
KubeCon
CloudNativeCon
Europe 2023
TiKV

Demystifying IPv6 Kubernetes


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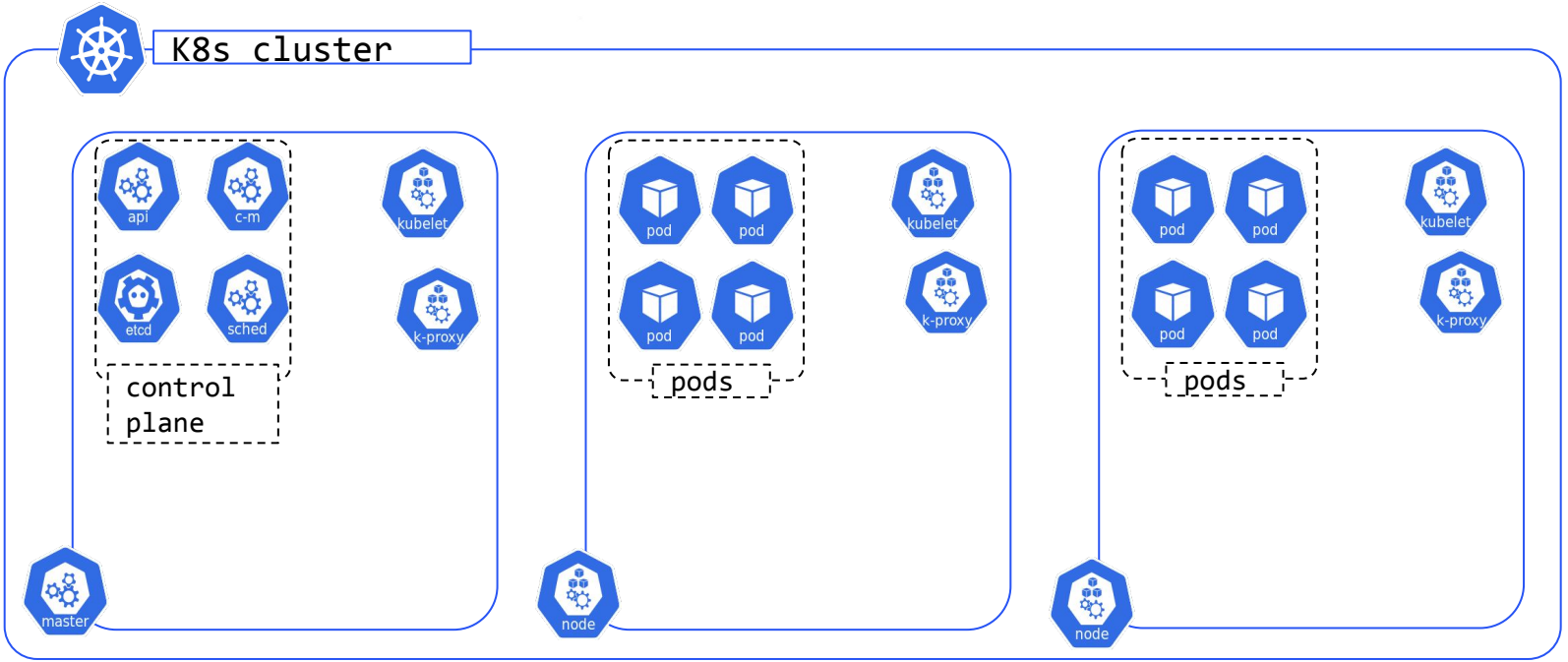
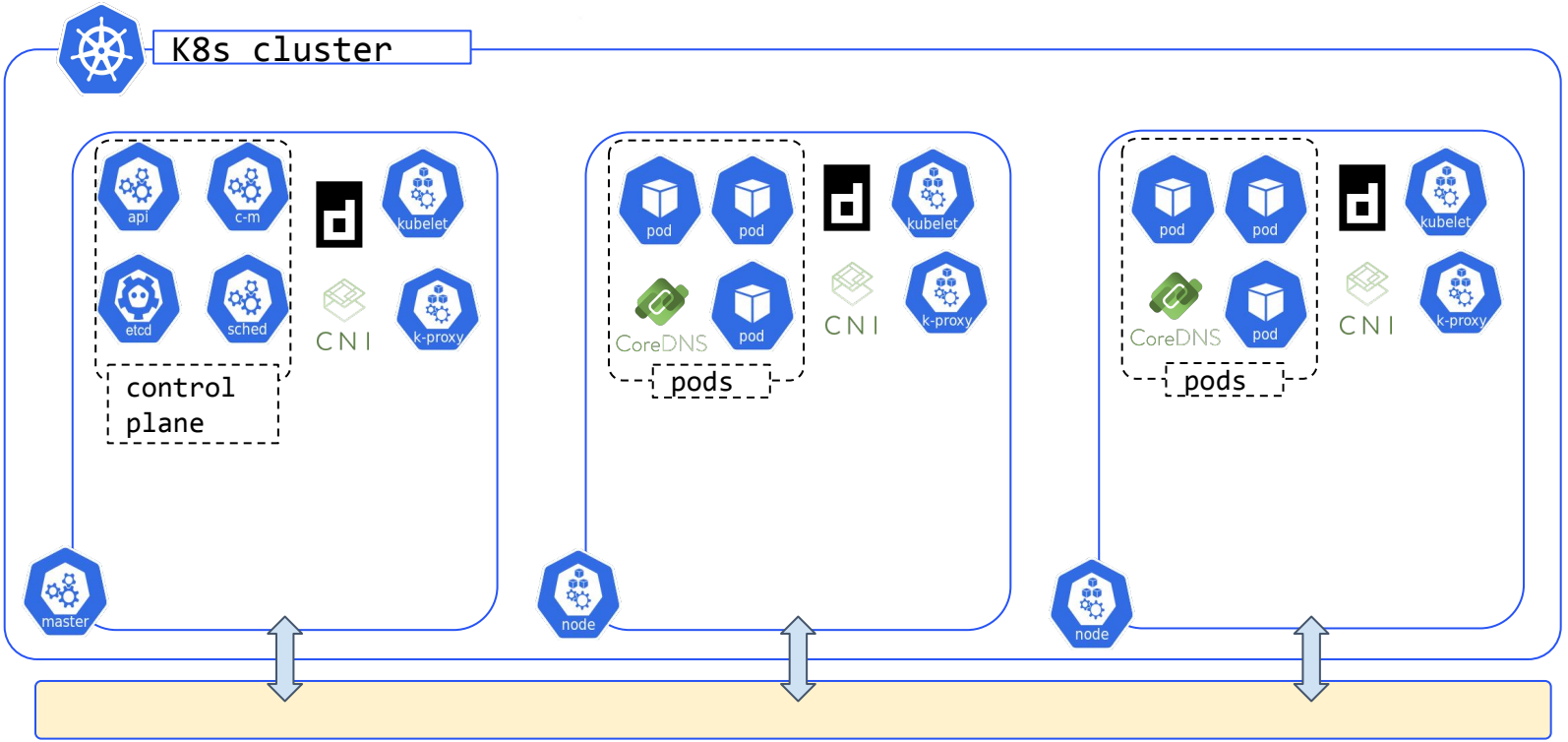
Kubernetes Networking Architecture

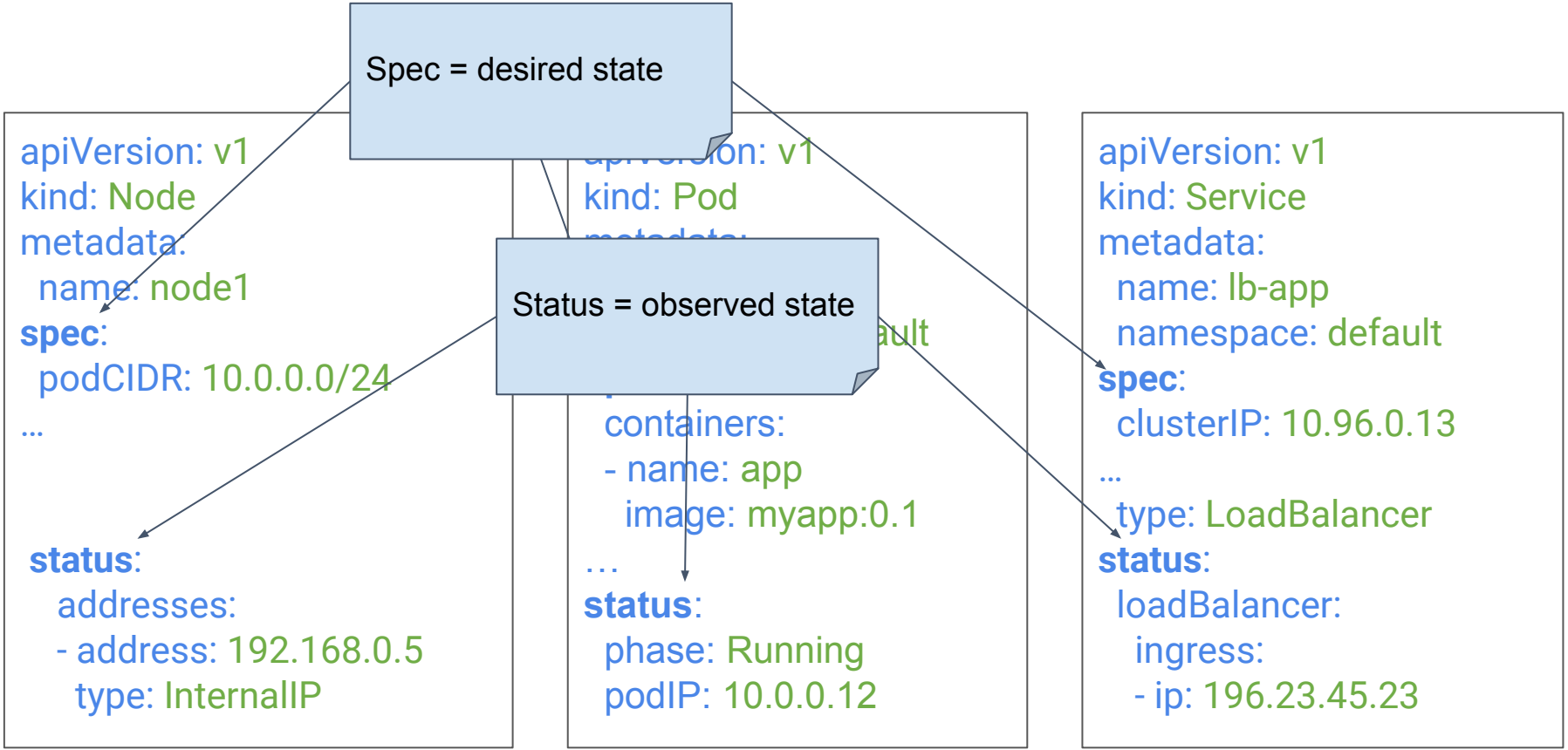
Kubernetes reference architecture



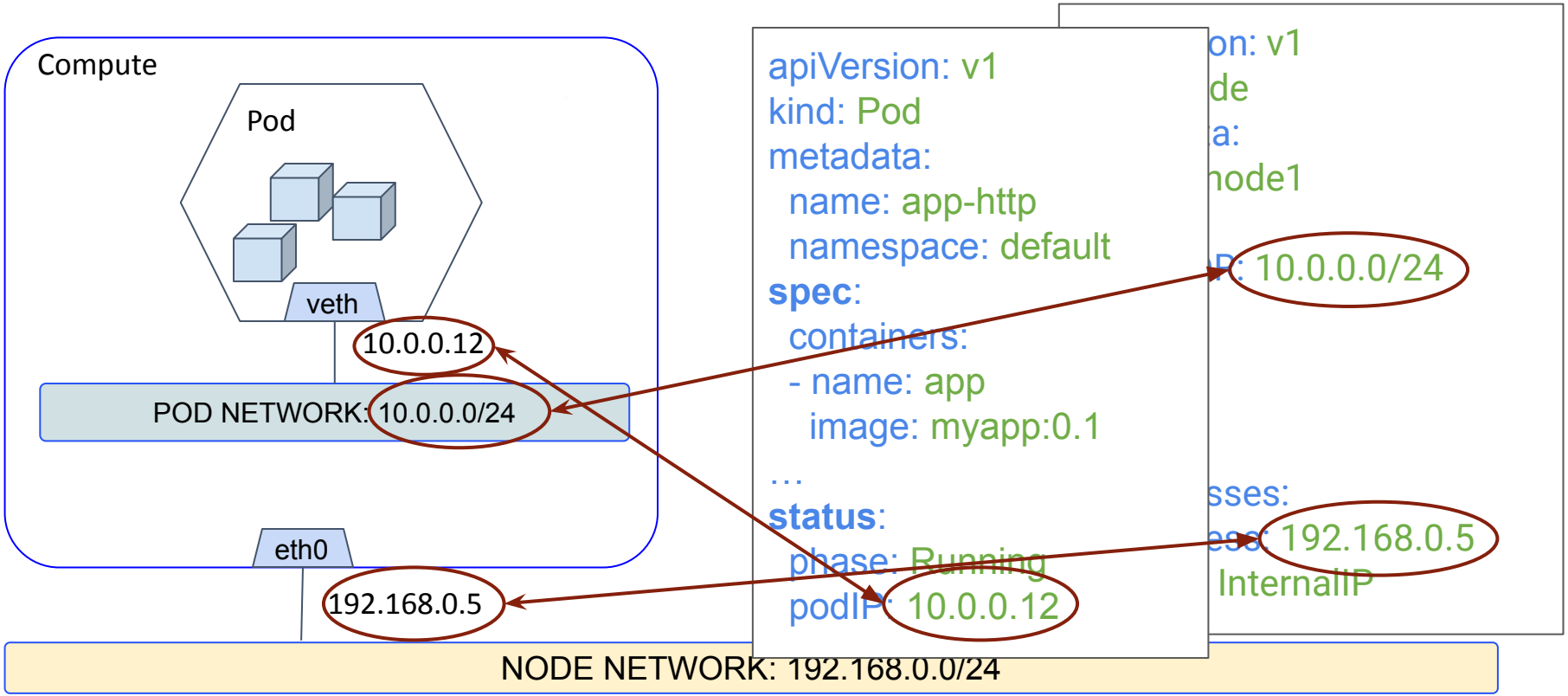
Kubernetes reference implementation



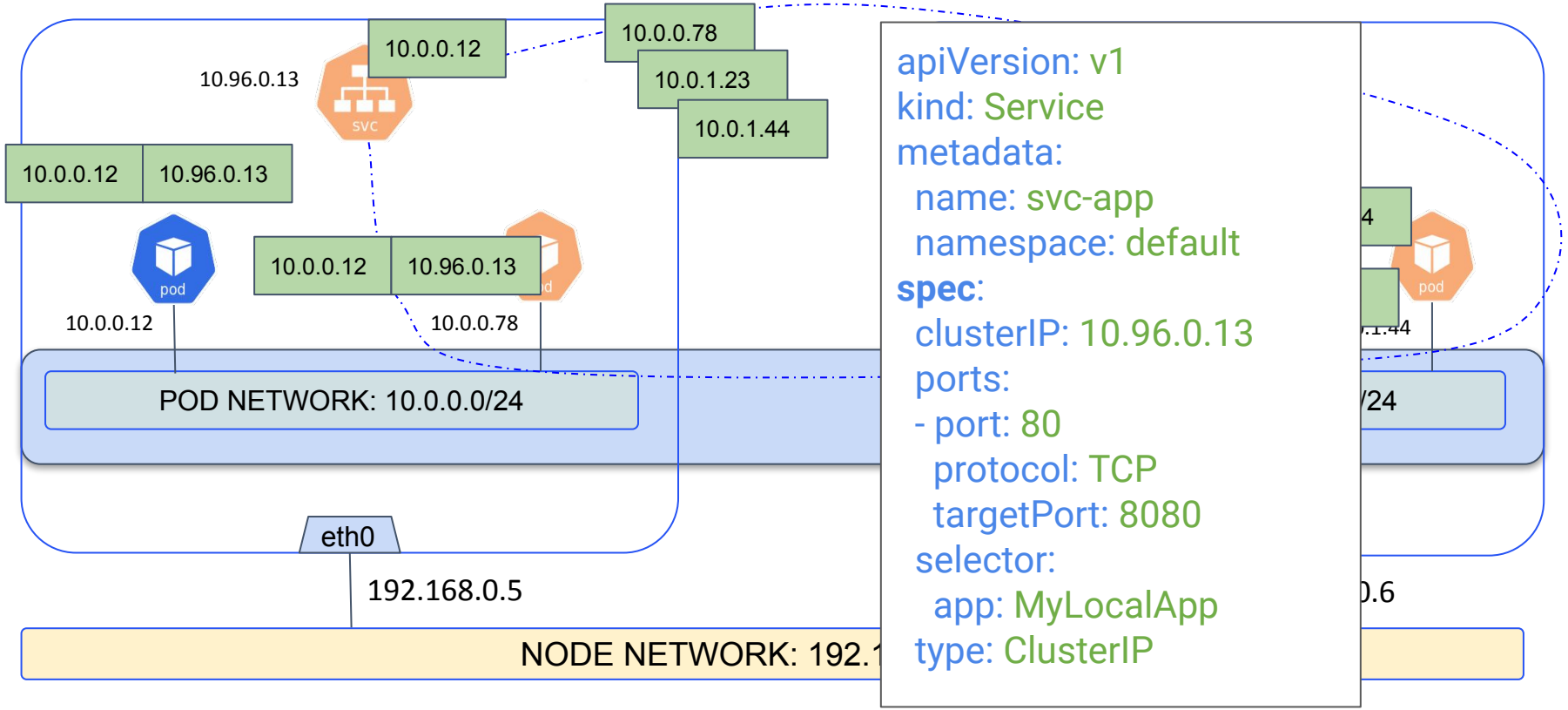
Kubernetes API



Kubernetes Networking: Pods

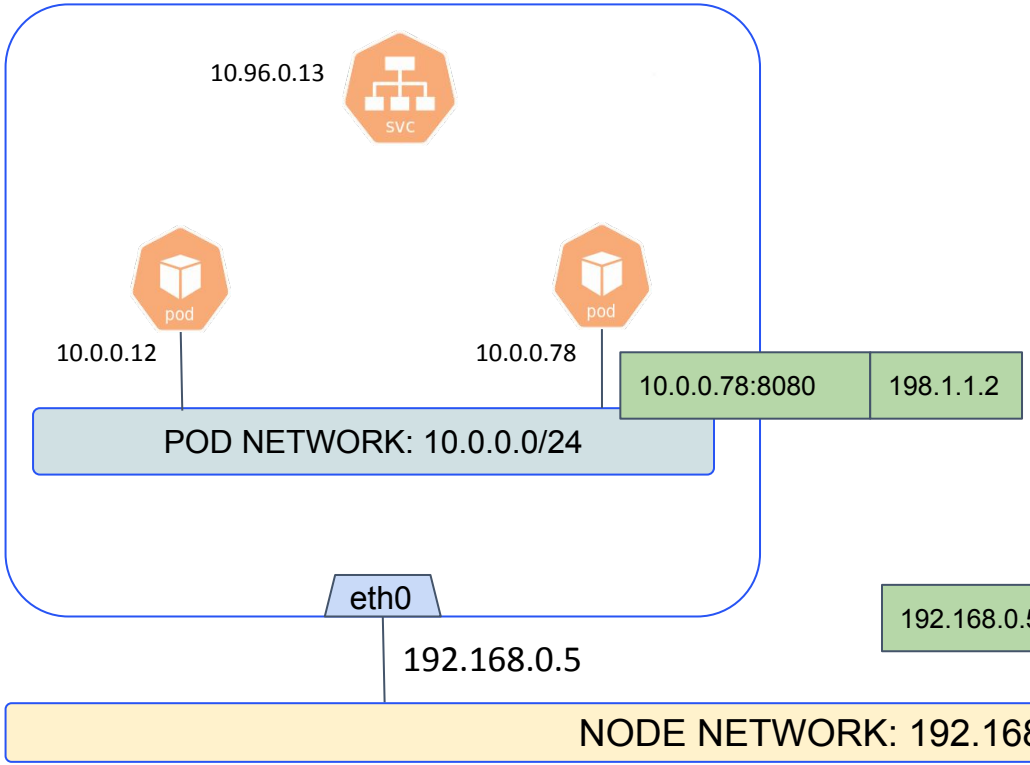


Kubernetes Networking: Services




```
apiVersion: v1
kind: Service
metadata:
  name: svc-app
  namespace: default
spec:
  clusterIP: 10.96.0.13
  ports:
  - port: 80
    protocol: TCP
    targetPort: 8080
  selector:
    app: MyLocalApp
  type: ClusterIP
```

Kubernetes Networking: Services



196.

192.168.0.5:32101

```yaml
apiVersion: v1
kind: Service
metadata:
  name: lb-app
  namespace: default
spec:
  clusterIP: 10.96.0.13
  ports:
  - nodePort: 32101
    port: 80
    protocol: TCP
    targetPort: 8080
  type: LoadBalancer
status:
  loadBalancer:
    ingress:
    - ip: 196.23.45.23
```

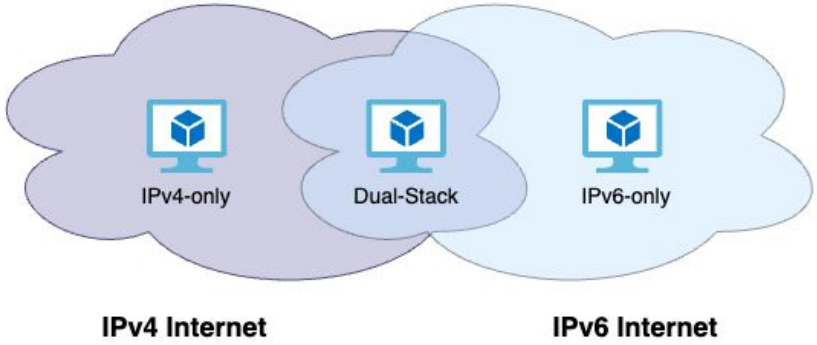
Internet Protocol version 6 (IPv6)

Brief history of IPv6

- The Internet relies on unique IP addresses for host communication
- But 20+ years ago it was evident IPv4 addresses would be exhausted
- Short-term solutions (stop-gaps):
  - Classless Internet Domain Routing (CIDR)
  - Variable Length Subnet Masking (VLSM)
  - NAT (industry-driven)
- Long term solution:
  - IPv6

IPv6 in a Nutshell

- Designed to tackle the problem of IPv4 address exhaustion
- Backwards **incompatible** with IPv4
- Original transition/deployment model: dual-stack



IPv6 Addressing Overview

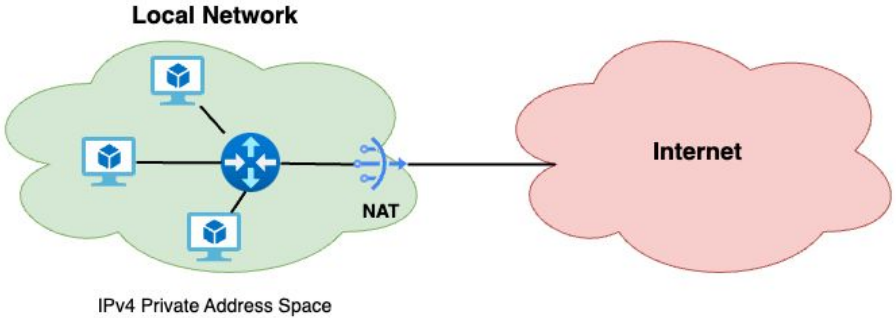
- IPv6 addresses are 128-bit long
- Similarly to IPv4:
  - Addresses can be aggregated into prefixes (e.g. for routing)
  - Multiple address types (unicast, multicast…)
  - Multiple address scopes (link-local, unique-local, global)
- But IPv6 hosts typically employ **multiple addresses** of different properties
- IPv6 subnets are typically a /64

IPv6 Unique Local Addresses (ULAs)

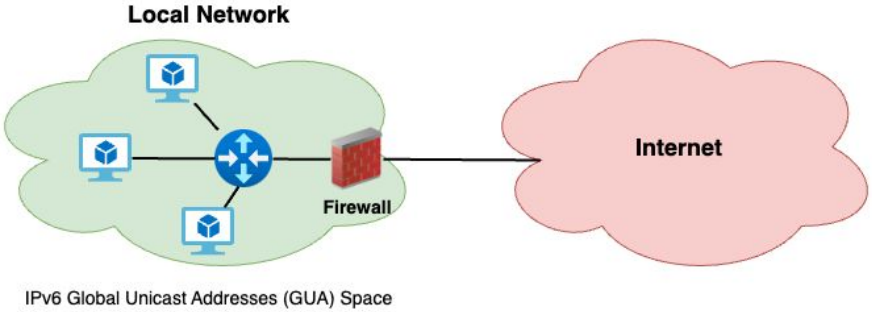
- Provide private address space for IPv6
  - IPv6-version of RFC1918 addresses
  - ULA prefix is randomized to avoid address space overlaps
  - Controversial feature in the IPv6 addressing architecture
- Expected use case:
  - Internal communications within a network
  - **Not** meant to be used in combination with IPv6 NAT

Deployment models: IPv4 vs. IPv6

IPv4



IPv6



Kubernetes & IPv6

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Kubernetes API: IPv4


```
apiVersion: v1
kind: Node
metadata:
  name: node1
spec:
  podCIDR: 10.0.0.0/24
...

status:
  addresses:
  - address: 192.168.0.5
    type: InternalIP
```

```
apiVersion: v1
kind: Pod
metadata:
  name: app-http
  namespace: default
spec:
  containers:
  - name: app
    image: myapp:0.1
…
status:
  phase: Running
  podIP: 10.0.0.5
```

```
apiVersion: v1
kind: Service
metadata:
  name: lb-app
  namespace: default
spec:
  clusterIP: 10.96.0.13
...
  type: LoadBalancer
status:
  loadBalancer:
    ingress:
    - ip: 196.23.45.23
```

Kubernetes API: IPv6

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```
apiVersion: v1
kind: Node
metadata:
  name: node1
spec:
  podCIDR: fd00:1234:1::/64
...

status:
  addresses:
  - address: fd01:789a:1::1
    type: InternalIP
```

```
apiVersion: v1
kind: Pod
metadata:
  name: app-http
  namespace: default
spec:
  containers:
  - name: app
    image: myapp:0.1
...
status:
  phase: Running
  podIP: fd00:1234:1::1
```

```
apiVersion: v1
kind: Service
metadata:
  name: lb-app
  namespace: default
spec:
  clusterIP: fd12:789a:1::1
...
  type: LoadBalancer
status:
  loadBalancer:
    ingress:
    - ip: 2001:db8:7:8::4
```

Kubernetes API: Dual Stack

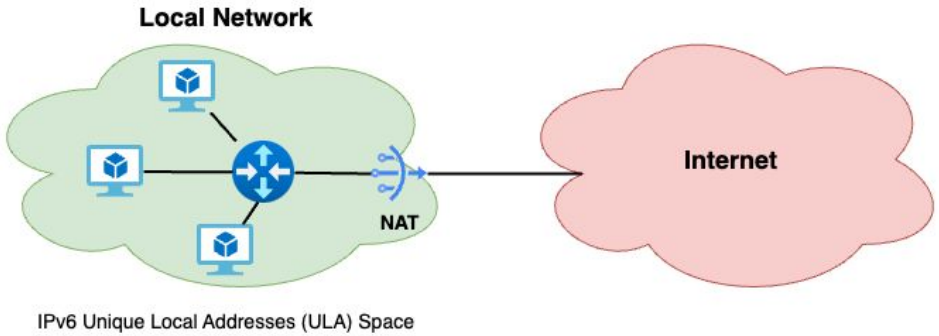

```
apiVersion: v1
kind: Node
metadata:
  name: node1
spec:
  podCIDR: 10.0.0.0/24
  podCIDRs:
    -    10.0.0.0/24
    -    fd00:1234:1::/64
...
 status:
    addresses:
    - address: fd01:789a:1::1
      type: InternalIP
    - address: 192.168.0.1
      type: InternalIP
```

```
apiVersion: v1
kind: Pod
metadata:
  name: app-http
  namespace: default
spec:
  containers:
  - name: app
    image: myapp:0.1
…
status:
  phase: Running
  podIP: 10.0.0.5
  podIPs:
    -    10.0.0.5
    -    fd00:1234:1::1
```

```
apiVersion: v1
kind: Service
metadata:
  name: lb-app
  namespace: default
spec:
  clusterIP: 10.96.0.13
  clusterIPs:
    -    10.96.0.13
    -    fd12:789a:1::1
...
  type: LoadBalancer
status:
  loadBalancer:
    ingress:
    - ip: 192.168.21.8
    - ip: 2001:db8:7:8::4
```

IPv6 support in Kubernetes

- One common implementation strategy is replicate the IPv4 architecture with IPv6:
  - Use Unique Local Addresses (private address space) virtually everywhere
  - Expose services with a global (public) address via a load-balancer
- Well-understood model: IPv6 architecture matches the IPv4 counterpart



Kubernetes & IPv6: The Future Ahead

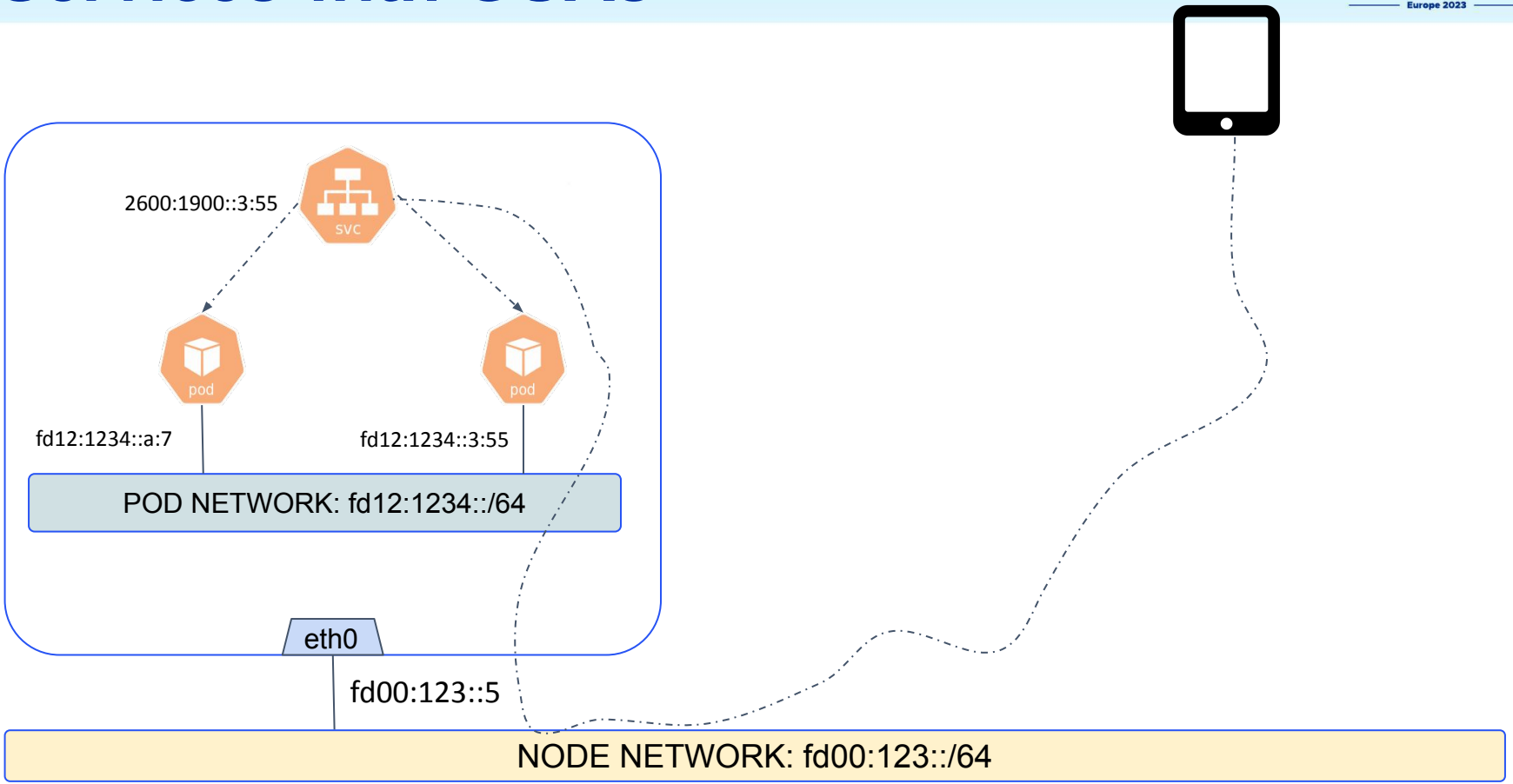
IPv6 support in Kubernetes (revisited)

- Kubernetes IPv6 support mimics its IPv4 counterpart
- Are we missing a chance to leverage IPv6 capabilities?
- How could we possibly evolve IPv6 support?
- What if we were to leverage Global Unicast Addresses?

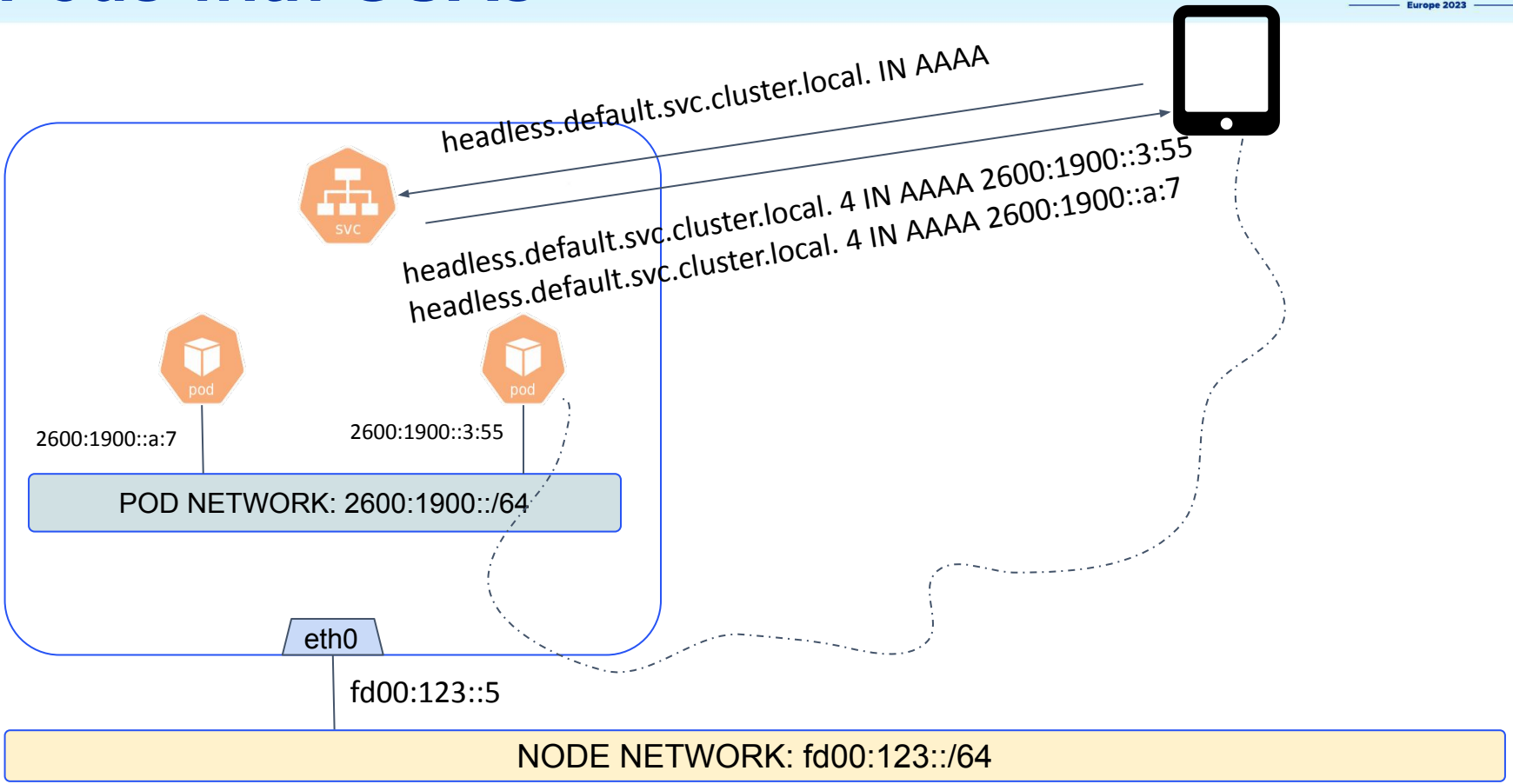
Leveraging global IPv6 addresses

- Services with Global Unicast Addresses (GUAs)
  - Remove one layer of translation!
- Pods with GUAs, and leverage the DNS
  - Remove two layers of translation!

Services with GUAs



Pods with GUAs

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