Docker Networking Workshop

Agenda

1. Detailed Overview
2. Docker Networking Evolution
3. Use Cases
   - Single-host networking with the Bridge driver
   - Multi-host networking with the Overlay driver
   - Connecting to existing VLANs with the MACVLAN driver
4. Service Discovery
5. Routing Mesh
6. HTTP Routing Mesh (HRM) with Docker Datacenter
7. Docker Network Troubleshooting
8. Hands-on Exercises

Detailed Overview

BACKGROUND, CONTAINER NETWORK MODEL (CNM), LIBNETWORK, DRIVERS…

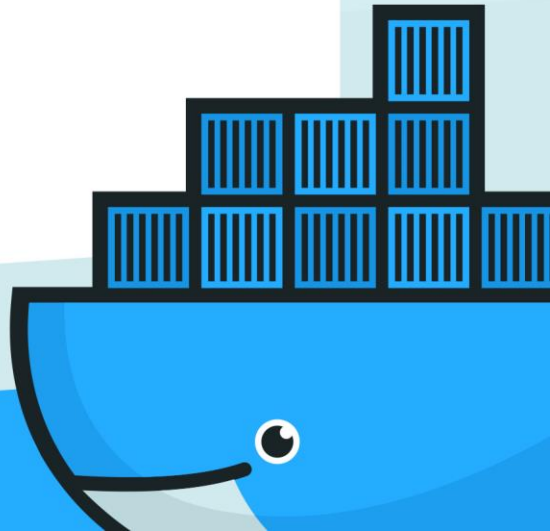
Background: Networking is Important!

Networking is integral to distributed applications

But networking is **hard, vast, and complex!**

Docker networking goal: **MAKE NETWORKING SIMPLE!**

“We’ll do for networking what we did for compute”



Docker Networking Goals

Make networks first class citizens in a Docker environment

Make applications more portable

Make multi-host networking simple

Make networks secure and scalable

Create a pluggable network stack

Support multiple OS platforms

Docker Networking Design Philosophy

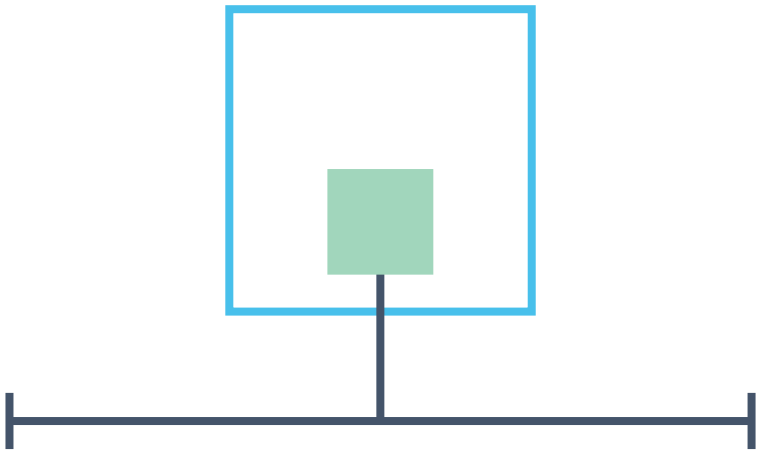
Put Users First

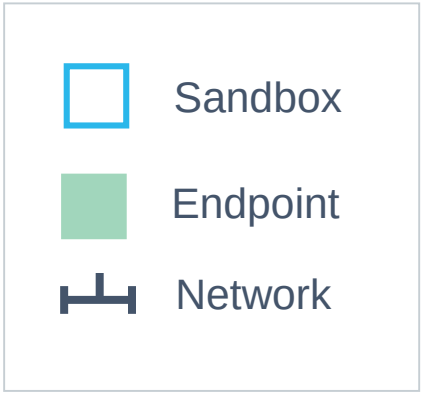
Developers and Operations

Plugin API Design

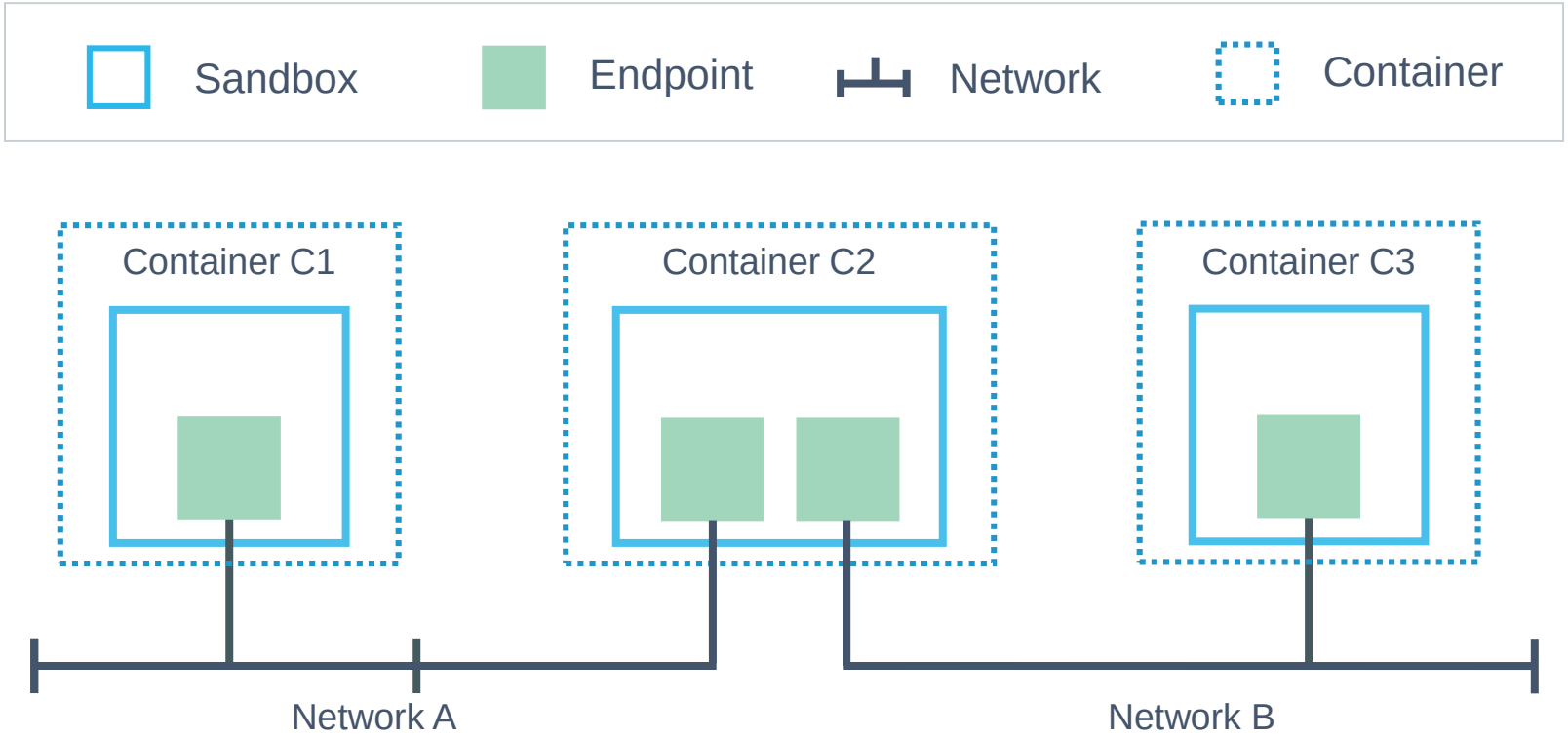
Batteries included but removable

Container Network Model (CNM)





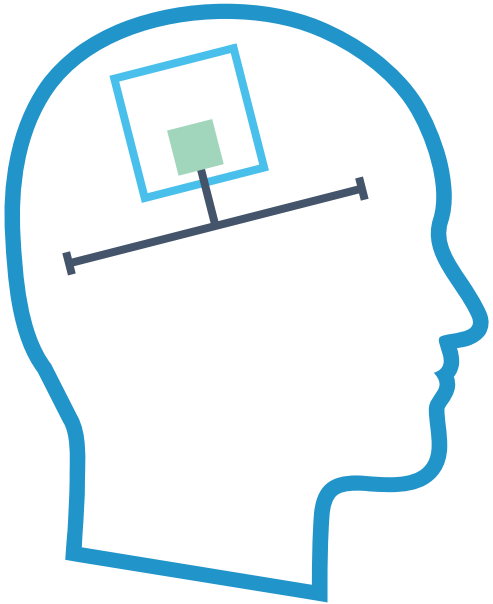
Containers and the CNM



docker

What is Libnetwork?

Libnetwork is Docker's native implementation of the CNM



CNM

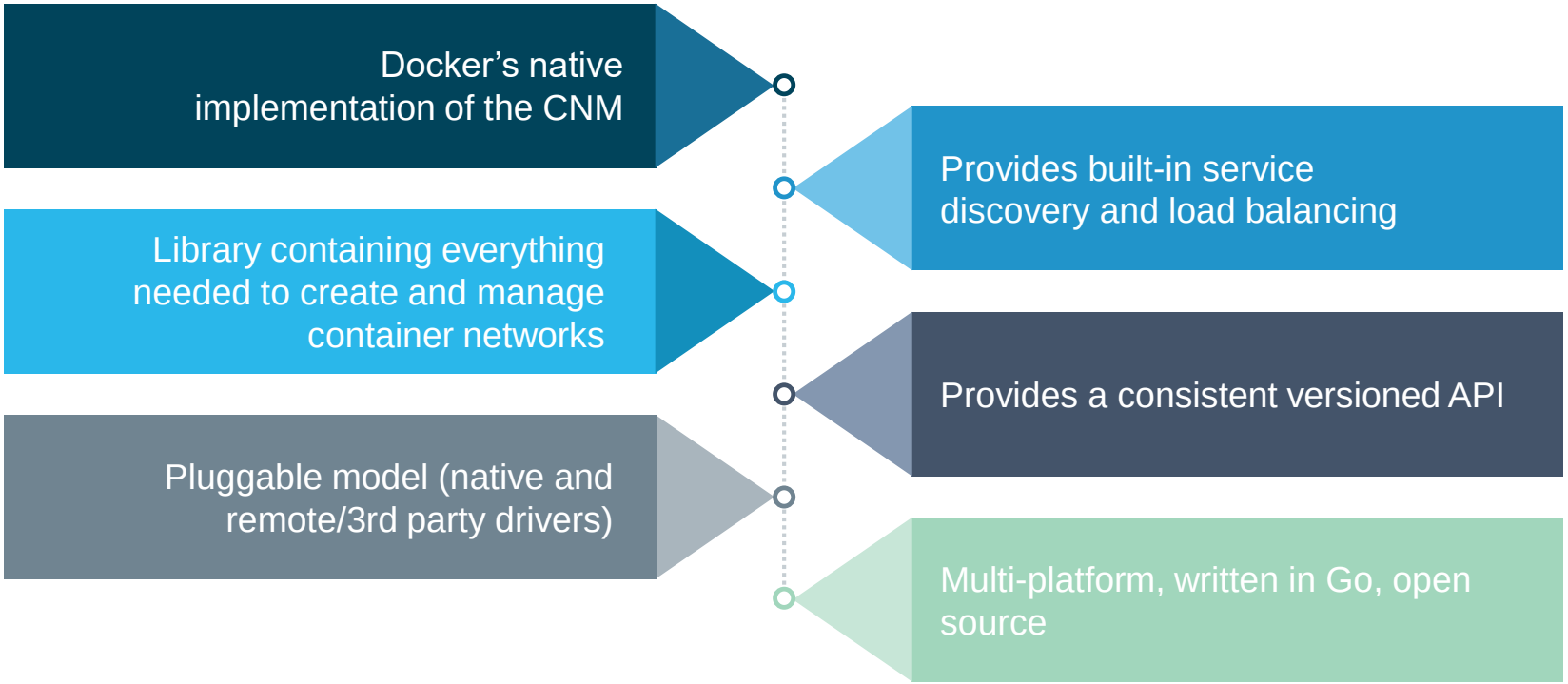
```
func main() {
    if reexec.Init() {
        return
    }

    // Select and configure the network driver
    networkType := "bridge"

    // Create a new controller instance
    driverOptions := options.Generic{}
    genericOption := make(map[string]interface{})
    genericOption[netlabel.GenericData] = driverOptions
    controller, err := libnetwork.New(config.OptionDriver
    if err != nil {
        log.Fatalf("libnetwork.New: %s", err)
    }
```

Libnetwork

What is Libnetwork?



Libnetwork and Drivers

Libnetwork has a pluggable driver interface

Drivers are used to implement different networking technologies

Built-in drivers are called local drivers, and include:
bridge, host, overlay, MACVLAN

3rd party drivers are called remote drivers, and include:
Calico, Contiv, Kuryr, Weave…

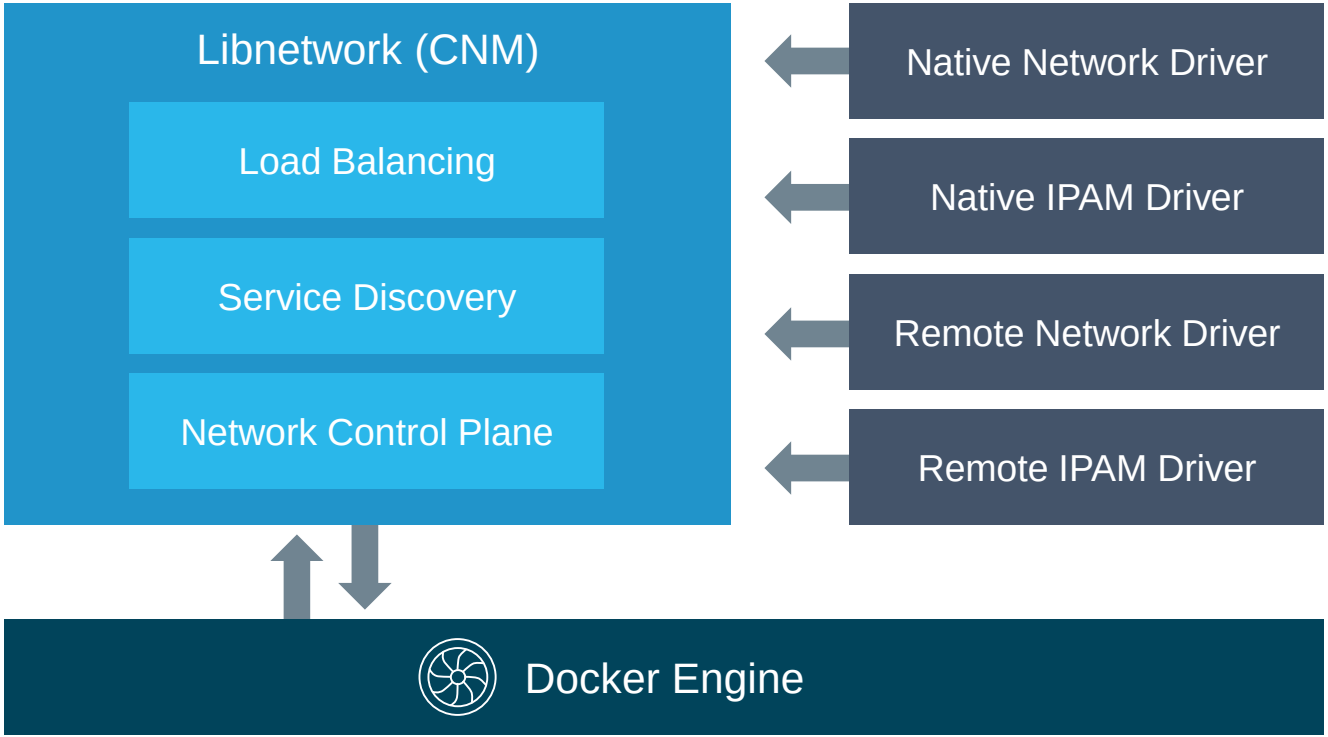
Libnetwork also supports pluggable IPAM drivers

Show Registered Drivers

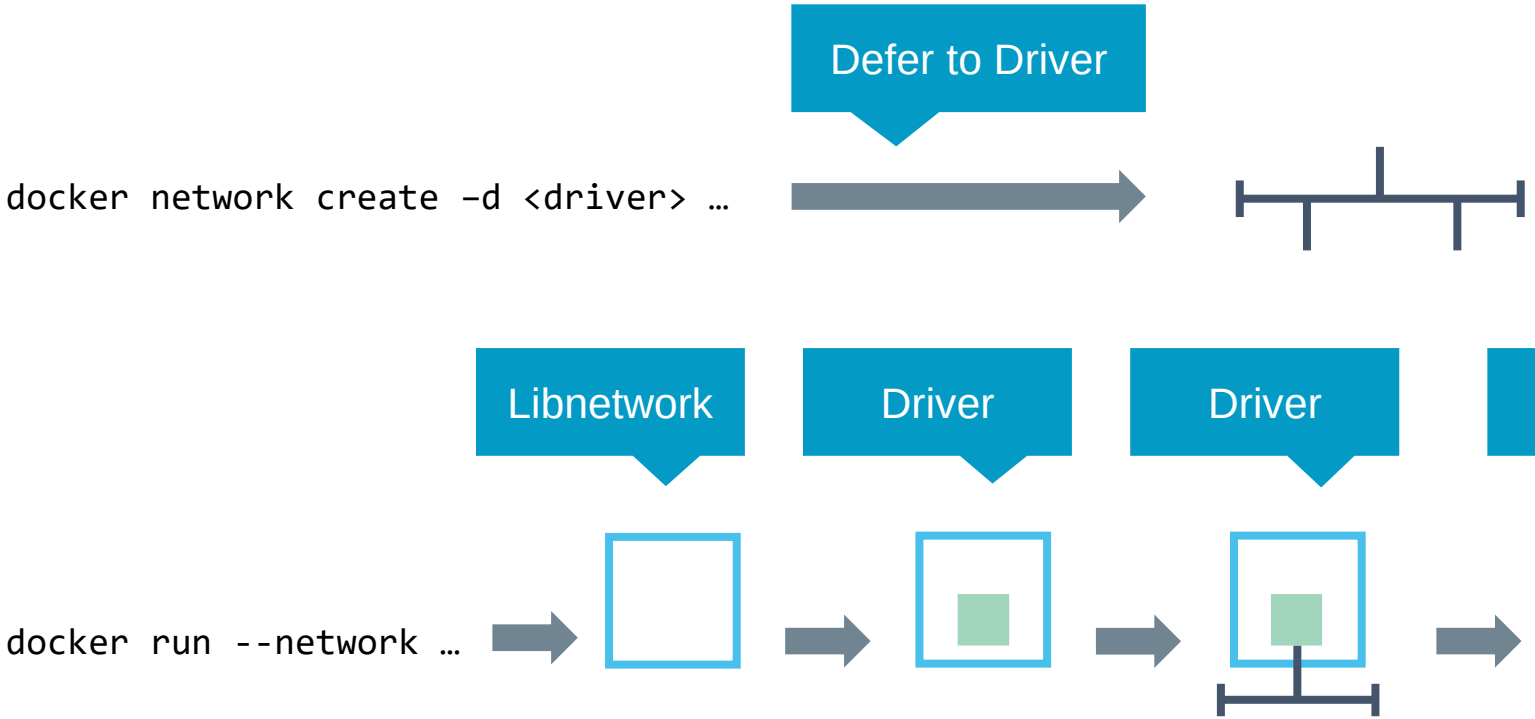
```
$ docker info

Containers: 0
 Running: 0
 Paused: 0
 Stopped: 0
Images: 2
<snip>
Plugins:
 Volume: local
 Network: null bridge host overlay
...
```

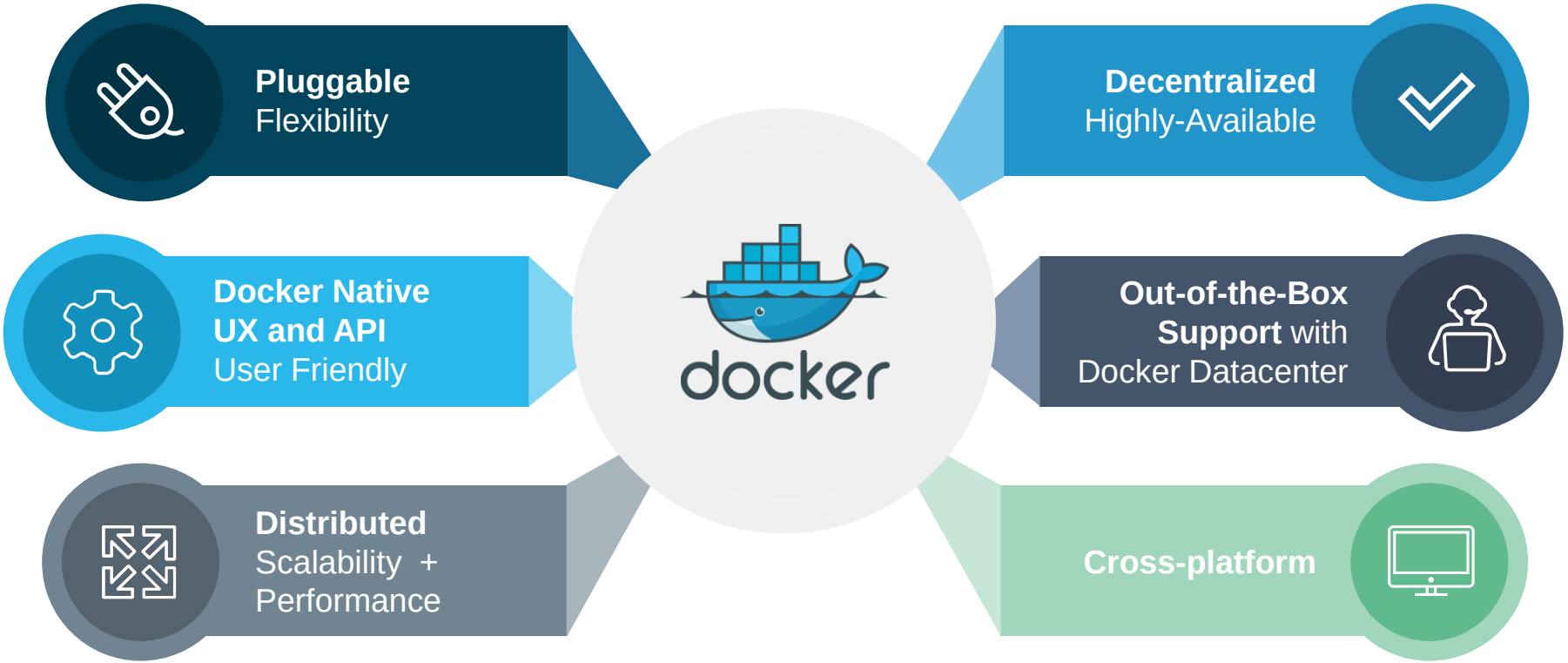
Libnetwork Architecture



Networks and Containers



Key Advantages



Detailed Overview: Summary

- The CNM is an open-source container networking specification contributed to the community by Docker, Inc.
- The CNM defines sandboxes, endpoints, and networks
- Libnetwork is Docker's implementation of the CNM
- Libnetwork is extensible via pluggable drivers
- Drivers allow Libnetwork to support many network technologies
- Libnetwork is cross-platform and open-source

The CNM and Libnetwork **simplify** container networking and improve **application portability**

Q & A

Break

Docker Networking Evolution

Libnetwork (CNM)

- Multihost Networking
- Plugins
- IPAM
- Network UX/API

- Aliases
- DNS Round Robin LB

Service Discovery

Distributed DNS

- Secure out-of-the-box
- Distributed KV store
- Load balancing
- Swarm integration
- Built-in routing mesh
- Native multi-host overlay
- …

Docker Networking on Linux

- The Linux kernel has extensive networking capabilities (TCP/IP stack, VXLAN, DNS…)
- Docker networking utilizes many Linux kernel networking features (network namespaces, bridges, iptables, veth pairs…)
- Linux bridges: L2 virtual switches implemented in the kernel
- Network namespaces: Used for isolating container network stacks
- veth pairs: Connect containers to container networks
- iptables: Used for port mapping, load balancing, network isolation…

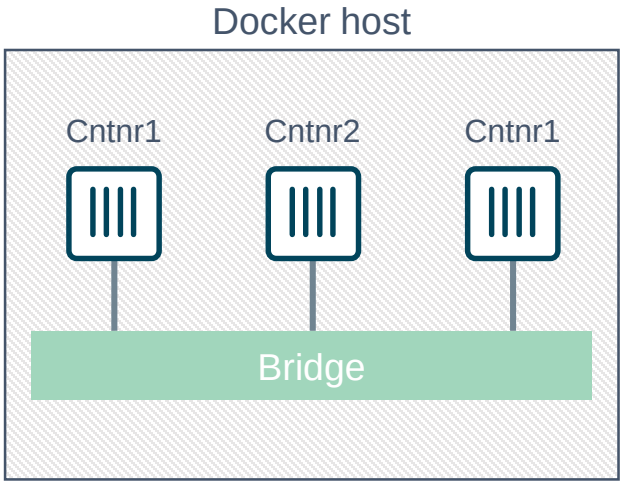
Use Cases

SINGLE-HOST NETWORKING WITH THE BRIDGE DRIVER

What is Docker Bridge Networking?

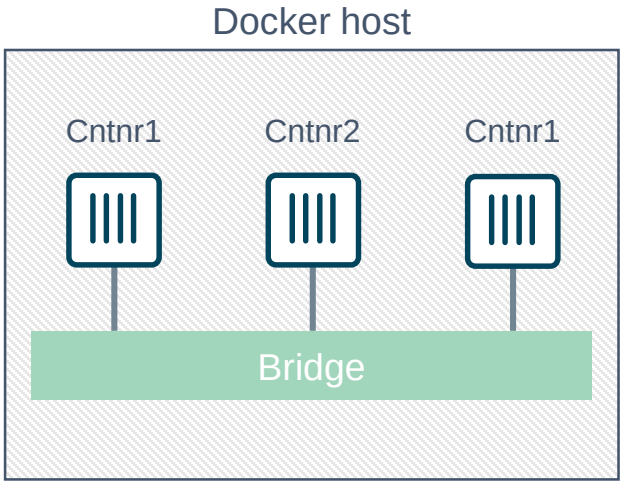
Single-host networking!

- Simple to configure and troubleshoot
- Useful for basic test and dev

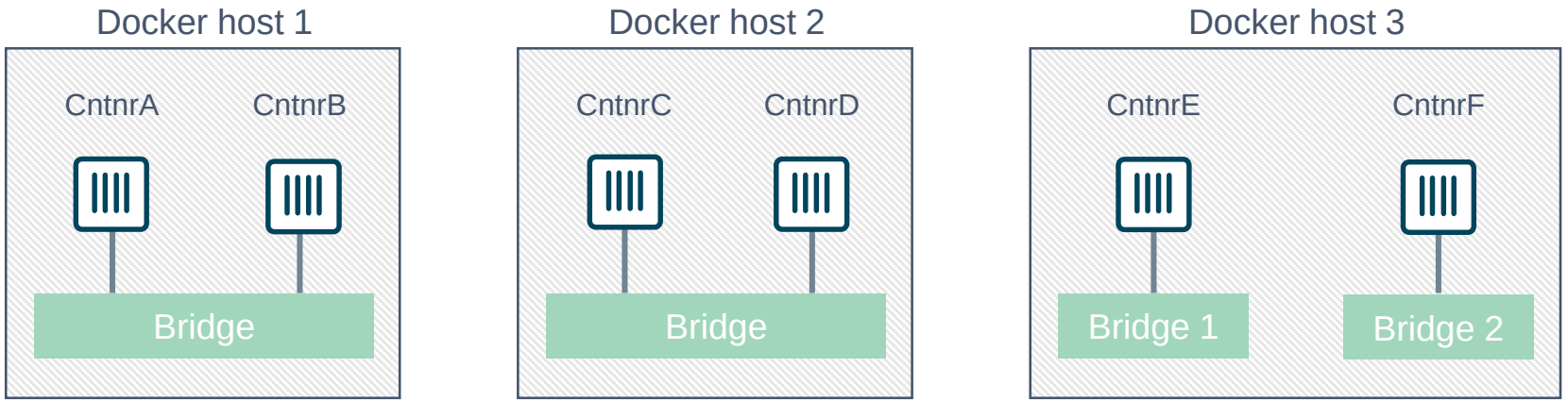


What is Docker Bridge Networking?

- The bridge driver creates a bridge (virtual switch) on a single Docker host
- Containers get plumbed into this bridge
- All containers on this bridge can communicate
- The bridge is a private network restricted to a single Docker host



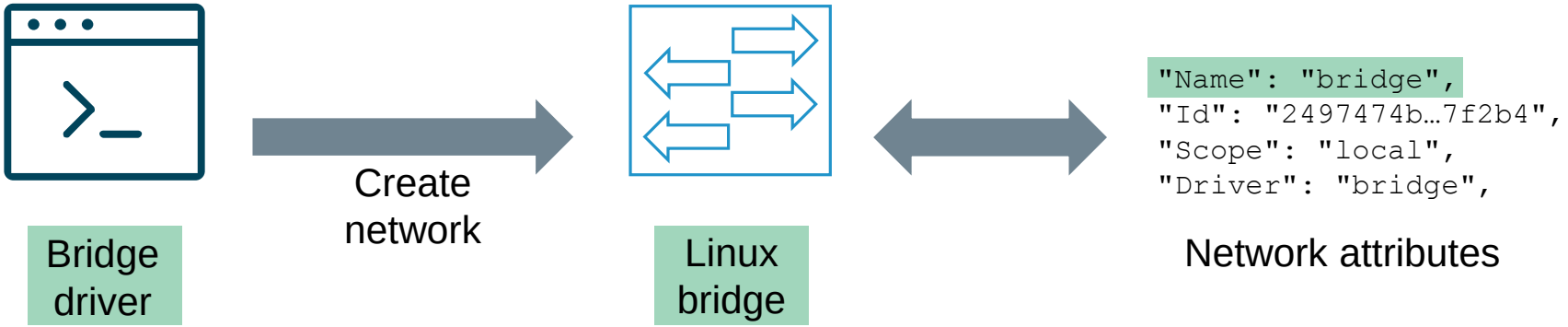
What is Docker Bridge Networking?



Containers on different **bridge** networks cannot communicate

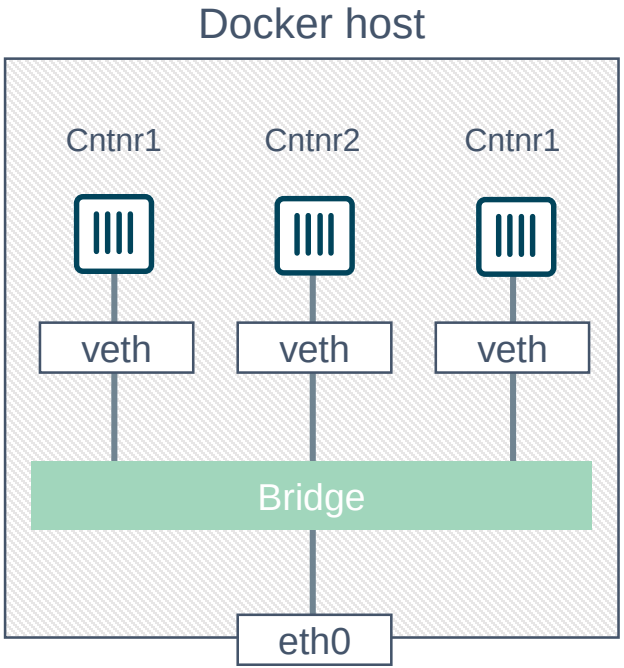
Use of the Term “Bridge”

- The bridge driver creates simple Linux bridges.
- All Docker hosts have a pre-built network called “bridge”
  - This was created by the bridge driver
  - This is the default network that all new containers will be connected to (unless you specify a different network when the container is created)
- You can create additional user-defined bridge networks

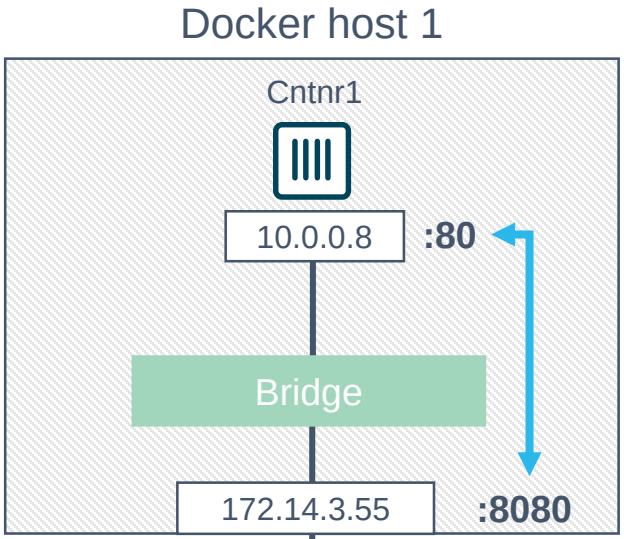


Bridge Networking in a Bit More Detail

- The bridge created by the bridge driver for the pre-built bridge network is called docker0
- Each container is connected to a bridge network via a veth pair
- Provides single-host networking
- External access requires port mapping



Docker Bridge Networking and Port Mapping



Host port

Container port

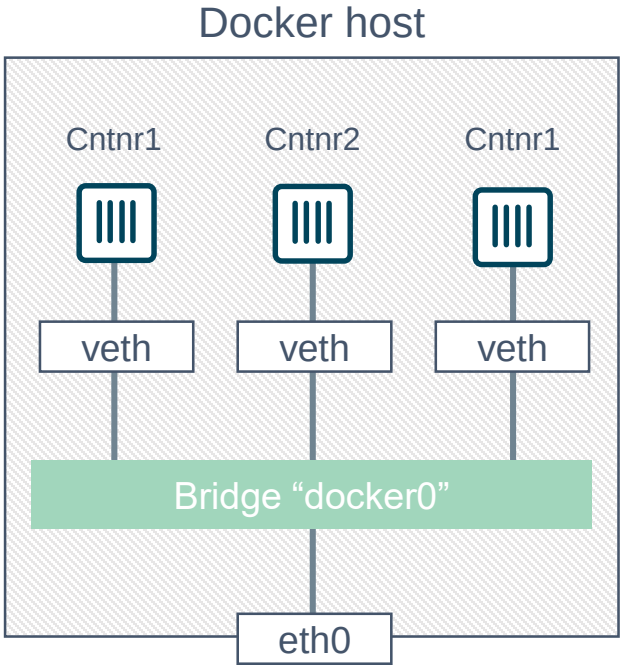
```
$ docker run -p 8080:80 ...
```

L2/L3 physical network

docker

Bridge Networking Summary

- Creates a private internal network (single-host)
- External access is via port mappings on a host interface
- There is a default bridge network called **bridge**
- Can create user-defined bridge networks



Demo

BRIDGE

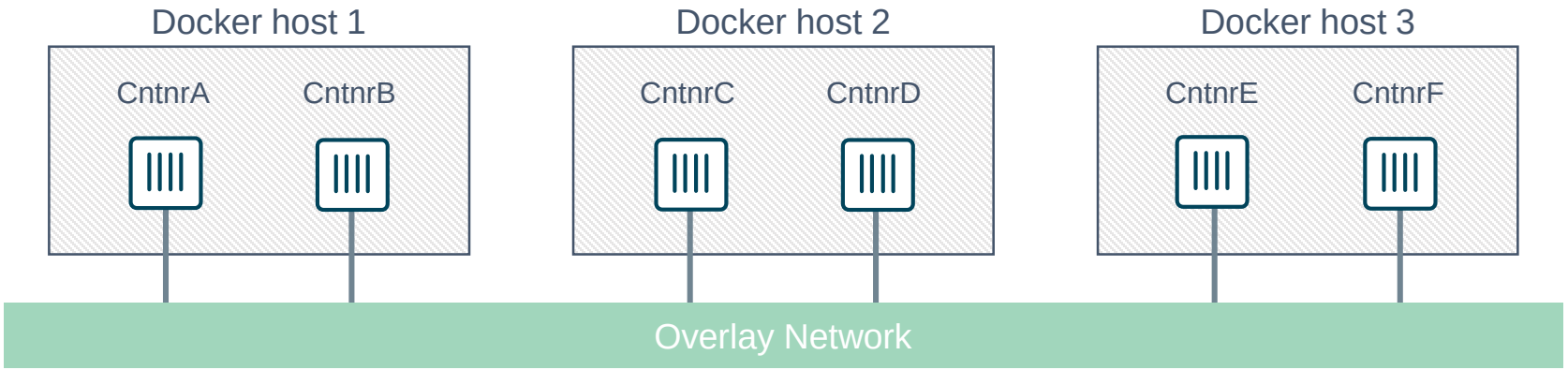
Q & A

Use Cases

MULTI-HOST NETWORKING WITH THE OVERLAY DRIVER (IN SWARM MODE)

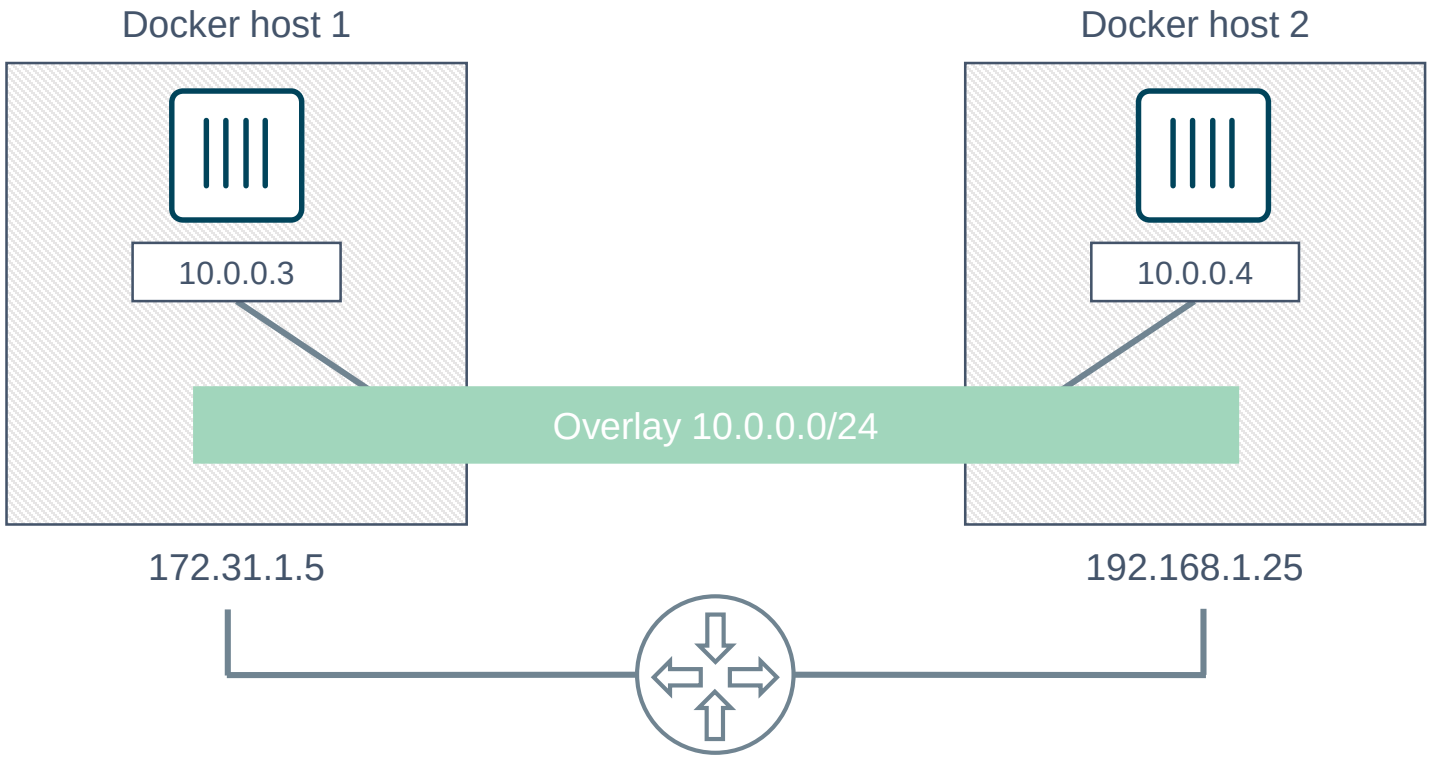
What is Docker Overlay Networking?

The **overlay** driver enables simple and secure **multi-host** networking



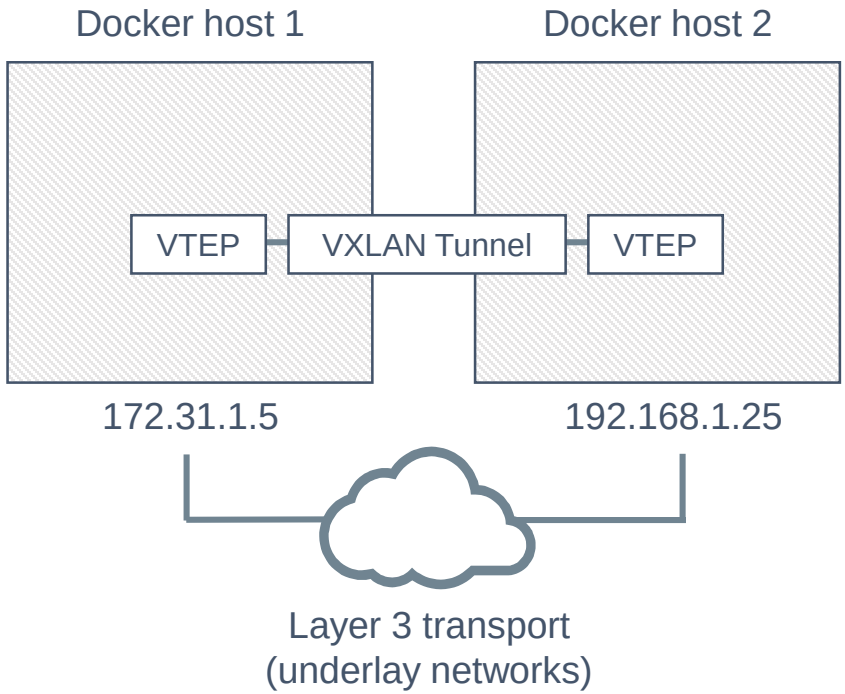
All containers on the **overlay** network can communicate!

Building an Overlay Network (High level)

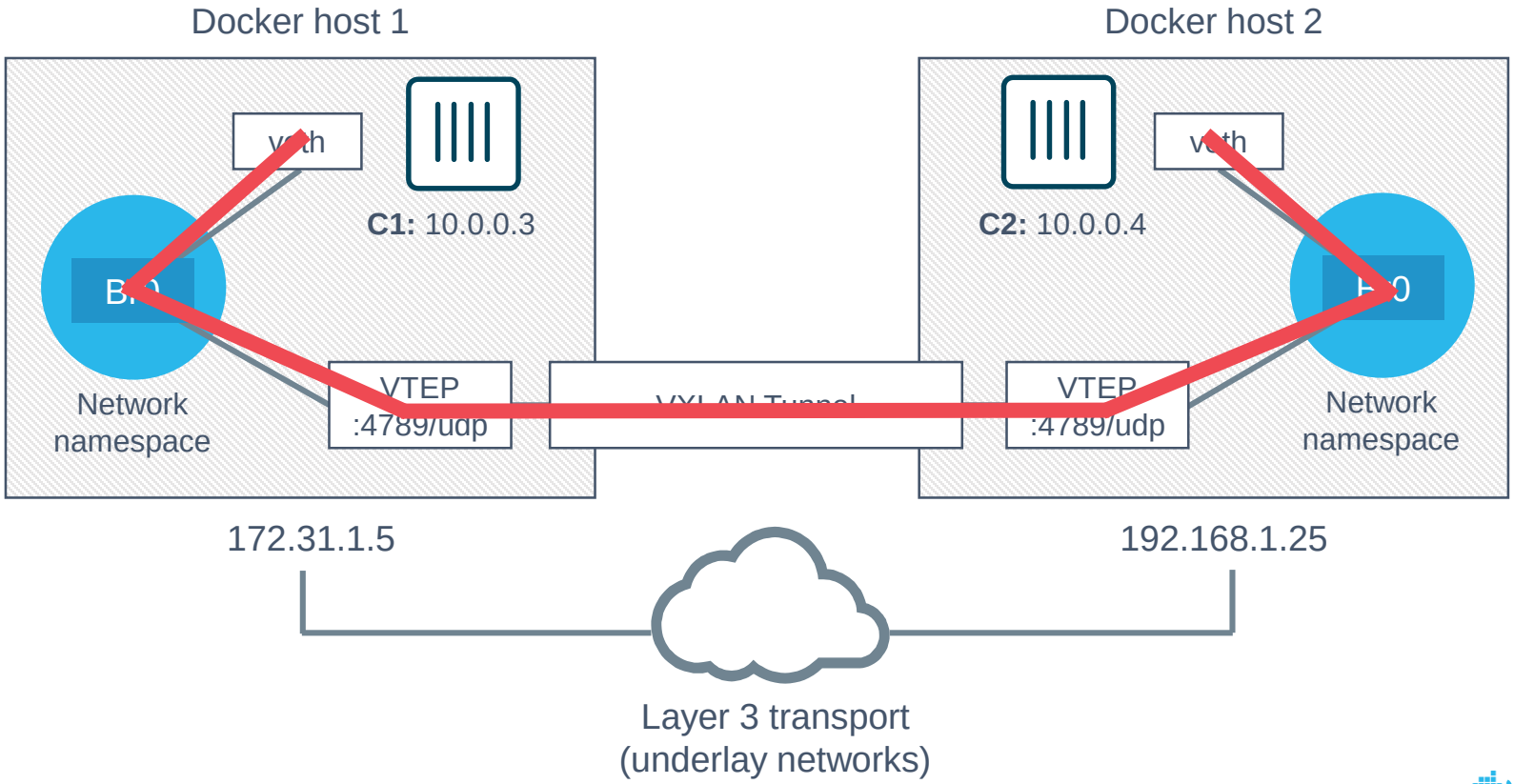


Docker Overlay Networks and VXLAN

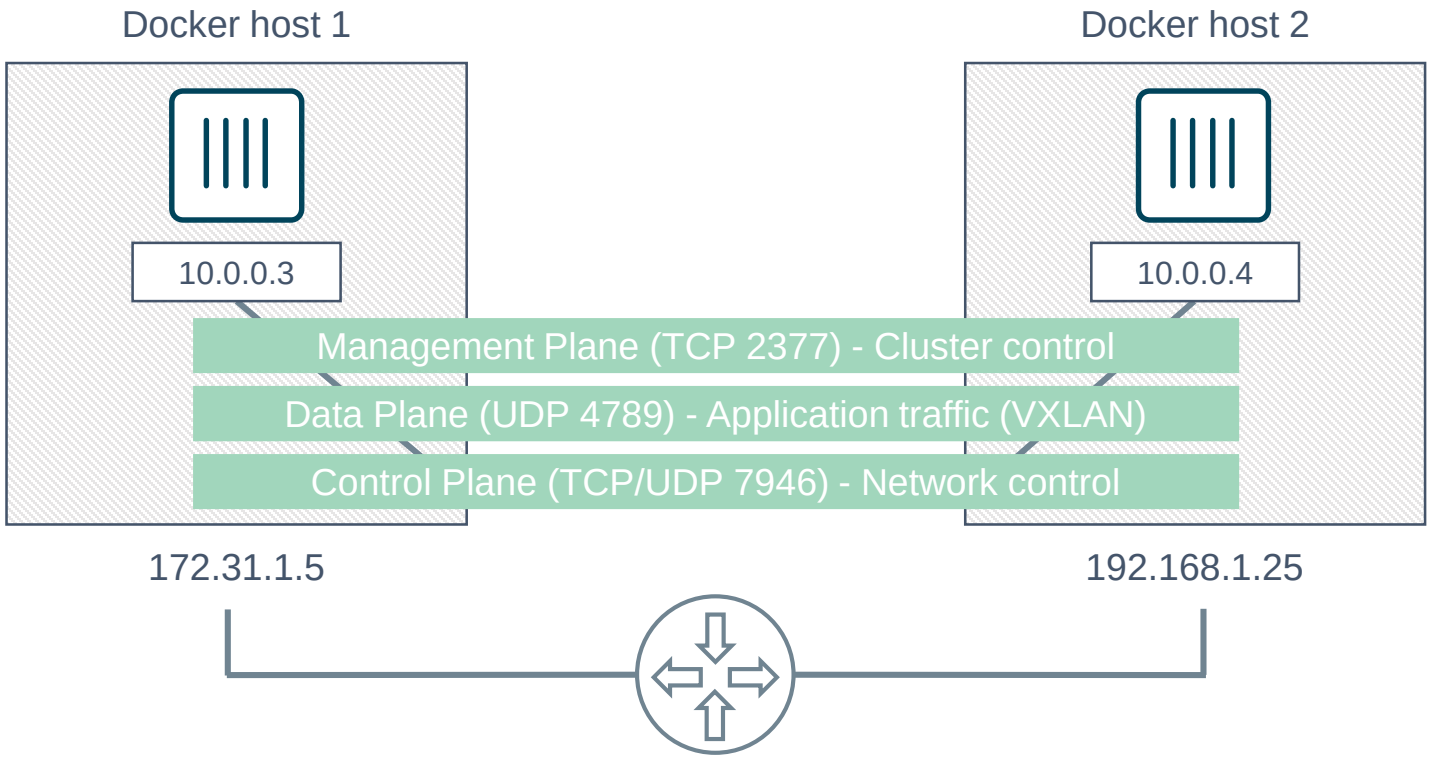
- The **overlay** driver uses VXLAN technology to build the network
- A **VXLAN tunnel** is created through the **underlay network(s)**
- At each end of the tunnel is a VXLAN tunnel end point (**VTEP**)
- The **VTEP** performs encapsulation and de-encapsulation
- The **VTEP** exists in the Docker Host's network namespace



Building an Overlay Network (more detailed)



Overlay Networking Ports



Overlay Networking Under the Hood

- Virtual eXtensible LAN **(VXLAN)** is the **data transport** (RFC7348)
- Creates a new L2 network over an L3 transport network
- Point-to-Multi-Point tunnels
- VXLAN Network ID (**VNID**) is used to map frames to VLANs
- Uses Proxy ARP
- Invisible to the container
- The **docker_gwbridge** virtual switch per host for default route
- Leverages the distributed KV store created by Swarm
- Control plane is encrypted by default
- Date plane can be encrypted if desired

Demo

OVERLAY

Q & A

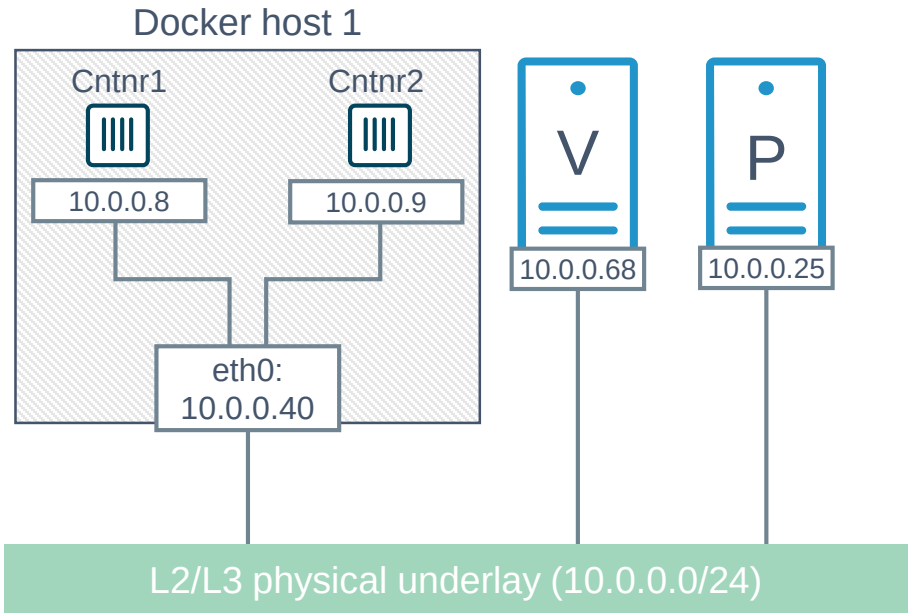
Break

Use Cases

CONNECTING TO EXISTING VLANS WITH THE MACVLAN DRIVER

What is MACVLAN?

- A way to attach containers to existing networks and VLANs
- Good for mixing containers with VMs and physical machines
- Ideal for apps that are not ready to be fully containerized
- Uses the well known MACVLAN Linux network type
- Nothing to do with Mac OS!



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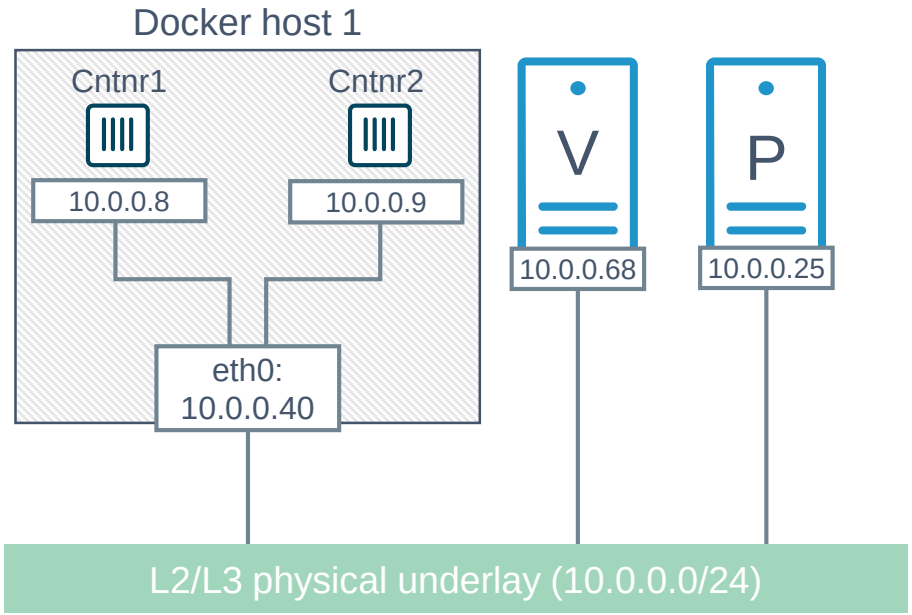

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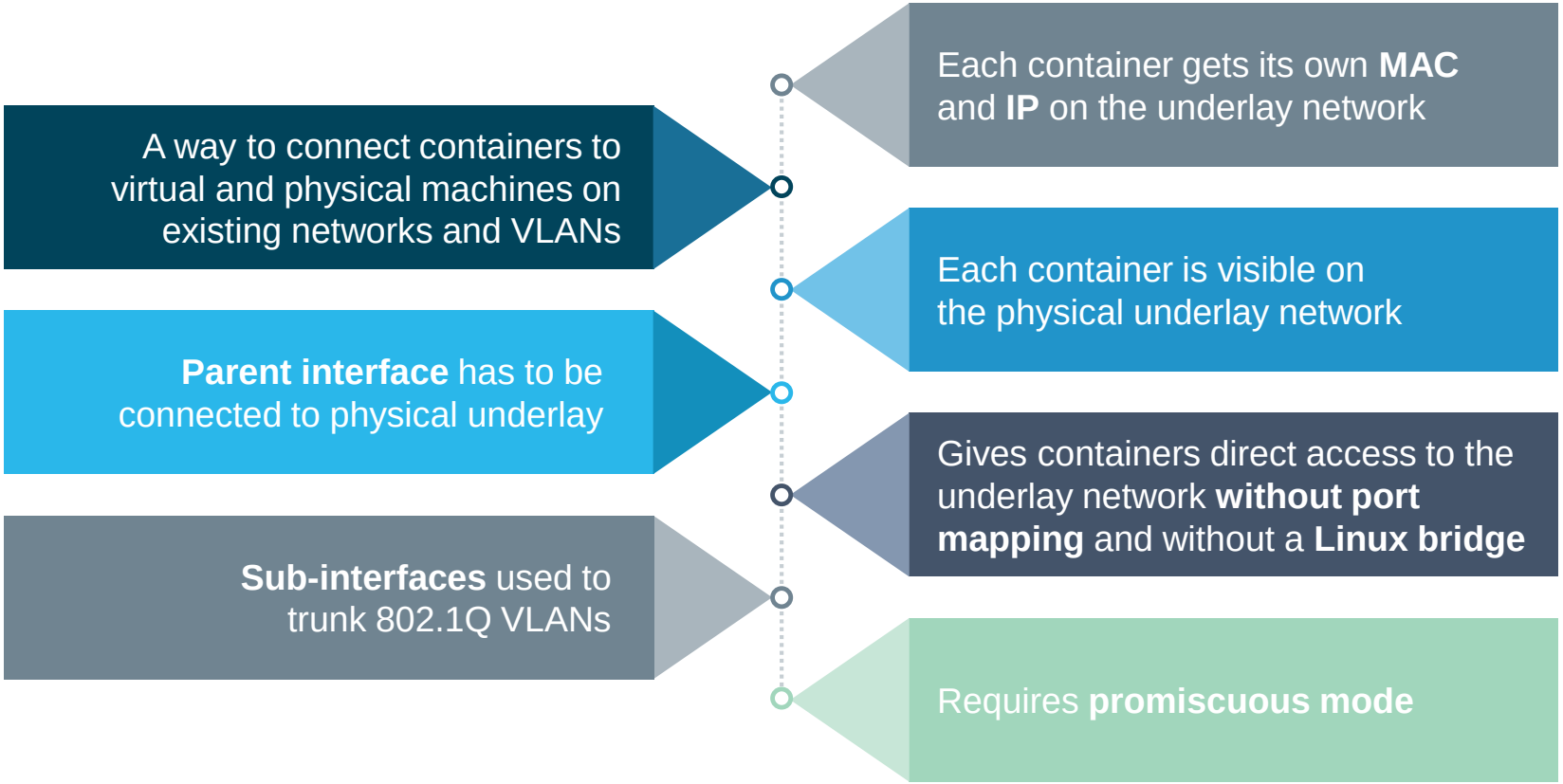
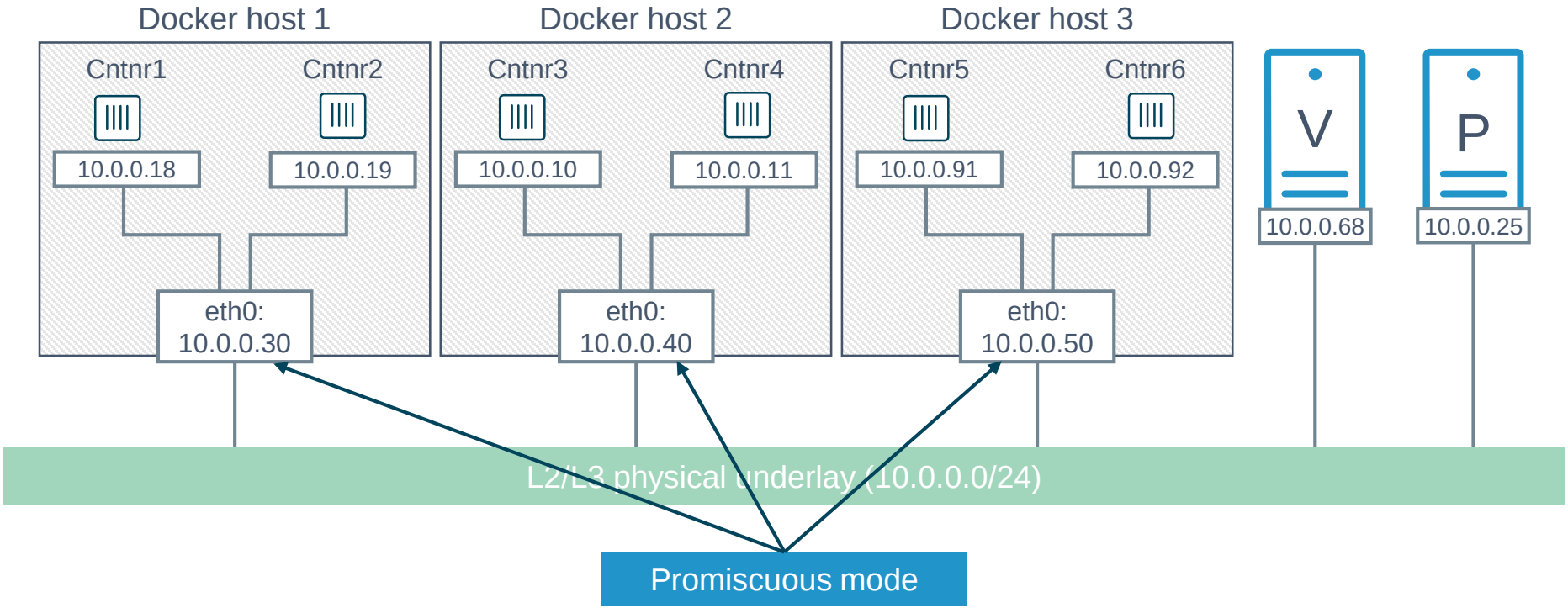
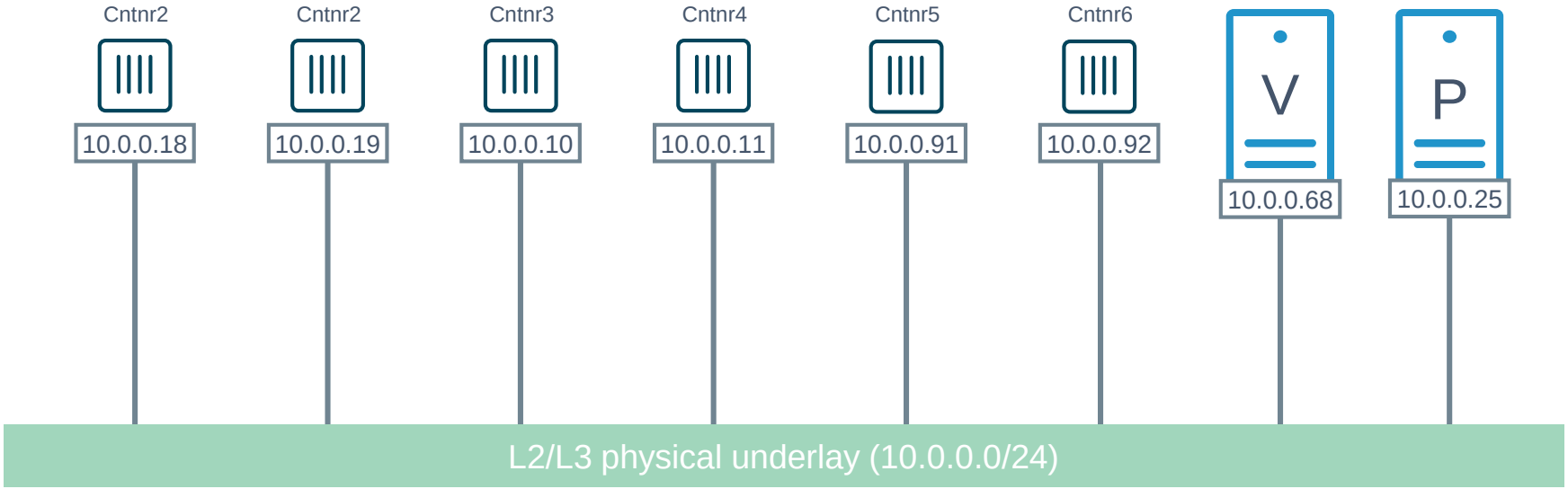


What is MACVLAN?



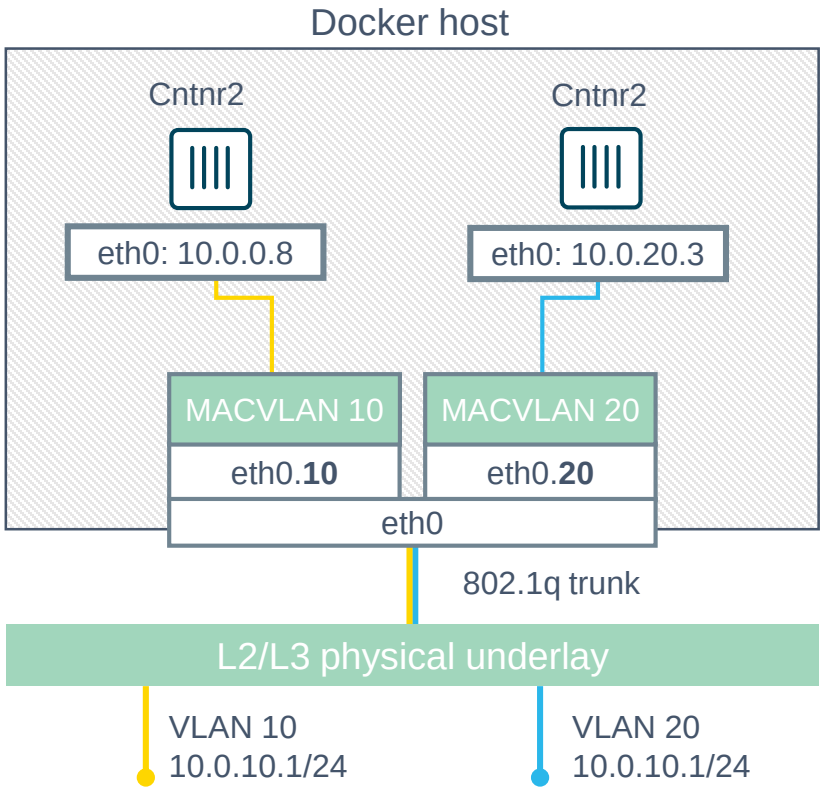
docker

What is MACVLAN?



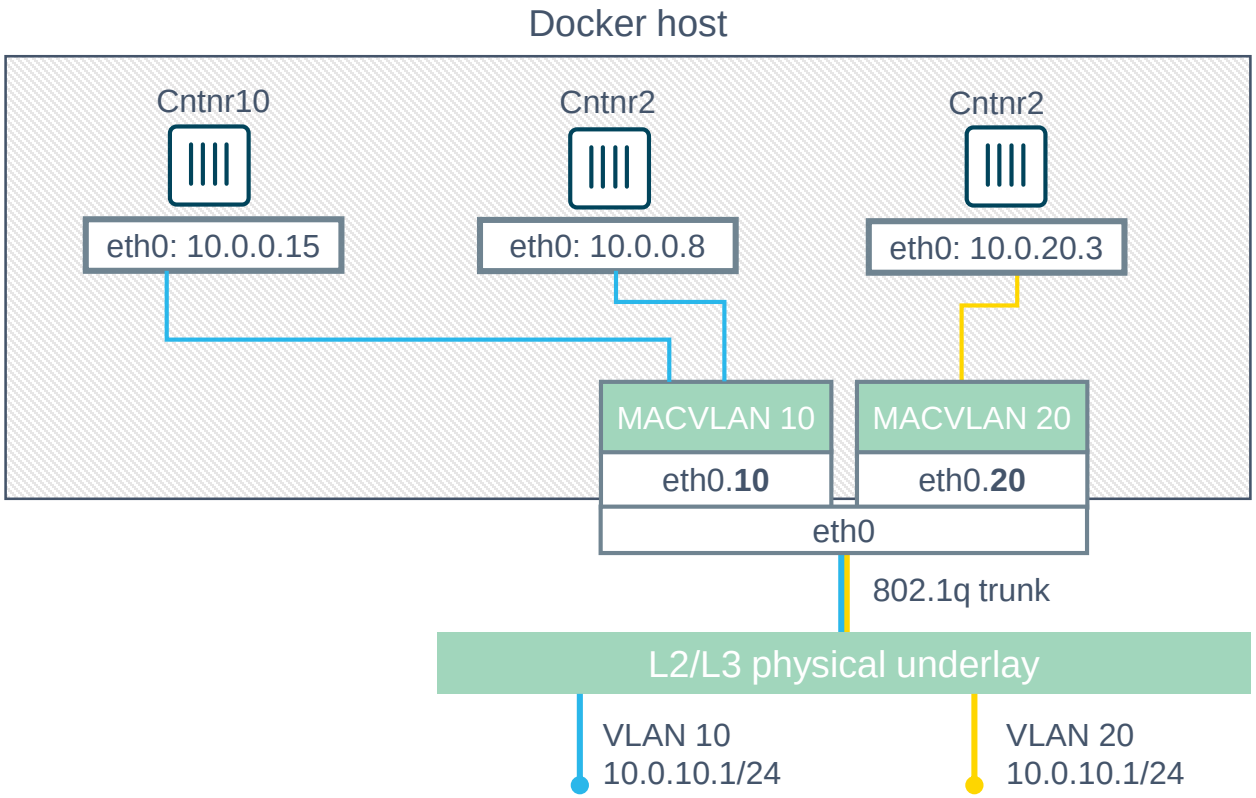
MACVLAN and Sub-interfaces

- MACVLAN uses **sub-interfaces** to process 802.1Q VLAN tags.
- In this example, two sub-interfaces are used to enable two separate VLANs
- Yellow lines represent VLAN 10
- Blue lines represent VLAN 20



docker

MACVLAN and Sub-interfaces



MACVLAN Modes

Bridged (default) switches packets inside the host

Private blocks traffic between two **MACVLAN interfaces** on the same host

VEPA requires a downstream switch that supports VEPA 802.1bg that will **hairpin** traffic back to the host if the if the destination is on the same host

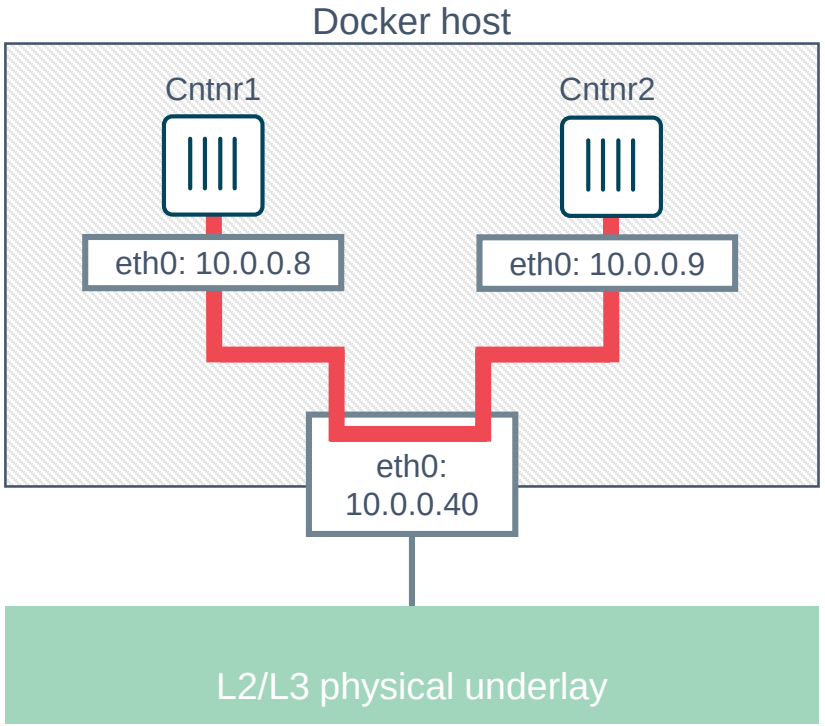
Passthru is similar to **private** but relies on an external switch not to hairpin the traffic back to the originating host

MACVLAN Modes

Bridged	Private	VEPA	Passthru
Bridged (default) switches packets inside the host	**Private** blocks traffic between two **MACVLAN interfaces** on the same host	**VEPA** requires a downstream switch that supports VEPA 802.1bg that will **hairpin** traffic back to the host if the if the destination is on the same host	**Passthru** is similar to **private** but relies on an external switch not to hairpin the traffic back to the originating host

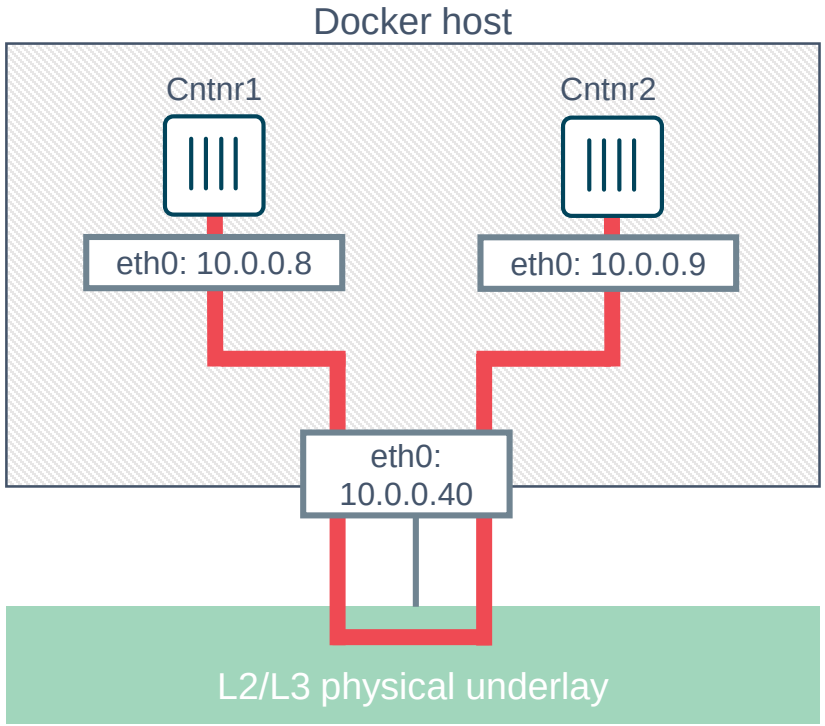
MACVLAN Modes in detail

- **Bridged**



MACVLAN Modes in detail

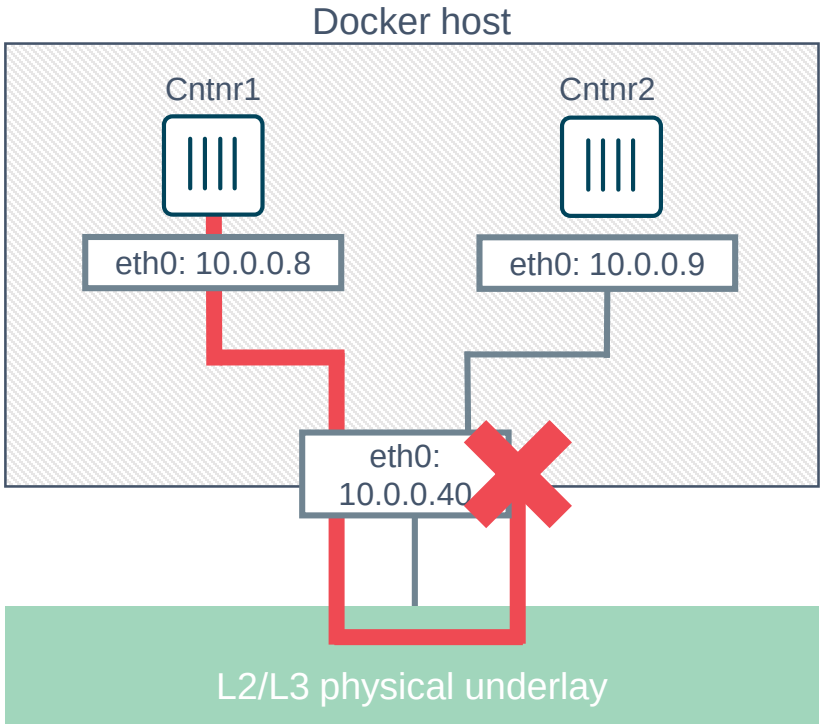
- Bridged
- **VEPA**



Requires a VEPA
802.1bg switch

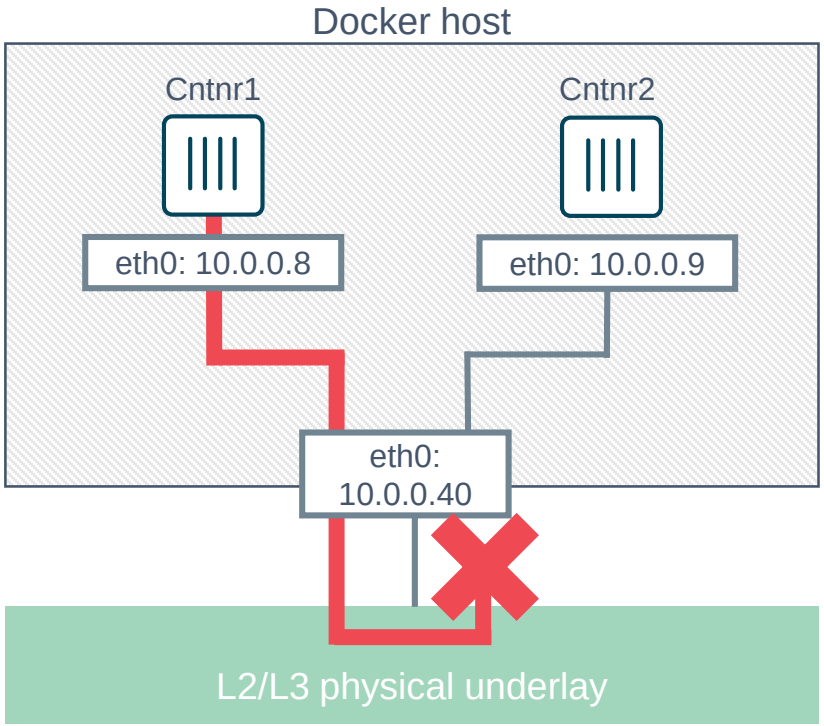
MACVLAN Modes in detail

- Bridged
- VEPA
- **Private**



MACVLAN Modes in detail

- Bridged
- VEPA
- Private
- **Passthru**



MACVLAN Summary

- Allow containers to be plumbed into existing VLANs
- Ideal for integrating containers with existing networks and apps
- High performance (no NAT or Linux bridge…)
- Every container gets its own **MAC** and **routable IP** on the physical underlay
- Uses **sub-interfaces** for 802.1q VLAN tagging
- Requires **promiscuous** mode!

Demo

MACVLAN

Q & A

Use Cases Summary

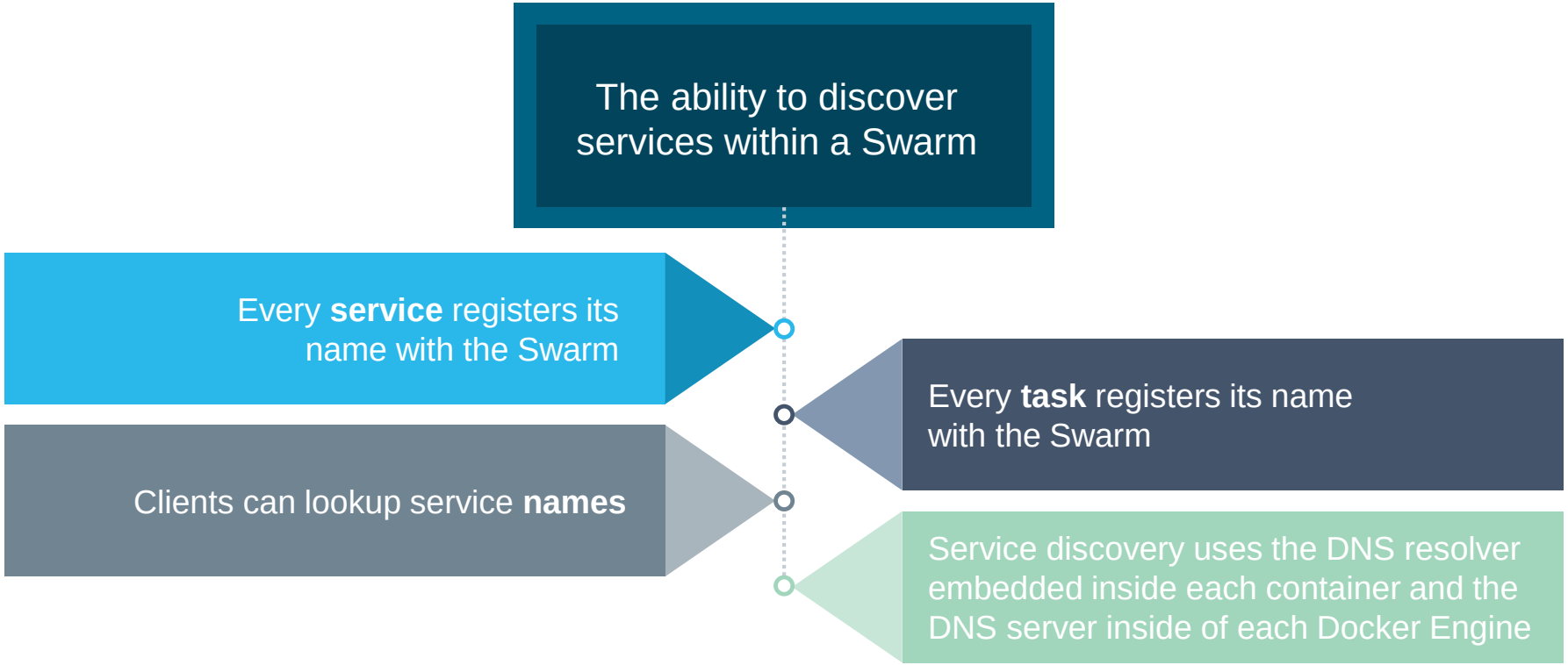
- The bridge driver provides simple single-host networking
  - Recommended to use another more specific driver such as overlay, **MACVLAN** etc…
- The overlay driver provides native out-of-the-box multi-host networking
- The MACVLAN driver allows containers to participate directly in existing networks and VLANs
  - Requires promiscuous mode
- Docker networking will continue to evolve and add more drivers and networking use-cases

Break

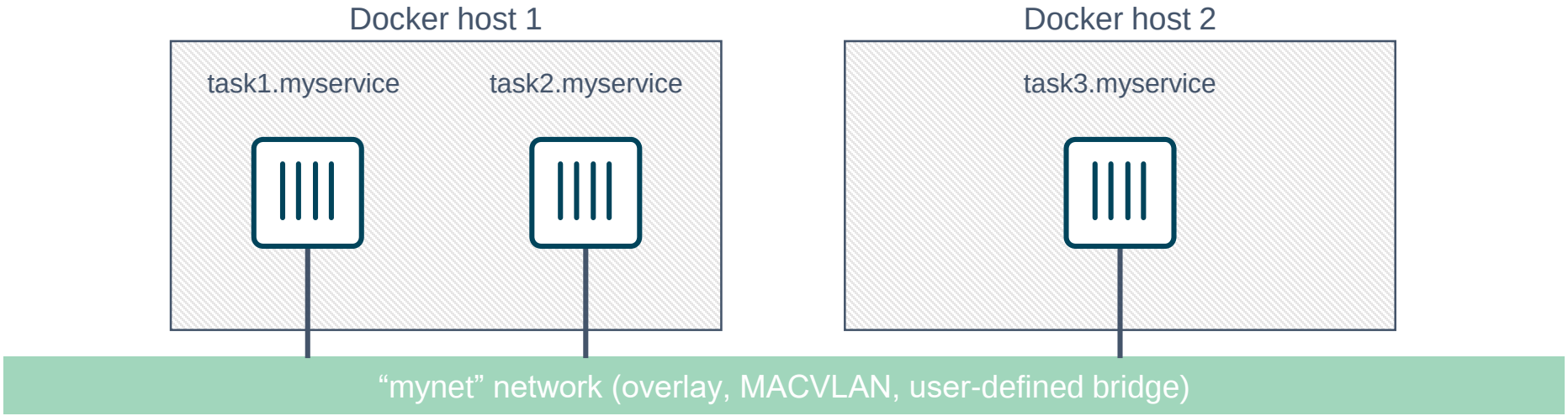
Service Discovery

SWARM MODE

What is Service Discovery?



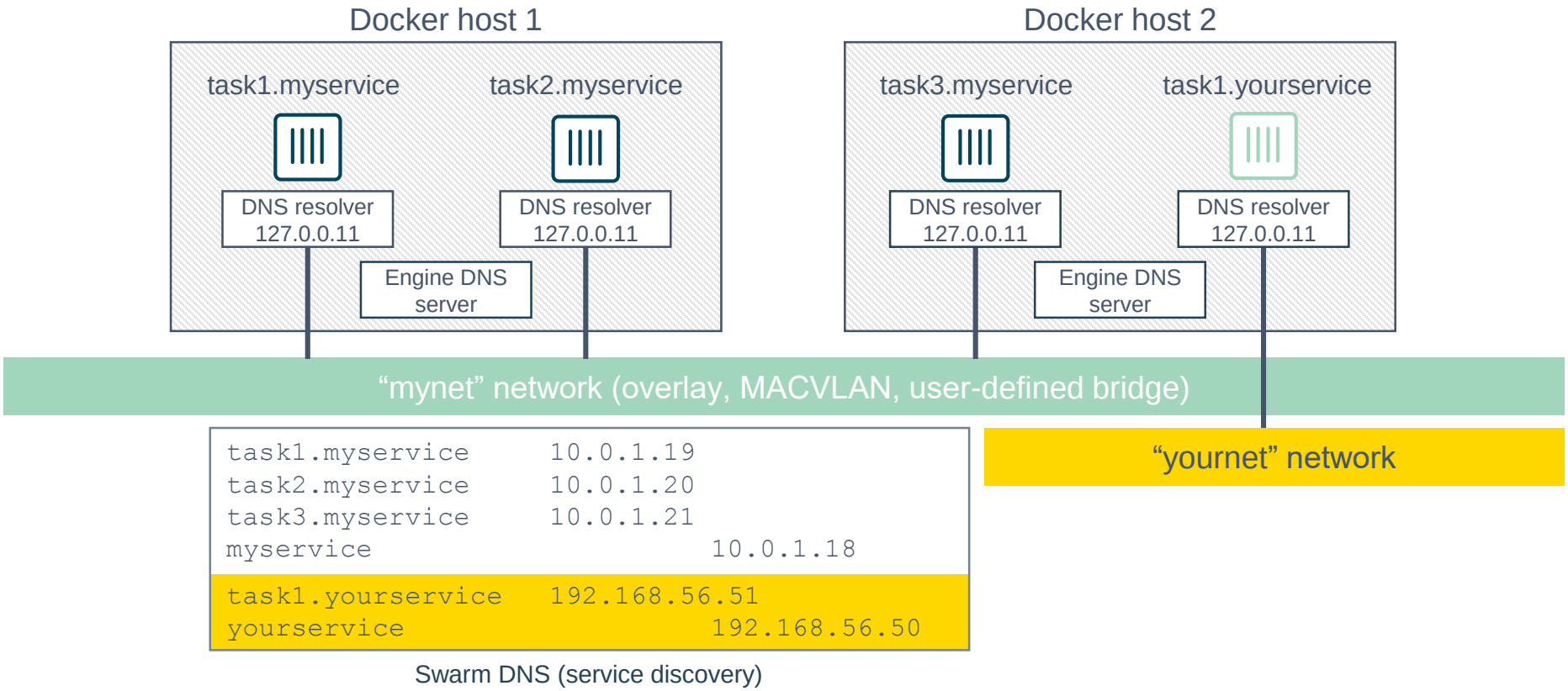
Service Discovery in a Bit More Detail




```
task1.myservice      10.0.1.19
task2.myservice      10.0.1.20
task3.myservice      10.0.1.21
myservice            10.0.1.18
```

Swarm DNS (service discovery)

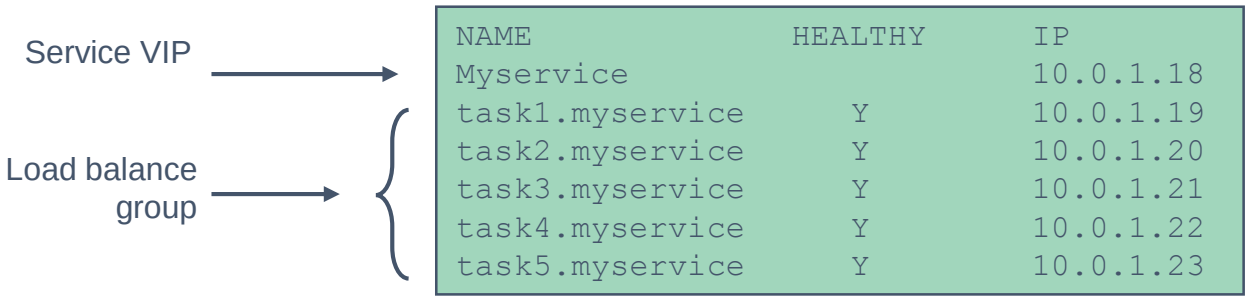
Service Discovery in a Bit More Detail



Swarm DNS (service discovery)

Service Virtual IP (VIP) Load Balancing

- Every **service** gets a **VIP** when it's created
  - This stays with the service for its entire life
- Lookups against the VIP get load-balanced across all **healthy tasks** in the service
- Behind the scenes it uses Linux kernel **IPVS** to perform transport layer load balancing
- `docker inspect <service>` (shows the service VIP)



Service Discovery Details

Service and task registration is automatic and dynamic

Name-IP-mappings stored in the Swarm KV store

Resolution is network-scoped

Container DNS and Docker Engine DNS used to resolve names

- Every container runs a local DNS resolver (127.0.0.1:53)
- Every Docker Engine runs a DNS service

Demo

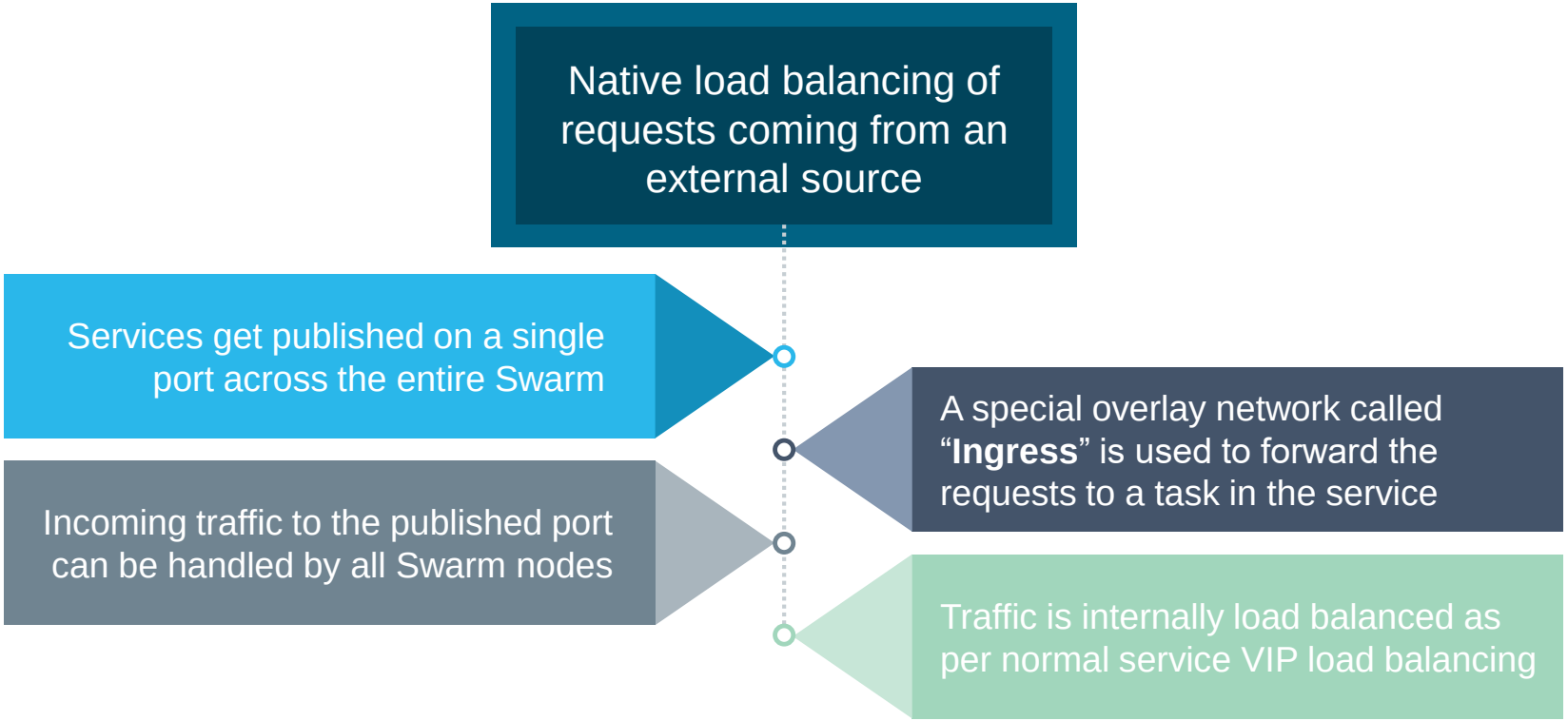
SERVICE DISCOVERY

Q & A

Load Balancing External Requests

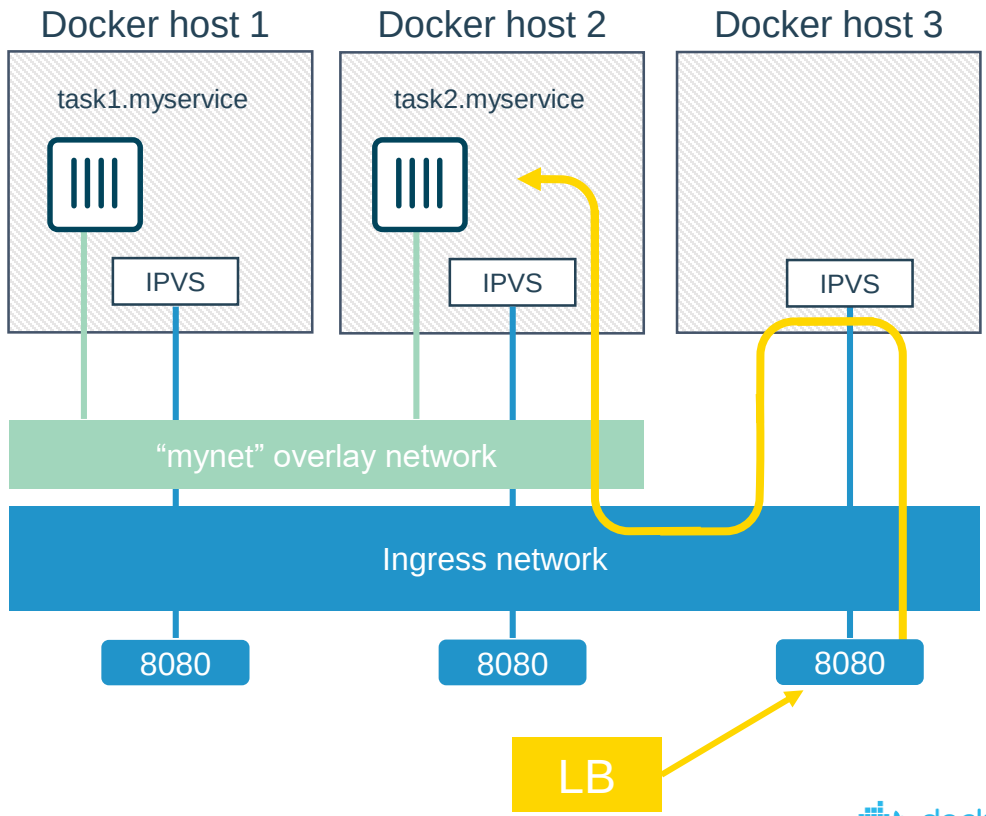
ROUTING MESH

What is the Routing Mesh?



Routing Mesh Example

1. Three Docker hosts
2. New service with 2 tasks
3. Connected to the **mynet** overlay network
4. Service published on port 8080 swarm-wide
5. External LB sends request to Docker host 3 on port 8080
6. Routing mesh forwards the request to a healthy task using the ingress network



docker

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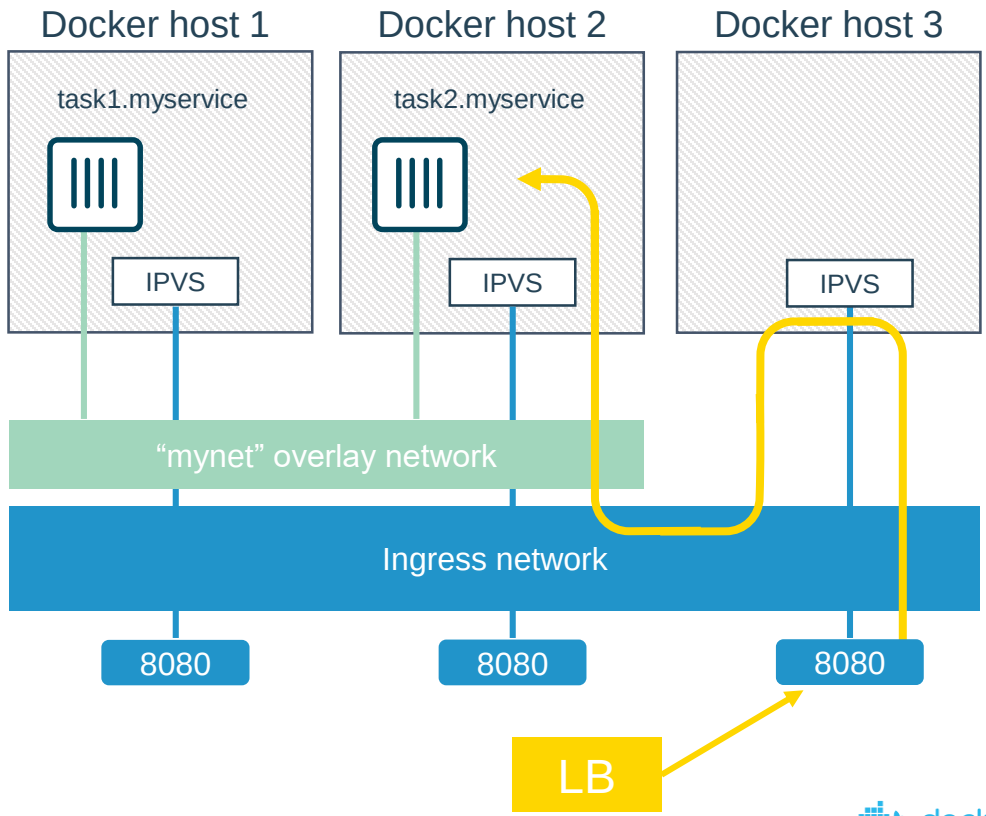
5. External LB sends request to Docker host 3 on port 8080
6. Routing mesh forwards the request to a healthy task using the ingress network



docker

Demo

ROUTING MESH

Q & A

Break

HTTP Routing Mesh (HRM) with Docker Datacenter

APPLICATION LAYER LOAD BALANCING (L7)

What is the HTTP Routing Mesh (HRM)?

Native **application layer (L7)** load balancing of requests coming from an external source

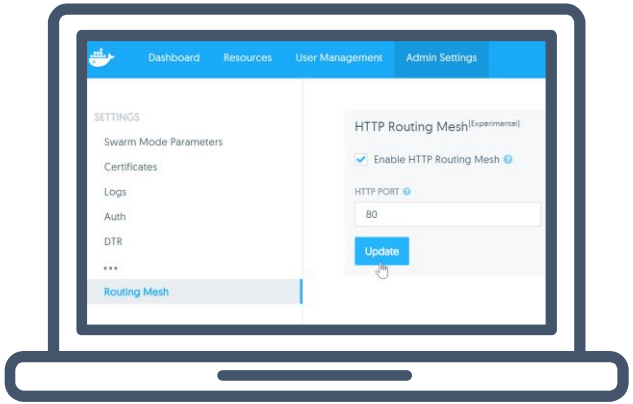
Load balances traffic based on hostnames from HTTP headers

Allows multiple services to be accessed via the same published port

Requires Docker Datacenter (DDC)

Builds on top of transport layer routing mesh

Enabling and Using the HTTP Routing Mesh




```
docker service create -p 8080 \
--network ucp-hrm \
--label
com.docker.ucp.mesh.http=8080=
http://foo.example.com \
...
```

1

Enable HTTP routing mesh in DDC

a) Creates **ucp-hrm** *network*

b) Creates **ucp-hrm** *service* and exposes it on a port (80 by default)

2

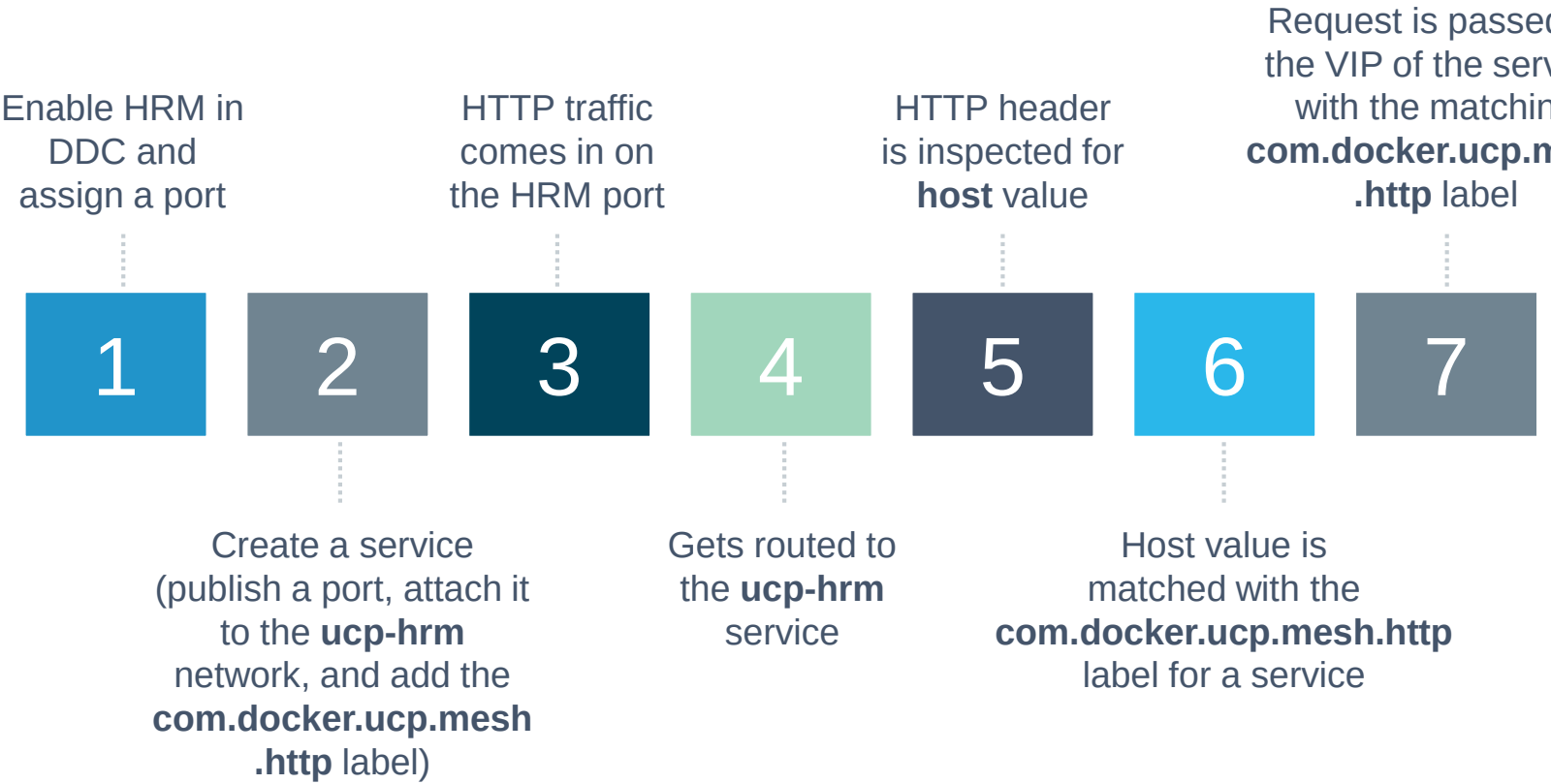
Create new service

a) Add to **ucp-hrm** network

b) Assign **label** specifying hostname
(links service to http://foo.example.com)

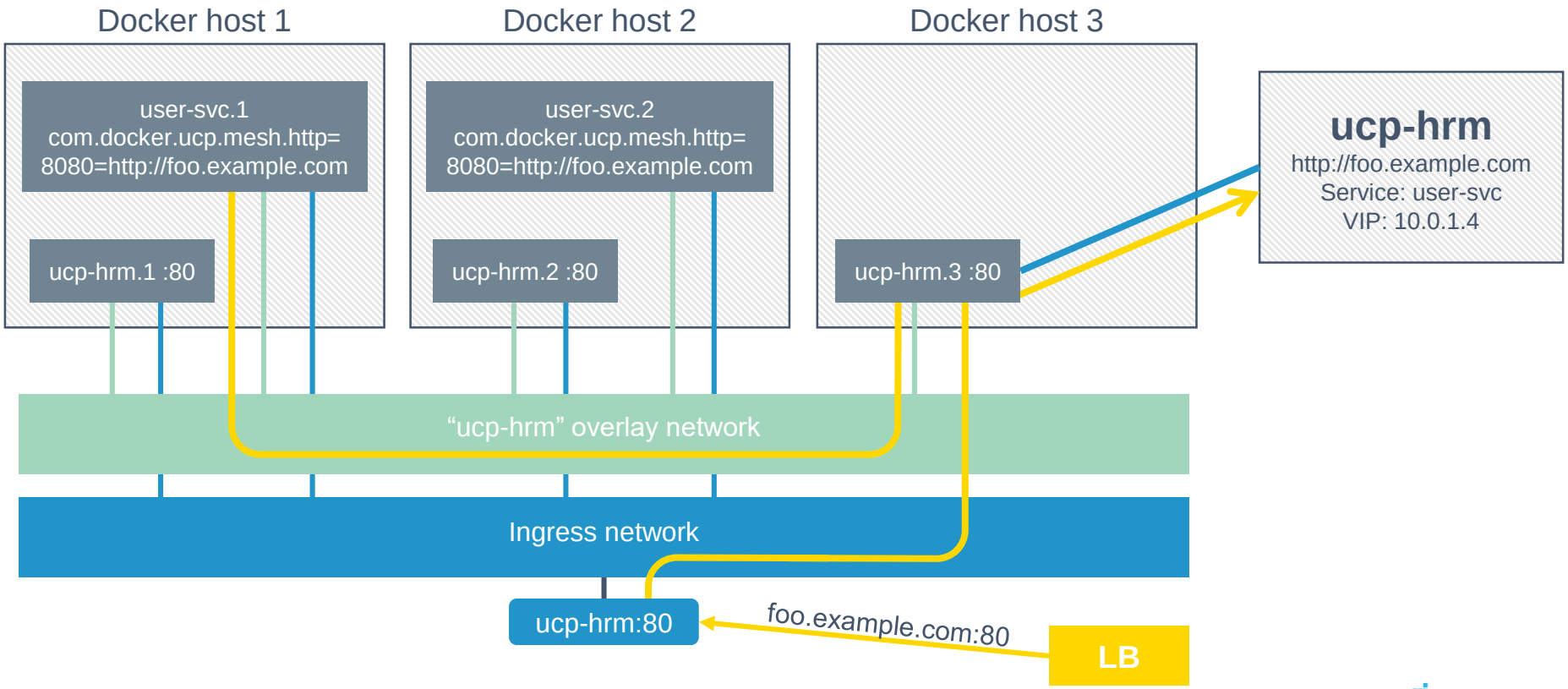
docker

HTTP Routing Mesh (HRM) Flow



docker

HTTP Routing Mesh Example



docker

Demo

HRM

Q & A

Docker Network Troubleshooting

Common Network Issues

Blocked ports, ports required to be open for network mgmt, control, and data plane

Iptables issues

Used extensively by Docker Networking, must not be turned off

List rules with $ iptables -S, $ iptables -S -t nat

Network state information stale or not being propagated

Destroy and create networks again with same name

General connectivity problems

General Connectivity Issues

Network always gets blamed first :(

Eliminate or prove connectivity first, connectivity can be broken at service discovery or network level

Service Discovery

Test service name resolution or container name resolution

`drill <service name> (returns the service VIP DNS record)`

`drill tasks.<service name> (returns all task DNS records)`

Network Layer

Test reachability using VIP or container IP

`task1$ nc -l 5000, task2$ nc <service ip> 5000`

`ping <container ip>`

Netshoot Tool

Has most of the tools you need **in a container** to troubleshoot common networking problems

```
iperf, tcpdump, netstat, iftop, drill, netcat-openbsd, iproute2, util-
linux(nsenter), bridge-utils, iputils, curl, ipvsadmin, ethtool…
```

Two Uses

Connect it to a specific **network namespace** (such as a container's) to view the network from that container's perspective

Connect it to a **docker network** to test connectivity on that network

Netshoot Tool

Connect to a container namespace

```
docker run -it --net container:<container_name> nicolaka/netshoot
```

Connect to a network

```
docker run -it --net host nicolaka/netshoot
```

Once inside the **netshoot** container, you can use any of the network troubleshooting tools that come with it

Network Troubleshooting Tools

Capture all traffic to/from port 999 on eth0 on a myservice container

```
docker run -it --net
container:myservice.1.0qlf1kaka0cq38gojf7wcatoa  nicolaka/netshoot
tcpdump -i eth0 port 9999 -c 1 -Xvv
```

See all network connections to a specific task in myservice

```
docker run -it --net
container:myservice.1.0qlf1kaka0cq38gojf7wcatoa  nicolaka/netshoot
netstat -taupn
```

Network Troubleshooting Tools

Test DNS service discovery from one service to another

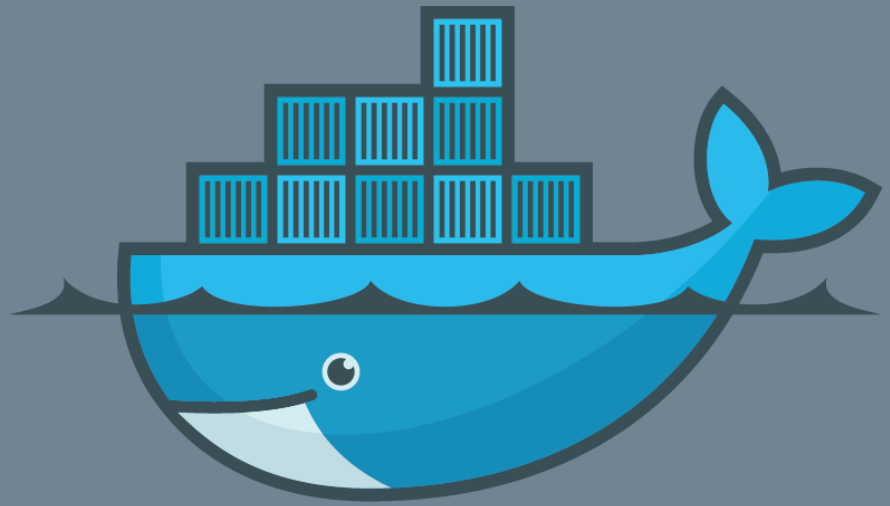
```
docker run -it --net
container:myservice.1.bil2mo8inj3r9nyrss1g15qav  nicolaka/netshoot drill
yourservice
```

Show host routing table from inside the netshoot container

```
docker run -it --net host nicolaka/netshoot ip route show
```

Break

Hands-on Exercises



THANK YOU