CI and Cloud Computing

17-313 Fall 2024

Foundations of Software Engineering

https://cmu-17313q.github.io

Eduardo Feo Flushing

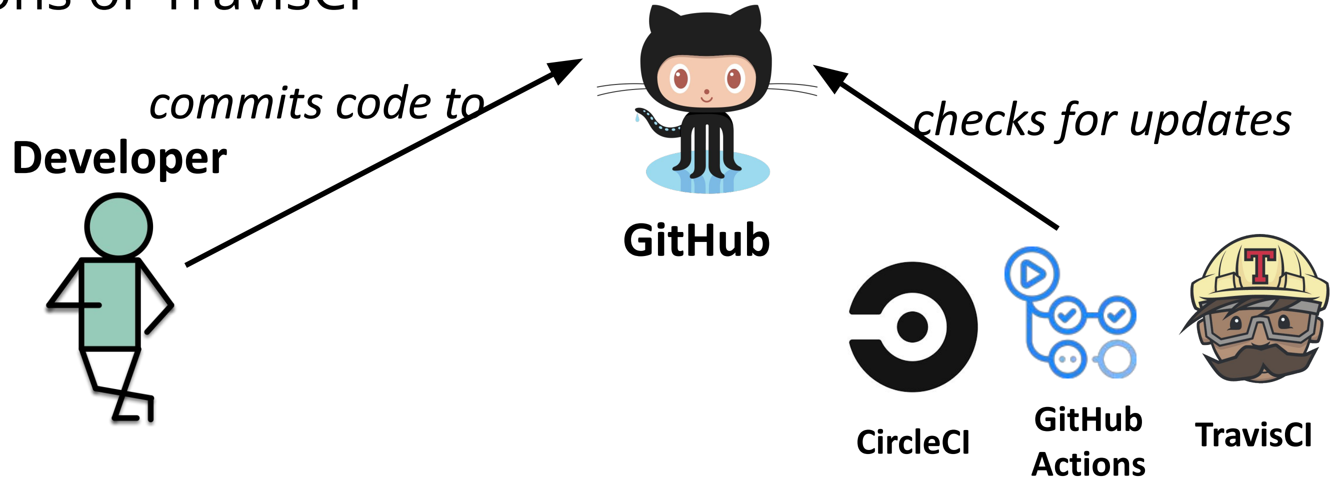
Review: Continuous Integration

Observation

CI helps us catch errors before others see them

CI is triggered by commits, pull requests, and other actions

Example: Small scale CI, with a service like CircleCI, GitHub Actions or TravisCI



Runs build for each commit

Agile values fast quality feedback loops

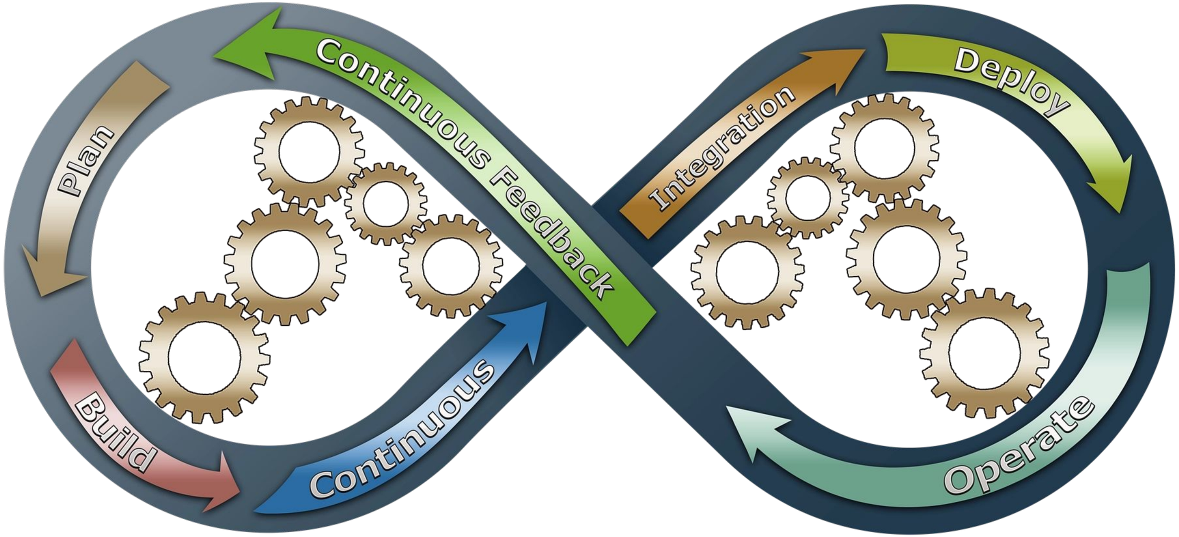
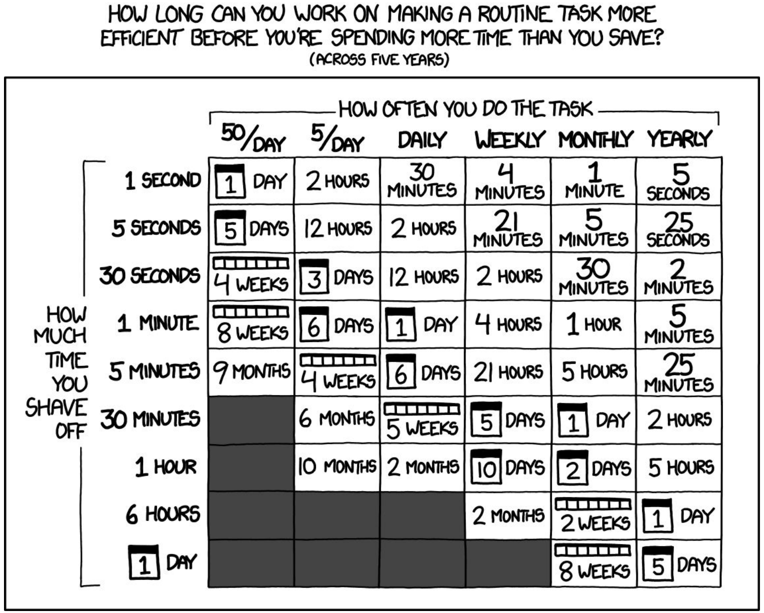


Image source: https://sdtimes.com/devops/feedback-loops-are-a-prerequisite-for-continuous-improvement/

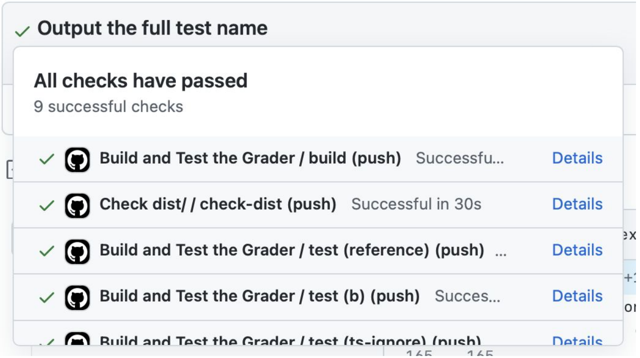
Automating Feedback Loops is Powerful

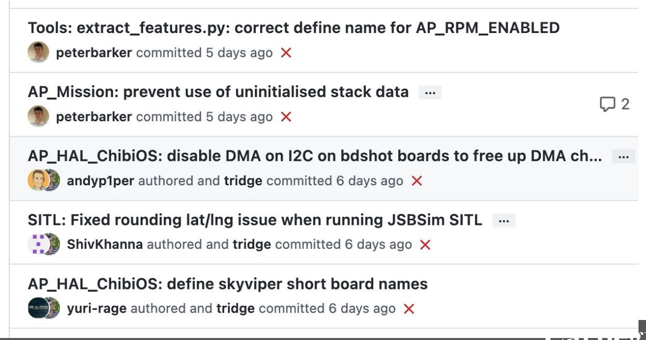
Consider tasks that are done by *dozens* of developers (e.g. testing/deployment)



Attributes of effective CI processes

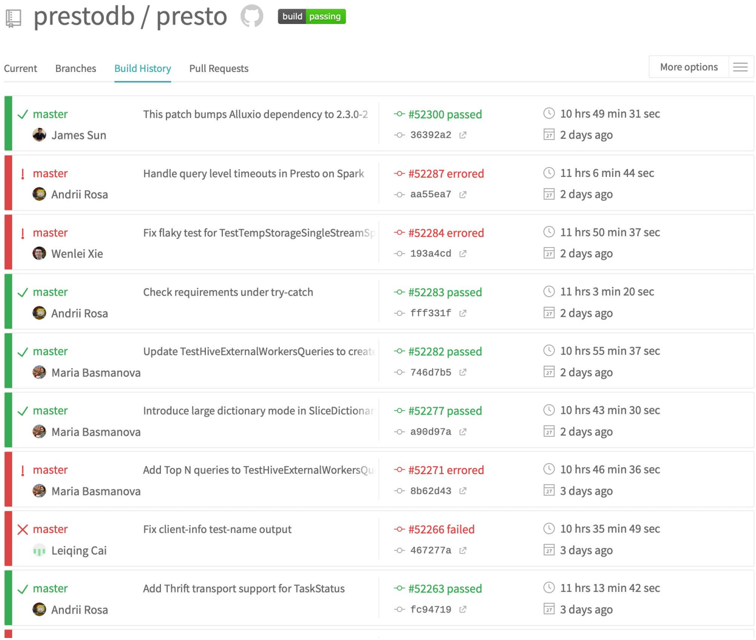
- Policies:
  - **Do not** allow builds to **<u>remain broken</u>** for a long time
  - CI should run for every change
  - CI should not completely replace pre-commit testing
- Infrastructure:
  - CI should be fast, providing feedback within minutes or hours
  - CI should be repeatable (**deterministic**)





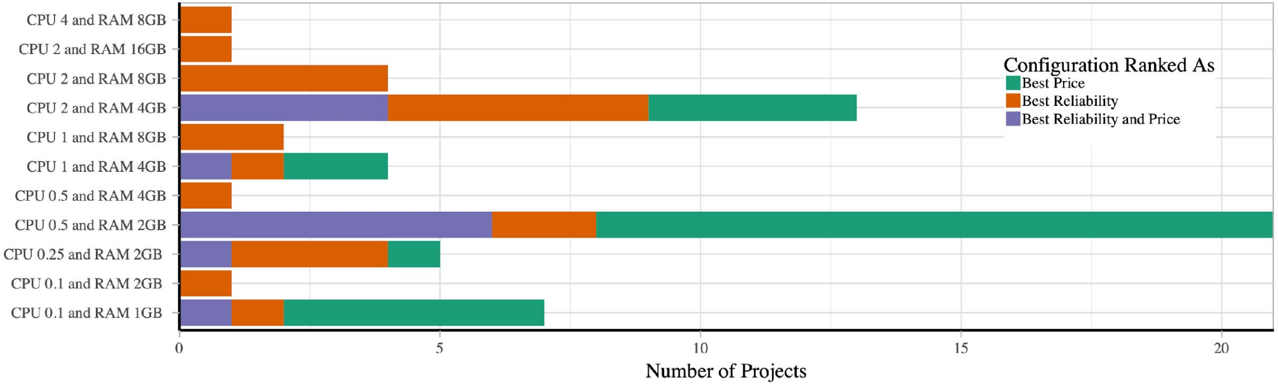
Effective CI processes are run often enough to reduce debugging effort

- Failed CI runs indicate a bug was introduced, and caught in that run
- More changes per-CI run require more manual debugging effort to assign blame
- A single change per-CI run pinpoints the culprit



Effective CI processes allocate enough resources to mitigate flaky tests

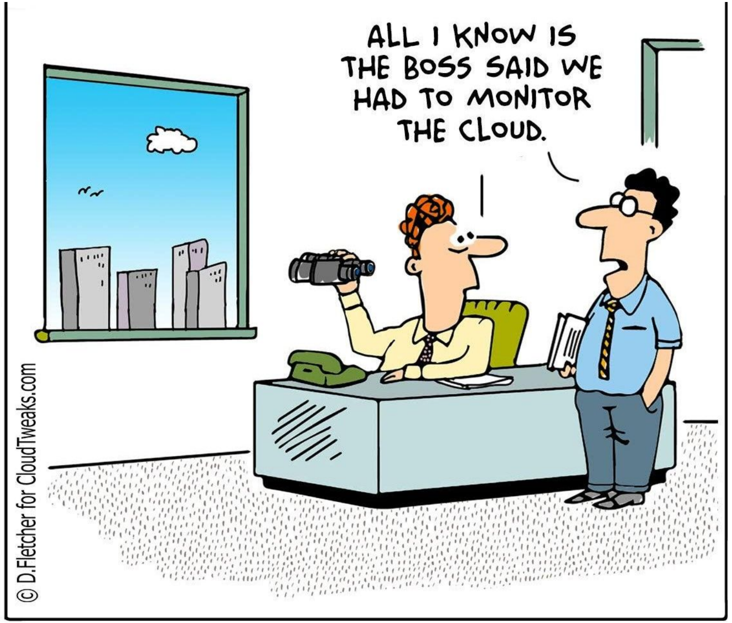
- *Flaky* tests might be dependent on timing (failing due to timeouts)
- Running tests without enough CPU/RAM can result in increased flaky failure rates and unreliable builds



Cloud Computing enables Continuous Integration and Deployment/Delivery

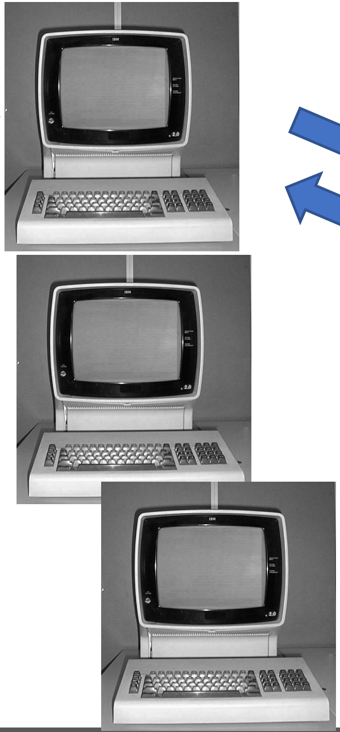
Cloud Computing

in a Nutshell



1970s Teleprocessing

Photo Credit: University of



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1980s & 1990s Personal Computing

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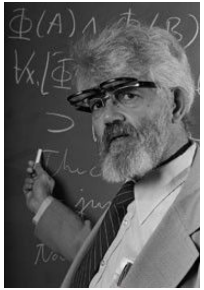
2000s Cloud Computing

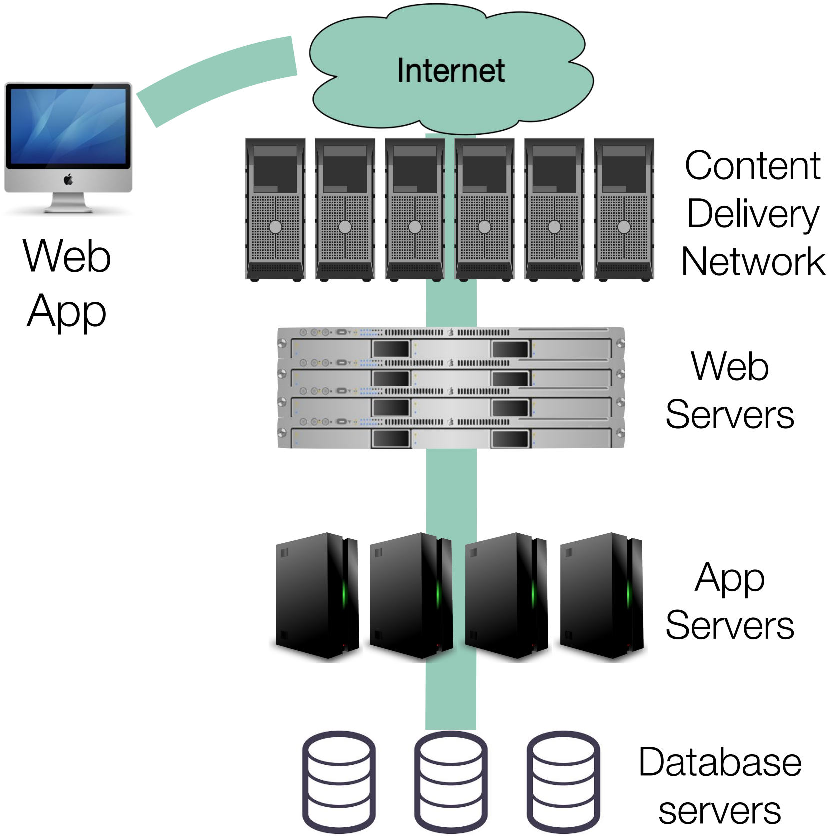


"Computing may someday be organized as a public utility just as the telephone system is a public utility...Each subscriber needs to pay only for the capacity he actually uses, but he has access to all programming languages characteristic of a very large system ..."

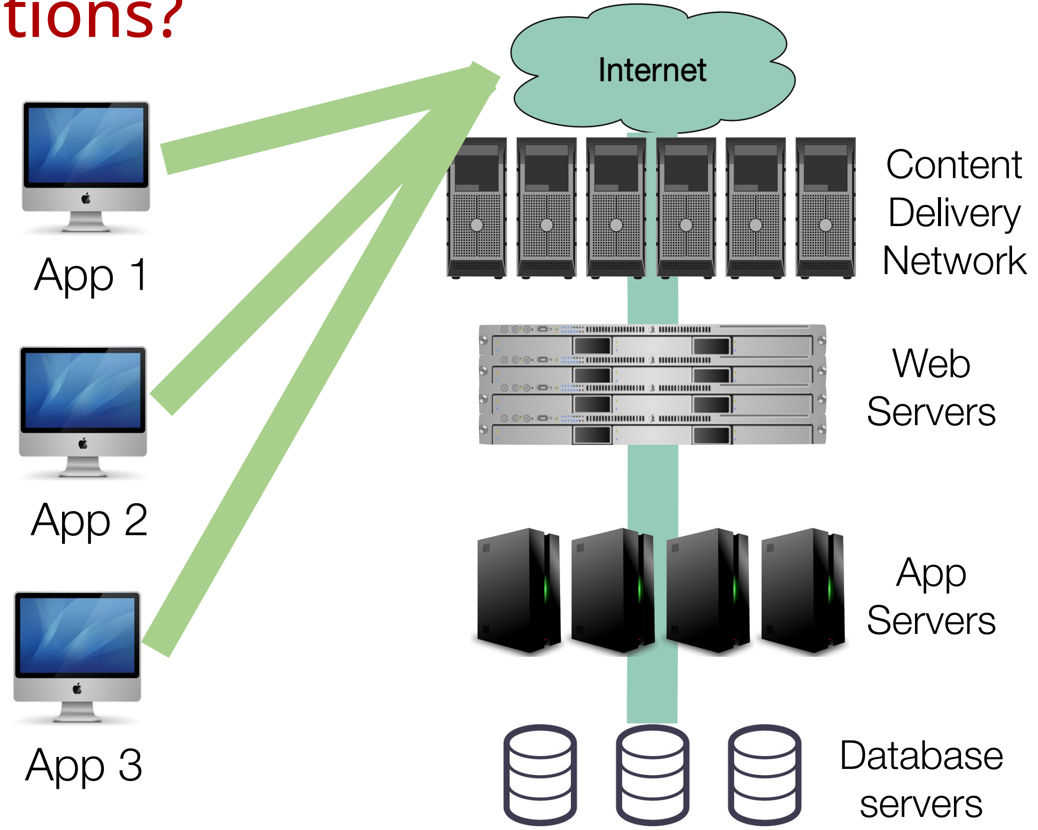
McCarthy's predictions come true!

A traditional deployment of a Web Application

- 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 (e.g. nodejs)
- Misc services: Logging, monitoring, firewall
- Database servers: Persistent data



What parts of this infrastructure can be shared across different applications?



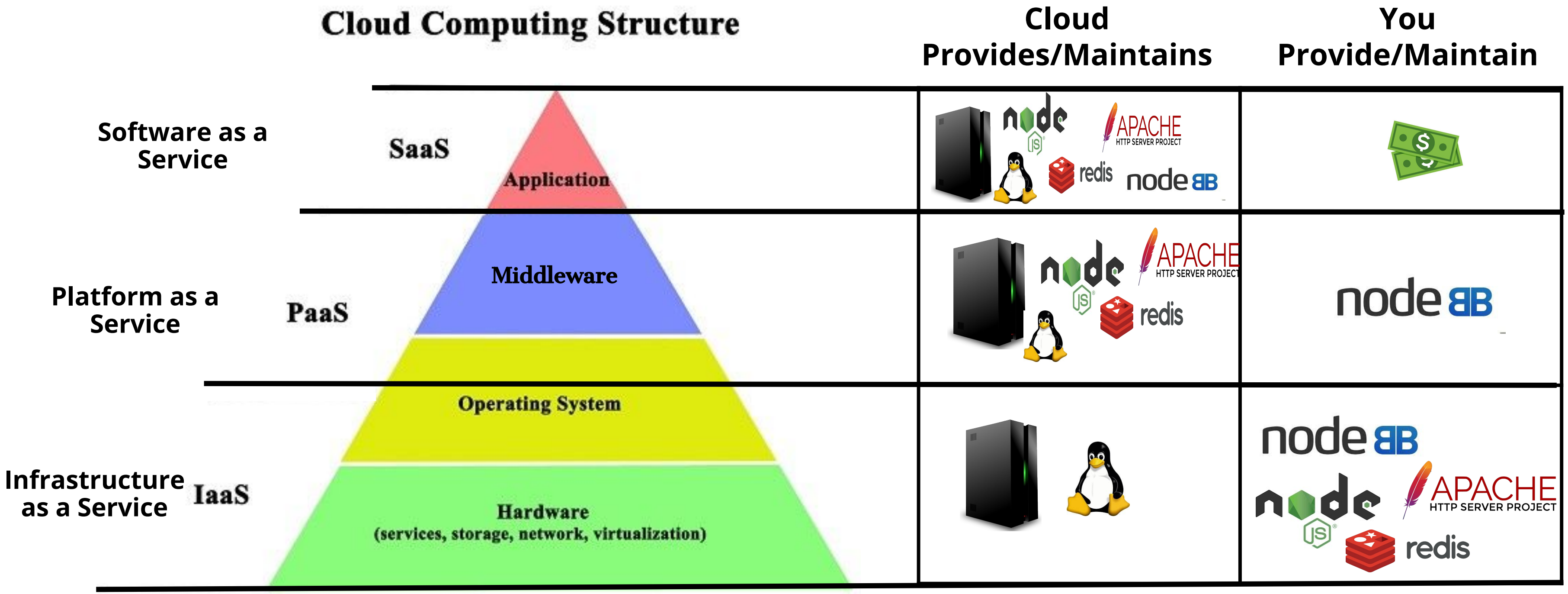
Multi-Tenancy creates economies of scale

- 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 – CPUs, RAM, disk)
- At the application level:
  - Multiple customer's applications hosted in **same virtual machine**
  - Save on resource overhead (eliminate redundant infrastructure like OS)
- "**Cloud**" is the natural expansion of multi-tenancy at all levels

Cloud infrastructure scales elastically

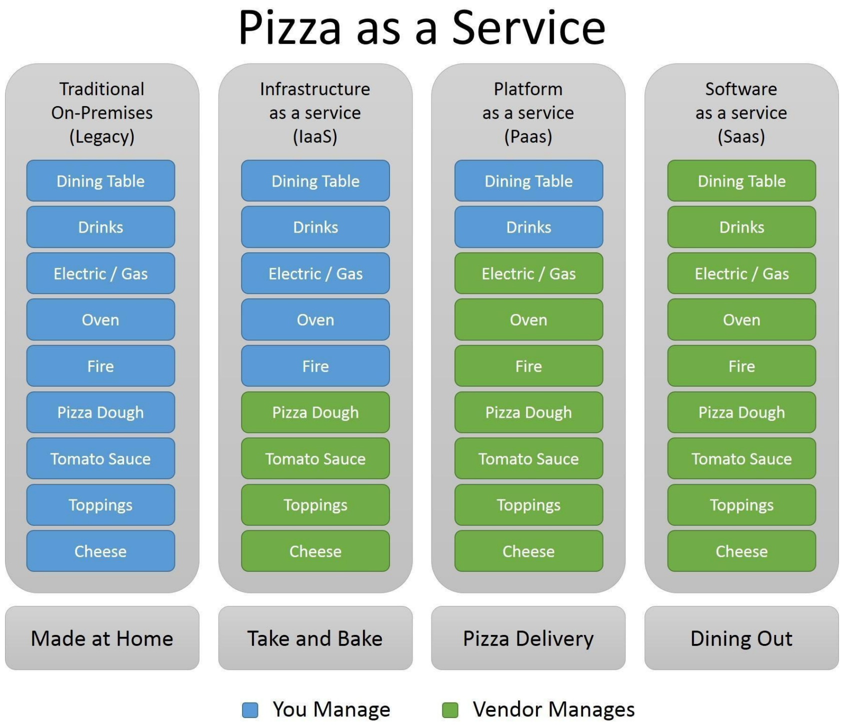
- “Traditional” computing infrastructure requires capital investment
  - “Scaling up” means buying more hardware, or maintaining excess capacity for when scale is needed
  - “Scaling down” means selling hardware, or powering it off
- Cloud computing scales elastically:
  - “Scaling up” means allocating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

Cloud Computing: Analogy using NodeBB



Shared infrastructure analogy: Pizza

- Four ways to get pizza: Make yourself, take and bake, delivery, dine out
- Vendor manages different levels of the stack, achieving economies of scale
- When would you choose one over the other?

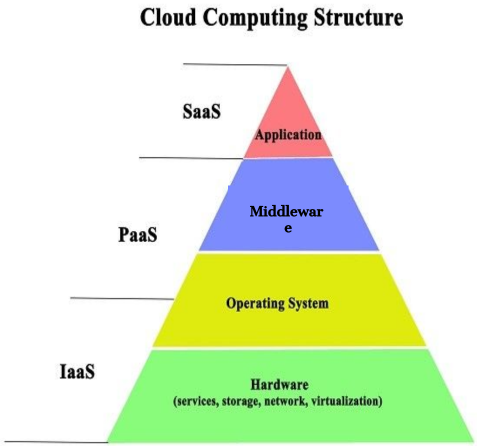


Pizza as a Service — by Albert Barron (unlicensed?)

Activity

Pick one scenario based on where you are seating

- Software as a Service - SaaS   (front rows)
- Platform as a Service - PaaS (middle rows)
- Infrastructure as a Service - IaaS (back rows)

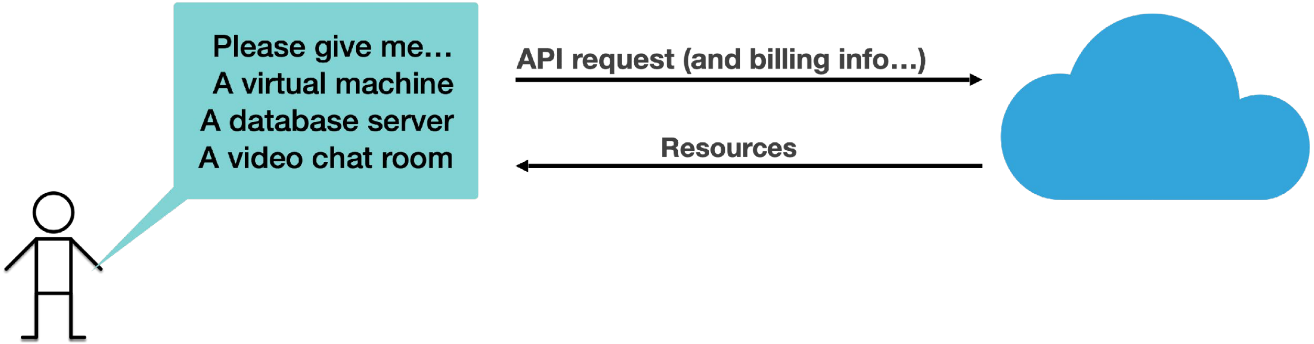


Discuss in groups of 2-3 the applicability of the assigned cloud service model (IaaS, PaaS, or SaaS)

- Brainstorm and come up with at least **two** real-world scenarios where the assigned cloud service model (IaaS, PaaS, or SaaS) would be the most convenient or optimal choice.
- Identify why their model is the best fit for the scenario and compare it briefly with the other two models to highlight the advantages of choosing their model.

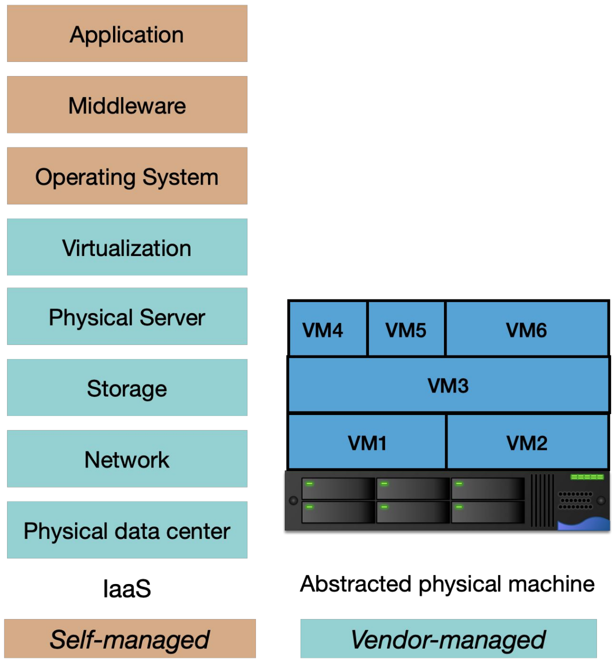
Cloud services gives on-demand access to infrastructure, "as a service"

- Vendor provides a service catalog of "*X as a service*" abstractions that provide infrastructure as a service
- API allows us to provision resources on-demand
- Transfers responsibility for managing the underlying infrastructure to a vendor



Infrastructure as a Service: Virtual Machines

- Virtual machines:
  - Virtualize a single large server into many smaller machines
  - Separates administration responsibilities for physical machine vs virtual machines
  - OS limits resource usage and guarantees quality per-VM
  - Each **VM runs its own OS**
  - Examples:
    - Cloud: Amazon EC2, Google Compute Engine, Azure
    - On-Premises: VMWare, Proxmox, OpenStack



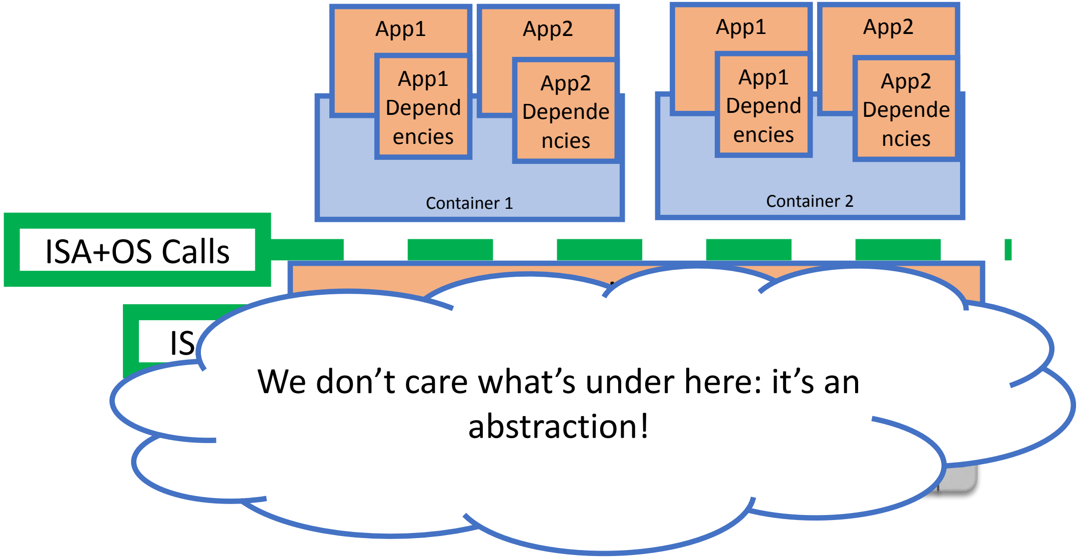
Virtual Machines to Containers

- 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 (base OS images are usually 3-10GB)

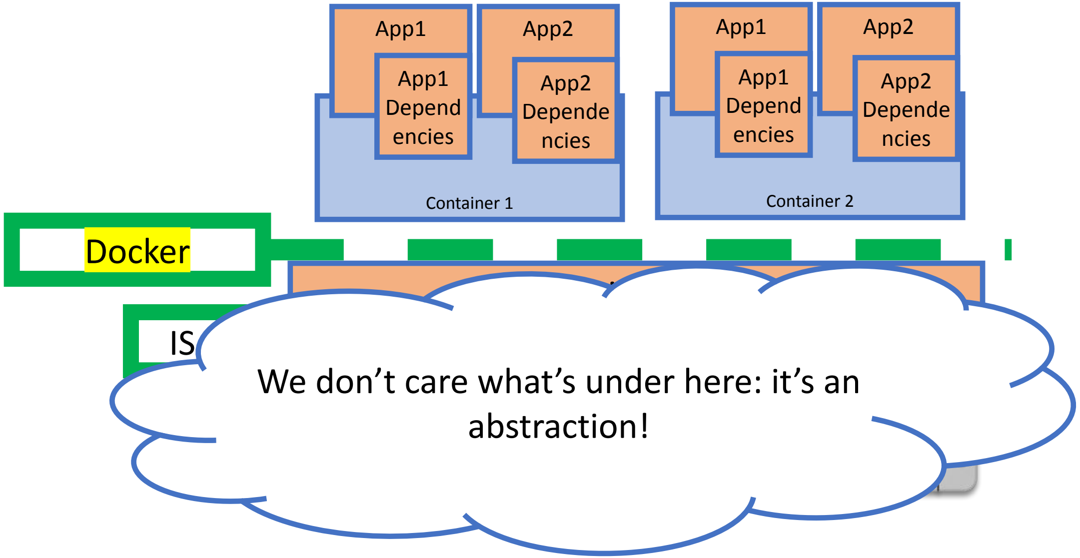
CaaS: Containers as a Service

- Vendor supplies an on-demand instance of an operating system
  - Eg: Linux version NN
- Vendor is free to implement that instance in a way that optimizes costs across many clients.



Docker is the prevailing container platform

- Docker provides a standardized interface for your container to use
- Many vendors will host your Docker container
- An open standard for containers also exists ("OCI")



A container contains your apps and all their dependencies

- 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)

NodeBB / Dockerfile

angelaz1 Initial NodeBB Commit b6951a8 · last year History

Code Blame 25 lines (16 loc) · 485 Bytes Raw

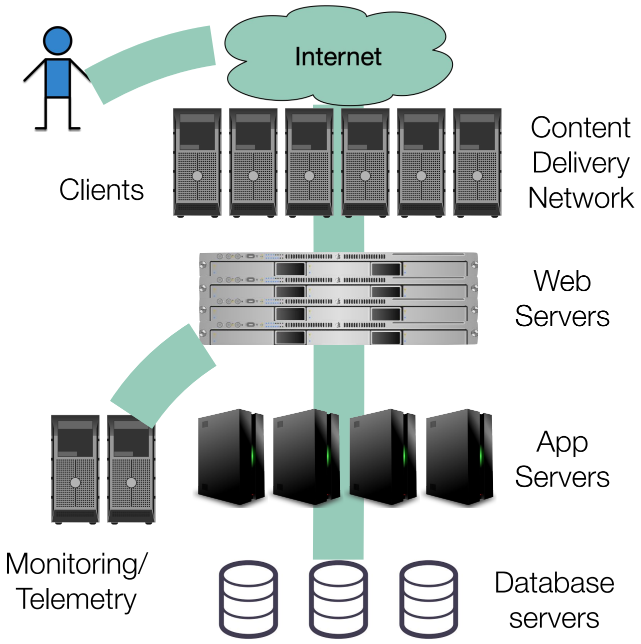
```
FROM node:lts

RUN mkdir -p /usr/src/app && \
    chown -R node:node /usr/src/app
WORKDIR /usr/src/app

ARG NODE_ENV
ENV NODE_ENV $NODE_ENV

COPY --chown=node:node install/package.json /usr/src/app/package.json

USER node

RUN npm install --only=prod && \
    npm cache clean --force

COPY --chown=node:node . /usr/src/app

ENV NODE_ENV=production \
    daemon=false \
    silent=false

EXPOSE 4567

CMD test -n "${SETUP}" && ./nodebb setup || node ./nodebb build; node ./nodebb start
```

Tradeoffs between VMs and Containers

- Performance is comparable
- Each VM has a copy of the OS and libraries
  - Higher resource overhead
  - Slower to provision
  - Support for wider variety of OS'
- Containers are "lightweight"
  - Lower resource overhead
  - Faster to provision
  - Potential for compatibility issues, especially with older software

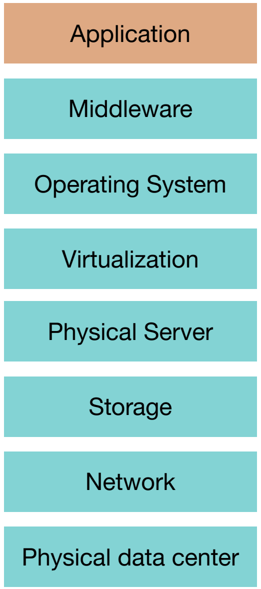
Platform-as-a-Service: vendor supplies OS + middleware

- Middleware is the stuff between our app and a user's requests:
  - Content delivery networks: Cache static content
  - Web Servers: 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 often the simplest choice for app deployment

- **Platform-as-a-Service** provides components most apps need, fully managed by the vendor: load balancer, monitoring, application server
- Some PaaS run your app in a container: Heroku, AWS Elastic Beanstalk, Google App Engine, Railway, Vercel…
- Other PaaS run your apps as individual functions/event handlers: AWS Lambda, Google Cloud Functions, Azure Functions
- Other PaaSs provide databases and authentication, and run your functions/event handlers: Google Firebase, Back4App



PaaS

Cloud Infrastructure is best for variable workloads

- Consider:
  - Does your workload benefit from ability to scale up or down?
  - Variable workloads have different demands over time (most common)
  - Constant workloads require sustained resources (less common)
- Example:
  - Need to run 300 VMs, each 4 vCPUs, 16GB RAM
- Private cloud:
  - Dell PowerEdge Pricing (AMD EPYC 64 core CPUs)
  - 7 servers, each 128 cores, 512GB RAM, 3 TB storage = $162,104
- Public cloud:
  - Amazon EC2 Pricing (M7a.xlarge instances, $0.153/VM-hour)
  - 10 VMs for 1 year + 290 VMs for 1 month: $45,792.90
  - 300 VMs for 1 year: $402,084.00

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