Intro: What is a System?

COS 316: Principles of Computer System Design

Lecture 1

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- Today: Systems!
- Next time: Course Overview, Syllabus, …

Example Systems

- Operating system (OS) kernel
- The Internet
- Database
- Distributed file system
- Web framework
- Game engine

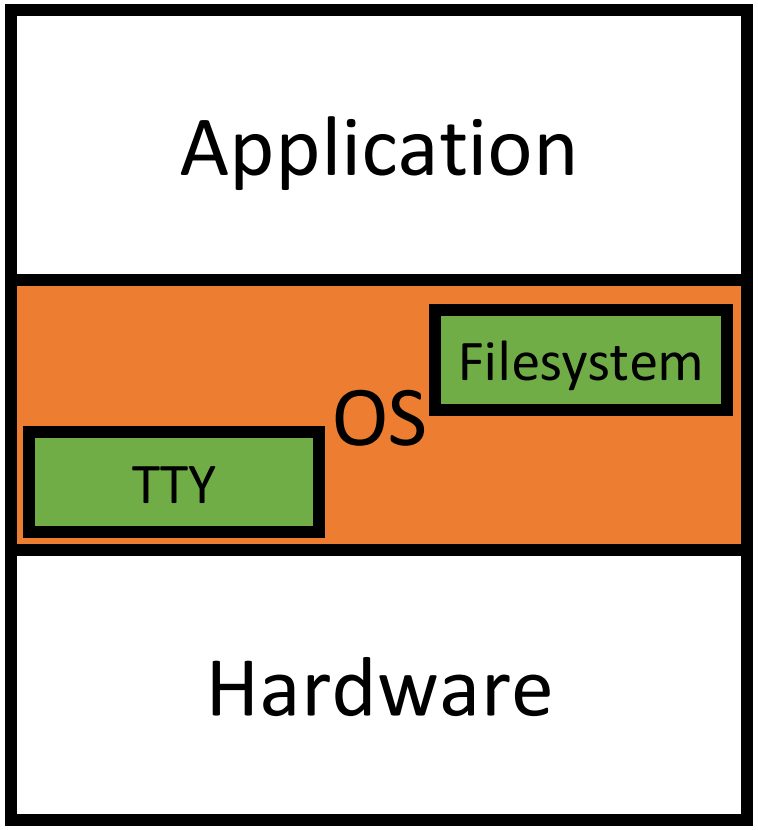
What is a System?

- Provides an interface to underlying resources
- Mediates access to shared resources
- Isolates applications
- Abstracts complexity
- Abstracts differences in implementation

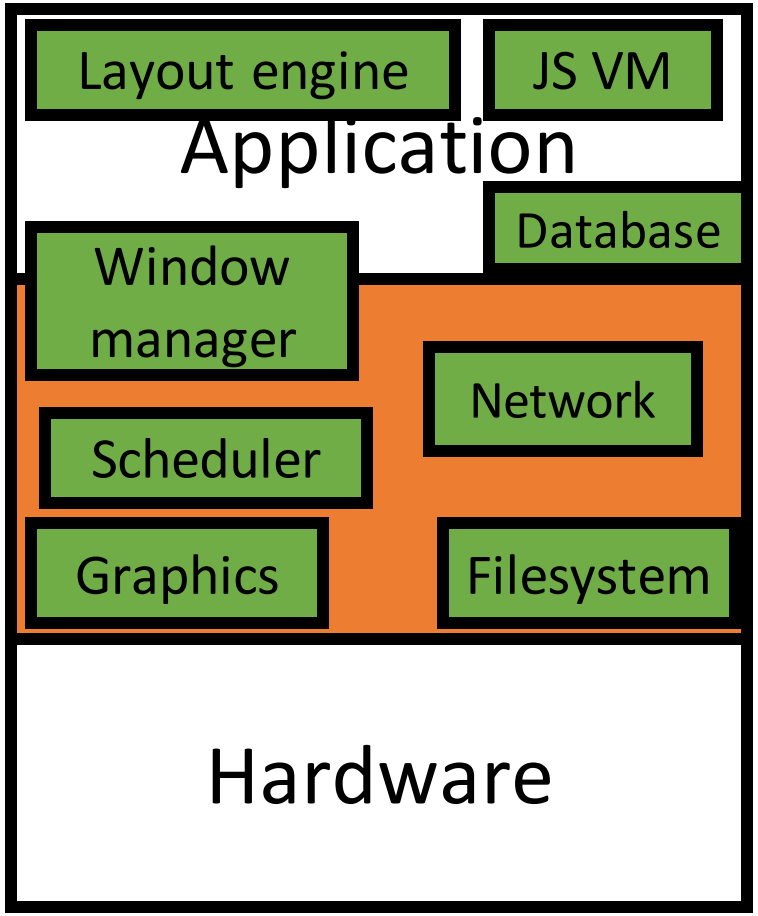
Example System: OS Kernel

- Interface: system calls
- Underlying resources: hardware (CPU, memory, network, disk)
- Isolation: Firefox, terminal, zoom, … don’t worry about each other
- Abstraction: Collection of system calls
  - Instead of specific protocols for using specific devices
  - Don’t need to rewrite Firefox to display on new monitors, or save to new disks, or …

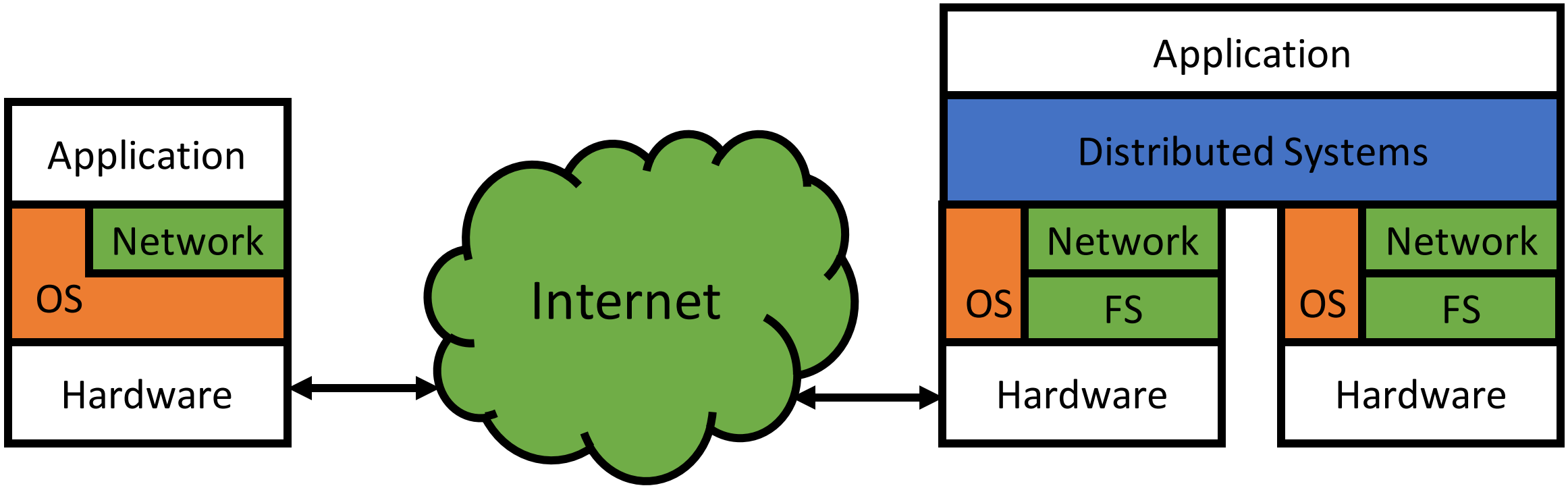
Systems Stack (terminal)



Systems Stack (Firefox)

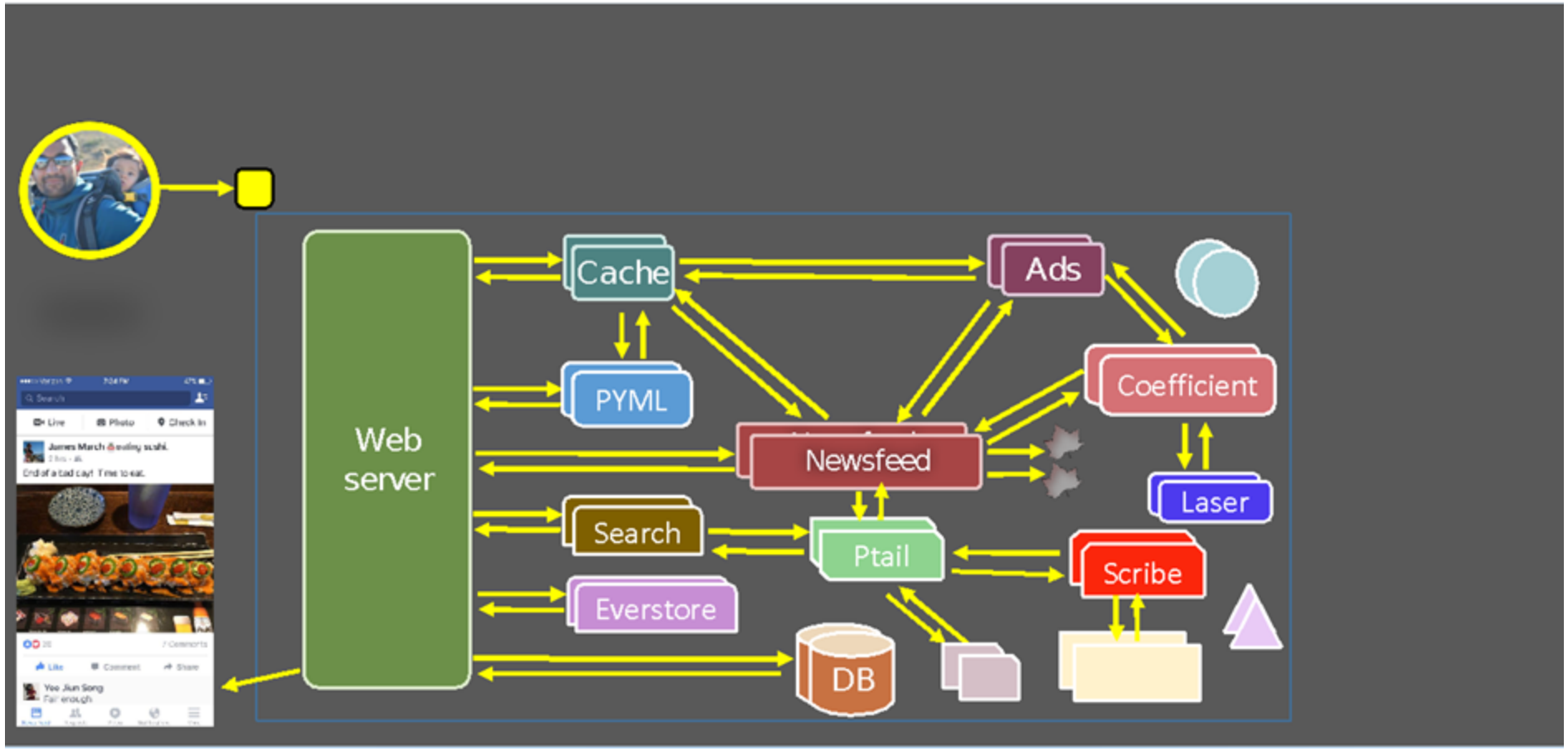


Systems Stack (Firefox to Wikipedia)



So Many Systems…

Each user request touches hundreds of systems

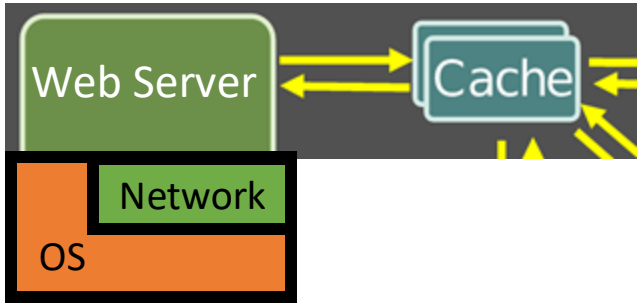


[Slide from Kaushik Veeraraghavan Talk's on Kraken at OSDI

Systems Are Everywhere!

- People use applications
  - Applications are built on systems
    - On systems on systems on systems…

- If you're building applications
  - Useful to understanding underlying systems
    - What could be causing X?
    - Why can't they do Y?
    - What can I trust Z to do or not?



- If you're building systems ☺
  - That's what this is all about!
  - Useful to understanding your underlying systems

Why do we build systems?

- **Sharing**: Mediates access to shared resources
- **Portability:** Abstract differences in underlying implementations
- **Safety:** Isolate resources and other applications from faulty apps
- **Abstraction:** Make complex resources easier to use

Build you a Netflix for Great Good

- Video storage
- Video encoding
- Video delivery over network
- User authentication
- Stream authorization
- Metadata indexer
- Search & recommendations
- Comments/reviews
- …

Build you a [mini-]Netflix for Great Good

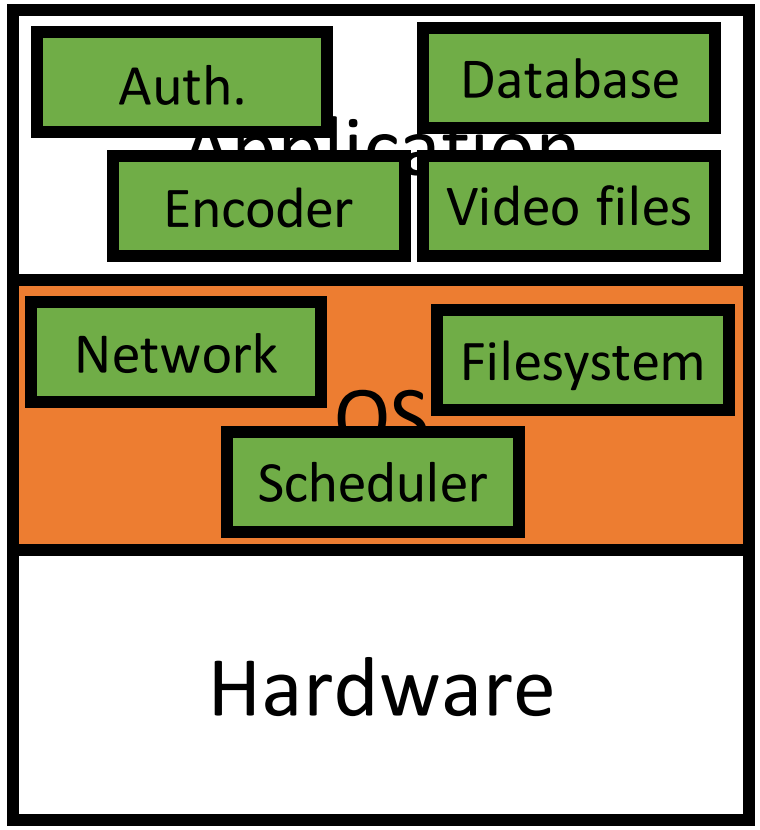
- How many users? *~5*
  - Can everyone access everything? *Yes*
- How many movies? *~100*
- How large are movies? *~20GB/hour x ~2 hours = ~40GB/movie*
- Max simultaneous streams? *~2*
- Lots of metadata to search? *No! Just 100 movies, a tiny list*
- How are movies acquired? *Hrmm.... let's ignore that ;)*

Build you a [mini-]Netflix for Great Good

- 5 users
- 100 movies
- 40GB per movie
- <=2 streams

- How much storage?
  - 100 * 40GB = ~4TB
- How much bandwidth?
  - 20GB / 3600 * 2 = ~91Mbps
  - Less with encoding
- How much CPU?
  - May be best to encode each stream on-the-fly
  - Only 2 streams, so a few cores at full capacity should work

Build you a [mini-]Netflix for Great Good



- ~4TB storage
- ~91Mbps max bandwidth
- ~8 cores

Build you a [large-]Netflix for Great Good

- How many users? *millions*
  - Can everyone access everything? *No*
- How many movies? *~1000s*
- Max simultaneous streams? *~1000s*
- Lots of metadata to search? *Yes! Milliions of movies*
- How are movies acquired? *let's stil ignore that ;)*

Why Are Systems Challenging? Part-1a

- Correctness
  - Incorrect system => incorrect applications
  - Correctly implement interface's guarantees
- Performance
  - Slow system => slow applications
  - Make system fast enough
- Security
  - Insecure system => insecure applications
  - Build security into the system

Why Are Systems Challenging? Part-1b

- Distributed storage system that keeps data forever (e.g., videos)

- Correctness
  - Accurately retain data forever. Really delete data on deletes.

- Performance
  - Fast and highly concurrent.

- Security
  - Only allow authorized users to retrieve data

Why Are Systems Challenging? Part-2a

- How general should an interface be?
  - More general => supports more application-level functionality
  - Less general => easier to implement, easier correctness, better performance, easier security
- How portable should an interface be?
  - More portable => supports more underlying resources
  - Less portable => …
- Design tradeoffs!

Why Are Systems Challenging? Part-2b

- Distributed cache that provides fast access to popular data

- How **general** should an interface be?
  - Read(key)
  - Write(key, value)
  - Read_transaction(<keys>)
  - Write_transaction(<keys>)
  - Read_and_write_transaction(<read_keys>, <write_keys>)
  - …

- Design tradeoffs!

Why Are Systems Challenging? Part-2c

- Distributed cache that provides fast access to popular data

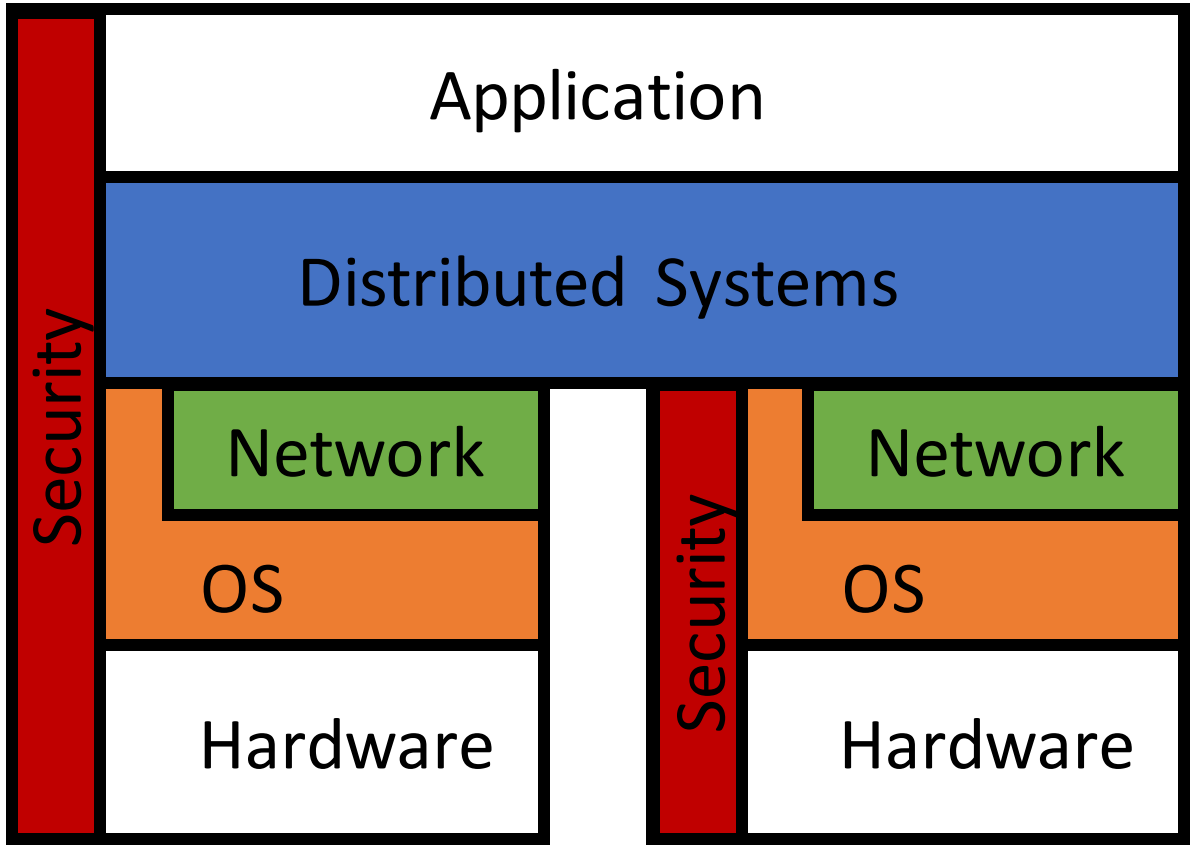
- How **portable** should an interface be?
  - Cache in DRAM
  - Cache on SSD
  - Cache on NVM
  - Cache on HDD
  - …

- Design tradeoffs!

General vs Portable Interfaces

- Cache A:
  - Read, Write on DRAM, SSD, NVM, HDD
- Cache B:
  - Read, Write, Read Transaction, Write Transaction on SSD
- Which cache is more general? More portable?
- PL Example: Javascript vs Assembly?

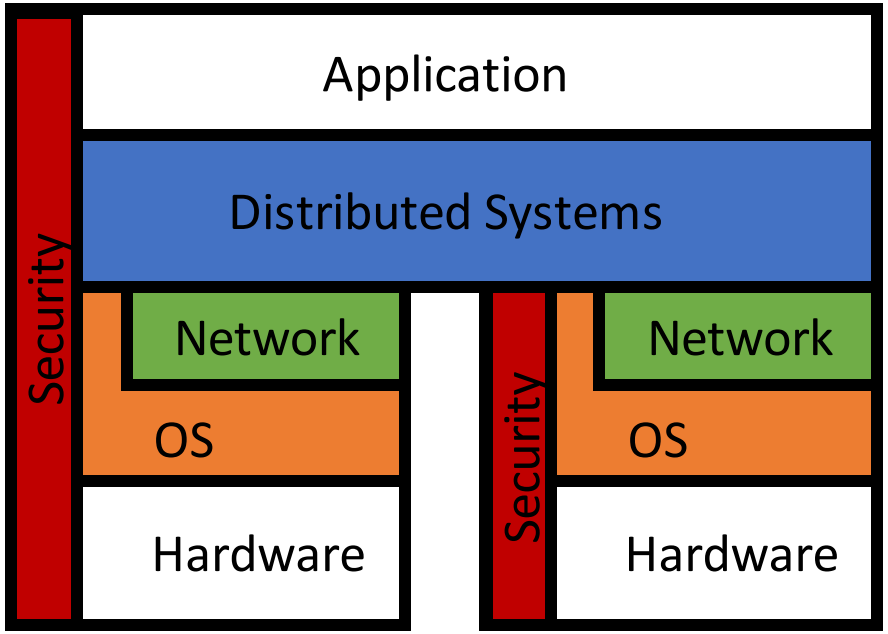
Systems We Will Cover In This Class



- Distributed Systems
- Networking
- Operating Systems
- Security

Summary

- Systems abstract underlying resources
- Systems are **everywhere**
- Systems are challenging and interesting and cool
- This class is about systems: details next lecture



Why Do I Love Systems?!

- Work on the “hard” problems, so applications don’t have to
- Correctness as a puzzle: reason through all corner cases
- Performance is a different type of puzzle:
  - Where are bottlenecks, how to speed them up?
- Art of reasoning about tradeoffs: e.g., Interface vs. Performance
- Multiplicative impact: improving systems improves all apps built on them