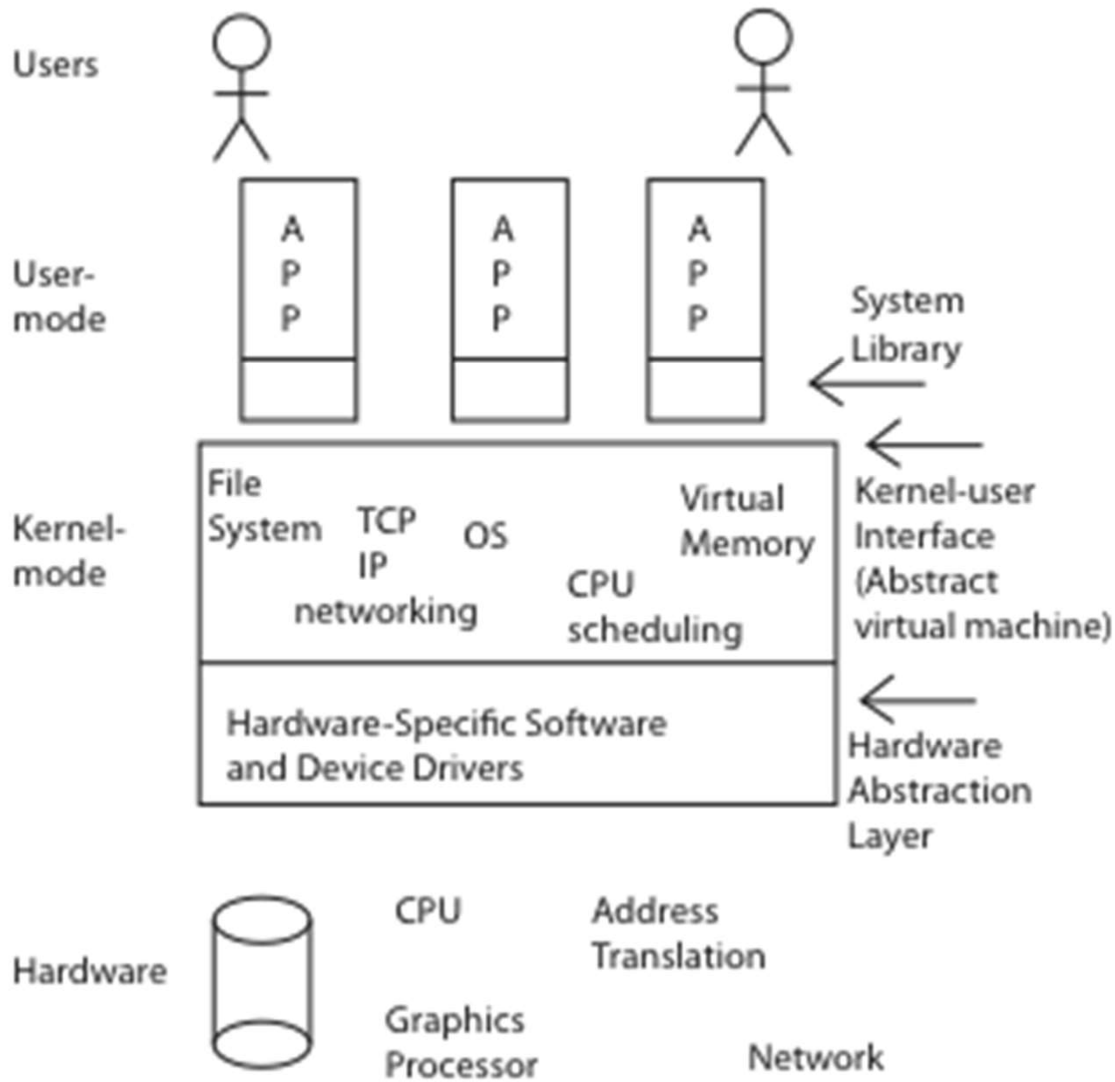
Operating Systems: Principles and Practice

Main Points

- Operating system definition
  - Software to manage a computer's resources for its users and applications
- OS challenges
  - Reliability, security, responsiveness, portability, …
- OS history
  - How are OS X, Windows 7, and Linux related?

What is an operating system?

- Software to manage a computer's resources for its users and applications



Operating System Roles

- Referee:
  - Resource allocation among users, applications
  - Isolation of different users, applications from each other
  - Communication between users, applications
- Illusionist
  - Each application appears to have the entire machine to itself
  - Infinite number of processors, (near) infinite amount of memory, reliable storage, reliable network transport
- Glue
  - Provide common, standard services to applications
  - Simplifies application development
  - Libraries, user interface widgets, …

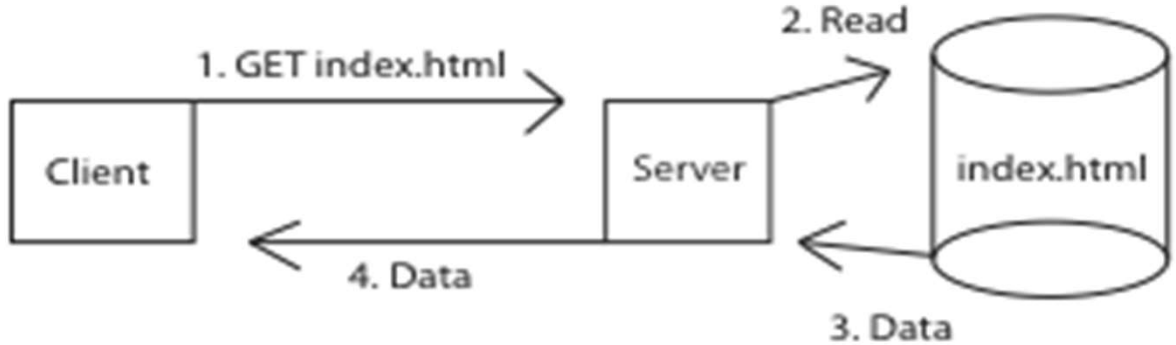
Operating system design patterns

- Cloud computing
  - Referee: how to allocate resources between competing applications in the cloud?
  - Illusionist: computing resources in a cloud evolve continuously, how to isolate applications from this evolution?
  - Glue: how to provide common, standardized access to the cloud services?
- Web services
  - Referee: ensure responsiveness when multiple tabs are opened at the same time
  - Illusionist: web services are geographically distributed for fault tolerance. Mask server failures to the users.
  - Glue: how does a browser achieve portable execution of scripts across different OS and HW platforms?

Operating system design patterns

- Multi-user database systems
  - Referee: how to enforce data access and privacy to different users ?
  - Illusionist: how to mask failures so that data remains consistent and available to users?
  - Glue: what common services to programs development?
- Internet
  - Referee: guarantee differentiated services to users and protect against DoS, spam, phishing etc…
  - Illusionist: internet appears as a unique, world-wide network but it is not!
  - Glue: internet protocols make applications independent of the underlying network architecture

Example: web service



- It defines an astonishingly simple behavior:
  - Receives a packet with a web page request
  - Retrieves the web page from disk
  - Sends back the page

Example: web service

However:

- Multiple users issue requests at the same time
  - These must be managed simultaneously
- Many requests involve data and computations
  - Think about search engines, a request may involve deep computations over large clusters of machines
- The server uses caches to speed up
  - Cache is shared among users, need for synchronized access mechanisms
- Servers send to clients scripts for pages customization
  - How does the client can protect itself from the execution of third party code that may embed viruses/spyware?

Example: web service

However:

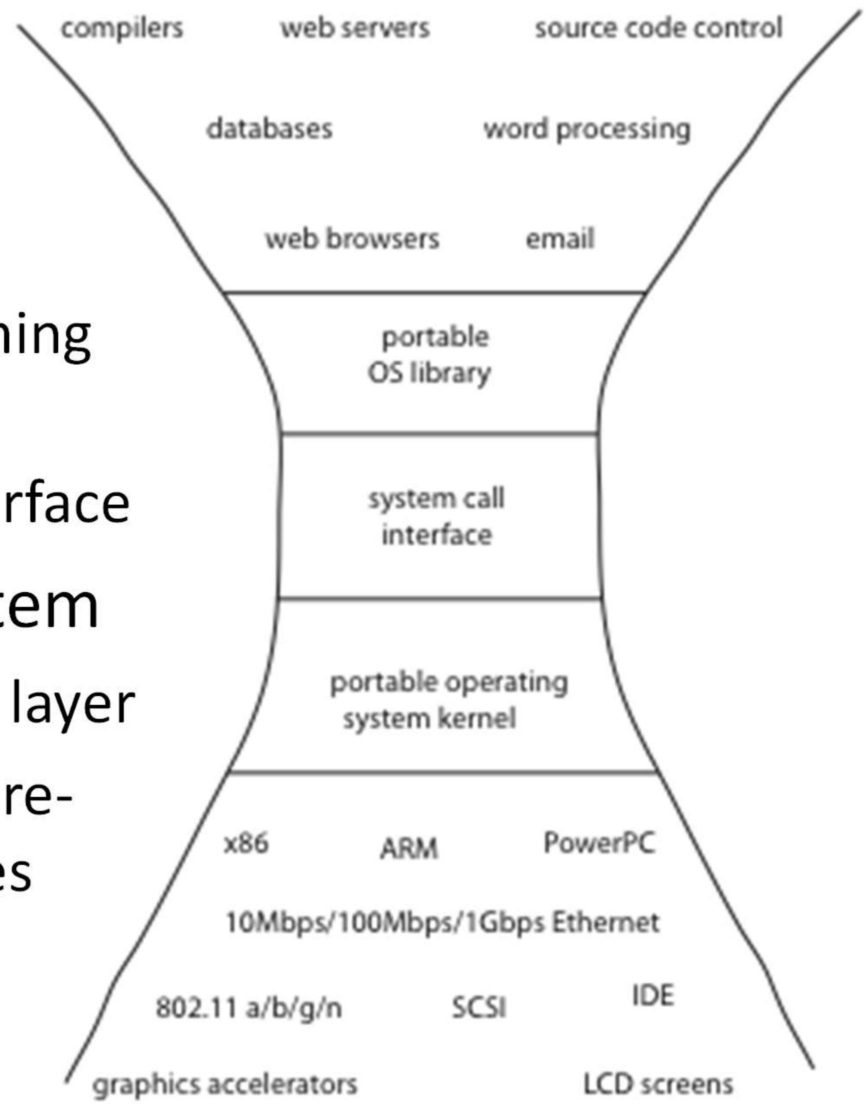
- Web sites need to be updated
  - How to manage consistency with concurrent read requests?
- Client and server may run at different speeds
  - Need for speed decoupling
- Hardware supporting the web site may be updated
  - How to take advantage of this without rewriting the web server code?

OS Challenges

- Reliability
  - Does the system do what it was designed to do?
  - Availability
    - What portion of the time is the system working?
    - Mean Time To Failure (MTTF), Mean Time to Repair
- Security
  - Can the system be compromised by an attacker?
  - Privacy
    - Data is accessible only to authorized users
- Both require very careful design and code

OS Challenges

- Portability
  - For programs:
    - Application programming interface (API)
    - Abstract machine interface
  - For the operating system
    - Hardware abstraction layer
    - Most OS have hardware-specific kernel routines



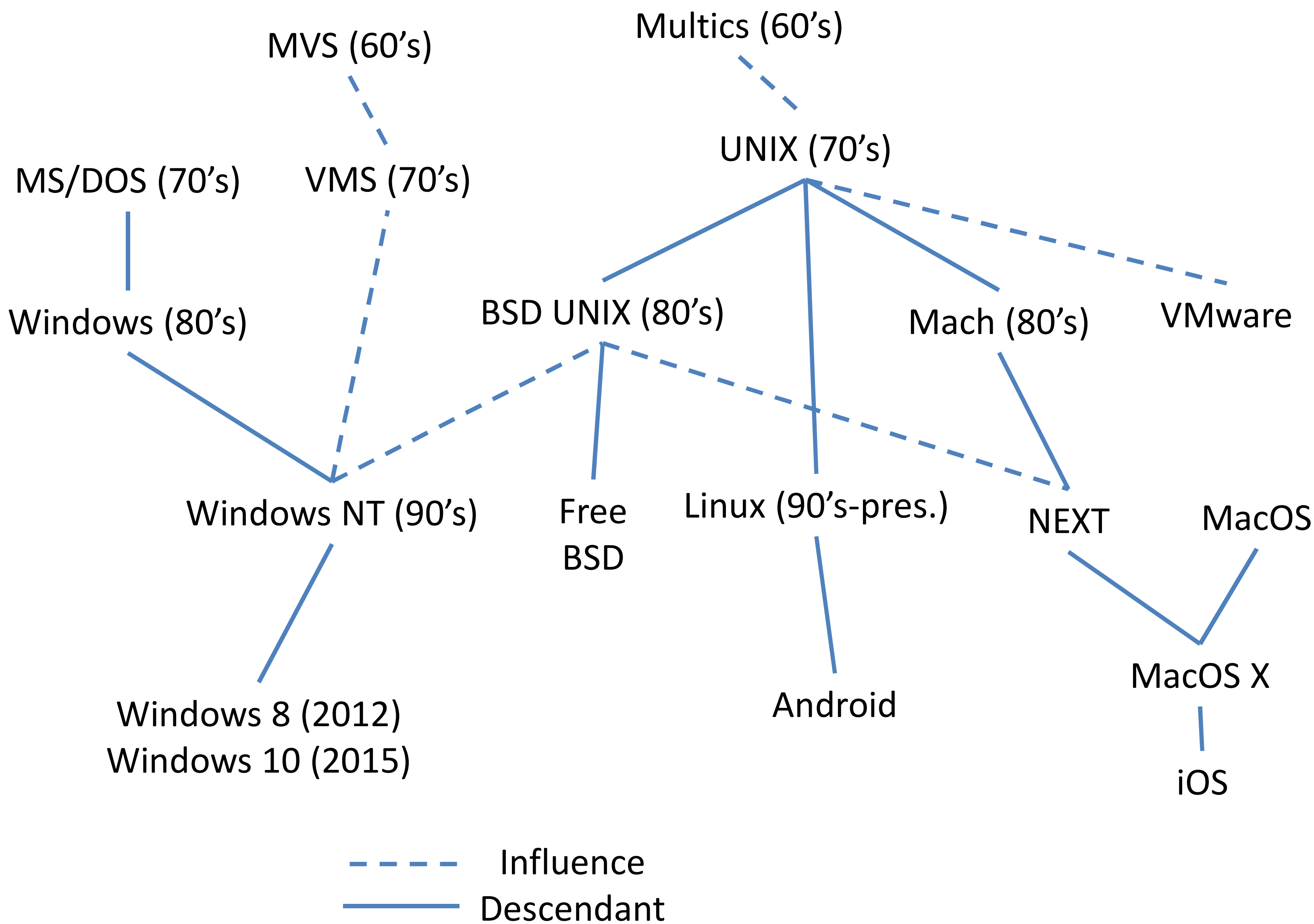
OS Challenges

- Performance
  - Latency/response time
    - How long does an operation take to complete?
  - Throughput
    - How many operations can be done per unit of time?
  - Overhead
    - How much extra work is done by the OS?
  - Fairness
    - How equal is the performance received by different users?
  - Predictability
    - How consistent is the performance over time?

OS Adoption

- Adoption is beyond control of an OS
  - Wide availability of applications
  - Wide availability of HW supporting it
- Network effect
  - App stores
  - Example: Android model vs iPhone model
- Proprietary vs open systems
  - Not a clear winner

OS History



MVS (60's)
Multics (60's)
UNIX (70's)
MS/DOS (70's)
VMS (70's)
BSD UNIX (80's)
Mach (80's)
VMware
Windows (80's)
Windows NT (90's)
Free BSD
Linux (90's-pres.)
NEXT
MacOS
MacOS X
Windows 8 (2012)
Windows 10 (2015)
Android
iOS
Influence
Descendant

Computer Performance Over Time

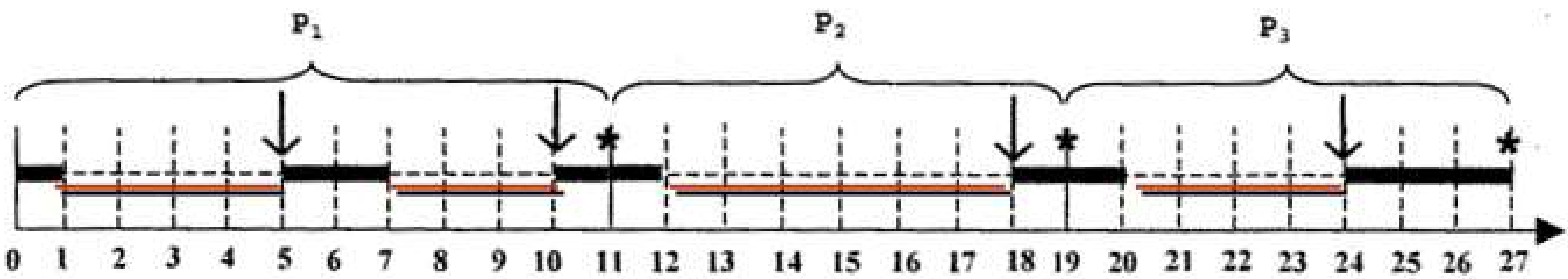
	1981	1996	2011	factor
MIPS	1	300	10000	10K
MIPS/$	$100K	$30	$0.5	200K
DRAM	128KB	128MB	10GB	100K
Disk	10MB	4GB	1TB	100K
Home internet	9.6 Kbs	256 Kbps	5 Mbps	500
LAN network	3Mbps (shared)	10 Mbps	1 Gbps	300
Users per machine	100	1	<<1	100+

Early Operating Systems: Computers Very Expensive

- One application at a time
  - Had complete control of hardware
  - OS was runtime library
  - Users would stand in line to use the computer
- Batch systems
  - Keep CPU busy by having a queue of jobs
  - OS would load next job while current one runs
  - Users would submit jobs, and wait, and wait, and..

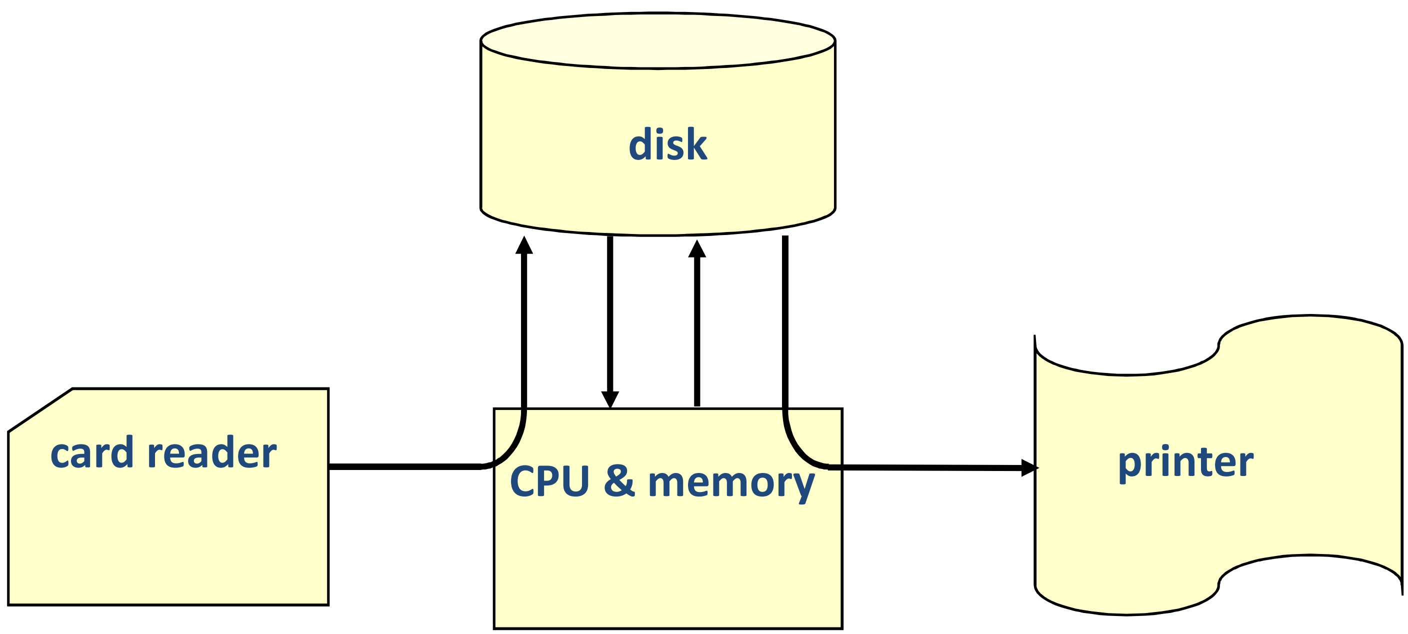
Single task systems

- Sequential execution
  - Black line: execution on the processor
  - Red line: I/O operation – the program stops & waits for the result of the operation



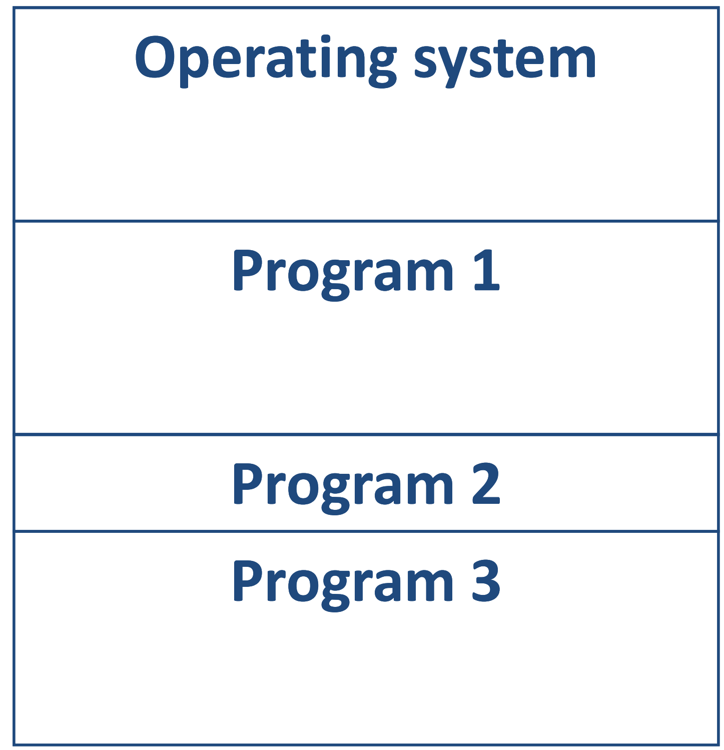
Early batch systems

- SPOOL: Simultaneous Peripheral Operation On-Line

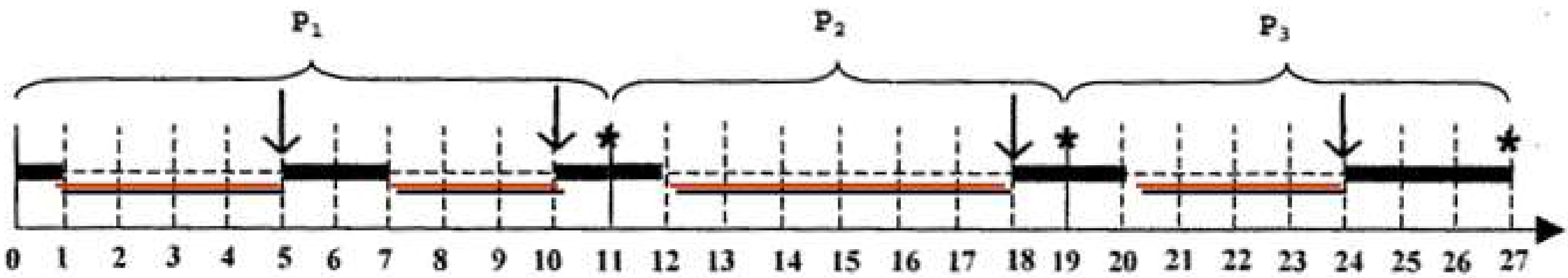


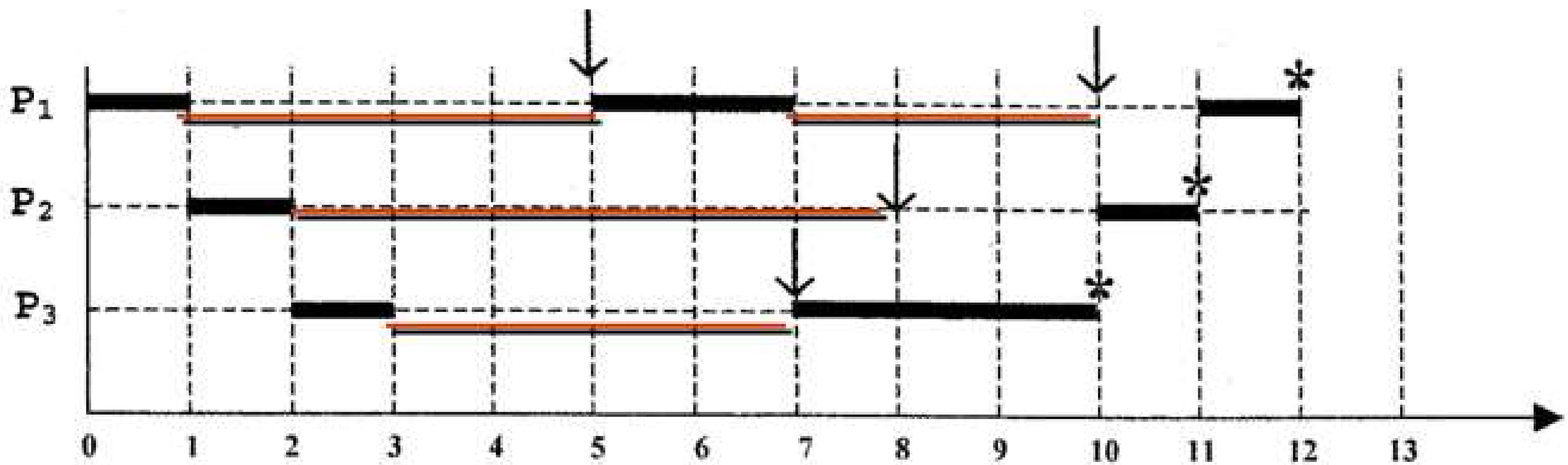
Multi-programmed batch systems

- multi-user system: several programs loaded in memory at the same time
- Spool optimization
- Resource optimization (processor, memory, devices)
  - Response time not important



Multi-tasking vs single-task





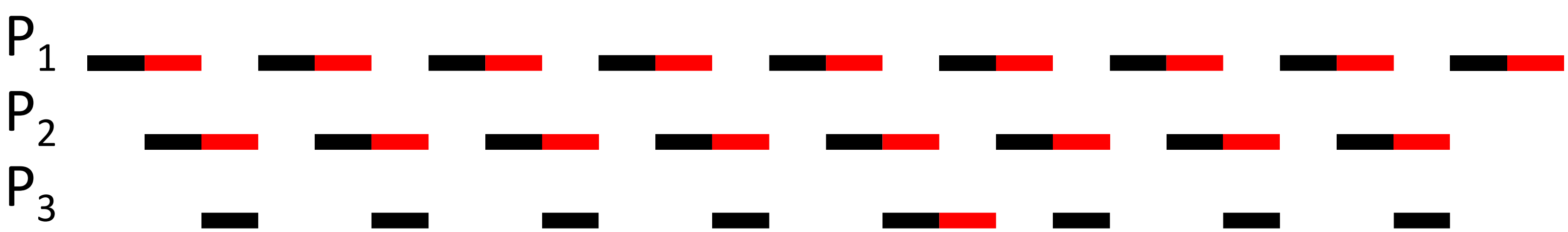
Time-Sharing Operating Systems: Computers and People Expensive

- Multiple users on computer at same time
  - Multiprogramming: run multiple programs at same time
  - Interactive performance: try to complete everyone's tasks quickly
  - As computers became cheaper, more important to optimize for user time, not computer time

Time-Sharing Operating Systems

- time sharing v.s. multitasking

Multi tasking systems (execution ; I/O)



Time sharing systems (execution ; I/O)

Today's Operating Systems: Computers Cheap

- Smartphones
- Embedded systems
- Web servers
- Laptops
- Tablets
- Virtual machines
- …

Tomorrow’s Operating Systems

- Giant-scale data centers
- Increasing numbers of processors per computer
- Increasing numbers of computers per user
- Very large scale storage

Bonus Thought Question

- How should an operating system allocate processing time between competing uses?
  - Give the CPU to the first to arrive?
  - To the one that needs the least resources to complete? To the one that needs the most resources?
  - What if you need to allocate memory?
  - Disk?

Textbook

- Lazowska, Spring 2012: “The text is quite sophisticated. You won't get it all on the first pass. The right approach is to [read each chapter before class and] re-read each chapter once we've covered the corresponding material… more of it will make sense then. *Don't save this re-reading until right before the mid-term or final – keep up.”*