# Operating Systems Design
# 1. Introduction

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In the beginning…

# There were no operating systems

"Preparing ENIAC for a series of runs was an incredibly involved process. First, detailed instructions had to be written defining the problem and a procedure for solving it. These instructions were programmed by adjusting switches manually and inserting thousands of cables into as many as forty large plug boards. A team of five operators might work several days on the external wiring and many more days searching for errors and correcting them."

— *Breakthrough to the Computer Age, Harry Wulforst, Charles Scribner's & Sons Pub., 1982*

1945

# Late 1940s – 1950s

- Stored program concept: reload a program
- Reusable code ("subroutines")
- IBM SHARE (Society to Help Alleviate Redundant Effort)
- The OS emerges
  - Batch systems
    - Branch to a location in the OS that would cause the next program to get loaded and run
  - Common I/O routines for device access
    - *Precursor to device drivers*
  - Programmatic transition to reduce overhead of starting new jobs
  - Job control languages to define resource needs

# 1960s

- Goal: improve throughput
  - Use every possible second of CPU time

- Multiprogramming
  - Keep several programs in memory at once; switch between them
  - Works because of the speed mismatch between I/O and CPU
- Conversational interaction (human I/O)
- Direct storage access (file systems)
- Transaction processing systems (SABRE)
- The System Call (Atlas Computer, Manchester)

# 1960s

- 1961: DEC PDP-1 – first minicomputer ($125,000+)
- 1964: IBM System/360
  - PCP/360: sequential jobs (batch)
  - MFT: Multiple job system, fixed number of tasks
  - MVT: Multiple jobs, variable number of tasks (direct memory)
- IBM 360 introduced:
  - Direct Address Translation
    (precursor of virtual memory & the Memory Management Unit)
  - Channels: specialized processors for transferring data between main memory and an I/O device
    (*precursor of DMA*)
- Time sharing: preemption

# Late 1960s – 1970s

- 1968-1969:
  - User-friendly interfaces: mouse, windowing
  - Data networking
- 1970s: UNIX
  - Portable operating system
  - Written in a high level language
- 1972: Virtual Machines (VM/370)
- Microprocessors emerge
  - CP/M: dominant OS for 8080 family of machines
    - CCP: command interpreter
    - BDOS: file operations, printing, and console I/O
    - BIOS: character I/O, disk sector read/write
  - 1977: Apple II

# 1980s-1990s

- 1981: IBM PC
  - Open architecture; Microsoft OS
  - Only proprietary component was the BIOS
- 1982: BIOS was reverse engineered
  - PC clones (Compaq, Columbia, Dell, HP, …)
- Client-server networking
  - Network file systems
- Open Source Operating Systems
  - Linux, FreeBSD, NetBSD, OpenBSD
- Network PC, Thin clients

# 2000s

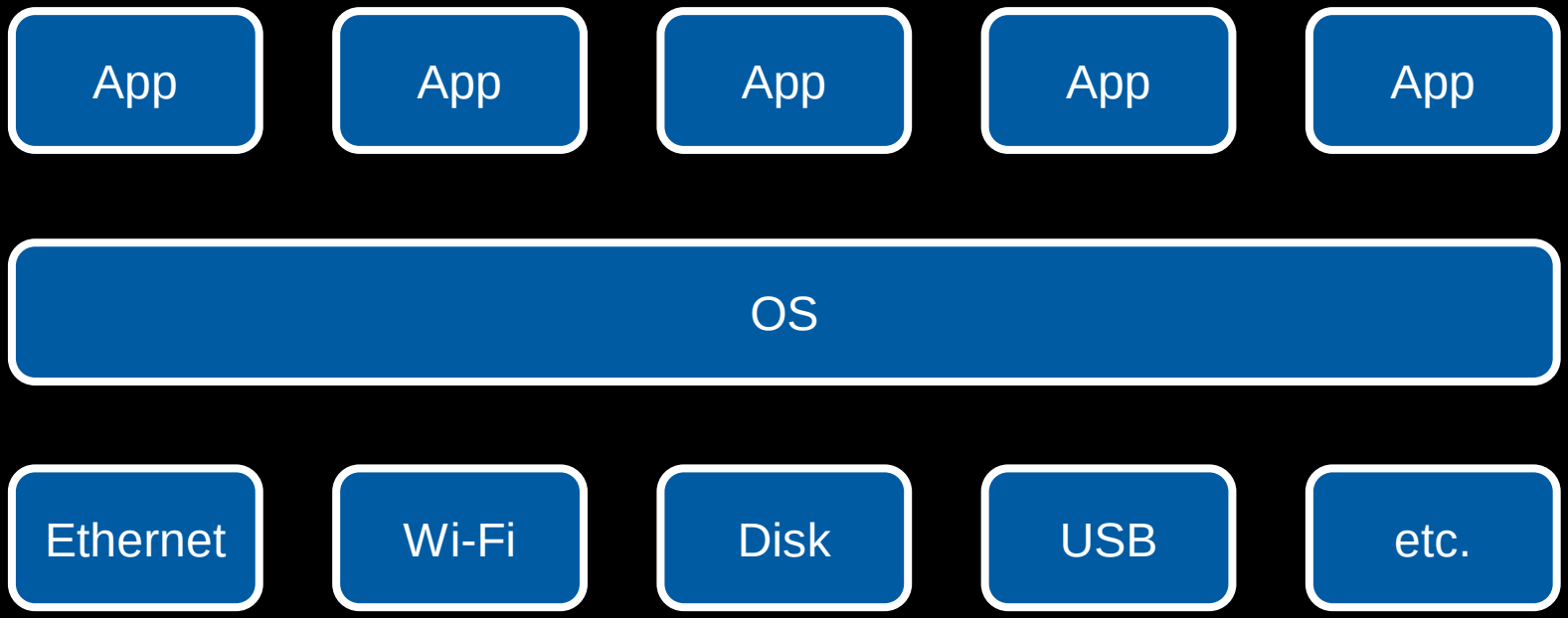
- PC-based machine virtualization
  - Virtualization support added by Intel & AMD (2006)
  - Virtual machine migration
- Cloud computing, on-demand data centers
- Focus on mobility
  - iOS, Android, BlackBerry OS, Windows Mobile
- Security
  - Hardware authentication, Storage encryption, digital rights management
    - Trusted Platform Module
  - Personal firewalls
  - Address space layout randomization

# The Operating System

# What is an operating system?

- The first program
- A program that lets you run other programs
- A program that provides controlled access to resources:
  - CPU
  - Memory
  - Display, keyboard, mouse
  - Persistent storage
  - Network

# The Operating System



# Big Ideas In Operating Systems

# The Big Ideas

- Interrupts
- Reusable code (→ I/O libraries → drivers)
- Subroutines
- Indirection
- Supervisor mode execution
- I/O processors (IBM's channels, DMA, SCSI)
- I/O redirection (abstracting I/O)
- File systems
- Cache
- Virtual memory & virtual addresses
- Time sharing & preemption
- OS portability
- Multithreading
- Intelligent and discoverable I/O (e.g., PCI bus)
- Virtual machines (hypervisors)

# Mechanisms & Policies

# OS Mechanisms & Policies

- Mechanisms:
  - Presentation of a software abstraction:
    - Memory, data blocks, network access, processes
- Policies:
  - Procedures that define the behavior of the mechanism
    - Allocation of memory regions, replacement policy of data blocks
  - Permissions
- Keep mechanisms, policies, and permissions separate

# Processes

- Mechanism:
  - Create, terminate, suspend, switch, communicate
- Policy
  - Who is allowed to create and destroy processes?
  - What is the limit?
  - What processes can communicate?
  - Who gets priority?

# Threads

- Mechanism:
  - Create, terminate, suspend, switch, synchronize
- Policy
  - Who is allowed to create and destroy threads?
  - What is the limit?
  - How do you assign threads to processors?
  - How do you schedule the CPU among threads of the same process?

# Virtual Memory

- Mechanism:
  - Logical to physical address mapping
- Policy
  - How do you allocate physical memory among processes and among users?
  - How do you share physical memory among processes?
  - Whose memory do you purge when you're running low?

# File Systems

- Mechanism:
  - Create, delete, read, write, share files
  - Manage a cache; memory map files

- Policy
  - What protection mechanisms do you enforce?
  - What disk blocks do you allocate?
  - How do you manage cached blocks of data (Per file? Per user? Per process?)

# Messages

- Mechanism:
  - Send, receive, retransmit, buffer bytes
- Policy
  - Congestion control, dropping packets, routing, prioritization, multiplexing

# Character Devices

- Mechanism:
  - Read, write, change device options
- Policy
  - Who is allowed to access the device?
  - Is sharing permitted?
  - How do you schedule device access?

# The End