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Kubernetes and the CNI: Where we are and What's Next

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Who am I?

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Outline

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Prologue

- What is CNI, actually?
    - It’s OK to be confused… it’s an overloaded term
- Why is it the way it is?

Quick poll

Have you run:

```
ip netns (add|exec|delete)
```

What is CNI?

CNI is at least three different things:

1. A vendor-neutral protocol
   - Used by container runtimes to make request to networking providers
   - Not just for kubernetes!
2. A set of commonly used network plugins maintained by the community
3. A “kubelet network plugin”
   - E.g. “`--network-plugin=cni`” on the command line

How does it work with Kubernetes?

1. You write a configuration file
2. You put some binaries on disk
3. You create a pod
4. Kubelet executes the binaries
   - And passes the configuration file on stdin
5. Your pod is online!

Why is it designed the way it is?

or: Why isn't it a gRPC + daemon, like every other Kubernetes plugin?

CNI came out of rkt, a daemonless container runtime.
Rkt focuses on clean integration points.

Aside: network namespaces

Also, managing network namespaces in long-running Go processes is **unreliable!**

This was only fixed in go v1.10

No choice, you have to use subprocesses.

Outline

0: Prologue

1: How CNI is typically used.

2: Best practices for operators.

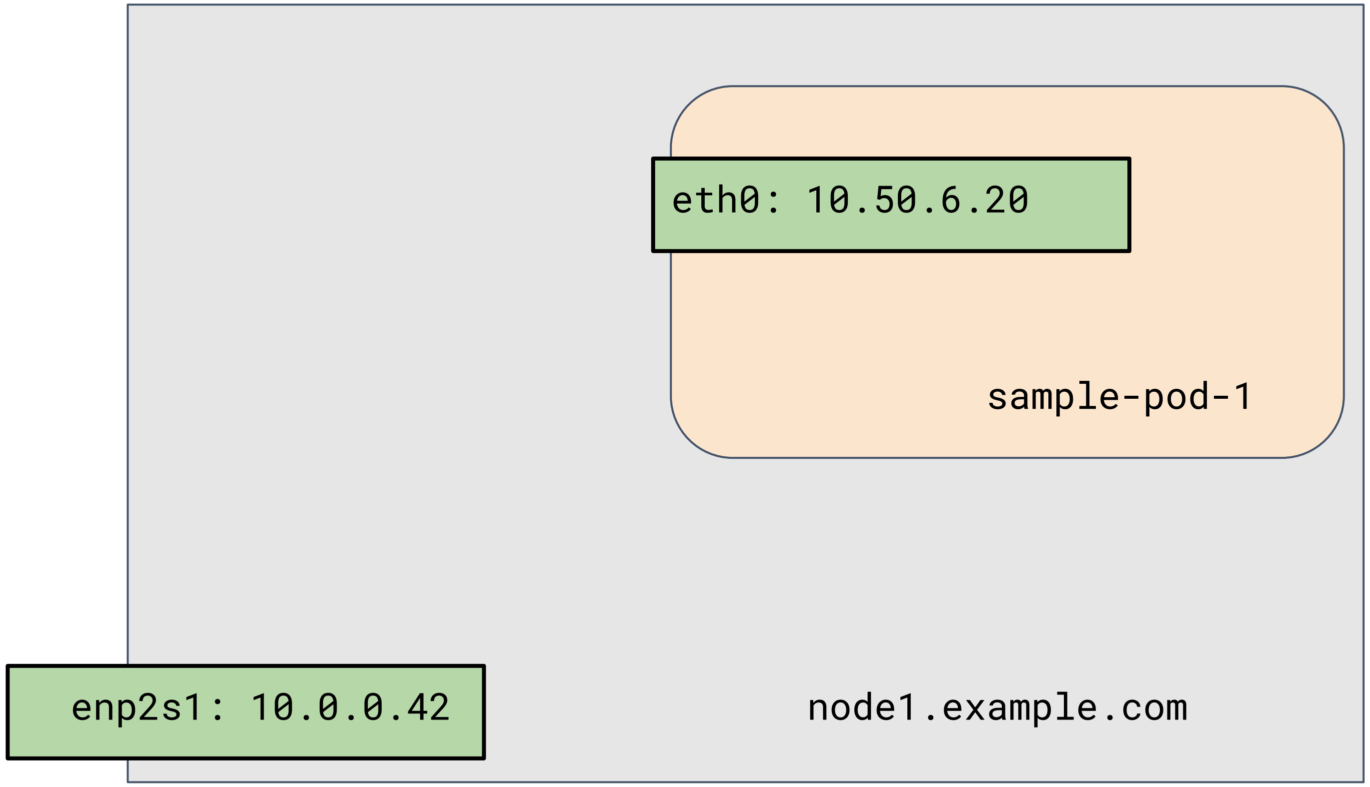
3: Best practices for plugin development.

4: What’s next?

How is CNI used?

```
apiVersion: v1
kind: Node
…
status:
  addresses:
    - type: InternalIP
      address: 10.0.0.42
spec:
  podCIDR: 10.50.6.0/24
```

```
apiVersion: v1
kind: Pod
…
status:
  hostIP: 10.0.0.42
  podIP: 10.50.6.20
```



Some terminology

We have a node

- The node has a single network interface.
- The node has an address pool called the PodCIDR
- There is an API object that reflects this

The node has pods

- Each pod has a network interface always called eth0
- The interface has a single IP. The api object reflects this IP.

What is CNI doing?

When a pod is added to a node, a CNI plugin is called on to do 3 basic things:

1. Create `eth0` inside the pod's network namespace
   - In other words, connect the pod - somehow - to the network
2. Allocate the PodIP
   - Usually from the PodCIDR
3. Make this PodIP reachable by the whole cluster

What is CNI doing?

The CNI plugins must provide:

1. **Connectivity**
2. **Reachability**

Why plugins?

Connectivity might depend on

- Network interface hardware
- Isolation technology
- Performance requirements

Reachability depends on

- Networking hardware
  - Can you touch them?
  - Are they in "the cloud?"
- Router "interfaces"
  - BGP?
  - OSPF?
  - REST?
- Performance requirements

Reachability

Traditional environments:

- Nodes have long, predictable lifetimes
- Addressing is manual and topology-aware
- One interface = one IP

Kubernetes:

- Topology unaware
- Allocates hundreds of IPs per node
- Lifetimes are short; churn is constant

How is CNI used?

How do CNI plugins work?

How do CNI plugins work

CNI plugins for kubernetes typically have two components:

1. A CNI binary that configures the pod’s interface.
2. A daemon that manages routing.

Connectivity

Most CNI plugins provide connectivity in the same way:

1. Create a “veth” pair
   - Veth is a point-to-point virtual tunnel
2. Move one end of the pair in to the container’s namespace
3. Configure an ip and route in the container’s namespace

Packets leaving the container are simply routed through the host’s IP stack. They are usually masqueraded.

Connectivity

Play along at home: https://lwn.net/Articles/580893/

Namespaces in operation, by Jake Edge

(`ip netns`) is a container runtime...

Reachability

Goal: make every PodCIDR reachable from every Node

Reframe: Announce dynamic routes to some peers.

Sound familiar?

Essentially all CNI plugins for Kubernetes include a daemon that:

- Runs on every host
- Programs the network with learned routes

Reachability

Programming the network takes many forms:

- Overlay networks (e.g. Flannel, Weave, Calico)
  - Don’t program your routers, program every node’s route table
- Cloud provider APIs (cp-azure, Flannel)
  - Watch your resource limits!
- Routing protocols (Calico, Romana)
  - PodCIDRs are now fully reachable!

Reachability

Why two components? Why can’t we use the binary?

CNI only has two methods: Add Container and Delete Container

- Route lifecycle is per-node

Most networks require a long-running process:

- Overlay networks need to watch **all nodes**
- Routing protocols require persistent sessions
- Deletion is always hard

Outline

Best Practices: Configuration

Kubelet learns which CNI plugin to use from a CNI configuration file.

How do you tell it where this configuration file is?

```
--cni-network? --cni-configuration?
```

Best Practices: Configuration

Answer: You don’t!

The kubelet scans `--cni-conf-dir` every 5 seconds and uses whichever one has the lowest-ordered filename.

It keeps scanning and parsing forever.

Best practice: Only ever write one CNI configuration file to disk.

Best Practices: Configuration

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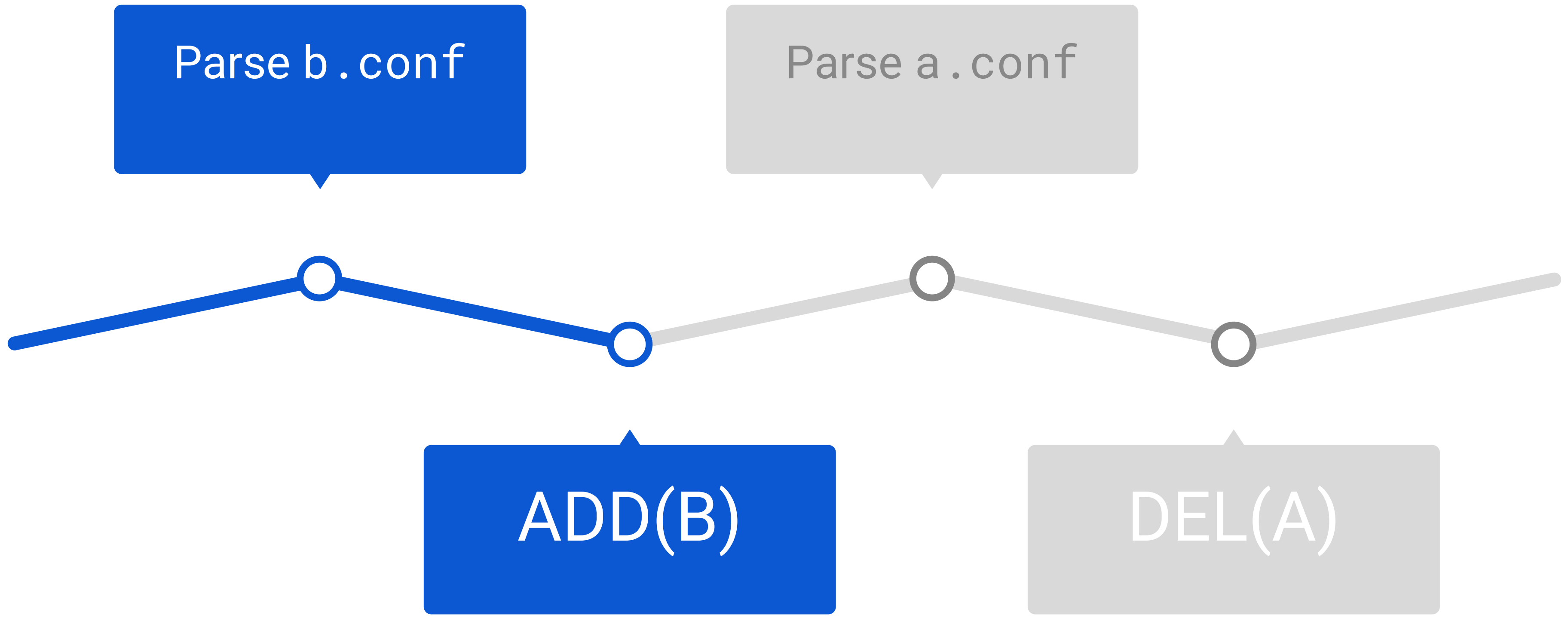

Best Practices: Configuration

CNI now supports plugin chaining.

This is a powerful tool for the operator to adjust their network.

Current chained plugins:

- Set up host-port forwarding
- Tweak sysctl parameters
- Bandwidth limits

```
{ “cniVersion:” “0.3.1”,
  “name": “myNetwork”,
  “plugins”: [
    { “type”: “ptp” },
    { “type”: “iptables-allow”},
    { “type”: “tuning”,
      “sysctl”: {
        “net.core.somaxconn”: “9001”
      }
    }
  ]
}
```

Best Practices: Self-hosting

Deploy your plugins using kubernetes!

A manifest for a CNI plugin should:

1. Set up the routing daemon
2. Copy the plugin binaries to the host
3. Install the configuration file

Installing the configuration file tells the host that the network is up.
Do it last.

Best Practices: Self-hosting

Some important things to get right:

- Run in host network
- Ignore all taints
  - So we can run on master!
- Use magic grace period
  - Narrows the window between running daemons

```
spec:
  hostNetwork: true
  tolerations:
    - effect: NoSchedule
      operator: Exists
    - effect: NoExecute:
      operator: Exists
  terminationGracePeriodSeconds: 0
```

Best Practices: Disaster Recovery

Self-hosted control-planes need to be careful here.

- Always run your APIServer in host networking
- Make sure your daemonset will start up without any other running services

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3: Best practices for plugin development.

4: What’s next?

1: Understand the kubelet lifecycle

- The kubelet doesn’t run pods, it runs sandboxes
- Sandbox and Pod lifecycle are only loosely coupled
- Expect the unexpected

You know that:

- A pod that runs will have at least one sandbox created
- You will see at most one ADD request per sandbox

1. Understand the kubelet lifecycle

You **can’t assume** that you will see a DELETE...

- A comfortable amount of time after the sandbox is deleted
- Before the node is rebooted
- Before 1000 crashlooping sandboxes are created and immediately stopped and you run out of IPs
- Before the node catches on fire / is launched into space

Be prepared to GC resources externally where necessary.

Use /run to store state if it makes sense.

1. Understand the kubelet lifecycle

The kubelet **does** guarantee that:

You will see exactly one ADD request for each CNI_CONTAINERID.

(In this case, CNI_CONTAINERID $\mapsto$ SandboxID)

1. Understand the kubelet lifecycle

This has caused real-world bugs.

You **will** see “out-of-order” requests if you use the PodID “A” as a key:

ADD A1

A1 Crash!

ADD A2

(time passes)

DELETE A1

A2 Offline!

2. Understand the Host Network

Kubernetes generally expects that all packets traverse the host.

Let’s look at some of the implications of this.

2. Understand the Host Network

Most plugins will do most of their work in the host's namespace

1. Duplicating functionality in every pod is a waste
    - Especially of iptables rules and conntrack entries
2. HostNetwork pods should be (mostly) equivalent
3. Programming the pod's namespace could be a leak or security issue

2. Understand the host network

A lot of pod-facing functionality is usually implemented on the host-side:

1. Kube-proxy (ServiceIP, NodePort)
    - Uses iptables or ipvs to do DNAT
2. Most NetworkPolicy provders
3. Traffic shaping
4. Overlay networks

2. Understand the Host Network

If you're willing to re-implement this, or give some of it up, you can choose to have packets go directly on the wire.

E.g. macvlan, SR-IOV, etc.

As always, you can trade clean abstractions for speed.

3. Be wary of hairpin

Hairpin is any time a packet goes back to its destination.

CNI plugins must handle two cases.

1. Pod A -> Service -> Pod B on same host
2. Pod A -> Service -> Pod A

3. Be wary of hairpin

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A lot of production plugins didn’t handle case 2… mine included.

In general, the solution is to

1. Masquerade the source address (to the host’s) (sigh)
2. Configure your bridge to allow hairpin.

Be sure you have a test case for this!

4. Use Capability args

The kubelet will fill in some dynamic configuration. This means you can reduce your dependency on the apiserver.

Current capabilities:

- Host port mappings

Future capabilities:

- PodCIDR
- Bandwidth limits

4. Use Capability args

```
{ “name”: “mynet”,
  “type”: “example”,
  “capabilities”: {
    “portMappings”:
true,
  }
}
```

```
{ “name”: “mynet”,
  “type”: “example”,
  “runtimeConfig”: {
    “portMappings”: [
      {“hostPort”: ... }
    ]
  }
}
```

5. Use Plugin Chaining

CNI configurations can include multiple plugins in a row.

Useful for common post-set-up tweaking.

(NOT multiple interfaces)

- Port-forwarding
- Iptables-allow
- Firewalld-allow
- Sysctl tweaking

5. Plugin Chaining

```
{ “cniVersion:” “0.3.1”,
  “name": “myNetwork”,
  “plugins”: [
    { “type”: “ptp” },
    { “type”: “iptables-allow”},
    { “type”: “tuning”,
      “sysctl”: {
        “net.core.somaxconn”: “9001”
      }
    }
  ]
}
```

```
{ “cniVersion:” “0.3.1”,
  “name": “myNetwork”,
  “type”: “iptables-allow”,
  “prevResult”: {
    “interfaces”: [
      {“name”: “veth1023”},
      {“name”: “eth0”}
    “ips”: [
      { “address”: “10.0.56.1”,
        “interface”: 0
      { “address”: “10.0.56.42”,
        “interface:” 1}
    ]
  }
}
```

5. Use Plugin Chaining

For ADD:

- Plugins are executed first to last.
- The output of the previous plugin is passed to the next
- The last result is passed back to the kubelet.

For DELETE:

- Plugins are run in reverse order
- The “last” plugins don’t know the IP addresses
  - Can be difficult to know what to tear down
- Being fixed in spec 0.4.0

5. Use Plugin Chaining

If your plugin **only** touches the host-side, it could easily be a chained plugin.

Using plugin chaining allows administrators to swap out “connectivity” plugins.

Enables diverse workloads, e.g. VMs.

Outline

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What’s Next? CNI v0.4.0

CNI Spec 0.4.0 (2018 Q2) will include:

- A new GET verb
    - Lots of corner cases, come see me after class.
- Result caching
    - To pass in to GET and DELETE
- More capability args

What’s Next? CNI v1.0

CNI Spec 1.0 will include:

- RFC-style spec
- Acceptance tests

What’s Next? IPv6

Kubernetes 1.9 includes alpha IPv6 support.

CNI has supported IPv6 for years.

Dual-stack support is desired but still has some unsolved design issues:

- The Pod Object has one IP
- Services expect 1:1 IP mapping

What’s Next? Multi-network

Attaching multiple network interfaces to a pod.

Use cases:

- Direct-on-wire interfaces
- VRF / non-uniform routing
- Special interfaces, e.g. infiniband

What’s Next? Multi-network

Lots to figure out:

- Will pods always have the “default” network?
  - Yes
- How are additional interfaces exposed? Services?
  - No, need to use the APIServer
  - This might change
- What about security?
  - Not on the plan for now
- What about hairpin?
  - Good question!

What’s Next? Device Plugins

There is a desire to combine device plugins and CNI / multi-network.

- Device plugin allocates a device
- Device plugin manages schedulable resources
- CNI plugin initializes the network and hands it to the pod

Currently in design.

What’s Next?

That’s up to you!

CNI is an active specification, and welcomes community involvement. Kubernetes’ use of the CNI has lots of room to grow.

Thanks!

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