbi
Concordia University
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Last Week...

Basic OS Functions (pp. 89-94)

1. Device Management
2. Process and Resource Management
3. Memory Management
4. File Management

Note: different definitions exist for "OS functions"

Implementation Issues (pp. 94-103)

Processor Modes

Supervisor vs. User: controls available instructions, memory ("user space" vs. "system space")

Kernels

Only Kernel Code Executed in Supervisor Mode

Requesting OS Services

system call vs. message passing

Software Modularization

...or not.

Contemporary OS Kernels (pp. 104-110)

UNIX Kernels

A *Monolithic* Kernel

Windows NT Executive Kernel

Based on *Microkernel* approach

Process, Thread, and Resource Management

Implements Abstract Machines

...including scheduling processes/threads and managing their associated resources

- usually implemented as a single module, defining the abstract machine environment as a whole
- If OS allows threaded processes, then processes and threads must be managed separately

Resource Manager

- Allocates and book-keeps available and utilized resources
- Change in resource often related to change in a process: so resource management often discussed as part of process management

Process, Thread, and Resource Management, Cont'd

Process Manager

- Provides multiple abstract machines (execution contexts)
- Allows multiple users, processes and/or threads to share the processor

Key issue: how will processor time be allocated between processes?

This Week...Process Management

Managing Classic and Modern Processes (pp. 199-206)

- Resources
- Process Address Space
- OS Families

The Hardware Process (pp. 206-208)

Abstract Machine Interface & Implementation (pp. 208-225)

- Process and Thread Abstractions
- Execution States
- Resource Management

Generalizing Process Management Policies (pp. 226-228)

Managing Classic and Modern Processes

(pp. 199-206)

The Process Manager

External View: See Figure 6.2

The (Classic) Process Abstraction

See Figure 6.1

- Note that the register connected to all the processes in memory is the **Program Counter**
- Each process represented in memory
- Abstract machines represent the CPU and executable memory used by the process ("Abstract CPU," "Abstract Memory")
- Machine represented by "Classic Process" is a *von Neumann* architecture machine

The Modern Process Abstraction (Fig 6.3)

Modern Process Abstraction

- Abstract machines now simulate multiprogramming machines on which threads run
- Abstract machines simulate multiprogramming for threads

User Space Threads vs. Kernel Threads

User Space Threads

Classic processes are time-multiplexed

Thread library simulates multiprogramming within the abstract machine (in user space)

e.g. Mach C, POSIX thread libraries

Kernel Threads

Thread execution is time-multiplexed (*not processes*)

- when one thread blocks, other threads in process can execute

OS manages processes and threads separately (process becomes a *passive* context)

e.g. Windows, (Modern) Linux

Process Address Space

Definition

Collection of addresses (bytes) a thread can reference

Modern OS: fixed size (2^{32} for 32-bit machines, 4 GB)

Represented in Address Space:

Executable Memory Locations

- as **bound** (assigned) by the memory resource manager

e.g. containing program, data, thread states, thread stacks

Memory-mapped resources

- as bound by resource managers (if resource policy permits)
- **some resources cannot be mapped** (e.g. processor)

e.g. in some OS's files may be represented in the address space

Address Space, Cont'd

Suggestion

Compare this new view of the address space to the one presented in Week 6, where only the thread states, stacks, program, and data are represented in the address space

Visualizing the Process Address Space

See Figure 6.4

Note: new processes and threads data (state, stack) also mapped into the address space

OS Families

OS Family

A group of OS's that share a common system call interface (i.e. abstract machine model)

UNIX Family

Implement POSIX.1

e.g. Linux, OpenBSD, FreeBSD, MacOS X

Windows Family

Implement subsets of the Win32 API

e.g. Windows 95/98/ME, NT/2000/XP, CE ("Pocket PC")

The Hardware Process

(pp. 206-208)

The Hardware Process and Scheduling

Definition

The sequence of instructions physically executed by the computer's CPU

Process Scheduler (part of Process Manager)

- Allocates processes (abstract machines) for simulation within the hardware process
- Switches between threads/processes made by altering the Program Counter register, set by:
  - scheduler actions, traps (system calls), interrupts

The Initial Process and the Idle Thread/Process

OS Initialization

- Process, thread, resource descriptors initialized
- Initial process with single thread created
  - process and thread descriptors are initialized

Initial Process

- The first process created; root of process hierarchy
- Spawns another thread or process, which does nothing (executes an empty loop); if executed, soon interrupted. This is the idle thread or idle process
- Idle thread chosen by Process Scheduler only when there is no ready thread in the system

Tracing the Hardware Process

Figure 6.5

Note that execution keeps returning to the process manager: this is necessary for keeping processes properly synchronized

Abstract Machine Interface

Processor Modes, Revisited

User: instructions that do not affect resource sharing models

Supervisor: instructions that are used to implement robust resource sharing models

Abstract Machine Instruction Set

User mode instructions + System Calls (Kernel Fns)

See Fig 6.6, Tables 6.1 and 6.2

Traps, Also Revisited...

- OS systems calls in the Abstract Machine Interface
- When called, code in OS kernel executed in supervisor mode

Example: Compiling a C Program to Use an Abstract Machine Interface

C Program

```
...
a = b + c;
pid = fork();
...
```

Compiled machine user instructions:

```
...
// a = b + c
load            R1,b
load            R2, c
add             R1, R2
store           R1, a
// now do the system call
trap            sys_fork
...
```

User mode machine instructions

System call (OS executes privileged instructions)

Abstract Machine Interface & Implementation

(pp. 208-225)

Context Switching

Definition

Changing the process (abstract machine) to simulate in the hardware process

- Performed by the Process Scheduler (in Process Manager)

Context Switches Occur for...

– process/thread system calls
– device interrupts

***Process states are recorded in the Process Descriptor for each process**

***See Figure 6.7:* try tracing the arrows in order**

Process Creation

Process Descriptor Initialization by the Process Manager:

- process descriptor is initialized
- address space is created
  - program addresses bound into address space
  - memory-mapped resources bound into address space
- additional resources represented in process descriptor, fields set to reflect allocated resources
- base thread created
  - classic process: represented in process descriptor
  - modern process: threads have separate descriptors

Process Descriptor Fields Used to:

Manage address space

Coordinate thread execution, record execution state (e.g. registers)

Book-keep allocated and requested resources

Support protection/isolation and sharing of resources

Process Descriptors, Cont'd

See Table 6.3

- Note that in Table 6.3, this is a partial list of process descriptor fields
- Example process descriptors in Linux, Windows outlined in pp. 214-216

See Figure 6.8

- Note: kernel implements thread scheduling, interrupt handling; NT Executive implemented on top of the NT kernel

Thread Management

As Part of Process Management

- Specifically, the *thread management algorithm*
- Tasks: create, destroy, manage thread resources, scheduling and switching threads
- Thread resources (e.g. stack, state) are bound into the associated process' address space

Thread Descriptor (See Table 6.4)

Another "book-keeping" data structure for the Process Manager

Manages thread-specific resources and state information (e.g. process resources not represented)

Linux: threads implemented via alteration of "forking" method; thread descriptor is a modification of process descriptor type

Windows: thread descriptors combine Kernel and Executive components, as for processes

Process and Thread States (as seen in the Process/Thread Descriptors)

Purpose

Indicate execution and resource request status for thread/process

1. "Running" State

Process/thread is allocated to the processor (running in hardware process)

2. "Blocked" State

Process/thread is waiting for a resource

3. "Ready" State

Process is ready to run; **on entry to this state, requests scheduling by the Process Manager**

e.g. after initialization, or after a resource has been allocated

Example State Diagrams

Simple State Diagram (Fig. 6.10)

- Requesting unavailable resource blocks process
- Resource becoming available sets process state to “Ready”
- Requests for available resources don’t block process

UNIX Process State Transition Diagram (Fig. 6.11)

Note: “blocked” state now has three different types:

- uninterruptible sleep: blocked for I/O
- sleep: blocked for some other resource
- traced/stopped: parent process has sent a signal to stop the process (e.g. in debuggers)

“Zombie:” process has finished, but has not returned to the parent process (prevents data loss!)

- In Zombie state, resources are still held for the process
- On exiting Zombie state, resources released, process descriptor erased

Resource Managers (See Fig. 6.12)

Mechanism Component

"Generic", components present in all resource managers

Policy Component

Resource-specific behaviour

Resource Descriptors (See Table 6.5)

Records state of the resource, including available units, and total number of units in the system *(for reusable resources)*

...and Process State

Resource managers alter process as well as resource descriptors when resources are allocated to a process

- e.g. changes state of "blocked" process to "ready"

Reusable and Consumable Resources

Resource

Anything a process may request and be blocked because it is unavailable

Reusable Resources

All resources with a fixed, reusable quantity (e.g. memory)

Processes must request and release (give back) "units" of the resource from/to the system

Cannot resource more units than exist in the system

Requests/release occur when the process is running (i.e. in the running state)

Consumable Resources

Resources produced by processes ("unbounded" quantity), and are not released back to the system

No restriction on the quantity of resource requested

– e.g. messages, no bound on number of messages requested

Resource Model

$R = \{Rj \mid 0 \leq j < m\}$ = resource types

$C = \{cj \geq 0 \mid \forall\ Rj \in R\ (0 \leq j < m)\}$ = units of each resource (Rj) available

Resources and Process Termination

Reusable Resources

Released from the terminating process, made available for allocation to other processes

Consumable Resources

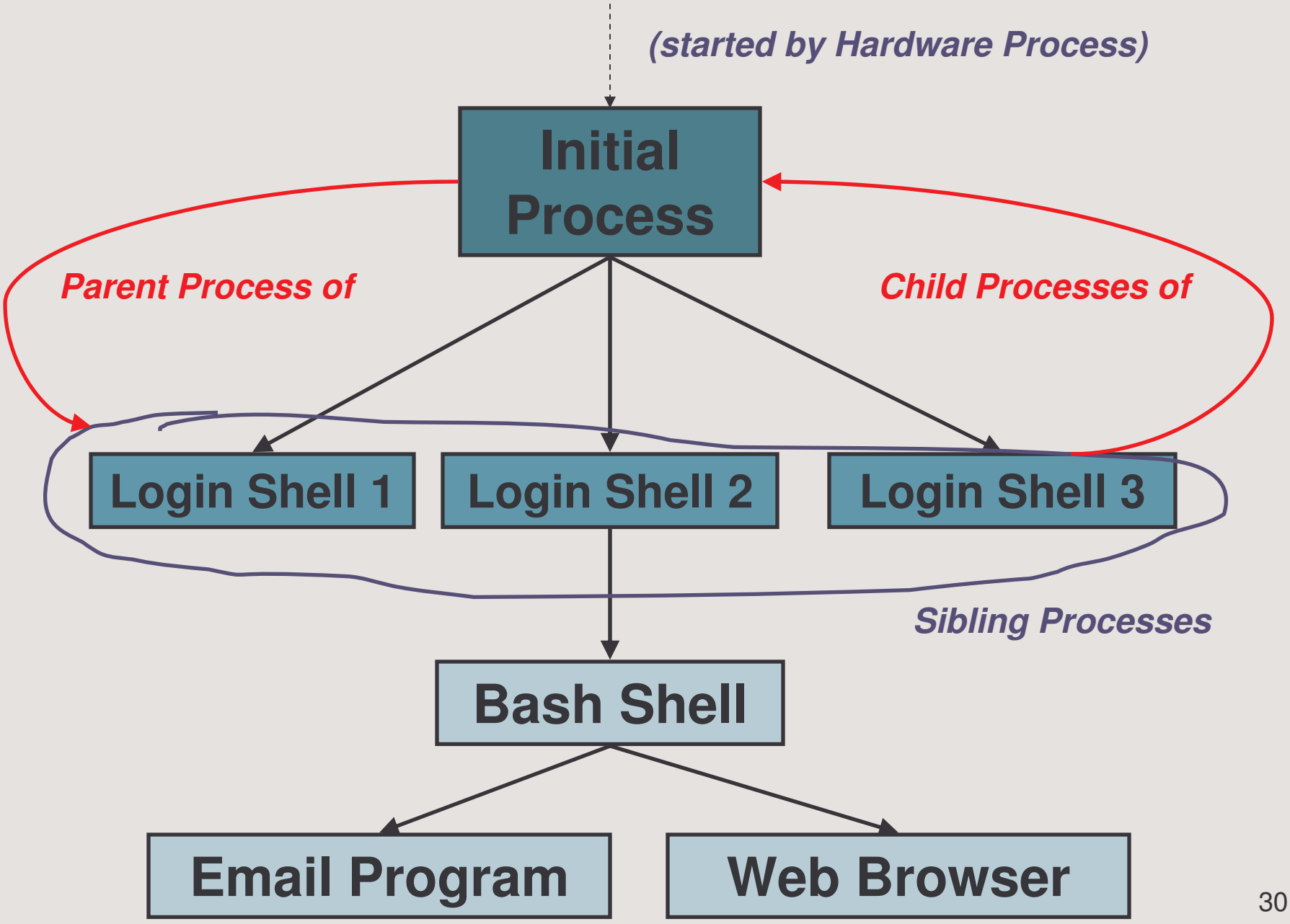
Assumed to be “consumed” by associated process

Lost on process termination

Generalizing Process Management Policies

(pp. 226-228)

Process Hierarchy



State Diagram Generalization

See Fig. 6.14 (Compare with Fig. 6.10)

- Blocked, Ready states have been split to allow parent processes to place children in a “suspended” state
  - (similar to “trace” state in Unix state diagram)
- Also added: a “Yield” edge, where a process voluntarily allows another process to run
- We looked briefly at the Windows NT Thread State Diagram: blocked and ready states also split in that diagram.

Further Generalizations of the Process Hierarchy

RC 4000

- An early instigator for microkernel-based systems
- Nucleus: implements fundamental resource management mechanisms ("microkernel")
- Resource policies implemented by processes
- Children created from nucleus process
  - each was a special-purpose OS implementing a resource policy
  - allowed simultaneous real-time, batch, and timesharing-based scheduling
  - Resources allocated by parent process: not the OS
- Allows very flexible process hierarchies (more than Unix, for example)

Next Week...

File Management

Part II, Chapter 13, pp. 514-544