VISUALIZING SECURITY BOUNDARIES IN DOCKER SWARM OVERLAY NETWORKS

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Introduction

Docker Swarm

- Mode for managing a cluster of docker nodes
- The Swarm keeps services running and distributes containers over the nodes
- Has a feature for overlay networks between containers

Docker Swarm overlay network

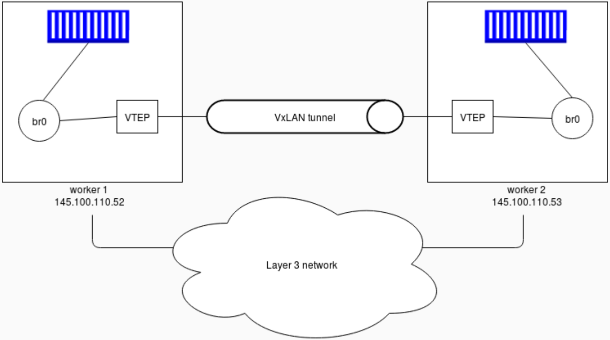
- VxLAN [1] based overlay networks. (Layer 2 over Layer 3)
- Containers can be connected to multiple Swarm overlay networks
- Networks are created from the manager nodes
- Serf used for mapping [2]

[1] https://tools.ietf.org/html/rfc7348

[2] https://github.com/docker/libnetwork/blob/master/drivers/overlay/ov_serf.go

VxLAN

- RFC 7348
- Layer 2 over layer 3
- 24 bits Virtual Network Identified (VNI)
- UDP port 4789



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    - Which security measures are there for Docker Swarm overlay networks and what can be done on the overlay network if a container or host gets compromised?
    - Which strategies are there to find out what gets exposed by containers and hosts in (overlay) networks?
    - Is it feasible to consolidate all the information about exposure and visualize it in a comprehensible way?

Related work

- Layer 2 attacks on a VxLAN overlay network, Author: G. Peneda, March 11, 2014
- Secure Virtual Network Configuration for Virtual Machine (VM) Protection Author: NIST, March 2016
- Docker swarm mode overlay network security model Author: Docker Project, 2017 [3]

[3] https://docs.docker.com/engine/userguide/networking/overlay-security-model/

Security measures for Swarm overlays

- Encryption possible: IPSEC tunnel
- Encryption for overlay network not used by default

What's possible?

- Tested: ARP spoofing, MAC flooding
    - Tested using: Arpspoof tool (Dsniff), Ettercap, Macof (Dsniff)
    - Using non-privileged containers and privileged containers
    - Monitored ARP tables and sniffed network traffic

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  - Monitored ARP tables and sniffed network traffic
  - Result: Not possible.

Why was that not possible?

```
root@manager1:~# ip netns exec 1—7x3gglxlba ip —d link show vxlan1
11: vxlan1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1450 qdisc noqueue master br0 state UNKNOWN mode
      DEFAULT group default
    link/ether 46:e6:48:5d:dd:92 brd ff:ff:ff:ff:ff:ff link—netnsid 0 promiscuity 1
    vxlan id 4097 srcport 0 0 dstport 4789 proxy l2miss l3miss ageing 300
```

Listing 1: Proxy ARP configured on VTEP

"In addition to a learning-based control plane, there are other schemes possible for the distribution of the VTEP IP to VM MAC mapping information"' [4]

FDB gets populated using a gossip protocol "Serf".

[4] https://tools.ietf.org/html/rfc7348#page-21

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    - Replay also works for an encrypted Swarm overlay network
- VNIs predictable: start at 4096
- UDP port 4789 (and tcp/udp 7946 for Serf)

Strategies for finding out what gets exposed

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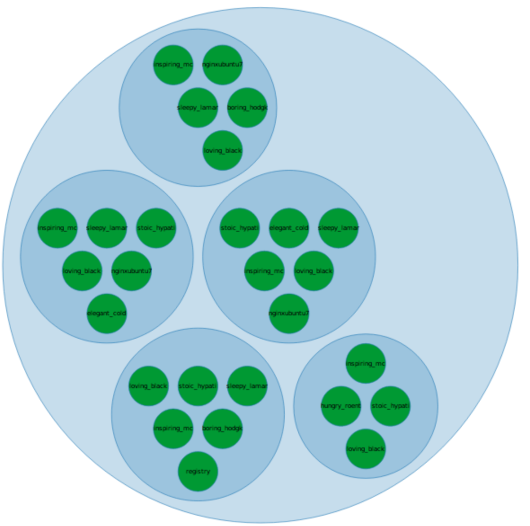
- Scan the network
  - Pro: One container that runs a scanner
  - Con: Should be connected to all overlay networks
  - Con: Scan can take a long time
- Have each host report netstat output and firewall status for the containers
  - Pro: Containers can not be overlooked
  - Pro: Can be relatively fast

Visualizing

- D3.js
- Visualizations in the browser
- Collected data using Swarm API and scripts on hosts

Visualizing



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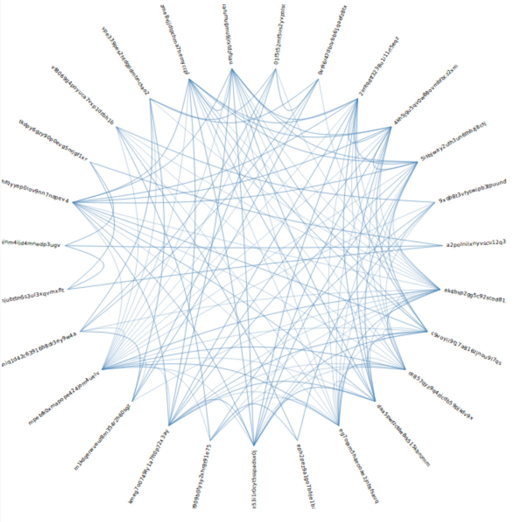

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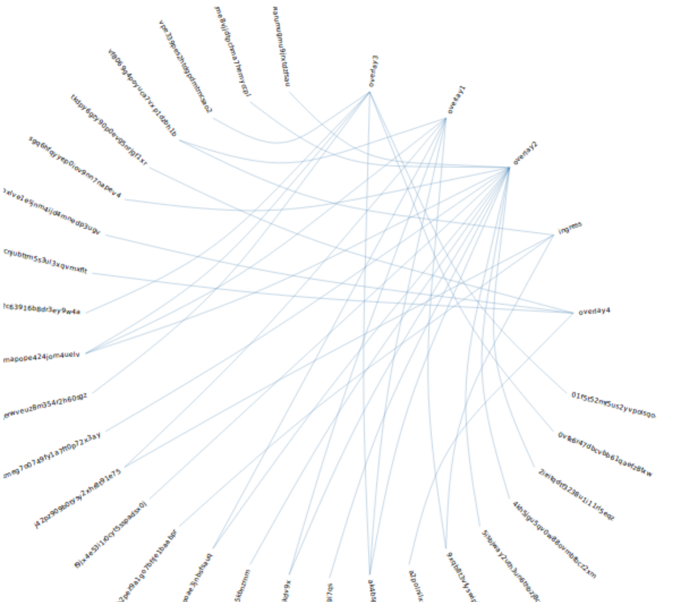

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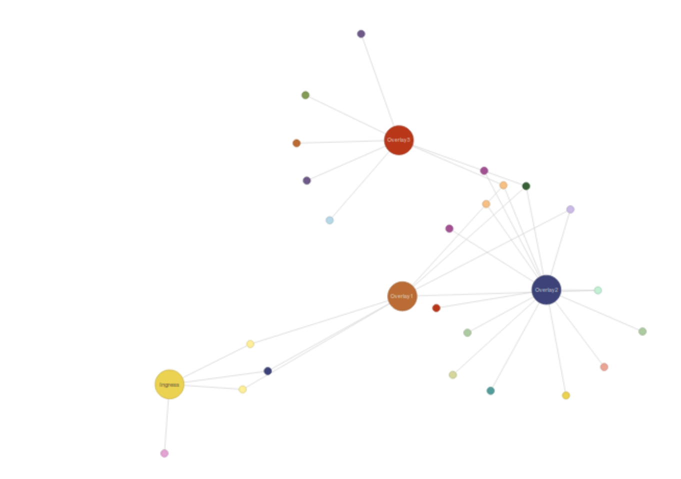

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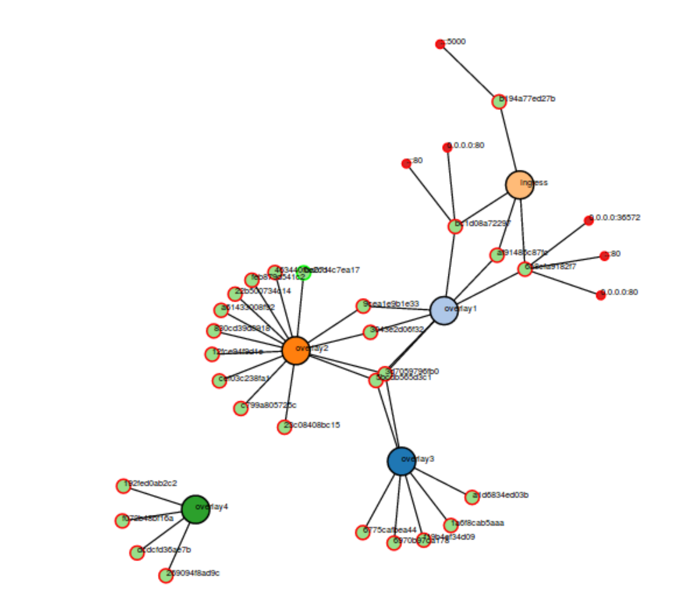

Visualizing

Demo

Conclusion

- Layer 2 attacks based on ARP injecting seems not possible on a Swarm overlay network
- It is possible to inject something in a Swarm overlay network when standard configuration is used
- Encrypted Swarm overlay traffic can be successfully replayed
- Creating visualizations of the Swarm overlay networks taking security boundaries into account is possible

Future work

- Research the mechanism that updates the mapping for the VTEPs
- Work on visualizations for single nodes showing more detail for firewall configuration

Questions?