CS 4530 Software Engineering

Module 13: Principles and Patterns of Cloud Infrastructure

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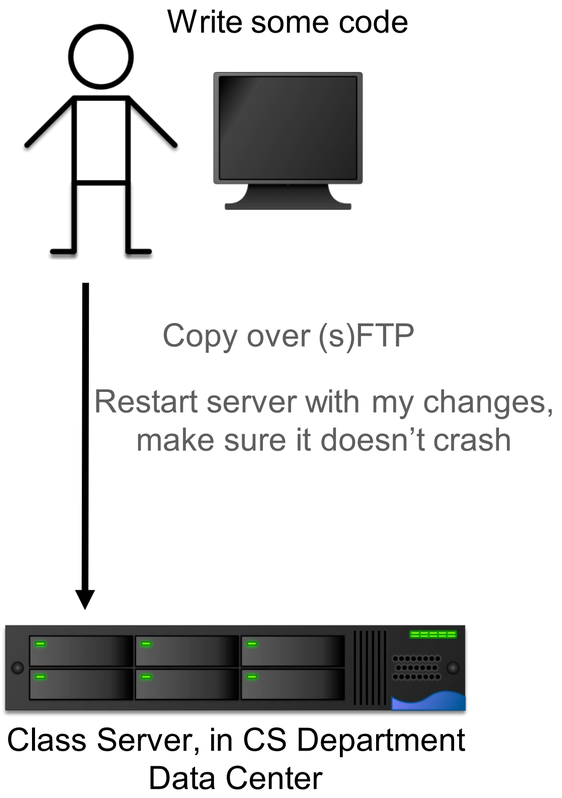
Learning Objectives for this Lesson

By the end of this lesson, you should be able to…

- Describe what “cloud” computing is
- Understand the role of virtual machines and containers in cloud computing
- Deploy a web app to the cloud

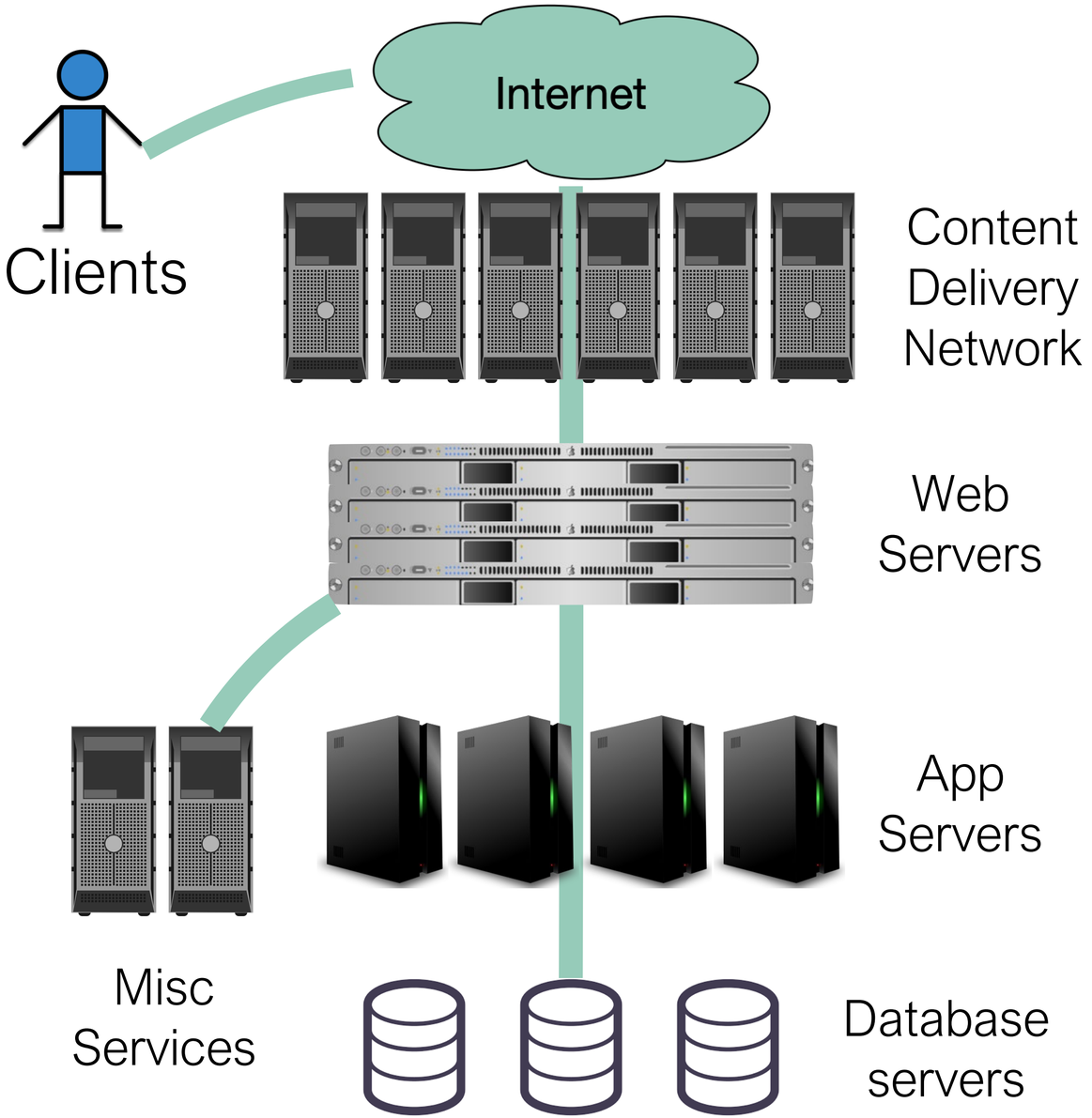
How to Deploy Web Applications?

- What we need:
  - A server that can run our application
  - A network that is configured to route requests from an address to that server
- Questions to think about:
  - What software do we need to run besides our application code?
  - Where does this server come from?
  - Who else gets to use this server?
  - Who maintains the server and software?



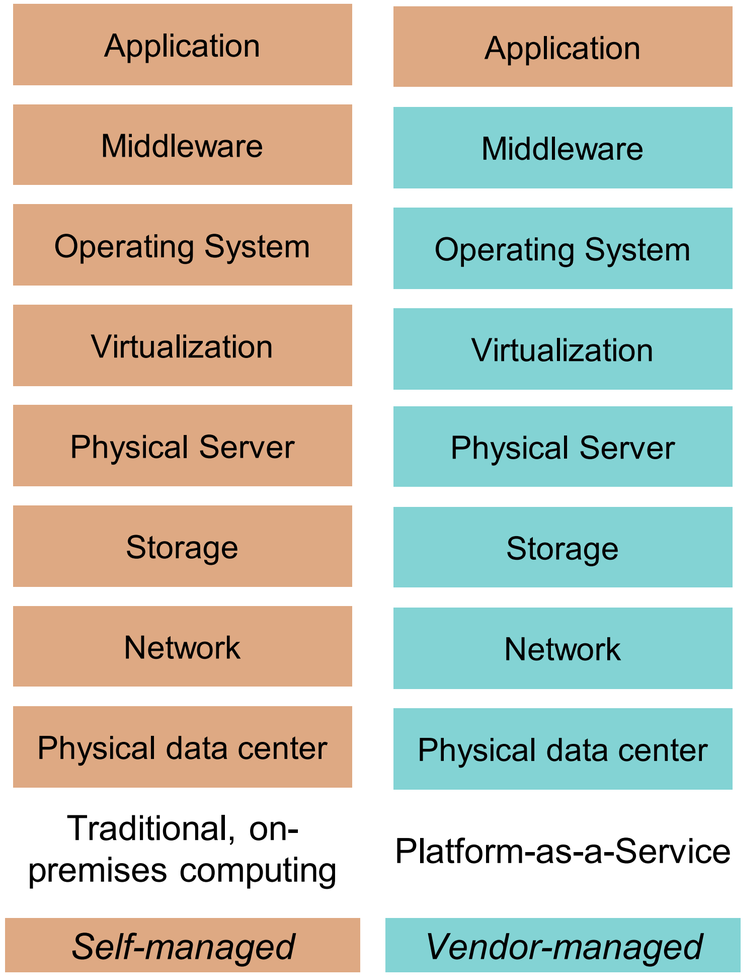
Many Applications Rely on Common Infrastructure

- Content delivery network: caches static content “at the edge” (e.g. cloudflare, Akamai)
- Web servers: Speak HTTP, serve static content, load balance between app servers (e.g. haproxy, traefik)
- App servers: Runs our application
- Misc services: Logging, monitoring, firewall
- Database servers: Persistent data



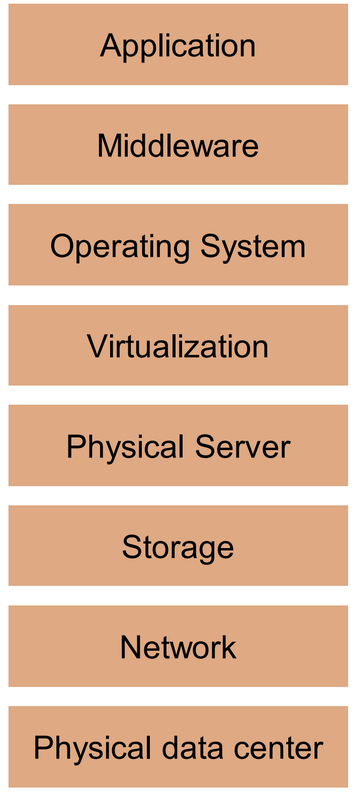
What is cloud infrastructure?

- Our apps run on a “tall stack” of dependencies
- Traditionally this full stack is self-managed
- Cloud providers offer a range of products that manage parts of that stack for us:
  - “Infrastructure as a service”
  - “Platform as a service”
  - “Software as a Service”



Cloud Infrastructure Creates Economies of Scale

- **At the physical level:**
  - Multiple customers' physical machines in the same data center
  - Save on physical costs (centralize power, cooling, security, maintenance)
- **At the physical server level:**
  - Multiple customers' virtual machines in the same physical machine
  - Save on resource costs (utilize marginal computing capacity)
- **At the application level:**
  - Multiple customer's applications hosted in same virtual machine
  - Save on resource overhead (eliminate redundant infrastructure like OS)



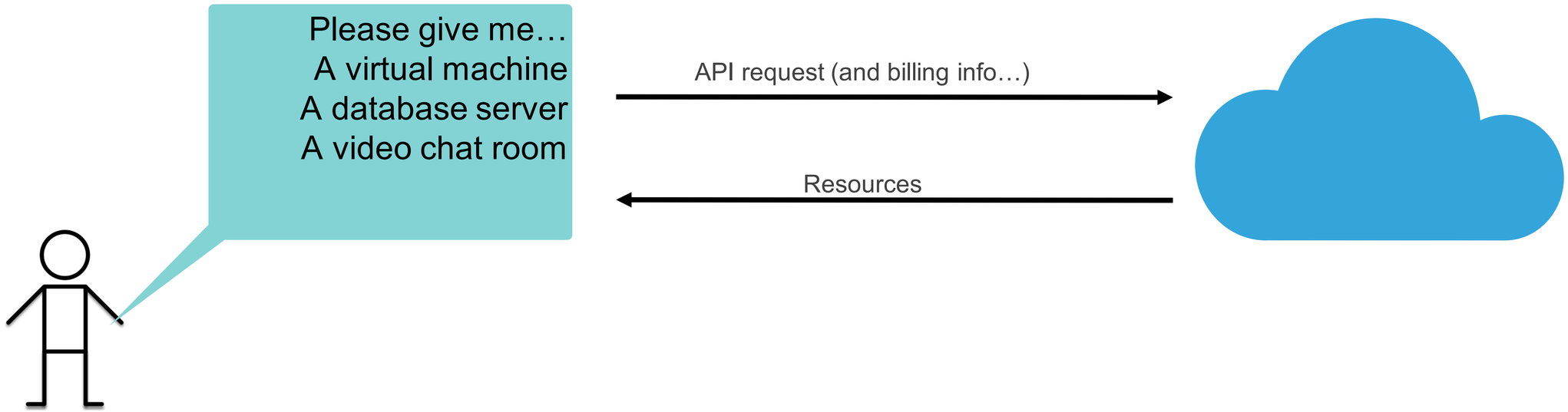
Multiple customers could share each of these tiers

Cloud Infrastructure Scales Elastically

- “Traditional” computing infrastructure requires capital investment
  - “Scaling up” means buying more hardware, or maintaining excess capacity for when scale is needed
  - “Scaling down” means selling hardware, or powering it off
- Cloud computing scales elastically:
  - “Scaling up” means allocating more shared resources
  - “Scaling down” means releasing resources into a pool
  - Billed on consumption (usually per-second, per-minute or per-hour)

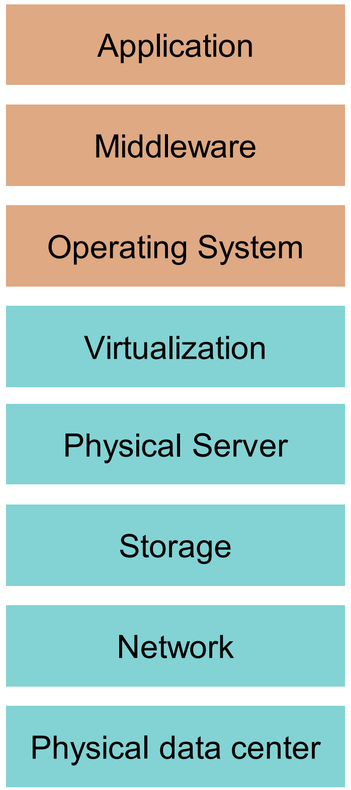
Cloud Infrastructure is On-Demand Access to Resources

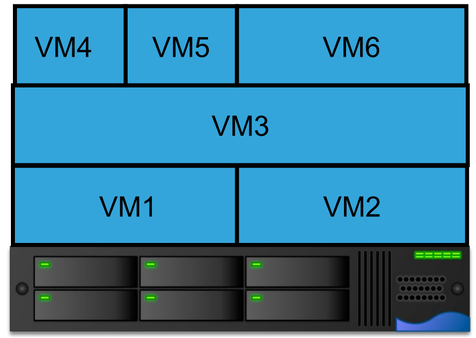
- Vendor provides a service catalog of "**X as a service**" abstractions
- Web interface or API allows us to provision resources on-demand



Infrastructure as a Service: Virtual Machines

- Rely on *virtualization* to slice a single large server into many smaller machines
- OS provides resource limits and quality guarantees per-VM
- Each VM runs its **own operating system**
- Examples: Amazon EC2, Google Compute Engine, Azure VMs





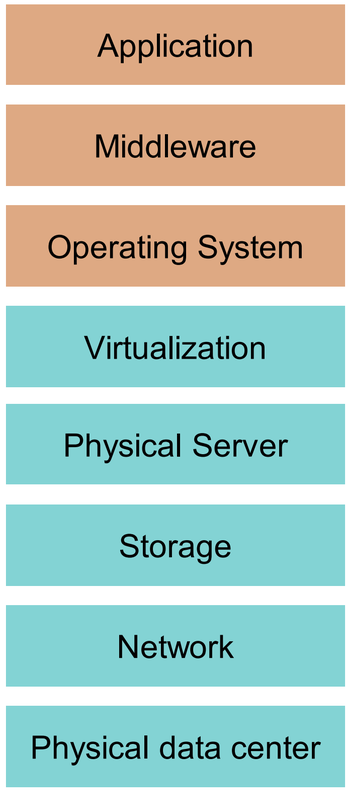
A single server in the cloud

IaaS

Self-managed | *Vendor-managed*

Virtual Machines are a Core Abstraction

- **Multi-Tenancy**: Multiple customers sharing same physical machine, oblivious to each other
- Decouples the entire application from physical machine: virtualization service can provide “live migration”
- Faster to provision and release than physical machines (max ~10 minutes vs ~hours/days)



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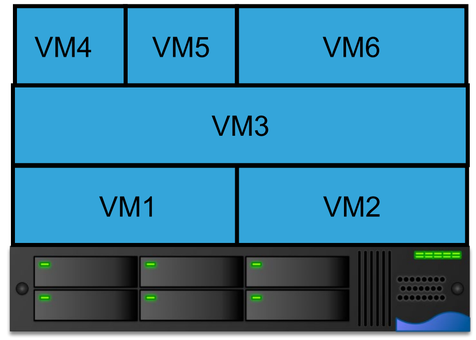
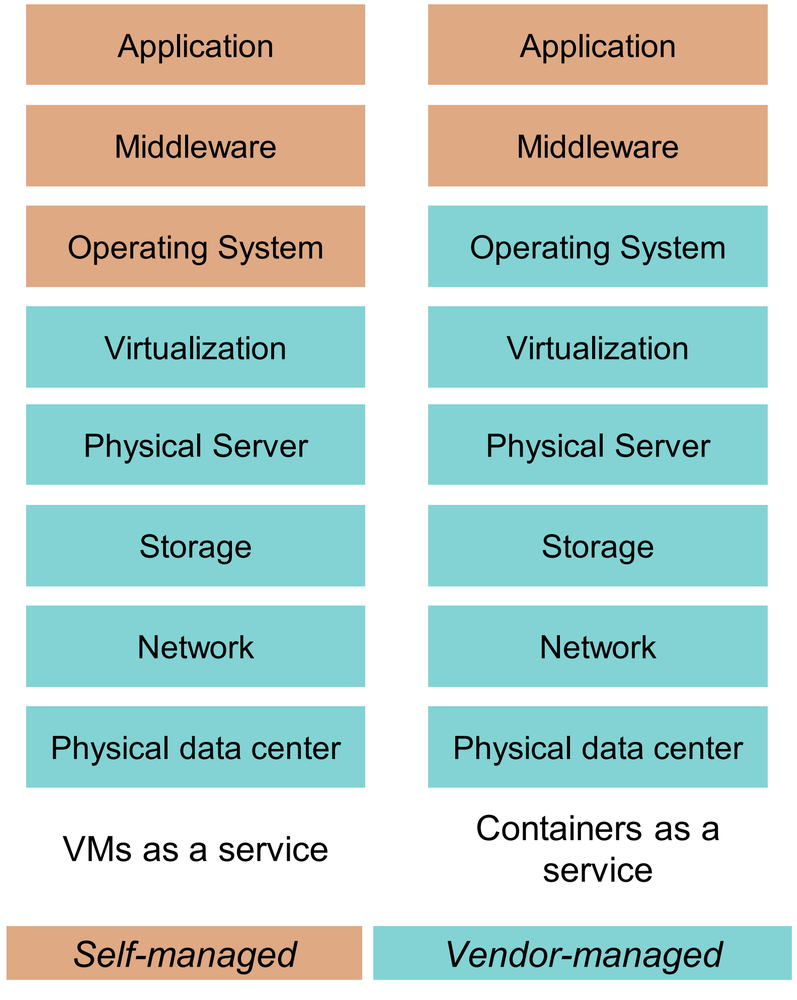


A single server in the cloud

Self-managed | *Vendor-managed*

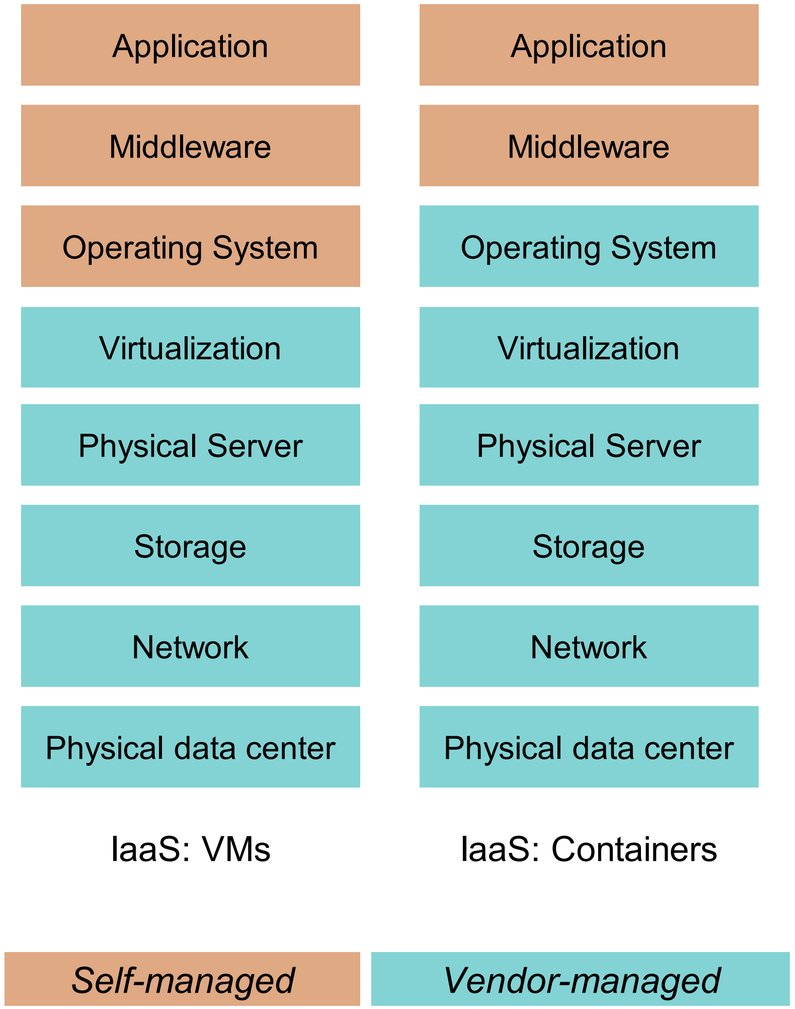
Virtual Machines to Containers

- Each VM contains a full operating system
- **What if** each application could run in the same (overall) operating system? Why have multiple copies?
- Advantages to smaller apps:
  - Faster to copy (and hence provision)
  - Consume less storage at rest



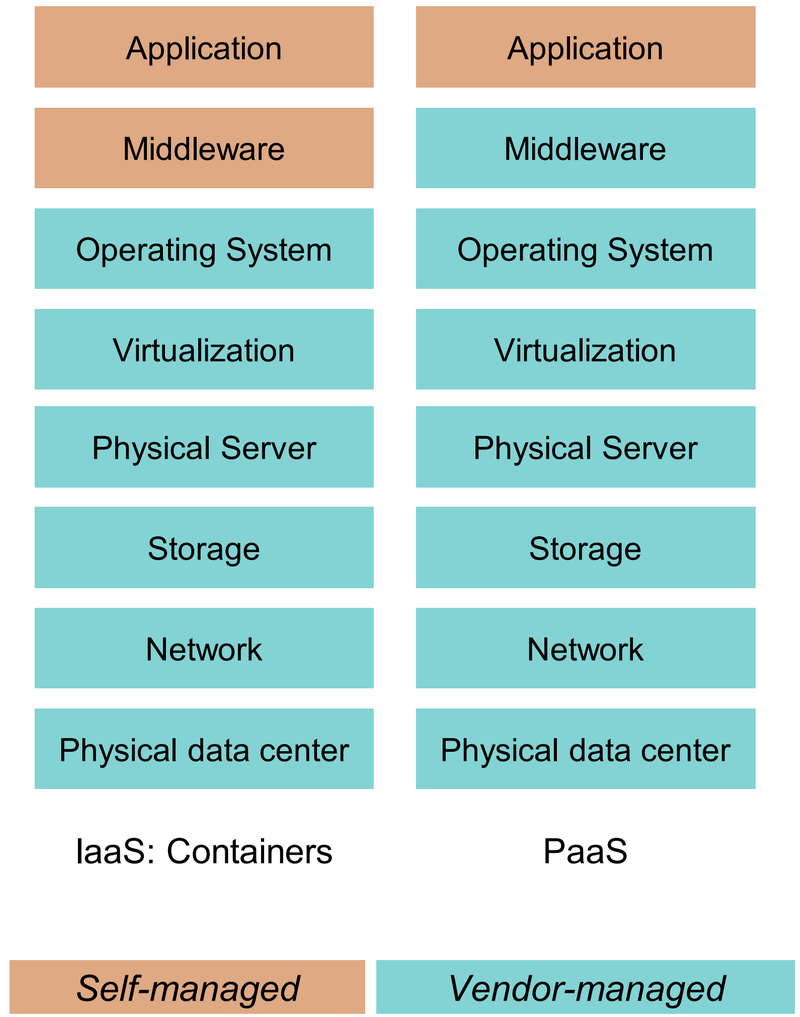
Infrastructure as a Service: Containers

- Each application is encapsulated in a “lightweight container,” includes:
  - System libraries (e.g. glibc)
  - External dependencies (e.g. nodejs)
- “Lightweight” in that container images are smaller than VM images - multi tenant containers run in the OS
- Cloud providers offer “containers as a service” (Amazon ECS Fargate, Azure Kubernetes, Google Kubernetes)



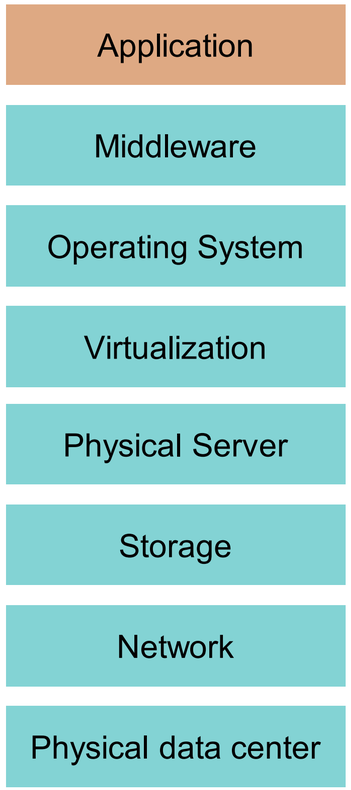
Many Apps Rely on Common Middleware

- Middleware is the stuff between our app and a user's requests:
  - Load balancer: route client requests to one of our app containers
  - Application server: run our handler functions in response to requests from load balancer
  - Monitoring/telemetry: log requests, response times and errors
- Cloud vendors provide managed middleware platforms too: "Platform as a Service"



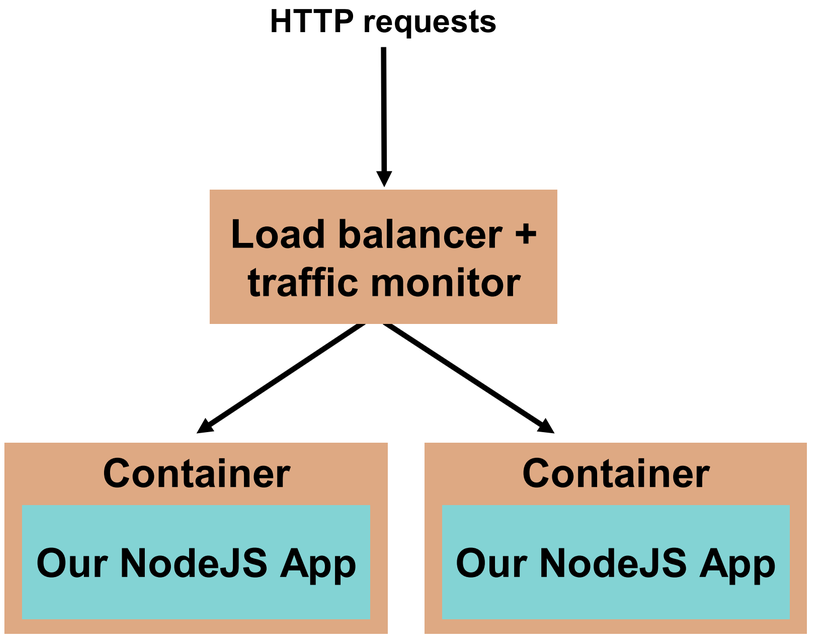
PaaS is the Simplest Choice for App Deployment

- Platform-as-a-Service (PaaS) products provide common components that most apps need, fully managed by the vendor: load balancer, monitoring, application server
  - Examples: Heroku, AWS Elastic Beanstalk, Google App Engine
- Some PaaS products are designed to deploy apps as *single functions* that are invoked when a web request is made, and don't run otherwise ("function-as-a-service")
  - Examples: AWS Lambda, Google Cloud Functions, Azure Functions
- Some PaaS products also provide databases and authentication
  - Examples: Google Firebase, Back4App



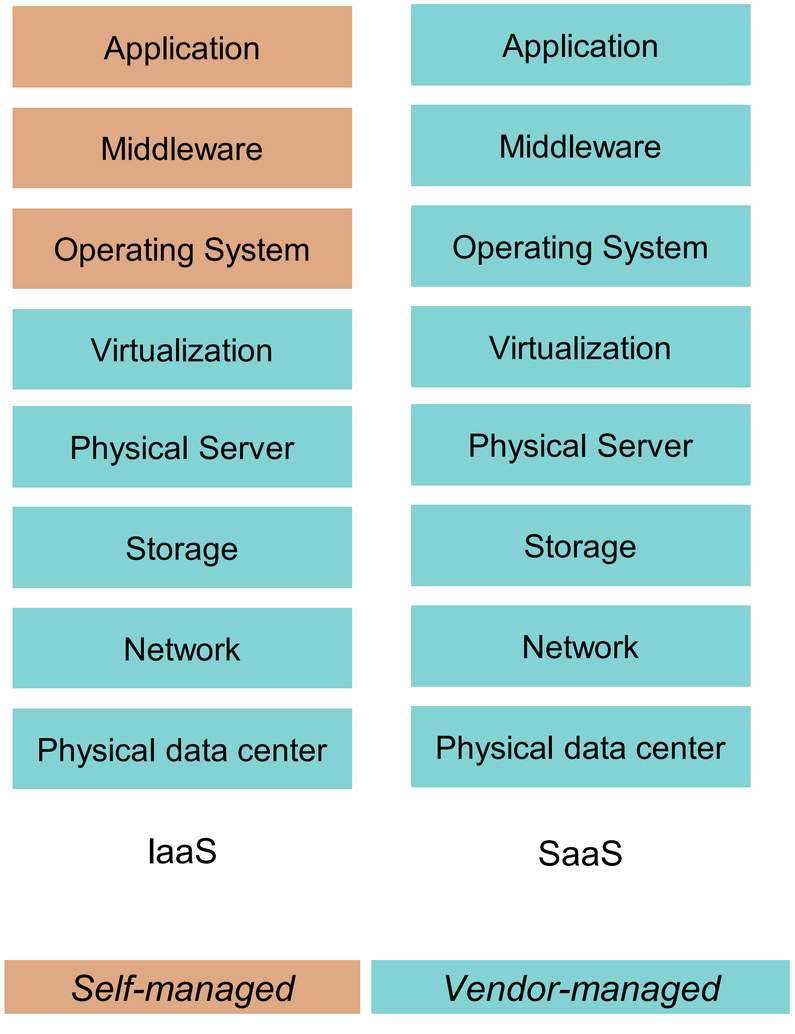
Heroku is a Platform as a Service

- Takes as input: a web app (e.g. NodeJS app)
  - No need to provide a container, entry point to our code is enough, e.g. “npm start”
- Provides: hosted web app at our choice of URL, with ability to scale resources up/down on-demand
  - Load balancer is fully managed by Heroku, makes scaling transparent
  - Can auto-scale down to use no resources, then only launch a container once a request has been received
  - Dashboard provides monitoring/reporting



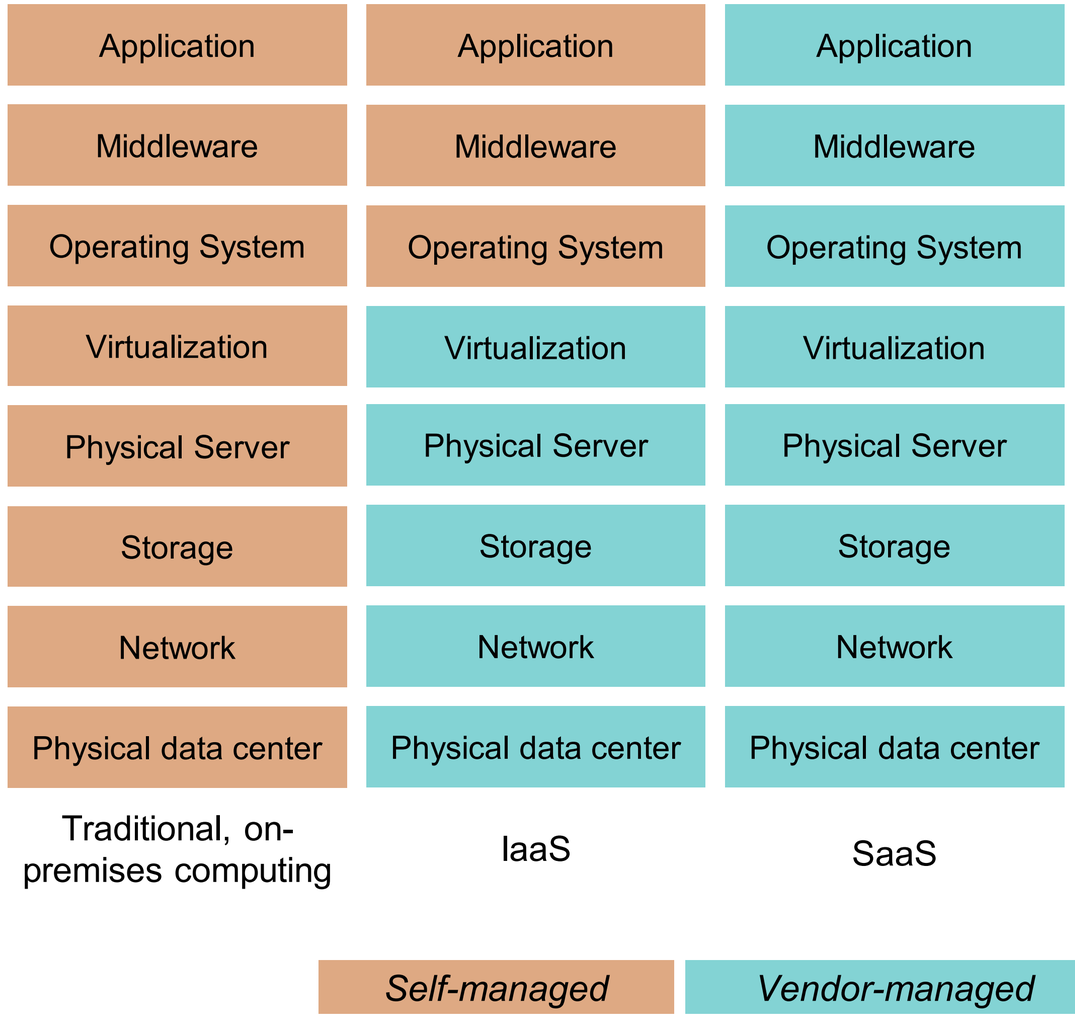
Software as a Service is Fully Managed

- Many applications require the *same* software components, cloud providers offer to operate those components for us
- Cloud providers also develop custom software for the market, offered only as a service
- Examples:
  - PostgreSQL database (open source product)
  - Twilio Programmable Video (proprietary video chat product)



Self-managed vs Vendor-managed Infrastructure

- Benefits to vendor-managed options:
  - Greater opportunity to reduce resource consumption, improve resource utilization
  - Less management burden
  - Less capital investment, greater operating expenses
- Benefits to self-managed options:
  - Greater flexibility and avoid vendor lock-in
  - More capital investment, less operating expenses



Cloud Infrastructure is Best Suited for Variable Workloads

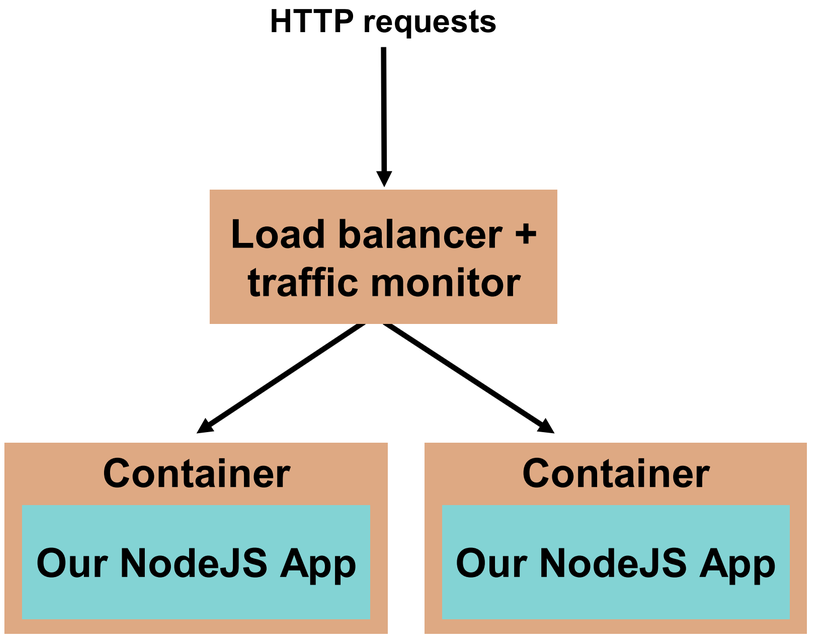
- Consider: Does your workload benefit from ability to scale up/down?
- Example: need to run 300 VMs, each with 4 vCPUs, 16GB RAM
- Private cloud: Dell PowerEdge Pricing (AMD EPYC 64 core CPUs)
  - 7 servers, each with 128 cores/256 threads, 512GB RAM, 3 TB storage = $162,104
- Public cloud: Amazon EC2 Pricing (M5.xlarge instances, $0.121/VM-hour)
  - 10 VMs for 1 year + 290 VMs for 1 month: $36,215.30
  - 300 VMs for 1 year: $317,988

Public clouds are not the only option

- “Public” clouds are connected to the internet and available for anyone to use
  - Examples: Amazon, Azure, Google Cloud, DigitalOcean
- “Private” clouds use cloud technologies with on-premises, self-managed hardware
  - Cost-effective when a large scale of baseline resources are needed
  - Example management software: OpenStack, VMWare, Proxmox, Kubernetes
- “Hybrid” clouds integrate private and public (or multiple public) clouds
  - Effective approach to “burst” capacity from private cloud to public cloud

Activity: Deploying Transcript Server to Heroku

- Heroku is one of the easiest platforms to use to host web apps
- Objective: deploy our (completed) transcript server to Heroku
- Download the handout from the module 13 page
- Handout has detailed README



Review: Learning Objectives for this Lesson

You should now be able to…

- Describe what “cloud” computing is
- Understand the role of virtual machines and containers in cloud computing
- Deploy a web app to the cloud