Principles of Software Construction: Objects, Design, and Concurrency

Containers & Cloud

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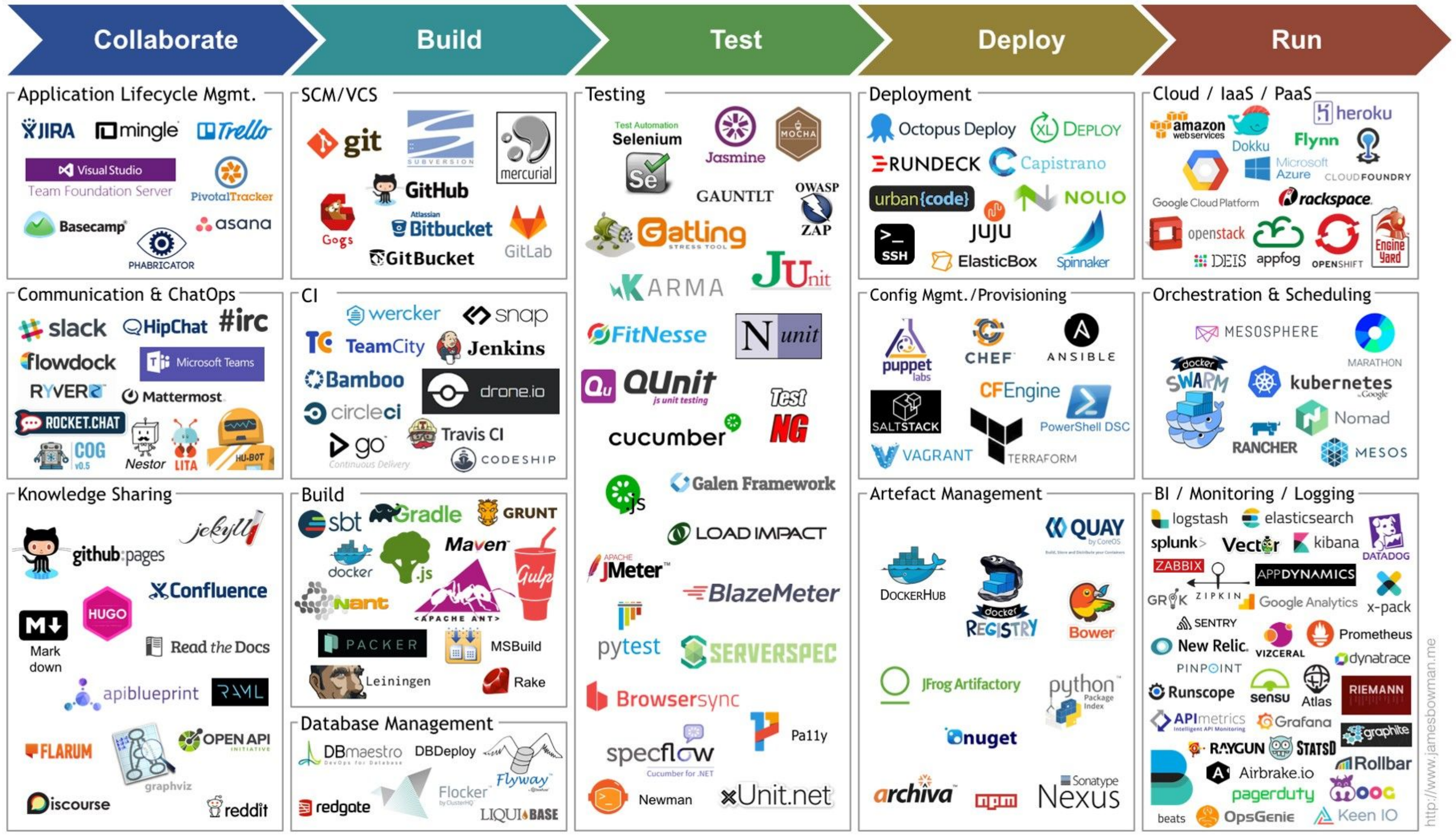
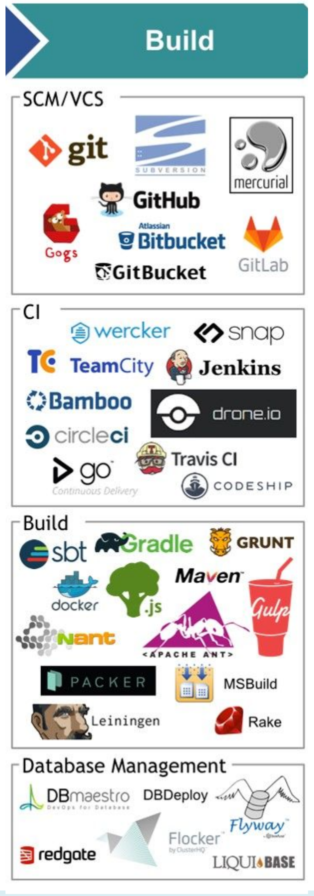
Administrative

- Frameworks 6c deadline on Friday
- Final on Thursday next week

Recall Programming Reality



Deeper into Docker



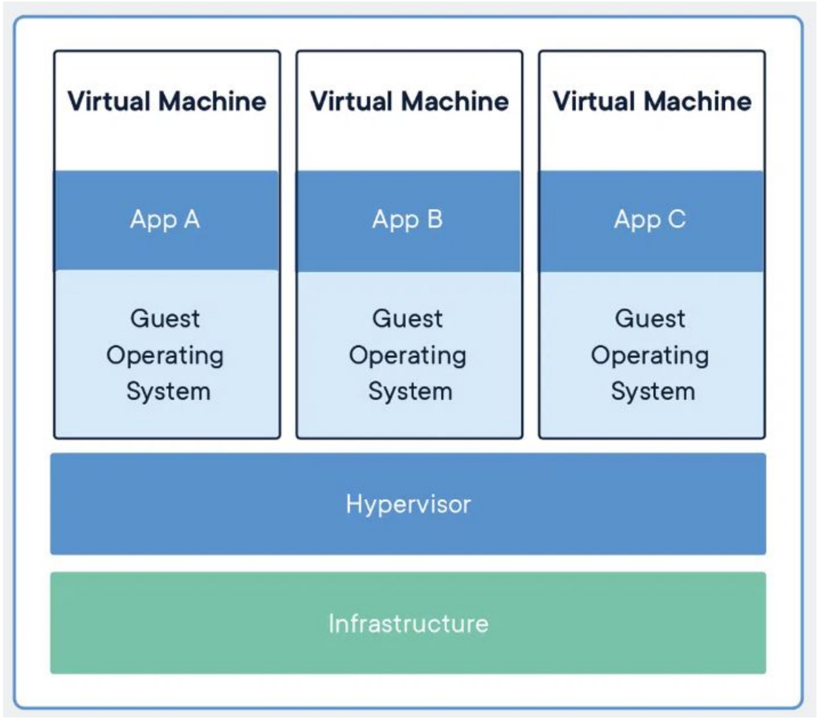
Virtual Machines offer Machines as Code

Multiple VMs can sit on one server

VMs provide complete isolation

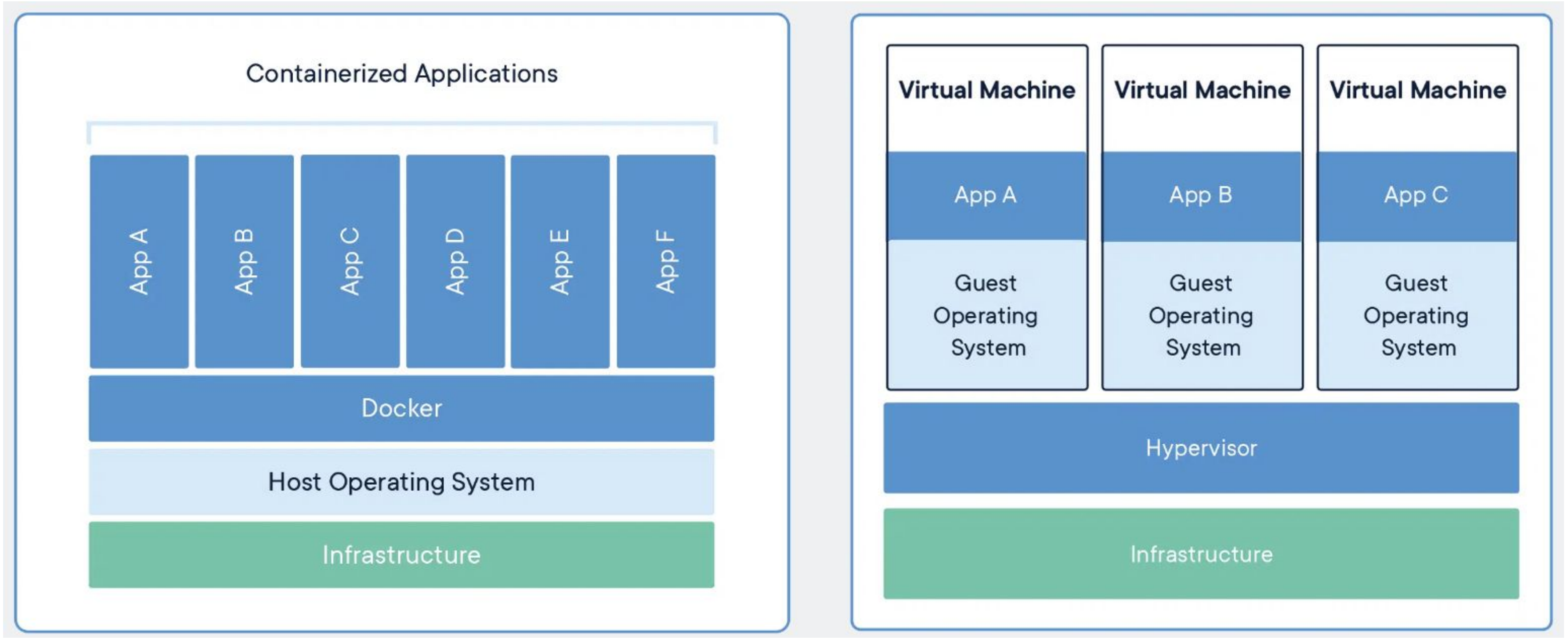
But, "translation" from guest OS to host is slow, clunky

And each VM has entire OS, filesys



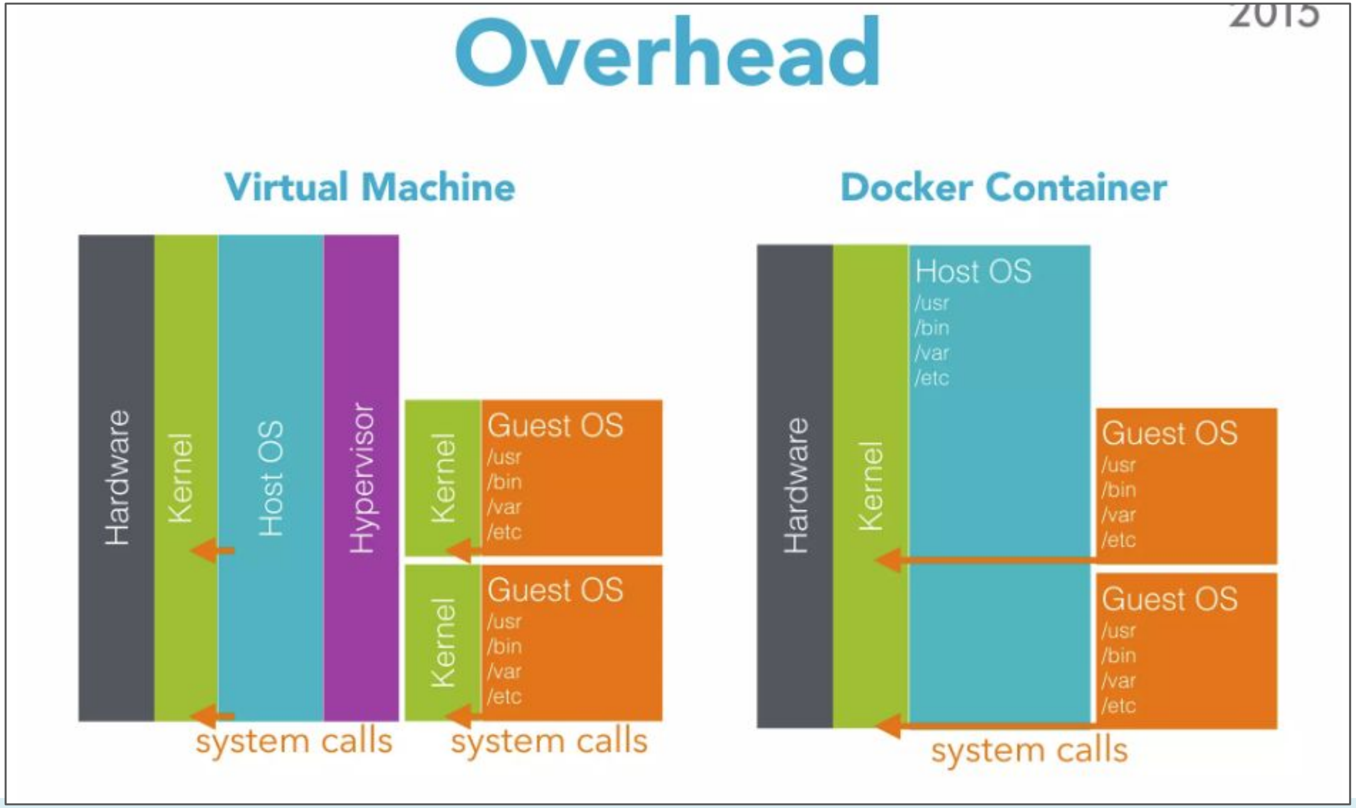
https://www.docker.com/resources/what-container/

Containers offer Virtualization on the OS



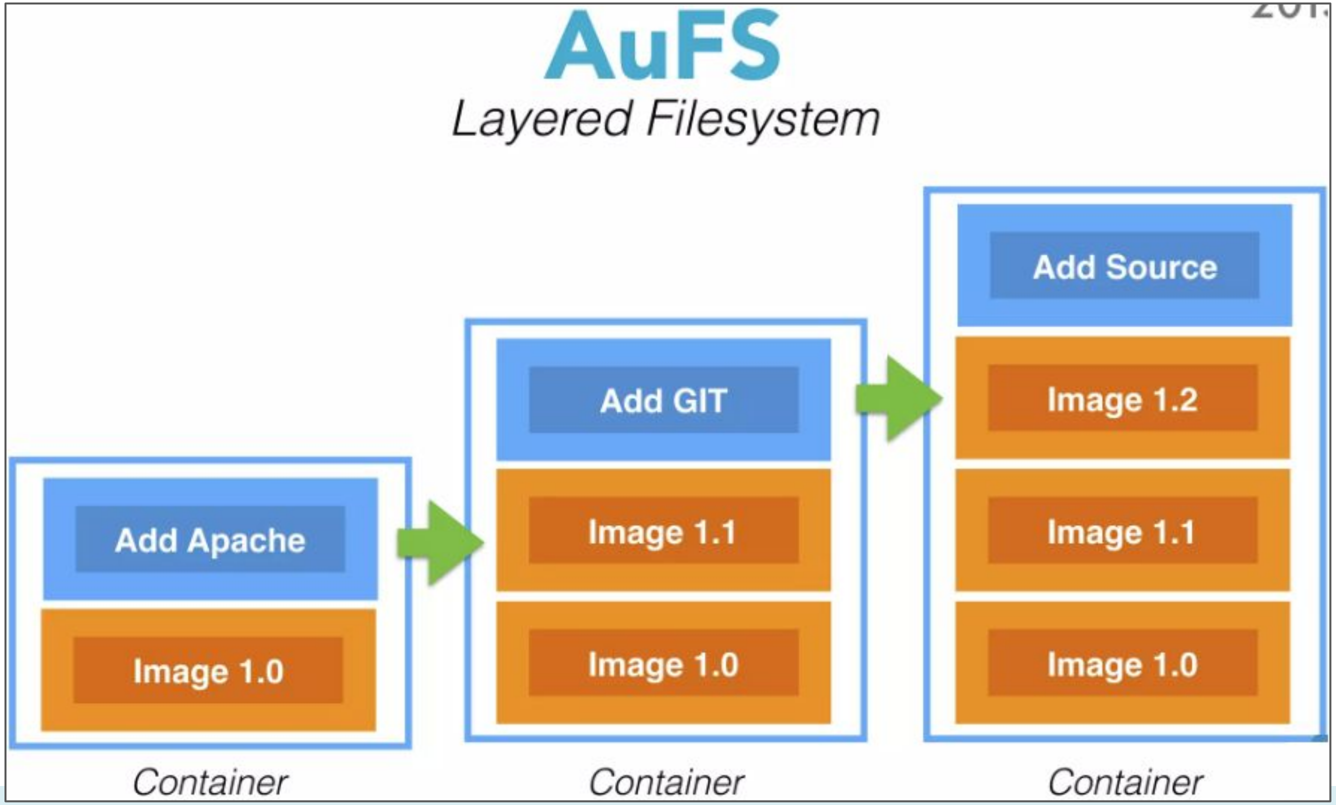
https://www.docker.com/resources/what-container/

In More Depth



https://www.slideshare.net/FabioFerrari31/docker-containers-talk-linux-day-2015

The Key: Layered file Systems



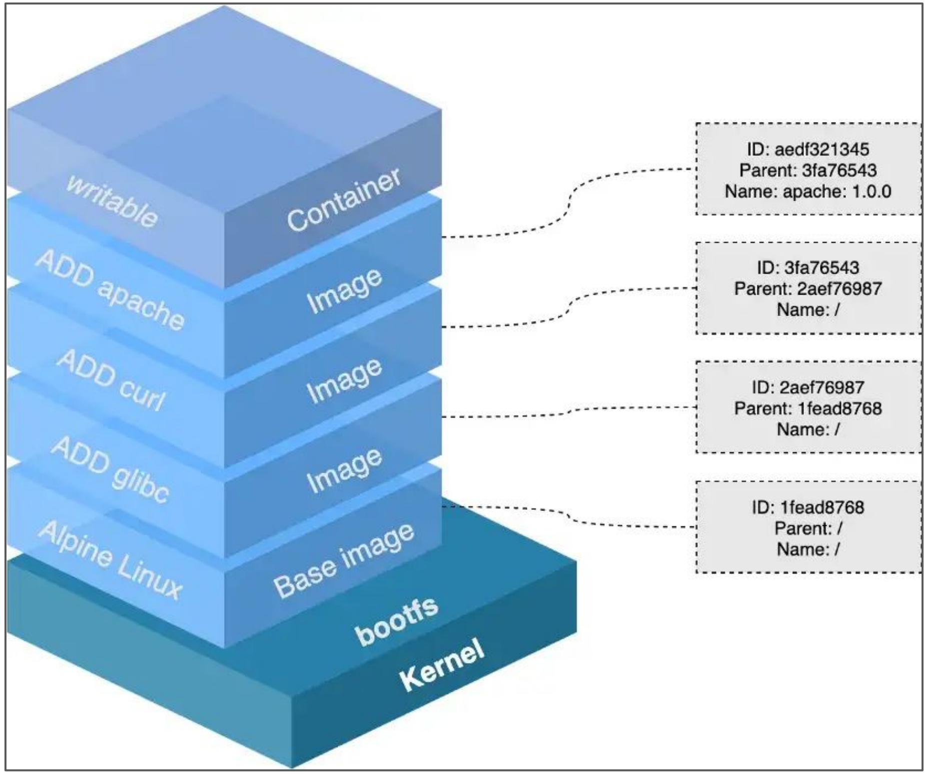
Quick Tangent: What’s the “downside”?

Docker images are *layers*

- Each action yields a new layer
- The base layer is typically an OS
  - E.g., “ubuntu:20.04”
- Data from previous layers is “copy-on-write”

Consequences:

- Layer-stacks are easily reused making images very light
- Security via IO permissions

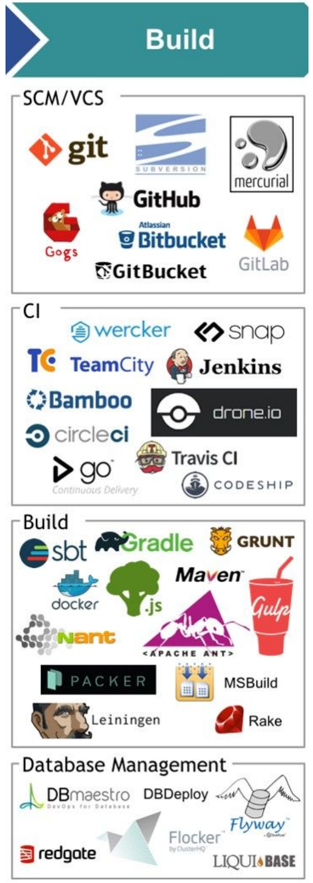


https://ragin.medium.com/docker-what-it-is-how-images-are-structured-docker-vs-vm-and-some-tips-part-1-d9686303590f

Hence,

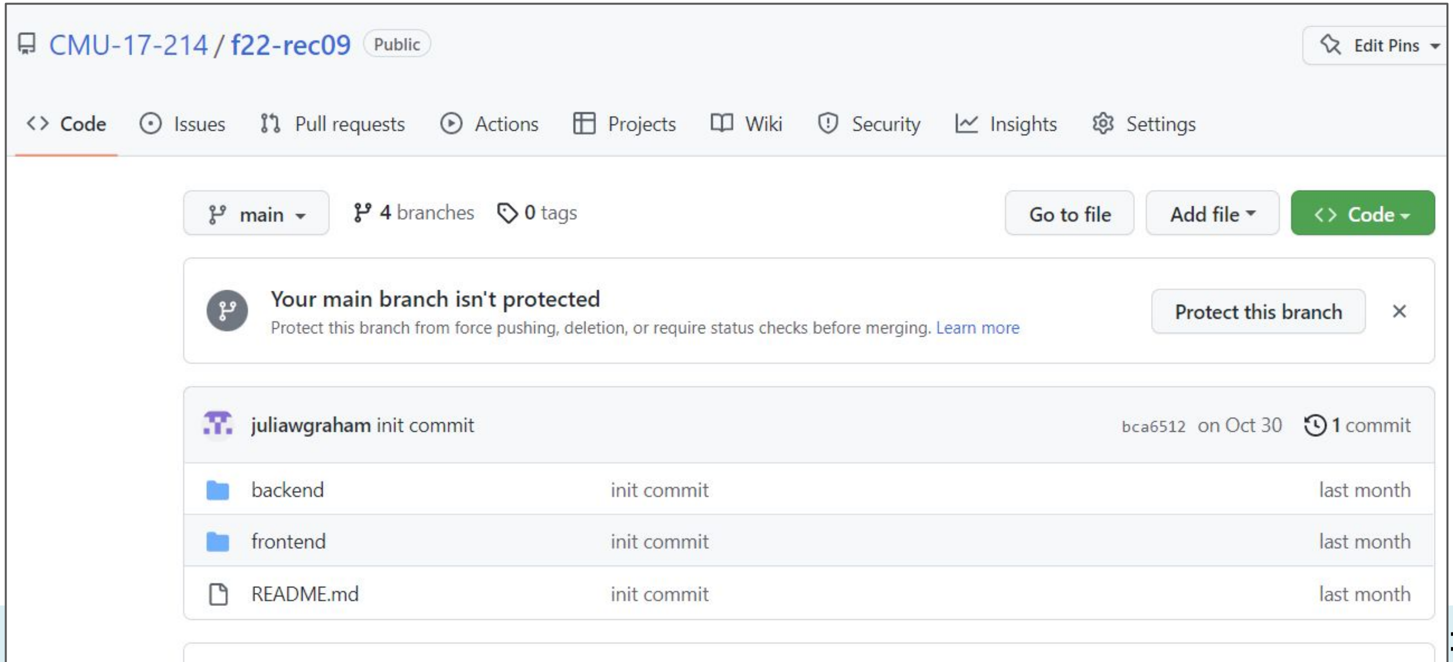
A virtual machine, but:

- Lightweight virtualization
- Sub-second boot time
- Shareable virtual images with full setup incl. configuration settings
- Used in development and deployment
- Separate docker images for separate services (web server, business logic, database, …)



Let's Take a Look

Remember the good old days?
→ Let's containerize this


CMU-17-214 / f22-rec09 Public

Your main branch isn't protected
Protect this branch from force pushing, deletion, or require status checks before merging. Learn more

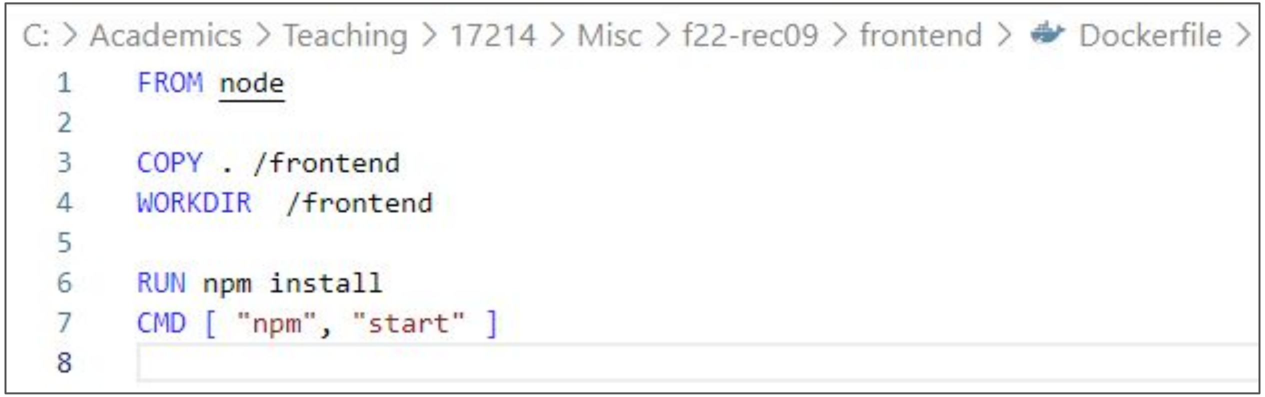
juliawgraham init commit bca6512 on Oct 30 1 commit

backend	init commit	last month
frontend	init commit	last month
README.md	init commit	last month

First, A Dockerfile

Instructs Docker how to build the image

- This one was added to ‘frontend’



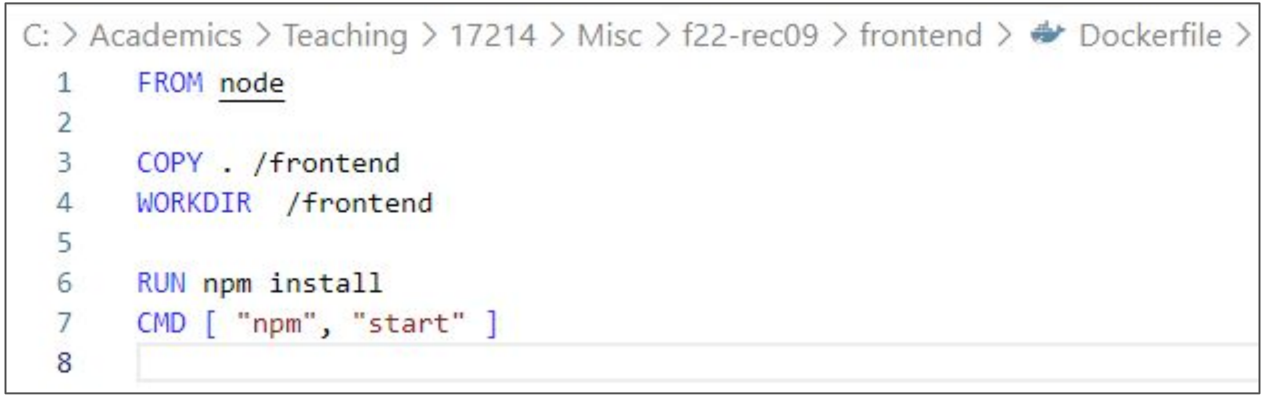
C: > Academics > Teaching > 17214 > Misc > f22-rec09 > frontend > Dockerfile >

```
FROM node

COPY . /frontend
WORKDIR  /frontend

RUN npm install
CMD [ "npm", "start" ]
```

First, A Dockerfile

Instructs Docker how to build the image

- FROM: the base "layer"
    - Doesn't need to be an OS! Very often isn't → reuse
    - Note: large layers can take a while to download

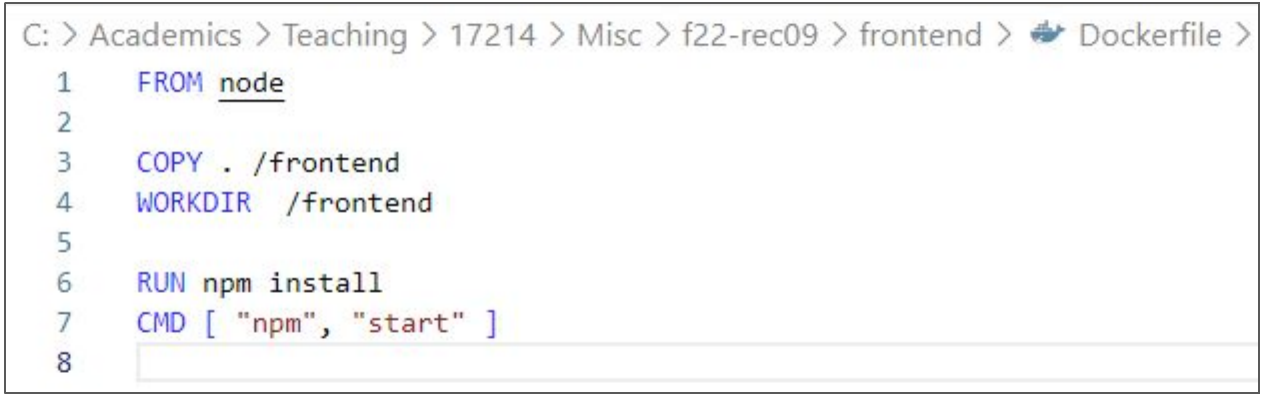

C: > Academics > Teaching > 17214 > Misc > f22-rec09 > frontend > Dockerfile >

```
FROM node

COPY . /frontend
WORKDIR  /frontend

RUN npm install
CMD [ "npm", "start" ]
```

First, A Dockerfile

Instructs Docker how to build the image

- COPY: duplicate file system data into image
    - Why?



C: > Academics > Teaching > 17214 > Misc > f22-rec09 > frontend > Dockerfile >

```
FROM node

COPY . /frontend
WORKDIR  /frontend

RUN npm install
CMD [ "npm", "start" ]

```

First, A Dockerfile

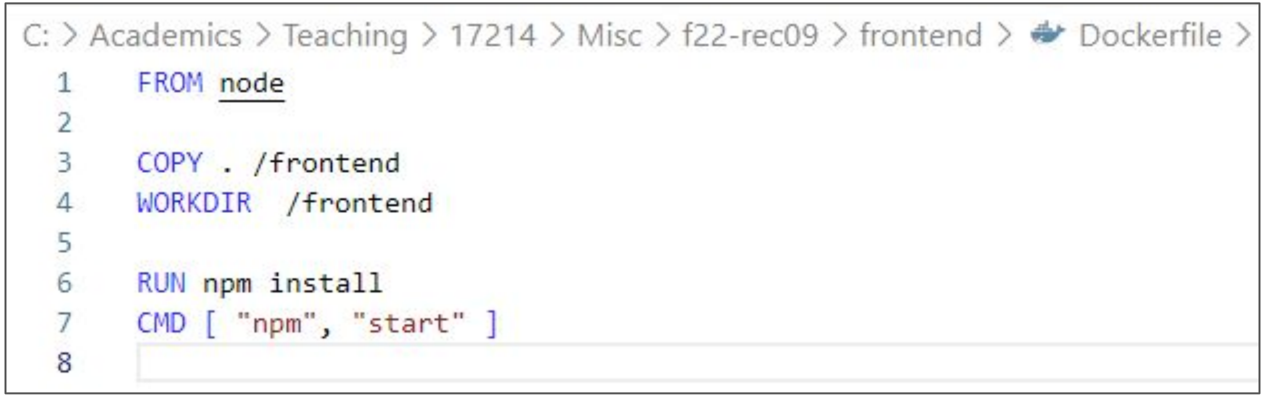
Instructs Docker how to build the image

- COPY: duplicate file system data into image
  - We can run many instances of an image, called *containers*
  - None of those will have access to the host file system!
  - We can either COPY data into them, or “mount” an external directory
    - For the latter, can use `readonly` or allow edits – use carefully!

First, A Dockerfile

Instructs Docker how to build the image

- WORKDIR: tell the builder to move into said directory



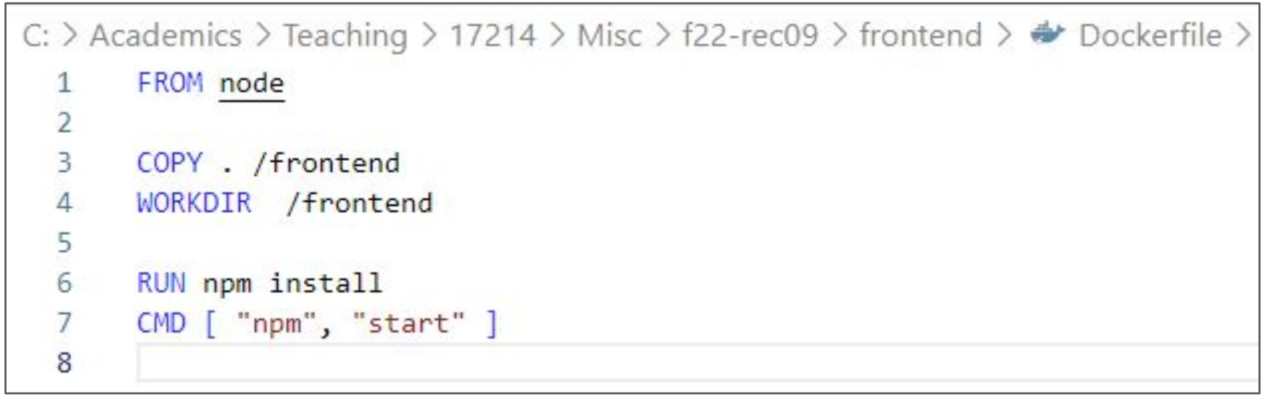
C: > Academics > Teaching > 17214 > Misc > f22-rec09 > frontend > Dockerfile >

```
FROM node

COPY . /frontend
WORKDIR  /frontend

RUN npm install
CMD [ "npm", "start" ]

```

First, A Dockerfile

Instructs Docker how to build the image

- RUN: execute a command now
    - This will create another layer (as did COPY)
    - Only happens on build, not when running a container

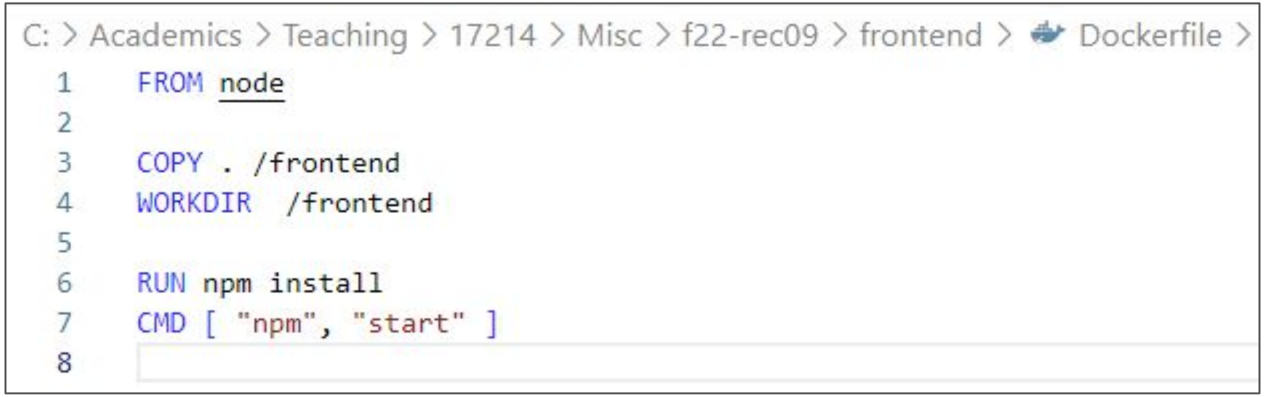

C: > Academics > Teaching > 17214 > Misc > f22-rec09 > frontend > Dockerfile >

```
FROM node

COPY . /frontend
WORKDIR  /frontend

RUN npm install
CMD [ "npm", "start" ]

```

First, A Dockerfile

Instructs Docker how to build the image

- CMD: command to execute *when launching a container*
  - This does not happen when we build
  - Can also provide an ENTRYPOINT script



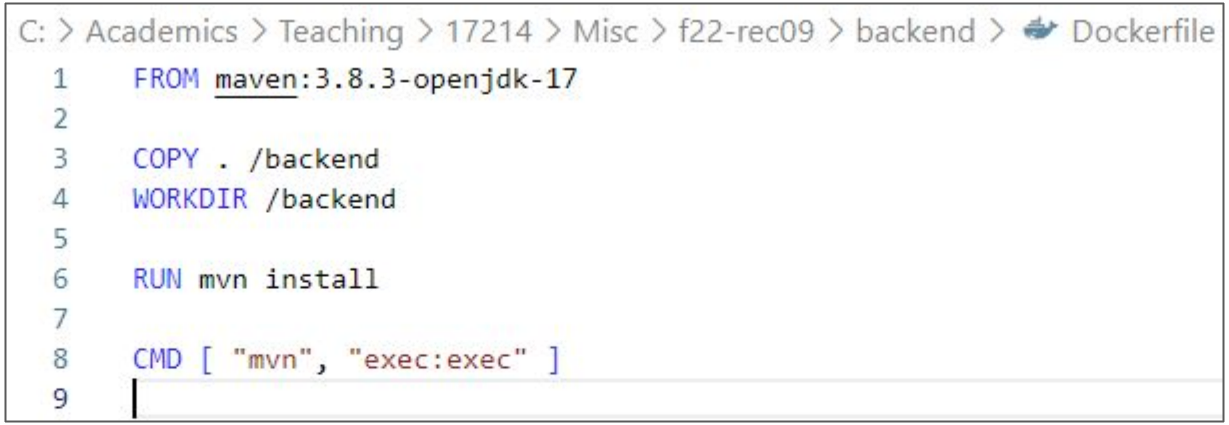
C: > Academics > Teaching > 17214 > Misc > f22-rec09 > frontend > Dockerfile >

```
FROM node

COPY . /frontend
WORKDIR  /frontend

RUN npm install
CMD [ "npm", "start" ]
```

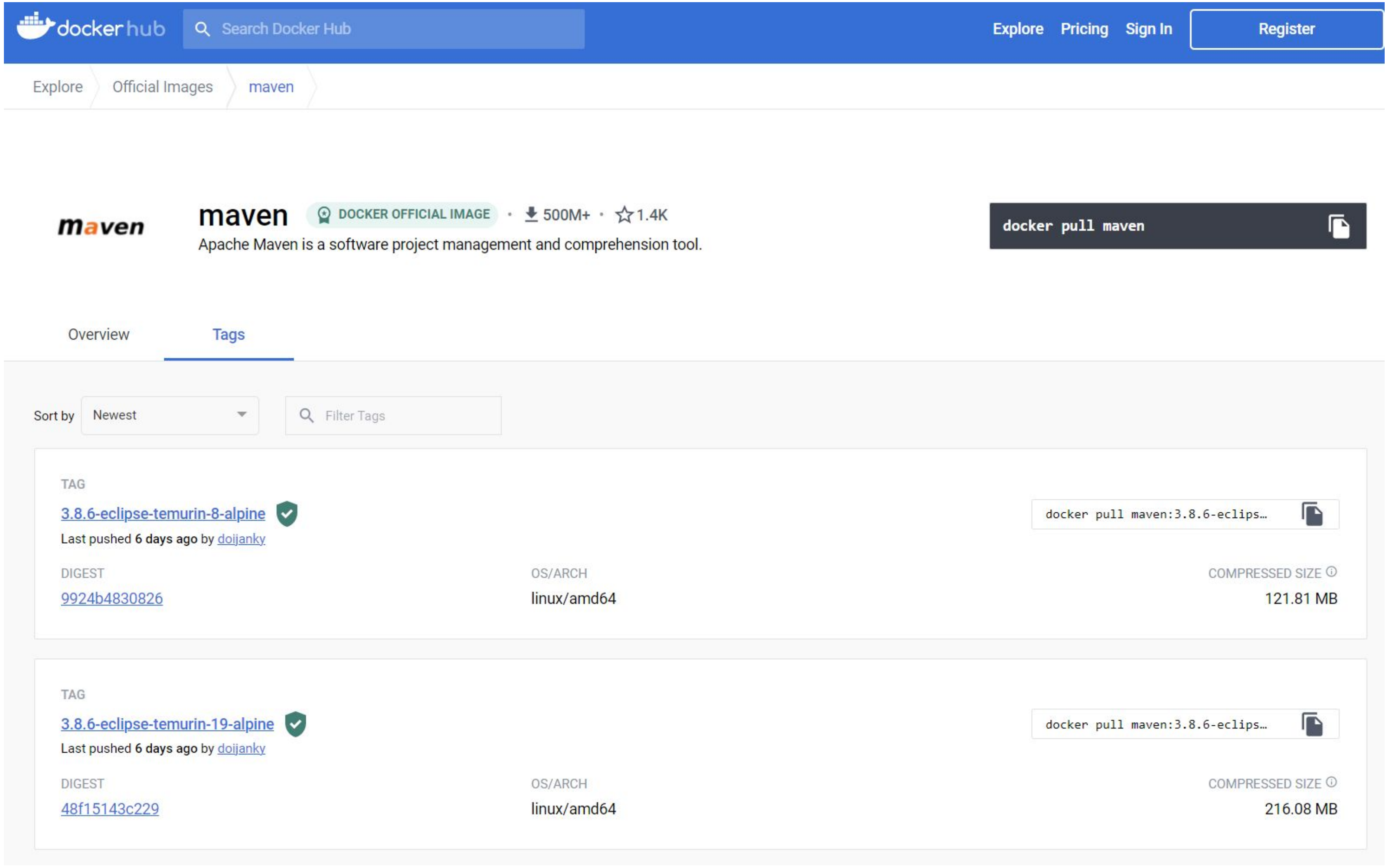
Same for the Backend

Note how the FROM image can have detailed *tags*

- These come from Dockerhub.


C: > Academics > Teaching > 17214 > Misc > f22-rec09 > backend > Dockerfile

```
FROM maven:3.8.3-openjdk-17

COPY . /backend
WORKDIR /backend

RUN mvn install

CMD [ "mvn", "exec:exec" ]

```


docker hub · Search Docker Hub · Explore · Pricing · Sign In · Register

Explore › Official Images › maven

maven DOCKER OFFICIAL IMAGE • 500M+ • 1.4K

Apache Maven is a software project management and comprehension tool.

```
docker pull maven
```

Overview · Tags

Sort by Newest · Filter Tags

TAG
3.8.6-eclipse-temurin-8-alpine
Last pushed **6 days ago** by doijanky

```
docker pull maven:3.8.6-eclips…
```

DIGEST	OS/ARCH	COMPRESSED SIZE
9924b4830826	linux/amd64	121.81 MB

TAG
3.8.6-eclipse-temurin-19-alpine
Last pushed **6 days ago** by doijanky

```
docker pull maven:3.8.6-eclips…
```

DIGEST	OS/ARCH	COMPRESSED SIZE
48f15143c229	linux/amd64	216.08 MB

Side note on DockerHub

We can push too!

- Just like GH, make an account and push images
    - Most images are formatted as `org/name:tag`
    - Tag is like a release; you must tag each image
- There are many other container registries. Most cloud providers have their own

What Now?

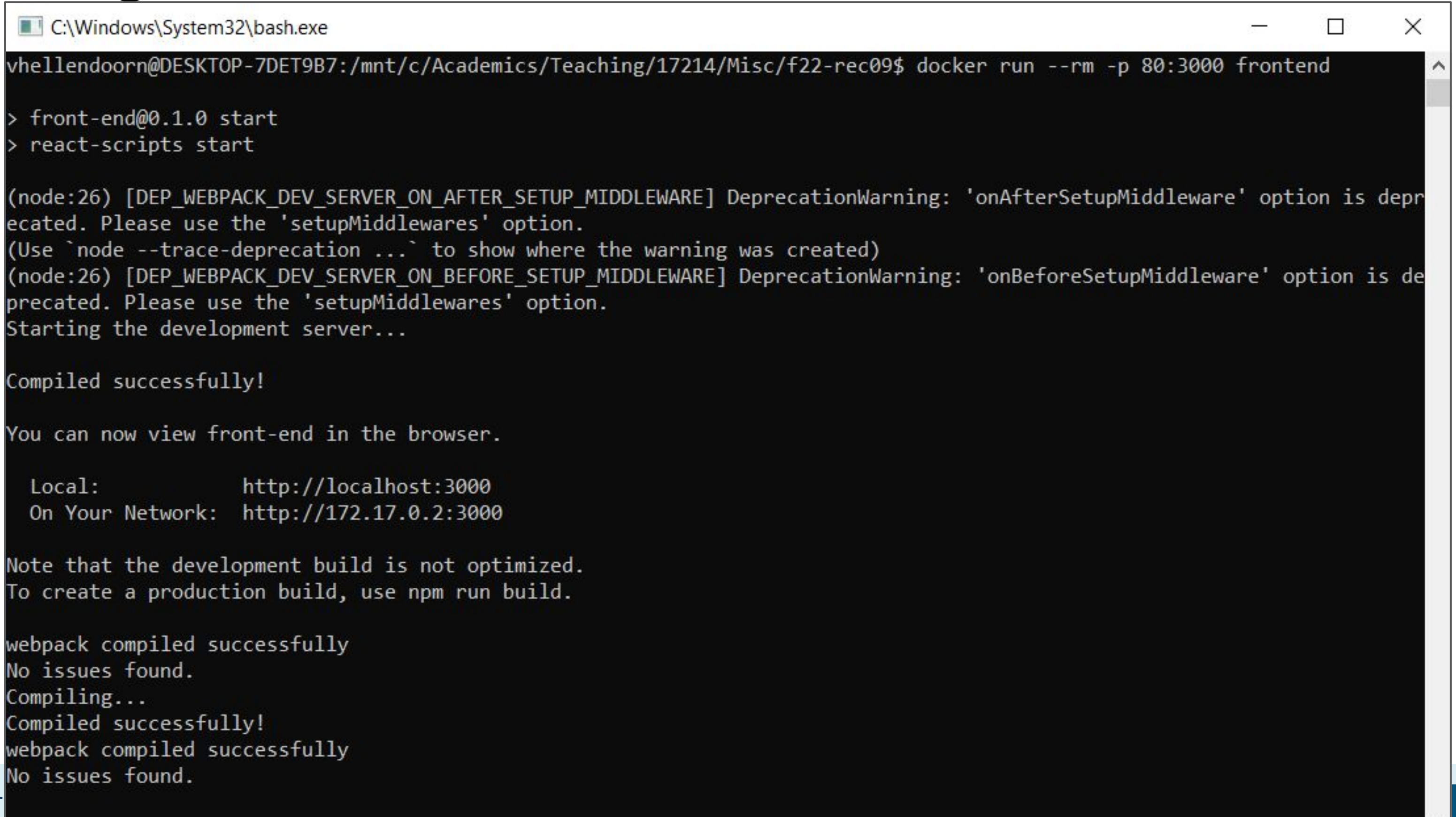
We’ve packaged frontend and backend as separate images

- Wait, why separate?

Now to make them talk

- Not quite obvious: containers isolate *everything*

Running Docker Containers



C:\Windows\System32\bash.exe

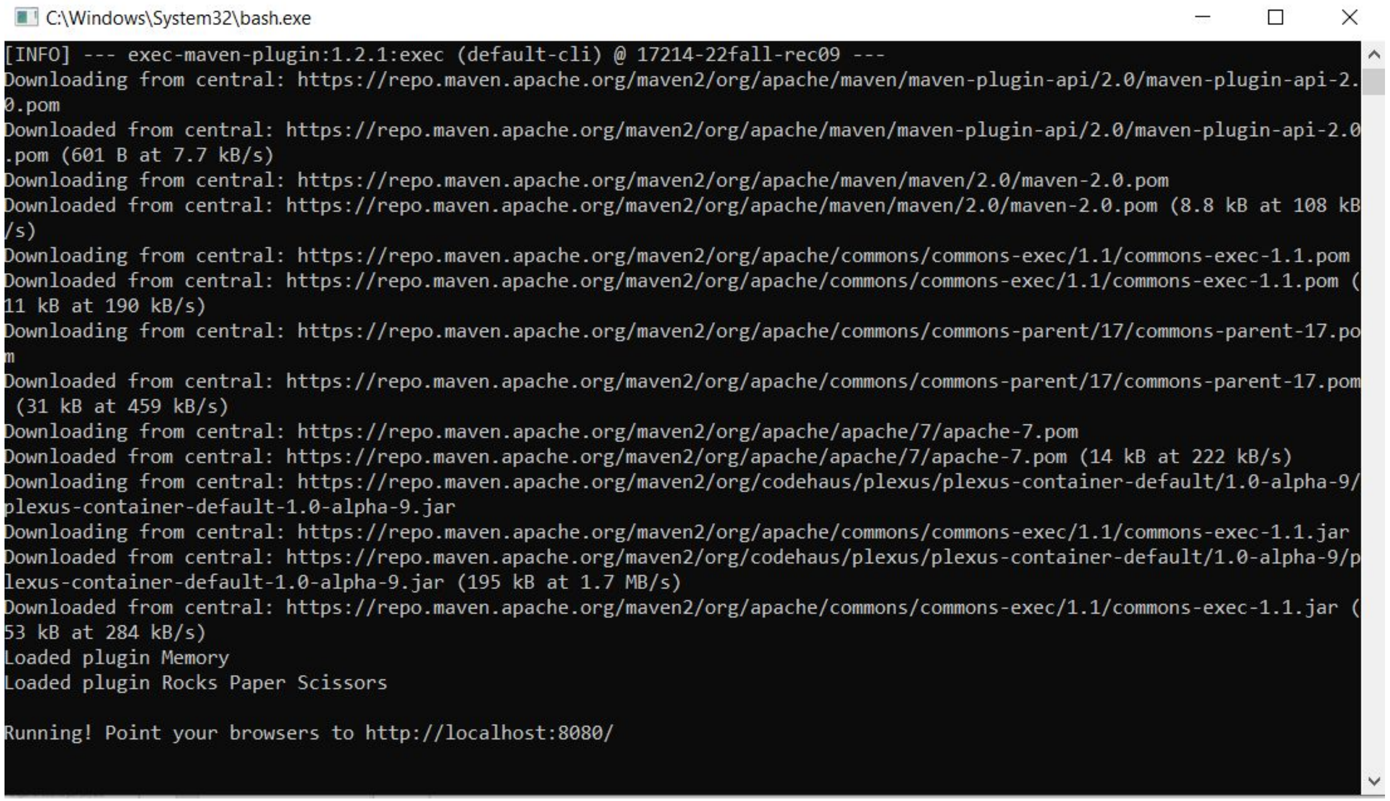
```
vhellendoorn@DESKTOP-7DET9B7:/mnt/c/Academics/Teaching/17214/Misc/f22-rec09$ docker run --rm -p 80:3000 frontend

> front-end@0.1.0 start
> react-scripts start

(node:26) [DEP_WEBPACK_DEV_SERVER_ON_AFTER_SETUP_MIDDLEWARE] DeprecationWarning: 'onAfterSetupMiddleware' option is depr
ecated. Please use the 'setupMiddlewares' option.
(Use `node --trace-deprecation ...` to show where the warning was created)
(node:26) [DEP_WEBPACK_DEV_SERVER_ON_BEFORE_SETUP_MIDDLEWARE] DeprecationWarning: 'onBeforeSetupMiddleware' option is de
precated. Please use the 'setupMiddlewares' option.
Starting the development server...

Compiled successfully!

You can now view front-end in the browser.

  Local:            http://localhost:3000
  On Your Network:  http://172.17.0.2:3000

Note that the development build is not optimized.
To create a production build, use npm run build.

webpack compiled successfully
No issues found.
Compiling...
Compiled successfully!
webpack compiled successfully
No issues found.
```

Running Docker Containers

We ran: `docker run --rm -p 80:3000 frontend`

- `--rm`: removes the container after shutdown
    - Important! Docker keeps machines around indefinitely otherwise
    - Containers can hold quite a bit of data
- `-p 80:3000`: instruct Docker to open an external port (80) and forward requests there to the internal one (3000)

Start the Backend too, go to localhost:80, and…

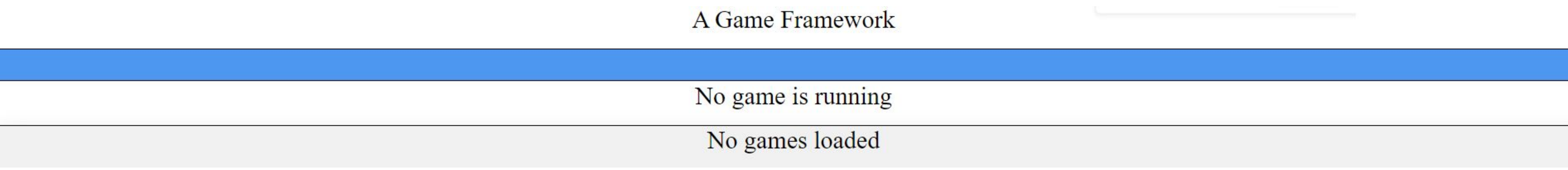


C:\Windows\System32\bash.exe

```
[INFO] --- exec-maven-plugin:1.2.1:exec (default-cli) @ 17214-22fall-rec09 ---
Downloading from central: https://repo.maven.apache.org/maven2/org/apache/maven/maven-plugin-api/2.0/maven-plugin-api-2.
0.pom
Downloaded from central: https://repo.maven.apache.org/maven2/org/apache/maven/maven-plugin-api/2.0/maven-plugin-api-2.0
.pom (601 B at 7.7 kB/s)
Downloading from central: https://repo.maven.apache.org/maven2/org/apache/maven/maven/2.0/maven-2.0.pom
Downloaded from central: https://repo.maven.apache.org/maven2/org/apache/maven/maven/2.0/maven-2.0.pom (8.8 kB at 108 kB
/s)
Downloading from central: https://repo.maven.apache.org/maven2/org/apache/commons/commons-exec/1.1/commons-exec-1.1.pom
Downloaded from central: https://repo.maven.apache.org/maven2/org/apache/commons/commons-exec/1.1/commons-exec-1.1.pom (
11 kB at 190 kB/s)
Downloading from central: https://repo.maven.apache.org/maven2/org/apache/commons/commons-parent/17/commons-parent-17.po
m
Downloaded from central: https://repo.maven.apache.org/maven2/org/apache/commons/commons-parent/17/commons-parent-17.pom
 (31 kB at 459 kB/s)
Downloading from central: https://repo.maven.apache.org/maven2/org/apache/apache/7/apache-7.pom
Downloaded from central: https://repo.maven.apache.org/maven2/org/apache/apache/7/apache-7.pom (14 kB at 222 kB/s)
Downloading from central: https://repo.maven.apache.org/maven2/org/codehaus/plexus/plexus-container-default/1.0-alpha-9/
plexus-container-default-1.0-alpha-9.jar
Downloading from central: https://repo.maven.apache.org/maven2/org/apache/commons/commons-exec/1.1/commons-exec-1.1.jar
Downloaded from central: https://repo.maven.apache.org/maven2/org/codehaus/plexus/plexus-container-default/1.0-alpha-9/p
lexus-container-default-1.0-alpha-9.jar (195 kB at 1.7 MB/s)
Downloaded from central: https://repo.maven.apache.org/maven2/org/apache/commons/commons-exec/1.1/commons-exec-1.1.jar (
53 kB at 284 kB/s)
Loaded plugin Memory
Loaded plugin Rocks Paper Scissors

Running! Point your browsers to http://localhost:8080/
```

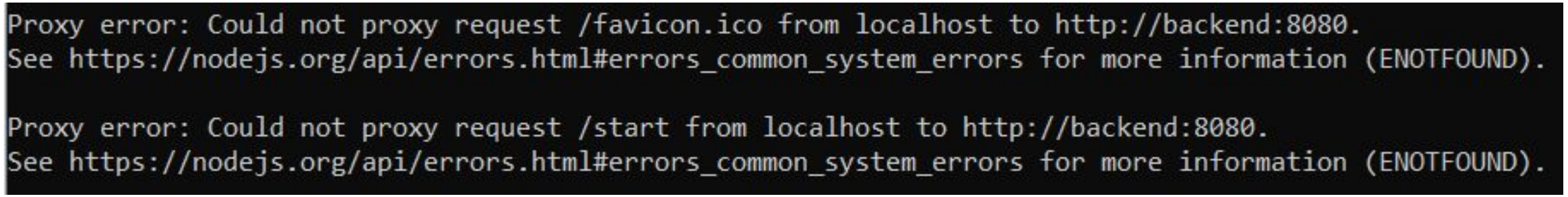
It doesn't work!?

The frontend loads, but can't talk to the backend


A Game Framework

No game is running

No games loaded



```
Proxy error: Could not proxy request /favicon.ico from localhost to http://backend:8080.
See https://nodejs.org/api/errors.html#errors_common_system_errors for more information (ENOTFOUND).

Proxy error: Could not proxy request /start from localhost to http://backend:8080.
See https://nodejs.org/api/errors.html#errors_common_system_errors for more information (ENOTFOUND).
```

Remember: containers means isolation

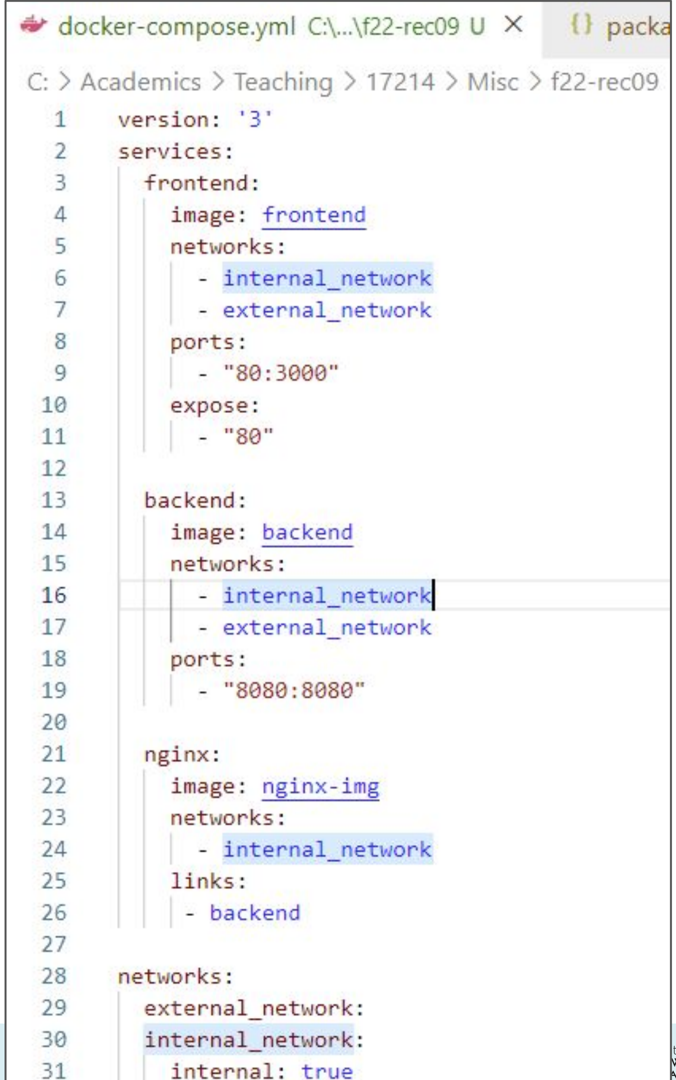
Networks are also virtual

- Each container subscribes to ‘bridge’ by default
- Containers are assigned unique IPs within each network
- We *could* make this work by (a) starting backend, (b) finding its IP on ‘bridge’, (c) rebuilding frontend with that IP hard-coded in package.json, and (d) launching frontend (trust me, I tried).

Docker Compose

We need container management tools

- Lowest level: docker compose
  - Specify images, networks & ports, links, etc.
  - Can launch many copies of each image

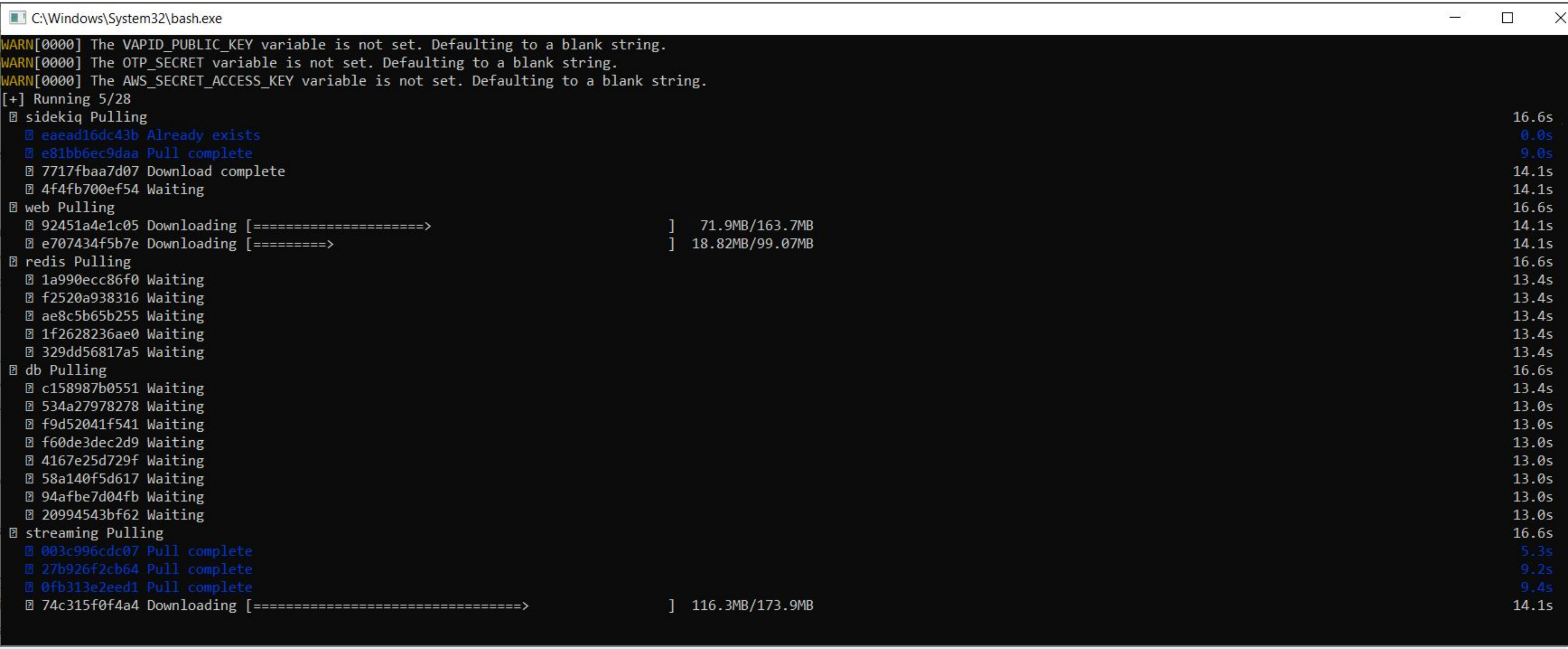


docker-compose.yml C:\...\f22-rec09 U × {} packa

C: > Academics > Teaching > 17214 > Misc > f22-rec09

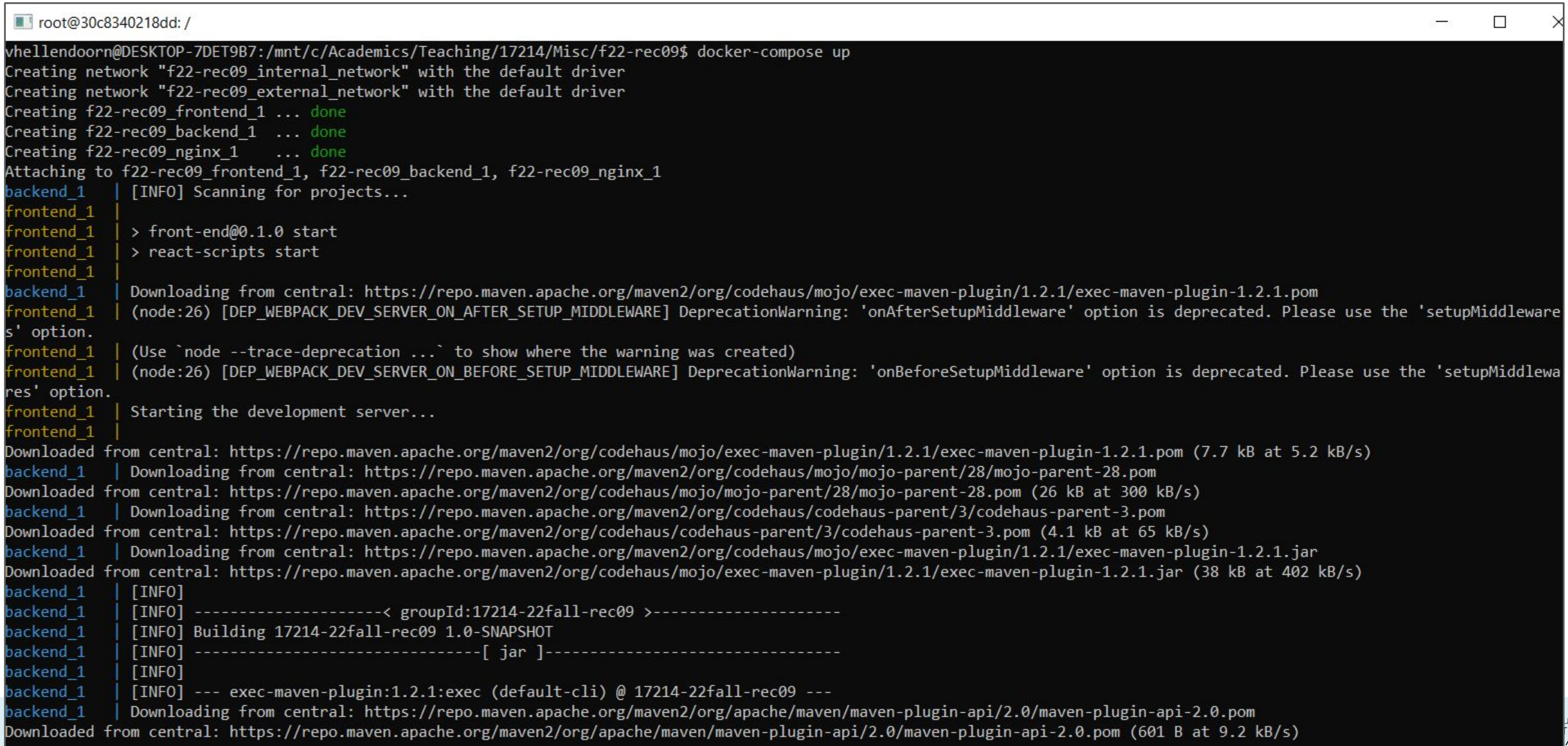
```yaml
version: '3'
services:
  frontend:
    image: frontend
    networks:
      - internal_network
      - external_network
    ports:
      - "80:3000"
    expose:
      - "80"

  backend:
    image: backend
    networks:
      - internal_network
      - external_network
    ports:
      - "8080:8080"

  nginx:
    image: nginx-img
    networks:
      - internal_network
    links:
     - backend

networks:
  external_network:
  internal_network:
    internal: true
```

E.g., Launching five images (for Mastodon)


C:\Windows\System32\bash.exe

```
WARN[0000] The VAPID_PUBLIC_KEY variable is not set. Defaulting to a blank string.
WARN[0000] The OTP_SECRET variable is not set. Defaulting to a blank string.
WARN[0000] The AWS_SECRET_ACCESS_KEY variable is not set. Defaulting to a blank string.
[+] Running 5/28
 ⍰ sidekiq Pulling                                                                                                                                                                     16.6s
   ⍰ eaead16dc43b Already exists                                                                                                                                                       0.0s
   ⍰ e81bb6ec9daa Pull complete                                                                                                                                                        9.0s
   ⍰ 7717fbaa7d07 Download complete                                                                                                                                                   14.1s
   ⍰ 4f4fb700ef54 Waiting                                                                                                                                                             14.1s
 ⍰ web Pulling                                                                                                                                                                         16.6s
   ⍰ 92451a4e1c05 Downloading [=====================>                             ]   71.9MB/163.7MB                                                                                   14.1s
   ⍰ e707434f5b7e Downloading [=========>                                         ]  18.82MB/99.07MB                                                                                   14.1s
 ⍰ redis Pulling                                                                                                                                                                       16.6s
   ⍰ 1a990ecc86f0 Waiting                                                                                                                                                             13.4s
   ⍰ f2520a938316 Waiting                                                                                                                                                             13.4s
   ⍰ ae8c5b65b255 Waiting                                                                                                                                                             13.4s
   ⍰ 1f2628236ae0 Waiting                                                                                                                                                             13.4s
   ⍰ 329dd56817a5 Waiting                                                                                                                                                             13.4s
 ⍰ db Pulling                                                                                                                                                                          16.6s
   ⍰ c158987b0551 Waiting                                                                                                                                                             13.4s
   ⍰ 534a27978278 Waiting                                                                                                                                                             13.0s
   ⍰ f9d52041f541 Waiting                                                                                                                                                             13.0s
   ⍰ f60de3dec2d9 Waiting                                                                                                                                                             13.0s
   ⍰ 4167e25d729f Waiting                                                                                                                                                             13.0s
   ⍰ 58a140f5d617 Waiting                                                                                                                                                             13.0s
   ⍰ 94afbe7d04fb Waiting                                                                                                                                                             13.0s
   ⍰ 20994543bf62 Waiting                                                                                                                                                             13.0s
 ⍰ streaming Pulling                                                                                                                                                                   16.6s
   ⍰ 003c996cdc07 Pull complete                                                                                                                                                        5.3s
   ⍰ 27b926f2cb64 Pull complete                                                                                                                                                        9.2s
   ⍰ 0fb313e2eed1 Pull complete                                                                                                                                                        9.4s
   ⍰ 74c315f0f4a4 Downloading [=================================>                 ]  116.3MB/173.9MB                                                                                   14.1s
```

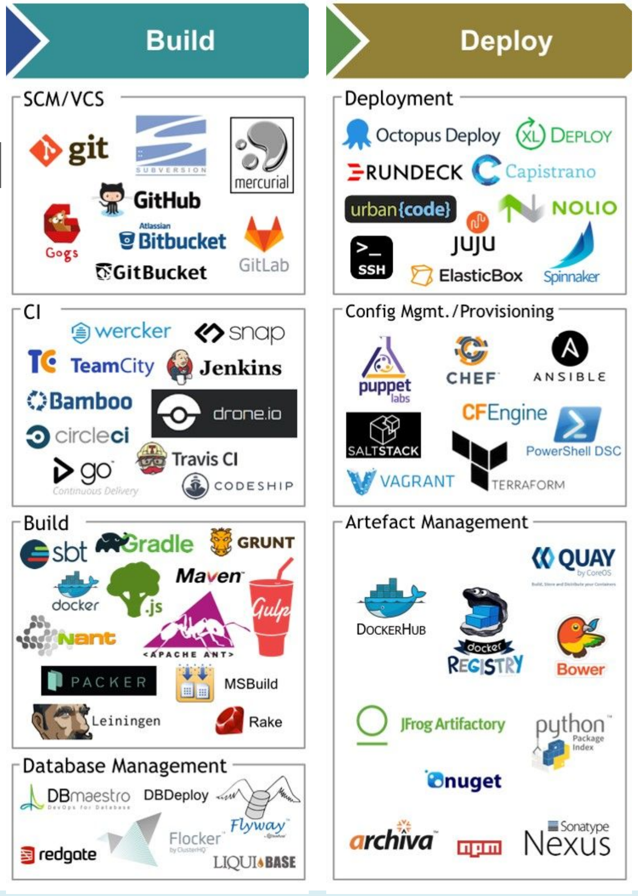
Launching Rec09


root@30c8340218dd: /

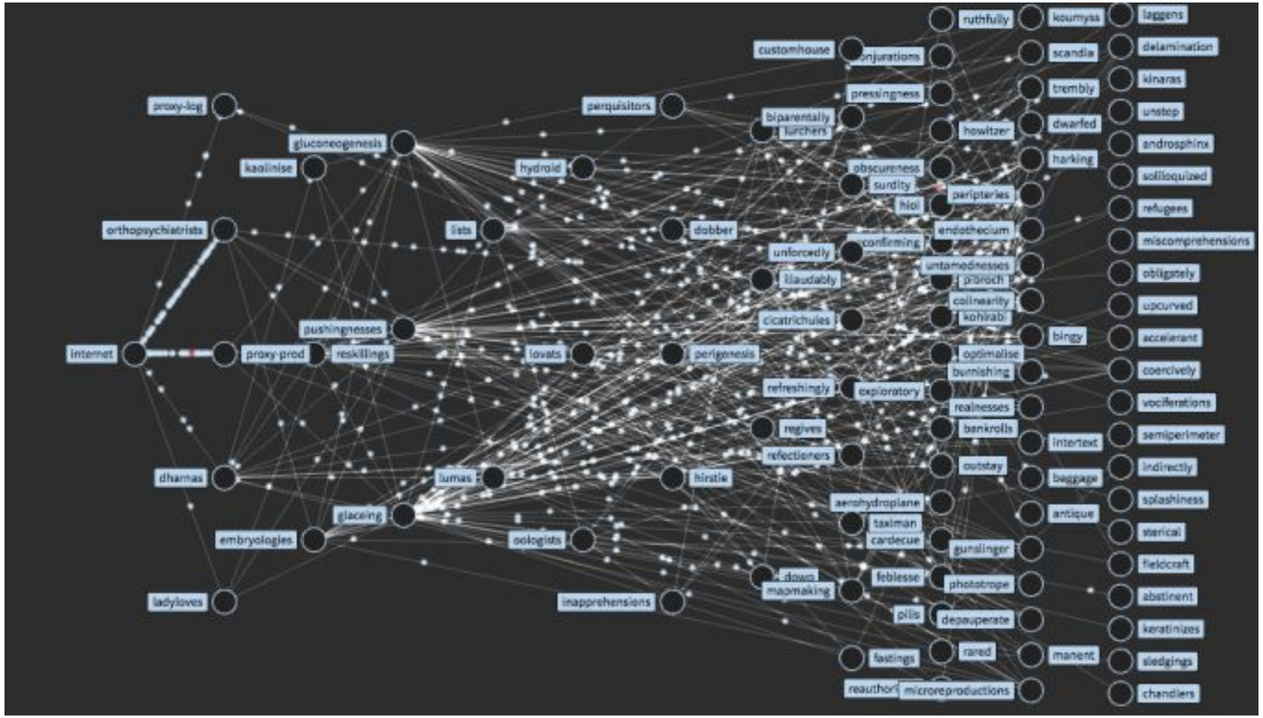
```
vhellendoorn@DESKTOP-7DET9B7:/mnt/c/Academics/Teaching/17214/Misc/f22-rec09$ docker-compose up
Creating network "f22-rec09_internal_network" with the default driver
Creating network "f22-rec09_external_network" with the default driver
Creating f22-rec09_frontend_1 ... done
Creating f22-rec09_backend_1  ... done
Creating f22-rec09_nginx_1    ... done
Attaching to f22-rec09_frontend_1, f22-rec09_backend_1, f22-rec09_nginx_1
backend_1   | [INFO] Scanning for projects...
frontend_1  |
frontend_1  | > front-end@0.1.0 start
frontend_1  | > react-scripts start
frontend_1  |
backend_1   | Downloading from central: https://repo.maven.apache.org/maven2/org/codehaus/mojo/exec-maven-plugin/1.2.1/exec-maven-plugin-1.2.1.pom
frontend_1  | (node:26) [DEP_WEBPACK_DEV_SERVER_ON_AFTER_SETUP_MIDDLEWARE] DeprecationWarning: 'onAfterSetupMiddleware' option is deprecated. Please use the 'setupMiddleware
s' option.
frontend_1  | (Use `node --trace-deprecation ...` to show where the warning was created)
frontend_1  | (node:26) [DEP_WEBPACK_DEV_SERVER_ON_BEFORE_SETUP_MIDDLEWARE] DeprecationWarning: 'onBeforeSetupMiddleware' option is deprecated. Please use the 'setupMiddlewa
res' option.
frontend_1  | Starting the development server...
frontend_1  |
Downloaded from central: https://repo.maven.apache.org/maven2/org/codehaus/mojo/exec-maven-plugin/1.2.1/exec-maven-plugin-1.2.1.pom (7.7 kB at 5.2 kB/s)
backend_1   | Downloading from central: https://repo.maven.apache.org/maven2/org/codehaus/mojo/mojo-parent/28/mojo-parent-28.pom
Downloaded from central: https://repo.maven.apache.org/maven2/org/codehaus/mojo/mojo-parent/28/mojo-parent-28.pom (26 kB at 300 kB/s)
backend_1   | Downloading from central: https://repo.maven.apache.org/maven2/org/codehaus/codehaus-parent/3/codehaus-parent-3.pom
Downloaded from central: https://repo.maven.apache.org/maven2/org/codehaus/codehaus-parent/3/codehaus-parent-3.pom (4.1 kB at 65 kB/s)
backend_1   | Downloading from central: https://repo.maven.apache.org/maven2/org/codehaus/mojo/exec-maven-plugin/1.2.1/exec-maven-plugin-1.2.1.jar
Downloaded from central: https://repo.maven.apache.org/maven2/org/codehaus/mojo/exec-maven-plugin/1.2.1/exec-maven-plugin-1.2.1.jar (38 kB at 402 kB/s)
backend_1   | [INFO]
backend_1   | [INFO] ---------------------< groupId:17214-22fall-rec09 >---------------------
backend_1   | [INFO] Building 17214-22fall-rec09 1.0-SNAPSHOT
backend_1   | [INFO] --------------------------------[ jar ]---------------------------------
backend_1   | [INFO]
backend_1   | [INFO] --- exec-maven-plugin:1.2.1:exec (default-cli) @ 17214-22fall-rec09 ---
backend_1   | Downloading from central: https://repo.maven.apache.org/maven2/org/apache/maven/maven-plugin-api/2.0/maven-plugin-api-2.0.pom
Downloaded from central: https://repo.maven.apache.org/maven2/org/apache/maven/maven-plugin-api/2.0/maven-plugin-api-2.0.pom (601 B at 9.2 kB/s)
```

Where are we now?

- We've discussed Docker as a build tool, DockerHub for deployment
- Something is off about our app



Remember this?



http://christophermeiklejohn.com/filibuster/2021/10/14/filibuster-4.html

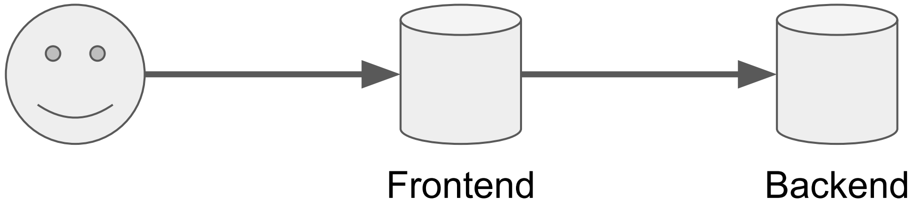
Towards Distributed Systems

- Docker compose helps us set up local systems
    - The result could be microservice or a larger app
    - Often very useful: enables modular development with all the ease of docker images for deployment
- But in our case, backend and frontend are both microservices
    - Why might we not want just one of each, hard-coded to talk to each other?

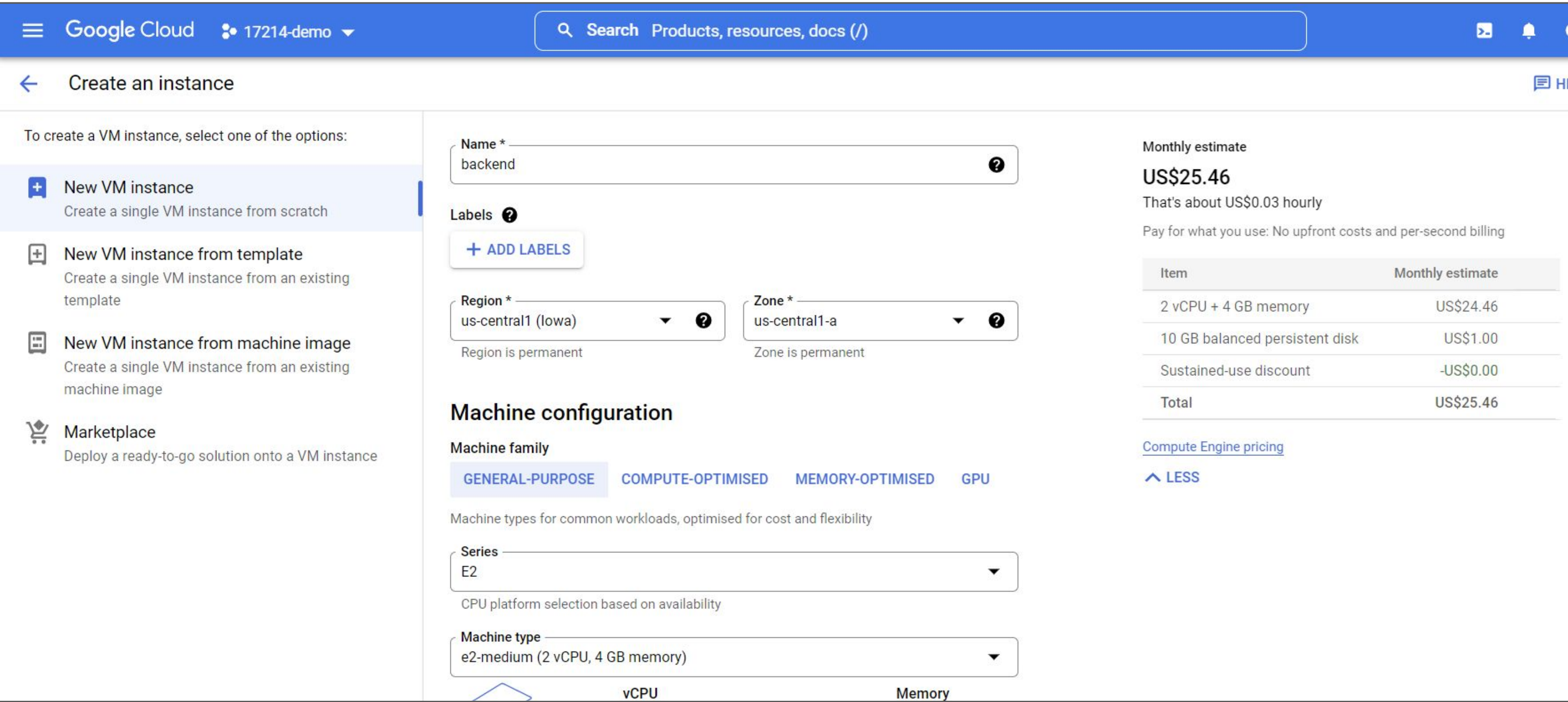
Towards Distributed Systems

How about:

- Put up two VMs in the cloud, deploy one image on each
- Tell ‘frontend’ where to find ‘backend’ by IP



Tangent: deploying in the Cloud



Google Cloud 17214-demo

Search Products, resources, docs (/)

Create an instance

To create a VM instance, select one of the options:

New VM instance
Create a single VM instance from scratch

New VM instance from template
Create a single VM instance from an existing template

New VM instance from machine image
Create a single VM instance from an existing machine image

Marketplace
Deploy a ready-to-go solution onto a VM instance

Name * backend

Labels
+ ADD LABELS

Region * us-central1 (Iowa)
Region is permanent

Zone * us-central1-a
Zone is permanent

Machine configuration

Machine family
GENERAL-PURPOSE COMPUTE-OPTIMISED MEMORY-OPTIMISED GPU

Machine types for common workloads, optimised for cost and flexibility

Series E2
CPU platform selection based on availability

Machine type e2-medium (2 vCPU, 4 GB memory)

vCPU Memory

Monthly estimate
US$25.46
That's about US$0.03 hourly
Pay for what you use: No upfront costs and per-second billing

Item	Monthly estimate
2 vCPU + 4 GB memory	US$24.46
10 GB balanced persistent disk	US$1.00
Sustained-use discount	-US$0.00
Total	US$25.46

Compute Engine pricing

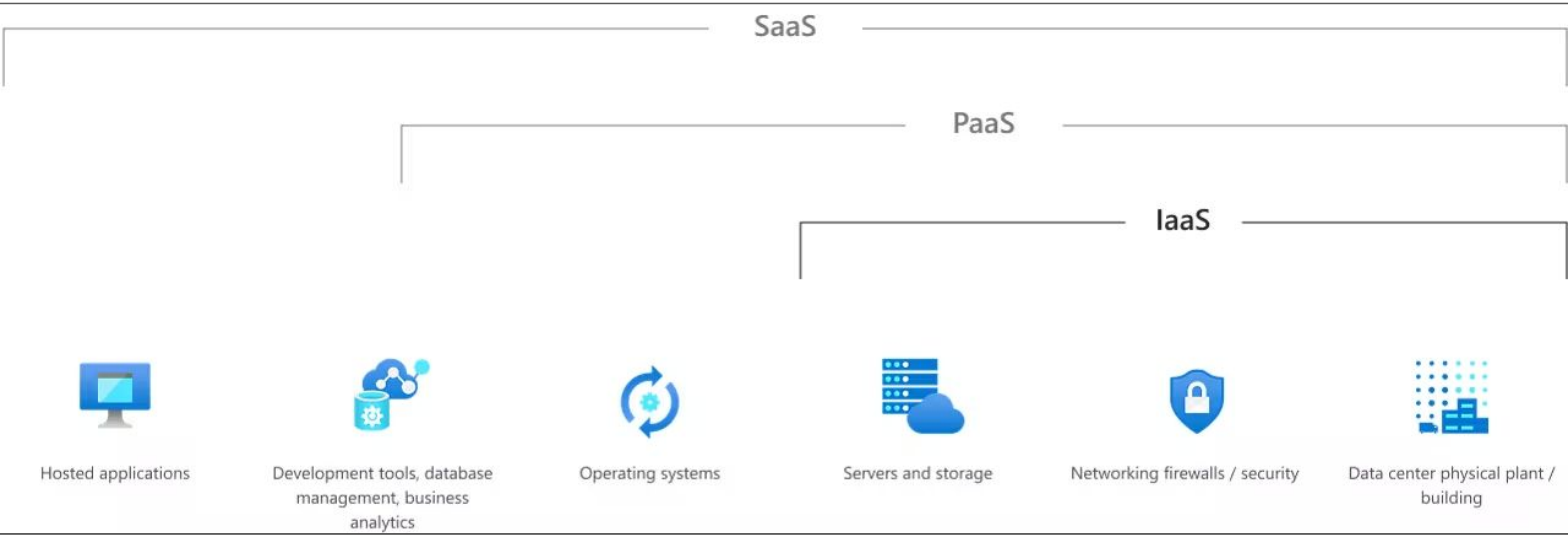
LESS

Deploying in the Cloud

Many types of cloud services are available

- Most natural: Infrastructure as a Service (IAAS)
  - Provision Virtual Machines (VMs) of a given size
    - That’s right, virtualization on top of virtualization
  - Or databases, firewalls, entire clusters – anything that would go in building your own data center

There’s more in the cloud


SaaS
PaaS
IaaS
Hosted applications
Development tools, database management, business analytics
Operating systems
Servers and storage
Networking firewalls / security
Data center physical plant / building

https://azure.microsoft.com/en-us/resources/cloud-computing-dictionary/what-is-iaas/

Note: not everyone thinks of these as nested categories

PaaS: why install your own software?

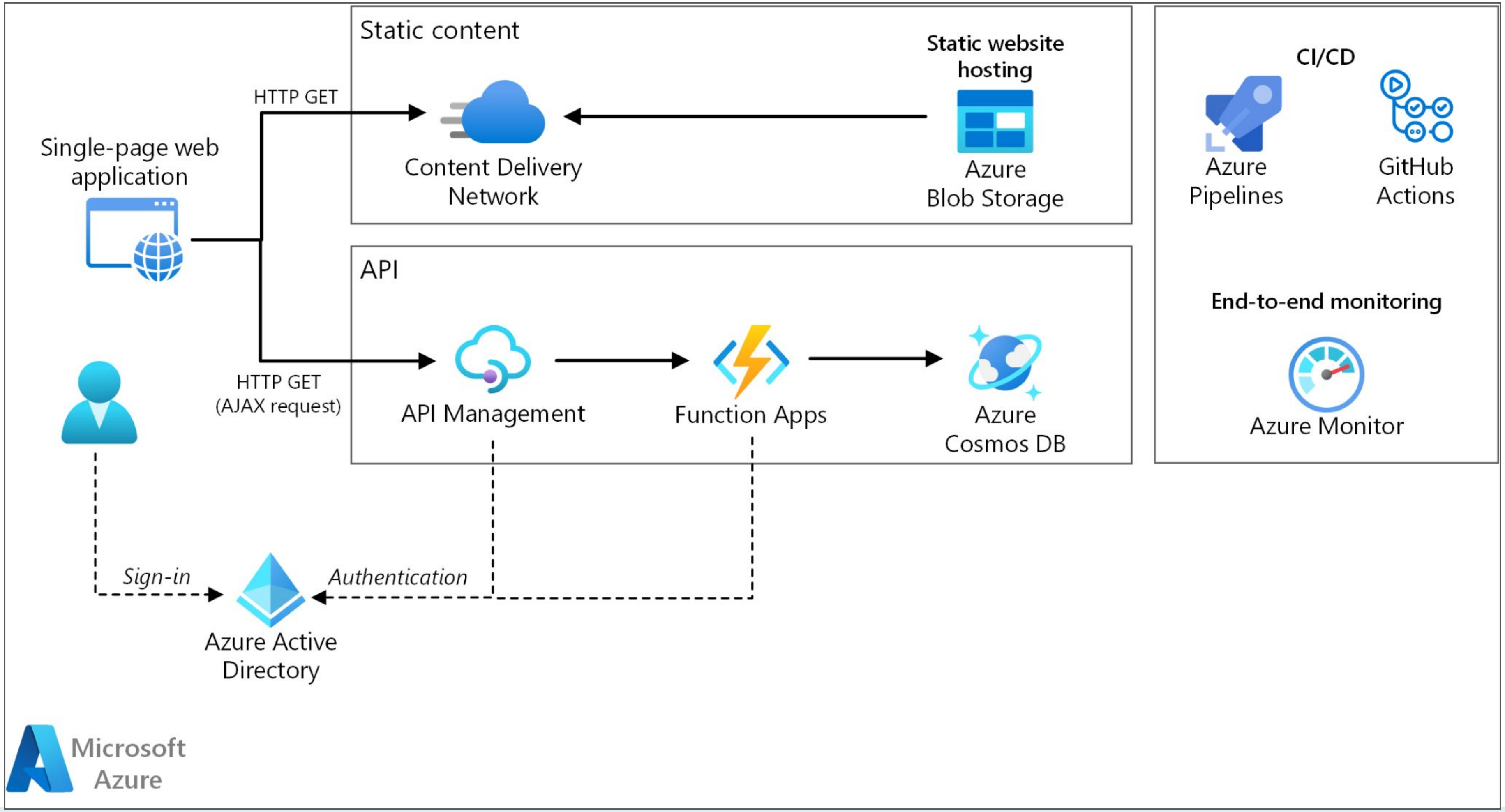
- Don’t just rent machines, rent systems
  - Distributed systems have many common components
    - Like design patterns!
  - Platform as a Service provides preconfigured machines, orchestrators
- Very handy for startups, small teams
  - Managing large distributed systems is hard.

SaaS: why think about machines at all?

- Rent apps, don’t think about where they run
  - Common example: email
  - GMail, Google Docs, Colab, etc. are all SaaS
- Very common use-case, major benefits
  - Leaves it to cloud provider to manage infrastructure and deployment. Often a win-win – they benefit from scale.
  - Seriously, don’t discount this as an option!
    - Obviously not always applicable, but if you can avoid building your own email client, you should, no matter how easy it seems to develop. A huge chunk of the cost is “hidden” in ops.

Recently Popular: Serverless Computing

- Doesn’t mean “no servers”, just “developers won’t see the servers”
  - Recall PaaS: time not spent managing ops is a big win
- Several instatiations:
  - Functions (e.g., AWS Lambda) – event-driven services that are scaled by the cloud provider (sometimes called **FaaS**)
  - Workflow orchestrators – low/no-code system design
  - Databases – data stores that resize seamlessly (part of **BaaS**)


Static content
Static website hosting
HTTP GET
Content Delivery Network
Azure Blob Storage
CI/CD
Azure Pipelines
GitHub Actions
Single-page web application
API
End-to-end monitoring
API Management
Function Apps
Azure Cosmos DB
HTTP GET (AJAX request)
Azure Monitor
Sign-in
Authentication
Azure Active Directory
Microsoft Azure

Cloud Computing: Getting to the Point

We talk a lot about how good design benefits from reuse

- Of familiar patterns, of libraries, of your own code

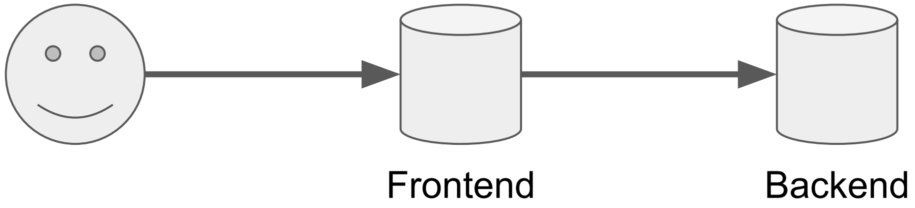
+ This isn’t a distributed systems course

= Take advantage of existing components unless you’re really sure what you are doing

Towards Distributed Systems

How about:

- Put up two VMs in the cloud, deploy one image on each
- Tell ‘frontend’ where to find ‘backend’ by IP
- Problems?



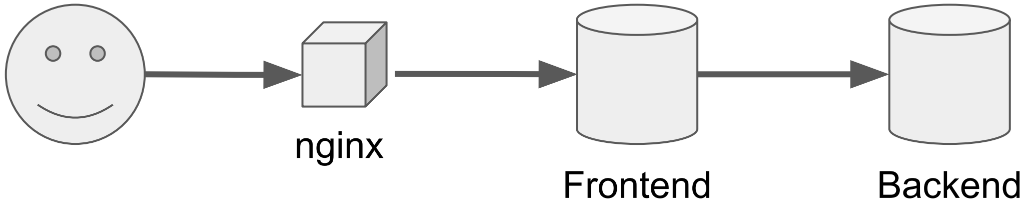
Things to consider in distributed systems

- How will VMs know where other VMs are?
- How will VMs know they can trust incoming messages?
- What parts of your topology may change?
- How will you change the topology without interruptions?
- Where will you need replication?
- How will clients find your application?

nginx

Is a reverse proxy*

- A reverse proxy does for servers what a regular proxy does for users – provide decoupling
  - Good for security, performance, robustness to system changes, ...

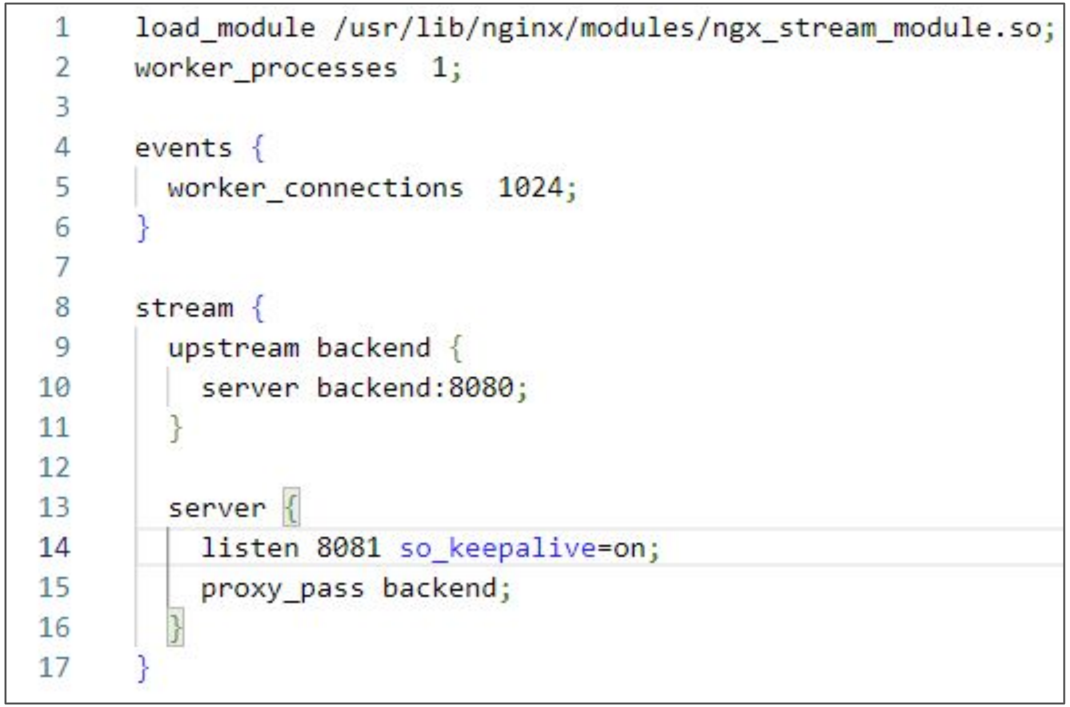


*Technically it's a web server that is really easy to set up as a reverse proxy server

Nginx Configuration Example

- Handles up to 1024 clients
- 'upstream' is the server being proxied for
  - There can be many
- 'server' is the proxy server
  - Listens on port, passes messages to upstream

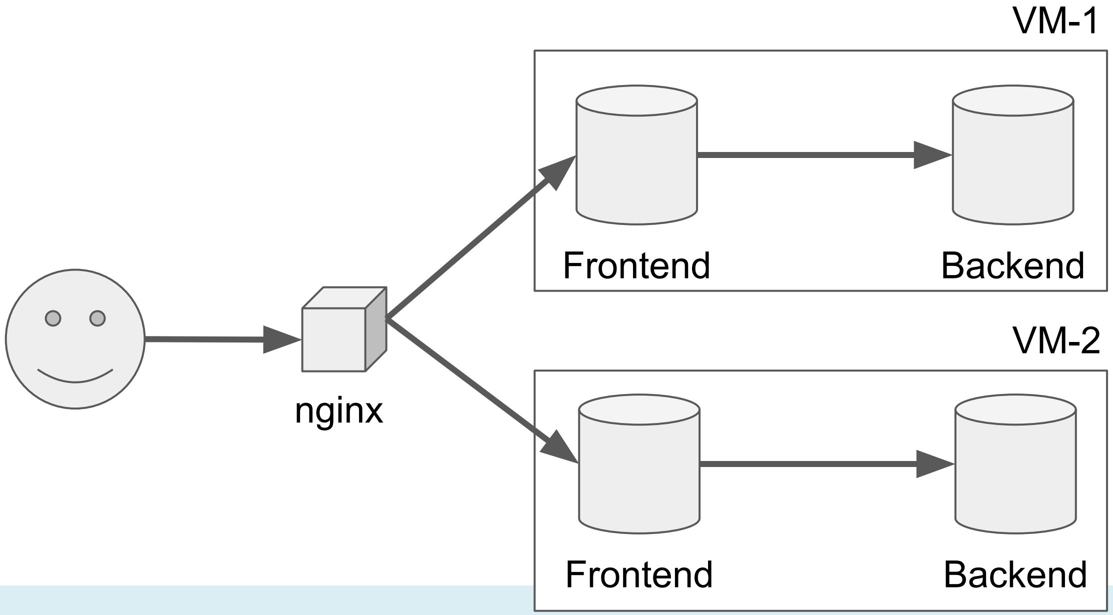
Note: here the proxy is between the frontend and backend



```
load_module /usr/lib/nginx/modules/ngx_stream_module.so;
worker_processes  1;

events {
  worker_connections  1024;
}

stream {
  upstream backend {
    server backend:8080;
  }

  server {
    listen 8081 so_keepalive=on;
    proxy_pass backend;
  }
}
```

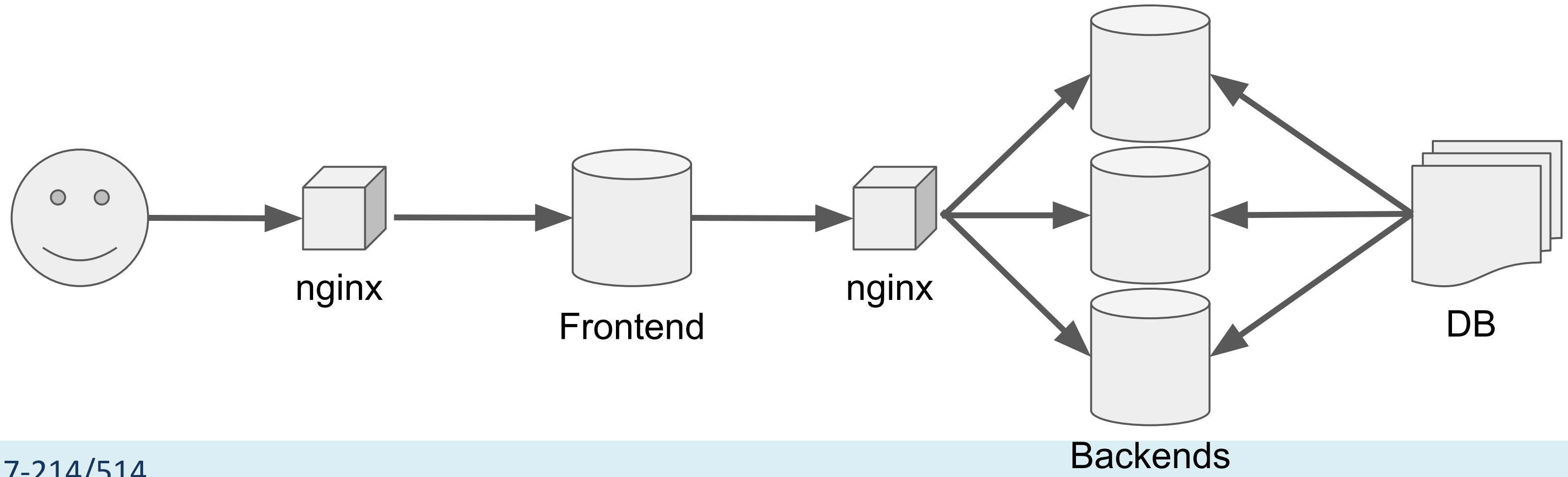
Load Balancing

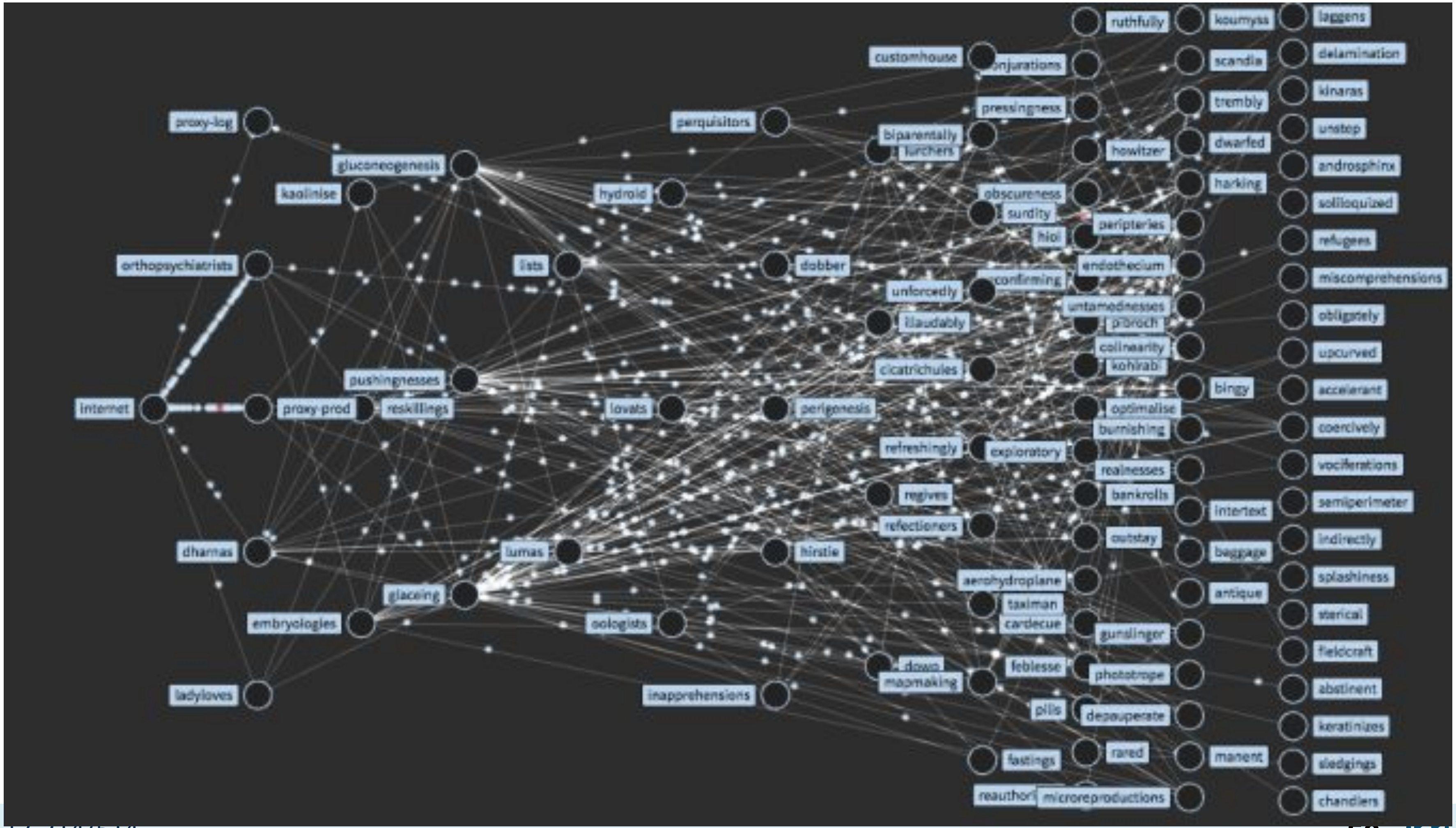
- Reverse proxies make it easy to divide web traffic
  - Nginx uses round robin if you give it multiple ‘upstreams’



Combine Creatively

- Not sufficient, but very helpful for:
    - Performance, through replication
        - Nginx server is often very powerful
    - Robustness, handle failing nodes via indirection




proxy-log
gluconeogenesis
kaolinise
orthopsychiatrists
pushingnesses
internet
proxy-prod
reskillings
dhamas
glaceing
embryologies
ladyloves
perquisitors
hydroid
lists
dobber
lovats
perigenesis
lumas
hirstie
oologists
inapprehensions
customhouse
onjurations
ruthfully
koumyss
laggens
scandia
delamination
pressingness
trembly
kinaras
biparentally
lurchers
howitzer
dwarfed
unstop
androsphinx
obscureness
harking
soliloquized
surdity
hioi
peripteries
refugees
endothecium
confirming
miscomprehensions
unforcedly
untamednesses
pibroch
obligately
illaudably
colinearity
upcurved
cicatrichules
kohlrabi
bingy
accelerant
optimalise
burnishing
coercively
refreshingly
exploratory
realnesses
vociferations
regives
bankrolls
intertext
semiperimeter
refectioners
outstay
indirectly
baggage
splashiness
aerohydroplane
antique
taximan
sterical
cardecue
gunslinger
fieldcraft
dowp
feblesse
mapmaking
phototrope
abstinent
pills
depauperate
keratinizes
fastings
rared
manent
sledgings
reauthori
microreproductions
chandlers

Let’s see Nginx in action

- Demo with multiple backends

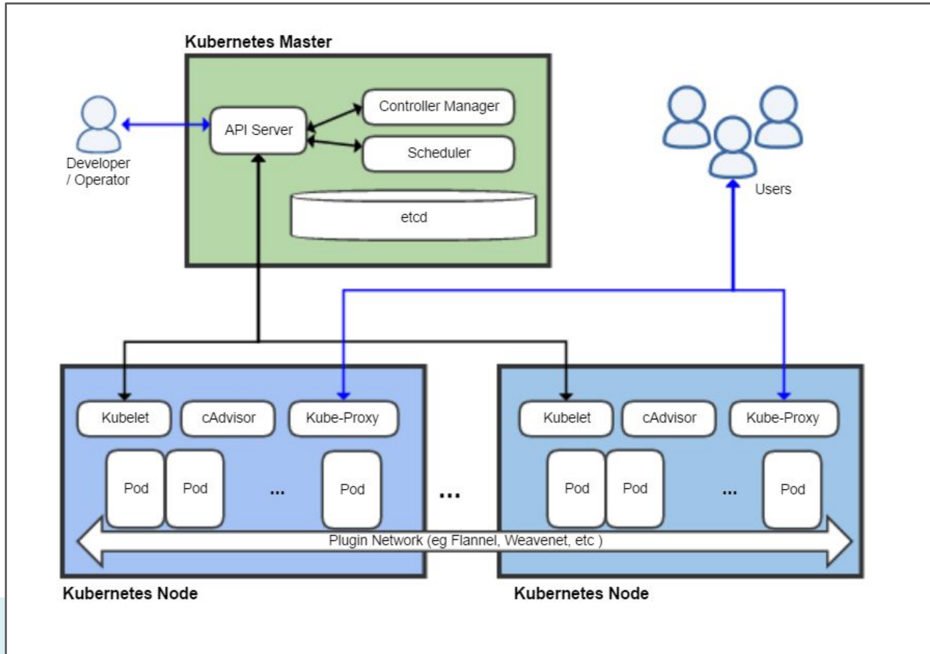
Who tells the proxies what to do?

- Note that Nginx doesn’t solve most of our problems!
  - How will VMs know where other VMs are?
  - How will VMs know they can trust incoming messages?
  - What parts of your topology may change?
  - How will you change the topology without interruptions?
  - Where will you need replication?
  - How will clients find your application?

Managing Distributed Topologies is Hard

So don't do it (yourself)!

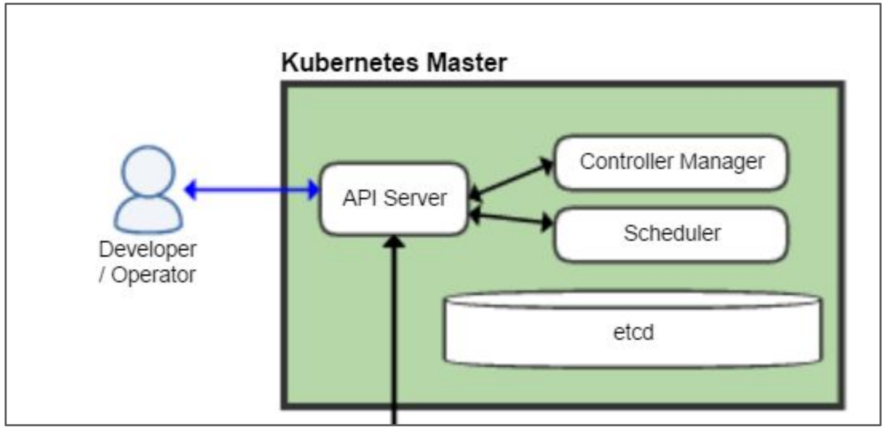
- Kubernetes (K8s), built by Google, manages containers
- Many now-familiar ideas; let's inspect them



Managing Systems with Kubernetes

The Master:

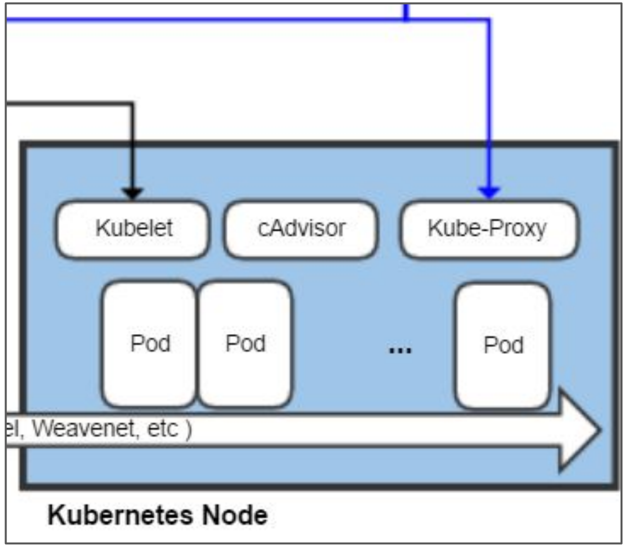
- Tracks global system state in etcd
- Scheduler tracks resource availa-bility, assigns work to hardware
- Controllers plan services to meet demands, goals
- API for monitoring, updating



Managing Systems with Kubernetes

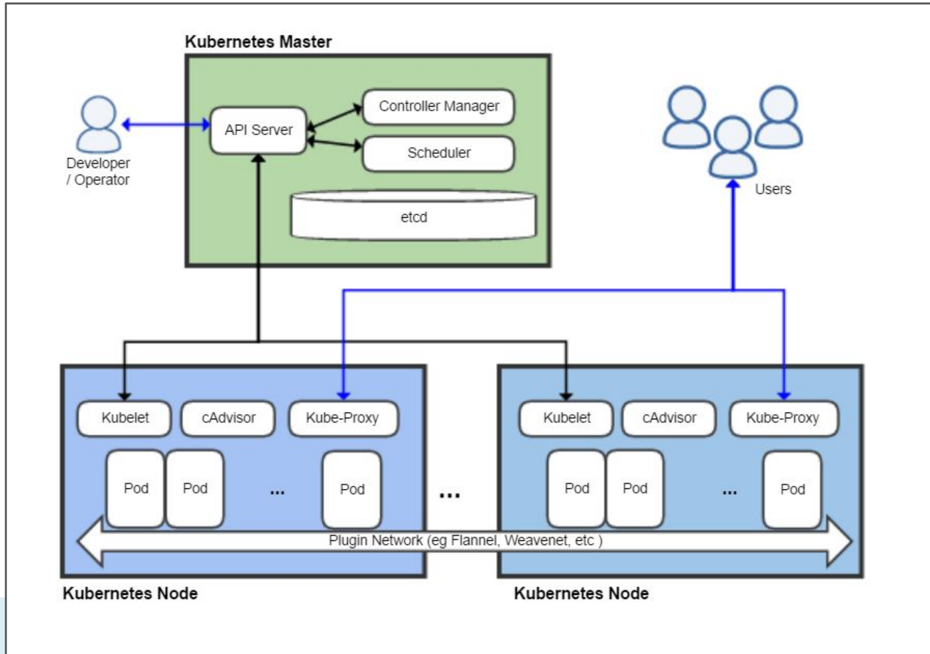
The workers

- Each node is a machine
- Pods consist of connected container(s)
  - Conf., a docker-compose system
  - In fact, containers are usually Docker
- Kubelets monitor the pods, can reprovision
  - Connected to the master
- Kube-proxy provides routing, load balancing
  - Conf., nginx



Managing Systems with Kubernetes

- Note how much this decouples the client from the code
    - In our previous systems, the client talked directly to the frontend
    - Now, to a load data center, which talks to a proxy, to a pod, to a container, to code



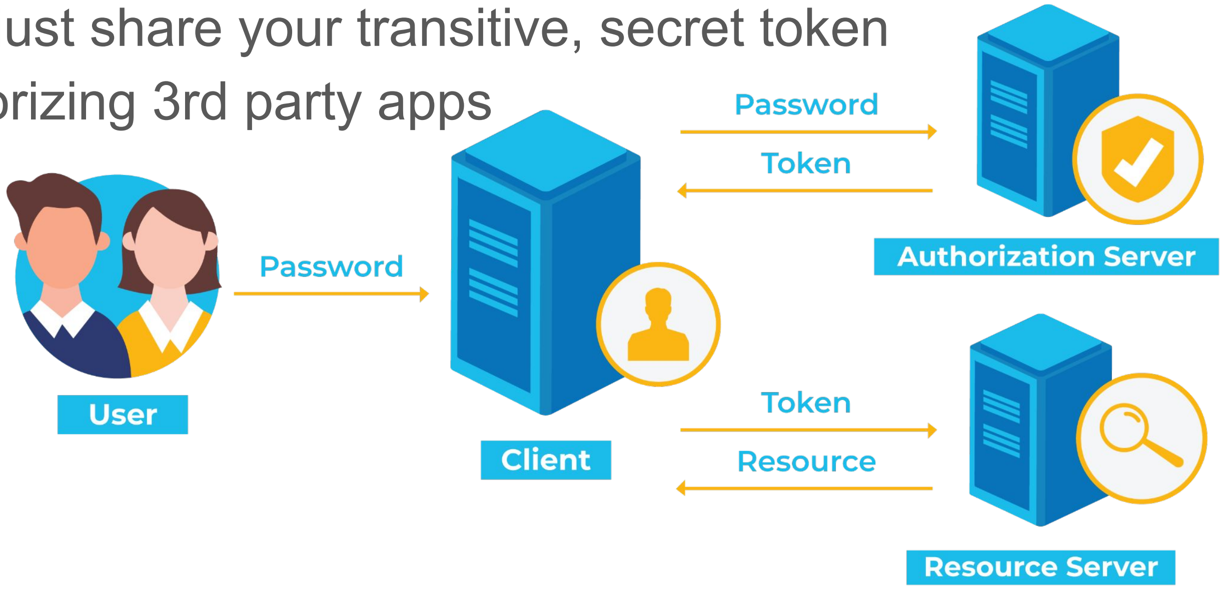
Addresses several questions

- **How will VMs know where other VMs are?**
- *How will VMs know they can trust incoming messages?*
- **What parts of your topology may change?**
- **How will you change the topology without interruptions?**
- Where will you need replication?
- How will clients find your application?

In Brief: Secure Communication

Auth tokens reign supreme these days

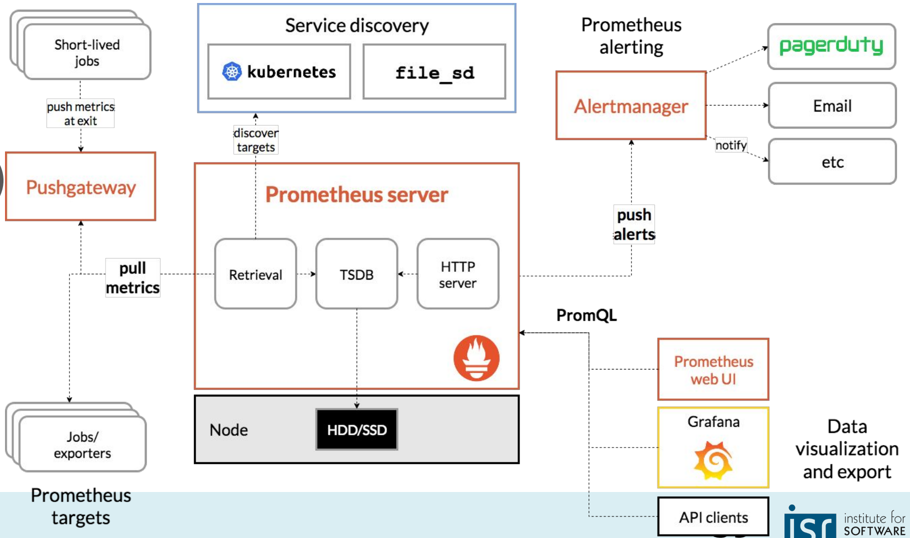
- Single sign on, then just share your transitive, secret token
- Also popular in authorizing 3rd party apps
  – see OAuth(2)



In Brief: Where to Replicate?

Complicated decision, but monitoring helps

- Cloud providers & tools like Kubernetes provide tons of telemetry
- Other tools tap into this to offer insight
- Of course, also financial aspects, legal considerations (geography), forecasting (nothing is ever instant)



Finally, is the Cloud right for you?

- You’re borrowing someone else’s computer
  - That comes at a big premium
    - Hosting on-prem can be many times cheaper
    - I recall a Twitter thread where an engineer said their AWS bill would be $100M+/month if they went that way
  - Also fewer guarantees
    - Some VMs are rarely available
    - Allocating large nrs of any kind almost certainly requires discussion
- Still worth it if you:
  - Are a small team, can’t spare cycles for system ops
  - Are growing quickly, won’t know your computing needs far out

Summary

- Containers provide isolation
  - Lighter than VMs, built with layers
  - Managed hierarchically, via configuration-as-code
- Proxies provide decoupling
  - Good for performance, robustness, security
  - Kubernetes takes this to massive scale
- Think carefully about how you put your app in the cloud
  - Consider tradeoffs between IaaS, PaaS, …
  - Also consider cost; cloud bills pile up fast