Rensselaer Polytechnic Institute
CSCI-4210 – Operating Systems
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Operating Systems {week 01.a}

What is an operating system?

- What is an *Operating System*?
  - The software interface between hardware and its users
- Operating systems:
  - Execute user and system programs
  - Manage and coordinate computer hardware
  - Serve as resource allocators
  - Are typically interrupt-driven

System software

- What is system software?
  - Computer programs that directly *control* the operations of the computer and its devices
- Operating systems:
  - Coordinate and orchestrate all activities of the hardware devices in a computer
  - Provide both a *Graphical User Interface* (*GUI*) and a *Command-Line Interface* (*CLI*) for its users

Operating system design goals

- From a user's perspective:
  - easy to use
  - easy to learn
  - reliable
  - safe
  - fast
  - etc.

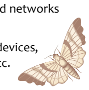
- System goals:
  - reliability
  - flexibility
  - extensibility
  - speed(y)
  - efficiency
  - maintainability
  - etc.

Operating system services (i)

- An operating system provides *services*:
  - Program execution
    - Load programs into memory, run/suspend/halt programs, handle/display errors
  - I/O operations
    - Seamlessly interact with I/O devices, including disks, networks connection, etc.
  - Filesystem manipulation
    - Read/write/traverse filesystem directories, read/write files, enforce permissions, search for files

Operating system services (ii)

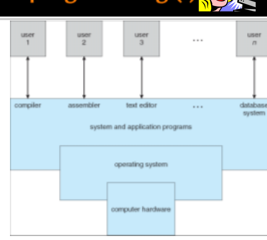
- Other operating system *services*:
  - Inter-Process Communications (IPC)
    - Processes exchange information via shared memory, message passing, sockets, pipes, files, etc.
    - Often spans multiple computers and networks
  - Error detection and recovery
    - Detect errors in CPU, memory, I/O devices, processes, network connections, etc.
    - Recover from errors gracefully, ensuring correct and consistent operations



Batch jobs

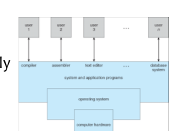
- A *job* is a unit of work submitted by a user to the operating system
- Jobs typically consist of:
  - a program either in a source language or in "executable" binary form
  - input data used by the program when it executes

Multiprogramming (i)



Multiprogramming (ii)

- In multiprogramming, several jobs reside in memory simultaneously
  - CPU use is shared and managed by the operating system

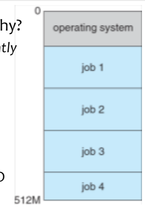


Multiprogramming (iii)

- Multiprogramming provides efficient use of the computer (CPU) and its resources (I/O)
  - One user cannot keep the CPU and I/O devices busy at all times
  - Multiprogramming organizes jobs such that the CPU always has exactly one to execute

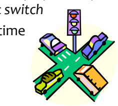
Multiprogramming (iv)

- Computer is often idle – why?
  - CPU and hardware *significantly* faster than I/O
  - When a user or process is blocked waiting for I/O, the operating system switches to another job
  - A subset of jobs is stored in memory, awaiting CPU or I/O



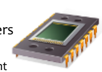
Timesharing (a.k.a. multitasking)

- To ensure fairness, use a *timesharing scheme* in which the CPU cycles through all jobs
  - Each job is given a fixed amount of CPU time
  - Switching from one running job (or process) to another is called a *context switch*
  - A process may relinquish its time if blocked on an I/O request



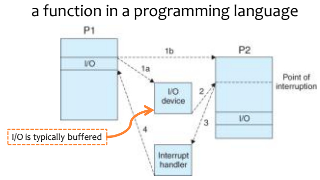
We interrupt this program...

- Software instructions are executed by a Central Processing Unit (CPU)
  - An external hardware event triggers an interrupt by signaling the CPU
    - e.g. mouse movement, keyboard event
  - Software triggers an interrupt by executing a system call
    - e.g. disk read, graphics output, printer output

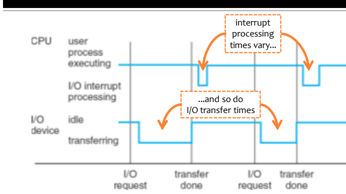


Interrupt mechanism

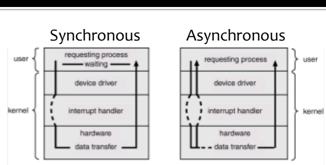
- Interrupts are handled much like calling a function in a programming language



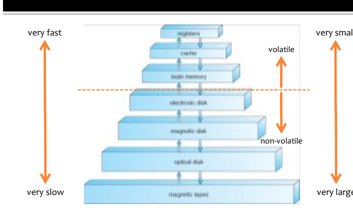
Typical interrupt timeline



Synchronous and Asynchronous I/O

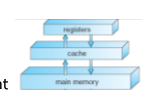


Hierarchical storage architecture



Caching (i)

- Caching is a technique in which data is temporarily stored in a smaller and faster memory component
  - Why implement caching in an operating system?



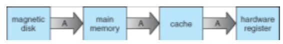
Caching (ii)

- A key goal in operating system design is achieving *fast and efficient performance*

Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	< 1 KB	> 16 MB	> 16 GB	> 100 GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	CMOS DRAM	magnetic disk
Access time (ns)	0.25 – 0.5	0.5 – 25	80 – 250	5,000.000
Bandwidth (MB/sec)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	compiler	hardware	operating system	operating system
Backed by	cache	main memory	disk	CD or tape

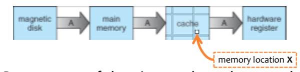
Caching (iii)

- What's the caching algorithm?
  - When the operating system attempts to read from memory, check to see if the requested data is already in the cache
  - If it is, data is read from the cache (*fast!*)
  - If not, data is copied from memory to the cache (*maybe next time...*)



Principle of locality

- When a running program reads from memory location **X**, the *principle of locality* predicts that the next memory location requested will be near **X**



- Store *pages* of data in a cache, where each page is typically the same size (e.g. 64KB)

Programming exercise

- Implement a program to simulate caching:
  - Write a function called `calculateAnswer()` that takes integer `n` as input and calculates (and returns) the sum `(1 + 2 + … + n)`
    - Pretend this method is computationally costly!
  - Initially, the cache is empty
    - Ask the user to input a number in range `1..100`
    - If the answer is not in the cache, call `calculateAnswer()` and display the resulting sum; store the result in the cache
    - If the answer is in the cache, simply display the answer