Introduction

CS 4410
Operating Systems

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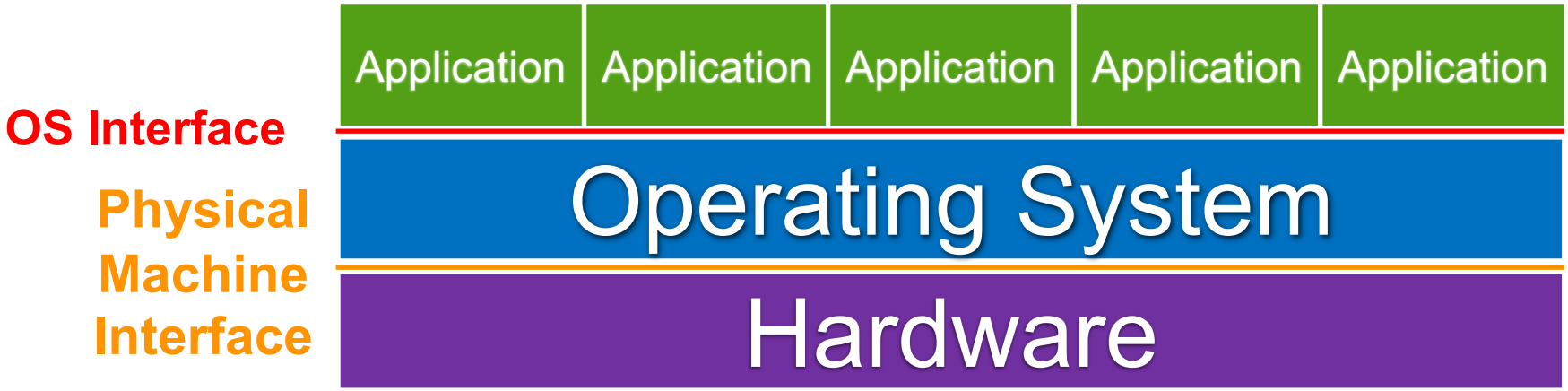
What an OS does

- OS is an intermediary between programs and hardware.
- OS creates an environment to execute programs in a convenient and efficient manner:
  - allocates resources (CPU and storage)
  - controls programs
    - cooperation (sharing and synchronization)
    - isolation (protection and resource management)



Ways to view an OS

- **Services** it provides to programs
- **Components** implementing those services
  - internal design and implementation
    - Real hardware is ugly.
  - interactions

Why Study OS?

Learn solutions to problems arising in all systems:

- Resource sharing (scheduling)
- Cooperation (concurrent programming: communication, synchronization)
- System structure (abstractions, interfaces)

Systems vs Programs (I)

How designing an OS differs from designing a program.

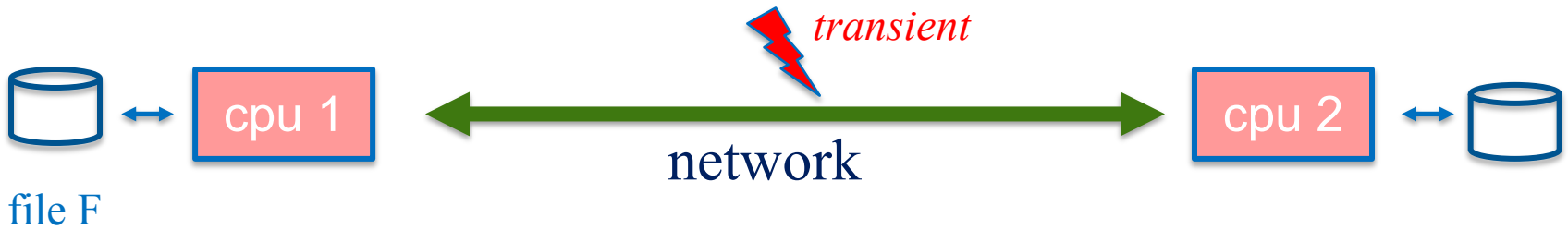
- **Measure of success**: OS concerned with extensibility, security, reliability, …
- **External interface**: OS more complicated and subject to change. Eg I/O devices.
- **Internal structure**: OS must pick boundaries between functions:
  - RISC vs CISC
  - C-time vs run-time (cf Java)
  - Heap with garbage collection vs stack allocation
- **Structuring techniques**: OS employs
  - modules, layers, client-server, event-handler, transaction

Systems vs Programs (II)

How designing an OS differs from designing a program.

- OS must bridge mismatched performance characteristics.
  - Registers vs RAM vs Disk
  - Desktop processor vs Cloud

End to End Argument: Trade-offs



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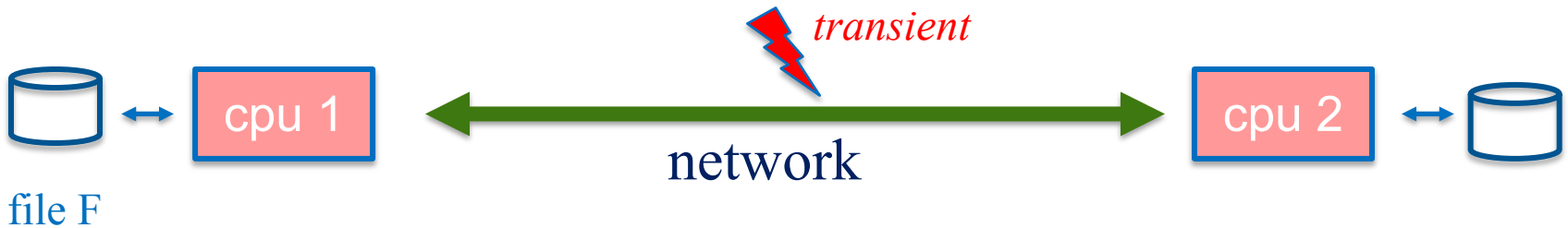
Copy proceeds one block b1, b2, b3, … at a time.
Packets size ≠ block size.

End to End Argument: Trade-offs



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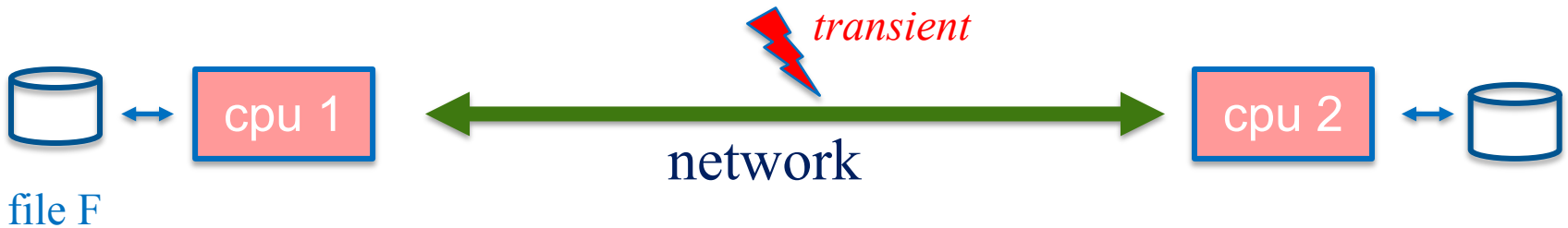

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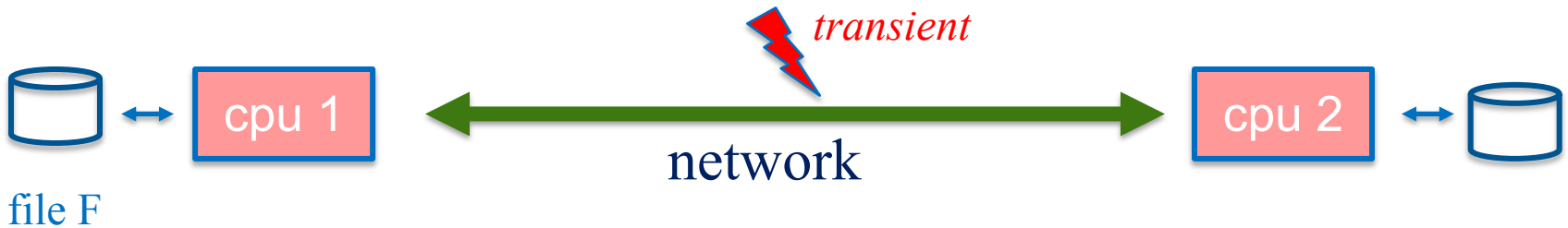

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Soln 3: Checksum successive file prefixes. So sends…

- B1 chk(b1), b2 chk(b1 b2), b3 chk(b1, b2, b3)

What makes systems complex?

Emergent properties: Evident only when components are combined.

Example: Millennium Bridge (London)

What makes systems complex?

Propagation of Effects: When small changes have disproportionate effects.

Examples:

- Power failures in power grid
- Change auto tire size from 13” to 15”
- Boeing 737 max 8 design

  4th generation of 737: new engines, same exit doors.

What makes systems complex?

Incommensurate Scaling: Different parts follow different scaling rules.

Examples:

- Height limits on skyscrapers
- Size limits on railroad trains and cargo ships
  - » Horizon distance is linear in size of object
  - » Stopping distance is proportional to object volume.

How to Manage Complexity

- **Modularity**: Good modularity minimizes connections between components.
- **Abstraction**: Separate interface from internals; separate specification from implementation
- **Hierarchy**: Constrains interactions so easier to understand.
  - L levels with N components / level
  - $(N \times L)^2$ vs $L \times N^2$ interactions

OS has many roles

Referee

- Manages shared resources: CPU, memory, disks, networks, displays, cameras, *etc.*

Illusionist

- Look! Infinite memory! Your own private processor!

Glue

- Offers set of common services (*e.g.*, UI routines)
- Separates apps from I/O devices

OS as Referee

Resource allocation

- Multiple concurrent tasks, how does OS decide who gets how much?

Isolation

- A faulty app should not disrupt other apps or OS
- OS must export less than full power of underlying hardware

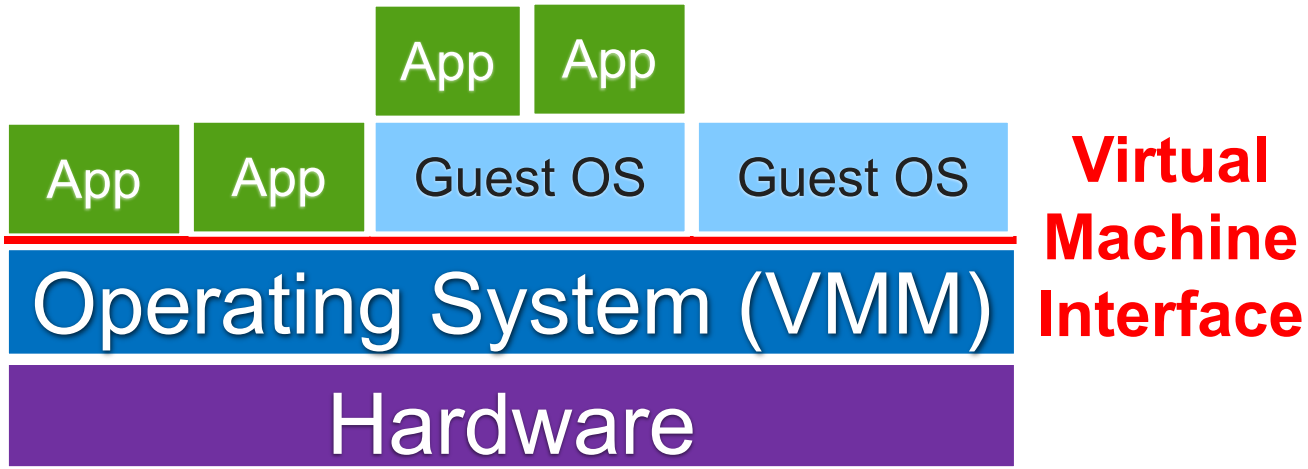
Communication/Coordination

- Apps need to coordinate and share state

OS as Illusionist (1)

Virtualization: Resources seem present but aren't.

- processor, memory, screen space, disk, network
- the entire computer:
  - fooling the illusionist itself!
  - ease of debugging, portability, isolation



OS as Illusionist (2)

Abstraction: Enables new assumptions for clients

- Atomic operations
  - HW guarantees atomicity at word level
    - what happens during concurrent updates to complex data structures?
    - what if computer crashes during a block write?
  - At the hardware level, packets are lost…

- Reliable communication channels

OS as Glue

Simplify app design and facilitate sharing due to:

- send/receive of byte streams
- read/write files
- pass messages
- share memory
- UI

Decouples HW and app development

Issues in OS Design

- **Structure:** how is the OS organized?
- **Concurrency:** how are parallel activities created and controlled?
- **Sharing:** how are resources shared?
- **Naming:** how are resources named by users?
- **Protection:** how are distrusting parties protected from each other?
- **Security:** how to authenticate, authorize, and ensure privacy?
- **Performance:** how to make it fast?

Issues in OS Design

- **Reliability:** how do we deal with failures??
- **Portability:** how to write once, run anywhere?
- **Extensibility:** how do we add new features?
- **Communication:** how do we exchange information?
- **Scale:** what happens as demands increase?
- **Persistence:** how do we make information outlast the processes that created it?
- **Accounting:** who pays the bill and how do we control resource usage?