Operating Systems Design
3. Definitions, Concepts, and Architecture

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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?

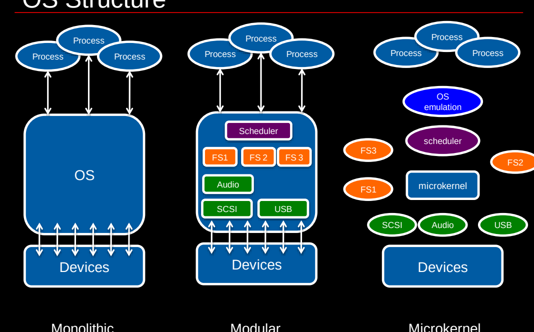
Definitions, Concepts, and Architecture

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

  This includes: naming, sharing, protection, communication

OS Structure



What's a kernel?

- Operating System
  - Often refers to the complete system, including command interpreters, utility programs, window managers, …
- Kernel
  - Core component of the system that manages resource access, memory, and process scheduling

UNIX Kernel (example)

Some of the things it does:

- Controls execution of processes
  - Creation, termination, communication
- Schedules processes for execution on the CPU(s)
- Manages memory
  - Allocates memory for an executing process
  - Sets memory protection
  - Coordinates swapping pages of memory to a disk if low on memory
- Manages a file system
  - Allocation and retrieval of disk data
  - Enforcing access permissions & mutual exclusion
- Provides access to devices
  - Disk drives, networks, keyboards, displays, printers, …
  - Enforces access permissions & mutual exclusion

User Mode vs. Kernel Mode

- Kernel mode = privileged, system, supervisor mode
  - Access restricted regions of memory
  - Modify the memory management unit
  - Set timers
  - Define interrupt vectors
  - Halt the processor
  - Etc.
- CPU knows what mode it's in via a status register
  - You can set the register in kernel mode
  - OS & boot loaders run in kernel mode
  - User programs run in user mode

Violations

- What if a CPU tries to execute something that is available only in kernel mode?
  - (a) nothing, or (more likely)
  - (b) trap (exception)
    - Memory access violation
    - Illegal instruction violation
    - Register access violation
- The OS processes the trap
  - Original program counter is saved
  - OS decides on course of action
  - If needed, restart the offending instruction
- Traps occur:
  - Via software (e.g., INT instruction)
  - Because of an access violation
  - Via a hardware interrupt (e.g., timer)

How do you switch to kernel mode?

Software interrupts (traps)

- Trap vectors are set up in kernel mode (at boot time)
  - Trap pushes the return address on the stack and jumps to a well-known address
  - That address usually contains a *jump* instruction (vector) to the code that will handle that trap
- Returning back to user mode: *return from exception*

Mode Switch: switching between user & kernel mode

System Calls: Interacting with the OS

- Use *trap* mechanism to switch to the kernel
  - Mode switch
- Pass a number that represents the OS service
  - System call number; usually set in a register
- A system call involves:
  - Set system call number
  - Save parameters
  - Issue the trap (jump to kernel mode)
    - OS gets control
    - Return from exception (back to user mode)
  - Retrieve results and return them to the calling function
- System call interfaces are encapsulated as library functions

Interrupts & Preemption

- How do we ensure that the OS gets control?
- Program a timer interrupt
  - On Linux/Intel systems,
    Set the 8254 Programmable Interval Timer to generate an interrupt (IRQ 0) approximately every 10 ms.
  - Since 2005: High Precision Event Timer (HPET) replaces 8254

Context switch & Mode switch

- An interrupt or trap results in a *mode switch*
  - CPU switches execution from user mode to kernel mode
- An operating system may save a process' state and restore another process' state.
  - Context switch
  - Save all registers
    (including stack pointers, PC, and flags)
  - Load saved registers (including SP, PC, flags)
  - To return to original context: restore registers and return from exception
- Context switch: switch to kernel mode, save state so that it can be restored later and reload another process' saved state

Devices

- Character: mice, keyboard, audio, scanner
  - *Byte streams*
- Block: disk drives, flash memory
  - *Addressable blocks (suitable for caching)*
- Network: ethernet & wireless networks
  - *Packet based I/O*
- Bus controllers
  - *Interface with communication busses*

Interacting with devices

- Devices have command registers
  - *Transmit, receive, data ready, read, write, seek, status*
- Memory mapped I/O
  - Map device registers into memory
  - Memory protection now protects device access
  - Standard memory load/store instructions can be used to interact with the device

Getting data to/from devices

- When is the device ready?
  - Polling
    - Wait for device to be ready
    - To avoid busy loop, check each clock interrupt
  - Interrupts from the device
    - Interrupt when device has data or when the device is done transmitting
    - No checking needed – but context switch may be costly

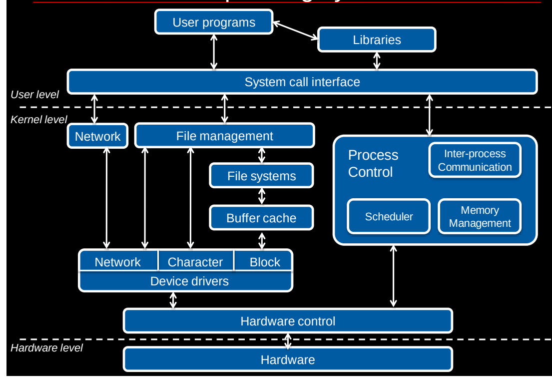
Getting data to/from devices

- How do you move data?
  - Programmed I/O (PIO)
    - Use memory-mapped device registers
    - The processor is responsible for transferring data to/from the device by writing/reading these registers
  - DMA
    - Allow the device to access system memory directly

Files and file systems

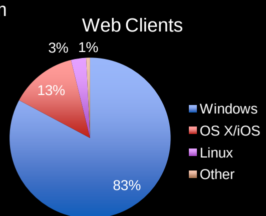
- Persistent storage of data
  - Handle allocation of disk space
- Provide user-friendly names to identify the data
- Associate attributes with the data
  - Create time, access time, owner, permissions, …
  - Device or data file?

Structure of an operating system



Which OS?

- Hundreds to choose from
- Dominant ones:
  - Windows NT family
    - Windows 7
    - Vista, XP
    - Windows Server 20xx
  - Mac OS X
    - Includes iOS
  - Linux
    - Includes Android
  - Symbian



Source: W3Counter data from http://en.wikipedia.org/wiki/Usage_share_of_operating_systems

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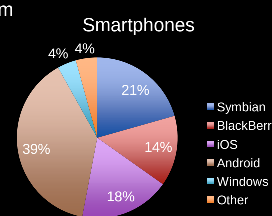

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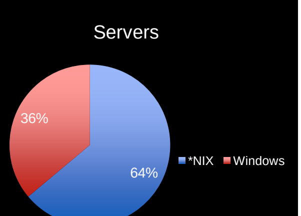

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POSIX

- UNIX → POSIX
- IEEE (ISO/IEC 9945): defines POSIX environment
  - System interfaces
  - Shell & scripting interface
  - Common utilities
  - Networking interfaces
  - Security interfaces
- POSIX (or close to) systems include
  - Solaris, BSD, Mac OS X, VxWorks, Microsoft Windows Services for UNIX
  - Linux, FreeBSD, NetBSD, OpenBSD, BeOS

The End.