Kubernetes and networks v5

Why is this so dang hard?

Tim Hockin
@thockin

What does “network model” mean?

Kubernetes clusters are made up of nodes

- Machines - virtual or physical

Those nodes exist on some network

Pods run on those nodes

Pods get IP addresses

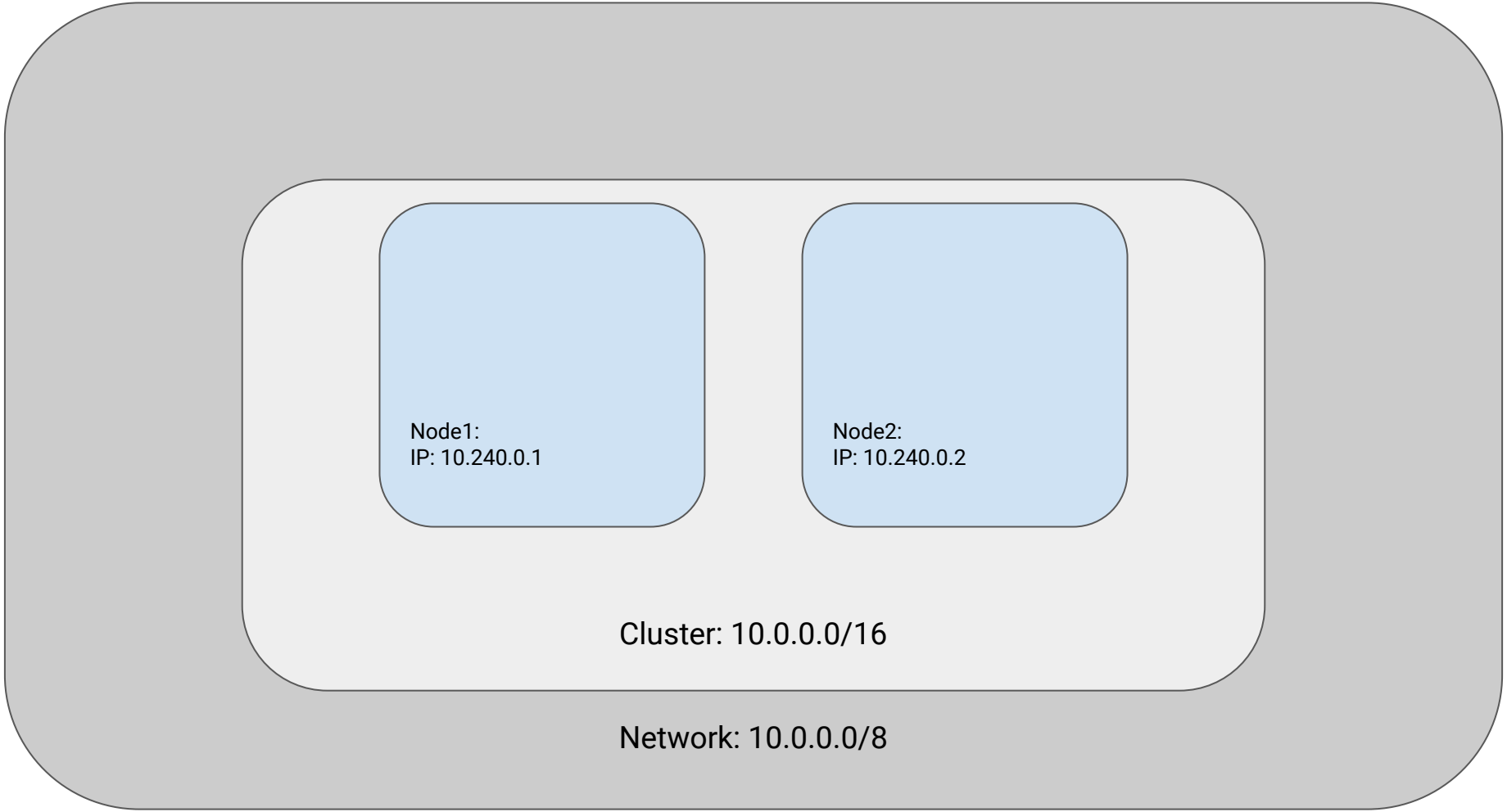
“Network model” describes how those pod IPs integrate with the larger network

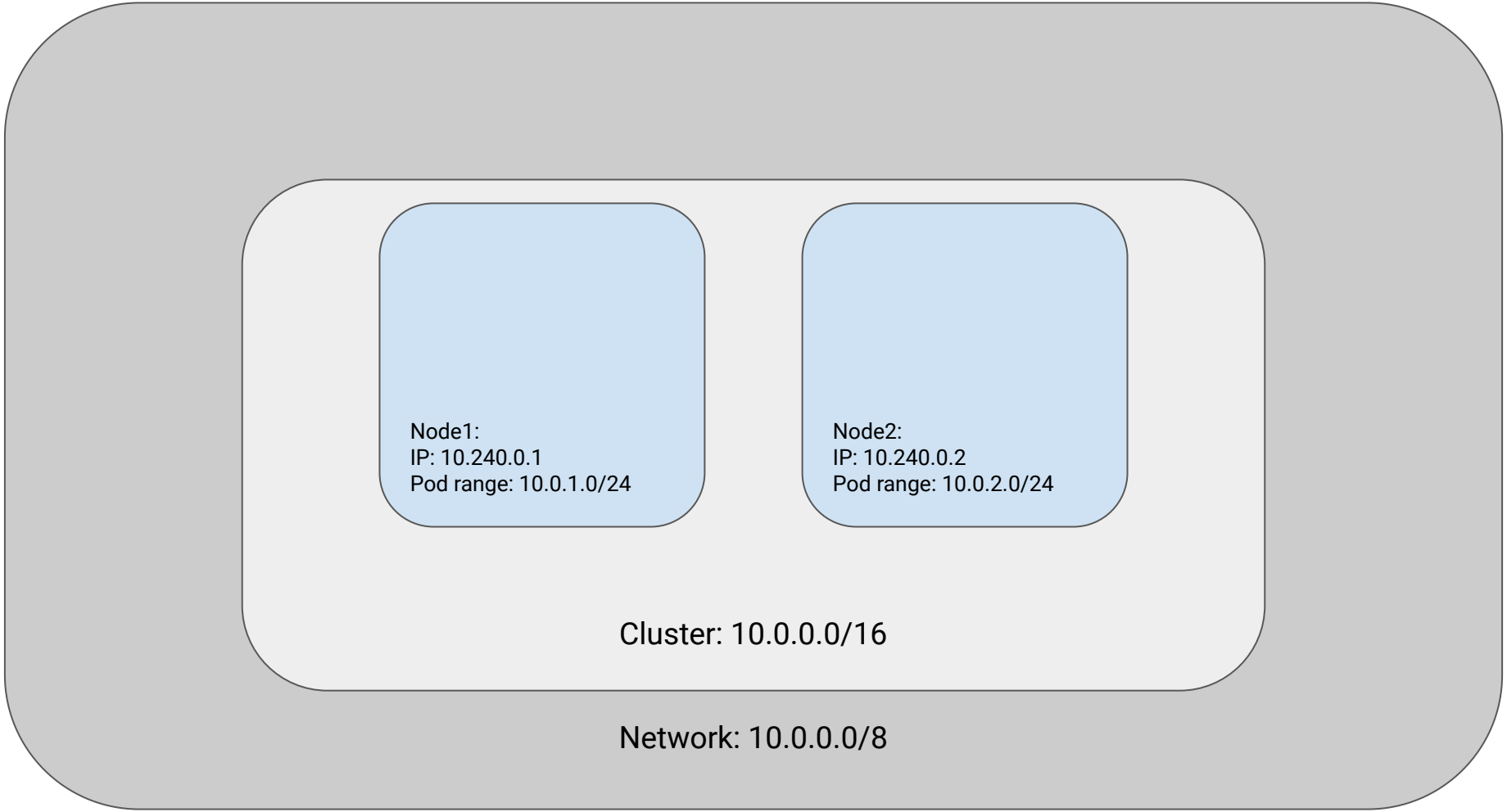
Start with a “normal” cluster

Network: 10.0.0.0/8


Cluster: 10.0.0.0/16
Network: 10.0.0.0/8

NOTE: It’s not *required* that a cluster be a single IP range, but it’s common and makes the pictures easier


Node1:
IP: 10.240.0.1
Node2:
IP: 10.240.0.2
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8


Node1:
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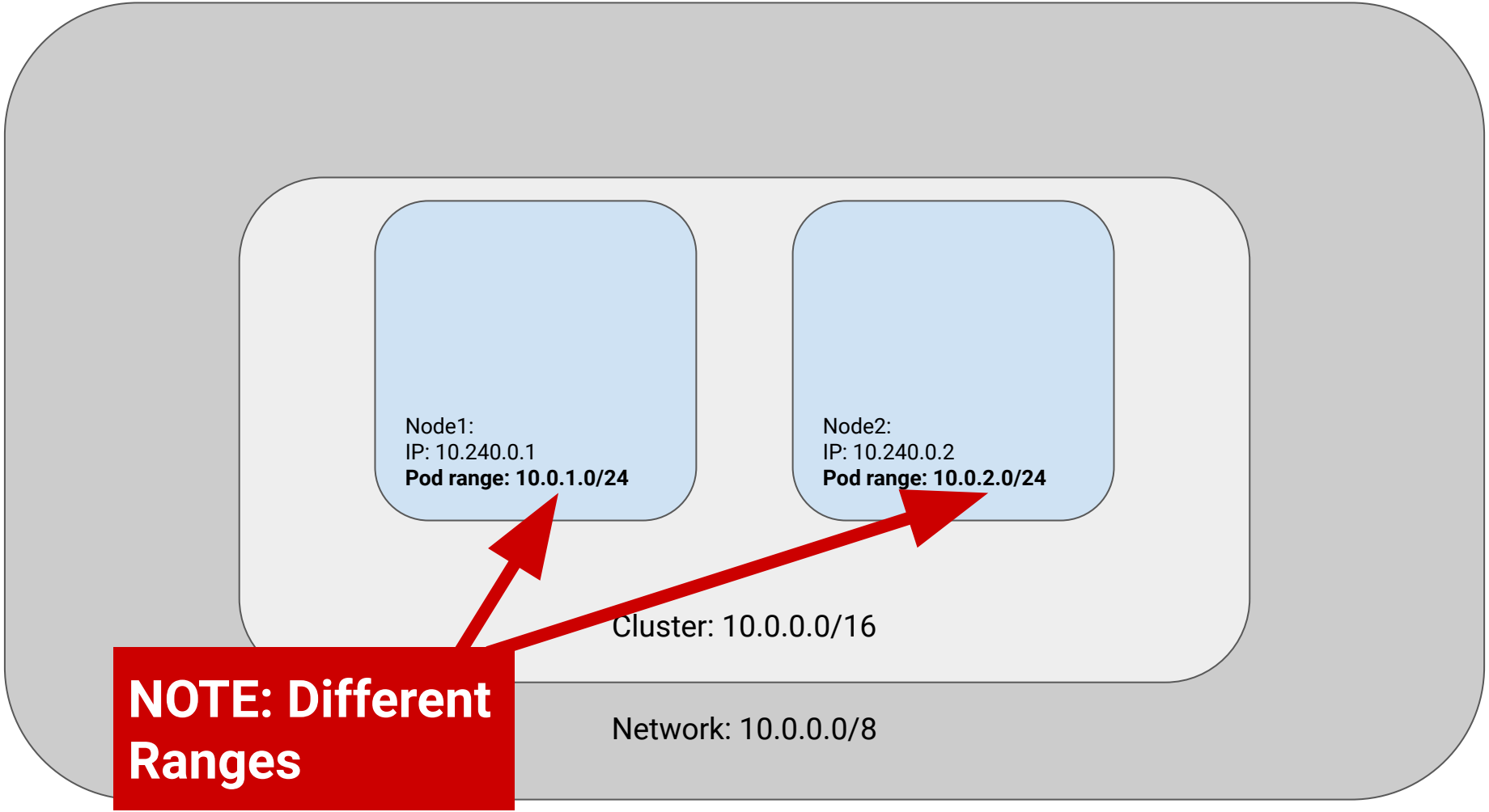
Pod range: 10.0.1.0/24
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8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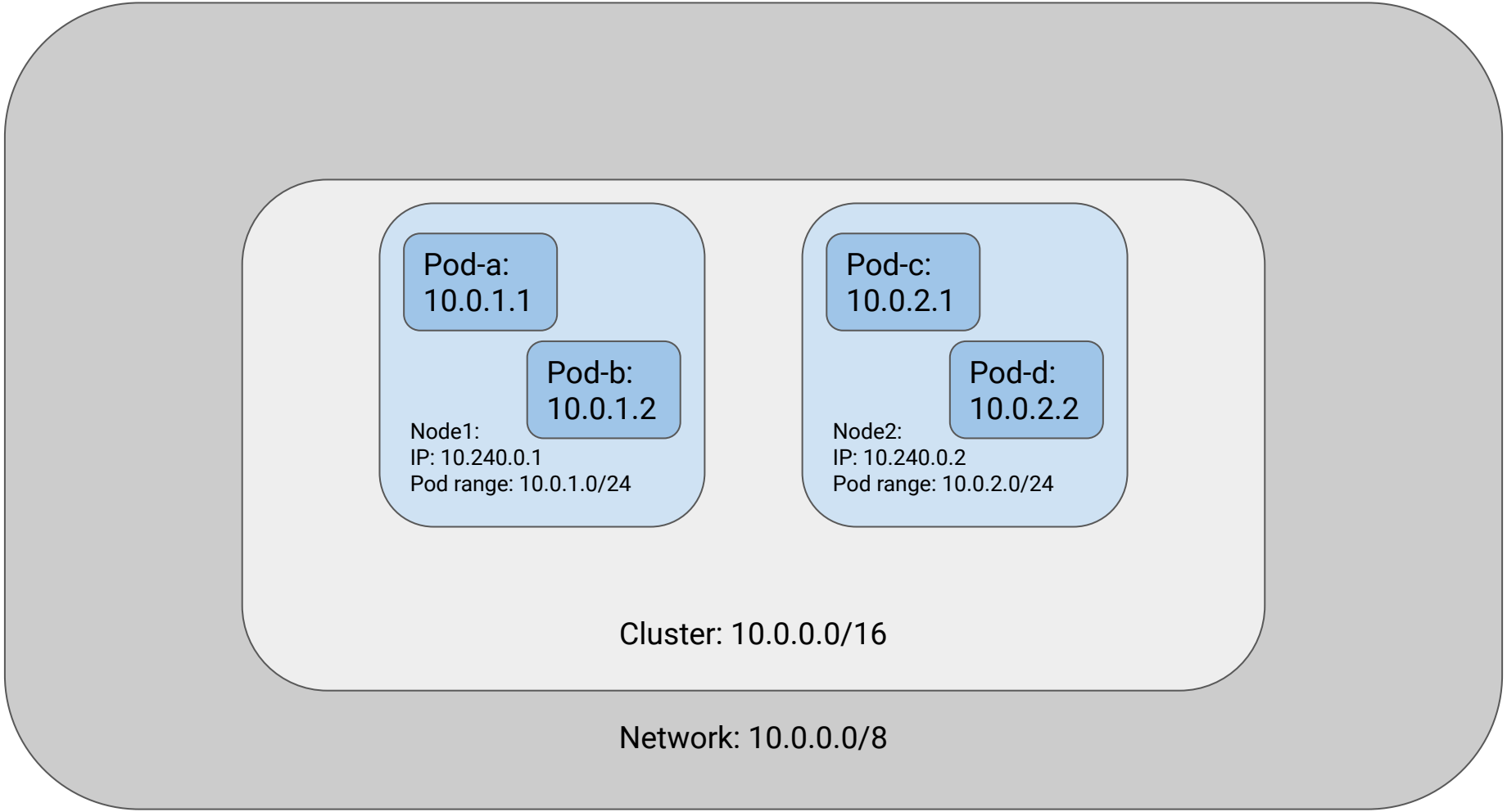
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8
NOTE: Different Ranges

NOTE: It’s not *required* that nodes have a predefined IP range, but it’s common and makes the pictures easier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10.0.2.1
Pod-d:
10.0.2.2
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IP: 10.240.0.2
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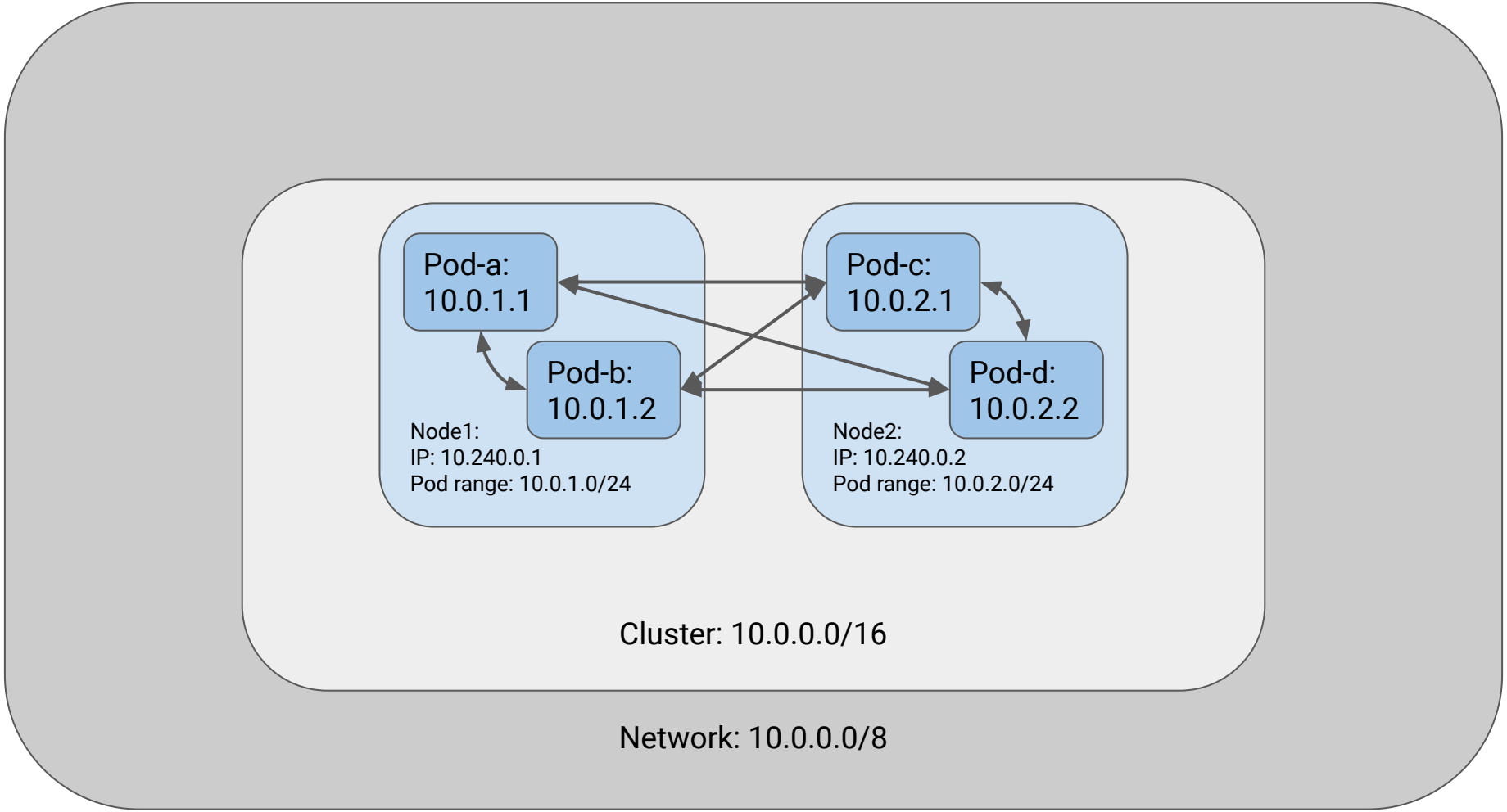
Pods get IPs from the node’s IP range (again, usually but not always)

Kubernetes demands that pods can reach each other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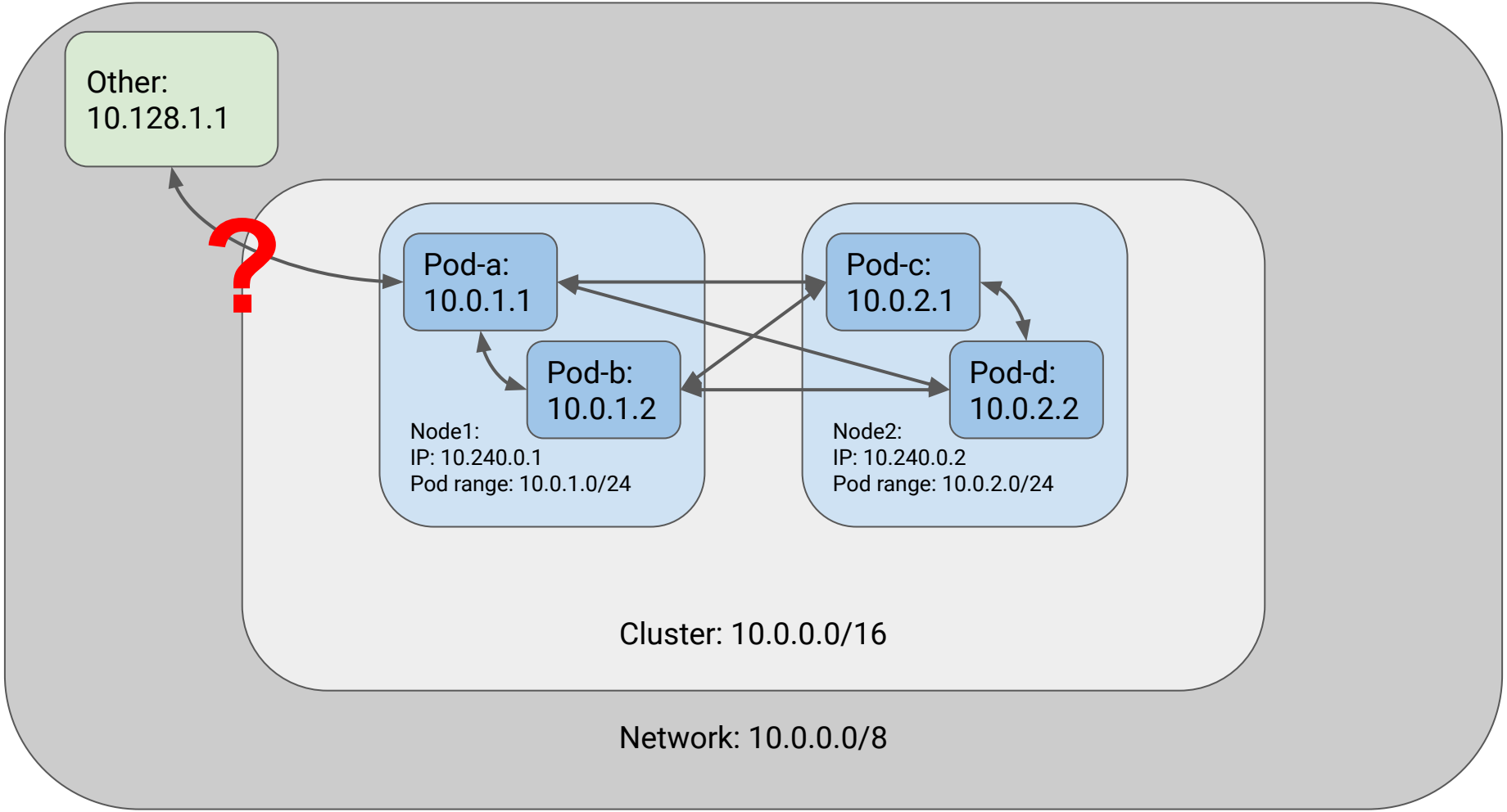
Kubernetes does not say anything about things outside of the cluster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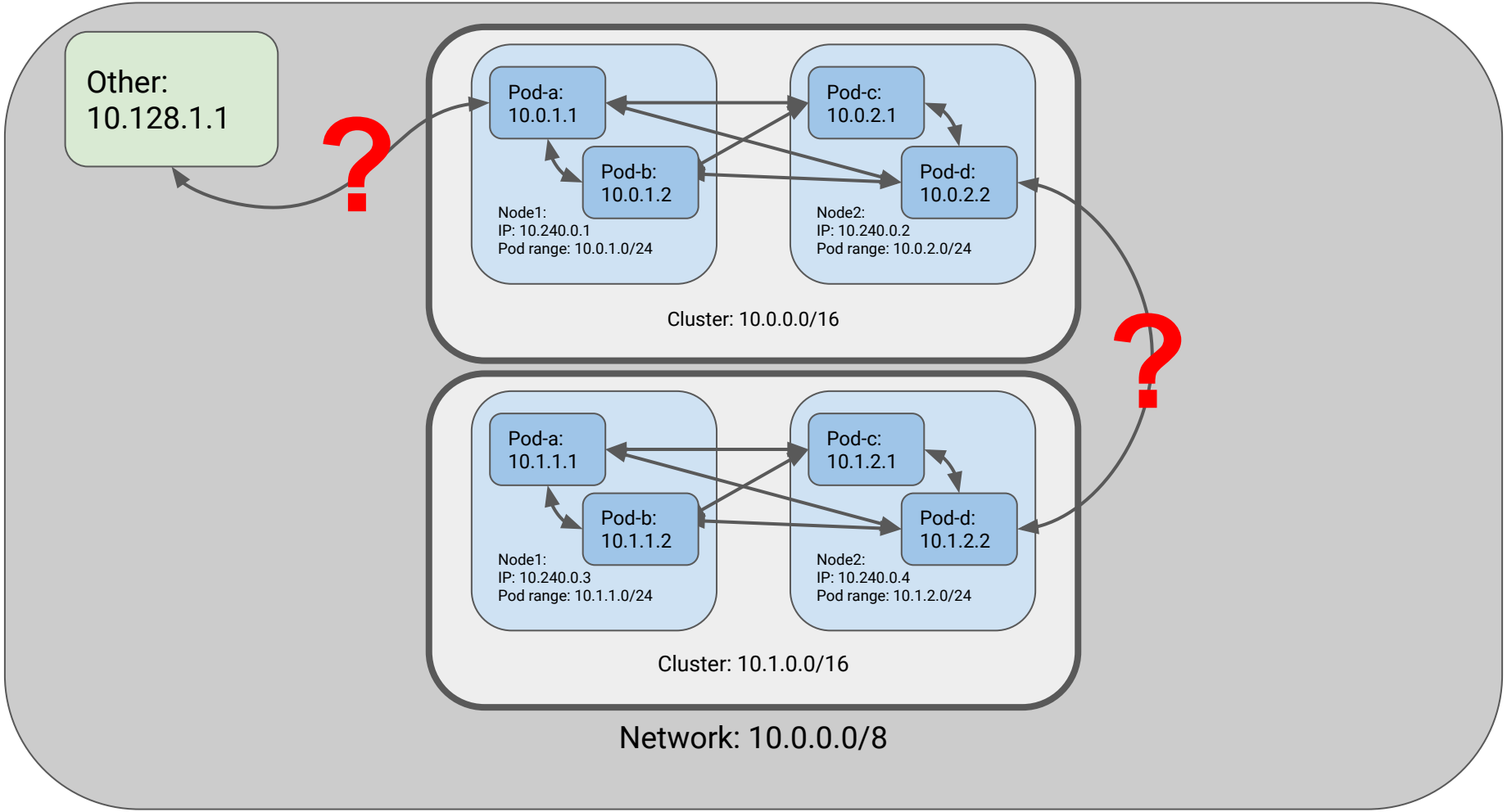
Multi-cluster makes it even more confusing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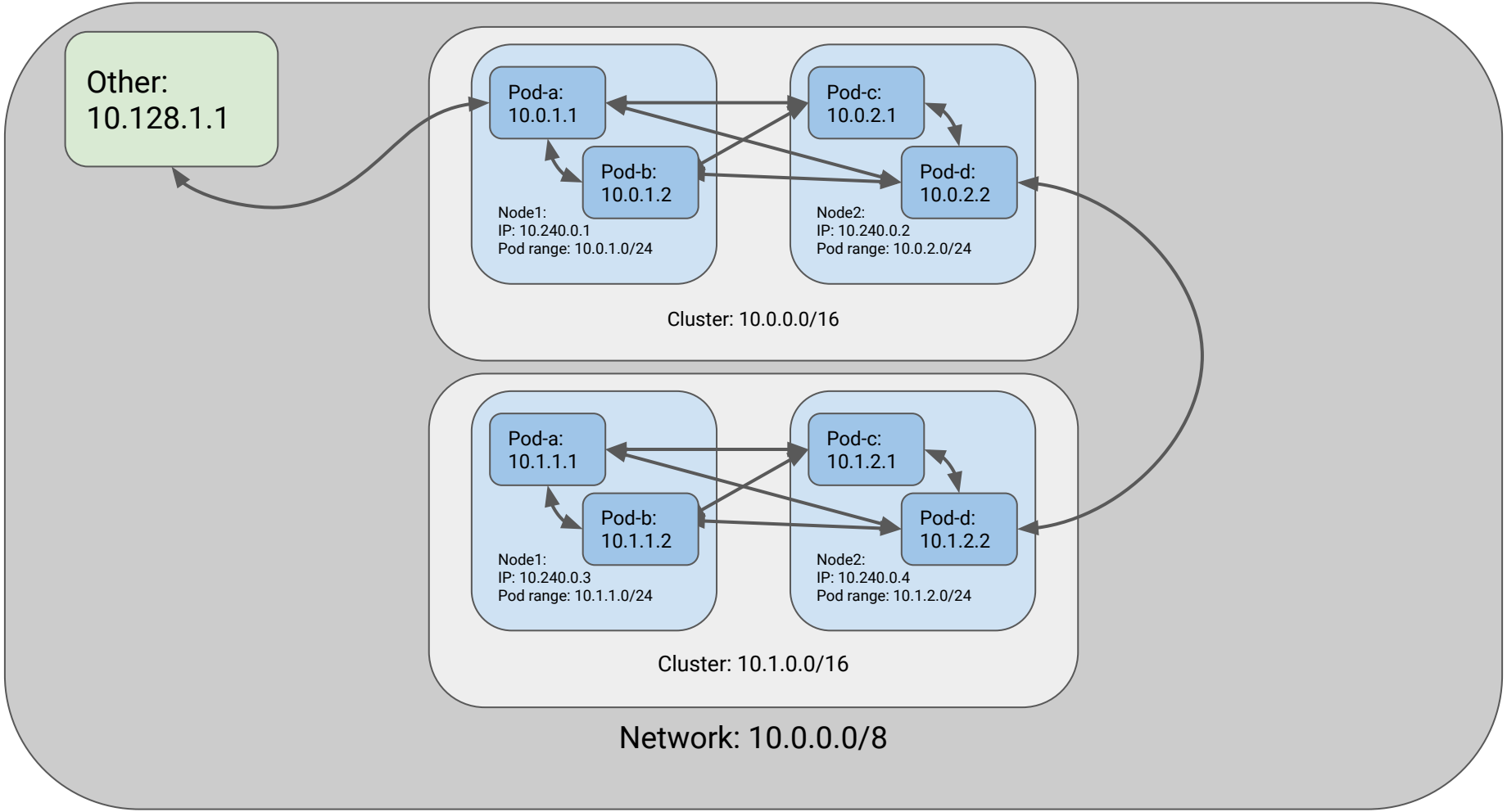
Network models (not exhaustive)

Fully-integrated (aka flat)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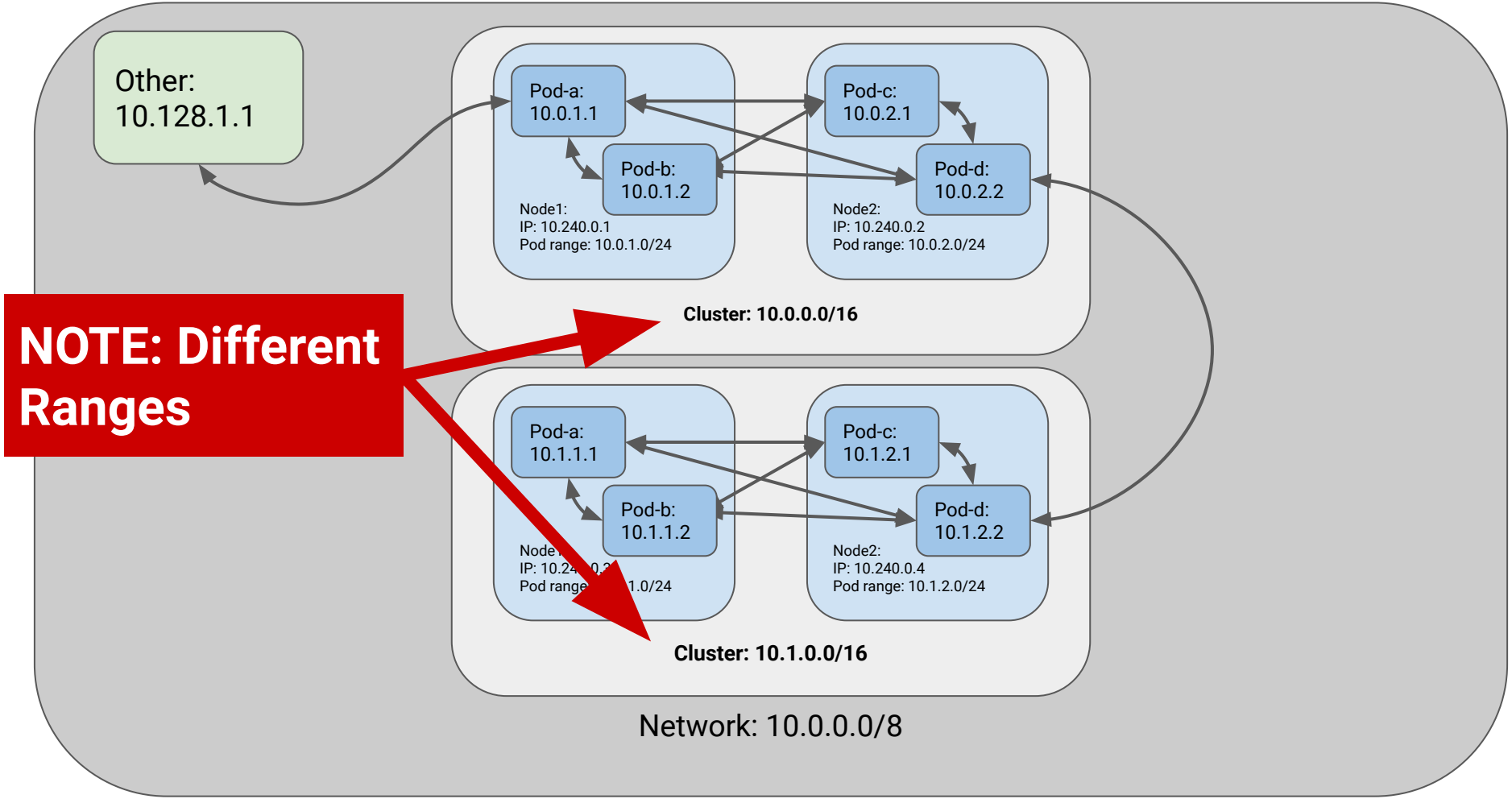
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Cluster: 10.1.0.0/16
Network: 10.0.0.0/8

Each node owns an IP range from the larger network

Everyone on the network knows how to deal with that (or the network deals with it for them)

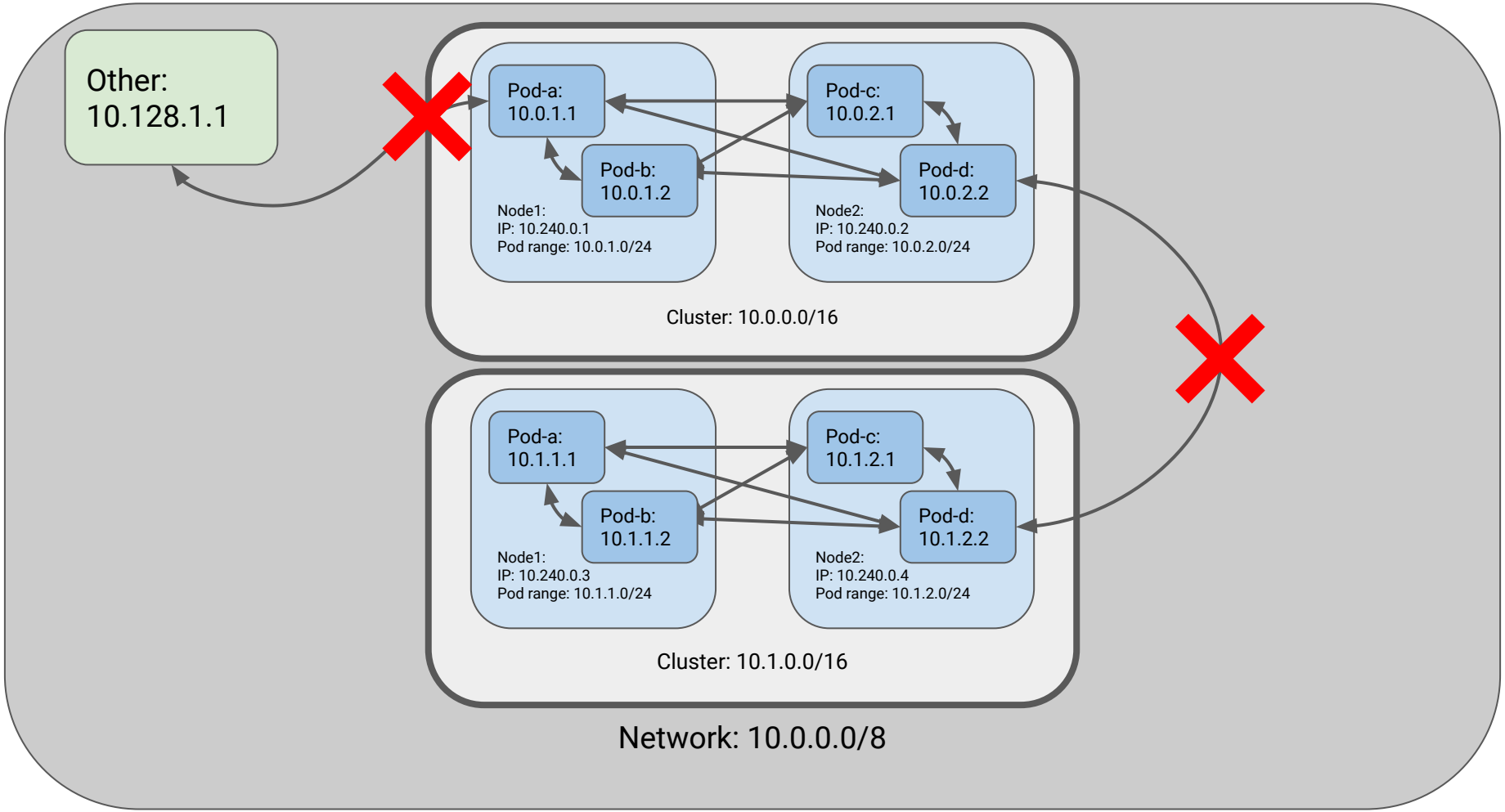
Good when:

- IP space is available
- Network is programmable / dynamic
- Need high integration / performance
- Kubernetes is a large part of your footprint

Bad when:

- IP fragmentation / scarcity
- Hard-to-configure network infrastructure
- Kubernetes is a small part of your footprint

Fully-isolated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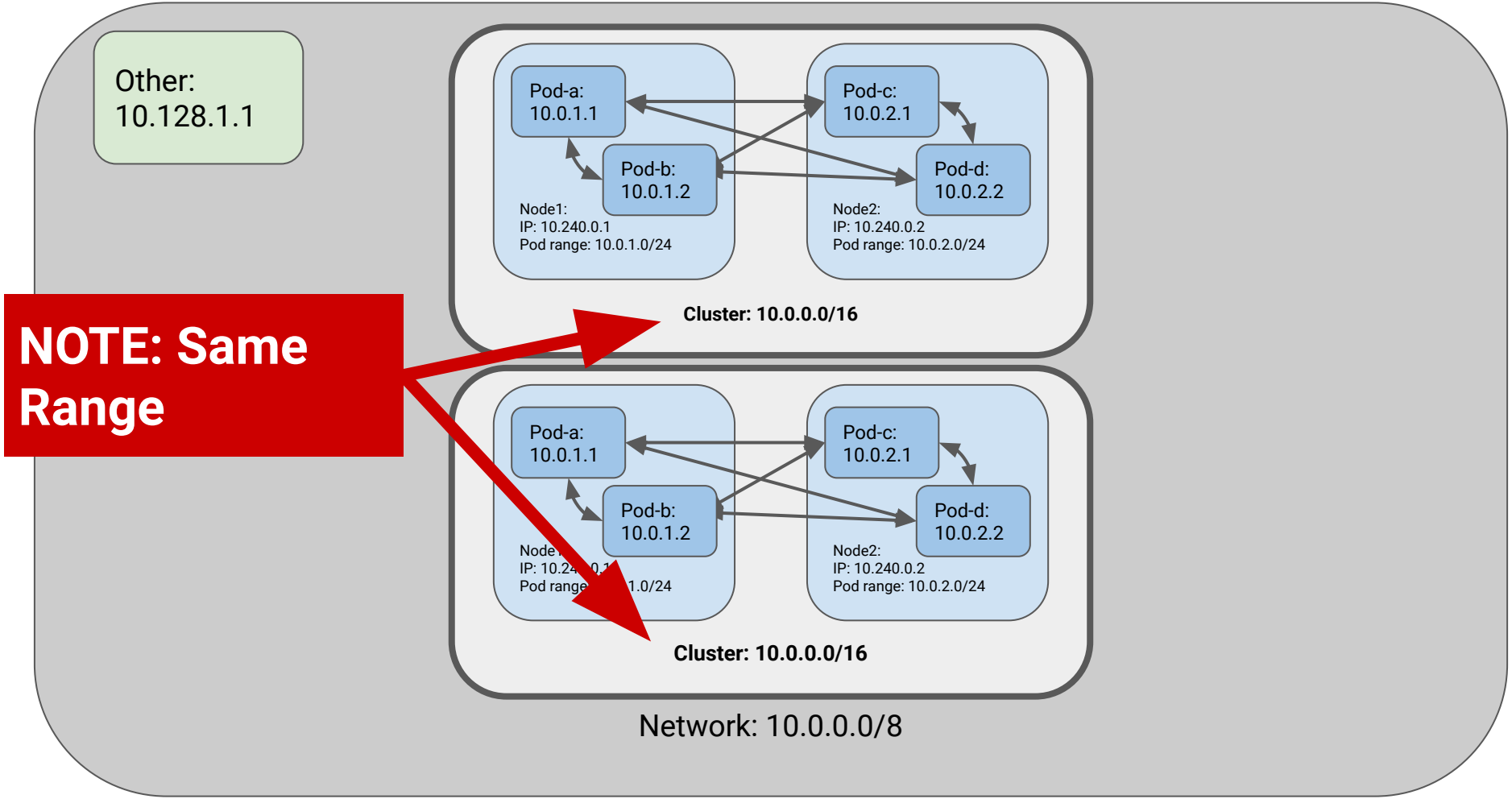
No connectivity from inside to outside or vice-versa!

In fact, you can re-use all of the IPs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10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
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NOTE: Same Range
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10.0.2.1
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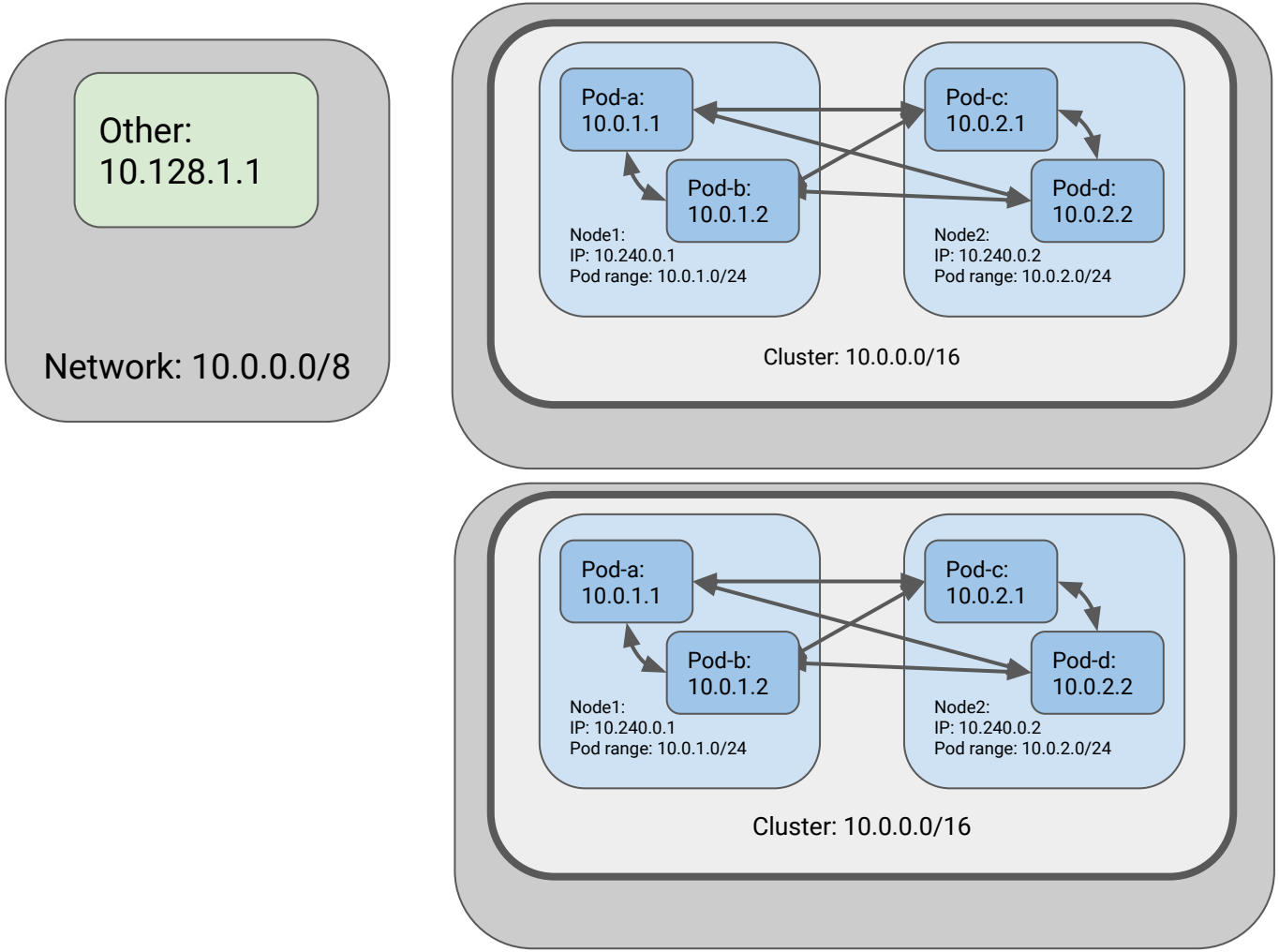
Network: 10.0.0.0/8

In fact, they are basically on different networks


Other:
10.128.1.1
Network: 10.0.0.0/8
Pod-a:
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Cluster: 10.0.0.0/16

May be easier to reason about security boundaries

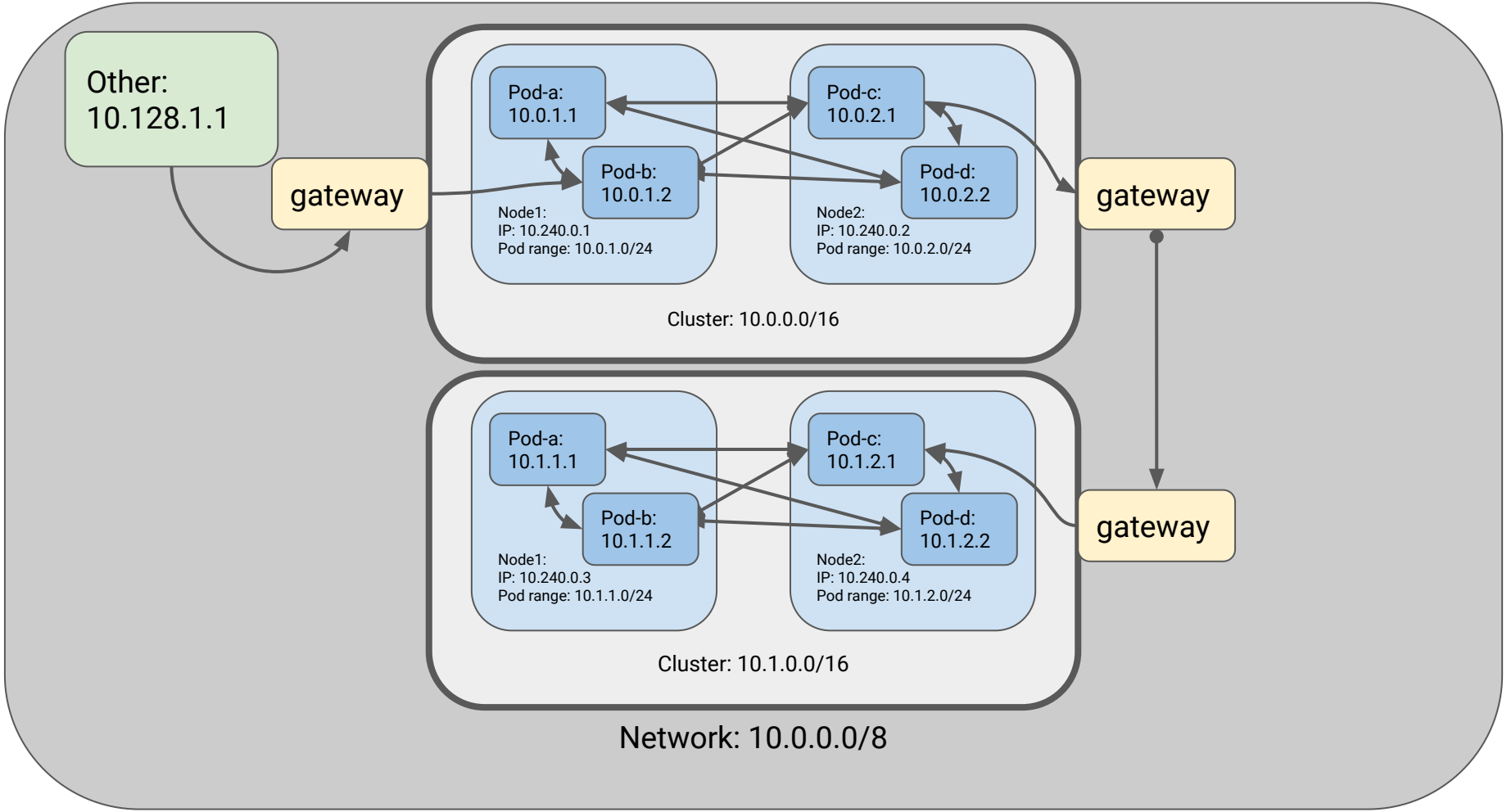
Good when:

- Don’t need integration
- IP space is scarce / fragmented
- Network is not programmable / dynamic

Bad when:

- Need communication across a cluster-edge

Island mode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gateway
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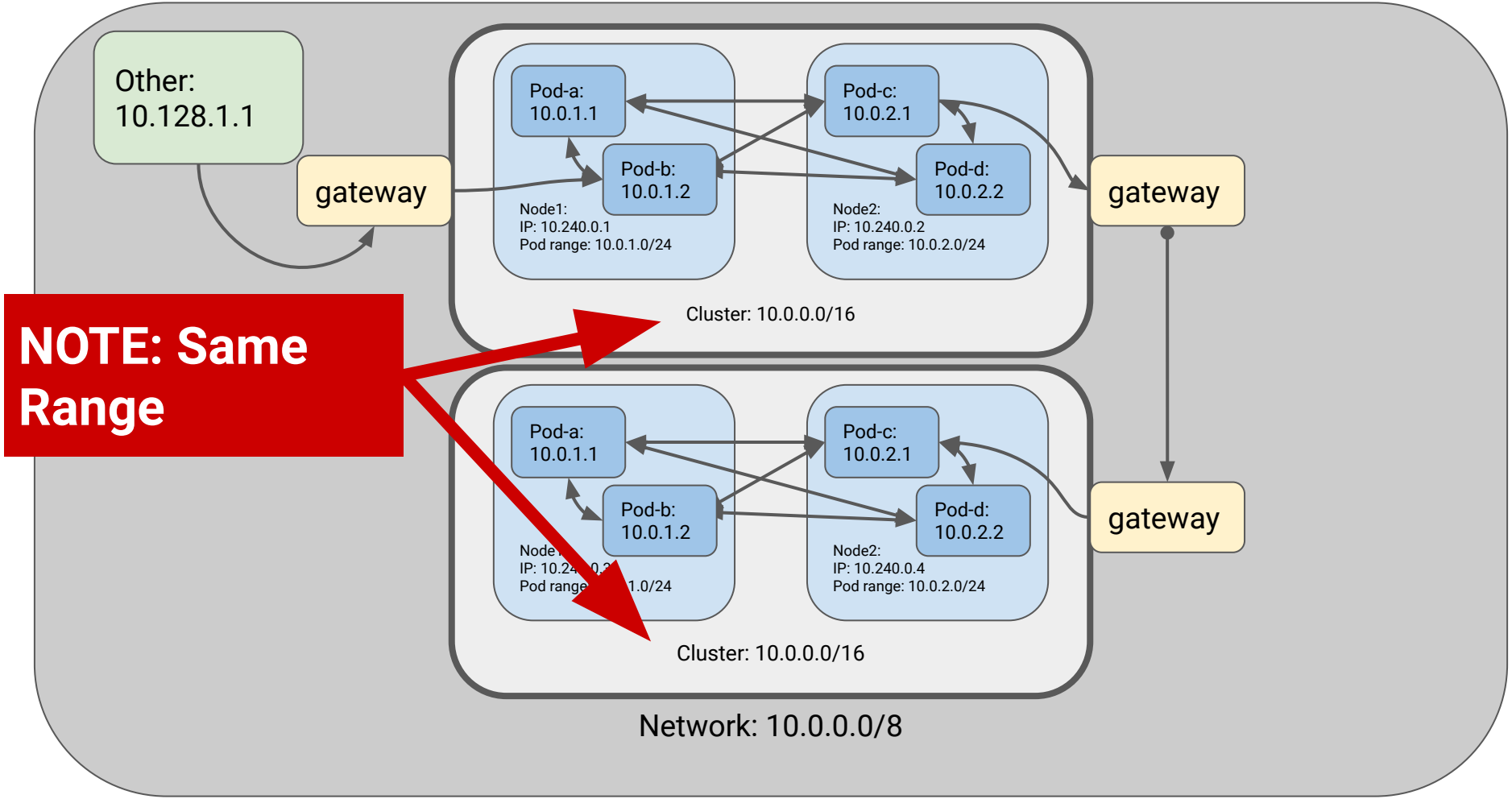
Cluster: 10.1.0.0/16
gateway
Network: 10.0.0.0/8

Ingress and egress traffic goes thru one or more abstract “gateways” (more on that later)

You can re-use the Pod IPs (a major motivation for this model), but node IPs come from the larger network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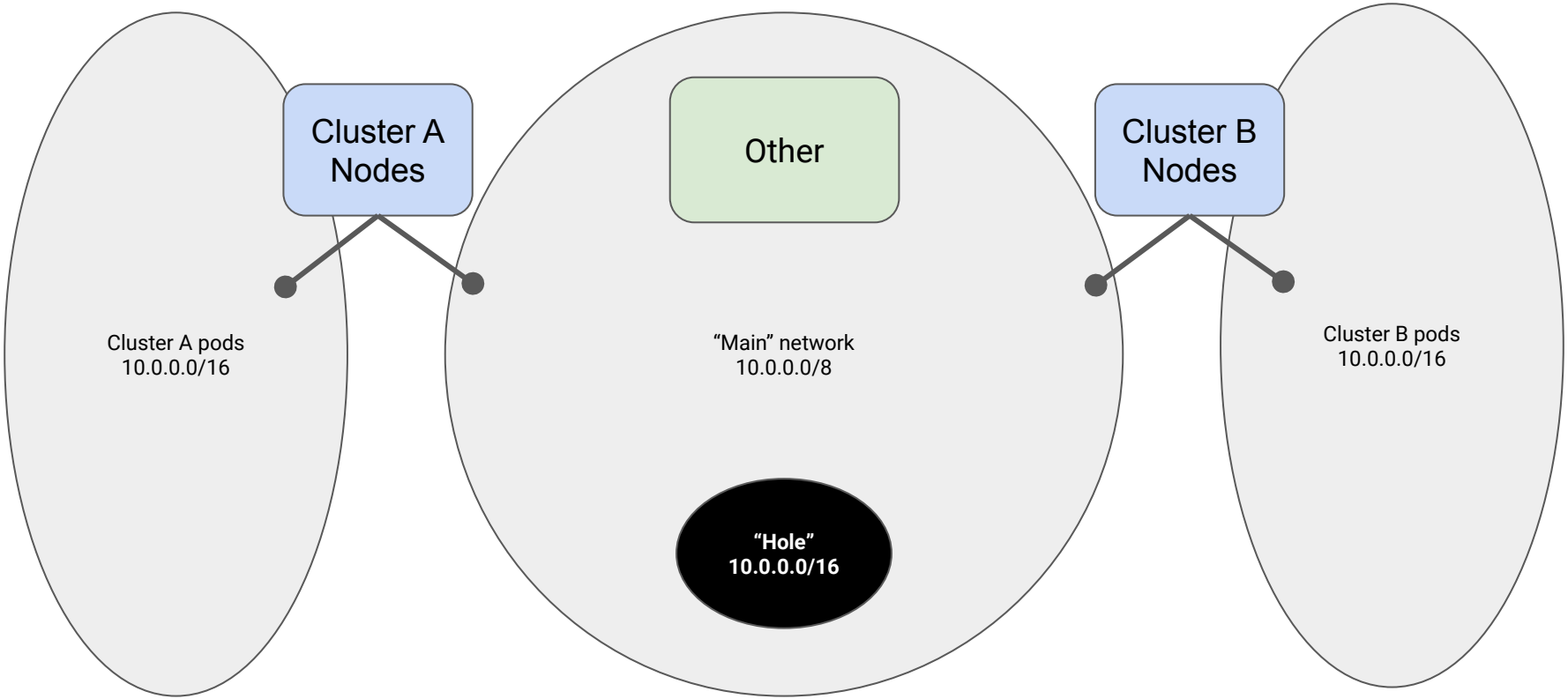
Can be implemented as an overlay network or not

Another way to think of this: clusters have a private network for their pods; nodes have one leg in the main network and one leg in the cluster network



Any pod can reach the “main” network by masquerading as its node, but not vice-versa (except via a gateway)

Good when:

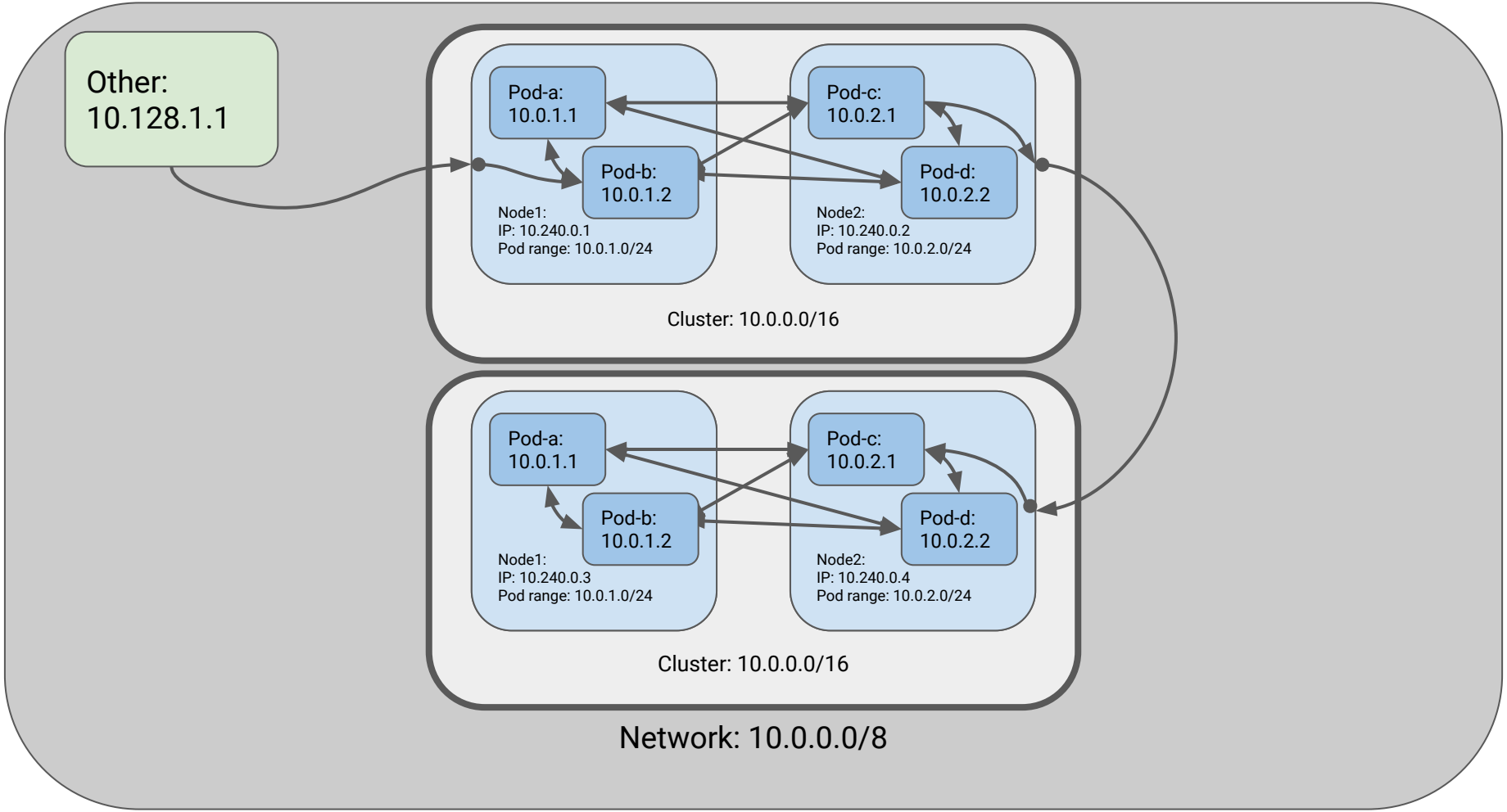
- Need some integration
- IP space is scarce / fragmented
- Network is not programmable / dynamic

Bad when:

- Need to debug connectivity
- Need direct-to-endpoint communications
- Need a lot of services exposed (especially non-HTTP)
- Rely on client IPs for firewalls
- Large number of nodes

Various forms of “gateway”

Gateway: nodes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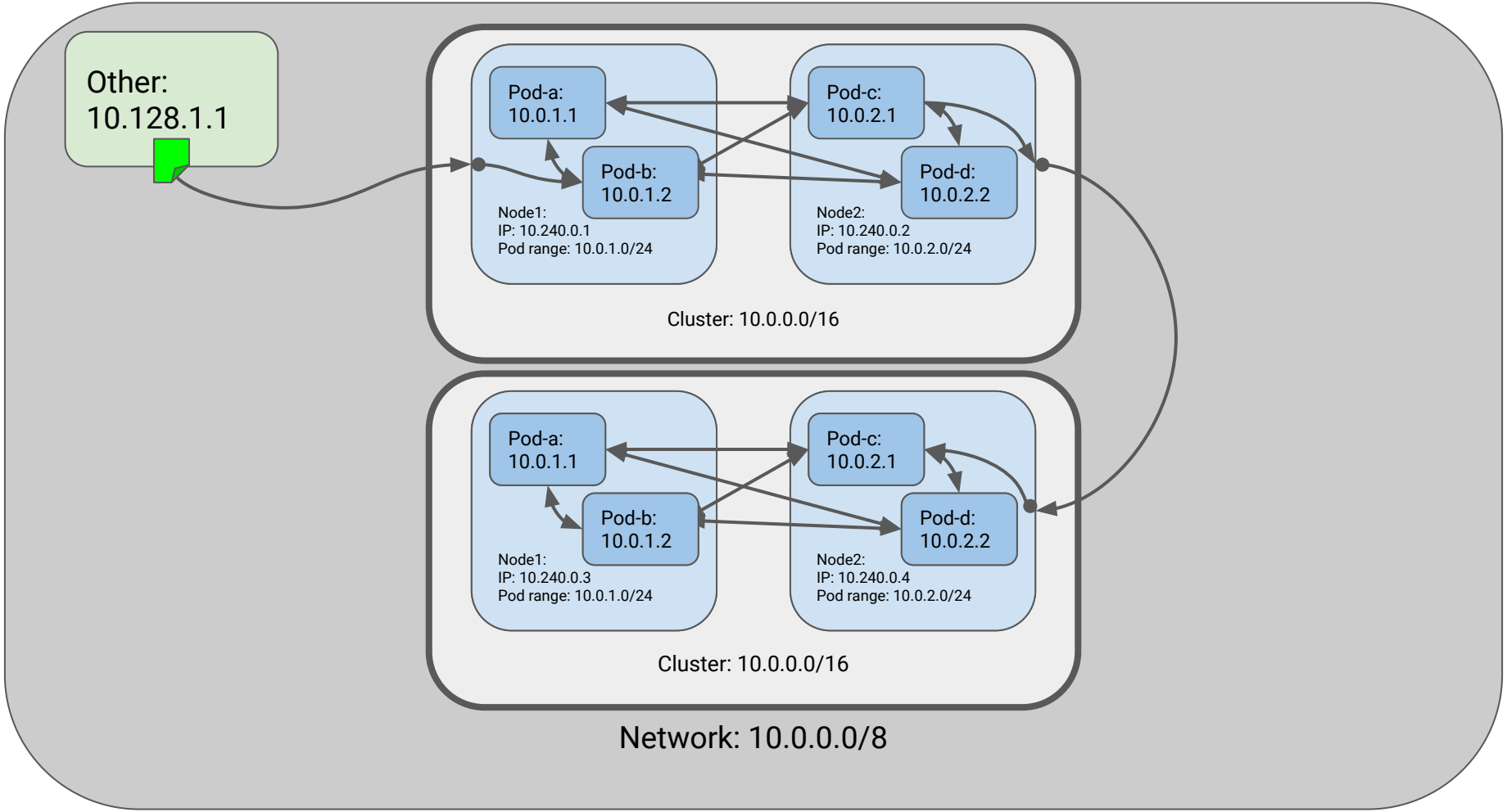
Ingress: Service NodePorts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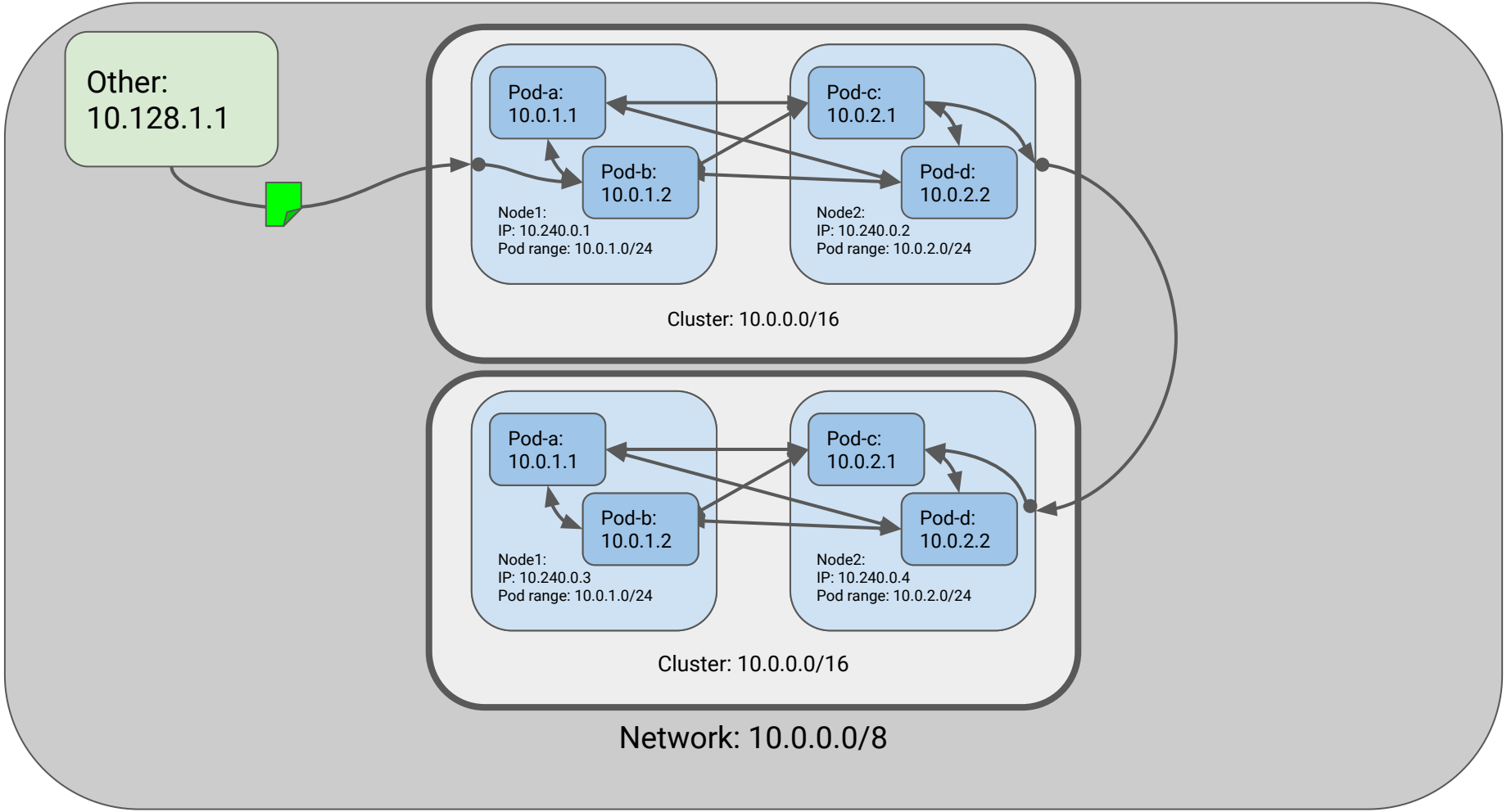
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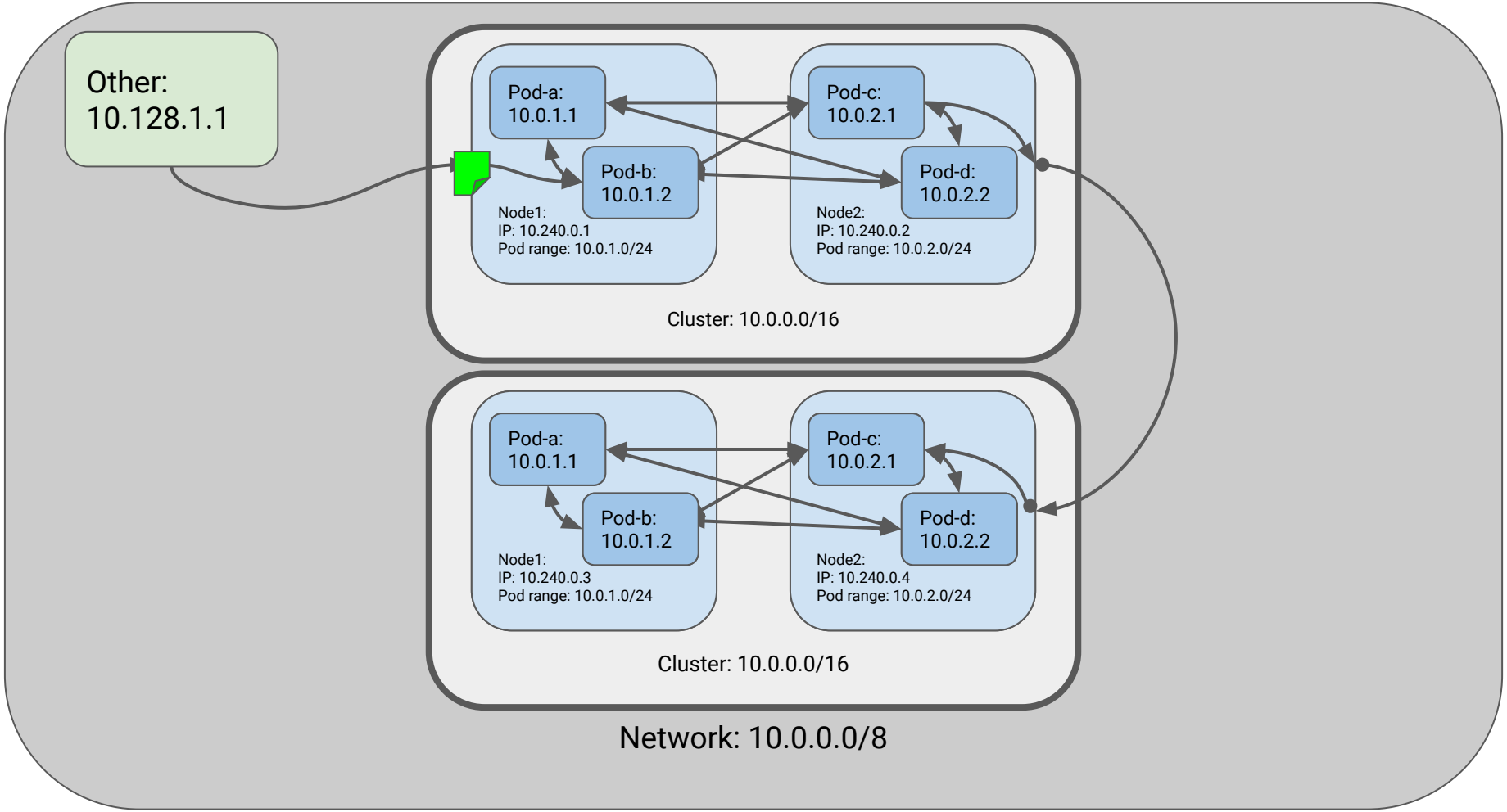
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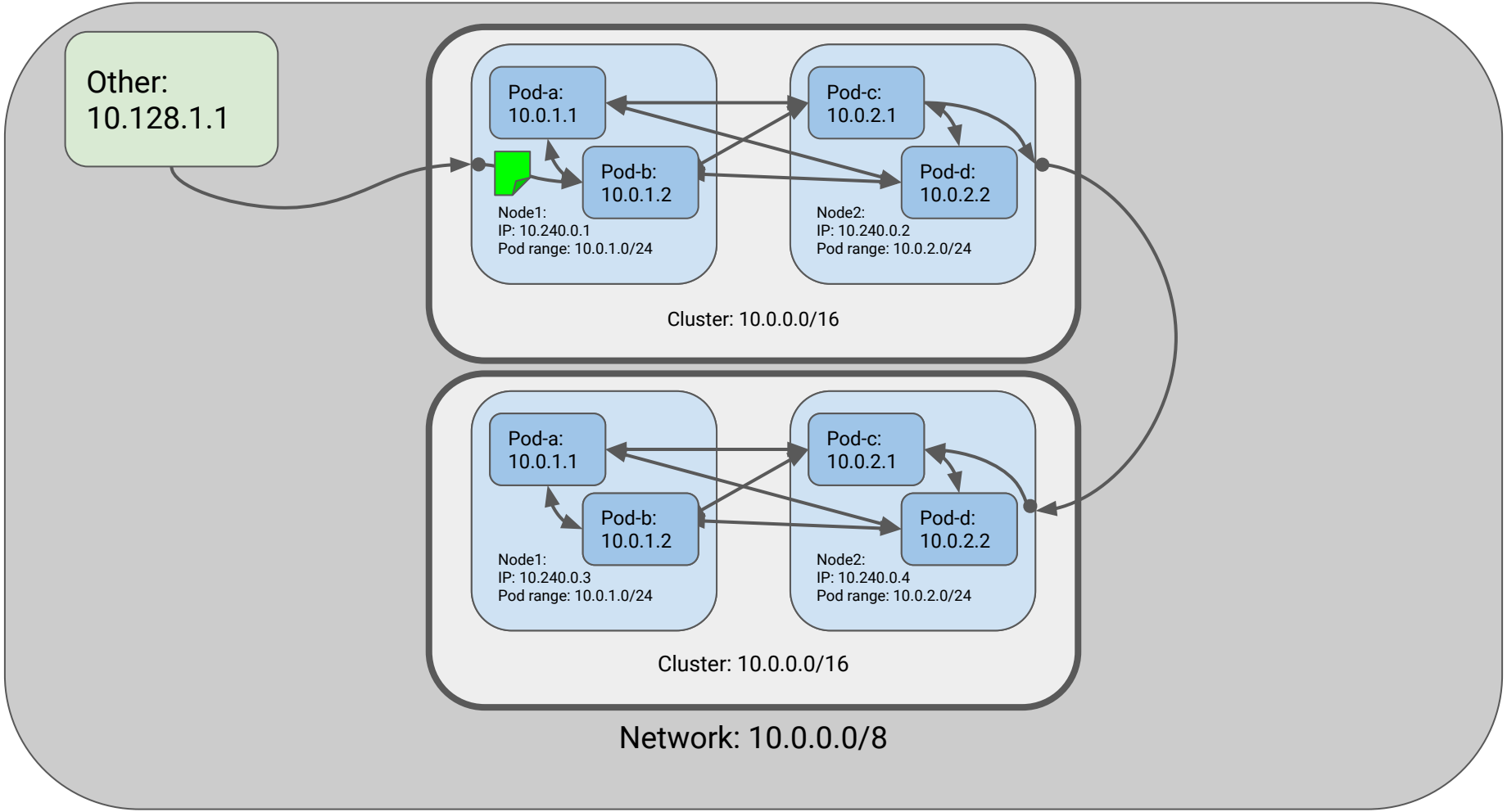
Node uses IP dst_port to route to correct service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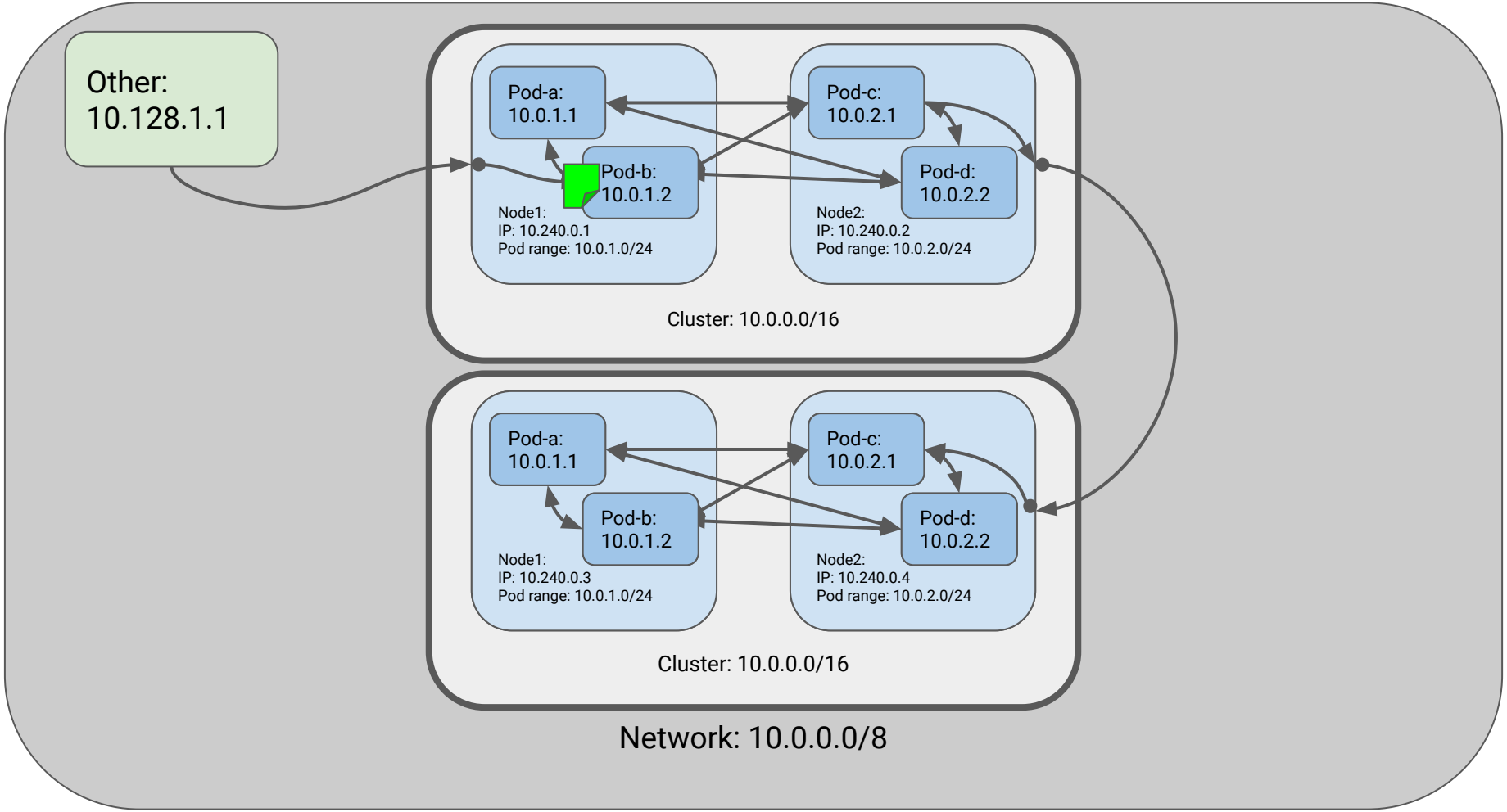
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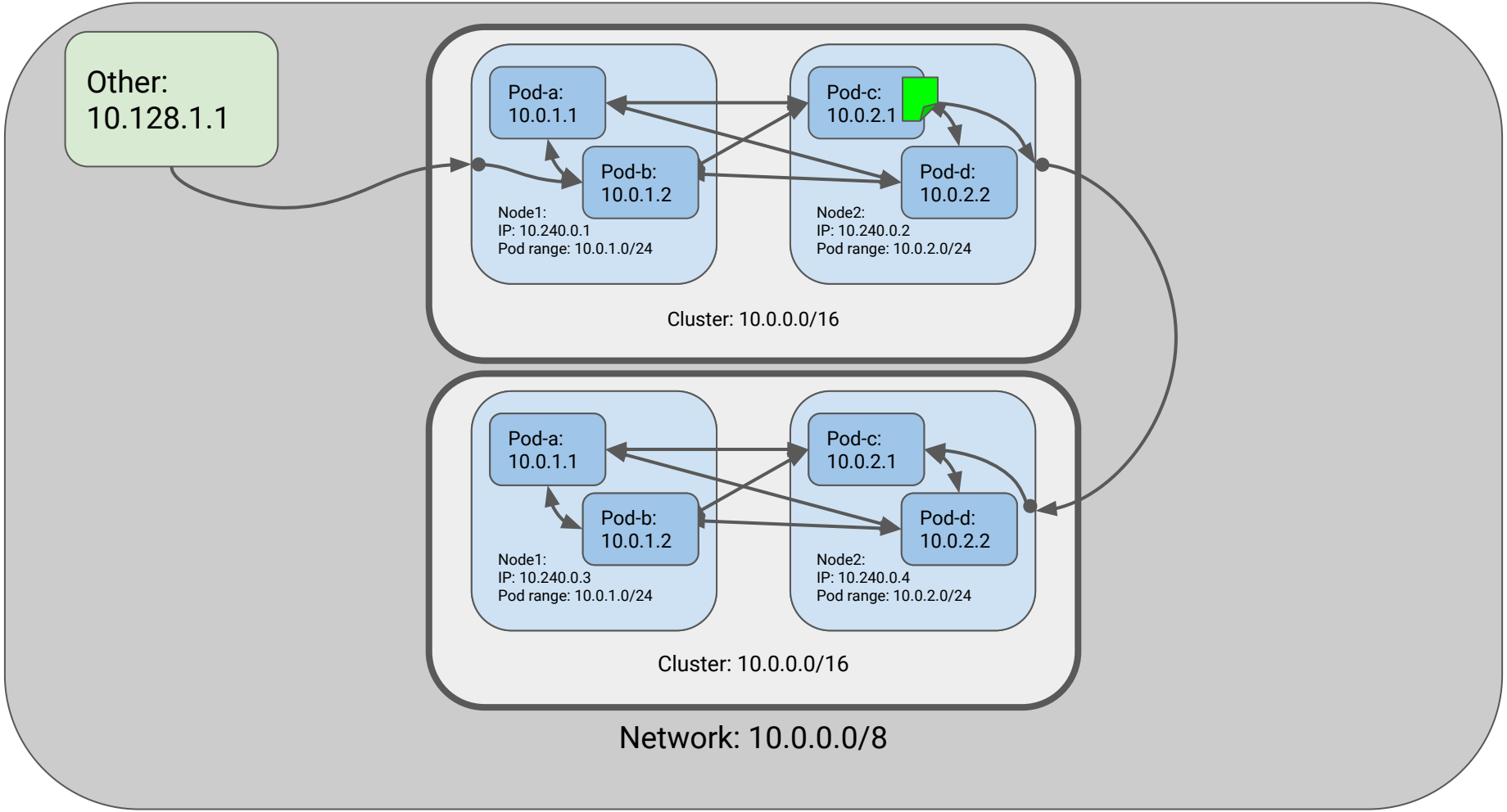
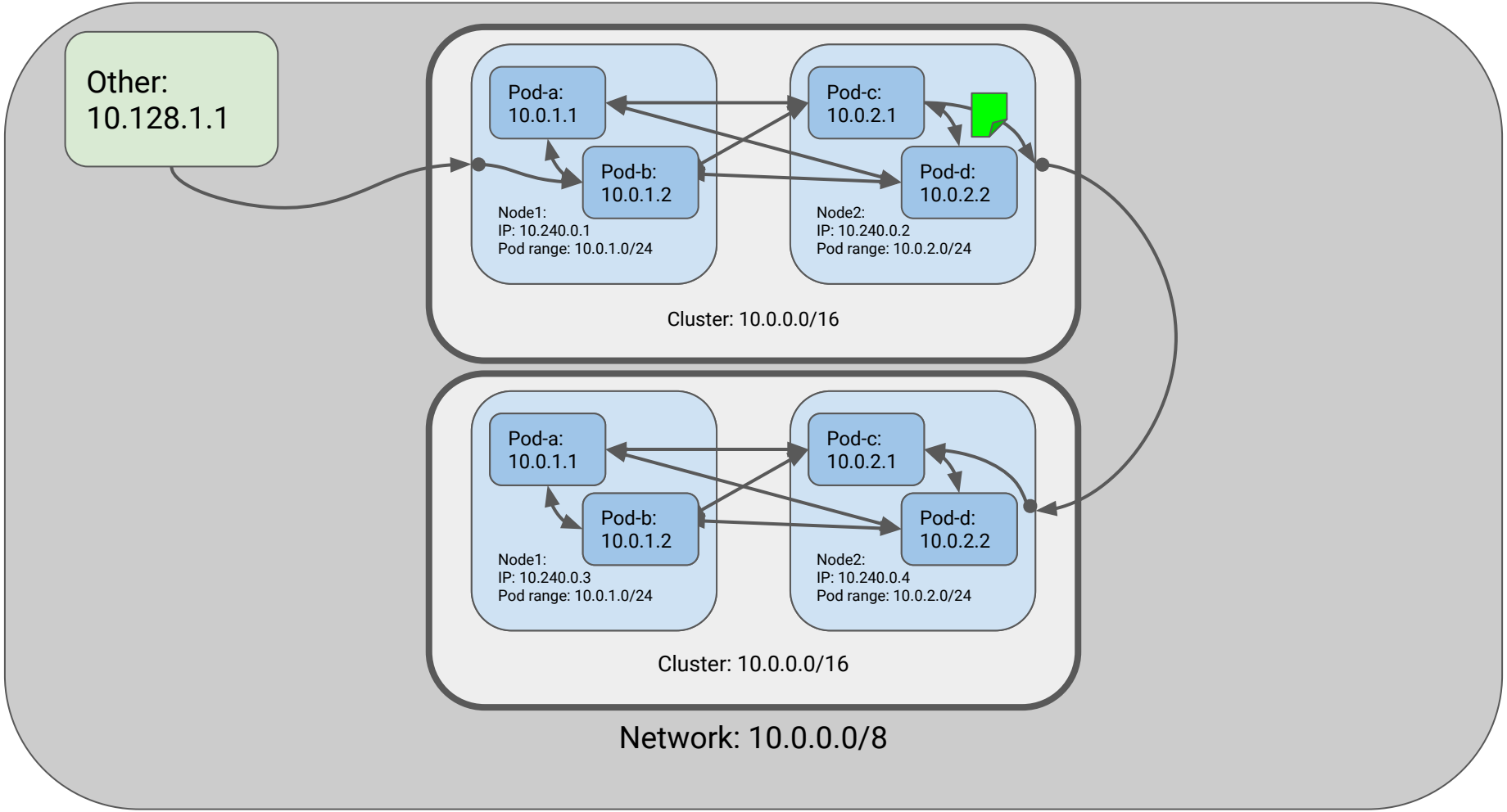
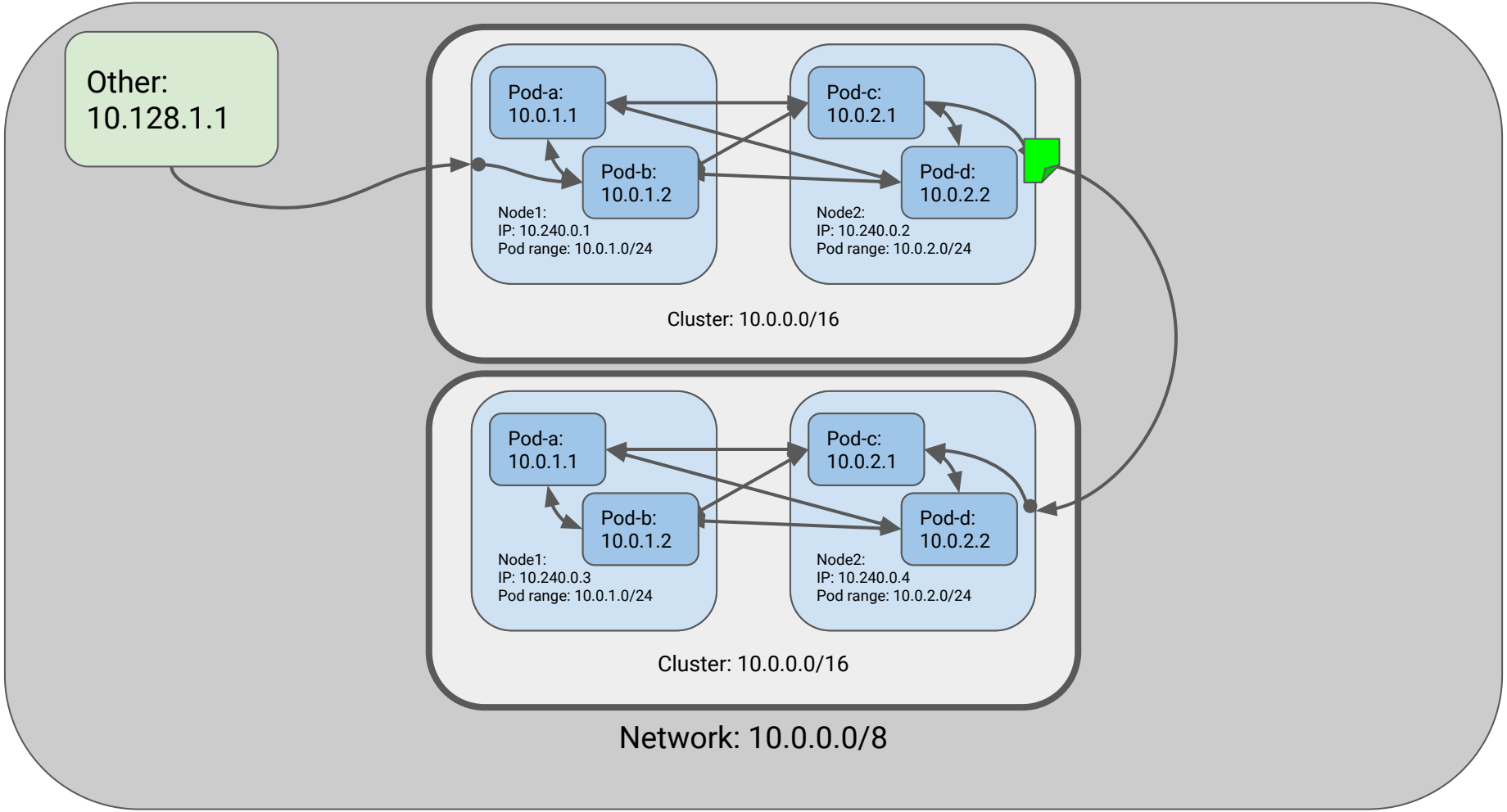
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8

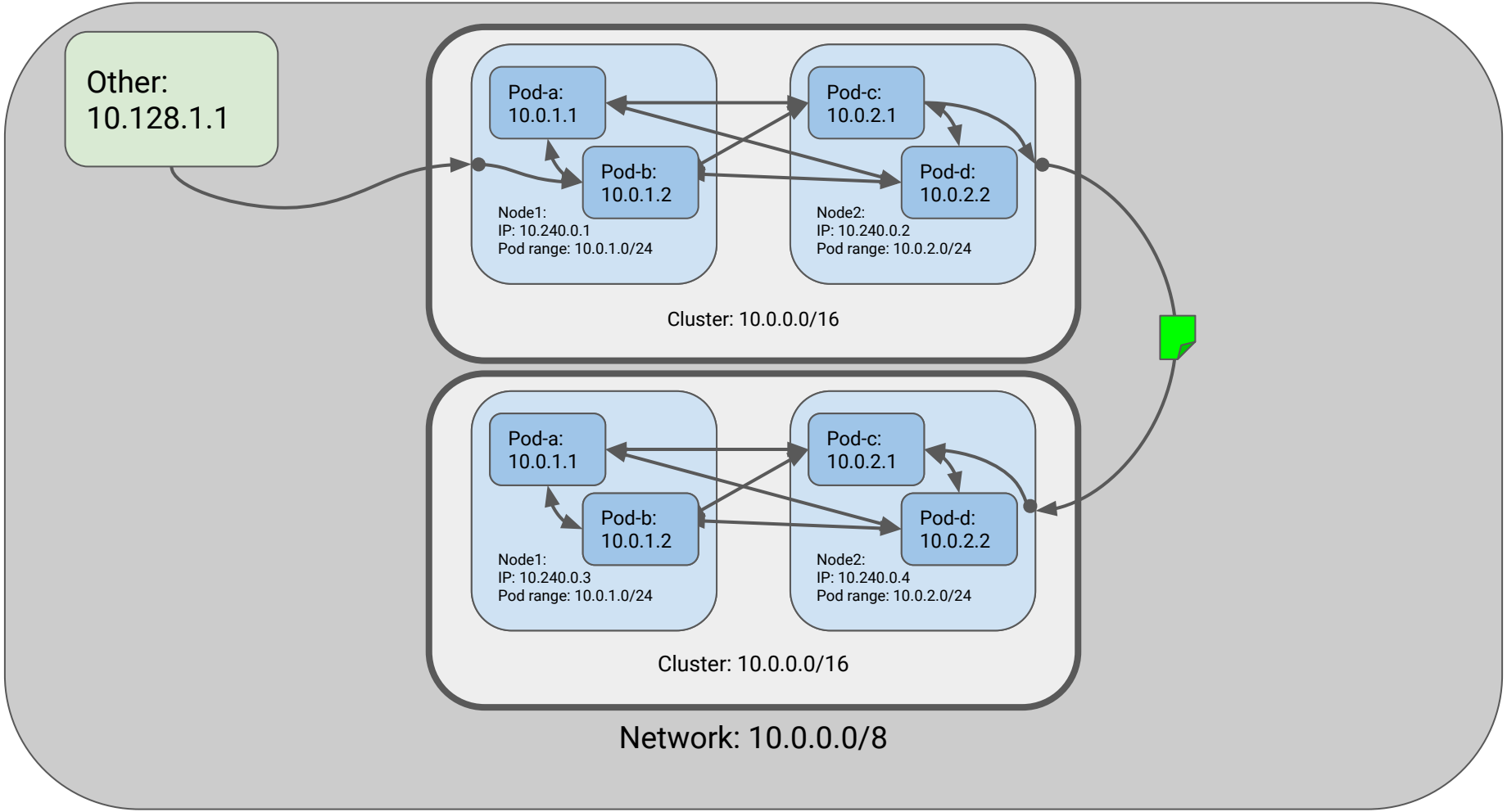
You can ingress L4 into an L7 proxy and forward from there (e.g. Ingress controllers)

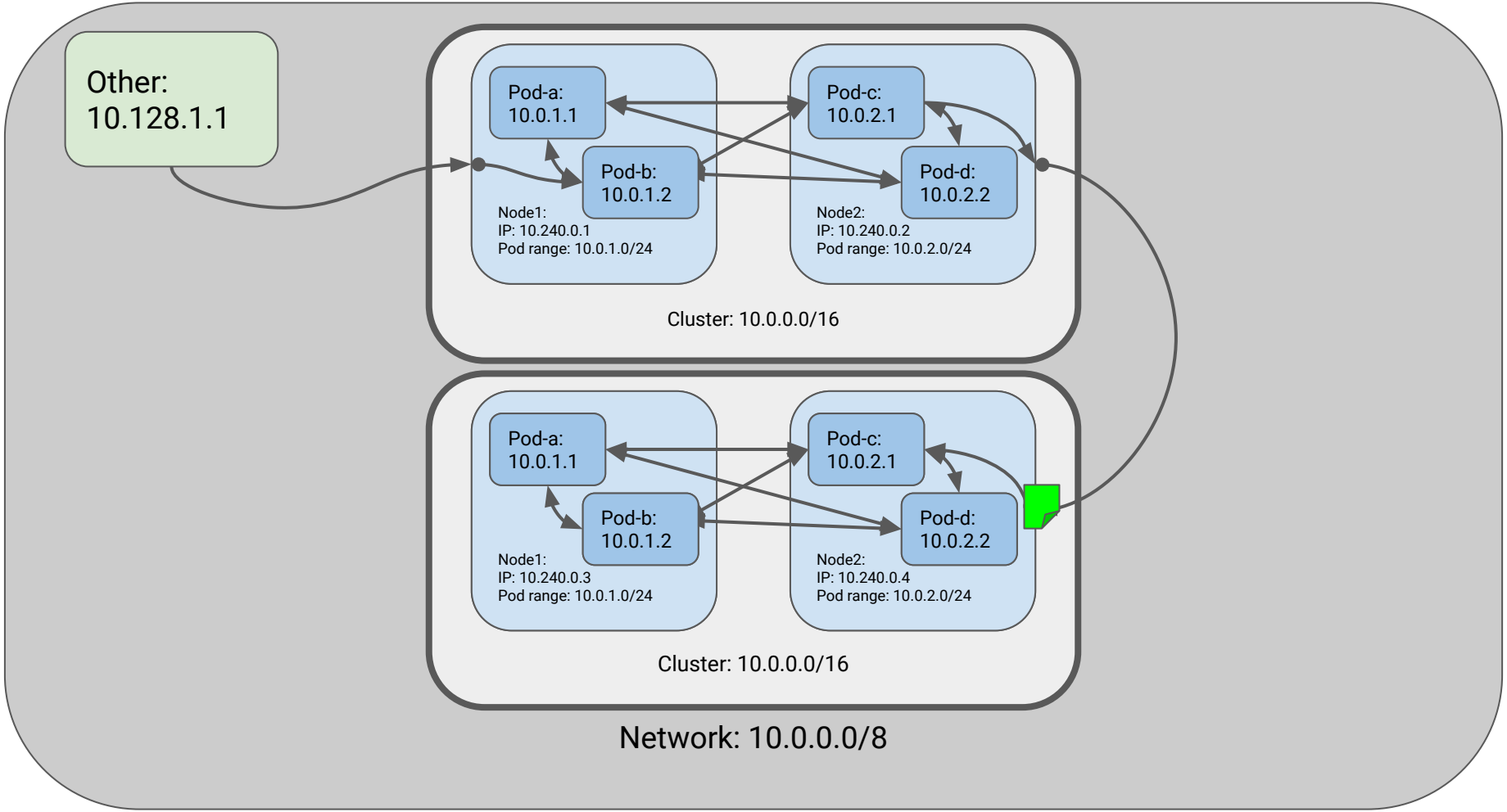
Egress: IP Masquerade (aka SNAT)

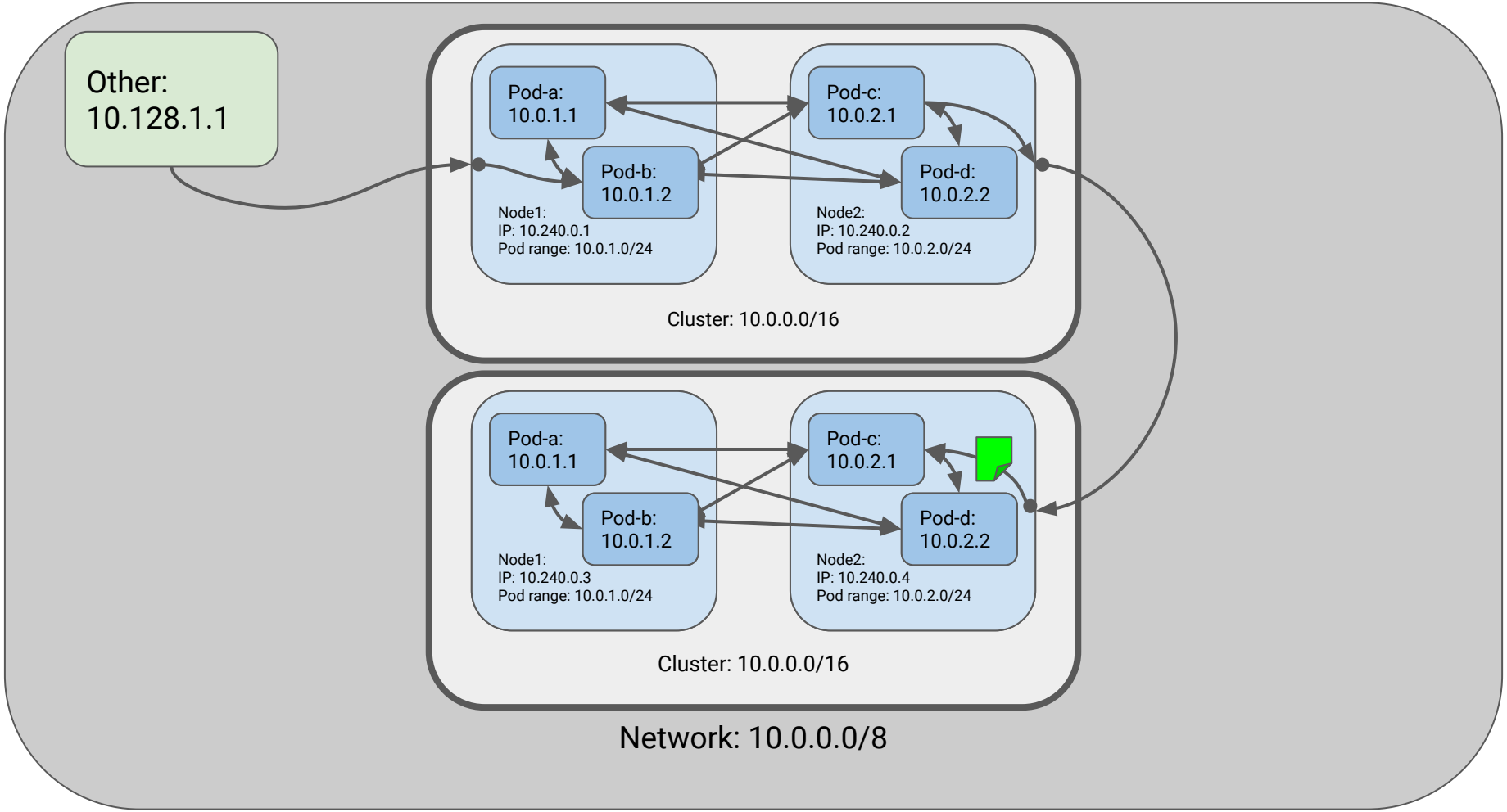

Other:
10.128.1.1
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8

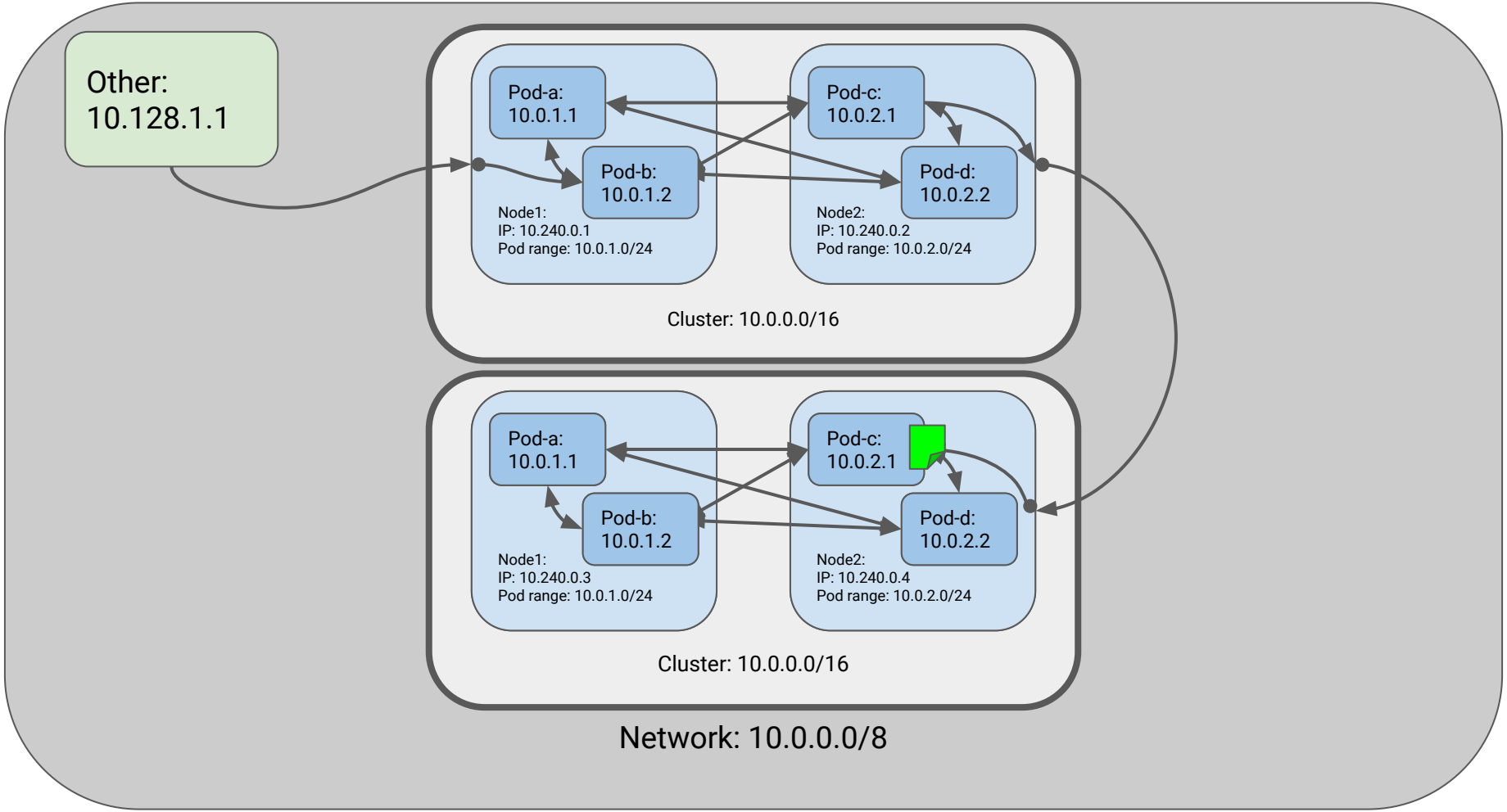

Other:
10.128.1.1
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8


Other:
10.128.1.1
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8


Other:
10.128.1.1
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8

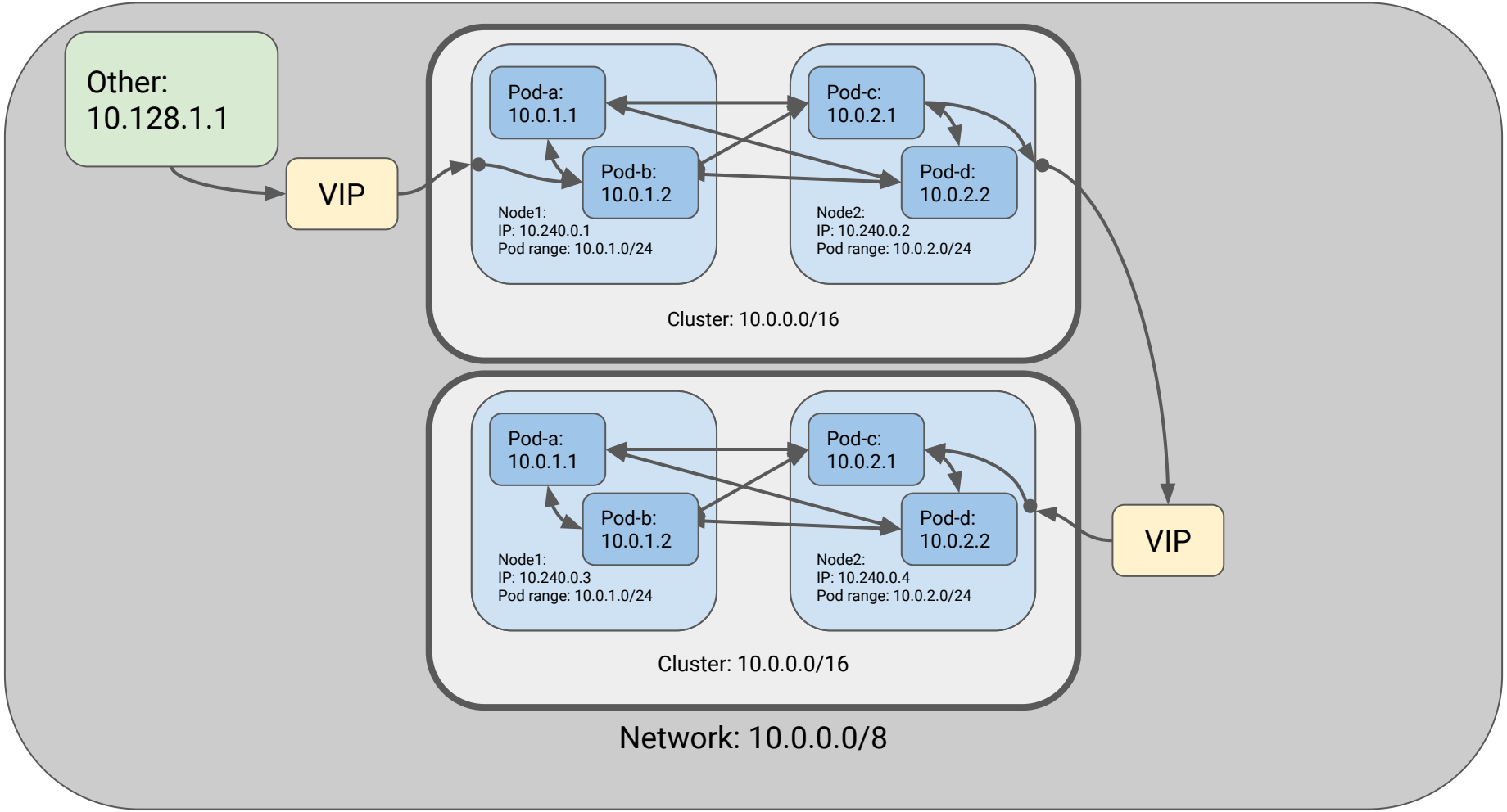

Other:
10.128.1.1
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8


Other:
10.128.1.1
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8


Other:
10.128.1.1
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Network: 10.0.0.0/8

SNAT obscures client IP (Traffic from pods on a node comes from the node’s IP)

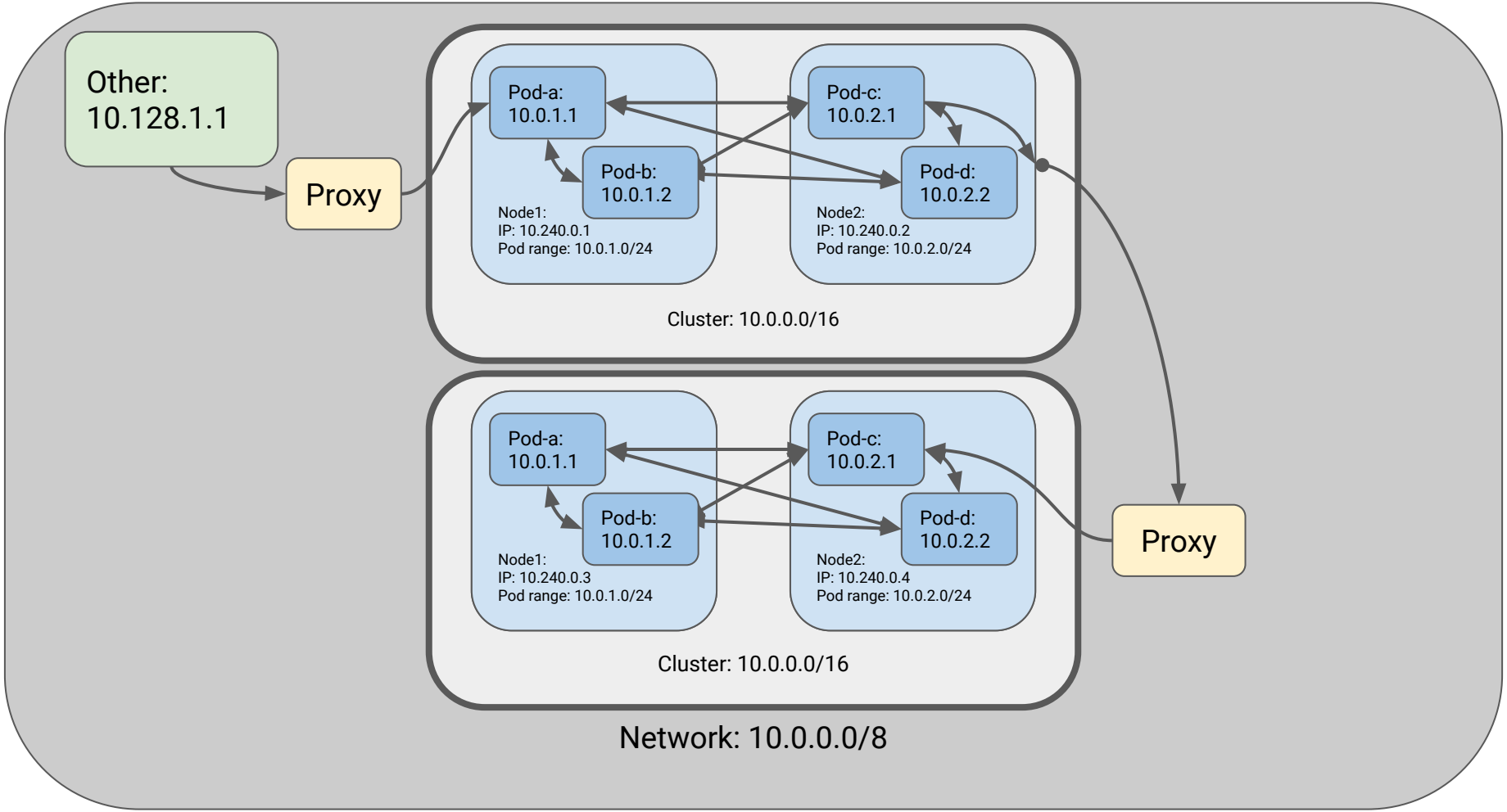
Gateway: VIP (ingress)


Other:
10.128.1.1
VIP
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
VIP
Network: 10.0.0.0/8

Similar to NodePort, but node uses IP dst_ip to route

Still needs something like SNAT to egress

Gateway: Proxy (ingress)


Other:
10.128.1.1
Proxy
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Proxy
Network: 10.0.0.0/8

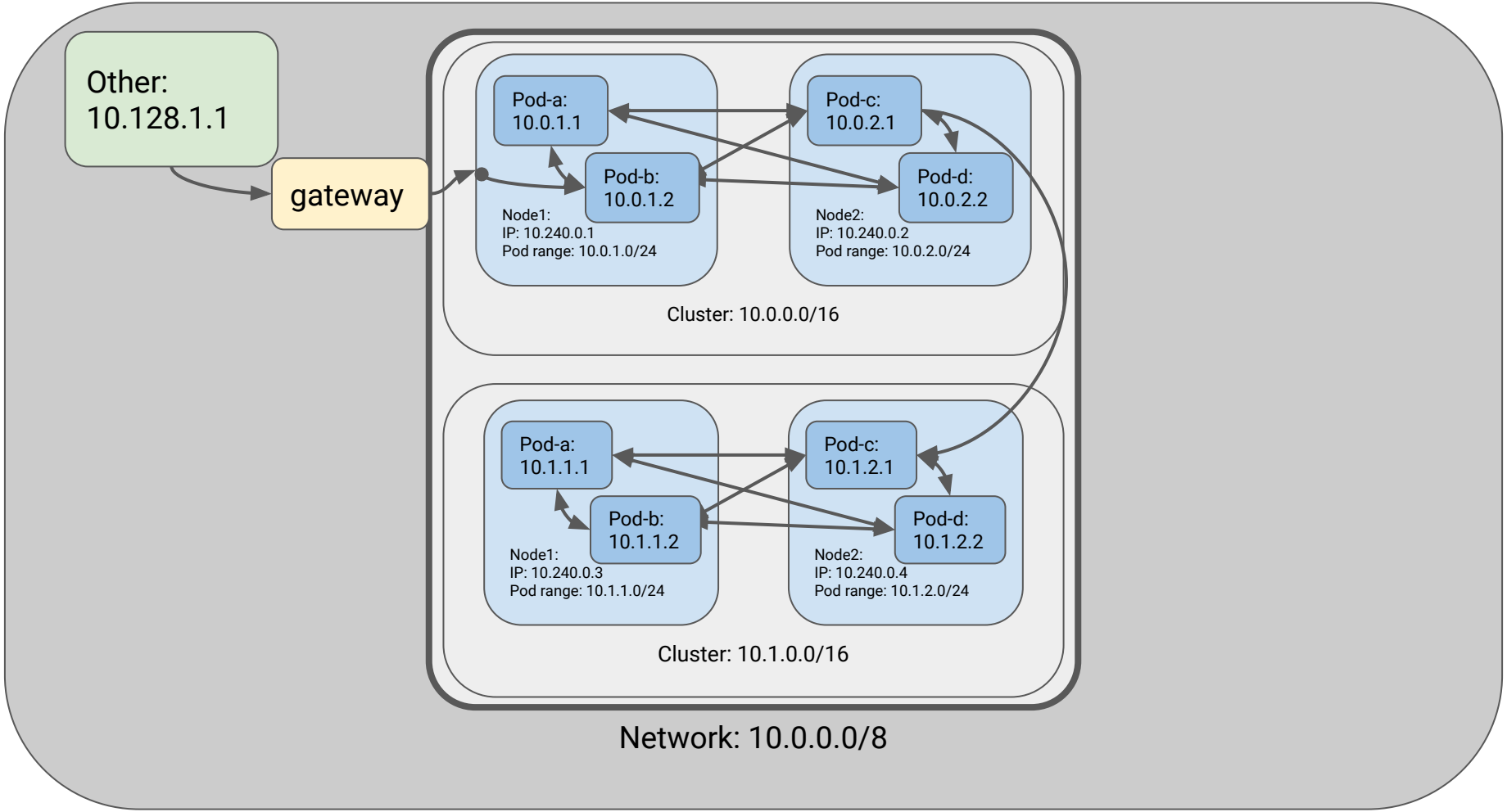
Can either route to NodePort or directly to pod IPs (e.g. proxy has special config to “get onto the island”)

Still needs something like SNAT to egress

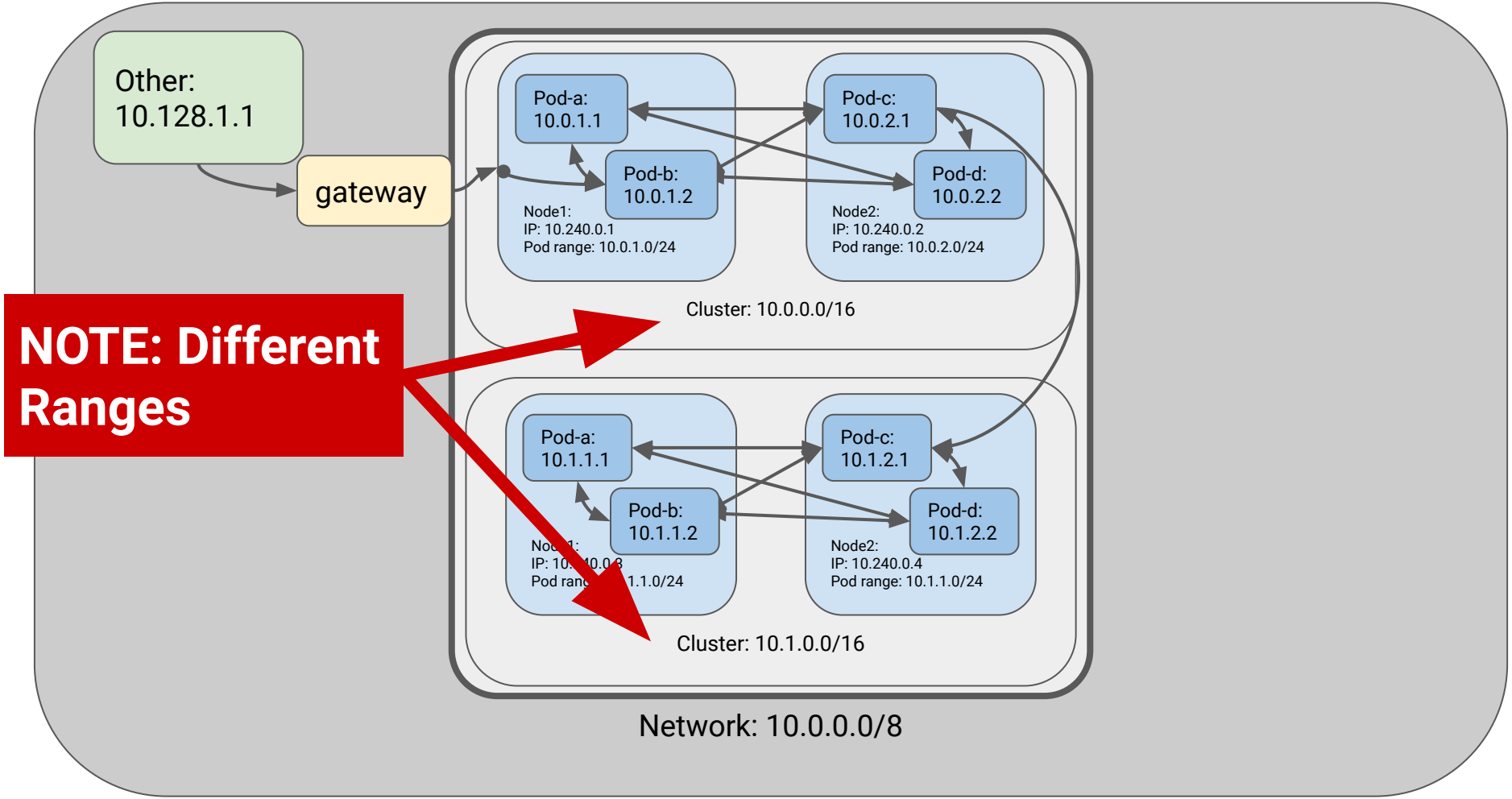
There’s a LOT more to know about ingress (for another presentation)

Options for egress are poorly explored, so far

Archipelago
(aka “bigger islands”)

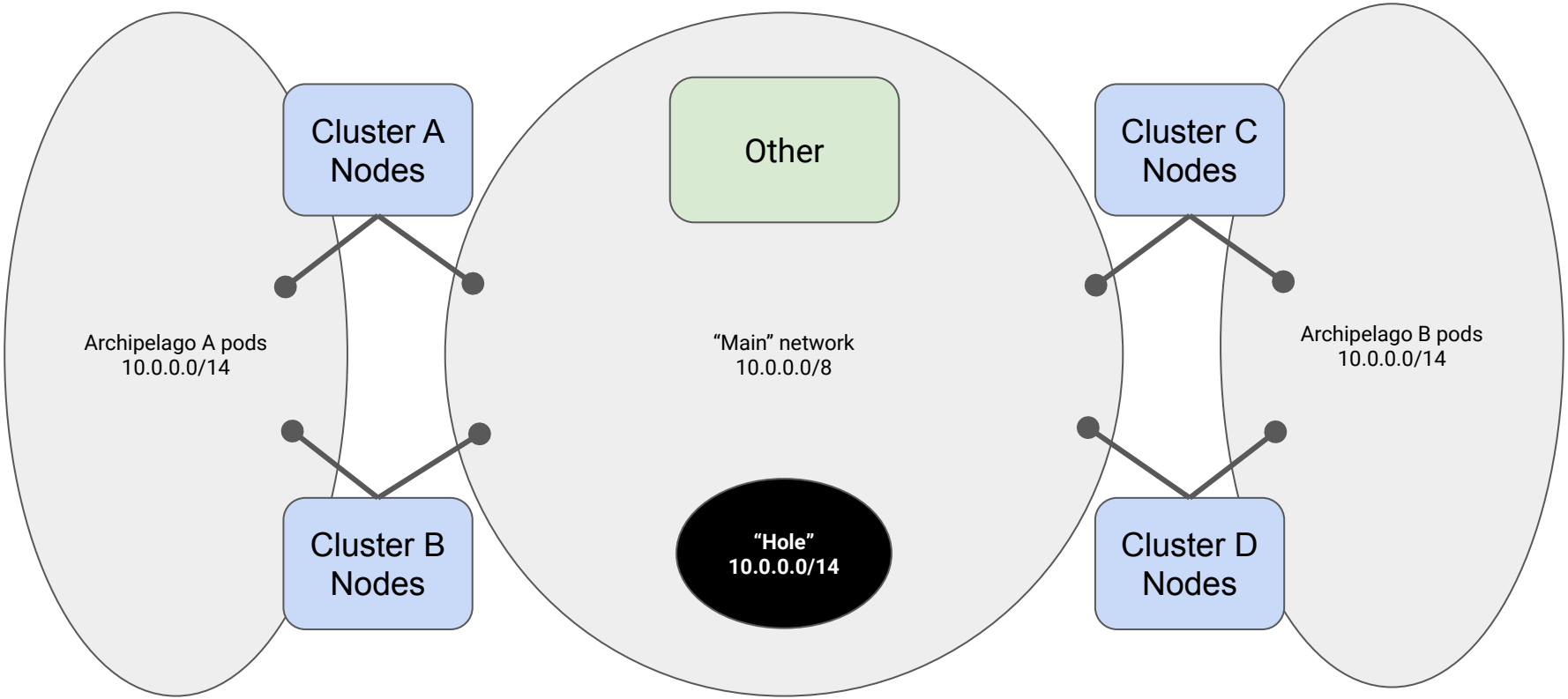

Other:
10.128.1.1
gateway
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
Pod-a:
10.1.1.1
Pod-b:
10.1.1.2
Node1:
IP: 10.240.0.3
Pod range: 10.1.1.0/24
Pod-c:
10.1.2.1
Pod-d:
10.1.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.1.2.0/24
Cluster: 10.1.0.0/16
Network: 10.0.0.0/8

Flat within the archipelago


Other:
10.128.1.1
gateway
Pod-a:
10.0.1.1
Pod-b:
10.0.1.2
Node1:
IP: 10.240.0.1
Pod range: 10.0.1.0/24
Pod-c:
10.0.2.1
Pod-d:
10.0.2.2
Node2:
IP: 10.240.0.2
Pod range: 10.0.2.0/24
Cluster: 10.0.0.0/16
NOTE: Different Ranges
Pod-a:
10.1.1.1
Pod-b:
10.1.1.2
Pod-c:
10.1.2.1
Pod-d:
10.1.2.2
Node2:
IP: 10.240.0.4
Pod range: 10.1.1.0/24
Cluster: 10.1.0.0/16
Network: 10.0.0.0/8

Can’t reuse pod IPs between clusters, but can between archipelagos

Island mode to the rest of the network


Cluster A Nodes
Other
Cluster C Nodes
Archipelago A pods
10.0.0.0/14
"Main" network
10.0.0.0/8
Archipelago B pods
10.0.0.0/14
Cluster B Nodes
"Hole"
10.0.0.0/14
Cluster D Nodes

Can be implemented as an overlay network or not

Good when:

- Need high integration across clusters
- Need some integration with non-kubernetes
- IP space is scarce / fragmented
- Network is not programmable / dynamic

Bad when:

- Need to debug connectivity
- Need direct-to-endpoint communications
- Need a lot of services exposed to non-k8s
- Rely on client IPs for firewalls
- Large number of nodes across all clusters

Gateway options are similar to plain island mode

Which one should you use?

There is no “right answer”. You have to consider the tradeoffs.

Sorry.