

Lecture 11: Exceptions & processor management

- Exceptions
- Operating system's main task:
Processor management



Exceptions – definition

- Exceptional events that interrupt normal program flow and require attention of the CPU
- External (“interrupts”) → not caused by program execution
 - E.g. I/O interrupt
- Internal (“traps”) → caused by program execution
 - E.g. illegal instruction
arithmetic overflow



Exception mechanism

- Step 1: Save the address of current instruction
 - into a special register, the exception program counter (EPC)
- Step 2: Transfer control to the OS at a known address
- Step 3: Handle the interrupt
 - Deal with the cause of the exception
 - All registers must be preserved, similar to a procedure call
- Step 4: Return to user program execution
 - Handler restores user program's registers and jumps back using EPC: special instruction **eret**



Exception handling

- What caused the exception?
 - “Cause” register records the reason, or
 - Jump to a specific address depending on the exception (vectored interrupt)
- For a critical time while the interrupt is being handled, other interrupts should not happen
 - Otherwise the EPC, Cause will be overwritten
 - This is forced by masking interrupts, i.e. resetting an enable bit in a status register



Software Exceptions

- Use exception mechanism to request some OS functions
 - e.g., I/O, dynamic memory allocation
- User program uses **syscal I** instruction
 - Cause register is set with a special value to identify the syscall exception
 - OS exception handler is invoked as usual
- Parameters are passed to the OS through agreed upon registers



Kernel vs. User Mode Protection

- Why make system calls through the exception mechanism rather than through normal procedure calls?
 - CPU has dual mode of operation identified by a bit in status reg.
 - Exception mechanism is used to force the **protection mode** to change from **user** to **kernel** (OS) for execution of OS functions
- “Privileged” instructions only executed in kernel mode
 - E.g. accessing I/O devices, handling memory, etc
- Kernel mode can only be entered through an exception
 - User programs cannot jump to OS instruction space
- `eret` instruction sets mode back to previous mode



Security and Stability

- Requires combination of hardware and OS
- Hardware must:
 - Guarantee that control is invariably transferred to OS when user programs attempt to perform potentially dangerous tasks
 - Guarantee that user programs do not have indefinite control of the processor (e.g., Windows 3.1 and 95 versus Windows NT)
- OS must:
 - Guarantee that programs do not interfere with each other (e.g., divide memory appropriately)
 - Guarantee that programs do not have access to resources for which they do not have permission (e.g., files)



Managing the Processor

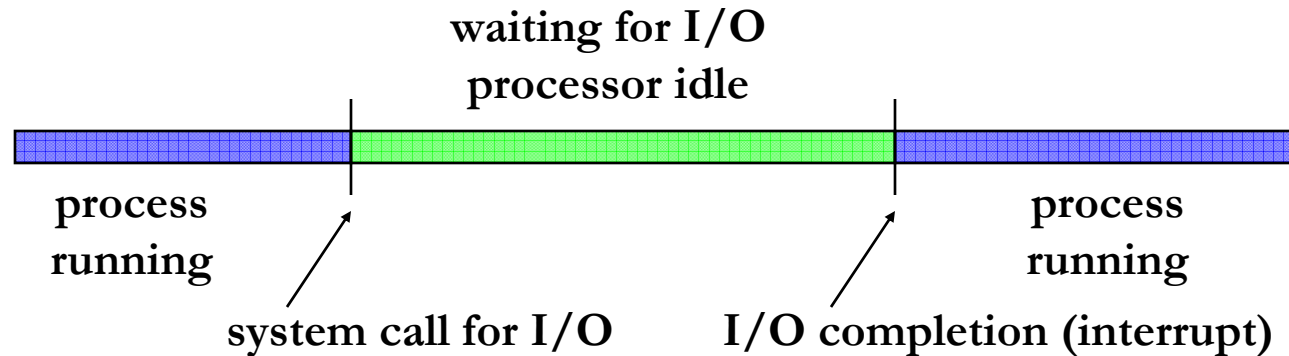
- Problem:
 - I/O takes too long → processor idle
 - User programs can crash or monopolize the CPU, unintentionally or maliciously
- Solution:
 - **Multiplex** or **time-share** the CPU and other resources among several user processes
 - Switch from one process to another when it performs I/O, or when it's time allocation (timeslice) expires

Process: “a program in execution” (Silberschatz, Galvin, Gagne)

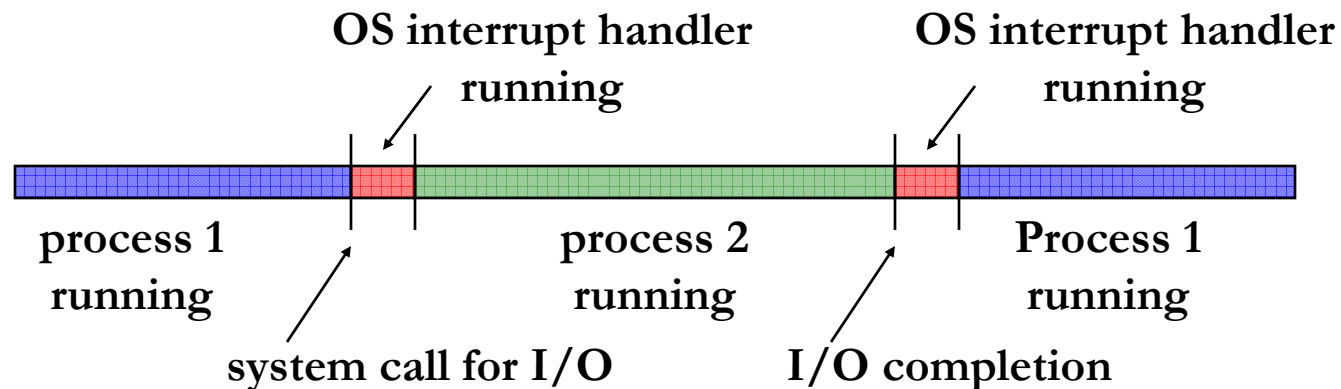


Multi-tasking

- Single-task system:



- Multi-tasking system:



Process States

States:

RUNNING: process is currently running in the CPU

READY: process is not running, but could run if brought into CPU

BLOCKED: process is not able to run because it is waiting for I/O to finish

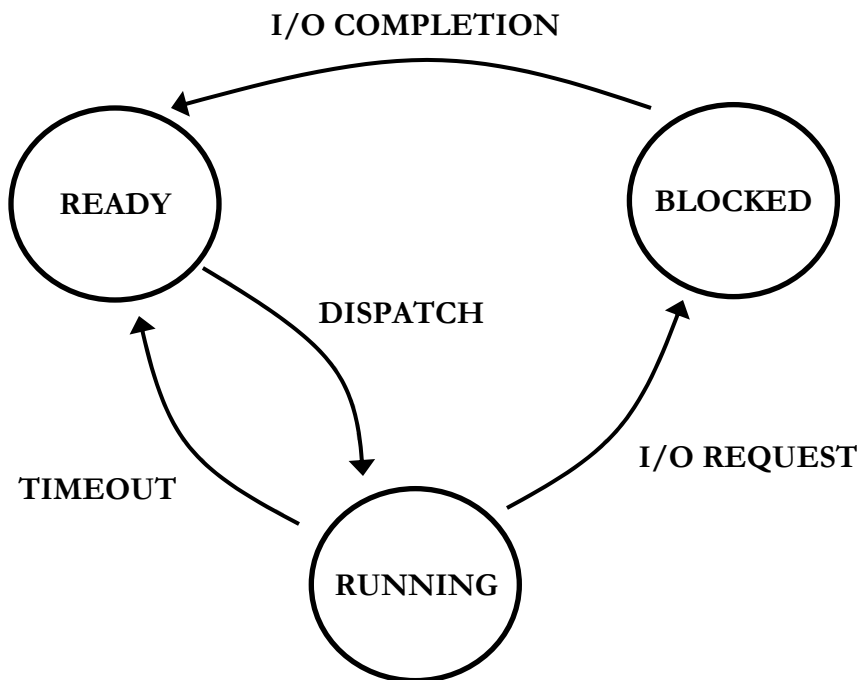
Transitions:

I/O REQUEST: process initiates I/O

I/O COMPLETION: I/O finishes

DISPATCH: OS moves process into CPU and it starts executing

TIMEOUT: process's timeslice is over (only in pre-emptive multi-tasking systems)



Process States

- Step 1: process calls the OS, interrupt is requested (e.g. timer)
- Step 2: OS's **dispatcher** performs **context-switch**:
 - Process' context is saved (registers, PC, etc) in **process control block** (PCB)
 - Dispatcher chooses new process to run
 - Processes' states are updated

PCB: OS data structure containing each process' information:

- Process id (PID)
- Process state (blocked, running, etc)
- Process priority
- Process permissions
- etc



Creating and Destroying Processes

- New processes can be explicitly created by the user, or implicitly by another process
- Original process → parent
New process → child
- Processes are managed by the OS “kernel”:
 - Process dispatcher chooses which process to run next from the pool of active processes



OS Kernel

- Kernel: (small, efficient)
 - Interrupt handling
 - Process creation and destruction
 - Process state switching
 - Memory management
 - Inter-process communication and synchronization
 - I/O support



Suspending and Resuming Processes

- Problem:
 - Memory may not be enough for all active processes (more on this in other lectures)
 - Some processes have higher priority and must run at the expense of others
- Solution:
 - Processes can be “swapped out” from memory to disk (i.e., data is moved to disk)
 - Such processes are moved into an “inactive” state (2 new process states)
 - PCB of inactive processes are still kept in OS memory
 - Inactive processes are resumed by “swapping in” the data from disk back to memory



Suspending and Resuming Processes

