

What is an Operating System? (Review)

- An *operating system* (OS) is the interface between the user and the hardware
 - It implements a virtual machine that is easier to program than bare hardware
 - An OS provides standard **services** (functionality) which are implemented on the hardware, including:
 - Processes, CPU scheduling, memory management, file system, networking
 - The OS **coordinates** multiple applications and users (multiple processes) in a fair and efficient manner
- ↪ The goal in OS development is to make the machine both **convenient** to use (a software engineering problem) as well as **efficient** (a system and engineering problem)

History of Operating Systems

- Phase 0 — hardware is a very expensive experiment; no operating systems exist
 1. One user at console
 - One function at a time (computation, I/O, user think/response)
 - Program loaded via card deck
 - Libraries of device drivers (for I/O)
 - User debugs at console
 - Phase 1 — hardware is expensive, humans are cheap
 2. Simple batch processing: load program, run, print results, dump, repeat
 - User gives program (cards or tape) to the operator, who schedules the jobs
 - *Resident monitor* automatically loads, runs, dumps user jobs
 - Requires memory management (relocation) and protection
 - More efficient use of hardware, but debugging is more difficult (from dumps)

History of Operating Systems (cont.)

- Phase 1 — hardware is expensive, humans are cheap
 3. Overlapped CPU & I/O operations
 - First: buffer slow I/O onto fast tape drives connected to CPU, replicate I/O devices
 - Later: *spool* data to disk
 4. Multiprogrammed batch systems
 - Multiple jobs are on the disk, waiting to run
 - *Multiprogramming* — run **several** programs at the “same” time
 - Pick some jobs to run (*scheduling*), and put them in memory (*memory management*)
 - Run one job; when it waits on something (tape to be mounted, key to be pressed), switch to another job in memory
 - First big failures:
 - MULTICS announced in 1963, not released until 1969
 - IBM’s OS/360 released with 1000 known bugs
 - OS design should be a science, not an art

History of Operating Systems (cont.)

- Phase 2 — hardware is less expensive than before, humans are expensive
 5. Interactive *timesharing*
 - Lots of cheap terminals, one computer
 - All users interact with system at once
 - Debugging is much easier
 - Disks are cheap, so put programs and data online
 - 1 punch card = 100 bytes
 - 1MB = 10K cards
 - OS/360 was several feet of cards
 - New problems:
 - Need *preemptive scheduling* to maintain adequate *response time*
 - Need to avoid *thrashing* (swapping programs in and out of memory too often)
 - Need to provide adequate security measures
 - Success: UNIX developed at Bell Labs so a couple of computer nerds (Thompson, Ritchie) could play Star Trek on an unused PDP-7 minicomputer

History of Operating Systems (cont.)

- Phase 3 — hardware is cheap, humans are expensive

6. Personal computing

- CPUs are cheap enough to put one in each terminal, yet powerful enough to be useful
 - Computers for the masses!
- Return to simplicity; make OS simpler by getting rid of support for multiprogramming, concurrency, and protection

7. Parallel systems

- User multiple CPUs with a shared memory in close communication
 - Increased throughput
- Mostly MIMD hardware, some SIMD
- Symmetric multiprocessing (SMP)
 - Each processor runs an identical copy of the OS, multiple processes running at once

History of Operating Systems (cont.)

- Phase 4 — hardware is cheap, ubiquitous, and pervasive

6. Distributed systems

- Distribute the computation among several (possibly different) physical processors, each with its own memory, in loose communication
 - Resource sharing
 - Increased throughput
 - Reliability
- Client-server computing
 - Server provides specified services (e.g., file service, directory service, print service) to a set of clients

7. Embedded / handheld systems

- PDAs, cell phones, CD players, etc.
- Small OS “footprint” (limited memory)
- Slow processors
- Small displays
- Power consumption is a primary consideration

Modern OS Functionality (Review)

- Textbook talks about OS as a:
 - Control program — manages the execution of user programs, prevents errors and improper use of the computer
 - Resource allocator — CPU time, memory space, file space, I/O devices
- OS must provide:
 - Processes & CPU scheduling
 - Multiple processes active concurrently
 - Processes may need to communicate
 - Processes may require mutually-exclusive access to some resource
 - Memory management — must allocate memory to processes, move processes between disk and memory
 - File system — must allocate space for storage of programs and data on disk