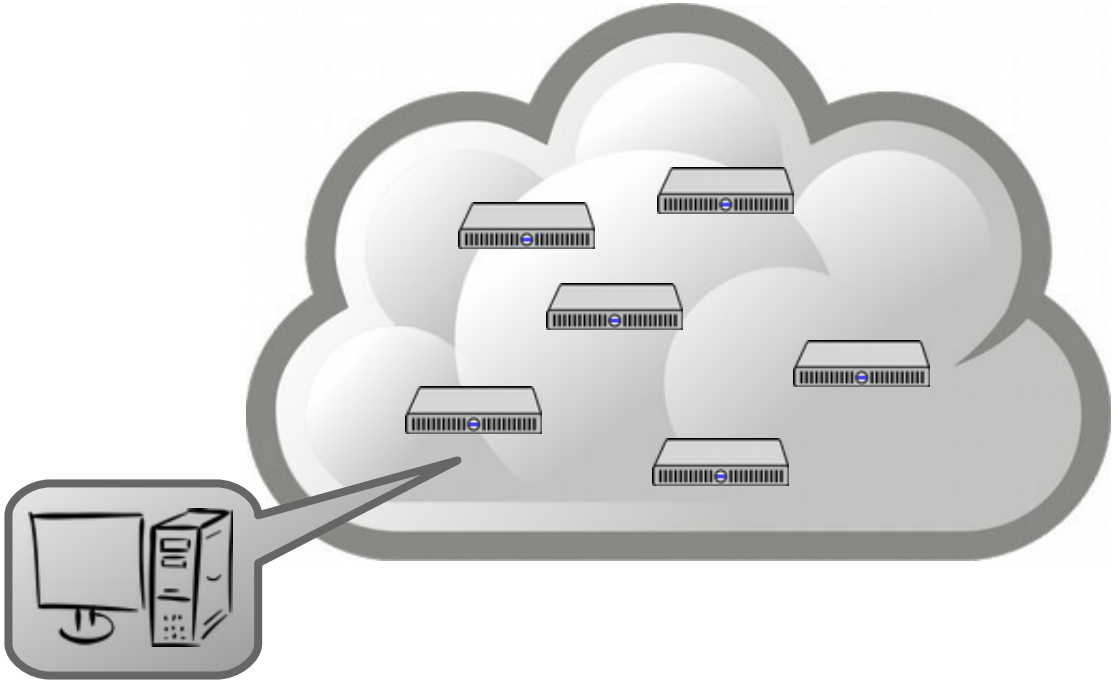
CS 470
Spring 2019

Mike Lam, Professor



Virtualization and Cloud Computing

Content taken from the following:

A. Silberschatz, P. B. Galvin, and G. Gagne. "*Operating System Concepts, 9th Edition*" (Chapter 16)

Various online sources

Problem

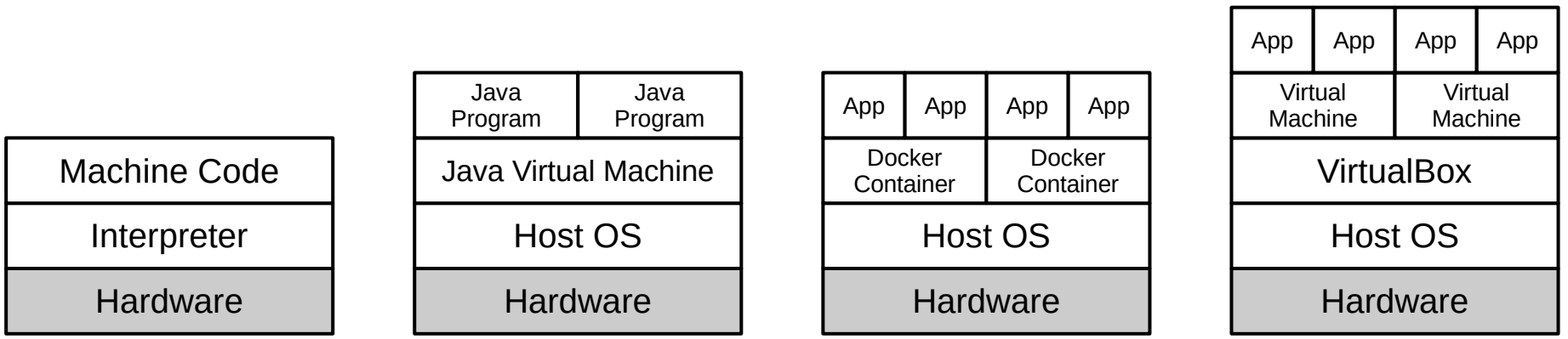
- Distributed systems are now ubiquitous
  - It's hard to provide any software service at a modern scale from a single server
    - (Although if you can, you SHOULD!)
  - Most companies don't need or want to manage their own hardware
    - High up-front costs, security vulnerabilities, etc.
  - Solution: abstraction!
    - In particular, abstracting away the hardware
      - Sometimes software too
    - Usually referred to as virtualization

Virtualization

- Virtual environment: abstract machine (guest) implemented on top of a physical machine (host)
  - Requires some kind of interpretation layer
- Various goals
  - Emulation: run programs designed for one architecture on another
  - Isolation: run programs in a sandbox
  - Scalability: spawn/destroy instances dynamically
  - Automation: reduce tedium and mistakes during deployment
  - Reproducibility: suspend/resume snapshots or configurations

Virtualization

- Various levels
  - Circuits / CPU (microcode emulating machine code)
  - Storage (e.g., RAID)
  - Networks (e.g., NAT or overlays)
  - Runtime environment (e.g., Java VM or Microsoft .NET)
  - Operating system (e.g., Docker)
  - Full desktops (e.g., QEMU, VMware or VirtualBox)



Hypervisors

- Native hypervisors (“type 1”)
  - Run directly on the host’s hardware in kernel mode
  - Sometimes as part of a general-purpose OS
  - Examples: VMware ESX, Microsoft Hyper-V, Oracle VM Server, Xen
- Hosted hypervisors (“type 2”)
  - Runs as a process inside the host OS
  - Often hardware-accelerated (e.g., Intel VT-x or AMD-V)
  - Examples: VMware Workstation, VirtualBox, QEMU
  - Sometimes referred to as an emulator if it virtualizes an entirely different architecture
    - Example: Project 4 in CS 261 is a Y86-64 emulator for x86-64

Windows: 3.1, 95, and 10 on 8.1

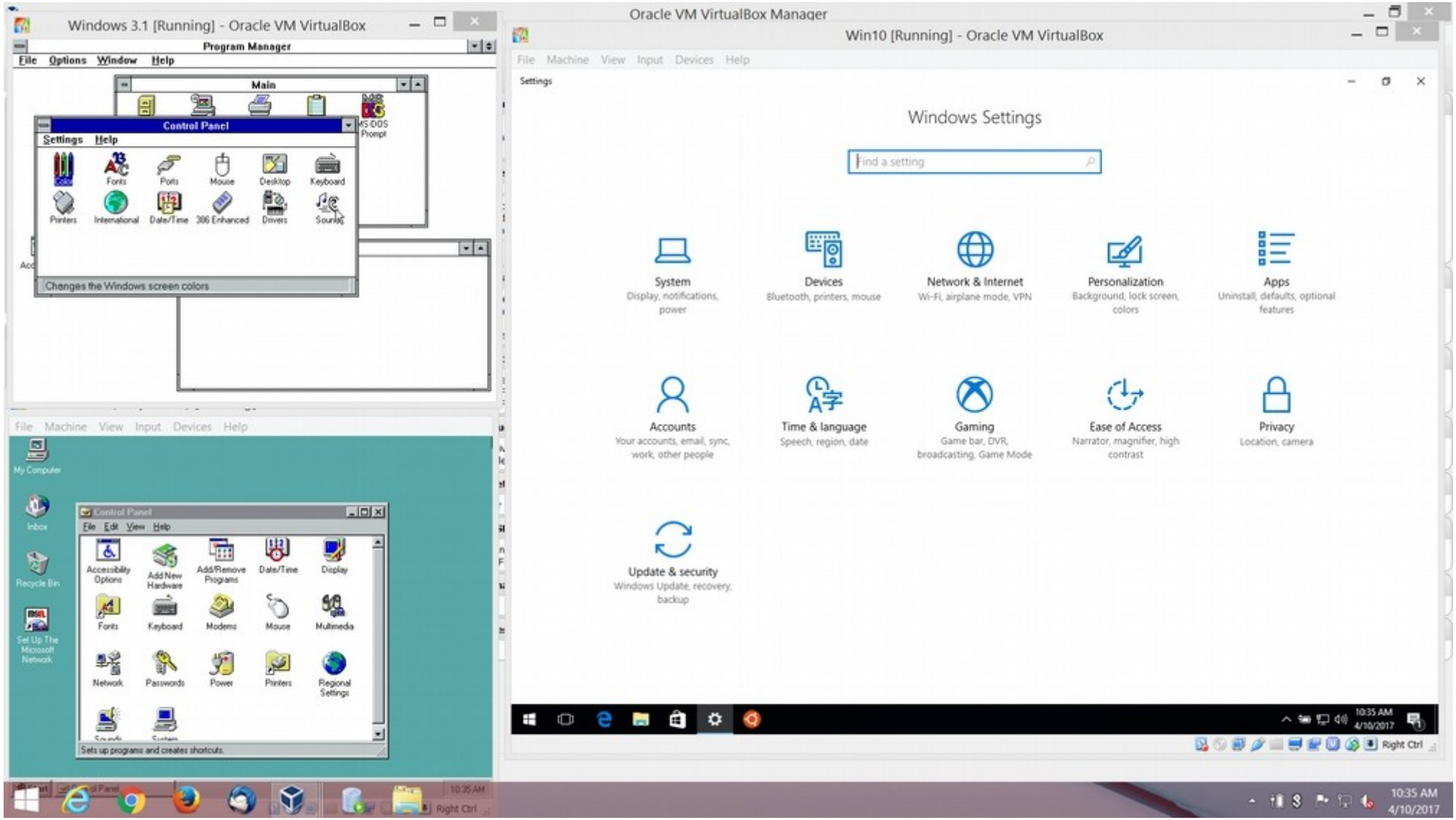


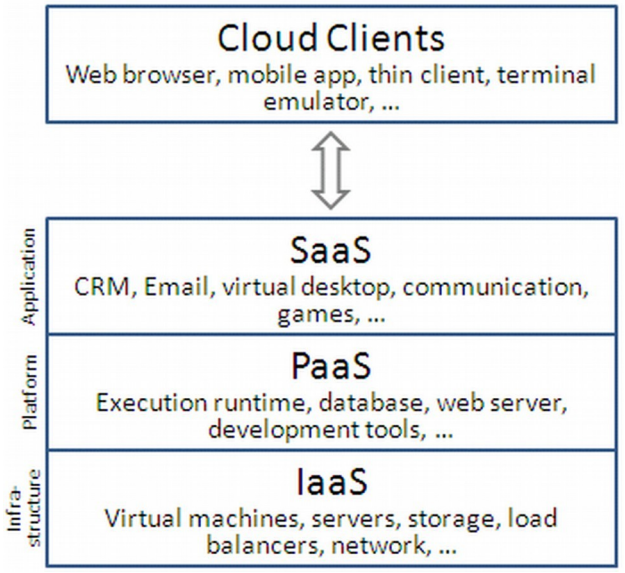
Image courtesy of Mike Ripley (JMU Infrastructure and Database Support)

OS-level virtualization

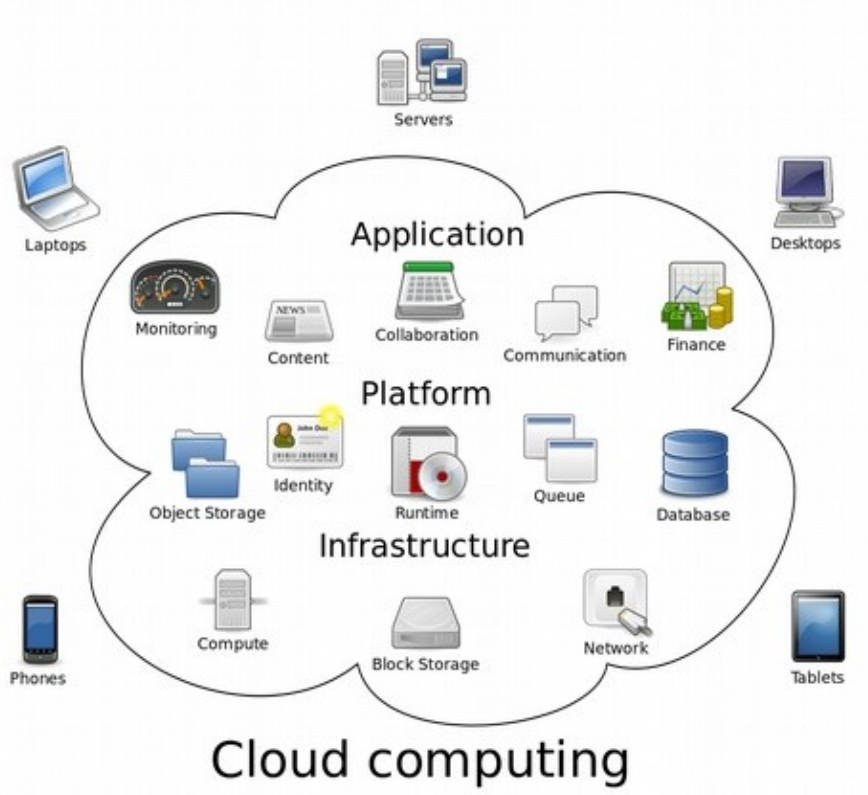
- Container: isolated user space for a program and its dependencies
  - Multiple user spaces implemented at the kernel level
  - Alternative viewpoints
    - Virtual memory extended to files and libraries
    - Sandboxed, lightweight, app-specific VMs that run natively (no guest OS)
    - “Packages” for a single program's file system
  - Portable: code in the container will run the same everywhere
  - Performant: minimal overhead vs. running natively
  - Examples: chroot, FreeBSD jail, Docker

Cloud computing

- Infrastructure-as-a-service (IaaS)
  - Cloud provider owns the hardware (servers and NAS)
  - Clients provide virtual software images (VMware, Docker, etc.)
  - Inherent scalability (including dynamic provisioning) and fault-tolerance
  - Amazon EC2, Google Cloud, Microsoft Azure, Rackspace

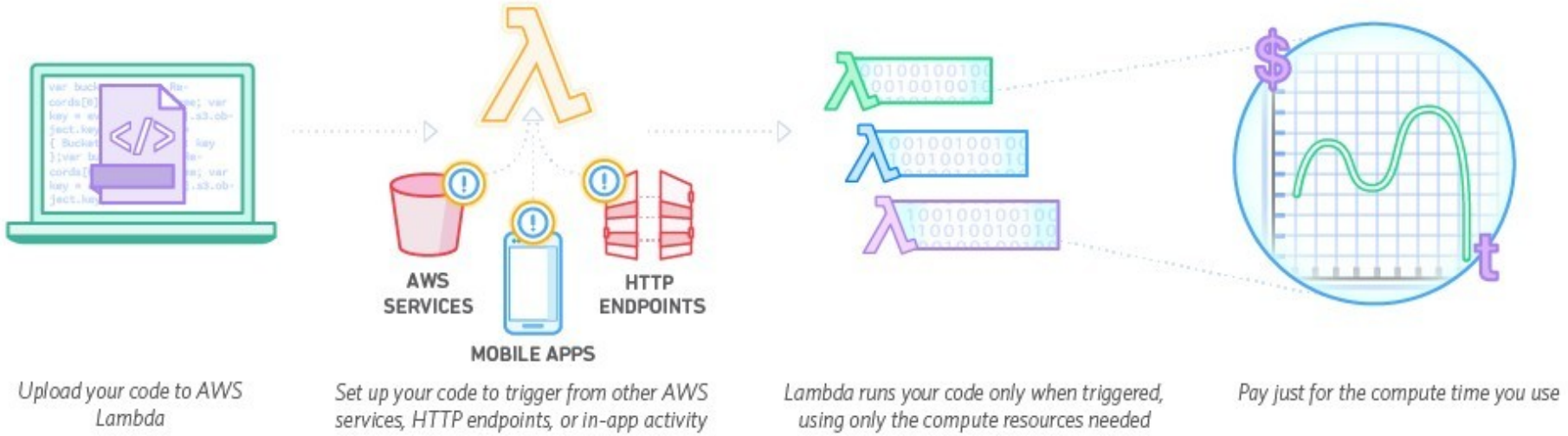


from `https://en.wikipedia.org/wiki/Cloud_computing`



Serverless computing

- Serverless computing
  - Pay for compute time, not a particular host or VM
  - FaaS: Function as a Service (another layer of abstraction!)
  - There's still a server, but the user doesn't interact with it directly
  - Code must be written using a supported language



https://aws.amazon.com/lambda/

Cloud engineering

- Emerging/developing field
  - Combines computer system engineering (EE), software engineering (CS), and computer information systems (business)
  - Focus on IaaS/PaaS/SaaS/FaaS applications
    - Often with a “big data” focus
  - Goals: performance, scalability, security, reliability
  - Challenge: integrating multiple solutions and layers
  - First IEEE International Conference on Cloud Engineering (IC2E) in March 2013

Thursday

- Cloud computing exercise
- Sign up for AWS account and apply for Educate credits:
  - `http://aws.amazon.com/`
  - `https://aws.amazon.com/education/awseducate/`

Also: check your posters!