Operating System Concepts

Lecture 2: Interactions between OS and Hardware

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MWF 12:00-12:50 VVC 2 215

Today's class

- A closer look at OS
  - Why do we study it?
- Interactions between Operating System and hardware
  - How does OS make it easier to use/program a computer?

Why do we study Operating Systems?

- knowledge of how OS works is crucial to proper, efficient, and secure programming
  - OS code is **efficient** (runs fast using minimum resources), **reliable** (fails infrequently), **complex** (addresses various timing and concurrency issues), and **secure**

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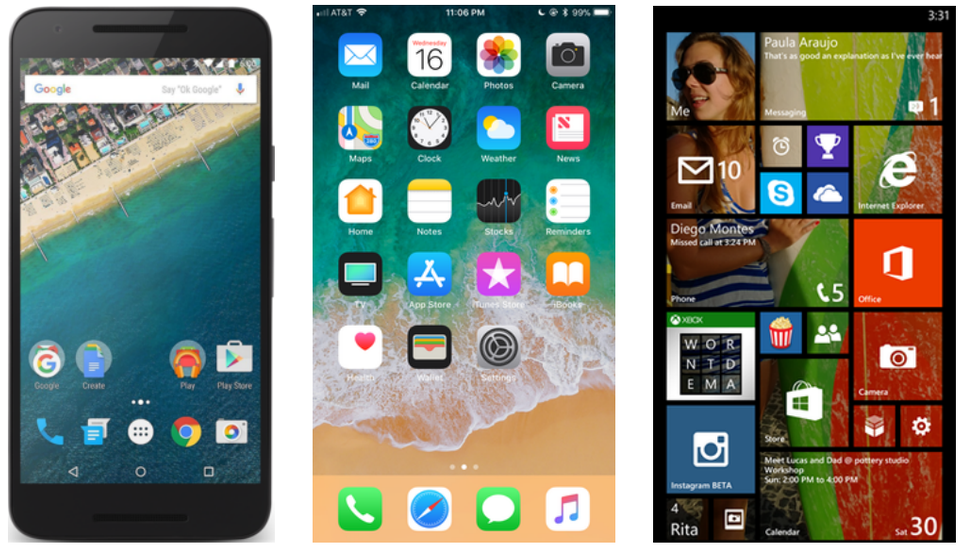
- it's an active area of research! 

  - new application spaces: cloud, mobile systems, embedded systems, cyber-physical systems
  - SOSP 2019: 27th ACM Symposium on Operating Systems Principles
  - OSDI 2018: 13th USENIX Symposium on Operating Systems Design and Implementation

And because Operating Systems are everywhere!

Desktop & Laptop Computers

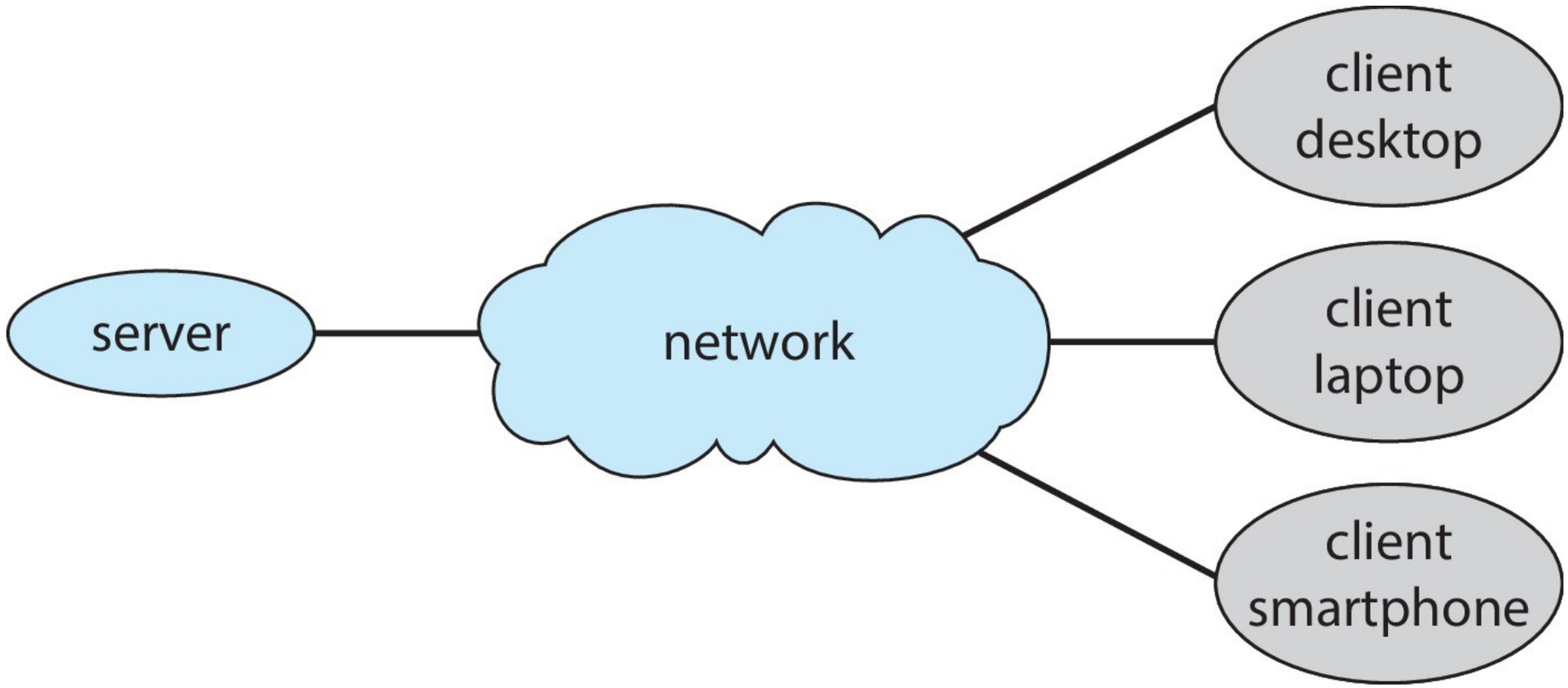


Mobile Devices

Embedded Computers

Wearables

An example: client-server model



- each client can send a request to the server to perform some operation (e.g., running a query)
- the server executes the operation upon receiving the request, and sends the results back to the client

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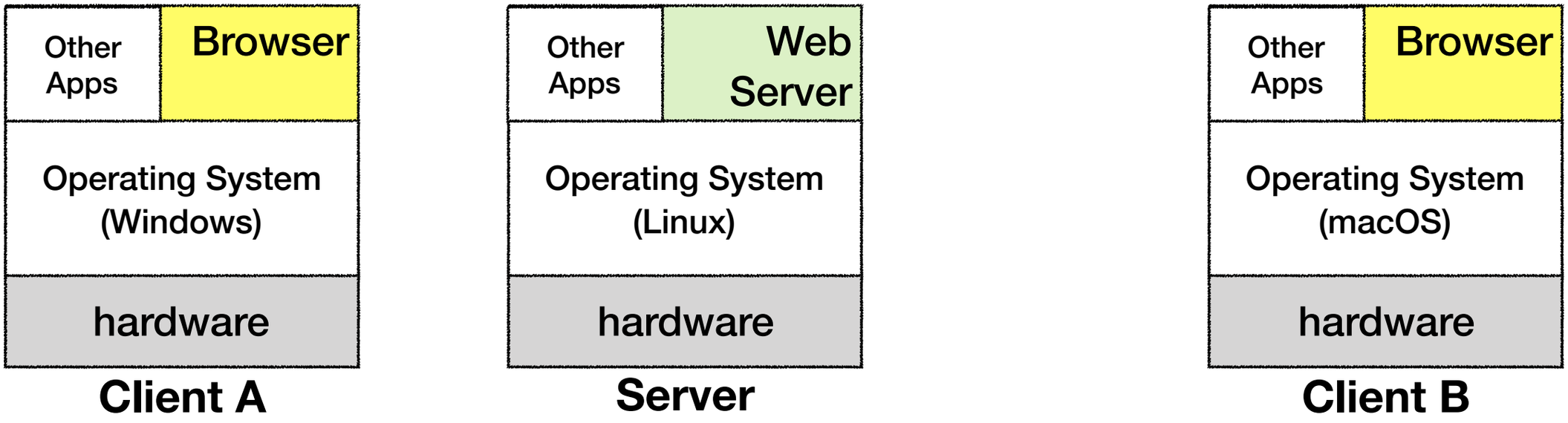

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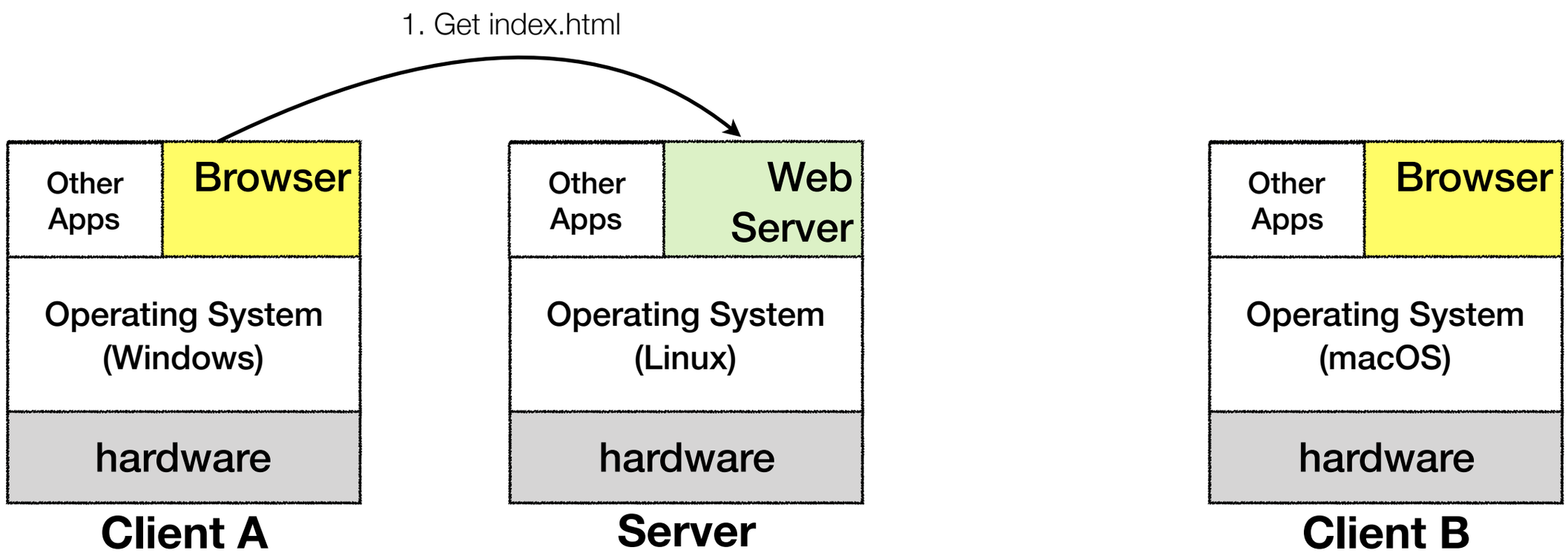

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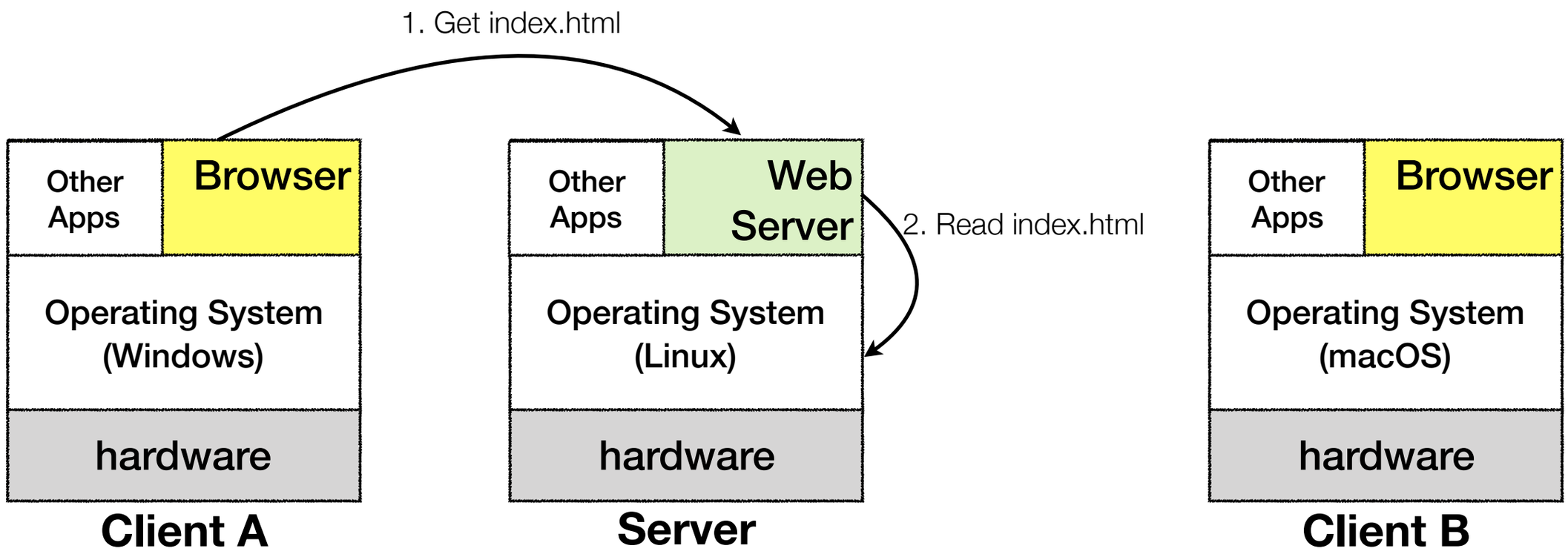

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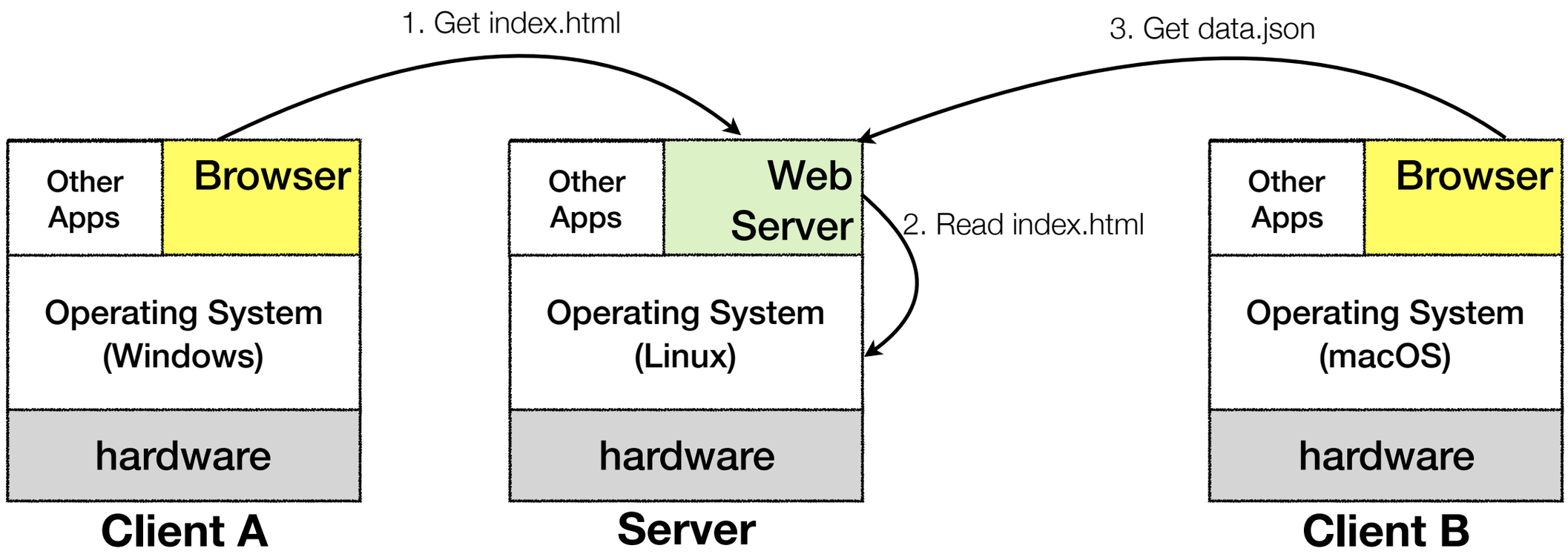

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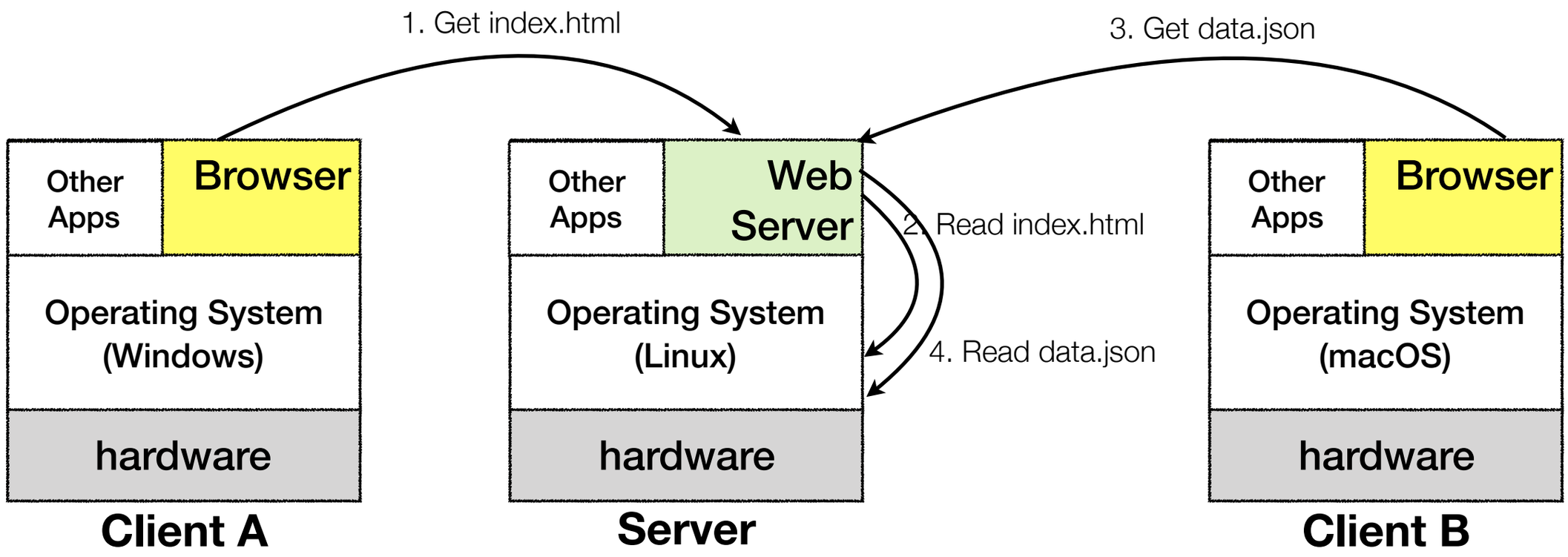

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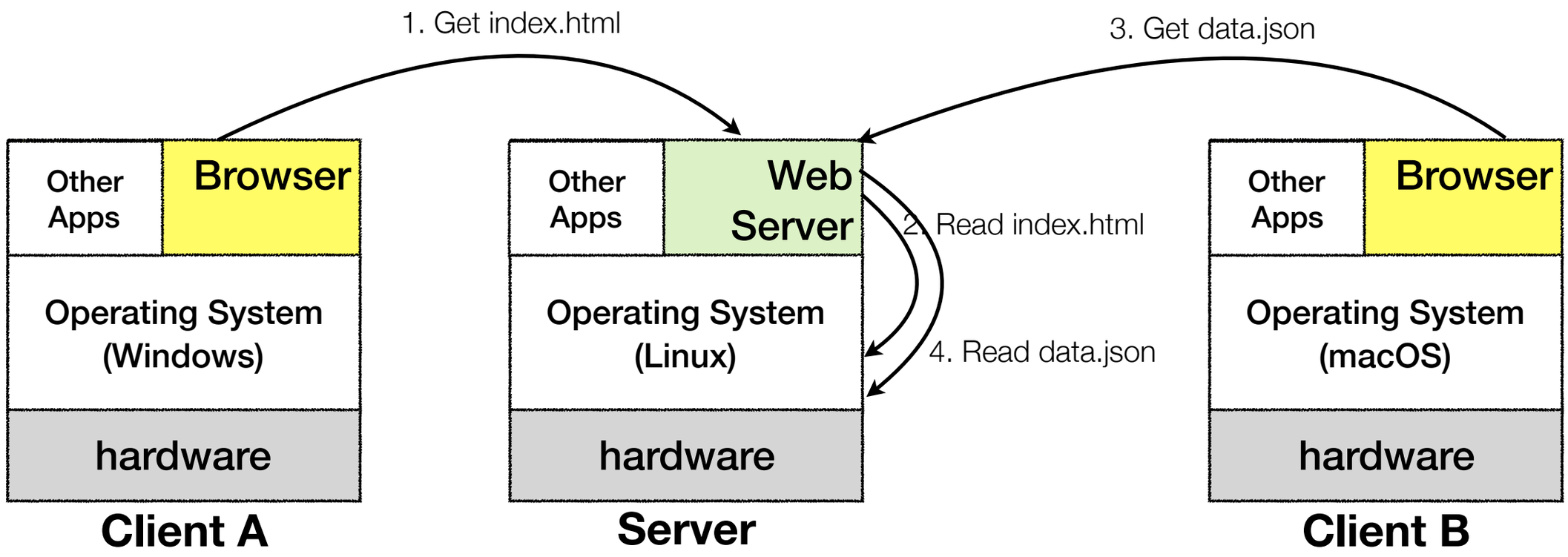

- In this course you will learn about how the OS
  - allows multiple local and remote user applications to communicate with each other and share data
  - handles multiple concurrent requests
  - supports access to shared data using atomic operations
  - protects the system against malicious scripts

Interfacing Hardware

Recap

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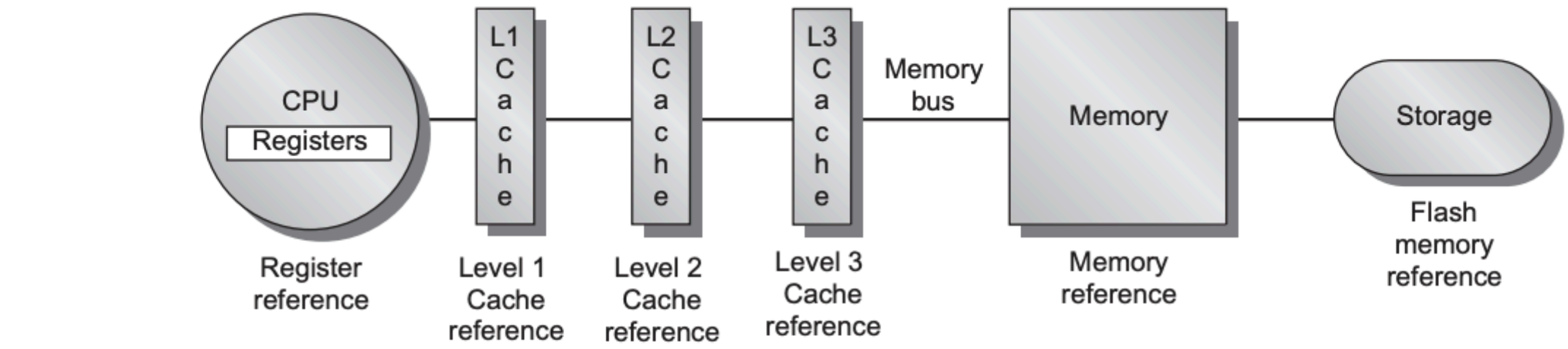

Memory hierarchy for a desktop and a laptop

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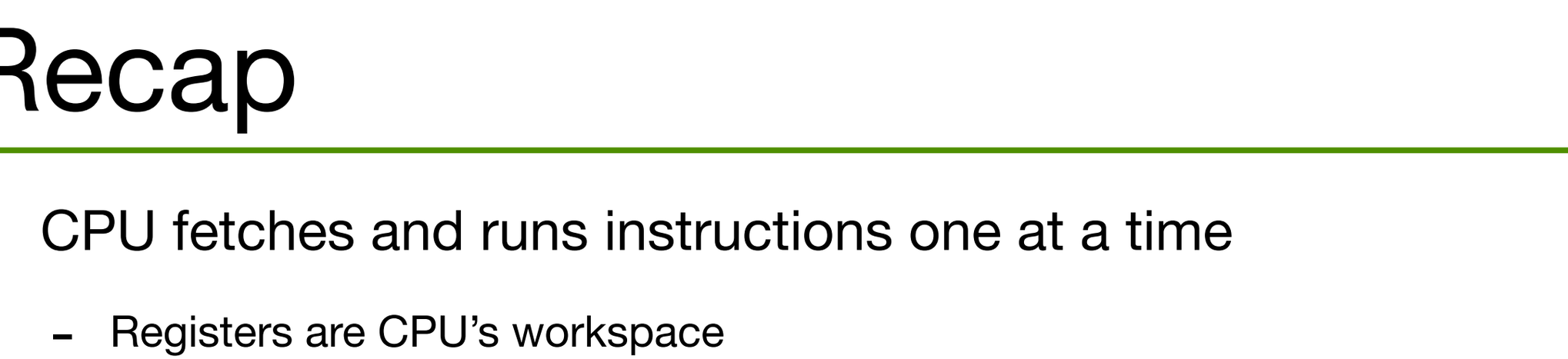

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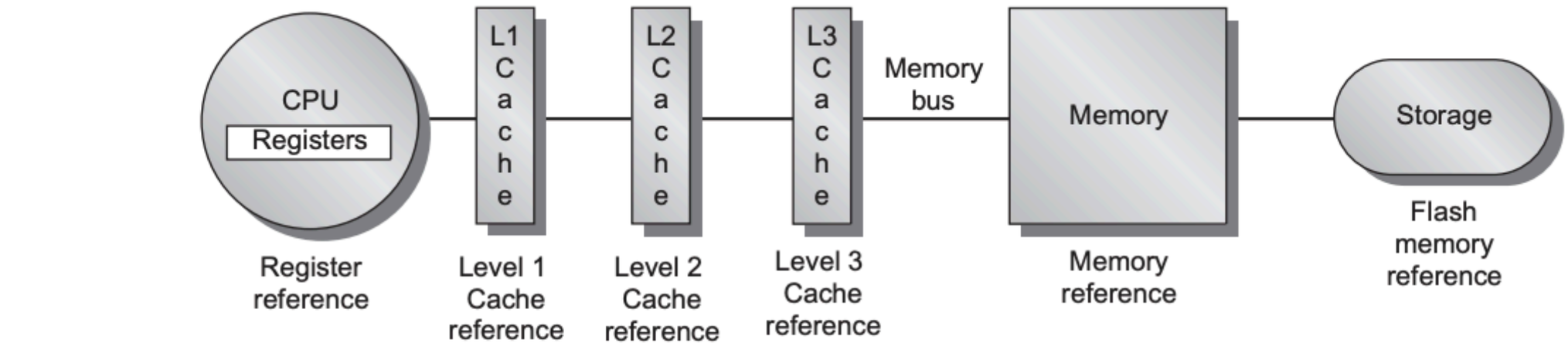
  - an economical solution: a memory hierarchy organized into several levels; each level is smaller, faster, and more expensive per byte than the next



Laptop	Size:	1000 bytes	64 KB	256 KB	4-8 MB	4–16 GB	256 GB-1 TB
	Speed:	300 ps	1 ns	3–10 ns	10–20 ns	50–100 ns	50-100 uS
Desktop	Size:	2000 bytes	64 KB	256 KB	8-32 MB	8–64 GB	256 GB-2 TB
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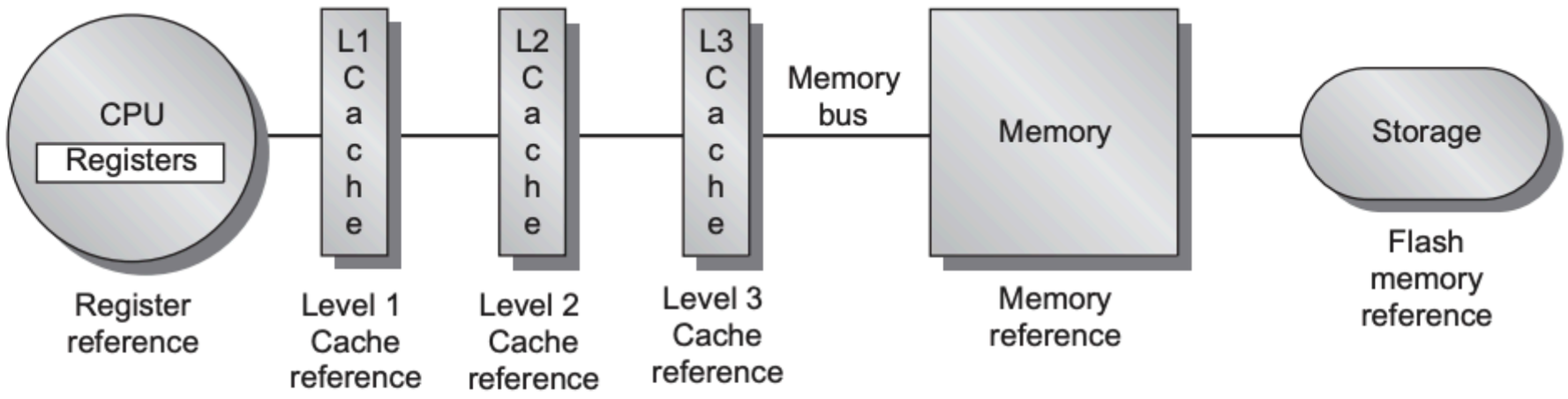
  - it takes advantage of **locality** and **cost-performance tradeoffs**



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10^{-12} 10^{-6}

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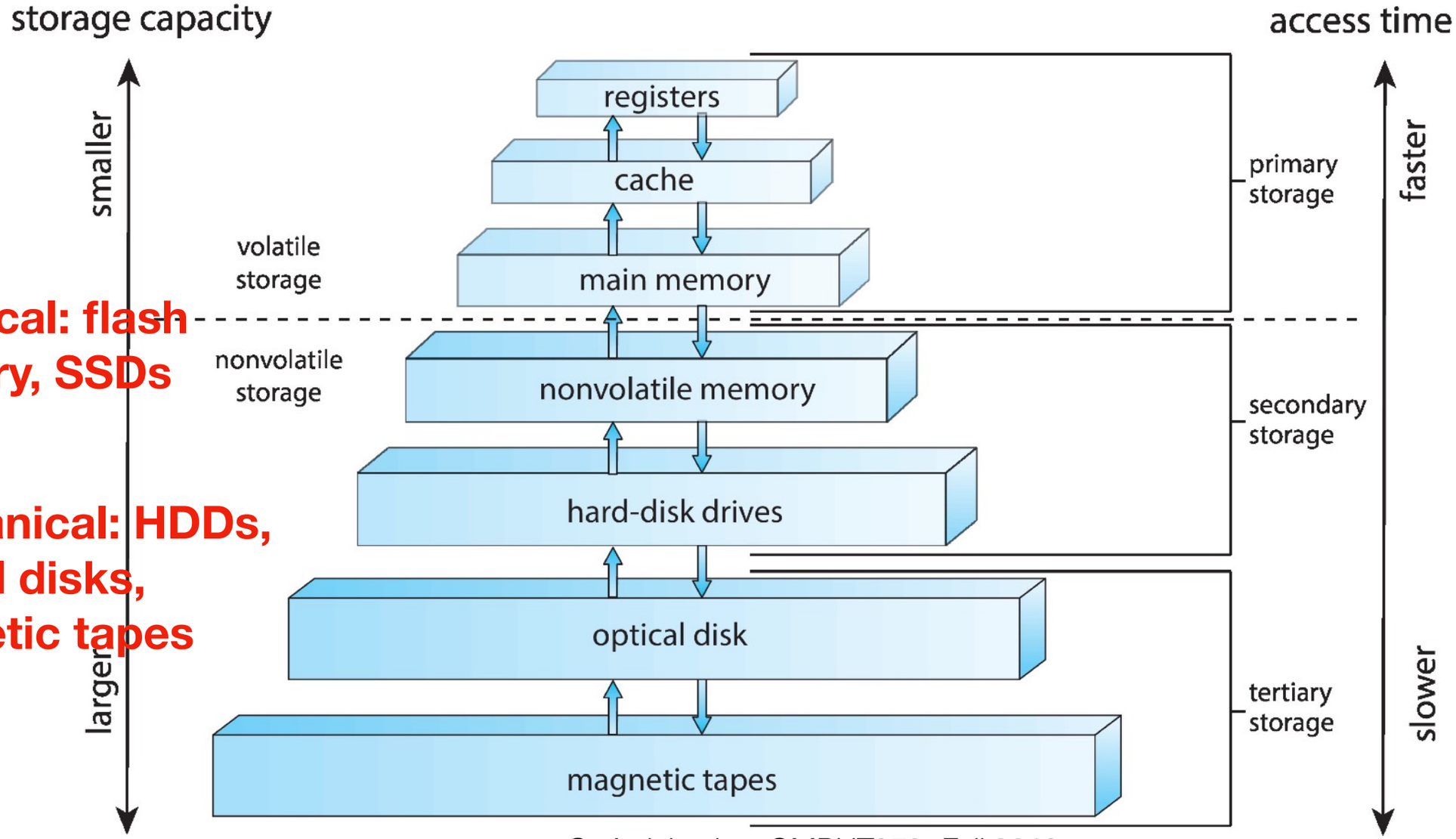
Memory hierarchy — recap

- The main differences among storage systems lie in speed (access time), size, and volatility
- Volatile storage loses its content when power is lost



Electrical: flash memory, SSDs

Mechanical: HDDs, optical disks, magnetic tapes

Single-processor, multiprocessor and multicore systems

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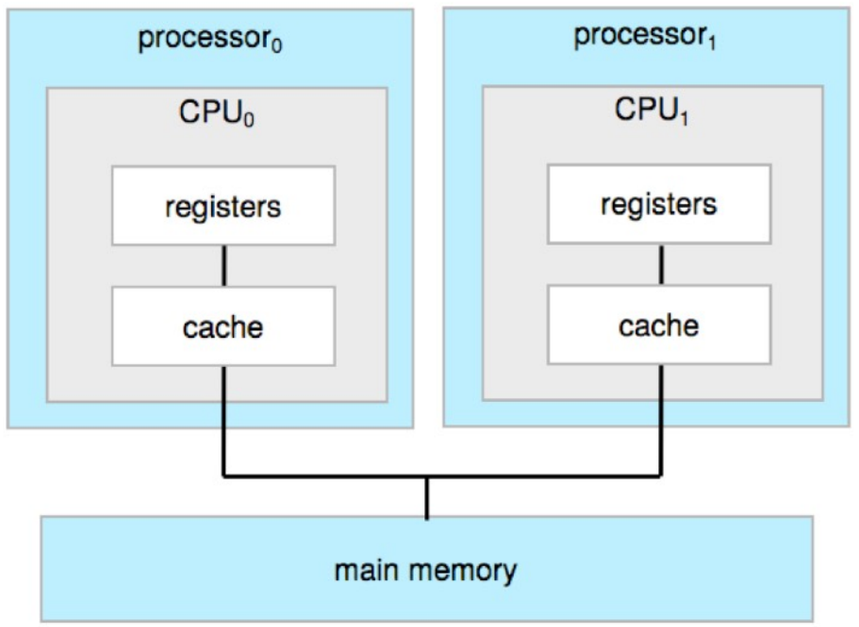
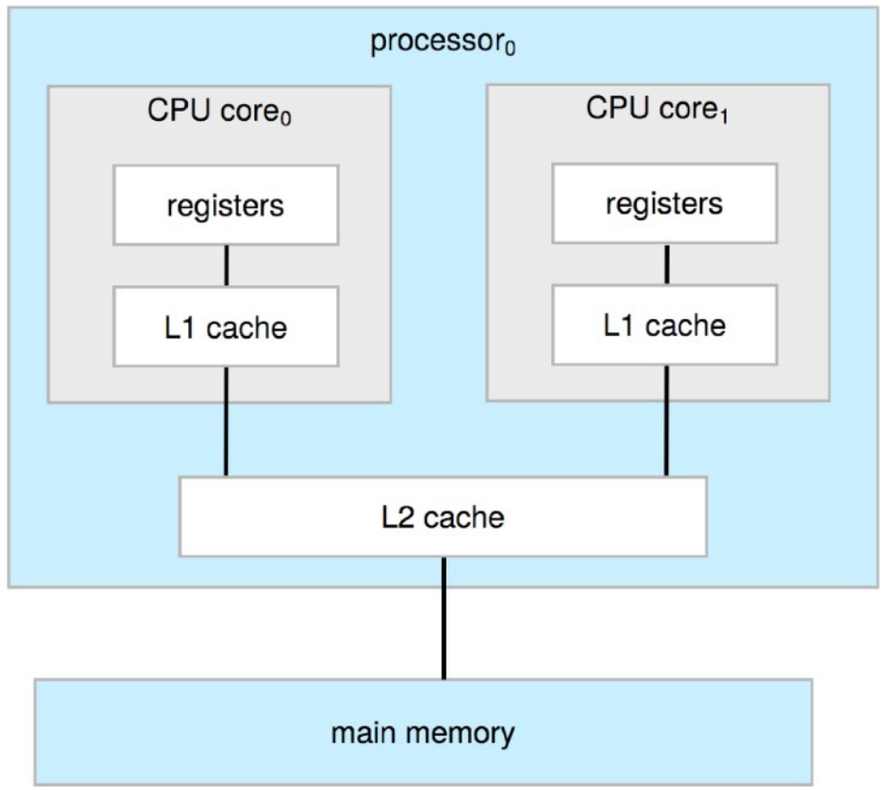
- a multiprocessor system contains two (or more) processors each with a single-core CPU
  - each processor has its own set of registers and cache but they all share the main memory
  - many processes can run simultaneously
  - **load balancing** might be necessary



Single-processor, multiprocessor and multicore systems

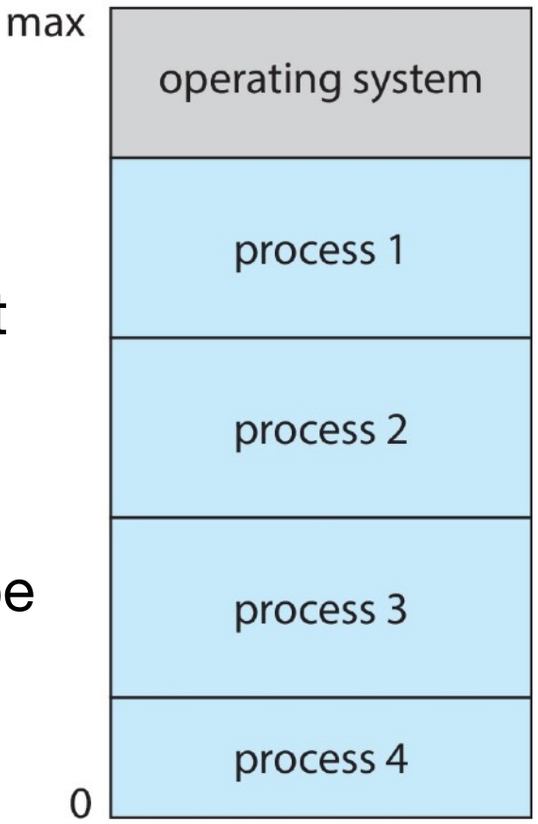
- a multicore system has multiple cores residing on a single processor chip
  - each core has its own registers and L1 cache; L2 cache is shared between processing cores
  - it can be more efficient than a multiprocessor system, because on-chip communication is **faster** than between-chip communication, and uses significantly **less power**

N cores appear to the OS as N standard CPUs



Multiprogramming and multitasking

- Multiprogramming
  - OS keeps several processes in memory simultaneously
  - OS picks one of them for execution (**scheduling**); when that process terminates or has to wait (e.g., for I/O), OS runs another process on the CPU
  - Unlike a non-multiprogrammed system, the CPU wouldn't be idle as long as at least one process has to execute
  - This increases **CPU utilization**



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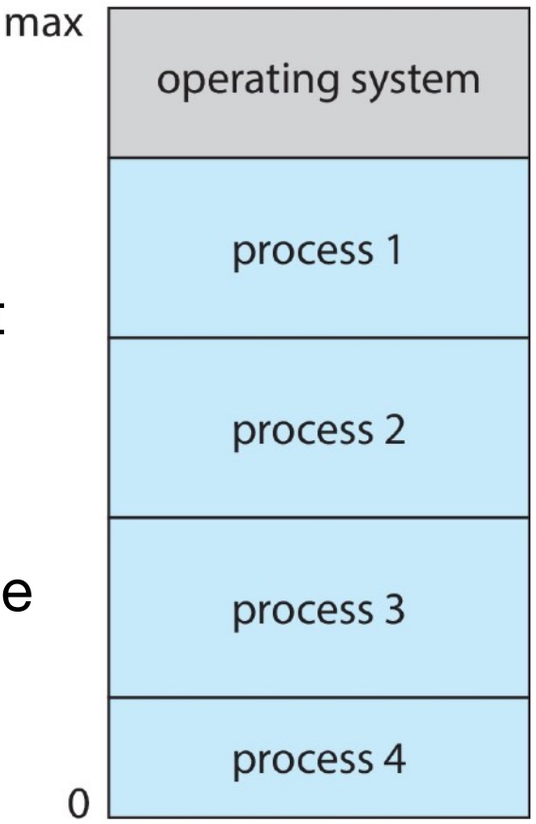

- Multitasking is an extension of multiprogramming
  - CPU executes multiple processes by switching between them frequently to ensure reasonable response time (typically less than 1 second)
  - Choosing the process that runs next requires CPU scheduling

How multiprogramming works?

- When a process waits for I/O, multiprogramming allows CPU to execute another process
  - the process waiting for I/O is added to the waiting queue of the I/O device (e.g., terminal, disks, video board, printer, network card)

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  - Data fills the buffer
- Adds interrupt handling
  - I/O events trigger a signal (known as **interrupt**)
  - control is then transferred to the OS
  - OS adds the process back into the ready queue

Interrupt handling — basic idea

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  - The handler also preserves the state of the CPU by storing registers and the program counter; it restores the state after clearing the interrupt

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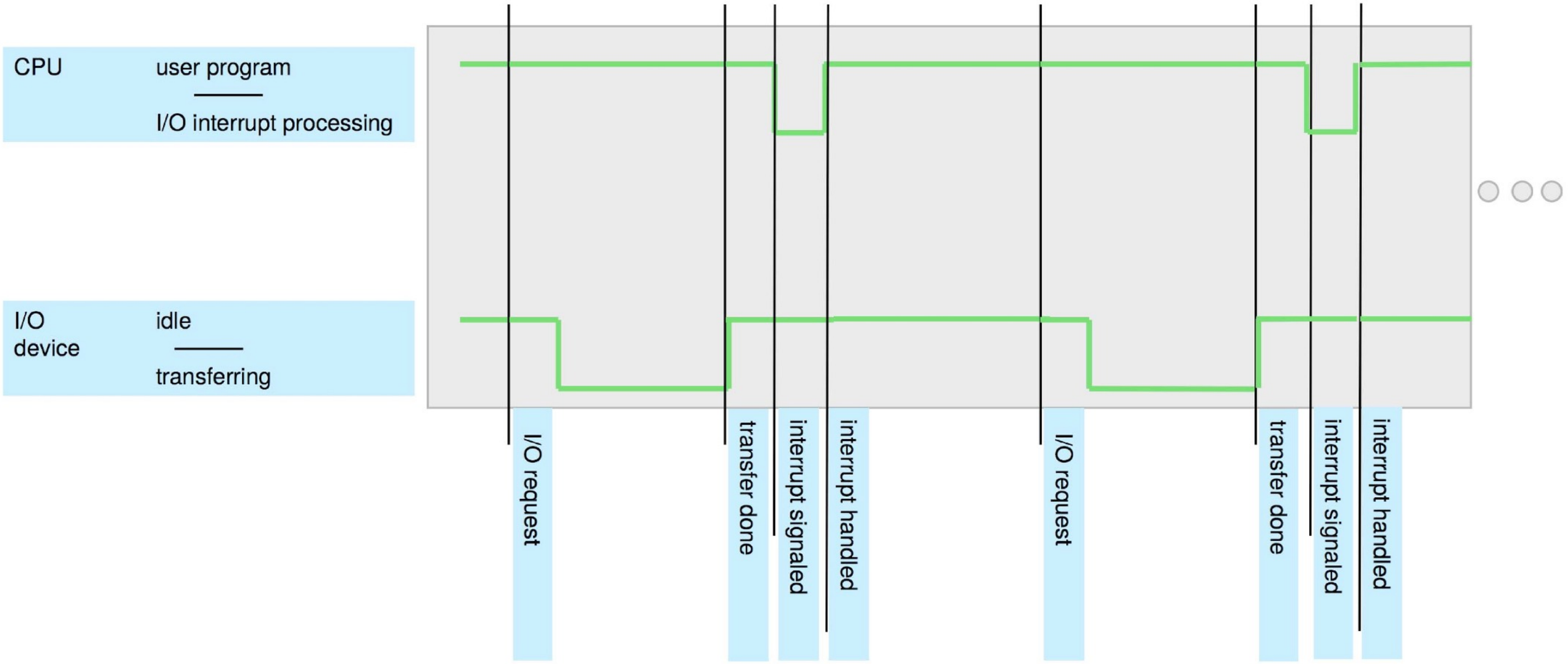
Interrupt-based asynchronous I/O

After I/O starts, control returns to user program without waiting for I/O completion



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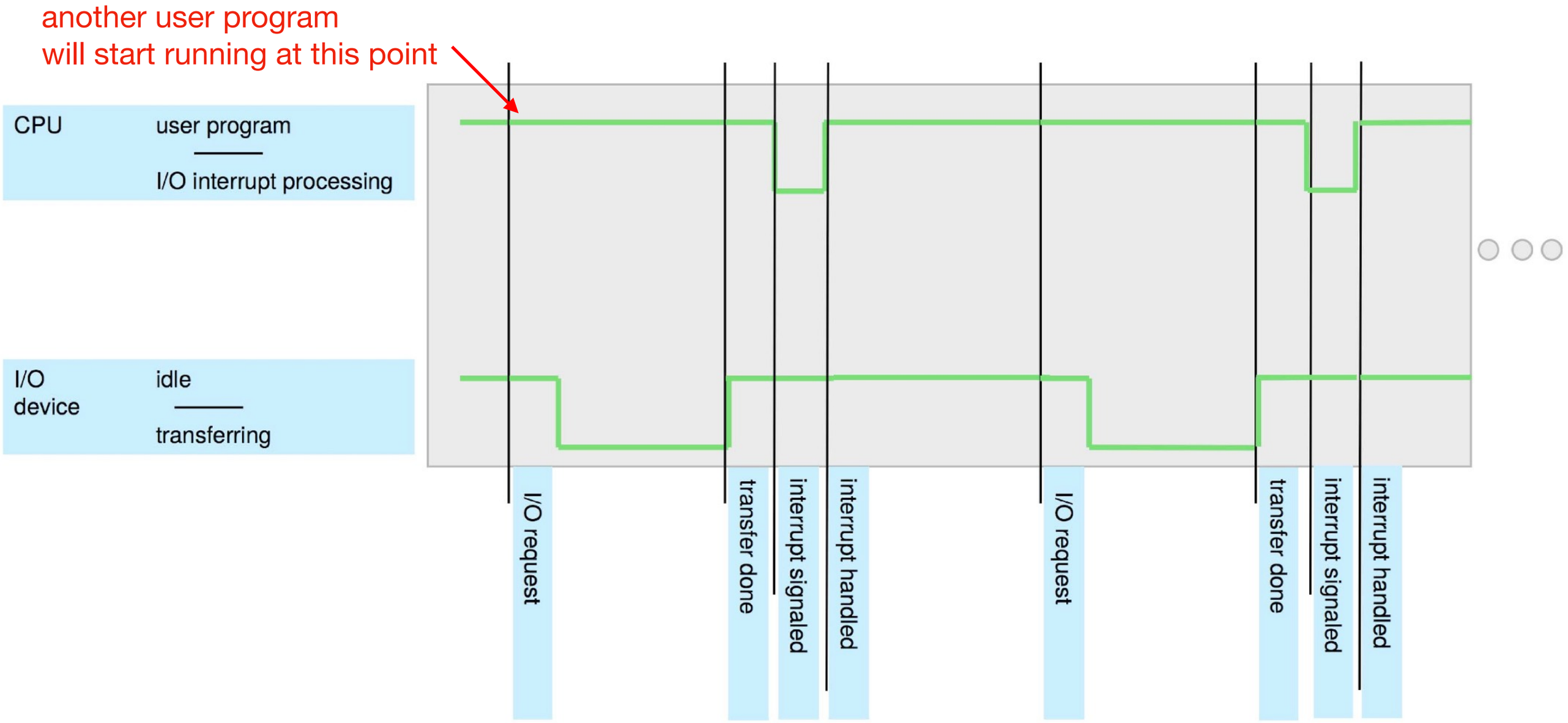

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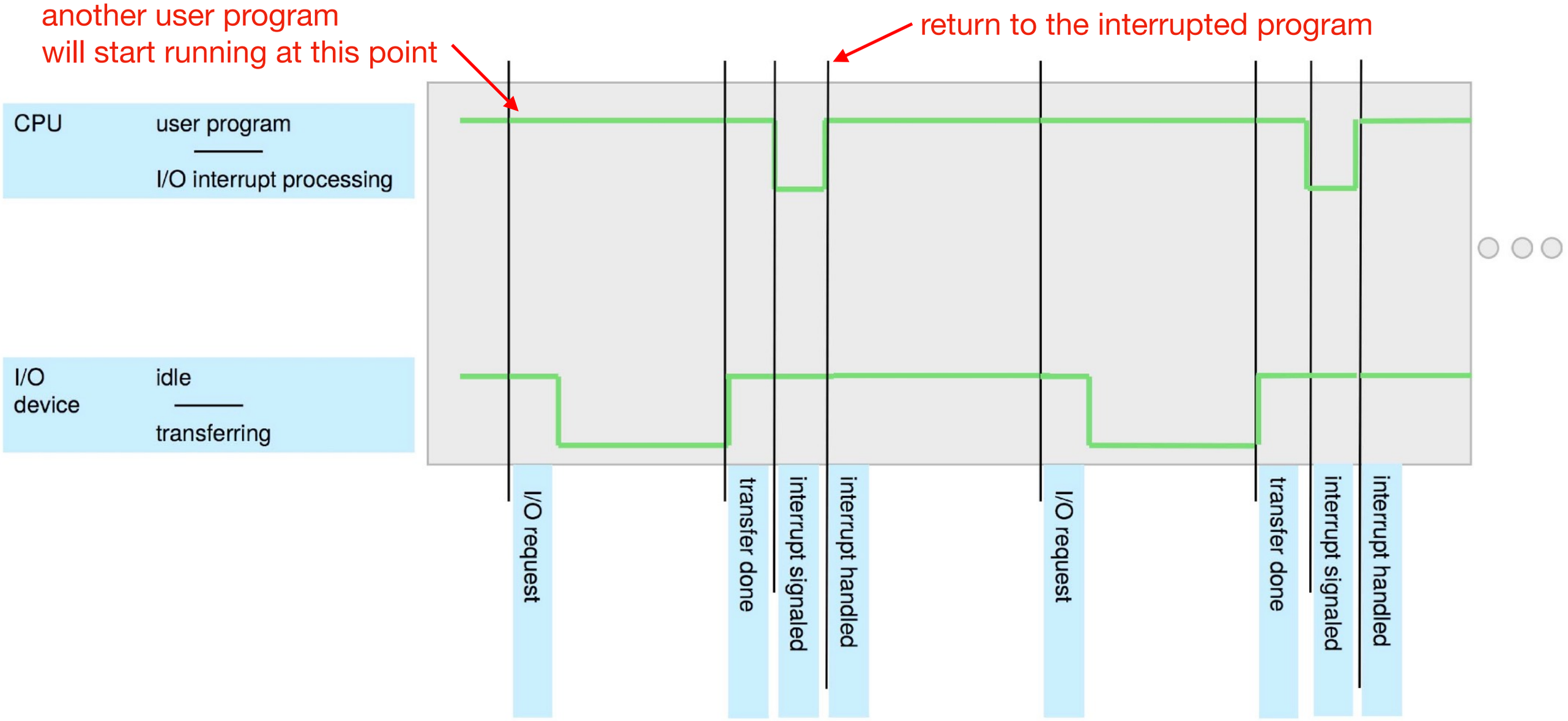

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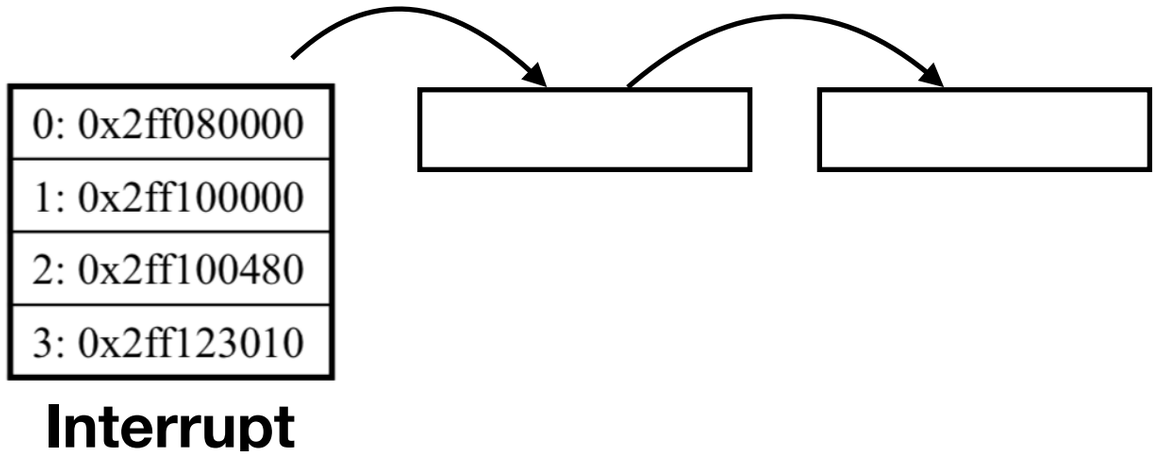

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- How to differentiate urgent events from non-urgent ones? interrupt priority levels
  - CPU defers the handling of low-level interrupts to handle a high-level interrupt

Interrupt handling — basic idea

- Definition: a trap or an exception is a software-generated interrupt caused either by an error (e.g., division by zero) or a user request for OS service (known as a system call)

0: 0x00080000	Illegal address
1: 0x00100000	Memory violation
2: 0x00100480	Illegal instruction
3: 0x00123010	System call

Trap Vector

Protection

- Hardware has a status bit that indicates the current mode (user or kernel)
  - there could be more than two operation modes
    e.g., ARMv8 systems have seven modes
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- invoking a system call allows a user program to run privileged instructions

crossing protection boundary