

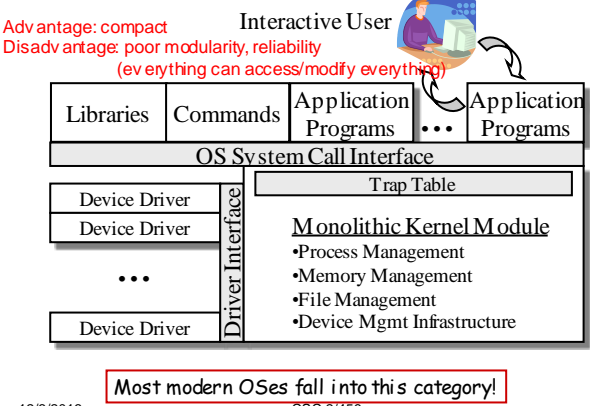
# Operating System Structure

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# Operation System Architectures

- Monolithic architecture
- Microkernel architecture
- Layered architecture
- Virtual machines

# OS Architecture: Monolithic Structure



# Microkernel System Architecture

- Microkernel architecture:
  - Moves as much from the kernel into "user" space (still protected from normal users).
  - Communication takes place between user modules using message passing.
- What must be in the kernel and what can be in user space?
  - Mechanisms determine how to do something.
  - Policies decide what will be done.
- Benefits:
  - More reliable (less code is running in kernel mode)
  - More secure (less code is running in kernel mode)
- Disadvantage?

### Layered Structure

- Layered structure
  - The operating system is divided into a number of layers (levels), each built on top of lower layers.
  - The bottom layer (layer 0), is the hardware.
  - The highest (layer N) is the user interface.
  - Decreased privileges for higher layers.
- Benefits:
  - more reliable
  - more secure
  - more flexibility, easier to extend
- Disadvantage?
  - Weak integration results in performance penalty (similar to the microkernel structure).

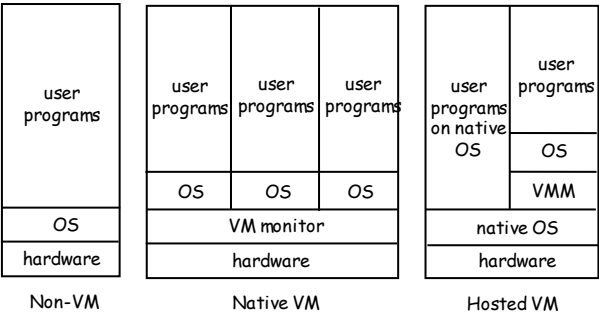
### Modern UNIX/Linux: Modules

- Object-oriented programming techniques
  - Kernel has a set of core components
  - Links in additional services during boot time or during run time
    - Dynamically loadable modules
      - E.g., scheduling classes, file systems, executable formats, device and bus drivers
    - Each module has defined, protected interfaces
    - Any module can still call any other module (no need for message passing) – flexible, efficient

### Virtual Machines

- Virtual machine architecture
  - **Virtualization:** A piece of software that provides an interface *identical* to the underlying bare hardware.
    - the upper-layer software has the illusion of running directly on hardware
    - the virtualization software is called virtual machine monitor
  - **Multiplexing:** It may provide several virtualized machines on top of a single piece of hardware.
    - resources of physical computer are shared among the virtual machines
    - each VM has the illusion of owning a complete machine
- Trust and privilege
  - the VM monitor does not trust VMs
  - only the VM monitor runs in full privilege
- Compared to an operating system
  - VM monitor is a resource manager, but not an extended machine

### Virtual Machine Architecture



### Exokernel [Engler et al. SOSP1995]

- Give each user a clone of the actual machine, but with a subset of resources
- Each user can run its own operating system
- Exokernel running in kernel mode
  - Allocate resources
  - Enforce allocation
- Advantages –
  - separates multiprogramming from user operating system code (interface)
  - no remapping needed

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