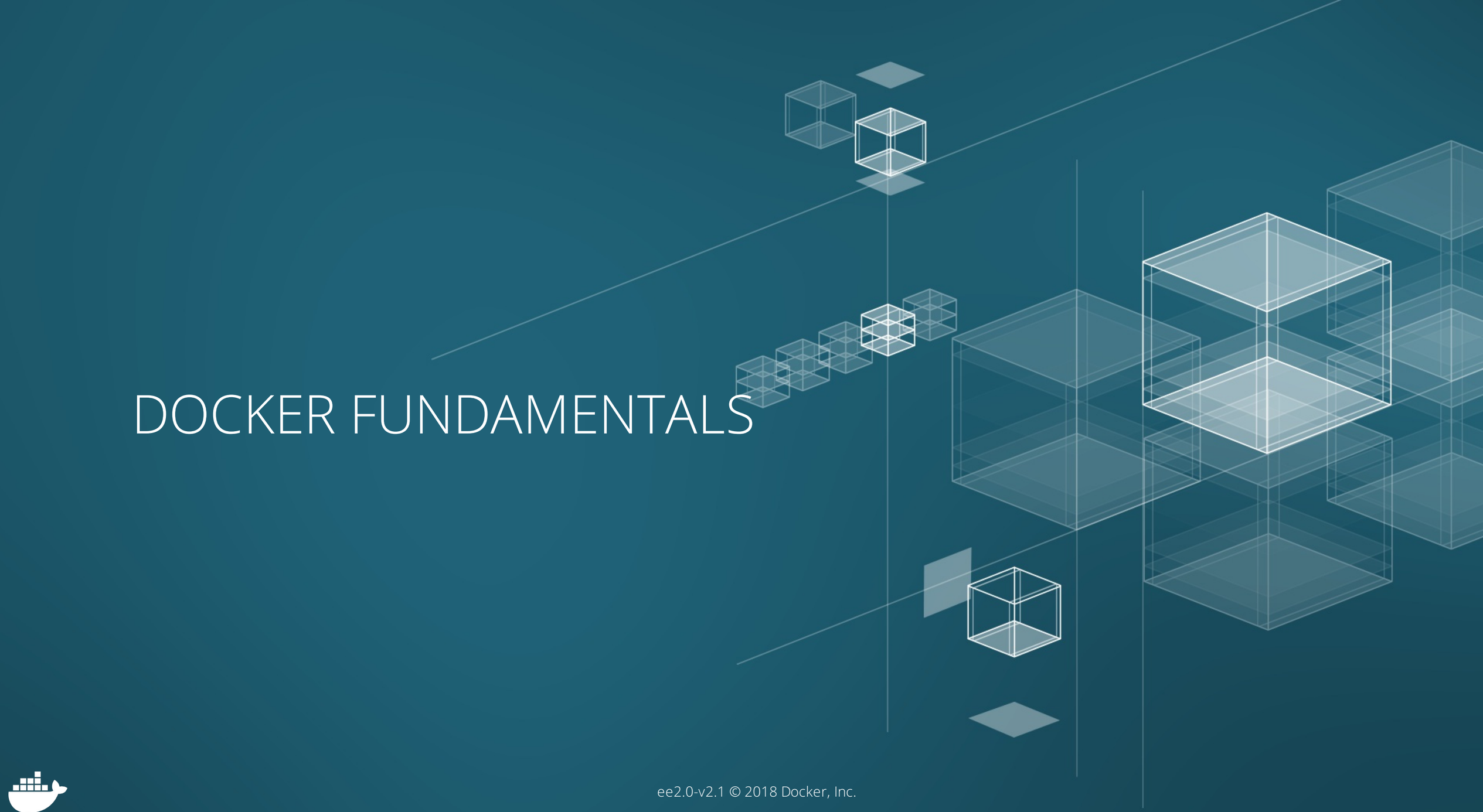
DOCKER FUNDAMENTALS



HOW WE TEACH

- Docker believes in learning by doing.
- The course is lab driven:
  - Demo Exercises
  - Signature Assignments
- Work together!
- Ask questions at any time.

SESSION LOGISTICS

- 2 days duration
- Mostly exercises
- Regular breaks

ASSUMED KNOWLEDGE AND REQUIREMENTS

- Familiarity with using the Linux command line
- Linux Cheat Sheet: http://bit.ly/2mTQr8l

YOUR LAB ENVIRONMENT

- You have been given several instances for use in exercises.
- Ask instructor for username and password if you don't have them already.

COURSE LEARNING OBJECTIVES

By the end of this course, learners will be able to:

- Assess the advantages of a containerized software development & deployment
- Use Docker engine features necessary for running containerized applications
- Utilize Swarm and Kubernetes orchestrators to deploy, maintain, and scale a distributed application

INTRODUCING DOCKER

MOVING SOFTWARE

- Difficult
- Insecure
- Resource intensive

Devops circa 1912

Photo Roel Hemkes, CC-BY 2.0

Photo Jay Phagan, CC-BY 2.0

Photo Roy Luck, CC-BY 2.0

Encapsulation eliminates friction across infrastructure, and standardization facilitates scale.

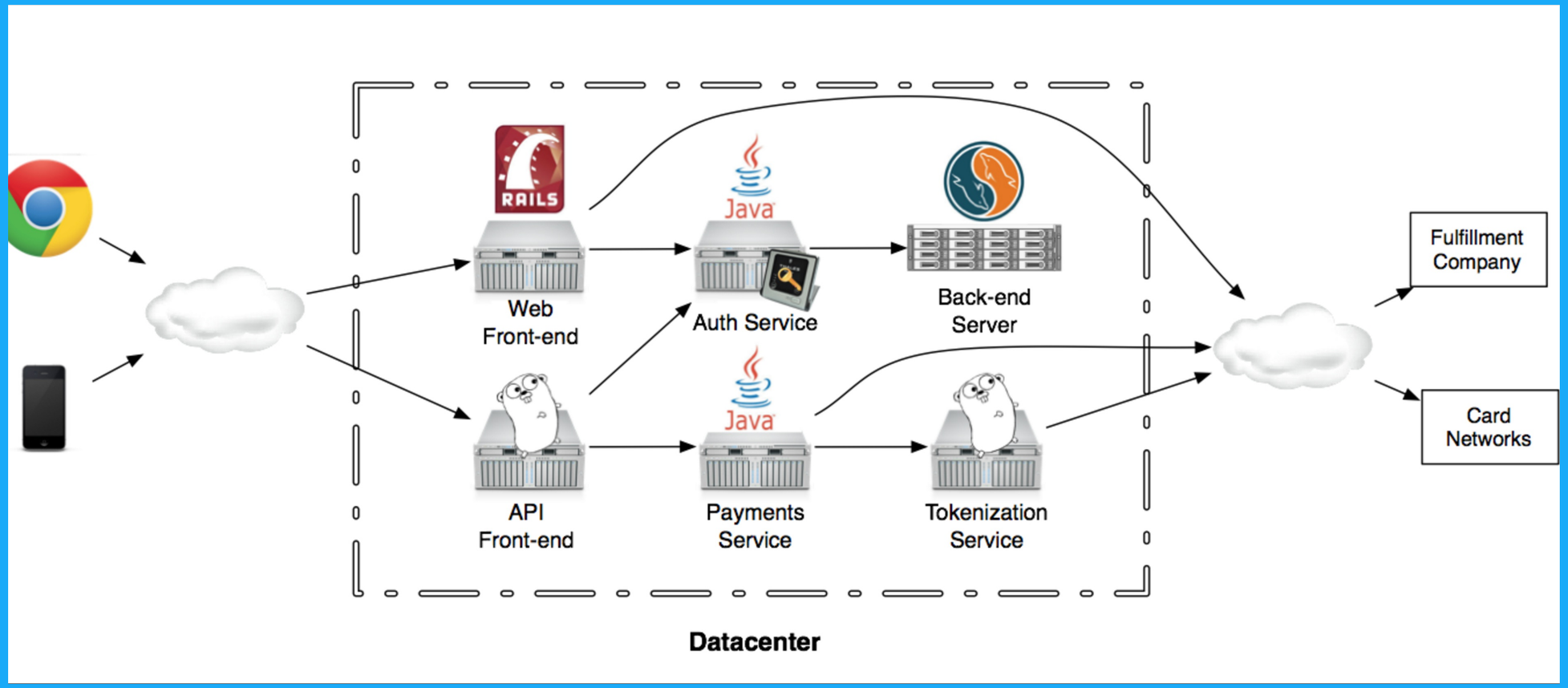
SECURITY

"Gartner asserts that applications deployed in containers are more secure than applications deployed on the bare OS."

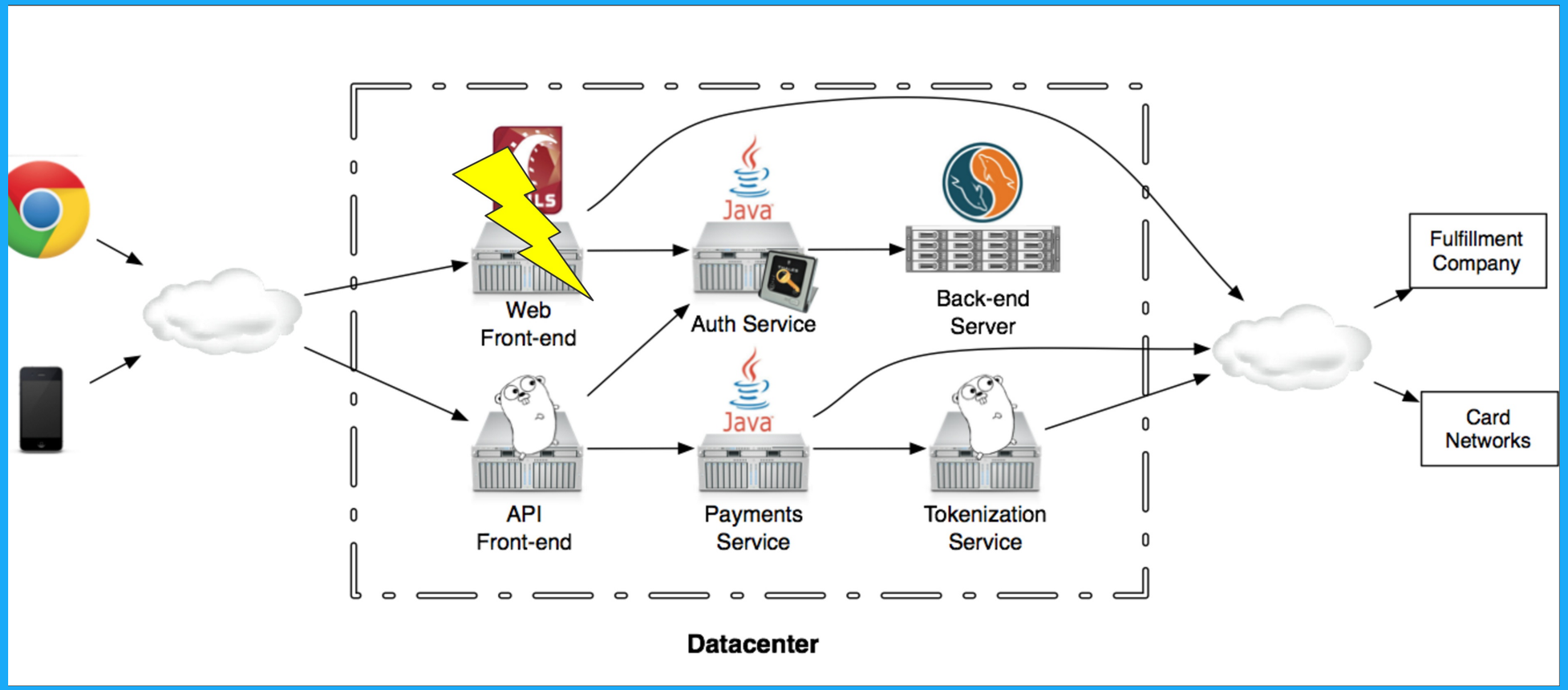
http://blogs.gartner.com/joerg-fritsch/can-you-operationalize-docker-containers/

SECURITY BREACHES

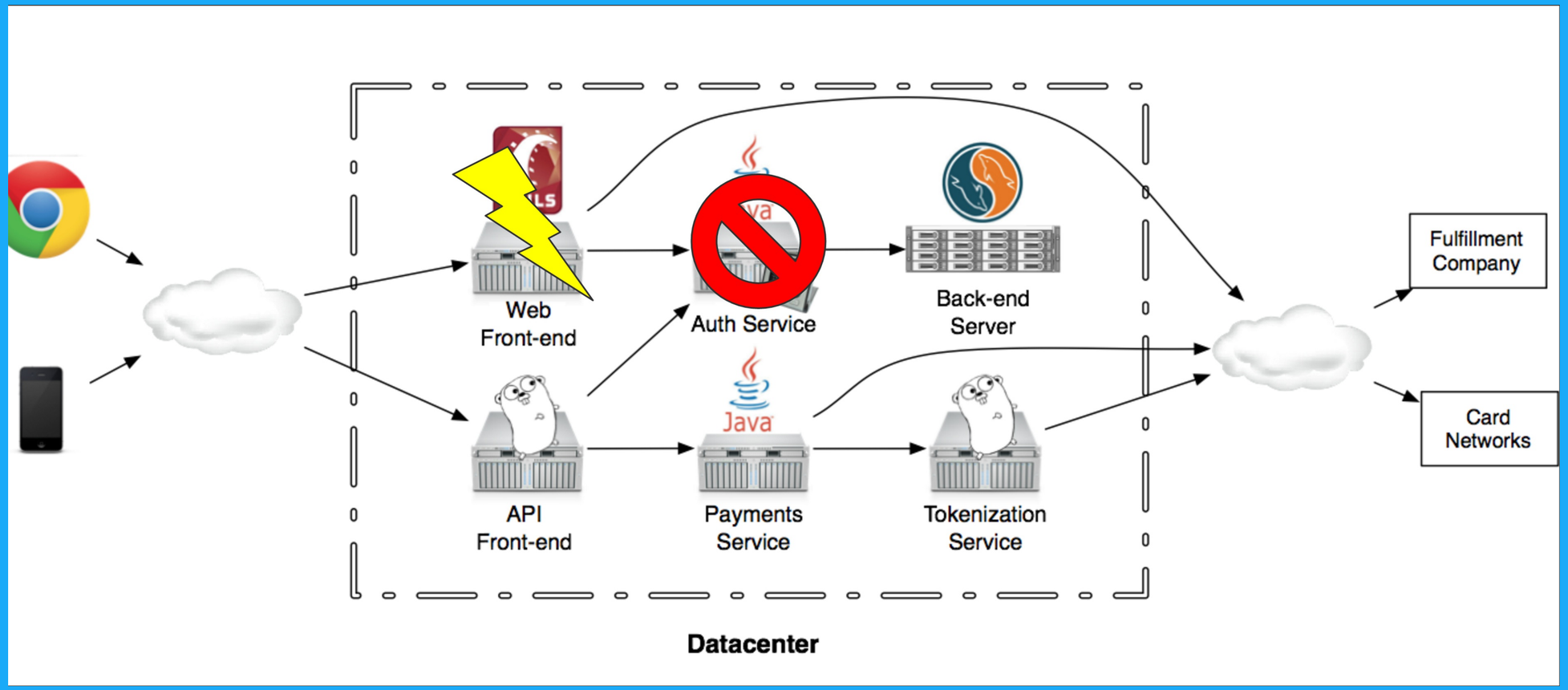
CASCADING ATTACKS



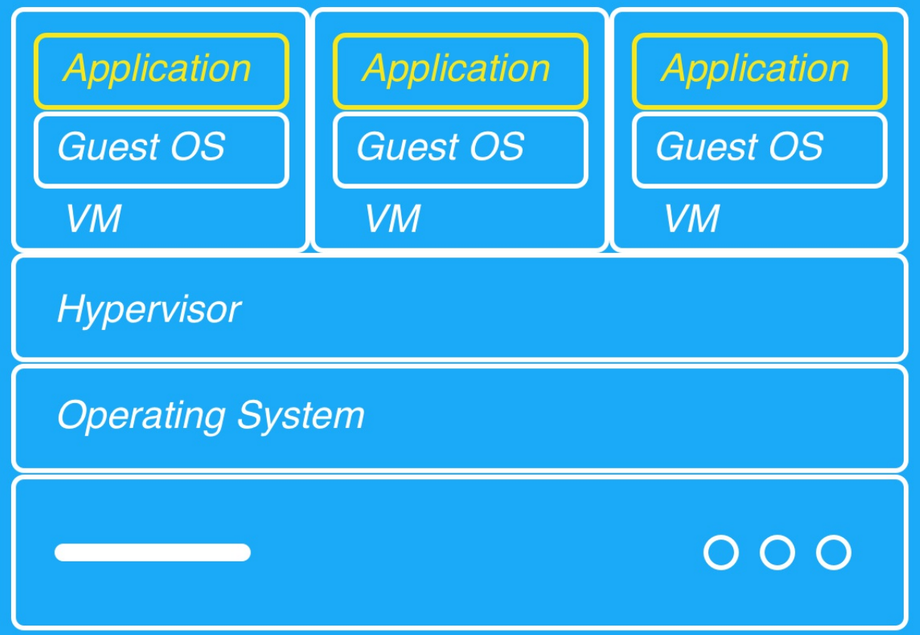
CASCADING ATTACKS



CASCADING ATTACKS



ENCAPSULATION: VIRTUAL MACHINES



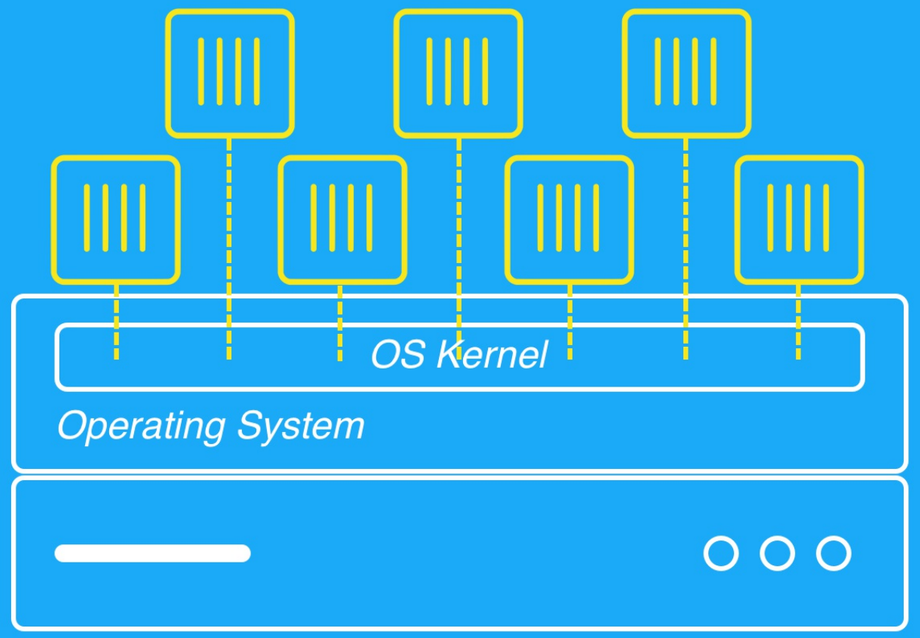
Pros:

- Multiple apps on one server
- Elastic, real time provisioning
- Scalable pay-per-use cloud models viable

Cons:

- Virtual Machines require CPU & memory allocation
- Significant overhead from guest OS

ENCAPSULATION: CONTAINERS



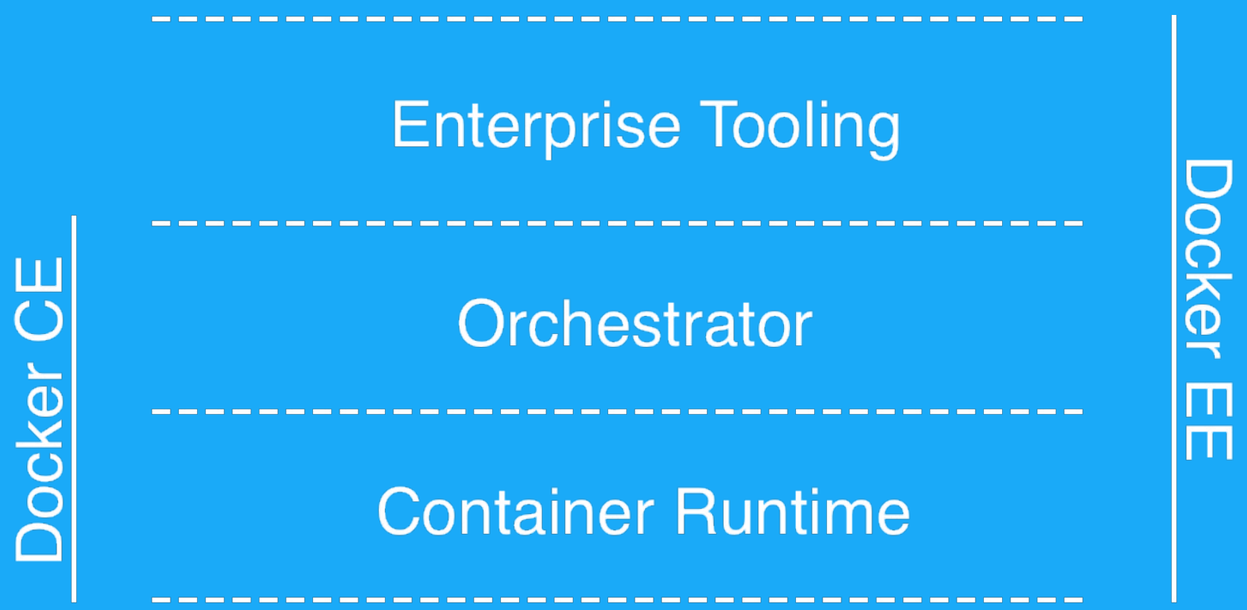
Containers leverage kernel features to create extremely light-weight encapsulation:

- Kernel namespaces
- Network namespaces
- Linux containers
- cgroups & security tools
- Results in faster spool-up and denser servers

THE SOFTWARE SUPPLY CHAIN

- Encapsulated, therefore portable
- Isolated, therefore secure
- Lightweight, therefore efficient

THE CONTAINERIZATION STACK



PART 1: CONTAINERS

CONTAINERIZATION FUNDAMENTALS

DISCUSSION: RUNNING CONTAINERS

What assurances would you need to run a process on an arbitrary host? Consider:

- Hostile environments
- Required resources

LEARNING OBJECTIVES

By the end of this module, learners will be able to:

- Describe what a container is in terms of processes and isolation tools
- Use the key commands for interacting with Docker containers

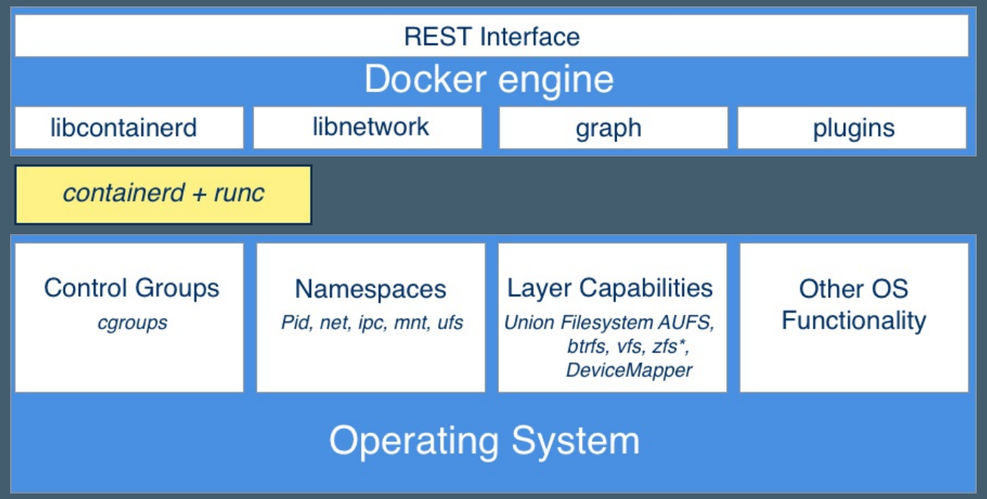
CONTAINERS ARE PROCESSES

Containers are processes sandboxed by:

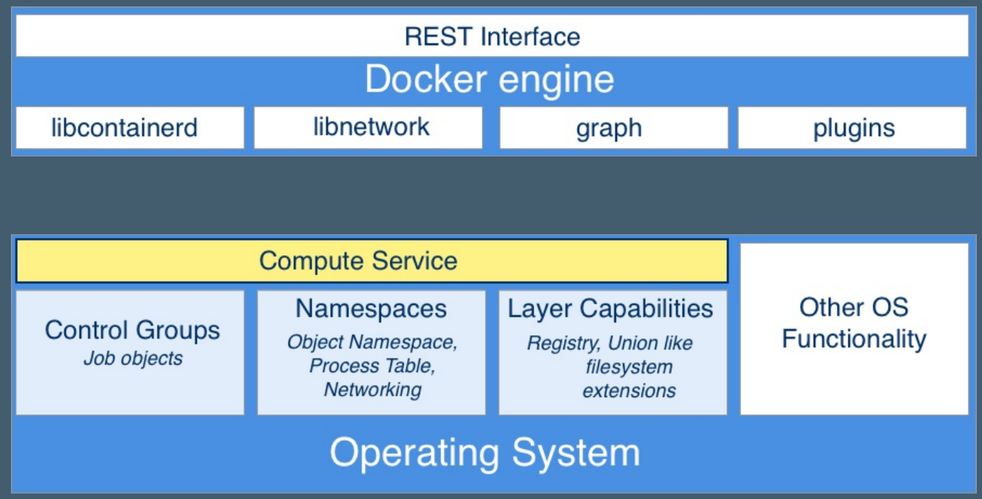
- Kernel namespaces
- Control Groups
- Root privilege management & syscall restrictions (Linux)
- VM isolation (Windows)

ARCHITECTURE

Architecture in Linux



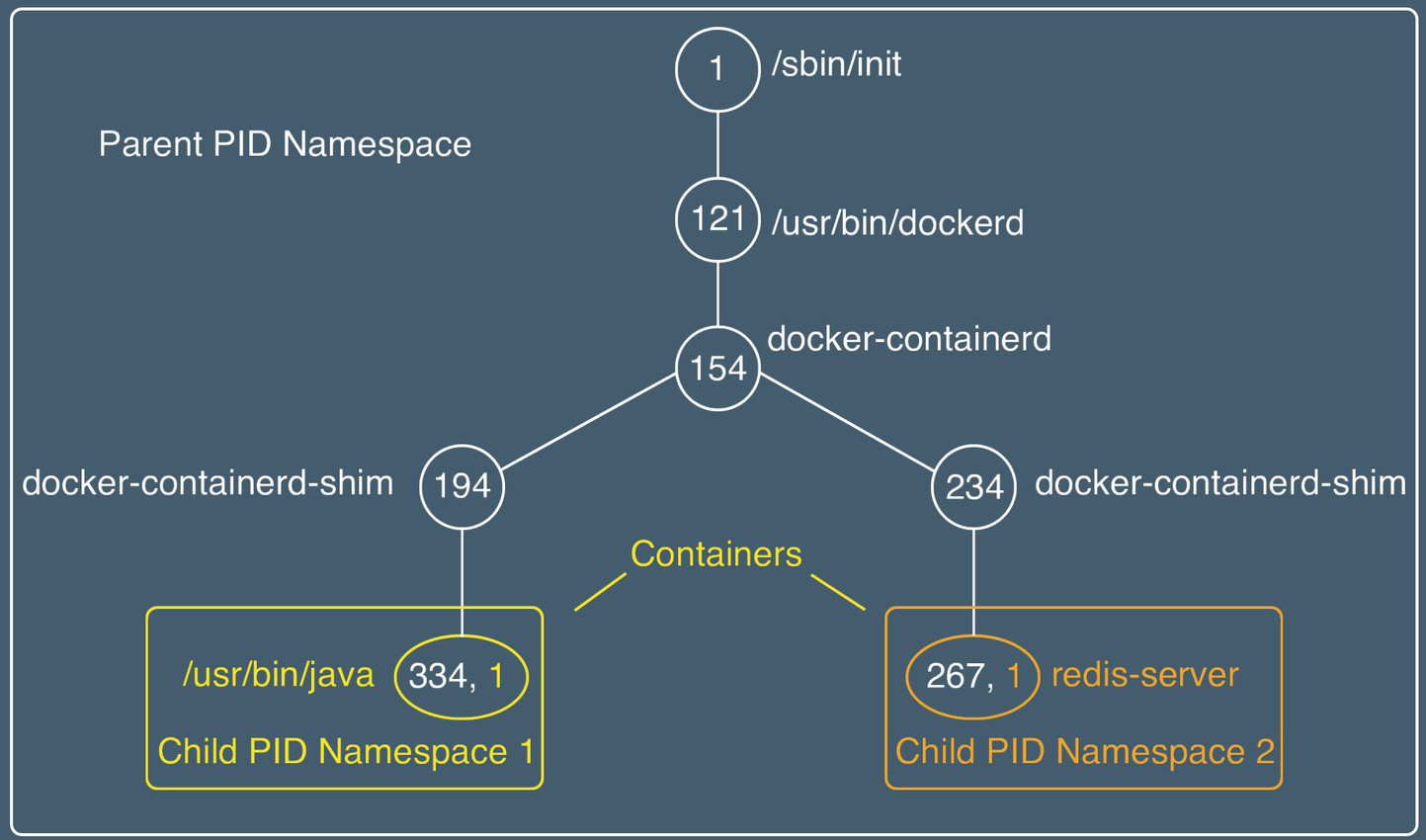
Architecture in Windows



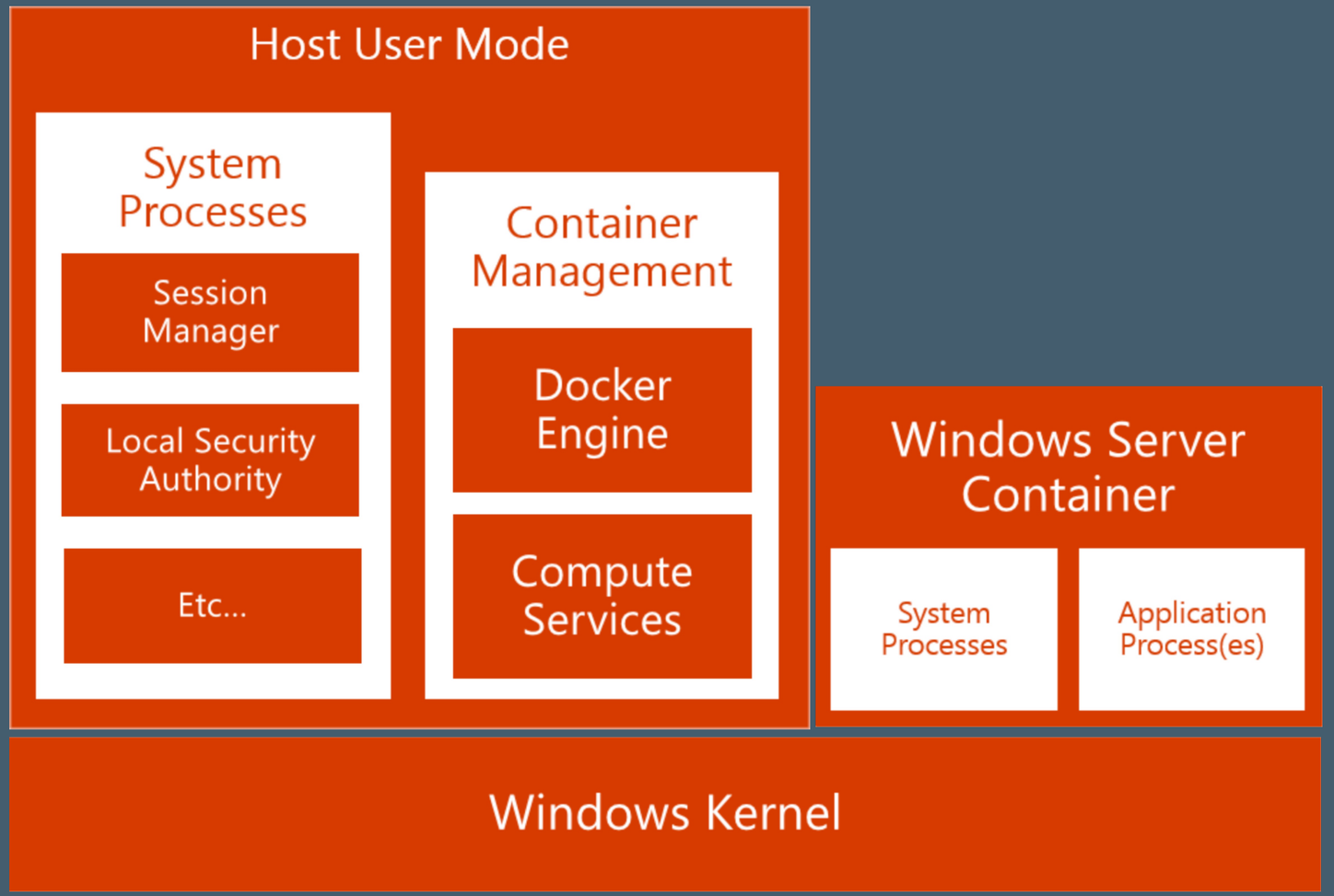
KERNEL NAMESPACES

- Default:
  - Process IDs
  - Network stacks
  - Inter-process communications
  - Mount points
  - Hostnames
- Optional:
  - User IDs

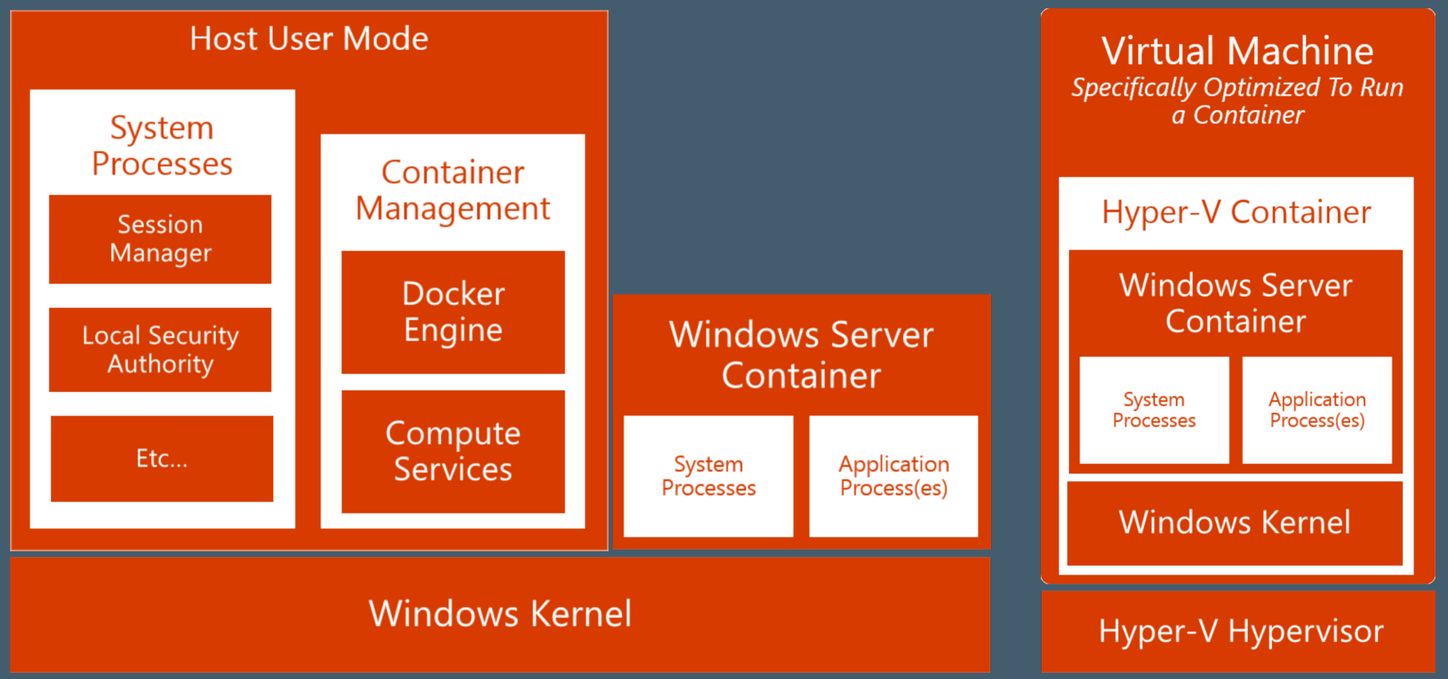
EXAMPLE: PID NAMESPACE



WINDOWS: HOST KERNEL CONTAINERS



WINDOWS: HYPER-V CONTAINERS



INSTRUCTOR DEMO: PROCESS ISOLATION

See the 'Process Isolation' demo in the Docker Fundamentals Exercises book.

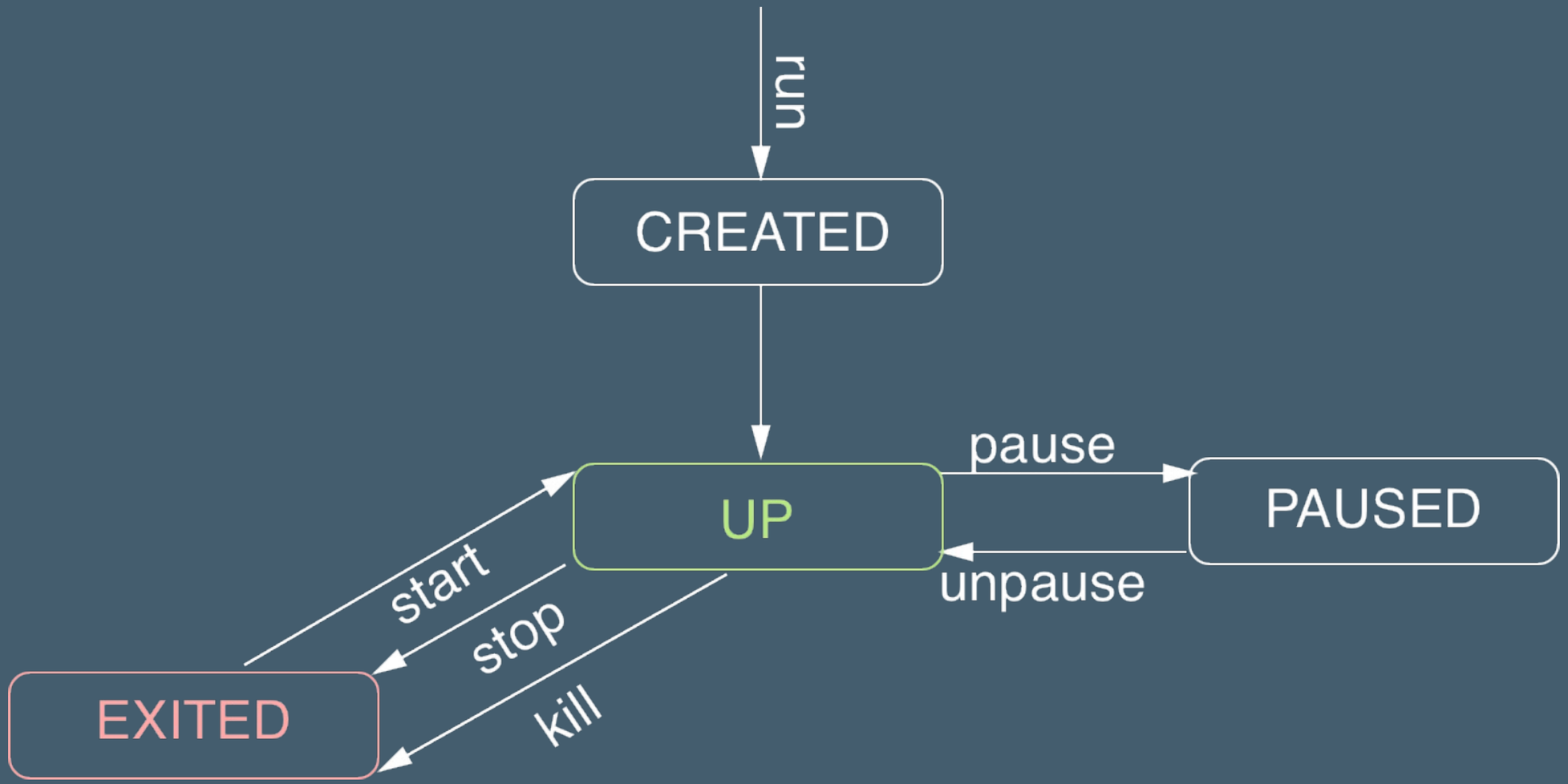
EXERCISE: CONTAINER BASICS

Work through:

- Running and Inspecting a Container
- Interactive Containers
- Detached Containers and Logging
- Starting, Stopping, Inspecting and Deleting Containers

In the Docker Fundamentals Exercises book.

CONTAINER LIFECYCLE



CONTAINER LOGS

- STDOUT and STDERR for a containerized process
- docker container logs <container name>

CONTAINER BASICS TAKEAWAYS

- Single process constrained by kernel namespaces, control groups and other technologies
- Private & ephemeral filesystem and data

FURTHER READING

- List of container commands: http://dockr.ly/2iLBV2I
- Getting started with containers: http://dockr.ly/2gmxKWB
- Start containers automatically: http://dockr.ly/2xB8sMl
- Limit a container's resources: http://dockr.ly/2wqN5Nn
- Keep containers alive during daemon downtime: http://dockr.ly/2emLwb5
- Isolate containers with a user namespace: http://dockr.ly/2gmyKdf
- Deep dive into Windows Server containers and Docker, Part 2: http://bit.ly/2xiAdJf

CREATING IMAGES

DISCUSSION: PROVISIONING FILESYSTEMS

What are some potential difficulties with provisioning entire filesystems for containers? How can we avoid these problems?

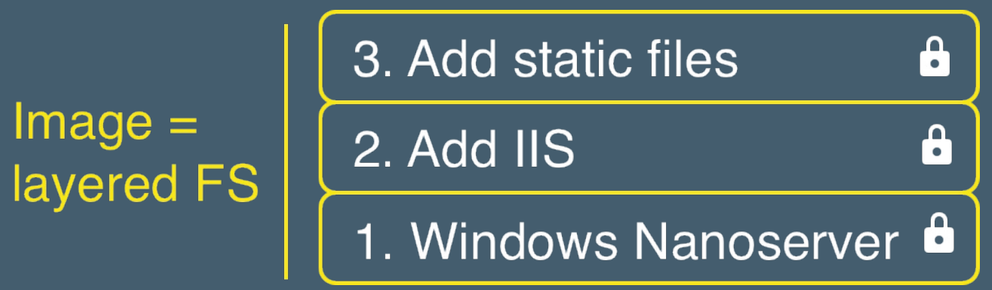
LEARNING OBJECTIVES

By the end of this module, learners will be able to:

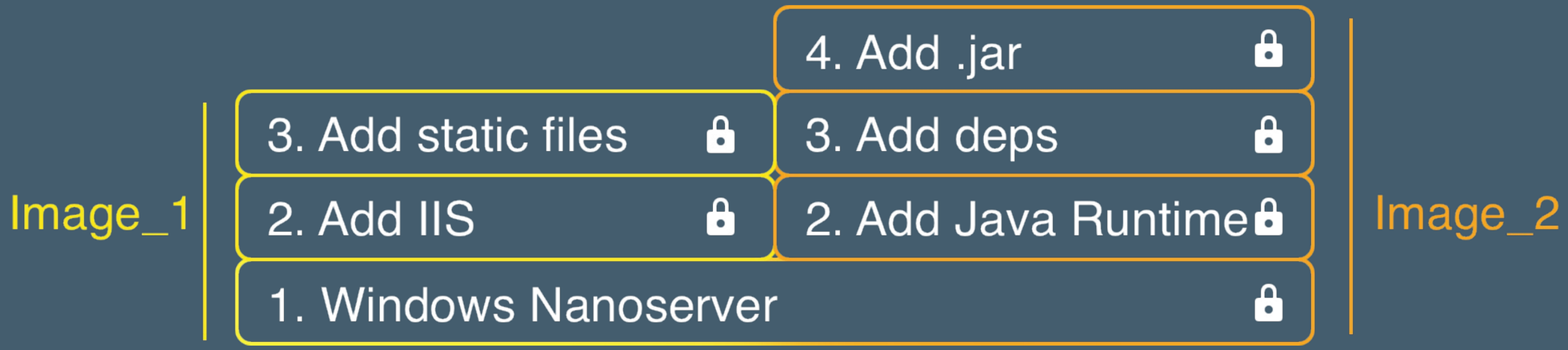
- Create images via several methods
- Describe the filesystem structure underlying an image
- Understand the performance implications of different image design decisions
- Correctly tag and namespace images for distribution on a registry

WHAT ARE IMAGES?

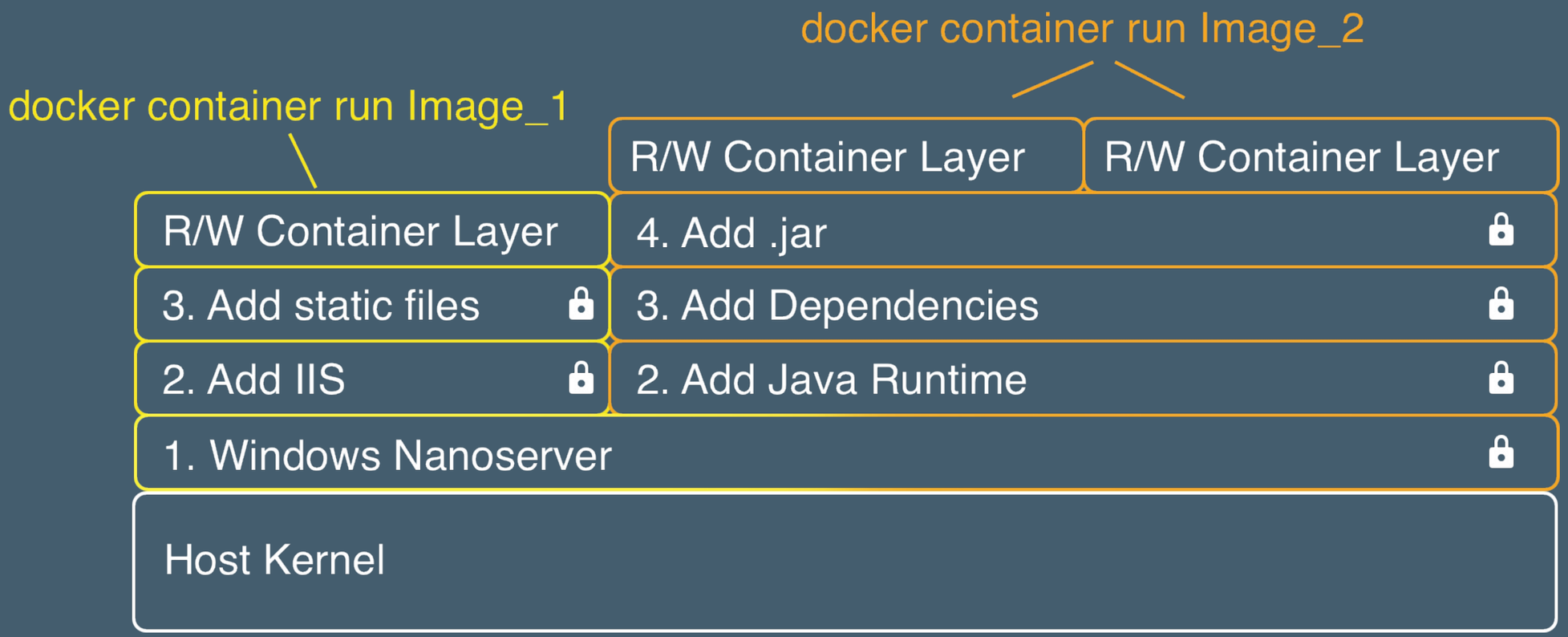
- A filesystem for container process
- Made of a stack of immutable layers
- Start with a base image
- New layer for each change



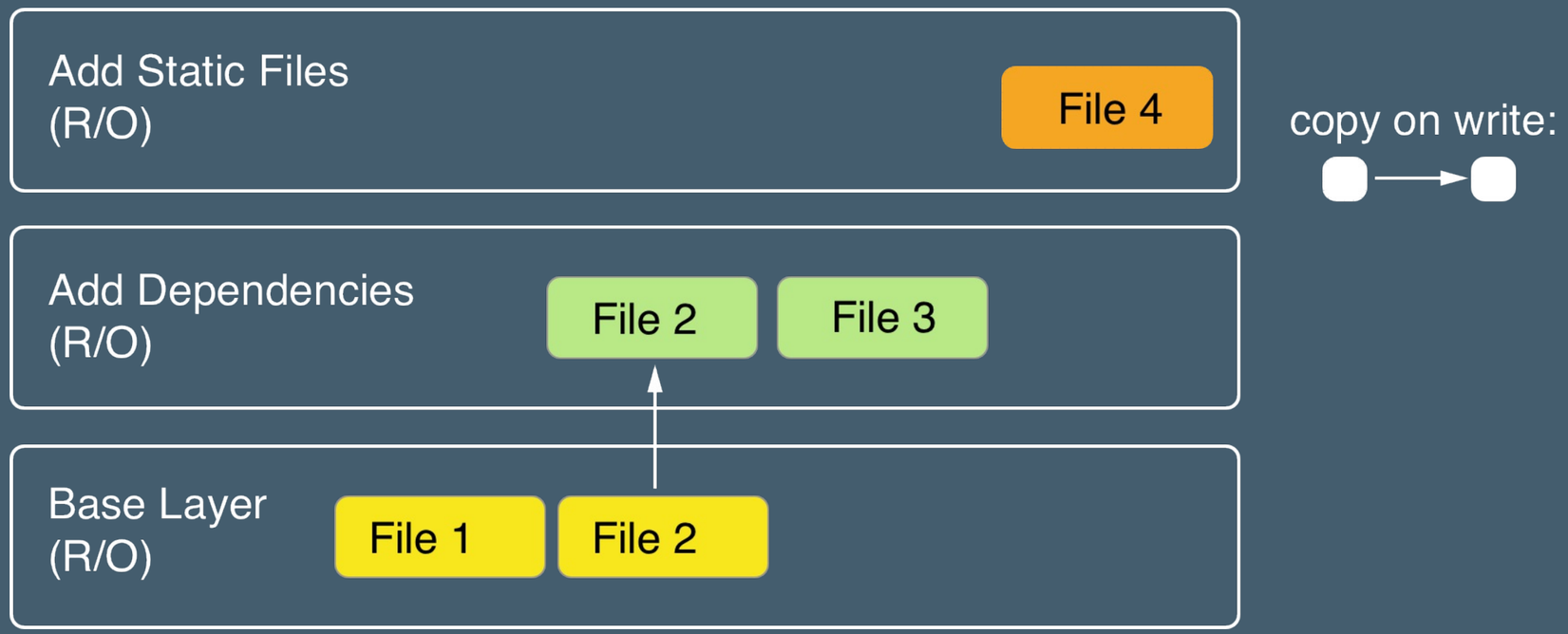
SHARING LAYERS



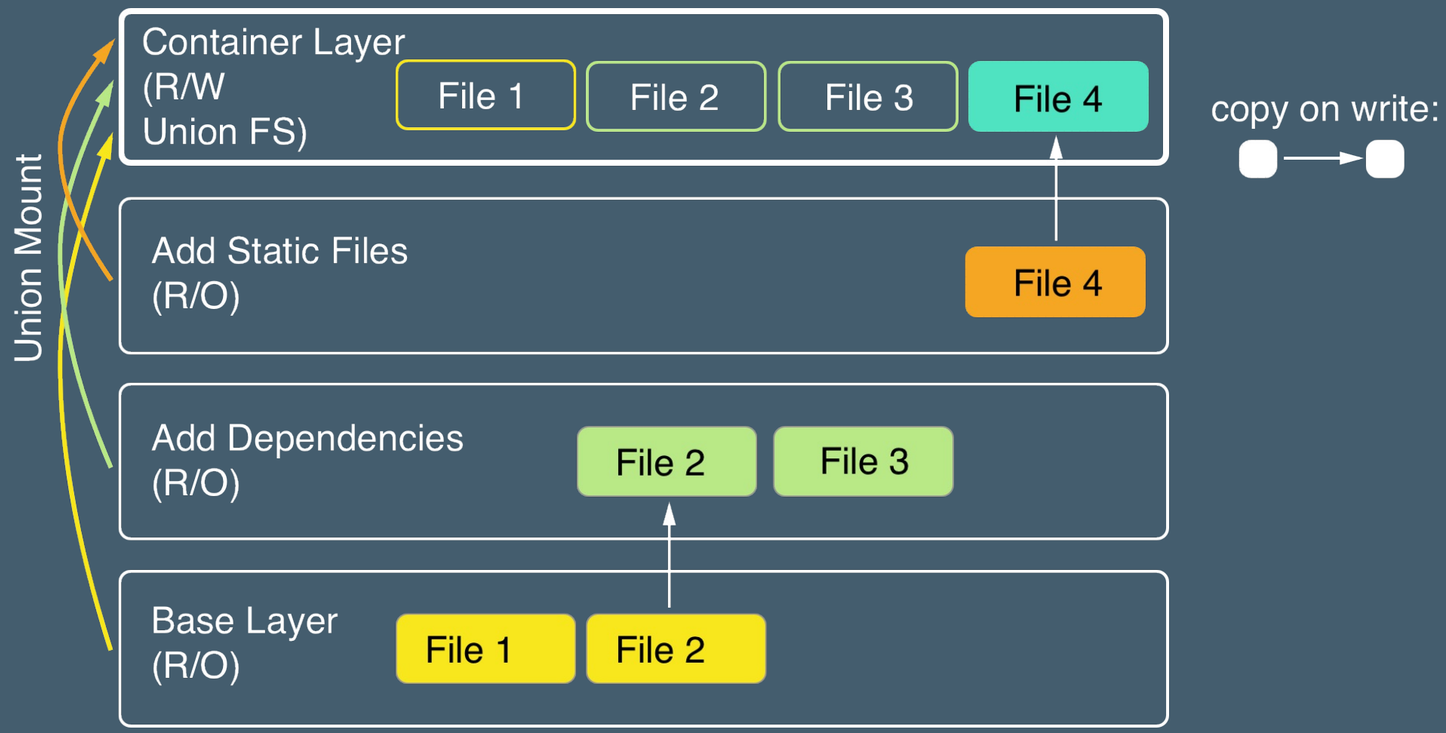
THE WRITABLE CONTAINER LAYER



IMAGES: COPY ON WRITE

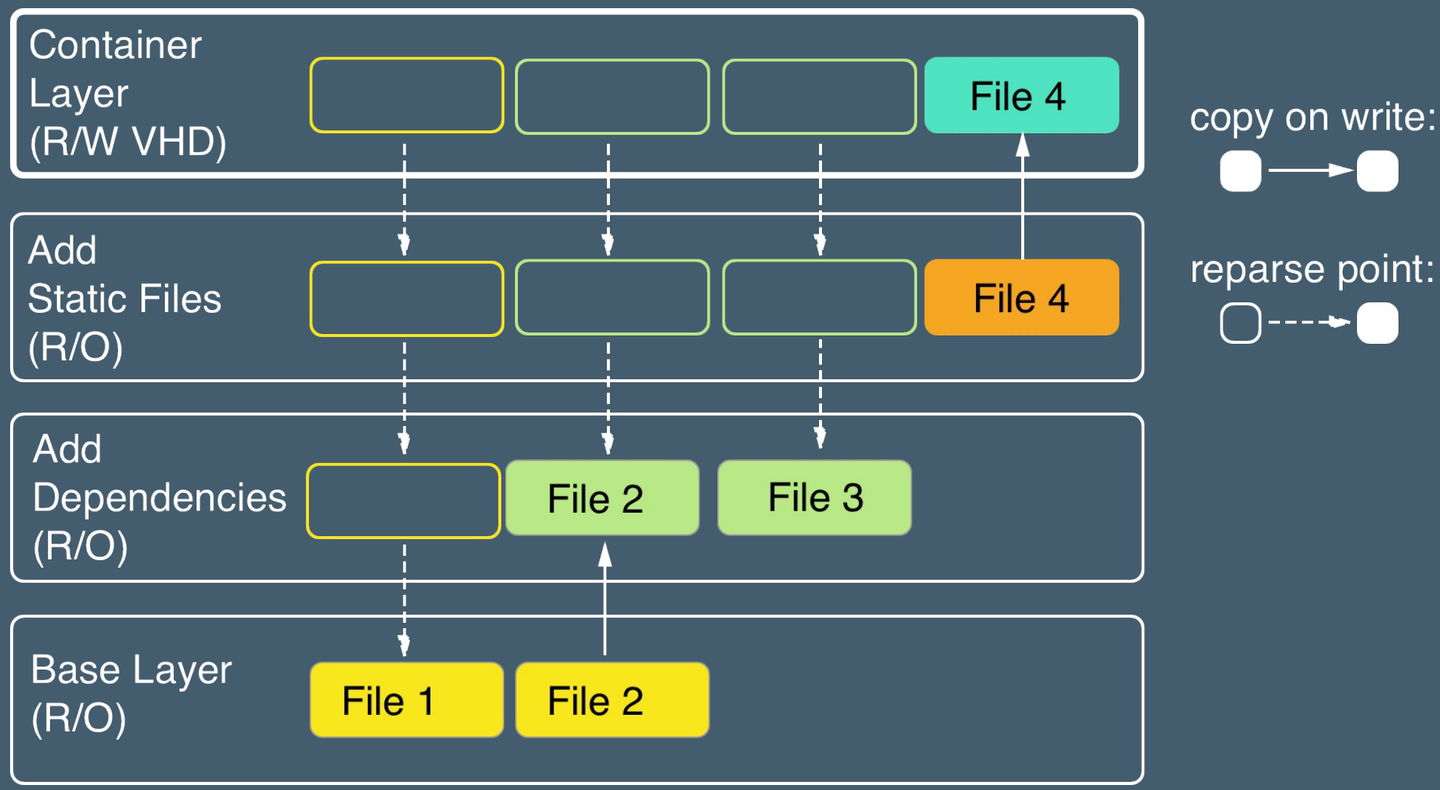


LINUX CONTAINERS: UNION FS



copy on write:

WINDOWS CONTAINERS: LINKED FS



CREATING IMAGES

Three methods:

- Commit the R/W container layer as a new R/O image layer.
- Define new layers to add to a starting image in a Dockerfile.
- Import a tarball into Docker as a standalone base layer.

COMMITTING CONTAINER CHANGES

- docker container commit

  saves container layer as new R/O image layer
- Pro: build images interactively
- Con: hard to reproduce or audit; avoid this in practice.

DOCKERFILES

- Content manifest
- Provides image layer documentation
- Enables automation (CI/CD)

DOCKERFILES

- FROM command defines base image.
- Each subsequent command adds a layer or metadata
- docker image build ... builds image from Dockerfile

Linux containers:

```
# Comments begin with the pound sign
FROM ubuntu:16.04
RUN apt-get update && apt-get install -y wget
ADD /data /myapp/data
...
```

Windows containers:

```
# Comments begin with the pound sign
FROM microsoft/nanoserver:latest
RUN Install-Module -Name Nuget -Force
ADD c:\\myapp\data c:\\app\data
...
```

EXERCISES: CREATING IMAGES

Work through:

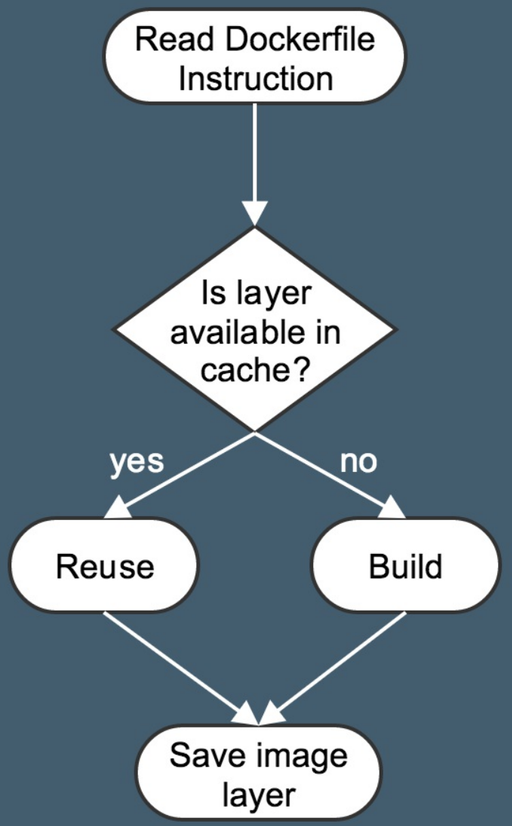
- Interactive Image Creation
- Creating Images with Dockerfiles (1/2)

in the Docker Fundamentals Exercises book.

INSTRUCTOR DEMO: CREATING IMAGES

See the 'Creating Images' demo in the Docker Fundamentals Exercises book.

BUILD CACHE



- After completion, the resulting image layer is labeled with a hash of the content of all current image layers in the stack.

CMD AND ENTRYPOINT

- Recall all containers run a process as their PID 1
- CMD and ENTRYPOINT allow us to specify default processes.

CMD AND ENTRYPOINT

- CMD alone: default command and list of parameters.
- CMD + ENTRYPOINT: ENTRYPOINT provides command, CMD provides default parameters.
- CMD overridden by command arguments to docker container run
- ENTRYPOINT overridden via --entrypoint flag to docker container run.

SHELL VS. EXEC FORMAT

Linux containers:

```
# Shell form
CMD sudo -u ${USER} java ...

# Exec form
CMD ["sudo", "-u", "jdoe", "java", ...]
```

Windows containers:

```
# shell form
CMD c:\\Apache24\\bin\\httpd.exe -w

# exec form
CMD ["c:\\Apache24\\bin\\httpd.exe", "-w"]
```

Note the "\\" in the expressions

EXERCISE: DOCKERFILES (2/2)

Work through the 'Creating Images with Dockerfiles (2/2)' exercise in the Docker Fundamentals Exercises book.

COPY AND ADD COMMANDS

COPY copies files from build context to image:

```
COPY <src> <dest>
```

ADD can also untar* and fetch URLs.

** Linux containers only!*

In both cases

- create checksum for files added
- log checksum in build cache
- cache invalidated if checksum changed

ENV AND ARG COMMANDS

- ENV sets environment variables inside container:

```
ENV APP_PORT 8080
```

- ARG defines arguments that can be passed in from the command line during build:

```
ARG DB_MOUNT=/my/default/path
ENV DB_PATH $DB_MOUNT
```

```
docker image build --build-arg DB_MOUNT=/my/custom/path
```

DOCKERFILE COMMAND ROUNDUP

- FROM: base image to start from (usually OS)
- RUN: run a command in the environment defined so far
- CMD and ENTRYPOINT: define default behavior
- COPY and ADD: copy files into container
- ENV: define environment variables inside container
- ARG: define build time argument (set with --build-arg)

Many more Dockerfile commands are available; see the docs at https://docs.docker.com/engine/reference/builder/

MULTI-STAGE BUILDS

Linux containers:

Hello World, in C:

```
FROM alpine:3.5
RUN apk update && \
    apk add --update alpine-sdk
RUN mkdir /app
WORKDIR /app
ADD hello.c /app
RUN mkdir bin
RUN gcc -Wall hello.c -o bin/hello
CMD /app/bin/hello
```

Windows containers:

Hello World, in Go:

```
FROM golang:nanoserver
COPY . /code
WORKDIR /code
RUN go build hello.go
CMD ["\\code\\hello.exe"]
```

builds to:

```
Bills-MBP:demo billmills$ docker image ls hwc
REPOSITORY          TAG                 IMAGE ID            CREATED             SIZE
hwc                 latest              142c29686b6a        15 hours ago        184 MB
```

MULTI-STAGE BUILDS

Hello World, lightweight:

Linux containers:

```
# Full SDK version (built and discarded)
FROM alpine:3.5 AS build
RUN apk update && \
    apk add --update alpine-sdk
RUN mkdir /app
WORKDIR /app
ADD hello.c /app
RUN mkdir bin
RUN gcc -Wall hello.c -o bin/hello

# Lightweight image returned as final product
FROM alpine:3.5
COPY --from=build /app/bin/hello /app/hello
CMD /app/hello
```

Windows containers:

```
FROM golang:nanoserver as gobuild
COPY . /code
WORKDIR /code
RUN go build hello.go

FROM microsoft/nanoserver
COPY --from=gobuild /code/hello.exe /hello.exe
EXPOSE 8080
CMD ["\\hello.exe"]
```

Builds to:

```
Bills-MBP:demo billmills$ docker image ls hwc
REPOSITORY          TAG                 IMAGE ID            CREATED             SIZE
hwc                 latest              5d925cfc9c96        39 seconds ago      4MB
```

BUILD TARGETS

Dockerfile

```
FROM <base image> as base
...

FROM <foo image> as foo
...

FROM <bar image> as bar
...

FROM alpine:3.4
...
COPY --from foo ...
COPY --from bar ...
...
```

Building the image

docker image build --target <name> ...

EXERCISE: MULTI-STAGE BUILDS

Work through the 'Multi-Stage Builds' exercise in the Docker Fundamentals Exercises book.

IMAGE CONSTRUCTION BEST PRACTICES

- Start with official images
- Use multi-stage builds to drop compilers, SDKs…
- More layers leverage the cache…
- …but fewer layers perform better.

DEVELOPMENT: MORE LAYERS

Bad caching:

```
FROM python:3.5-alpine
RUN mkdir /app
COPY /mypy /app/
RUN pip install -r app/reqs.txt
...
```

Good caching:

```
FROM python:3.5-alpine
RUN mkdir /app
COPY /mypy/reqs.txt /app/
RUN pip install -r app/reqs.txt
COPY /mypy /app/
...
```

PRODUCTION: LESS LAYERS

- To collapse image layers:

```
docker container run -d --name demo mytallimage:1.0
docker container export demo > image.tar
cat image.tar | docker image import - myflatimage:1.0
```

- Or combine commands in Dockerfile.
- Or build with **--squash** flag (experimental)
- Intermediate solution: shared OS layer, compressed application layer

BEST PRACTICE: PATCHING & UPDATES

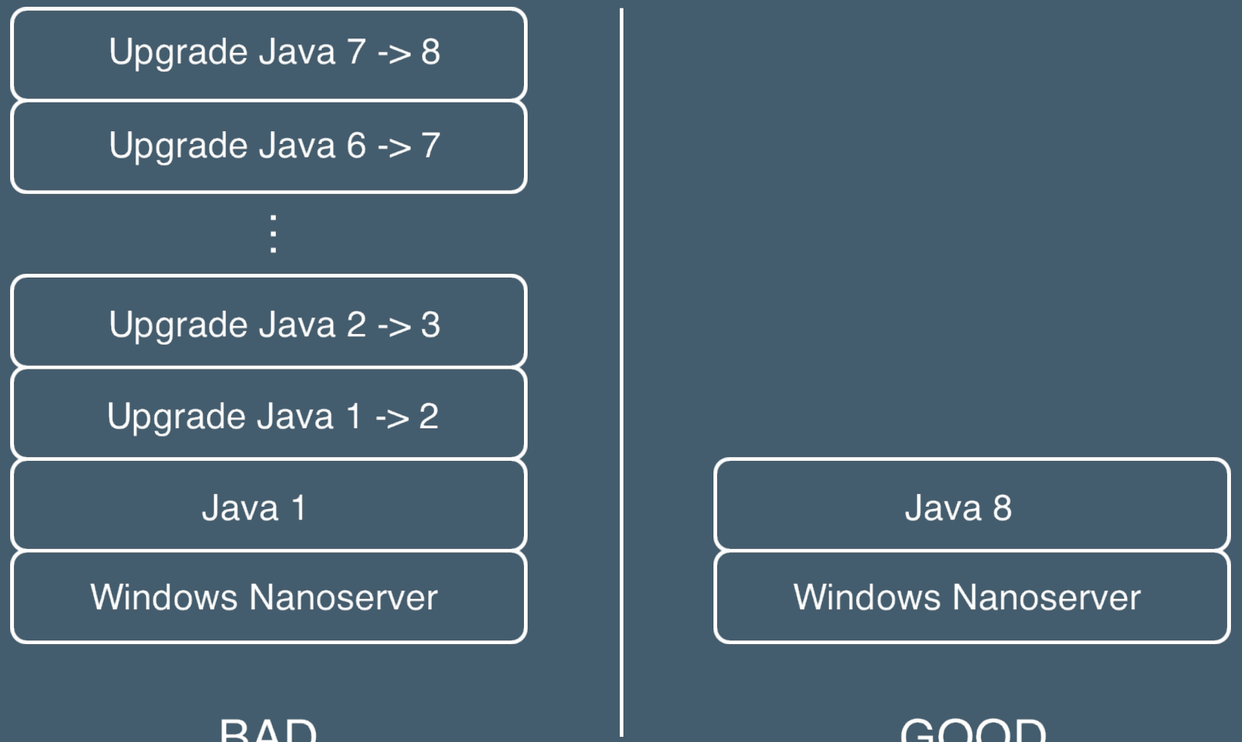


IMAGE TAGS

- Optional string after image name, separated by :
- :latest by default
- Same image with two tags shares same ID, image layers:

```
$ docker image ls centos*
REPOSITORY          TAG                 IMAGE ID            CREATED             SIZE
centos              7                   8140d0c64310        7 days ago          193 MB
$ docker image tag centos:7 centos:mytag
$ docker image ls centos*
REPOSITORY          TAG                 IMAGE ID            CREATED             SIZE
centos              7                   8140d0c64310        7 days ago          193 MB
centos              mytag               8140d0c64310        7 days ago          193 MB
```

IMAGE NAMESPACES

Images exist in one of three namespaces:

- Root (ubuntu, nginx, mongo, mysql, ...)
- User / Org (jdoe/myapp:1.1, microsoft/nanoserver:latest, ...)
- Registry (FQDN/jdoe/myapp:1.1, ...)

IMAGE TAGGING & NAMESPACING

- Tag on build:

```
docker image build -t myapp:1.0 .
```

- Retag an existing image:

```
docker image tag myapp:1.0 me/myapp:2.0
```

- Note **docker image tag** can set both tag and namespace.
- Names and tags are just pointers to image ID
- Image ID corresponds to immutable content addressable storage

SHARING IMAGES

- Docker Store
  - Provides certified commercial and free software distributed as Docker Images
- Docker Hub
  - Shares community-generated images and content
- All images accessible from Store and Hub - just optimized for different purposes.

EXERCISE: MANAGING IMAGES

Work through the 'Managing Images' exercise in the Docker Fundamentals Exercises book.

IMAGE CREATION TAKEAWAYS

- Images are built out of read-only layers.
- Dockerfiles specify image layer contents.
- Key Dockerfile commands: FROM, RUN, COPY and ENTRYPOINT
- Images must be namespaced according to where you intend on sharing them.

FURTHER READING 1/2

Linux Containers:

- Best practices for writing Dockerfiles: http://dockr.ly/22WiJiO
- Use multi-stage builds: http://dockr.ly/2ewcUY3
- More about images, containers, and storage drivers: http://dockr.ly/1TuWndC
- Details on image layering: https://bit.ly/2AHX7iW
- Graphdriver plugins: http://dockr.ly/2eIVCab
- Docker Reference Architecture: An Intro to Storage Solutions for Docker CaaS: http://dockr.ly/2x8sBw2
- How to select a storage driver: http://dockr.ly/2eDu8yO
- Use the AUFS storage driver: http://dockr.ly/2jVc1Zz
- User guided caching in Docker: http://dockr.ly/2xKafPf

FURTHER READING 2/2

WINDOWS CONTAINERS:

- Dockerfile on Windows: http://bit.ly/2waNvsS
- Optimize Windows Dockerfiles: http://bit.ly/2whpfn7
- Windows Container Samples:
  - http://bit.ly/2wCrPXy
  - http://bit.ly/2ghRr5o
- Powershell Tricks: http://bit.ly/2wb7Azn
- Multi-stage builds for Windows containers: http://bit.ly/2iBRmdN
- The SHELL command: http://dockr.ly/2whvyqZ

DOCKER VOLUMES

DISCUSSION: MANAGING DATA

If a container generates a lot of data, where should it be stored? What if you need to provision data to a container?

LEARNING OBJECTIVES

By the end of this module, learners will be able to:

- Define a volume and identify its primary use cases
- Describe the advantages and potential security risks of mounting volumes and host directories into containers

VOLUME USECASES

Volumes provide a R/W path separate from the layered filesystem.

- Mount data at container startup
- Persist data when a container is deleted
- Share data between containers
- Speed up I/O by circumventing the union filesystem

BASIC VOLUMES

- Named: managed by Docker; filesystem independent
- Host mounted: mount a specific path on the host; DIY management

INSTRUCTOR DEMO: VOLUMES

See the 'Basic Volume Usage' demo in the Docker Fundamentals Exercises book.

VOLUMES IN DOCKERFILES

- VOLUME instruction creates a mount point
- Can specify arguments in a JSON array or string
- Cannot map volumes to host directories
- Volumes are initialized when the container is executed

Linux containers:

```
FROM nginx:latest
…
# string example
VOLUME /myvolume

# string example with multiple volumes
VOLUME /www/website1 /www/website2

# JSON example
VOLUME ["myvol1", "myvol2"]
…
```

Windows containers:

```
FROM microsoft/iis:nanoserver
…
# string examples
VOLUME c:\\data
VOLUME c:\\data2 c:\\data3

# JSON examples
VOLUME ["c:\\\\data4", "c:\\\\data5"]
VOLUME ["c:/data6", "c:/data7"]
…
```

VOLUMES AND SECURITY

- Point of ingress to the host and other containers
- Don't mount things unnecessarily
- Use the :ro flag
- Linux: in-memory tmpfs mounts available

EXERCISE: VOLUMES USECASE

Work through 'Database Volumes' in the Docker Fundamentals Exercises book.

DOCKER VOLUME TAKEAWAYS

- Volumes persist data beyond the container lifecycle
- Volumes bypass the copy on write system (better for write-heavy containers)

FURTHER READING

- How to use volumes: http://dockr.ly/2vRZBDG
- Troubleshoot volume errors: http://dockr.ly/2vyjvbP
- Docker volume reference: http://dockr.ly/2ewrlew

CONTAINERIZATION FUNDAMENTALS CONCLUSION: ANY APP, ANYWHERE.

- Containers are isolated processes
- Images provide filesystem for containers
- Volumes persist data

PART 2: ORCHESTRATION

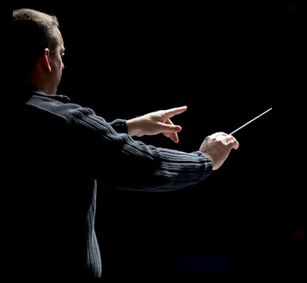


Image CC-BY Phil Roeder

DOCKER NETWORKING BASICS

DISCUSSION: PORTABLE NETWORKS

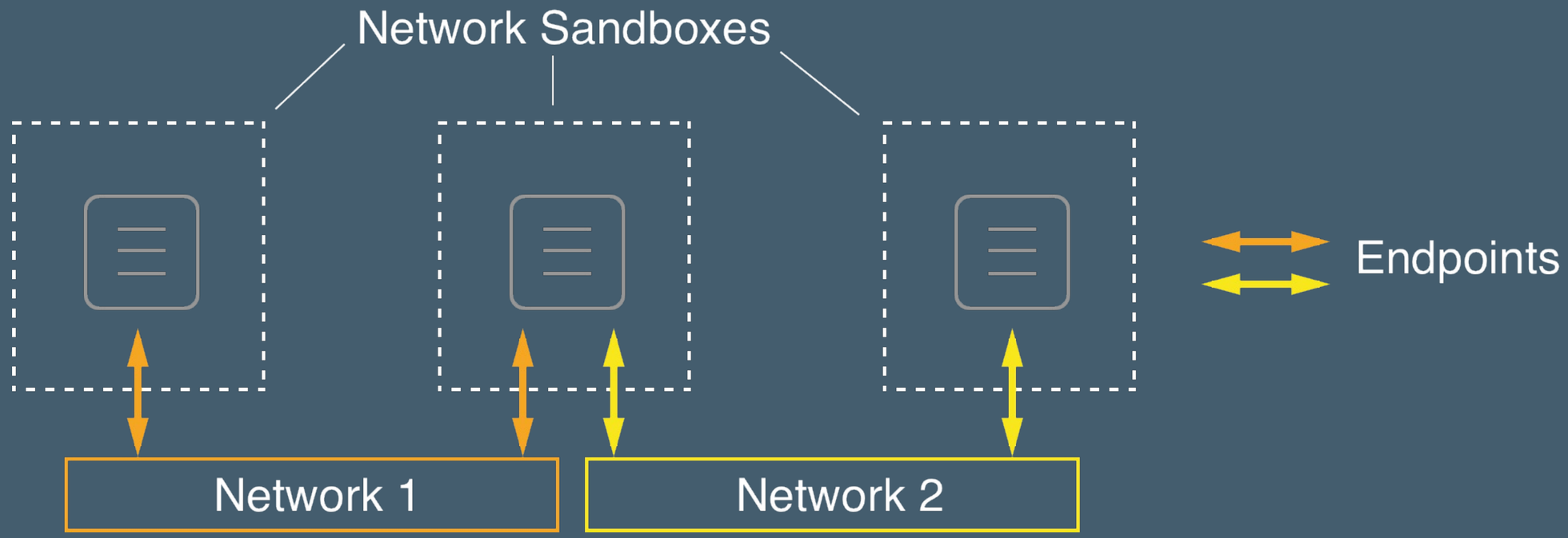
Network traffic must by definition traverse a network outside its originating container. How can we make inter-container communication as portable and secure as containers themselves?

LEARNING OBJECTIVES

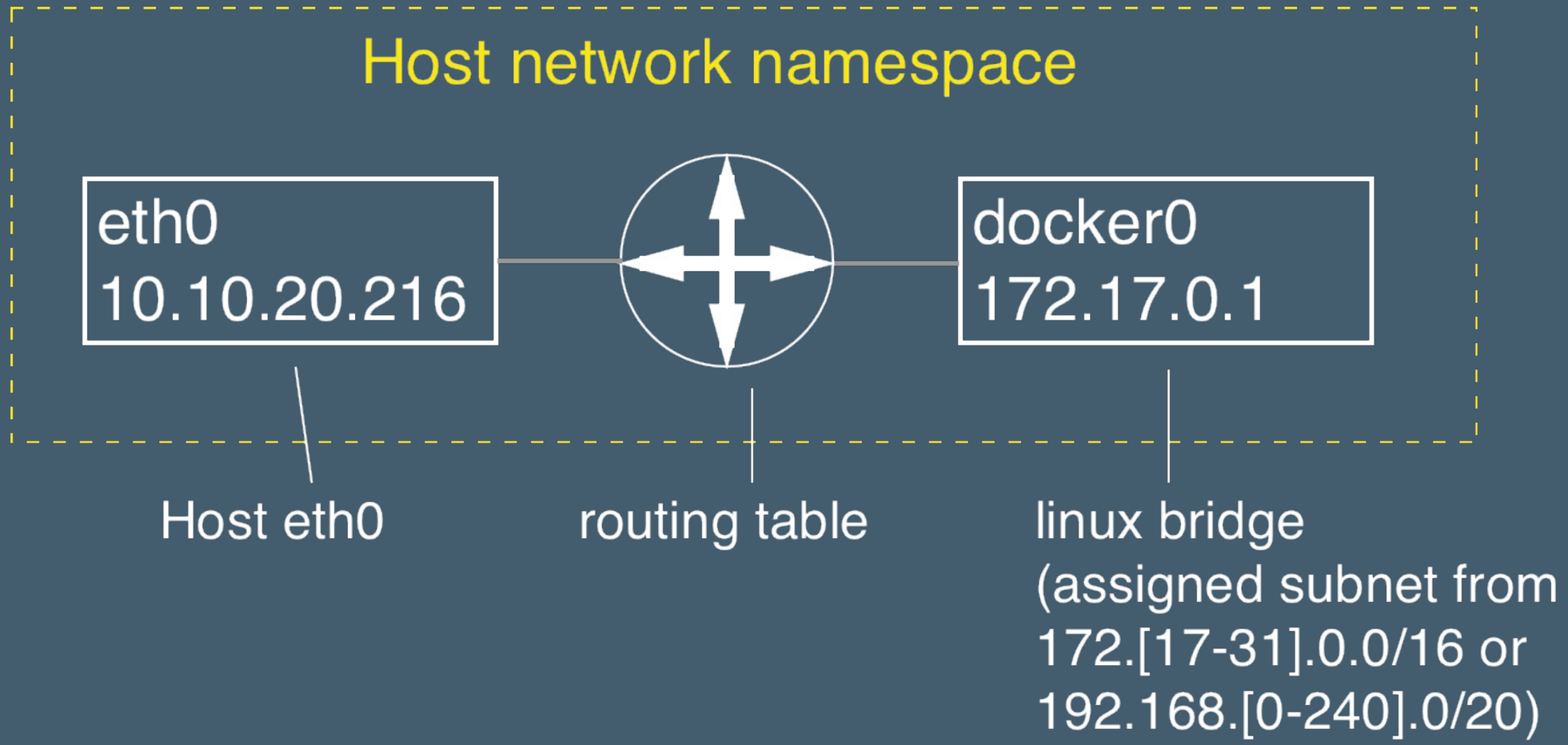
By the end of this module, learners will be able to:

- Describe Docker's container network model and its security implications
- Detail the use of linux bridges in single host networks
- Understand how Docker manipulates a host's IP tables to control container traffic

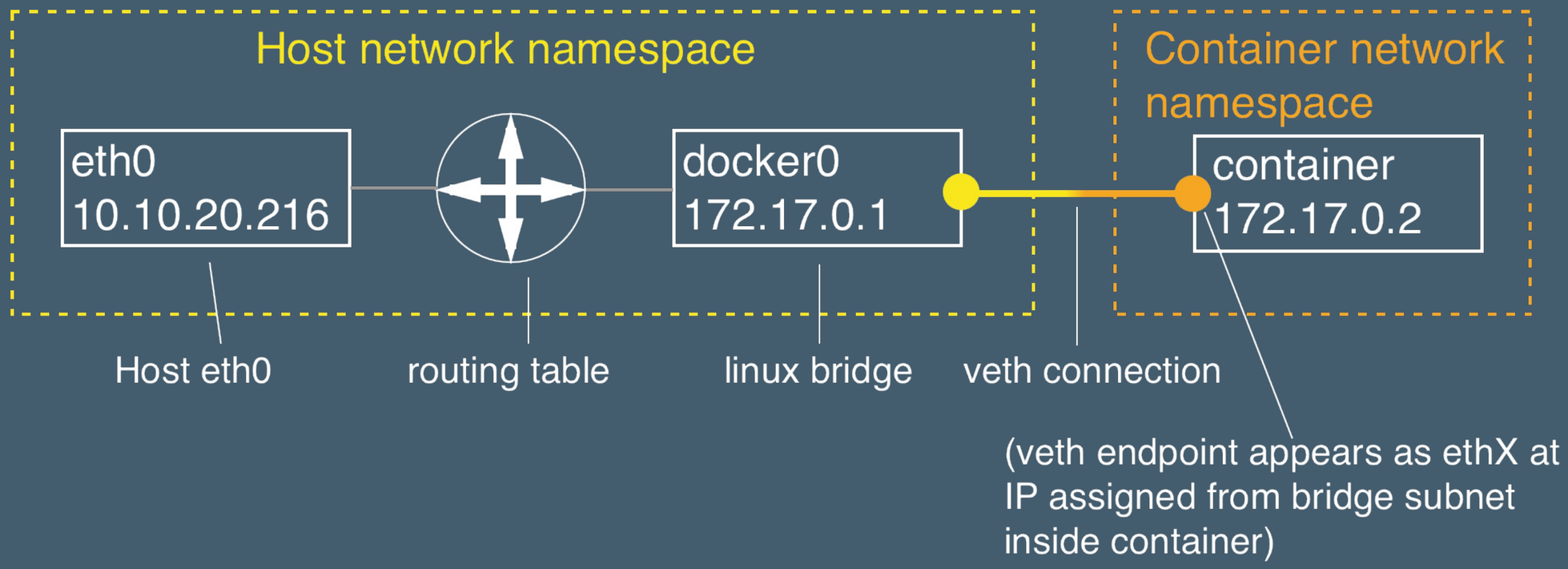
THE CONTAINER NETWORK MODEL



DEFAULT SINGLE-HOST NETWORK

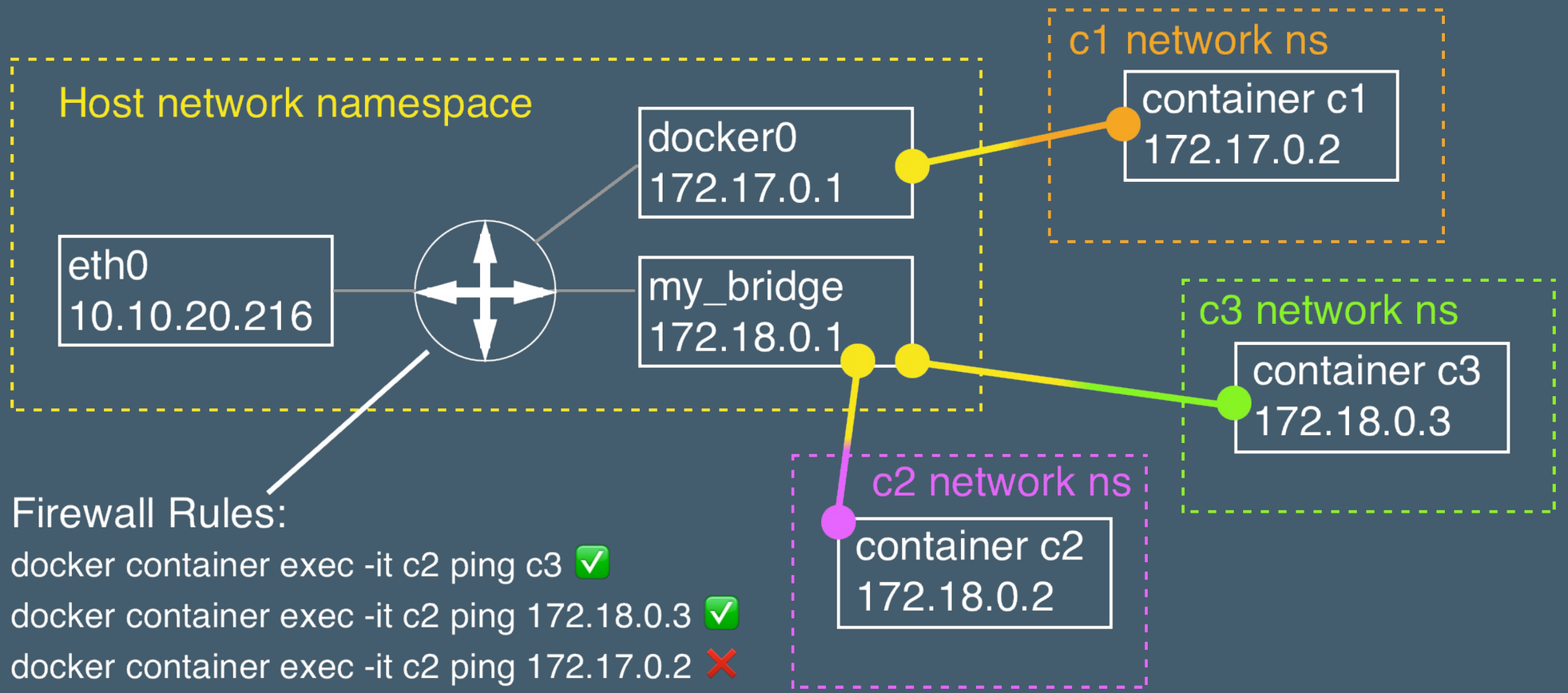


DEFAULT CONTAINER NETWORKING



Quiz: identify the sandbox, endpoint and network corresponding to the container networking model objects in this diagram.

CUSTOM BRIDGE NETWORKING & FIREWALLS



SECURITY WARNINGS

- Do not use the host network in production.
- Do not connect containers to the same network unecessarily.

EXPOSING CONTAINER PORTS

- Containers have no public IP address by default.
- Can forward host port -> container port
- Mapping created manually or automatically.
- Port mappings visible via
  `docker container ls` or
  `docker container port`

INSTRUCTOR DEMO: DOCKER BRIDGE NETWORKS

See the Docker Bridge Networks demo in the Docker Fundamentals Exercises book.

EXERCISE: DOCKER BRIDGE NETWORKS

Work through:

- Introduction to Container Networking
- Container Port Mapping

in the Docker Fundamentals Exercises book.

DOCKER NETWORKING TAKEAWAYS

- Linux bridges provide single-host routing
- Isolated by default:
  - network vs network
  - container vs outside world

FURTHER READING

- Docker Reference Architecture: Designing Scalable, Portable Docker Container Networks: https://dockr.ly/2q3O8jq
- Network containers: http://dockr.ly/2x1BYgW
- Docker container networking: http://dockr.ly/1QnT6y8
- Get started with multi-host networking: http://dockr.ly/2gtqRms
- Understand container communication: http://dockr.ly/2iSrHO0

WINDOWS CONTAINERS:

- Windows Container Networking: https://bit.ly/2JdIJ5V
- Windows NAT (WinNAT) — Capabilities and limitations: http://bit.ly/2vC23xS
- Docker Compose and Networking Blog Post: http://bit.ly/2watrqk
- Published Ports On Windows Containers Don't Do Loopback: http://bit.ly/2whltu4
- Cheatsheet to replace "netsh", "nslookup" and more with Powershell: http://bit.ly/2iB7pbw

INTRODUCTION TO DOCKER COMPOSE

DISCUSSION: PROCESSES VS. APPLICATIONS

Containers and images describe individual processes. What will we need to describe entire applications?

LEARNING OBJECTIVES

By the end of this module, learners will be able to:

- Design scalable Docker services
- Leverage Docker's built in service discovery mechanism
- Write a compose file describing an application

DISTRIBUTED APPLICATION ARCHITECTURE

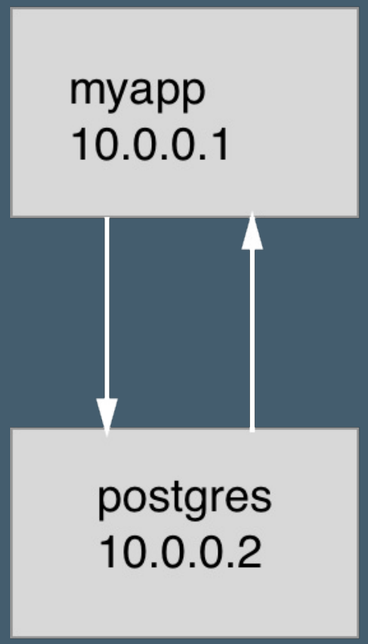
- Applications consisting of one or more containers across one or more nodes
- Docker Compose facilitates multi-container design on a single node.

DOCKER SERVICES

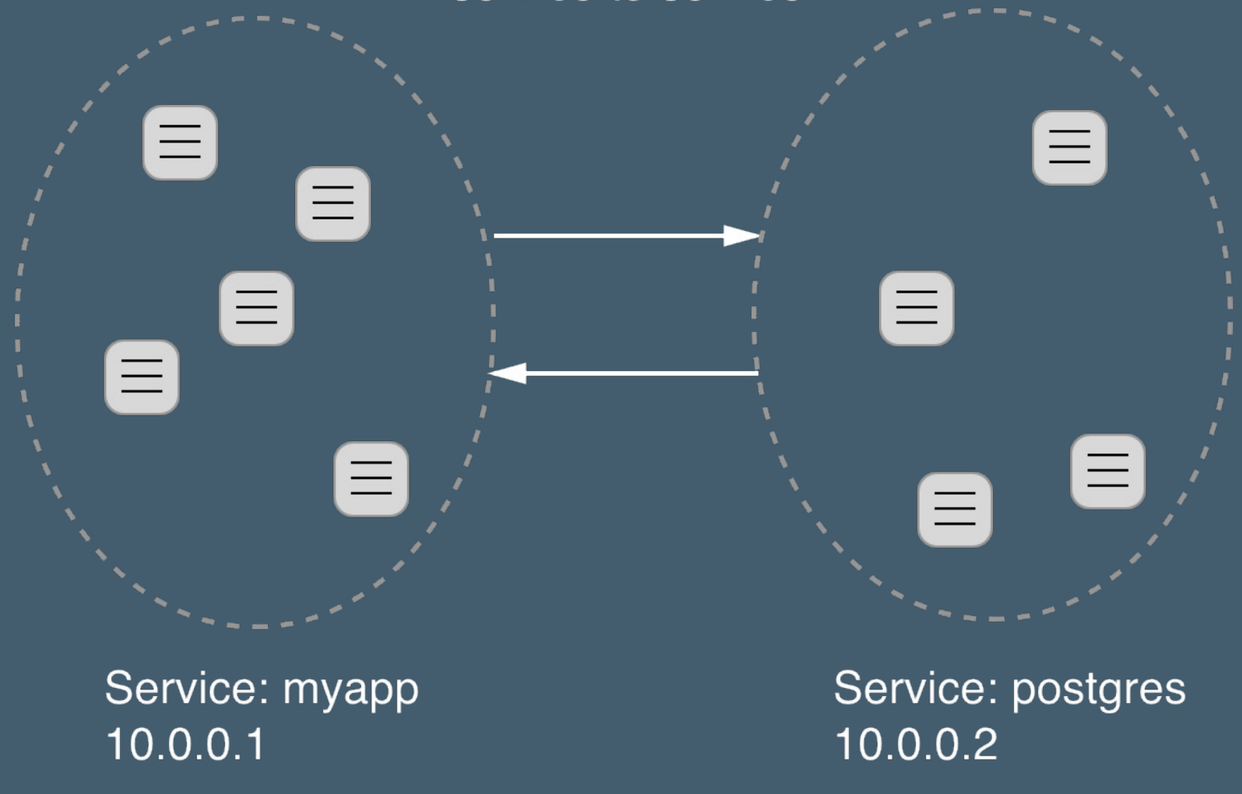
- Goal: declare and (re)configure many similar containers all at once
- Goal: scale apps by adding containers seamlessly
- A service defines the desired state of a group of identically configured containers.
- Docker provides transparent service discovery for Services.

SERVICE DISCOVERY

process to process



service to service

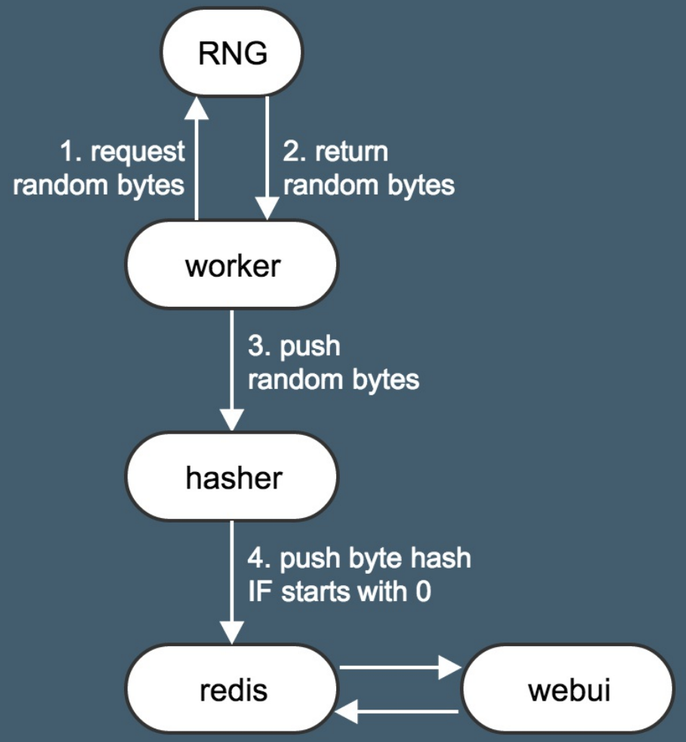


Services are assigned a Virtual IP which spreads traffic out across the underlying containers automatically.

OUR APPLICATION: DOCKERCOINS

(DockerCoins 2016 logo courtesy of @XtlCnslt and @ndeloof. Thanks!)

- It is a DockerCoin miner!
- Dockercoins consists of 5 services working together:



INSTRUCTOR DEMO: DOCKER COMPOSE

See the 'Docker Compose' demo in the Docker Fundamentals Exercises book.

EXERCISE: COMPOSE APPS

Work through

- Starting a Compose App
- Scaling a Compose App

in the Docker Fundamentals Exercises book.

DOCKER COMPOSE TAKEAWAYS

- Docker Compose makes single node orchestration easy
- Compose services makes scaling applications easy
- Bottleneck identification important
- Syntactically: docker-compose.yml + API

FURTHER READING

- Docker compose examples: http://dockr.ly/1FL2VQ6
- Overview of docker-compose CLI: http://dockr.ly/2wtQlZT
- Docker compose reference: http://dockr.ly/2iHUpeX

INTRODUCTION TO SWARM MODE

DISCUSSION: ANY APP, ANYWHERE?

Containers are portable. What does this imply about the best ways to manage a containerized data center?

LEARNING OBJECTIVES

By the end of this module, learners will be able to:

- Understand roles of swarm managers and workers
- Leverage default load balancing, self-healing and external routing for swarm services
- Identify the components of the swarm network topology
- Deploy an application across a swarm using a stack

DISTRIBUTED APPLICATION ARCHITECTURE

- Applications consisting of one or more containers across one or more nodes
- Docker Swarm facilitates multi-node design.
- Also supports multiple interacting services (like Compose)

INSTRUCTOR DEMO: SELF-HEALING SWARM

See the 'Self-Healing Swarm' demo in the Docker Fundamentals Exercises book.

NETWORKING REQUIREMENTS

- Control plane: enable service discovery for containers across hosts
- Data plane: enable moving a packet from host A to host B
- Management plane: decide where containers should be scheduled

AN UNSCALABLE CONTROL PLANE

- Heartbeat-style: all nodes register their containers with all other nodes
- Network traffic would scale like n^2
- Unacceptable, want multi-host applications with O(1000) nodes

CONTROL PLANE

SWIM PROTOCOL

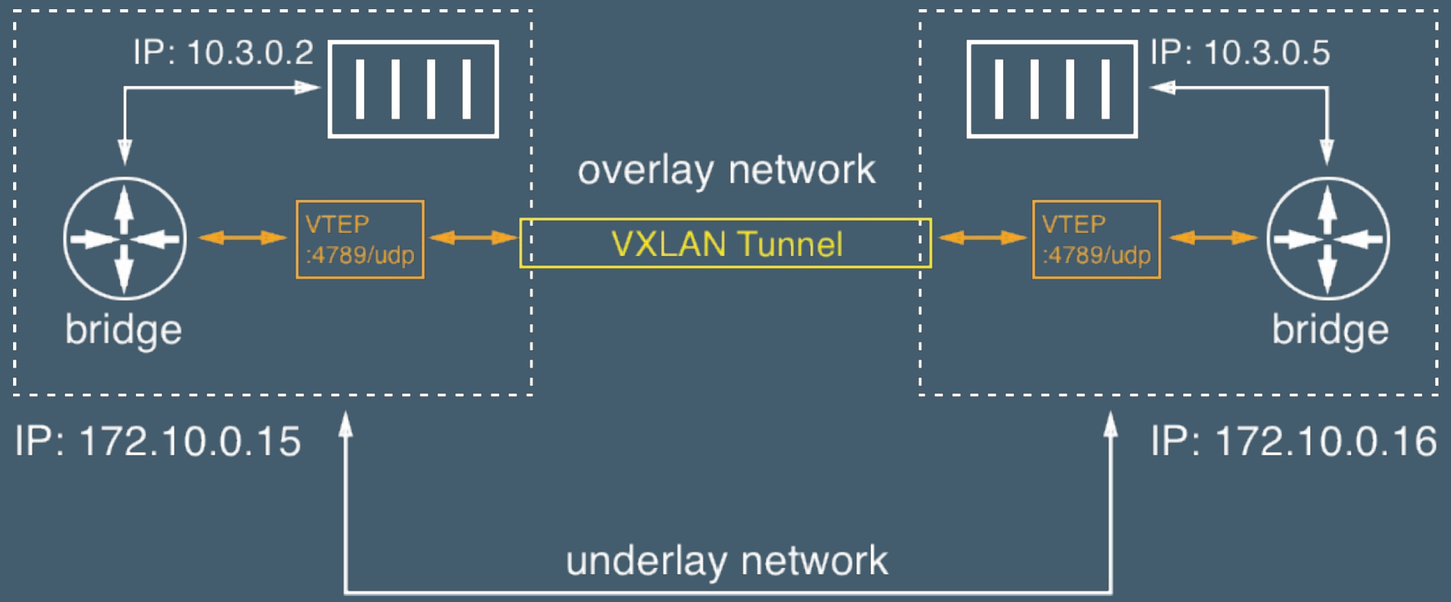
1. Ask neighbor A if they're still alive
2. Ask three other neighbors if they can reach neighbor A
3. No to both: conclude neighbor A is unhealthy / dead

Original ref: https://bit.ly/2G5Xgeh

GOSSIP CONTROL PLANE

- Docker control plane: piggyback DNS info on SWIM traffic
- DNS entries spread 'infectiously' through cluster.
- Gossip control plane scales independent of cluster size

OVERLAY DATA PLANE



MANAGEMENT PLANE

- Need a manager to decide where to schedule containers (ie update system state)
- Need multiple managers for high availability
- But how do we preserve an up-to-date system state in event of leader failure?

RAFT CONSENSUS

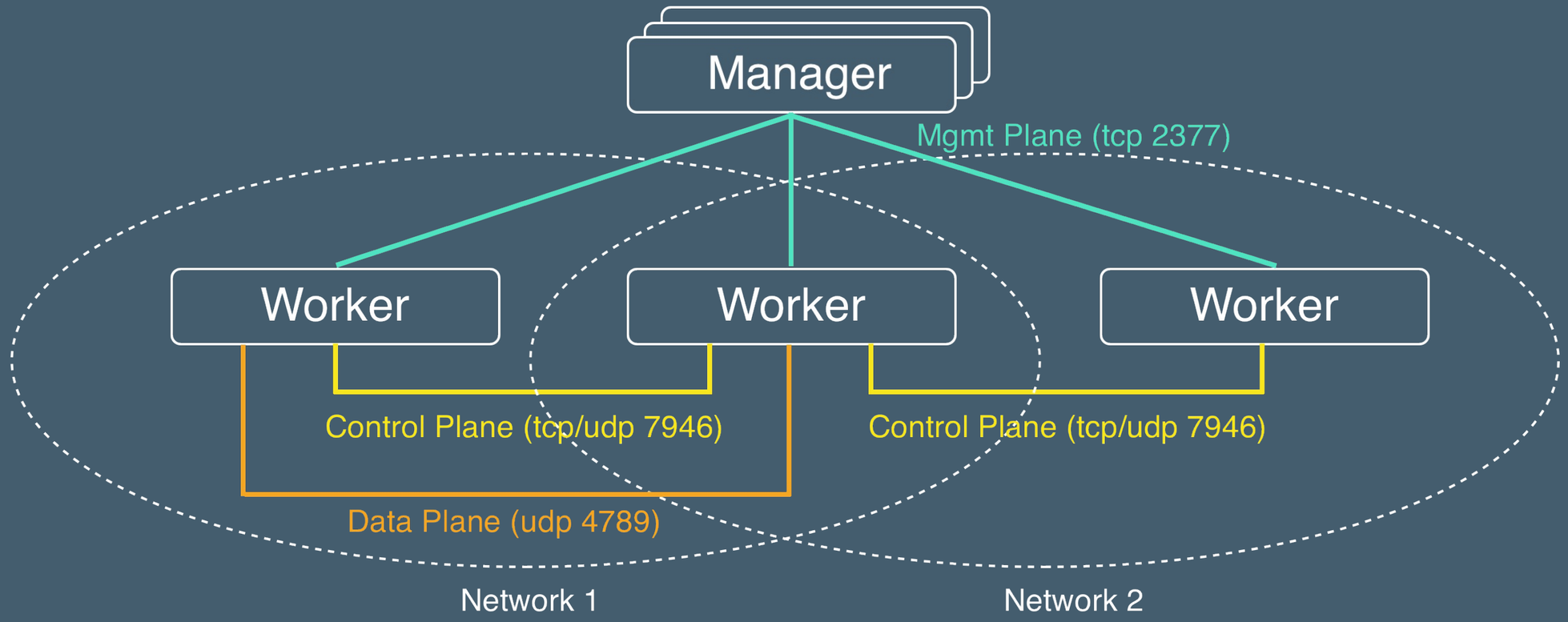
Raft radically oversimplified:

- State changes can only be proposed by a unique leader
- State cannot be changed unless a majority of members agree
- A member cannot become leader unless it is in the up-to-date majority

Result: valid leader always has an (almost) up-to-date record of state.

Requirement: a majority of managers must remain alive and reachable.

SWARM NETWORK TOPOLOGY



Note: fixed IPs for managers, dynamic IPs OK for workers

EXERCISE: SWARMS & SERVICES

Work through:

- Creating a Swarm
- Starting a Service
- Node Failure Recovery

in the Docker Fundamentals Exercises book.

SWARM INIT

- Create Raft consensus
- Establish certificate authority
- Prepare scheduler & networking
- All done by SwarmKit, integrated into Docker Engine

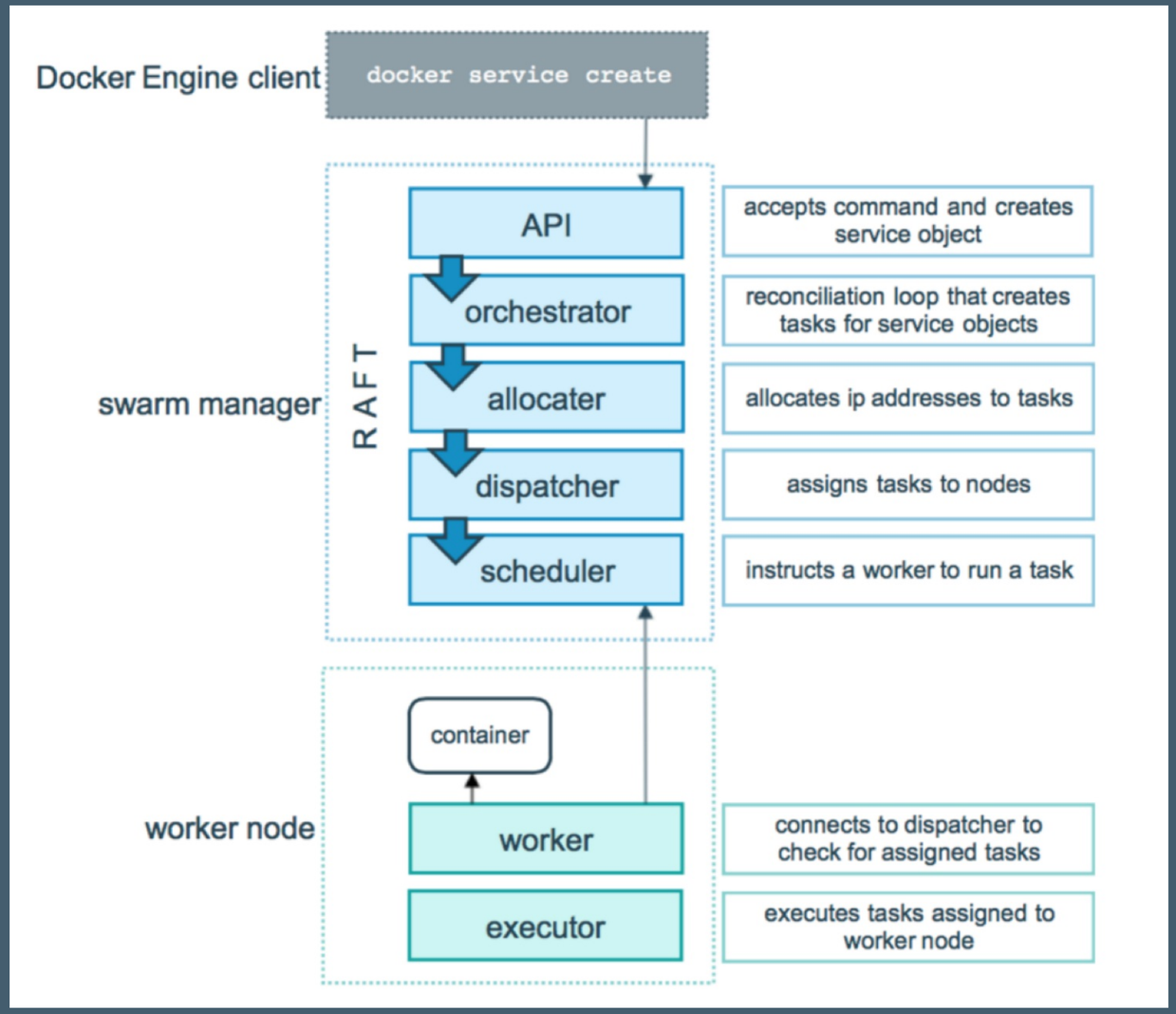
KEY CONCEPTS - SERVICES

- Service: abstracts a collection of tasks
- Defines desired state of tasks
- Primary SW design element on a Swarm
- Self healing

KEY CONCEPTS - TASKS

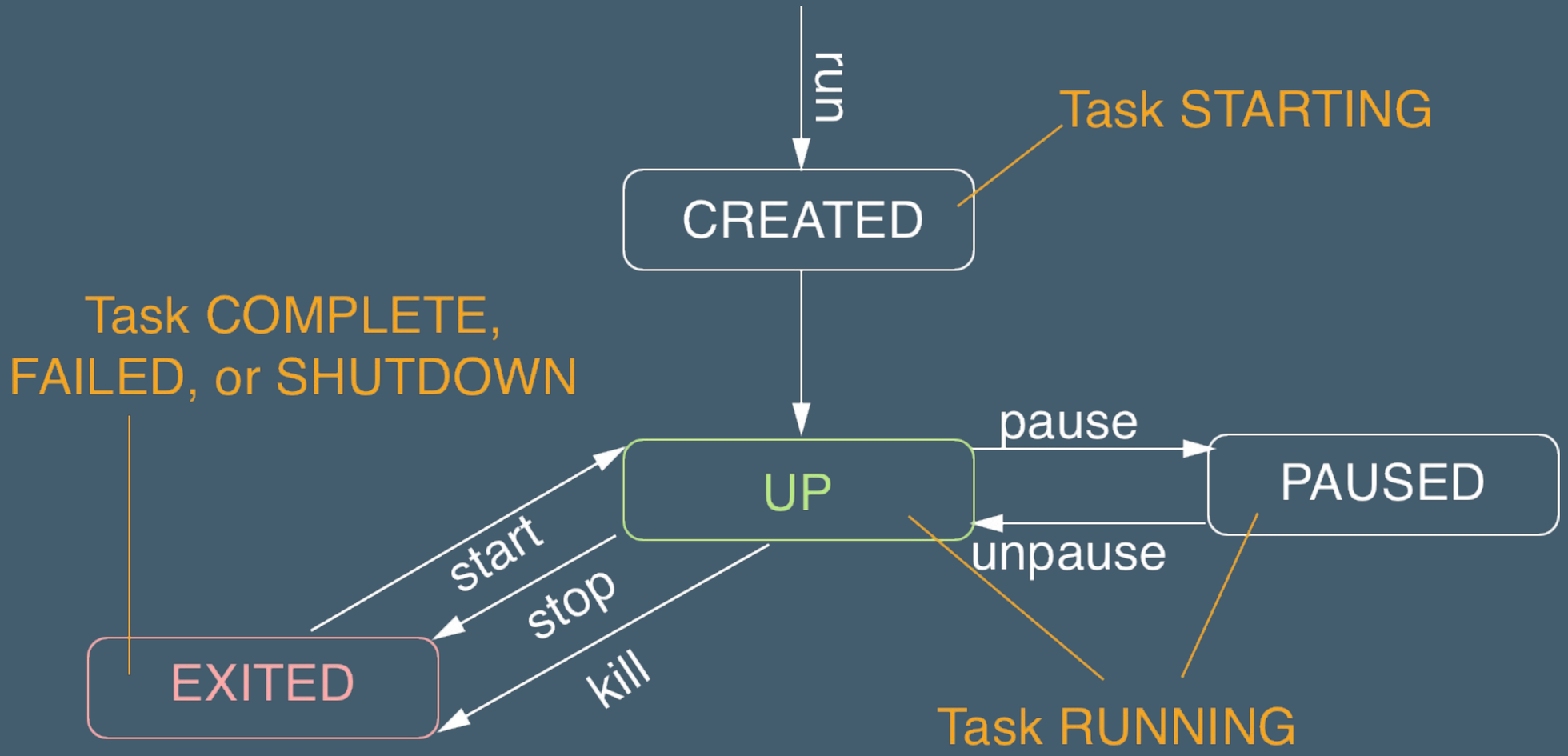
- Task: a unit of work assigned to a node
- One task abstracts exactly one container
- Atomic scheduling unit of Swarm

BEHIND THE SCENES: SERVICE MANAGEMENT

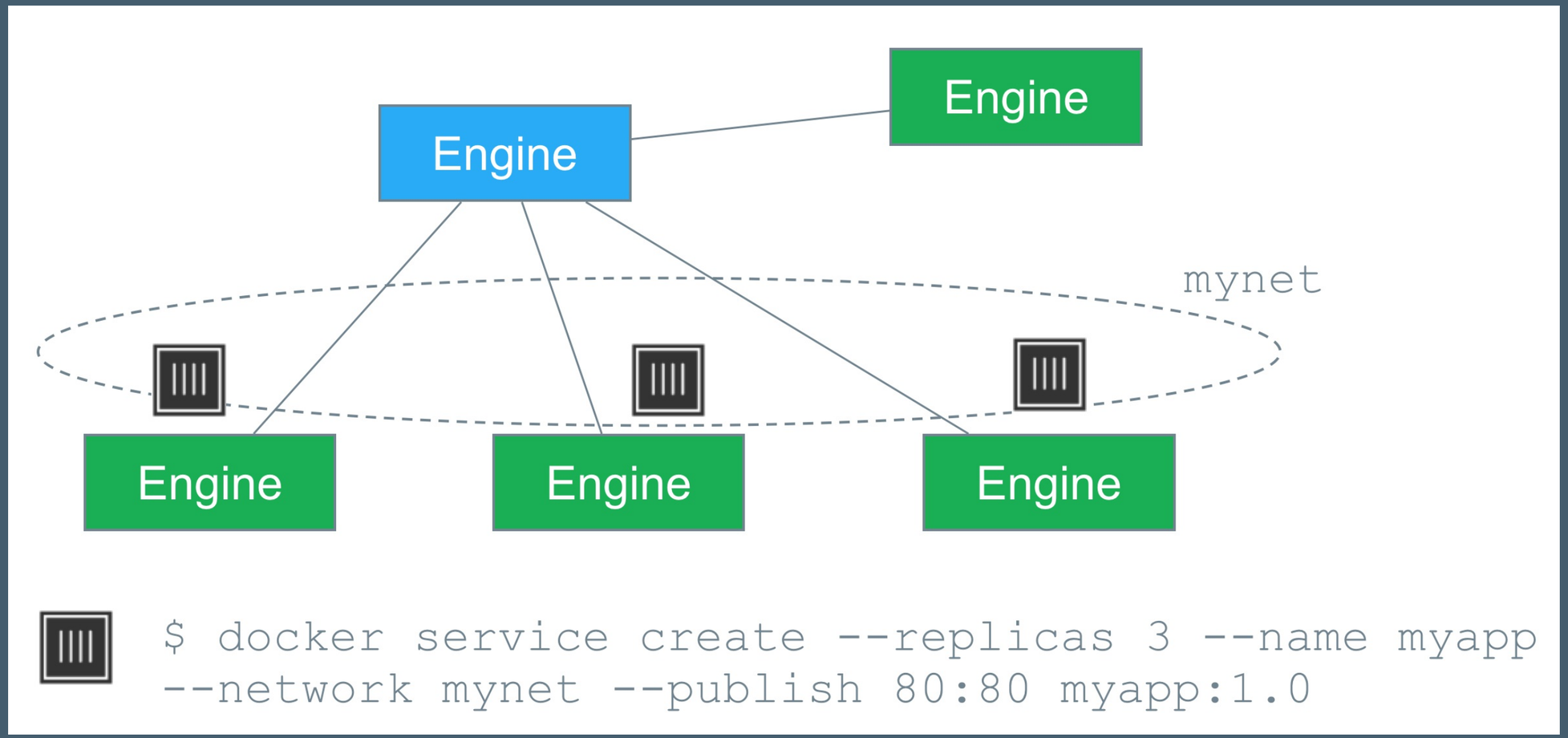


TASK LIFECYCLE

CONTAINER LIFECYCLE

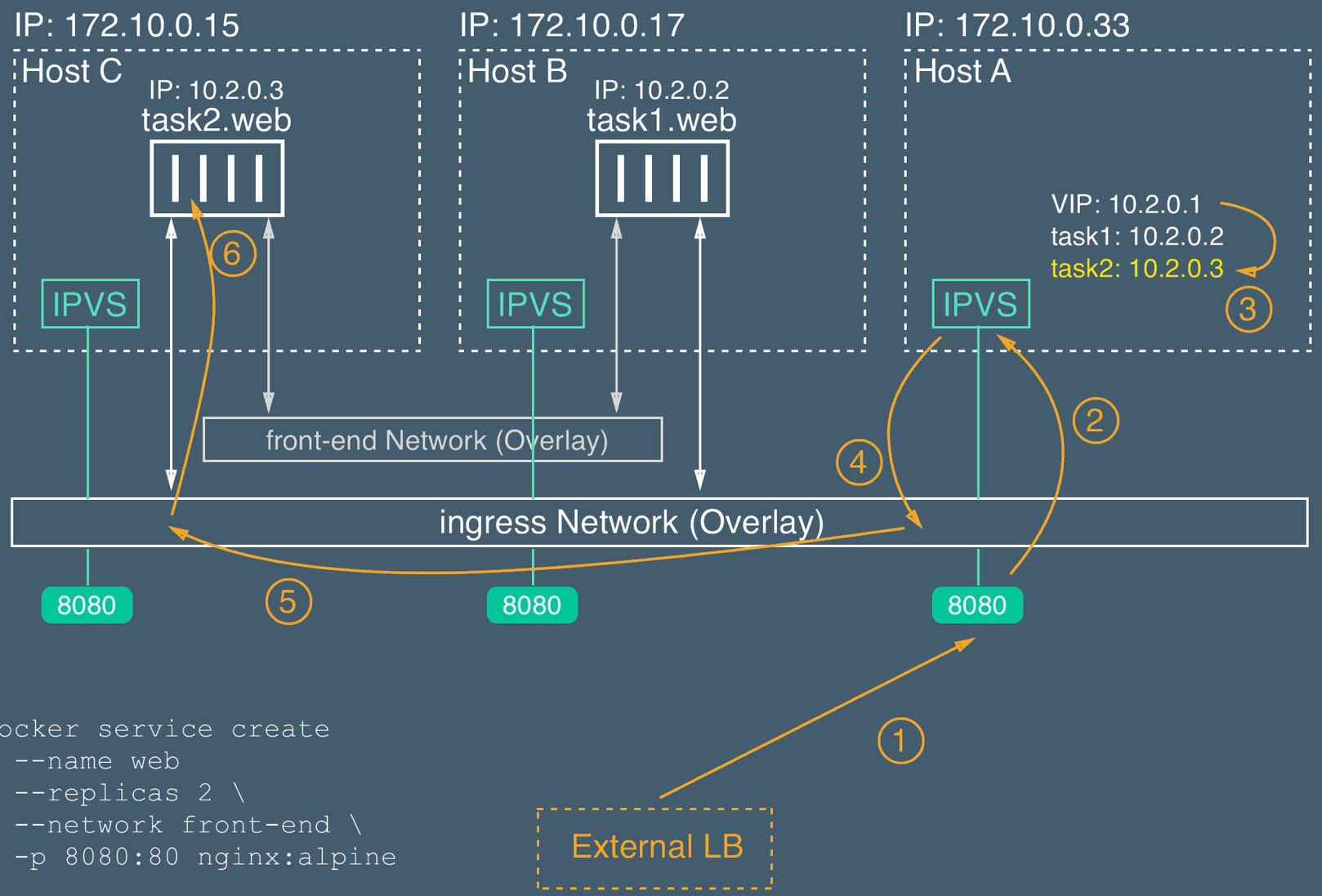


SERVICES & THE OUTSIDE WORLD



Problem: how does my load balancer know which nodes to send external traffic to?

THE ROUTING MESH




```
docker service create
  --name web
  --replicas 2 \
  --network front-end \
  -p 8080:80 nginx:alpine
```

EXERCISE: LOAD BALANCING & THE ROUTING MESH

Work through the 'Load Balancing & the Routing Mesh' exercise in the Docker Fundamentals Exercises book.

MANAGING APPLICATIONS

- Initial deployment: automatic and controllable
- Scheduler influence & control
- Upgrading services conservatively

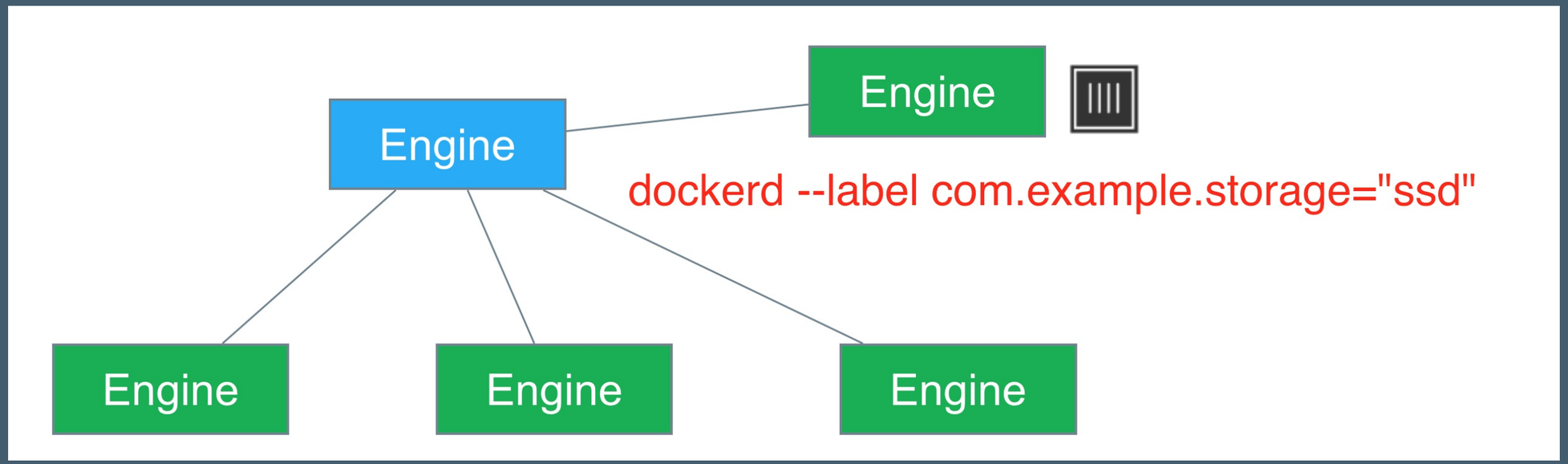
KEY CONCEPTS - STACKS

- Defined via a docker-compose.yml file
- Can specify services, networks, volumes etc
- Stand up & tear down an app in one command

SCALING & SCHEDULING SERVICES

- Service may have many scheduled tasks
- Load balancing:
  - VIP (Linux)
  - DNS round robin (Linux + Windows)
- Works best with stateless containers
- Scheduling strategies:
  - Replicated: is default
  - Global: one task for each worker in swarm

NODE CONSTRAINTS




```
docker service create --replicas 3 --name myapp \
    --network mynet --publish 80:80 \
    --constraint com.example.storage="ssd" \
    myapp:1.0
```

UPDATING SERVICES

- Apps get periodic updates
- Want updates with minimal service interruption
- Swarm mode provides tooling for:
  - rolling updates
  - parallel updates
  - rollback contingencies

EXERCISE: APPLICATION DEPLOYMENT

Work through:

- Dockercoins On Swarm
- Scaling and Scheduling Services
- Updating a Service

in the Docker Fundamentals Exercises book.

SWARM MODE ROBUSTNESS

It doesn't matter:

- which node a container runs on
- if a few nodes die
- if interacting processes are on different nodes
- which nodes are running user-facing containers

... everything will still work.

SWARM MODE TAKEAWAYS

- Distributed applications across infrastructure
- High availability
- Self healing service definitions
- Default security via mutual TLS encryption & certificate rotation
- Simple service discovery & load balancing

FURTHER READING

- Getting started with Docker swarm: http://dockr.ly/2vUFWTA
- Swarm mode overview: http://dockr.ly/2jh11Vd

INTRODUCTION TO KUBERNETES

DISCUSSION: CONTAINER COMMUNICATION

Suppose you have two services you want to guarantee can reach each other on the same host, to eliminate network latency. How would you do this in Swarm?

LEARNING OBJECTIVES

By the end of this module, learners will be able to:

- Understand the components and roles of Kubernetes masters and nodes
- Identify and explain the core Kubernetes objects (Pod, ReplicaSet, Deployment, Service)
- Explore the Kubernetes networking model
- Contrast Kubernetes and Swarm

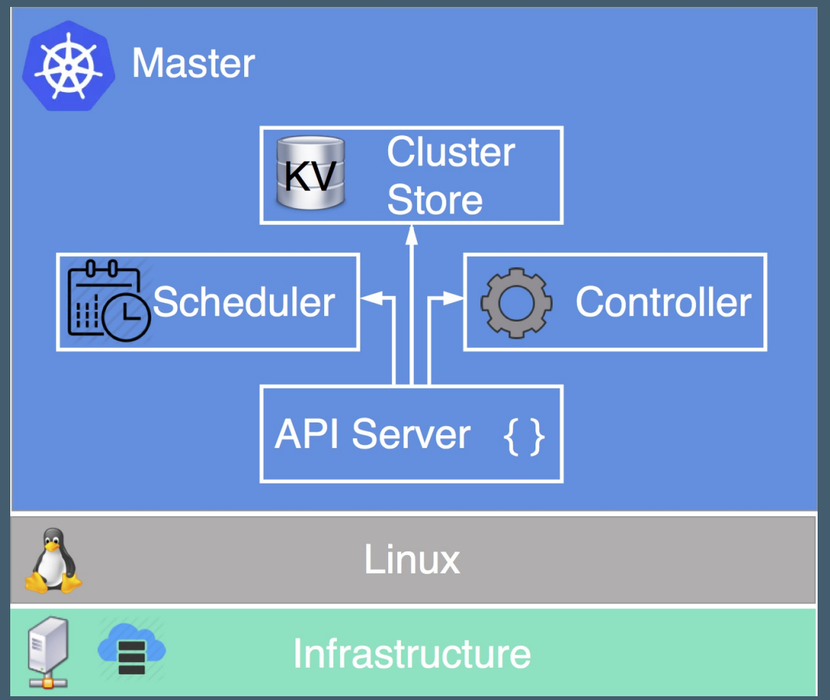
KUBERNETES VS. SWARM

- Kubernetes: modular, prioritizes communication model
- Swarm: monolithic, prioritizes security model

KUBERNETES MASTER

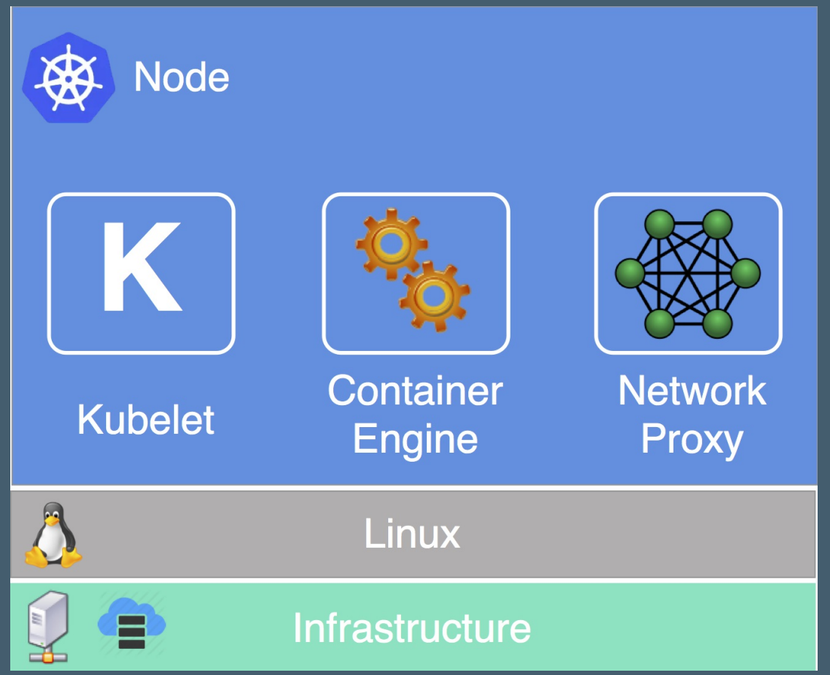
Important Components

- API Server: Frontend into Kubernetes control plane
- Cluster Store: Config and state of cluster
- Controller Manager: Assert desired state
- Scheduler: Assigns workload to nodes

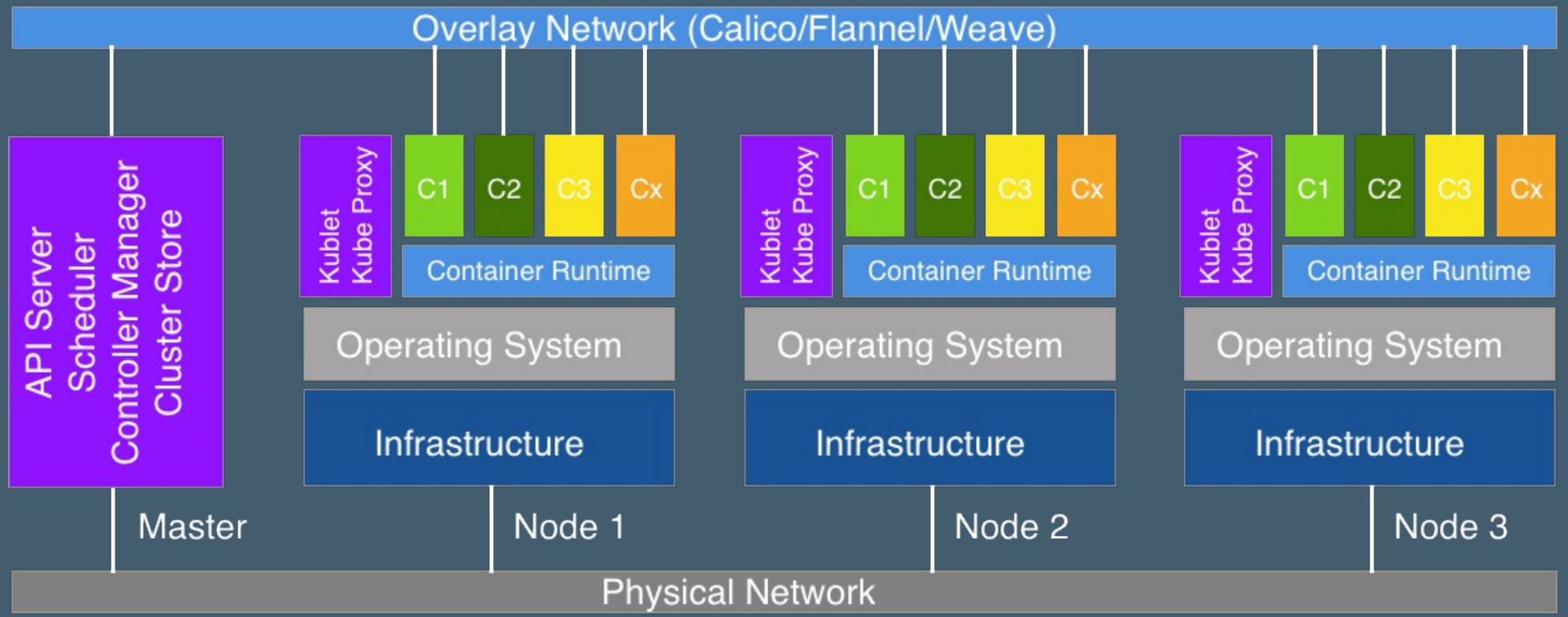


KUBERNETES NODE

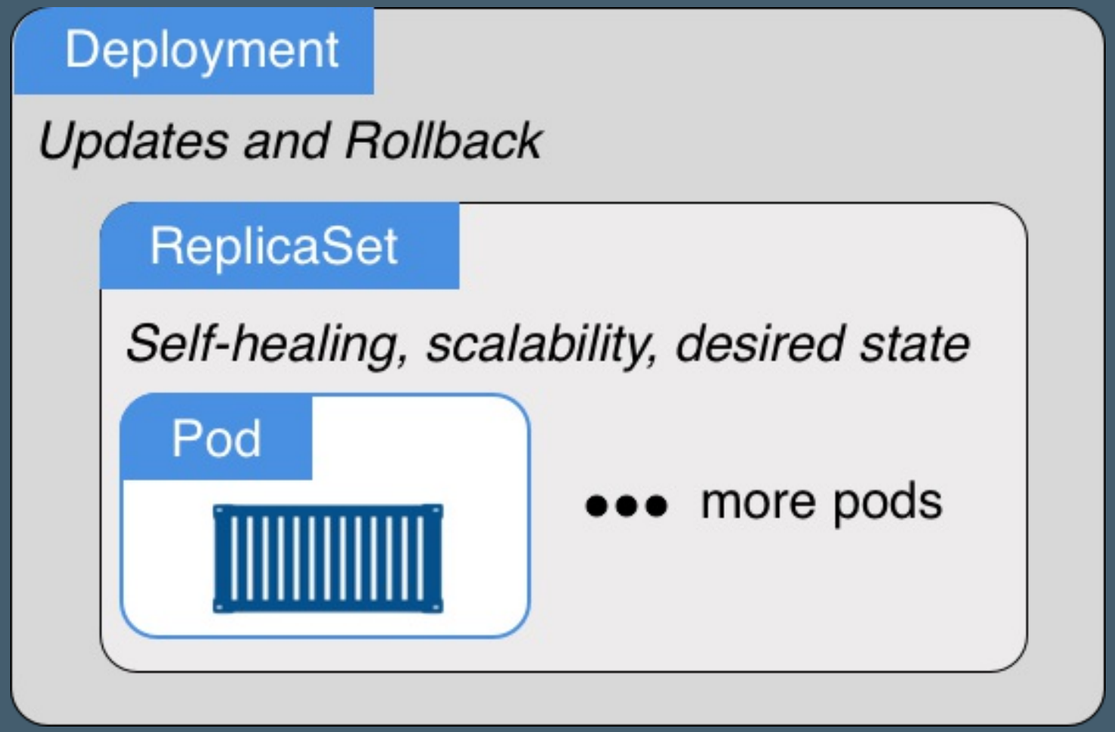
- Kubelet: Kubernetes Agent
- Container Engine: Host Containers
- Network Proxy: Networking & Load Balancing



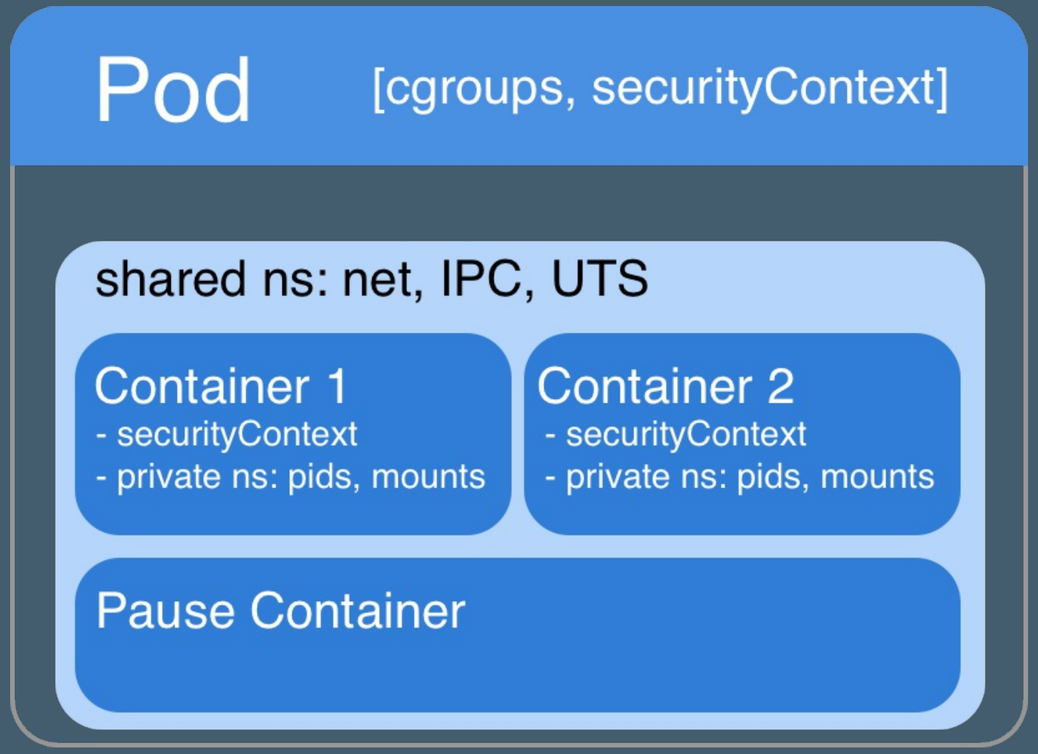
ARCHITECTURE



KUBERNETES ORCHESTRATION OBJECTS

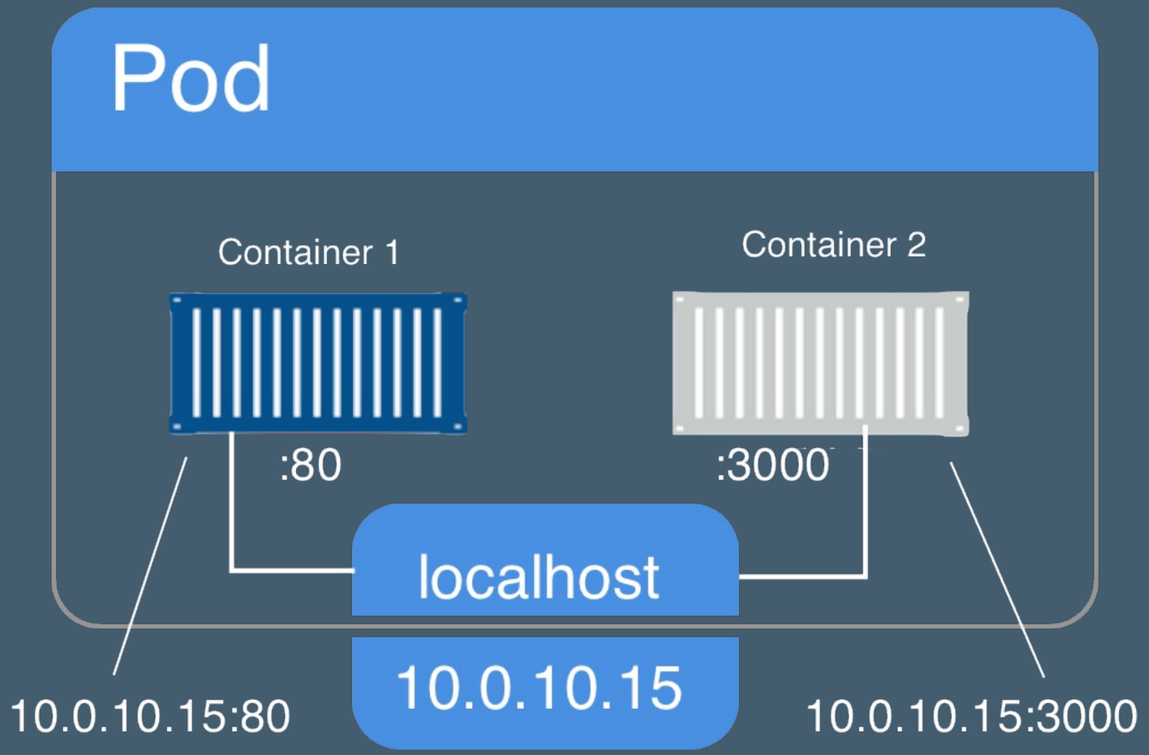


PODS



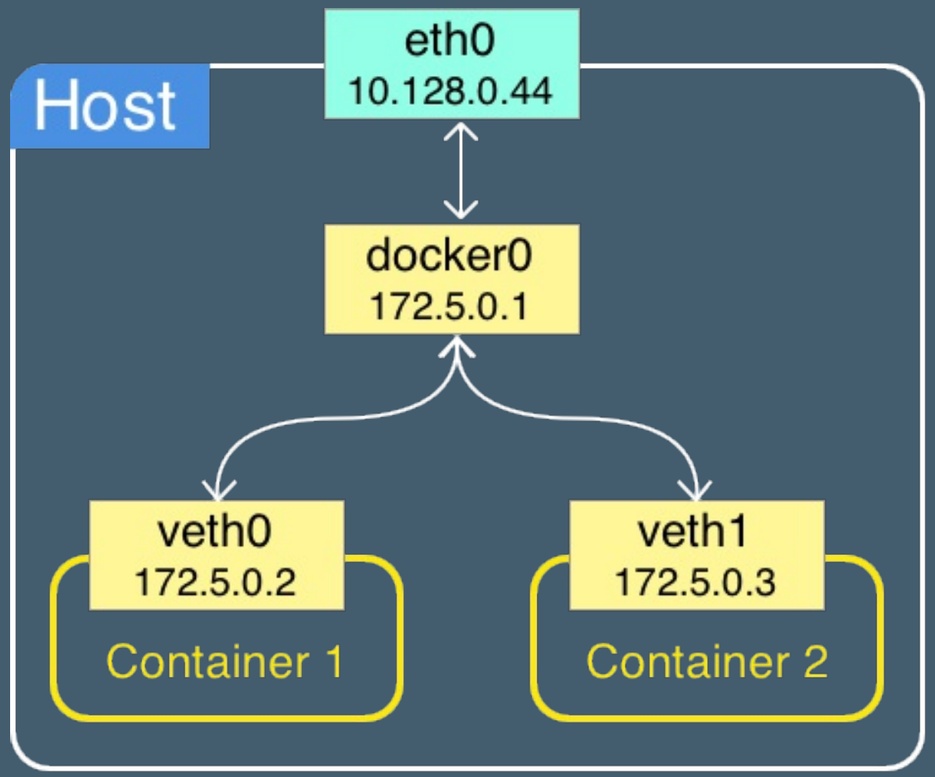
Logical host supporting interacting processes

PODS

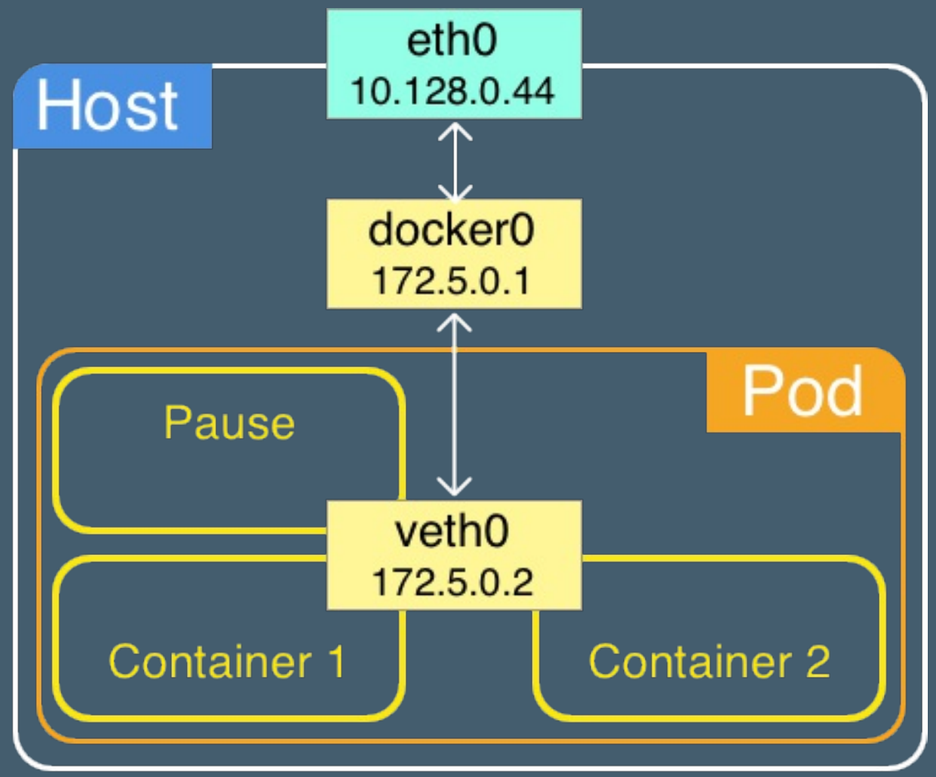


- Use localhost for intra-pod communication
- All containers in a pod share same IP

POD NETWORKING

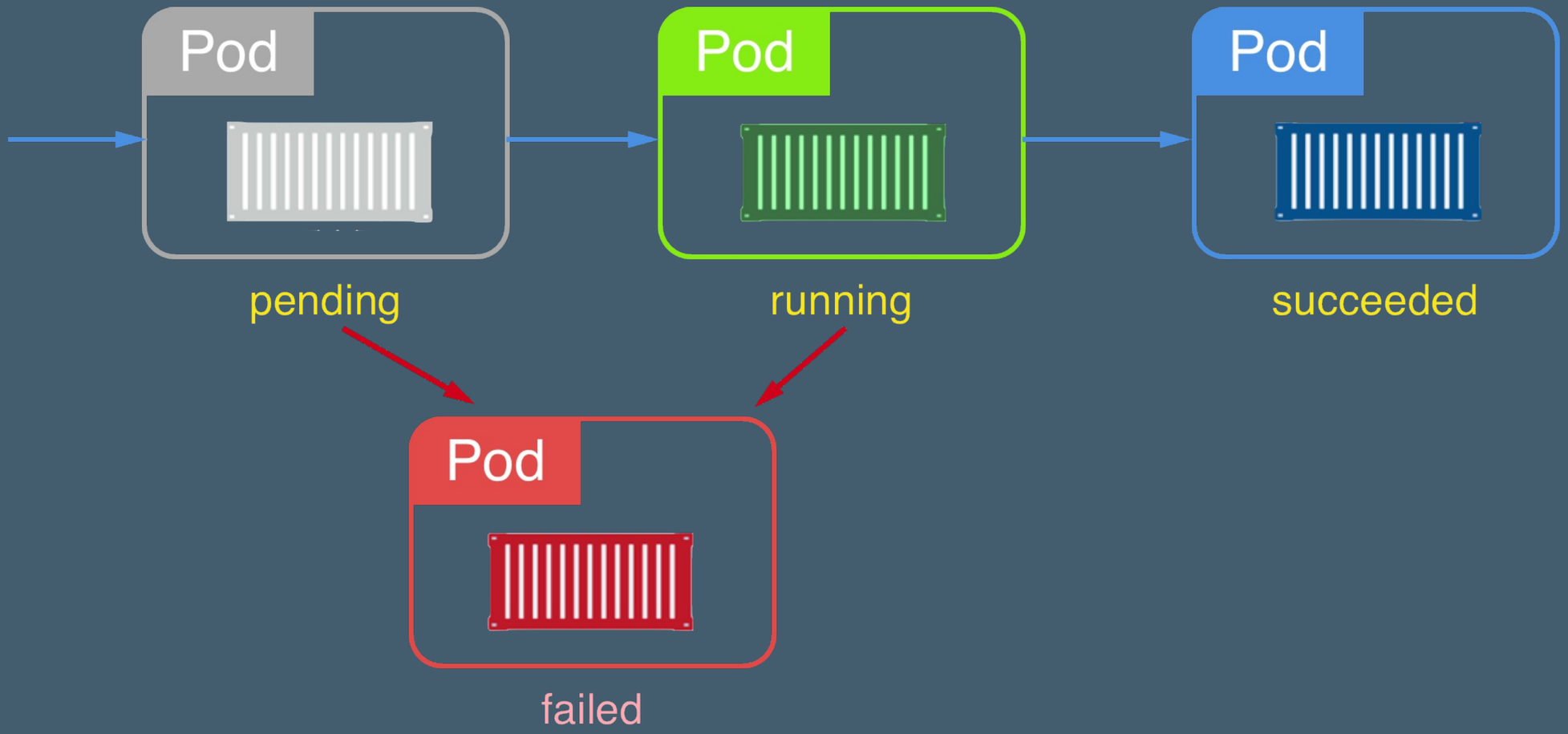


Docker Bridge Network



Kubernetes Network

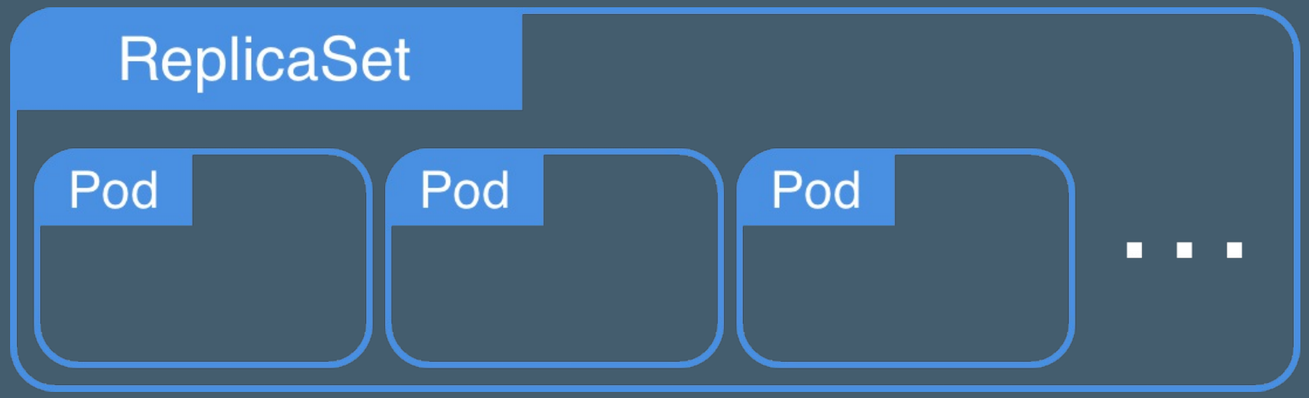
POD LIFECYCLE



INSTRUCTOR DEMO: KUBERNETES BASICS

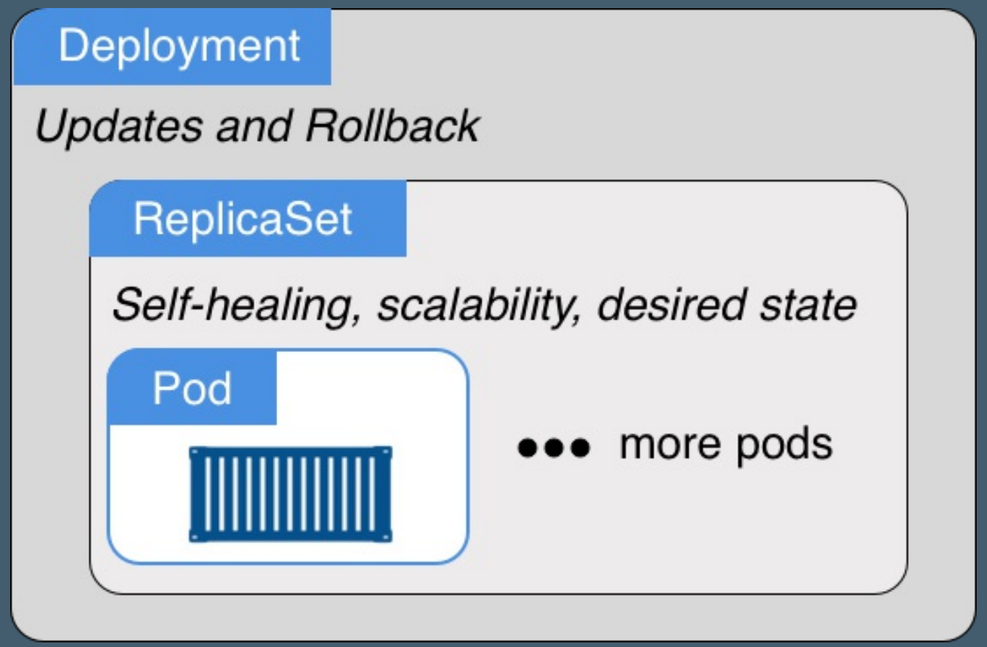
See the 'Kubernetes Basics' demo in the Docker Fundamentals Exercises book.

REPLICASET



- Scaling
- Keep-alive

DEPLOYMENT

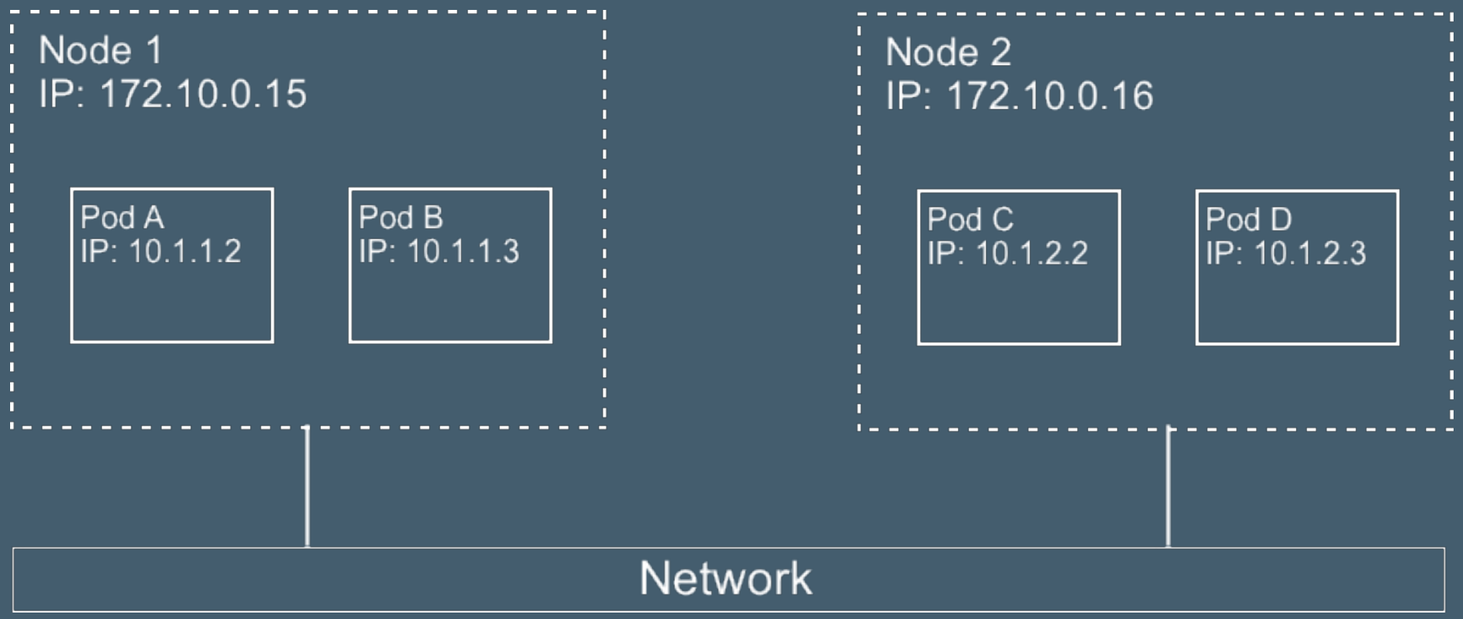


- Build on top of ReplicaSets
- Add configurable Updates and Rollback
- Older Versions of ReplicaSets stick around for easy Rollback

EXERCISE: KUBERNETES ORCHESTRATION

Work through the 'Kubernetes Orchestration' exercise in the Docker Fundamentals Exercises book.

KUBERNETES NETWORK MODEL



Requirements

- Pod <--> Pod without NAT
- Node <--> Pod without NAT
- Pod's peers find it at the same IP it finds itself
- Creates a flat network, like VMs

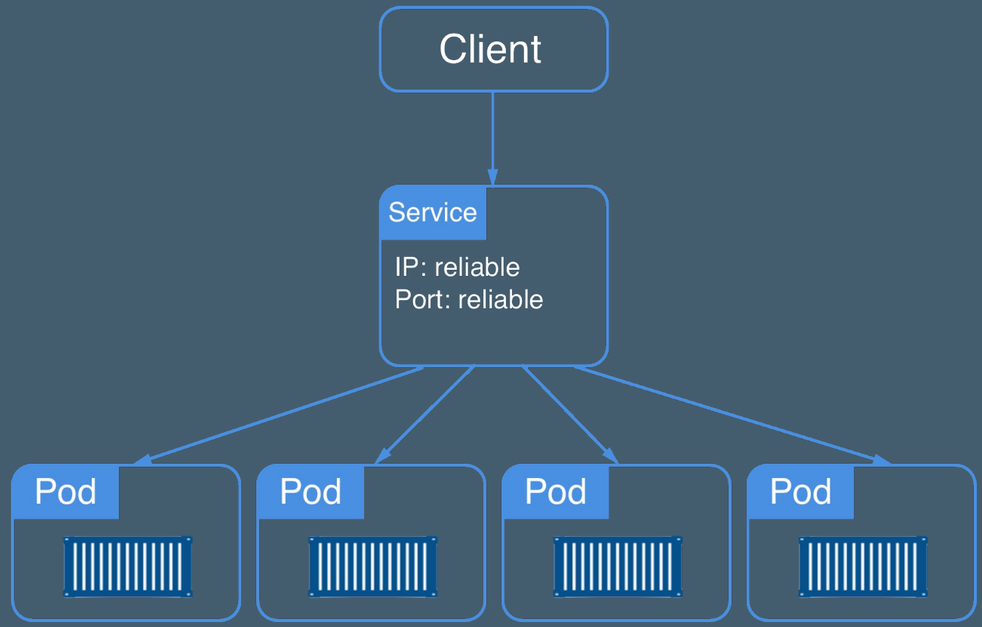
SERVICE

Problem:

- Pods are mortal
- Pods are never resurrected
- Pod IP Addr cannot be relied on

Solution:

- Service defines:
  - Logical set of Pods
  - Policy how to access them



CLUSTERIP & NODEPORT

Functional similarities:

- ClusterIP service <--> Swarm VIP
- NodePort service <--> Swarm L4 routing mesh

KUBERNETES LABEL SELECTORS

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: nginx-deployment
spec:
  replicas: 3
  selector:
    matchLabels:
      app: nginx
  template:
    metadata:
      labels:
        app: nginx
    spec:
      containers:
      - name: nginx
        image: nginx:1.7.9
```

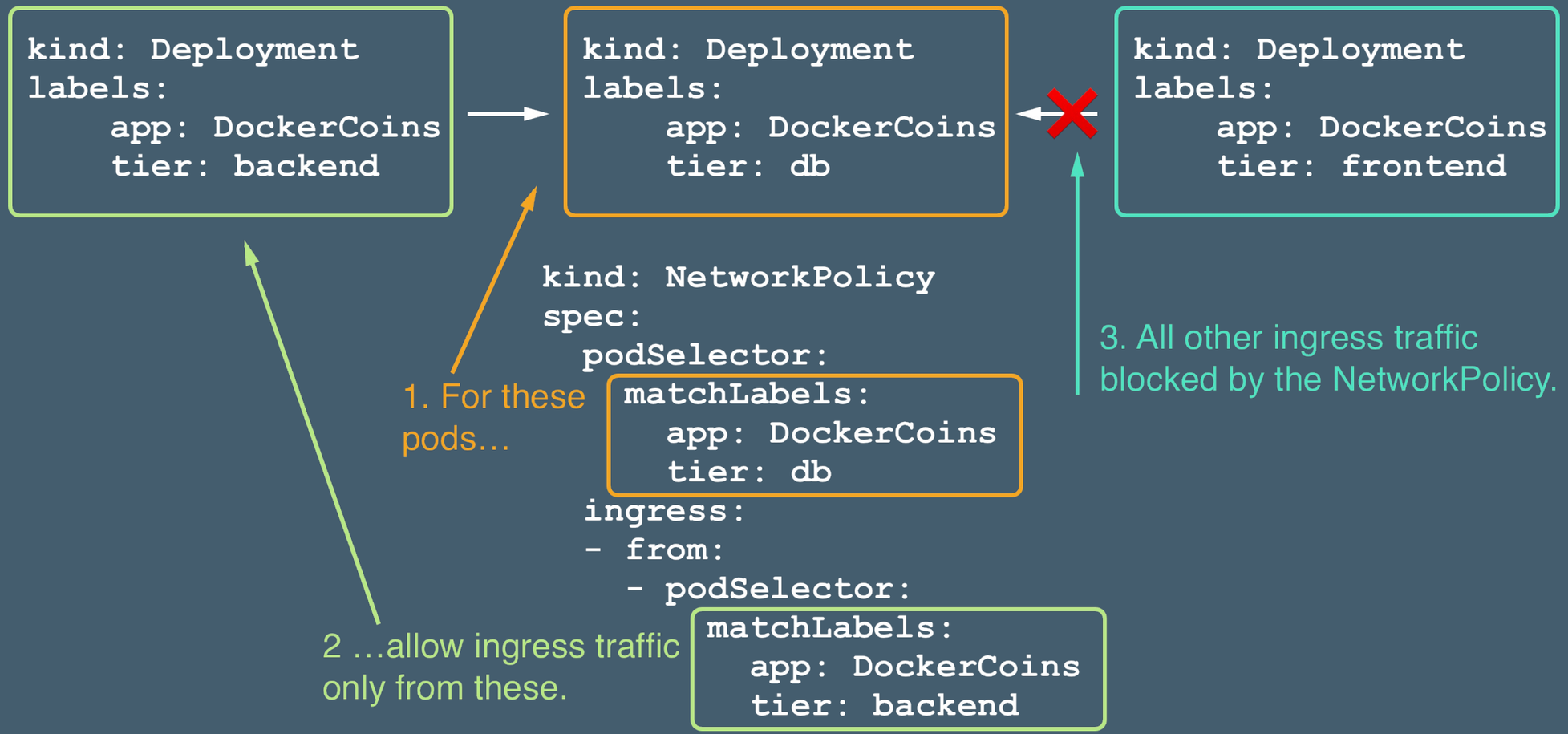
```
apiVersion: v1
kind: Service
metadata:
  name: my-service
spec:
  selector:
      app: nginx
  ports:
  - port: 8000
    targetPort: 80
```

NETWORK POLICIES

- Network policies control traffic
- Traffic allowed by default
- Traffic denied if network policy exist but no rule allows it
- Independent ingress & egress rules

```
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: ...
  namespace: ...
  ...
spec:
  podSelector: ...
  ingress:
  - ...
  - ...
  egress:
  - ...
  - ...
```

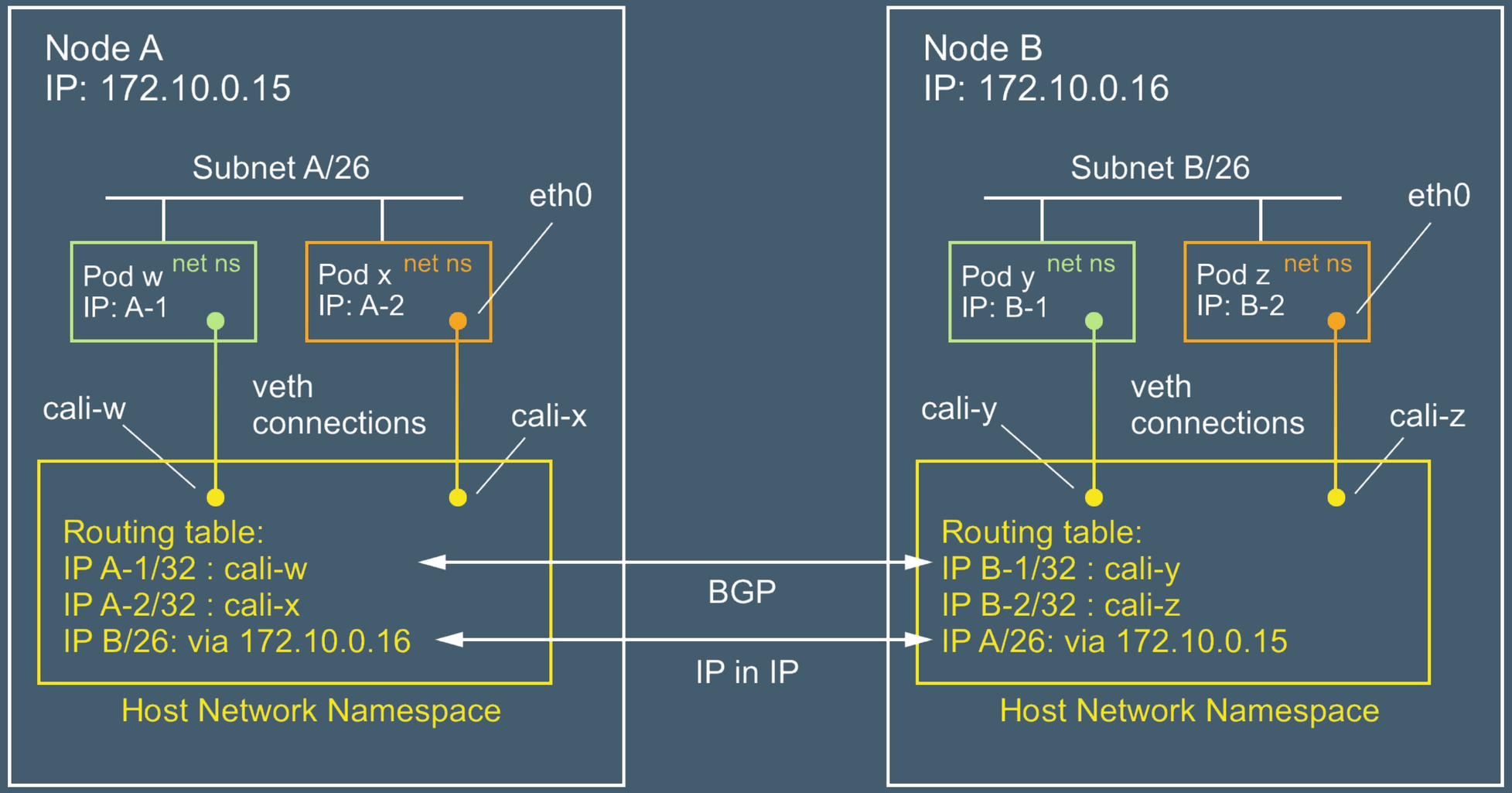
SAMPLE NETWORK POLICIES



KUBERNETES NETWORKING PLANES

- Management:
  - Master to Master: etcd Raft
  - Master to Node: apiserver (TCP 443) <-> kubelet (TCP 10250)
- Data & Control:
  - BYO networking
  - See Cluster DNS, http://bit.ly/2DMmdyt

CALICO



EXERCISE: KUBERNETES NETWORKING

Work through the 'Kubernetes Networking' exercise in the Docker Fundamentals Exercises book.

COMPARING SWARMKIT & KUBERNETES

SwarmKit	Kubernetes
Swarm	Cluster
Node	Cluster Member
Manager	Master
Worker	(Worker) Node
Container	Container **
Task	Pod
Service	ReplicaSet
Service	Deployment
Stack	Stack **
VIP	ClusterIP Service
Routing Mesh	NodePort Service
Network	Network Policies

KUBERNETES TAKEAWAYS

- Kubernetes is an alternative to Swarm
- Kube provides more flexibility in its orchestration objects at the cost of more config
- Kube prioritizes inter-container communication, compared to Swarm's prioritization of security.

FURTHER READING

- Docker & Kubernetes: https://www.docker.com/kubernetes
- Official Kubernetes Docs: https://kubernetes.io/docs
- Tutorials: http://bit.ly/2yLGn61
- Interactive Tutorials: http://bit.ly/2iqLAZd
- Understanding Kubernetes Networking: http://bit.ly/2kdI1qQ
- Kubernetes the Hard Way: http://bit.ly/29Dq4wC

SECRETS

DISCUSSION: KEEPING SECRETS

What's required for an orchestrator to distribute sensitive data to containers securely?

LEARNING OBJECTIVES

By the end of this module, learners will be able to:

- Explain the purpose and use cases for secrets
- Declare secrets in both Swarm and Kubernetes

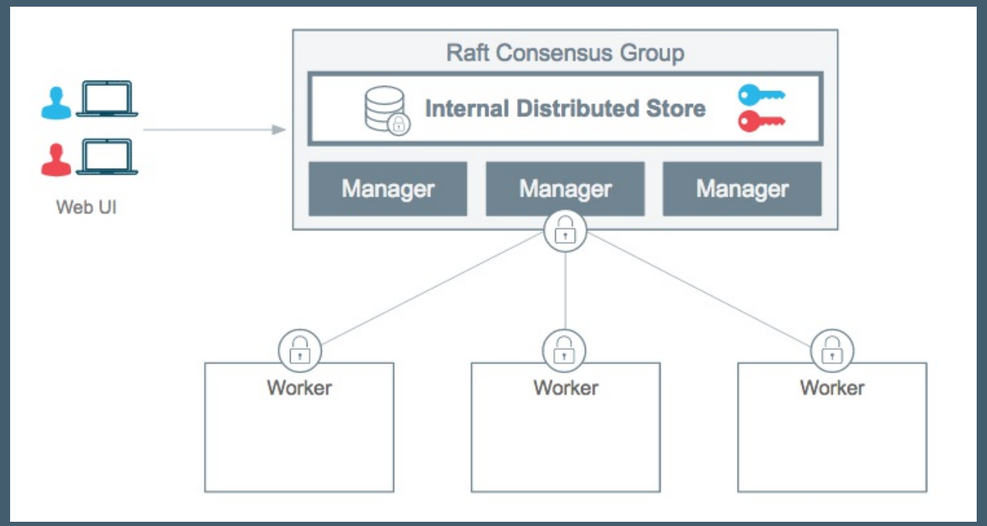
DISTRIBUTING SECRETS

- Apps need sensitive data like access tokens, ssh keys etc
- How to securely store and distribute secrets across a cluster?

SECRET REQUIREMENTS

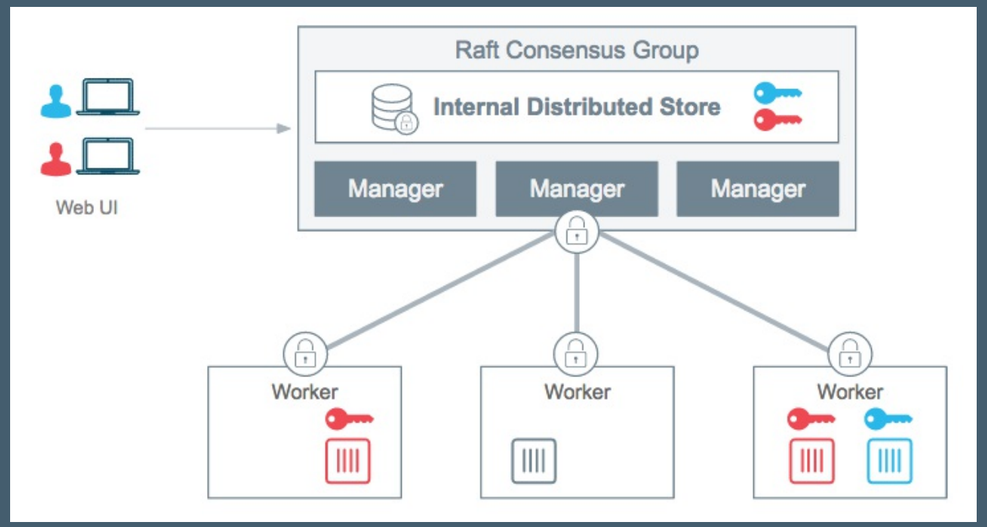
- Encrypted at rest
- Encrypted in transit
- Accessible only to intended containers

SECRETS WORKFLOW 1: CREATION & STORAGE



- Swarm:
  - Stored in state db
  - Automatically encrypted at rest
- Kubernetes:
  - Stored in etcd
  - Must configure encryption: http://bit.ly/2GCoPwE

SECRETS WORKFLOW 2: DISTRIBUTION



- Swarm:
  - Default mutual TLS
  - Associated with services
- Kubernetes:
  - TLS optional
  - Associated with pods or deployments
- Both:
  - Least Privilege: secrets available only exactly where needed
  - Deleted along with container

Linux containers:

tmpfs-mounted unencrypted in container at

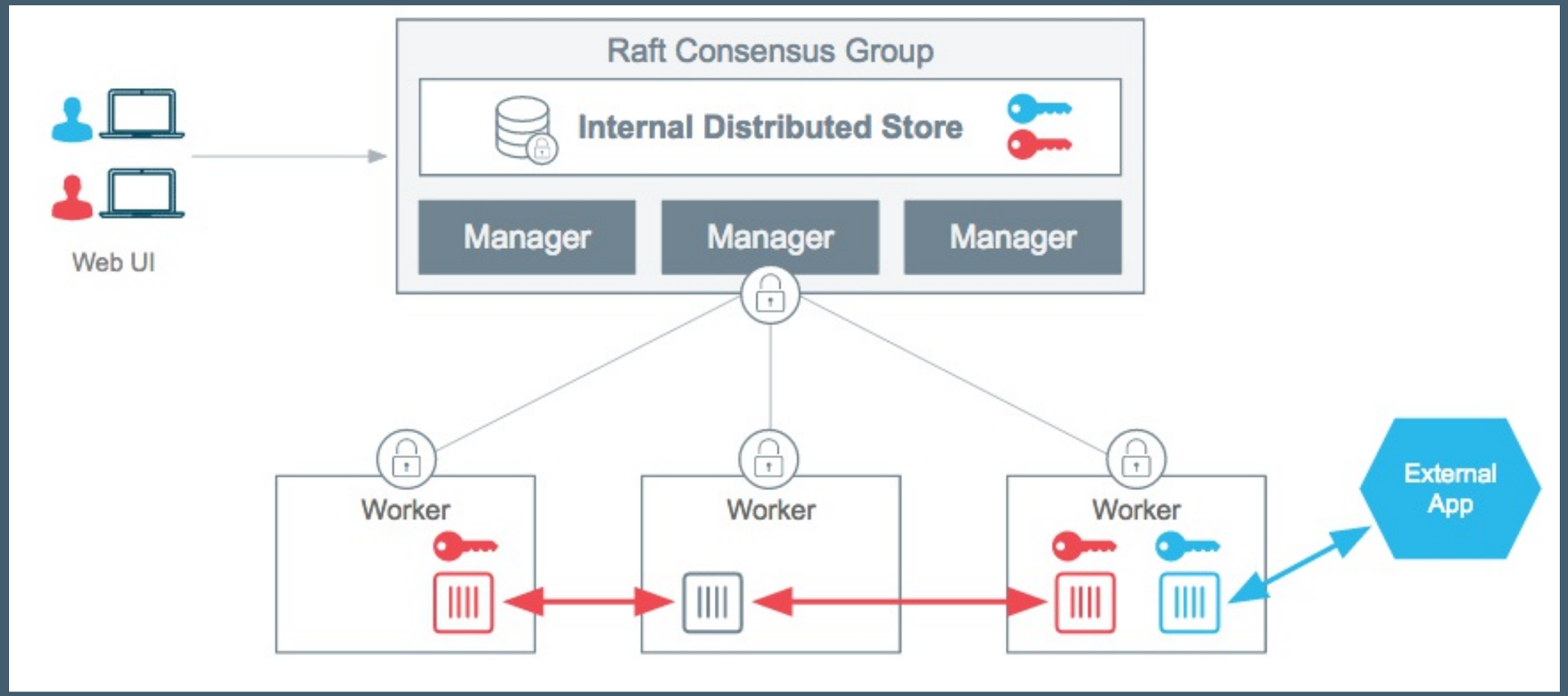
`/run/secrets/<secret_name>`

Windows containers:

Volume mounted unencrypted in container at

`c:\\ProgramData\\Docker\\secrets\\<secret_name>`

SECRETS WORKFLOW 3: SECRET USAGE



EXERCISE: SECRETS

Work through the 'Orchestrating Secrets' exercise in the Docker Fundamentals Exercise book.

FURTHER READING

- Manage sensitive data with Docker secrets: http://dockr.ly/2vUNbuH
- Docker secret reference: http://dockr.ly/2iSsNJC
- Introducing Docker secrets management: http://dockr.ly/2k7zwzE
- Securing the AtSea app with Docker secrets: http://dockr.ly/2wx5MyV
- Example of using Docker secrets in UCP: http://dockr.ly/2gtszUY

FUNDAMENTAL ORCHESTRATION TAKEAWAYS

- Distributed Application Architecture orchestrates one or more containers across one or more nodes
- Orchestrators abstract away the differences between processes and between nodes
- Orchestrators enhance scalability and stability

FUNDAMENTALS SIGNATURE ASSIGNMENT

CONTAINERIZING AN APPLICATION

You will containerize and orchestrate the following:

- Data Tier: Postgres
- API: Java / Maven / Springboot
- Frontend: NodeJS / express

SIGNATURE ASSIGNMENT: CONTAINERIZING AN APPLICATION

Work through the 'Containerizing an Application' exercise in the Docker Fundamentals Exercise book.

BONUS TOPICS

DOCKER SYSTEM COMMANDS

LEARNING OBJECTIVES

By the end of this module, learners will be able to:

- Execute clean-up commands
- Locate Docker system information

CLEAN-UP COMMANDS

- docker system df

```
TYPE            TOTAL     ACTIVE    SIZE        RECLAIMABLE
Images          39        2         9.01 GB     7.269 GB (80%)
Containers      2         2         69.36 MB    0 B (0%)
Local Volumes   0         0         0 B         0 B
```

- docker system prune

more limited...

- docker image prune [--filter "foo=bar"]
- docker container prune [--filter "foo=bar"]
- docker volume prune [--filter "foo=bar"]
- docker network prune [--filter "foo=bar"]

INSPECT THE SYSTEM

docker system info

```
Containers: 2
 Running: 2
 Paused: 0
 Stopped: 0
Images: 105
Server Version: 17.03.0-ee
Storage Driver: overlay2
 Backing Filesystem: extfs
 Supports d_type: true
 Native Overlay Diff: true
Logging Driver: json-file
Cgroup Driver: cgroupfs
Plugins:
 Volume: local
 Network: bridge host ipvlan macvlan null overlay
Swarm: active
 NodeID: ybmqksh6fm627armruq0e8id1
 Is Manager: true
 ClusterID: 2rbf1dv6t5ntro2fxbry6ikr3
 Managers: 1
 Nodes: 1
 Orchestration:
  Task History Retention Limit: 5
 Raft:
  Snapshot Interval: 10000
  Number of Old Snapshots to Retain: 0
  Heartbeat Tick: 1
  ...
```

SYSTEM EVENTS

Start observing with ...

docker system events

Generate events with ...

docker container run --rm alpine echo 'Hello World!'

```
2017-01-25T16:57:48.553596179-06:00 container create 30eb630790d44052f26c1081...
2017-01-25T16:57:48.556718161-06:00 container attach 30eb630790d44052f26c1081...
2017-01-25T16:57:48.698190608-06:00 network connect de1b2b40f522e69318847ada3...
2017-01-25T16:57:49.062631155-06:00 container start 30eb630790d44052f26c1081d...
2017-01-25T16:57:49.164526268-06:00 container die 30eb630790d44052f26c1081dbf...
2017-01-25T16:57:49.613422740-06:00 network disconnect de1b2b40f522e69318847a...
2017-01-25T16:57:49.815845051-06:00 container destroy 30eb630790d44052f26c108...
```

EXERCISE: SYSTEM COMMANDS

Work through:

- Cleaning up Docker Resources
- Inspection Commands

in the Docker Fundamentals Exercises book.

DISCUSSION

- What is the origin of dangling image layers?
- What are some potential pitfalls to automating system cleanup with prune commands, and how to avoid them?
- Questions?

FURTHER READING

- System commands reference: http://dockr.ly/2eMR53i

DOCKER PLUGINS

LEARNING OBJECTIVES

By the end of this module, learners will be able to:

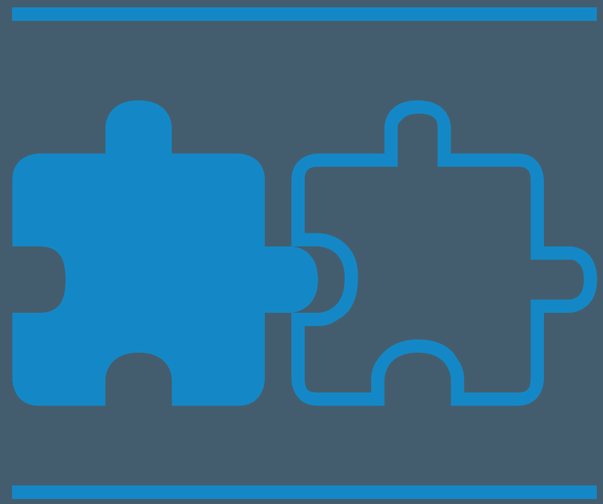
- Discuss the purpose and format of Docker plugins
- Witness the value of plugins by deploying a plugin

PLUGINS

- Extend the Docker platform
- Distributed as Docker images
- Hosted on store.docker.com

List plugins on system:

```
$ docker plugin ls
ID                  NAME                DESCRIPTION                 ENABLED
bee424413706        vieux/sshfs:latest  sshFS plugin for Docker     true
```



INSTALL A PLUGIN

```
$ docker plugin install vieux/sshfs
Plugin "vieux/sshfs" is requesting the following privileges:
 - network: [host]
 - mount: [/var/lib/docker/plugins/]
 - device: [/dev/fuse]
 - capabilities: [CAP_SYS_ADMIN]
Do you grant the above permissions? [y/N] y
latest: Pulling from vieux/sshfs
a23658ccfda2: Download complete
Digest: sha256:d33ffa08df2a4fa87f83fded4ac3ac2e3a96d296c55aa1a0afce33fb2cc7b9b0
Status: Downloaded newer image for vieux/sshfs:latest
Installed plugin vieux/sshfs
```

USING THE PLUGIN

Create a volume...

```
docker volume create -d vieux/sshfs \
    -o sshcmd=<user@host:path> \
    -o password=<password> \
    sshvolume
```

Use the volume...

```
docker container run -v sshvolume:/demo -it centos:7 bash
```

EXERCISE: PLUGINS

Work through the 'Docker Plugins' exercise in the Docker Fundamentals Exercises book.

DISCUSSION

- What sort of volume plugins would make sense for your applications in your datacenter?
- Questions?

FURTHER READING

- How to implement a plugin: http://dockr.ly/2vRIEcG
- Create an authorization plugin: http://dockr.ly/2wuxfBB
- List of Docker Engine plugins: http://dockr.ly/2vyXERe
- Docker network driver plugins: http://dockr.ly/2wqiill
- Volume plugins: http://dockr.ly/2vSbU2W
- Plugin configuration reference: http://dockr.ly/2er4bm2
- Plugin API reference: http://dockr.ly/2ewofHi

DOCKER FUNDAMENTALS

Please take our feedback survey:

http://bit.ly/2GwsqLA

Get in touch: training@docker.com

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