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# Implementing a Virtual Network System among Containers

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# Introduction

- Virtual machines are commonly used for **building and testing network system configurations** before getting deployed.
- Rise of **container technologies** has attracted attention from industry and academia as applications are moving to the cloud.
- There are many drawbacks in our usage for choosing **virtual machine**, and **container** is a good cure for those drawbacks. However, **no one has tried** to realize that using **Docker**.
- My paper investigates the possibility of implementing virtual network systems using **Docker containers** instead.

# Overview

# Network Drivers

- Docker employs a pluggable networking subsystem.
- Default drivers for Docker networking system include the **bridge, host, overlay, IPVLAN, MACVLAN, and none**.
- Possible candidates for implementing the virtual network system on one host machine are **bridge, IPVLAN, and MACVLAN**.
  - The **none** driver disables all networking.
  - The **host** driver shares the same network stack with the host.
  - The **overlay** driver creates a distributed network system among multiple Docker daemon hosts.

# MACVLAN

We choose **MACVLAN** finally:

**Table:** Network Drivers Comparison

| **Items** | **bridge** | **IPVLAN** | **MACVLAN** |
|---|---|---|---|
| **Resources** | High | Low | Lowest |
| **MAC Address** | Different | Same | Different |
| **VM Migration** | No | No | Yes |

- MACVLAN is a trivial bridge that does not need to learn as it already knows every **MAC address** it can receive.
- MACVLAN also supports **address configuration** and **discovery protocols**, as well as other **multicast protocols**.

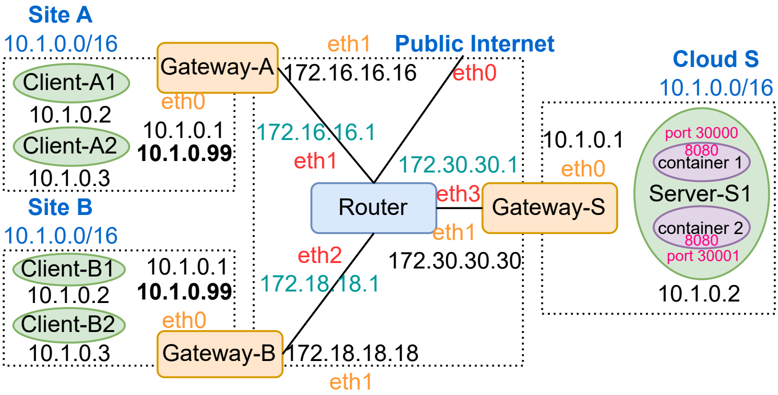
# Routing, Firewall and IPv6

- By default, Docker does not allow manipulating container network devices and setting routing tables or firewalls inside containers.
- However, **net_admin** capability in Linux allows us to:
  1. **Make interface configuration.**
  2. **Administrate IP firewall, masquerading, and accounting.**
  3. **Modify routing tables.**
  4. Bind to any address for transparent proxying.
  5. Set the type-of-service (TOS).
  6. Clear driver statistics.
  7. Set the promiscuous mode.
  8. Enable multicasting.
  9. Use setsockopt(2) to set several socket options.
- **IPv6** is also supported in Docker containers.

# VPN Overview

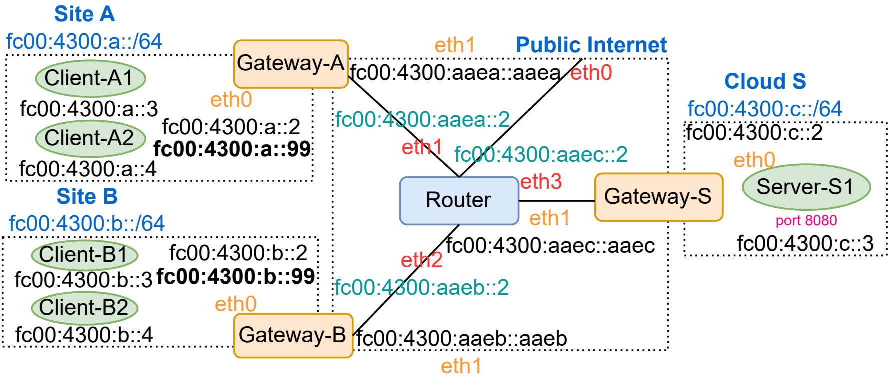
- Simulate IoT devices in **sites A, B** connect to server in **cloud S**.
  - **Site A, B**, and **cloud S** both use the private IP addresses to improve security and save the IPv4 addresses.
  - **Gateways A, B, S** connect **sites A, B, S** to the public Internet.
  - The **router** represents the Internet between the sites and cloud.
  - The address space between the **gateway** and **router** simulates public, routable IPv4 addresses, although they are all private.
  - **Site A, B**, and **cloud S** use the **router** to access the Internet.
- We experiment with 2 types of VPN using strongSwan (IPsec):
  1. **Site to Site**
  2. **Host to Host**

# Host to Host



Site A
10.1.0.0/16
Client-A1
10.1.0.2
Client-A2
10.1.0.3
Gateway-A
eth0
10.1.0.1
10.1.0.99
eth1
172.16.16.16
Public Internet
eth0
172.16.16.1
eth1
172.30.30.1
Router
eth3
eth2
eth1
172.30.30.30
172.18.18.1
Site B
10.1.0.0/16
Client-B1
10.1.0.2
Client-B2
10.1.0.3
10.1.0.1
10.1.0.99
eth0
Gateway-B
172.18.18.18
eth1
Gateway-S
10.1.0.1
eth0
Cloud S
10.1.0.0/16
port 30000
8080
container 1
Server-S1
container 2
8080
port 30001
10.1.0.2

# Site to Site in IPv6



# Usability and Portability

With **Docker Compose**, the Docker orchestration tool, containers **outperforms** VirtualBox-based Vagrant in many aspects:

**Table:** Functionalities Comparison

| **Items** | **Vagrant + VirtualBox** | **Docker Compose** |
|---|---|---|
| **Resources** | Heavy | Lightweight |
| **Kernel** | Own | Shared (Namespaces) |
| **Scalability** | Hard | Easy |
| **M1/M2 Support** | Limited | Fully |
| **Image Hub** | Unavailable | Available (Docker Hub) |
| **Seamless** | No | Yes |

# Performance

Table below shows the metrics for the performance evaluation:

**Table:** Performance Test Result in Average

| Solution | Boot Time[1] | Memory[2] |
|---|---|---|
| Docker Compose | 75 s | 278 MB |
| Vagrant + VirtualBox | 689 s | 4.5 GB |

The container based solution *reduces*:

1. **Fresh boot time**[1] by nearly *90%*
2. **Memory consumption**[2] by nearly *94%*

[1] Also include the running environment building time for the host platform

[2] Maximum value during the whole running process

# Security and Limitations

- We can’t visit the host network interfaces inside containers, and vice versa. The container network stacks are **isolated** from host.
- Limitations of the Docker networking model include:
  1. Disallowing to assign **overlapped IP address ranges** by Docker, even for network interfaces that won’t directly connected.
  2. Disallowing to assign **IP address ending in ".1"** by Docker, as these addresses are reserved by Docker for gateways or routers.
- However, we can always choose to configure the IP addresses manually inside containers to bypass these limitations.

# Conclusion

- **It's possible to have a virtual network system with Docker!**
- Containers are much more **lightweight** than virtual machines.
- As a mature virtualization technology, containers can **realize every functionality** we require for virtual network systems.
- Container is a suitable **replacement** for virtual machines if you want to migrate the virtual network systems away from VMs.
- Hope it can inspire researchers and engineers to migrate their network systems testing environment from VMs into containers.

# Thanks for listening!

## Any Questions?

**Figure:** Scan to get the case study implementation source code