Basic Operating System Concepts

A Review

Main Goals of OS

1. Resource Management: Disk, CPU cycles, etc. must be managed efficiently to maximize overall system performance
2. Resource Abstraction: Software interface to simplify use of hardware resources
3. Virtualization: Supports resource sharing – gives each process the appearance of an unshared resource

System Call

- An entry point to OS code
- Allows users to request OS services
- API's/library functions usually provide an interface to system calls
  - *e.g*, language-level I/O functions map user parameters into system-call format
- Thus, the run-time support system of a prog. language acts as an interface between programmer and OS interface

Some UNIX System Calls

- System calls for low level file I/O
  - creat(name, permissions)
  - open(name, mode)
  - close(fd)
  - unlink(fd)
  - read(fd, buffer, n_to_read)
  - write(fd, buffer, n_to_write)
  - lseek(fd, offest, whence)

- System Calls for process control
  - fork()
  - wait()
  - execl(), execlp(), execv(), execvp()
  - exit()
  - signal(sig, handler)
  - kill(sig, pid)
- System Calls for IPC
  - pipe(fildes)
  - dup(fd)

Execution Modes (Dual Mode Execution)

- User mode vs. kernel (or supervisor) mode
- Protection mechanism: critical operations (e.g. direct device access, disabling interrupts) can only be performed by the OS while executing in kernel mode
- Mode bit
- Privileged instructions

Mode Switching

- System calls allow boundary to be crossed
  - System call initiates **mode switch** from user to kernel mode
  - Special instruction – “software interrupt” – calls the kernel function
    - transfers control to a location in the interrupt vector
  - OS executes kernel code, mode switch occurs again when control returns to user process

Processing a System Call*

- Switching between kernel and user mode is time consuming
- Kernel must
  - Save registers so process can resume execution
    - Other overhead is involved; e.g. cache misses, & prefetch
  - Verify system call name and parameters
  - Call the kernel function to perform the service
  - On completion, restore registers and return to caller

Review Topics

- Processes &Threads
- Scheduling
- Synchronization
- Memory Management
- File and I/O Management

Review of Processes

- Processes
  - process image
  - states and state transitions
  - process switch (context switch)
- Threads
- Concurrency

Process Definition

- A process is an instance of a program in execution.
- It encompasses the static concept of program and the dynamic aspect of execution.
- As the process runs, its context (state) changes – register contents, memory contents, etc., are modified by execution

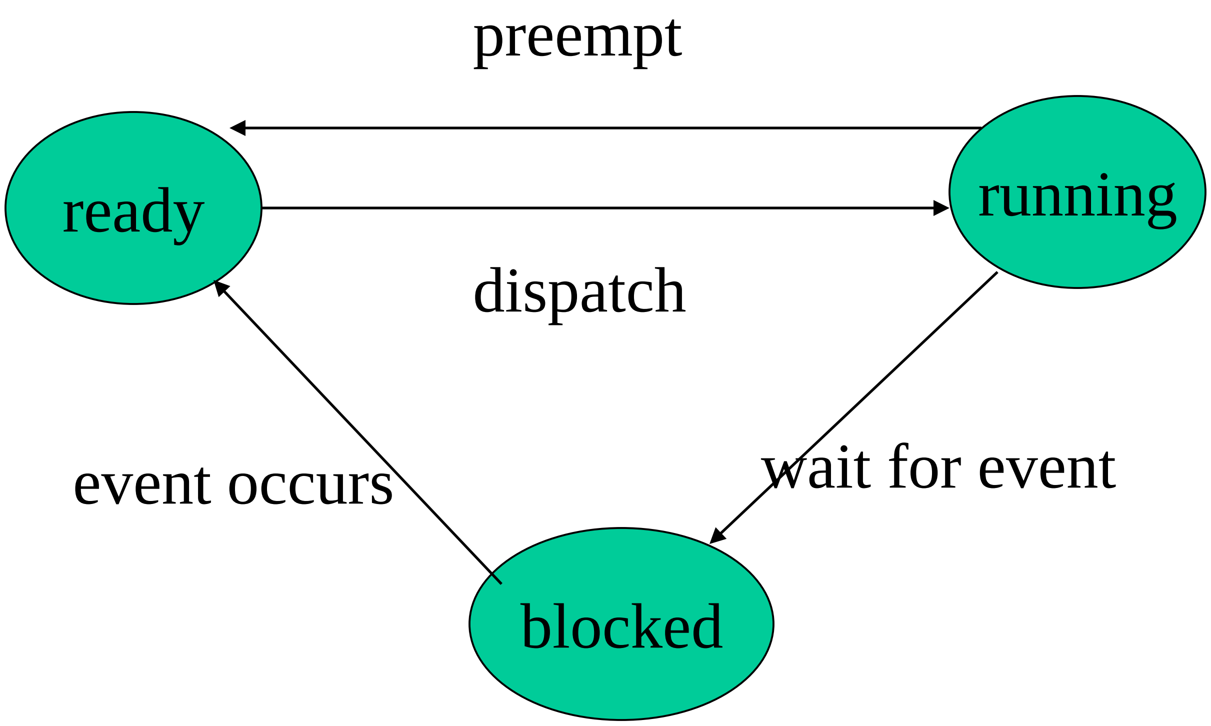
Processes: Process Image

- The process image represents the current status of the process
- It consists of (among other things)
  - Executable code
  - Static data area
  - Stack & heap area
  - Process Control Block (PCB): data structure used to represent execution context, or state
  - Other information needed to manage process

Process Execution States

- For convenience, we describe a process as being in one of several basic states.
- Most basic:
  - Running
  - Ready
  - Blocked (or sleeping)

Process State Transition Diagram



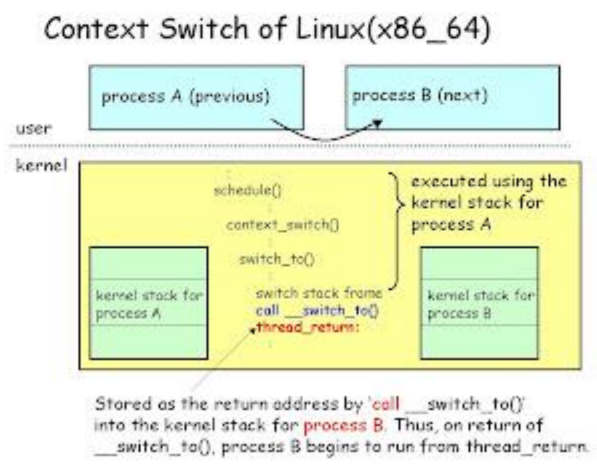
Other States

- New
- Exit
- Suspended (Swapped)
  - Suspended blocked
  - Suspended ready

Context Switch

(sometimes called process switch)

- A context switch involves two processes:
  - One leaves the Running state
  - Another enters the Running state
- The status (context) of one process is saved; the status of the second process restored.
- Don't confuse with mode switch.



Concurrent Processes

- Two processes are concurrent if their executions overlap in time.
- In a uniprocessor environment, multiprogramming provides concurrency.
- In a multiprocessor, true parallel execution can occur.

Forms of Concurrency

Multi programming: Creates logical parallelism by running several processes/threads at a time. The OS keeps several jobs in memory simultaneously. It selects a job from the ready state and starts executing it. *When that job needs to wait for some event the CPU is switched to another job*. Primary objective: eliminate CPU idle time

Time sharing: An extension of multiprogramming. *After a certain amount of time the CPU is switched to another job regardless of whether the process/thread needs to wait for some operation.* Switching between jobs occurs so frequently that the users can interact with each program while it is running.

Multiprocessing: Multiple processors on a single computer run multiple processes at the same time. Creates physical parallelism.

Protection

- When multiple processes (or threads) exist at the same time, and execute concurrently, the OS must protect them from mutual interference.
- Memory protection (memory isolation) prevents one process from accessing the physical address space of another process.
- Base/limit registers, virtual memory are techniques to achieve memory protection.

Processes and Threads

- Traditional processes could only do one thing at a time – they were single-threaded.
- Multithreaded processes can (conceptually) do several things at once – they have multiple threads.
- A thread is an "execution context" or "separately schedulable" entity.

Threads

- Several threads can share the address space of a single process, along with resources such as files.
- Each thread has its own stack, PC, and TCB (thread control block)
  - Each thread executes a separate section of the code and has private data
  - All threads can access global data of process

Threads versus Processes

- If two *processes* want to access shared data structures, the OS must be involved.
  - Overhead: system calls, mode switches, context switches, extra execution time.
- Two threads in a single process can share global data automatically – as easily as two functions in a single process.

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Process (Thread) Scheduling

- Process scheduling decides which process to dispatch (to the Run state) next.
- In a multiprogrammed system several processes compete for a single processor
- Preemptive scheduling: a process can be removed from the Run state before it completes or blocks (timer expires or higher priority process enters Ready state).

Scheduling Algorithms:

- FCFS (first-come, first-served): non-preemptive: processes run until they complete or block themselves for event wait
- RR (round robin): preemptive FCFS, based on time slice
  - Time slice = length of time a process can run before being preempted
  - Return to Ready state when preempted

Scheduling Goals

- Optimize turnaround time and/or response time
- Optimize throughput
- Avoid starvation (be “fair”)
- Respect priorities
  - Static
  - Dynamic

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Interprocess Communication (IPC)

- Processes (or threads) that cooperate to solve problems must exchange information.
- Two approaches:
  – Shared memory
  – Message passing (copying information from one process address space to another)

- Shared memory is more efficient (no copying), but isn't always possible.

Process/Thread Synchronization

- Concurrent processes are *asynchronous:* the relative order of events within the two processes cannot be predicted in advance.
- If processes are related (exchange information in some way) it may be necessary to synchronize their activity at some points.

Instruction Streams

Process A: A1, A2, A3, A4, A5, A6, A7, A8, …, Am

Process B: B1, B2, B3, B4, B5, B6, …, Bn

Sequential
I: A1, A2, A3, A4, A5, …, Am, B1, B2, B3, B4, B5, B6, …, Bn

Interleaved
II: B1, B2, B3, B4, B5, A1, A2, A3, B6, …, Bn, A4, A5, …

III: A1, A2, B1, B2, B3, A3, A4, B4, B5, …, Bn, A5, A6, …, Am

Process Synchronization – 2 Types

- Correct synchronization may mean that we want to be sure that event 2 in process A happens before event 4 in process B.
- Or, it could mean that when one process is accessing a shared resource, no other process should be allowed to access the same resource. This is the *critical section problem*, and requires *mutual exclusion.*

Mutual Exclusion

- A critical section is the code that accesses shared data or resources.
- A solution to the critical section problem must ensure that *only one process at a time can execute its critical section (CS)*.
- Two separate shared resources can be accessed concurrently.

Synchronization

- Processes and threads are responsible for their own synchronization, but programming languages and operating systems may have features to help.
- Virtually all operating systems provide some form of **semaphore**, which can be used for mutual exclusion and other forms of synchronization such as event ordering.

Semaphores

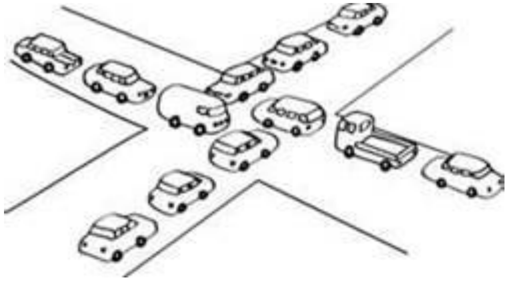
- **Definition:** A semaphore is an integer variable (S) which can only be accessed in the following ways:
  - Initialize (S)
  - P(S) // {wait(S)}
  - V(S) // {signal(S)}
- The operating system must ensure that all operations are indivisible, and that no other access to the semaphore variable is allowed

Other Mechanisms for Mutual Exclusion

- **Spinlocks**: a *busy-waiting* solution in which a process wishing to enter a critical section continuously tests some lock variable to see if the critical section is available. Implemented with various machine-language instructions
- **Disable interrupts** before entering CS, enable after leaving

Deadlock

- A set of processes is deadlocked when each is in the Blocked state because it is waiting for a resource that is allocated to one of the others.
- Deadlocks can only be resolved by agents outside of the deadlock



Deadlock versus Starvation

- Starvation occurs when a process is repeatedly denied access to a resource even though the resource becomes available.
- Deadlocked processes are permanently blocked but starving processes may eventually get the resource being requested.
- In starvation, the resource being waited for is continually in use, while in deadlock it is not being used because it is assigned to a blocked process.

Causes of Deadlock

- Mutual exclusion (exclusive access)
- Wait while hold (hold and wait)
- No preemption
- Circular wait

Deadlock Management Strategies

- **Prevention**: design a system in which at least one of the 4 causes can never happen
- **Avoidance**: allocate resources carefully, so there will always be enough to allow all processes to complete (Banker’s Algorithm)
- **Detection**: periodically, determine if a deadlock exists. If there is one, abort one or more processes, or take some other action.

Analysis of Deadlock Management

- Most systems do not use any form of deadlock management because it is not cost effective
  - Too time-consuming
  - Too restrictive
- Exceptions: some transaction systems have roll-back capability or apply ordering techniques to control acquiring of locks.

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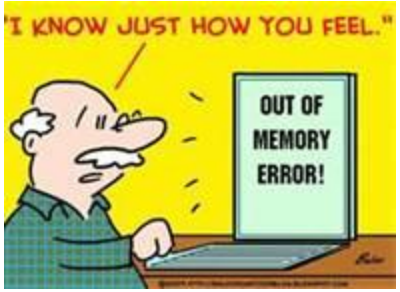


Memory Management

- Introduction
- Allocation methods
  - One process at a time
  - Multiple processes, contiguous allocation
  - Multiple processes, virtual memory

Memory Management - Intro

- Primary memory must be shared between the OS and user processes.
- OS must protect itself from users, and one user from another.
- OS must also manage the sharing of physical memory so that processes are able to execute with reasonable efficiency.

Allocation Methods: Single Process

- Earliest systems used a simple approach: OS had a protected set of memory locations, the remainder of memory belonged to one process at a time.
- Process “owned” all computer resources from the time it began until it completed

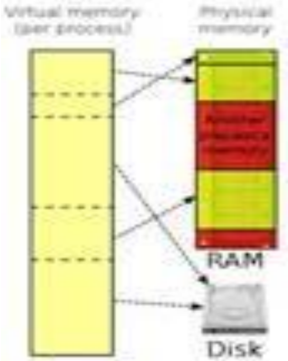
Allocation Methods:
Multiple Processes, Contiguous Allocation

- Several processes resided in memory at one time (multiprogramming).
- The entire process image for each process was stored in a contiguous set of locations.
- Drawbacks:
  - Limited number of processes at one time
  - Fragmentation of memory

Allocation Methods:

Multiple Processes, Virtual Memory

- Motivation for virtual memory:
  - to better utilize memory (reduce fragmentation)
  - to increase the number of processes that could execute concurrently
- Method:
  - allow program to be loaded non-contiguously
  - allow program to execute even if it is not entirely in memory.



Virtual Memory - Paging

- The address space of a program is divided into “pages” – a set of contiguous locations.
- Page size is a power of 2; typically at least 4K.
- Memory is divided into page frames of same size.
- Any “page” in a program can be loaded into any “frame” in memory, so no space is wasted.

Paging - continued

- General idea – save space by loading only those pages that a program needs now.
- Result – more programs can be in memory at any given time
- Problems:
  - How to tell what’s “needed”
  - How to keep track of where the pages are
  - How to translate virtual addresses to physical

Solutions to Paging Problems

- How to tell what’s “needed”
  - Demand paging
- How to keep track of where the pages are
  - The page table
- How to translate virtual addresses to physical
  - MMU (memory management unit) uses logical addresses and page table data to form actual physical addresses. All done in hardware.

OS Responsibilities in Paged Virtual Memory

- Maintain page tables
- Manage page replacement

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File Systems

- Maintaining a shared file system is a major job for the operating system.
- Single user systems require protection against loss, efficient look-up service, etc.
- Multiple user systems also need to provide access control.

File Systems – Disk Management

- The file system is also responsible for allocating disk space and keeping track of where files are located.
- Disk storage management has many of the problems main memory management has, including fragmentation issues.

End of OS Review