Operating Systems

What is an Operating System

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Operating System

Program that

- Controls the execution of other programs
- Provides to the running programs an abstraction of the underlying hardware

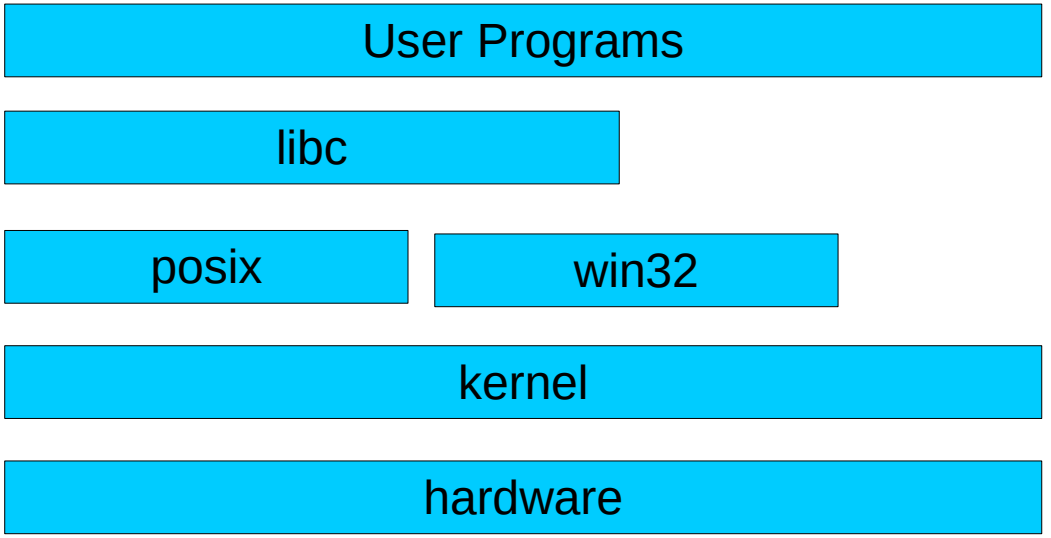
To offer these functionalities an OS

- Manages resources by preventing conflicts
- Deals with error conditions raised by programs or by hardware

From a user perspective an OS should

- Manage resources in an efficient manner
- Make it easy to access these resources
- Run the programs correctly

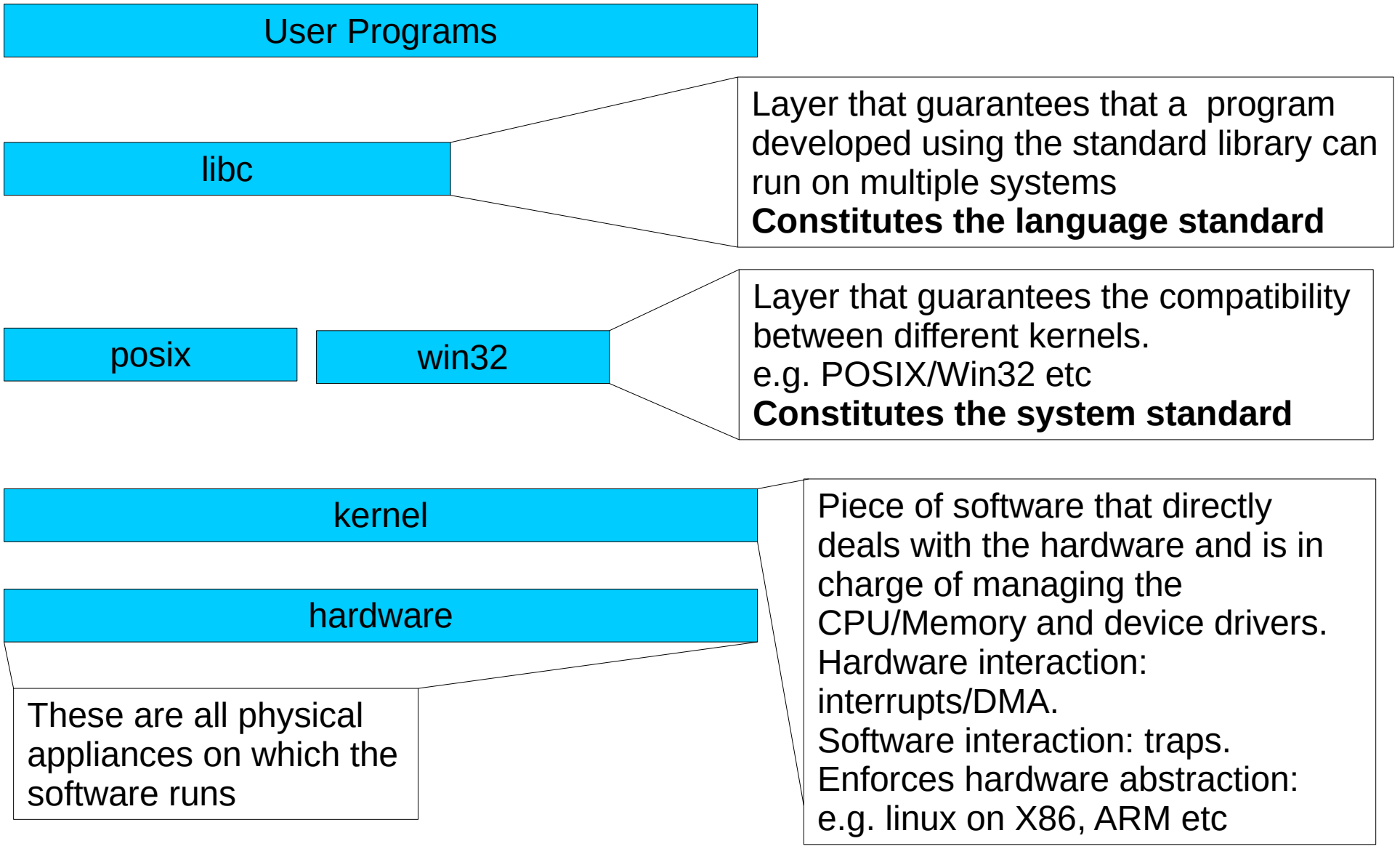
Computing System



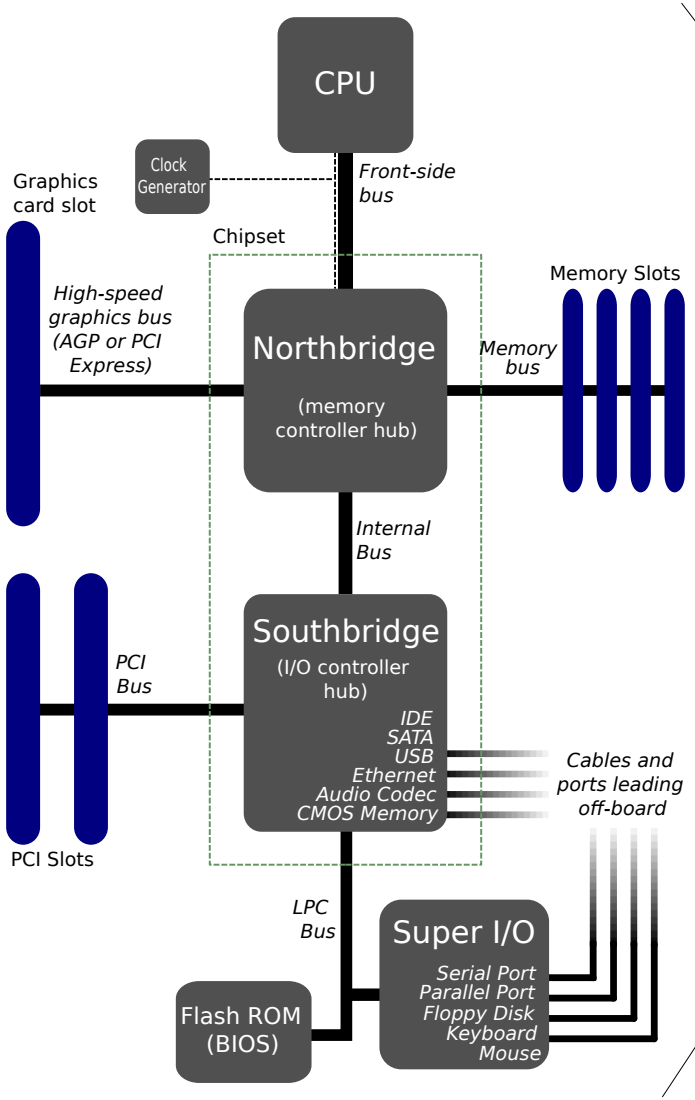
Computing systems are organized in layers

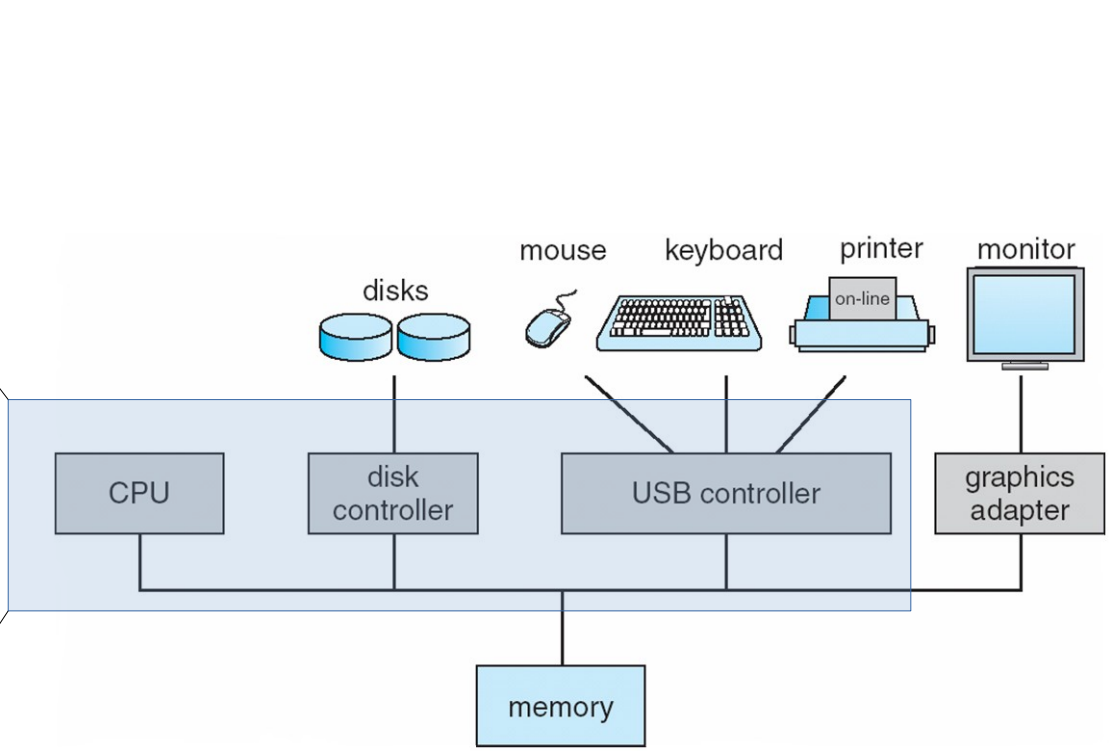
- Typically a higher layer can access to the functionalities of the lower layers only through the API of the layer immediately below
- This ensures portability

Standards


User Programs
libc
Layer that guarantees that a program developed using the standard library can run on multiple systems
Constitutes the language standard
posix
win32
Layer that guarantees the compatibility between different kernels.
e.g. POSIX/Win32 etc
Constitutes the system standard
kernel
hardware
These are all physical appliances on which the software runs
Piece of software that directly deals with the hardware and is in charge of managing the CPU/Memory and device drivers.
Hardware interaction: interrupts/DMA.
Software interaction: traps.
Enforces hardware abstraction:
e.g. linux on X86, ARM etc

Organization of a Computer





OS: Services

- Run programs
- Protected access to shared resources (I/O and memory)
- Error Handling
- Collects Statistics (e.g. CPU/Memory/Disk usage and so on)

- Typically an OS comes “packaged” with a bunch of tools: editors, compilers, debuggers, command interpreters, etc..
- These are not part of the kernel, but constitute the OS ecosystem.

OS: Resources

CPU: Maximize usage

- Multiprogramming

Memory: Implement protection, Reduce access time, Virtualization

- Paging/Segmentation
- Virtual Memory

I/O: Simplify usage Minimize access time, Maximize throughput, Implement Permissions

- Buffering
- I/O Scheduling

OS: Evolution (overview)

Sequential Computing (1945-1955)

- A program at a time, no OS, machine language

Batch Computing(1955-1965)

- A program after the other, monitor, JCL (Job Control Language), memory protection

Multiprogrammed Batch Computing (1965-1980)

- Better use of the CPU through concurrent program execution
- Fancier Hardware (interrupt, DMA, MMU)
- Process Management

- **Time-sharing**
  - Interactive jobs, CPU virtualization

OS Evolution (1945-55)

- **Serial Computation**
  - A program at a time
  - The user went on the machine to mechanically load the software
  - Data entry done through switches, punched card readers, punched tapes
  - No Operating System (bare metal)
  - Programs written in binary
  - Errors reported through light bulbs
  - When all goes well → The printer outputs the result
  - Unhandy, but it is where we come from..

OS Evolution (1955-65)

Batch Computing

- A program after the other.
- The **batch monitor** (a memory resident program) loads and executes the programs one at a time, together with their input data, from an input device (punched card or tapes), printing the results.
- The user does not see the machine but rather handles a bunch of punched cards to an employee that loads them on an input device.
- To manage the execution of programs, between jobs the operator puts instructions for the monitor. These cards contain instructions for the monitor (**JCL - Job Control Language**).

Evolution: Hardware

Facts:

- CPU were getting faster, much faster than I/O
- RAM was getting cheaper (thus computers could have larger memories)
- I/O devices were getting smarter
  - Can do the task without CPU supervision through DMA
  - When an event that requires the CPU intervention occurs, they raise an interrupt.

Issues:

- How to use the CPU while waiting for I/O?

OS Evolution (1965...)

Multiprogramming

- A pool of programs is loaded on the machine, sequentially
- When a program requests an I/O operation to the **OS**, the OS assigns the CPU to another process that is ready for execution
- Upon termination of the I/O, a peripherial notifies the **OS** that the operation finished. The OS in turn wakes up the process that requested the operation and puts it in an execution queue.

- Multiprogramming improves
  - CPU usage (cpu time/total time)
  - throughput (processes completed/time).

Evolution: Hardware

Facts:

- First interactive I/O systems allow the users to enter directly program/data in the system
- Users want to sit in front of a terminal and shorten the latency in the edit/compile/run loop
- Computers still expensive

OS Evolution (1965...)

Time Sharing

- Let multiple users run concurrently their programs on a computer in an interactive fashion
- Single CPU is shared between multiple users/processes with a round robin mechanism on top of the I/O eviction typical for batch systems
- System not controlled by JCL, but by a Terminal/Shell program

Different performance metrics:

- Response Time: time spent when the process is in the ready state and gets the CPU for the first time

Evolution: Hardware

Facts:

- First home computers become available. Multi-user capabilities not initially required
- Rather limited hardware and little RAM (~1KB)

OS Evolution (1975...)

OS for Personal computers

- **Single user/single task, ROM resident**
  - AppleII OS, Commodore Kernal

    They provide a BASIC interpreter that acts as a SHELL
- **OS loaded from disk** (supports hardware from different vendors)
  - CP/M: supports multiple computers
  - MS-DOS built on CP/M concepts
- **GUI**
  - Apple LISA
  - Mac-OS
  - AmigaOS (adds preemptive multitasking)
  - Atari TOS
  - Windows 3x
  - RISC-OS (acorn arm)
  - ....

Evolution: Hardware

Facts:

- CPUs get more and more powerful. They offer hardware support for memory protection and dual mode (Priviledged/User-mode).
- Memory is ridiculously cheap (compared to the ancient times)
- The market is converging to standard ABI for personal computers
  - X86
  - ARM
  - PowerPC (later become a niche market)
- Discrete Video Cards allow for powerful graphics
- Standard buses, support multiple CPUS

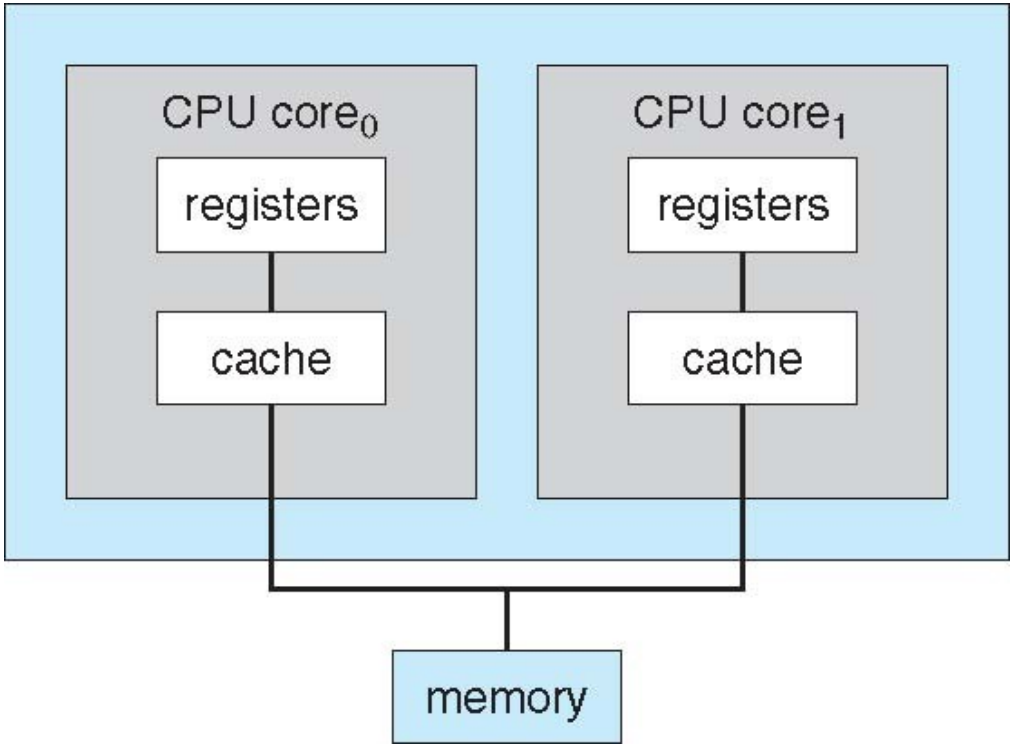
OS Evolution

- Multi-tasking
  - Windows 95
- Multi-user
  - Windows NT (XP,7,8,9,10...)
  - Unix (Darwin)
  - Linux (Ubuntu/Android)

Evolution: Hardware

Facts:

- CPU clock cannot be pimped any longer
- Increase performances by packaging multiple CPUs in a single chip.
- LAN are common



OS Evolution

- Symmetric Multi Processing
  - Spreads the load over multiple CPUs
  - Preemptive/Non Preemptive Kernel
- Clusters
  - Beowulf
  - Grids

Modern Operating Systems

Components

- Process Manager
- Memory Manager
- I/O Managers
  - Off-Core Memory Manager (Disk)
  - Network Card Manager
  - Video Card Manager
  - ...
- File Manager
- Network Manager
- Login Manager
- Command Interpreter

Modern Operating Systems

Services

- Executes Programs
- Provides I/O abstractions
- Provides access to a file system
- Allows for inter process communication/synchronization
- Manages resources
  - RAM
  - CPU
  - Disk
  - Devices
- Offers primitives to enforce protection
- Manages exceptions
- Collects statistics about program/resources usage

Modern Kernel Structures

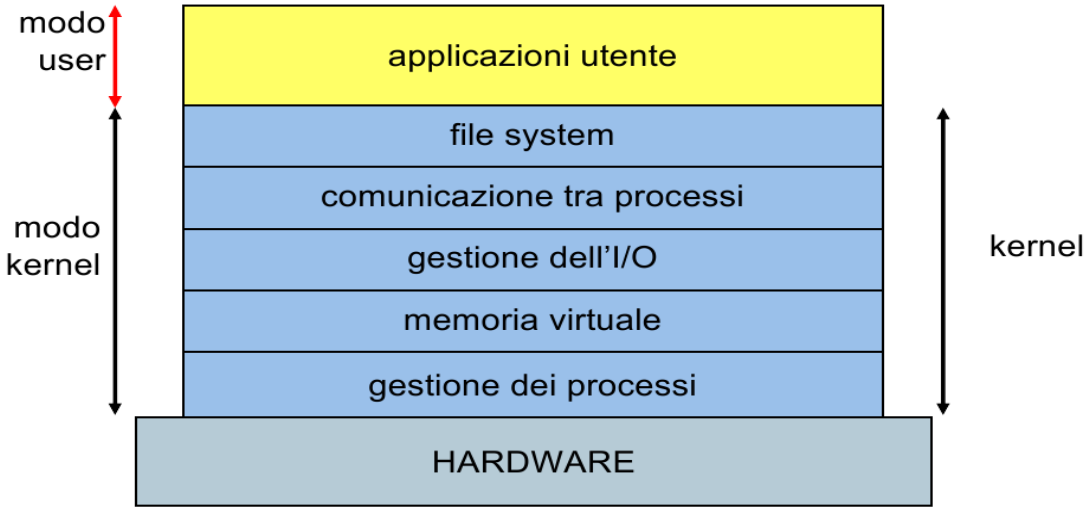
Monolithic

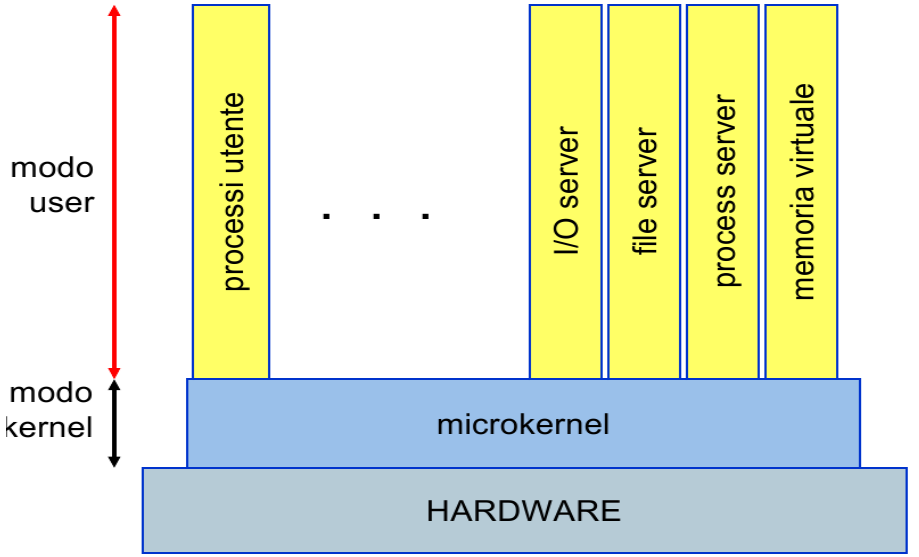
Kernel is one big program that manages all interaction between hardware and programs

Microkernel

Kernel is composed by

- a light core managing memory and processes and
- a bunch of modules running in less privilidged mode that handle all the rest.





Linux Architecture