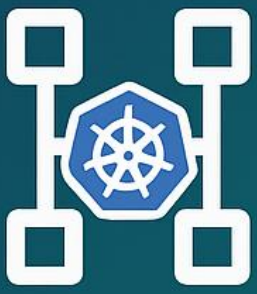
🚀 Master Kubernetes Networking

From Basics to Advanced eBPF & Enterprise SDN



42 slides of pure networking mastery

CNI Plugins • Service Types • OVN-K8s
eBPF • Production Tips

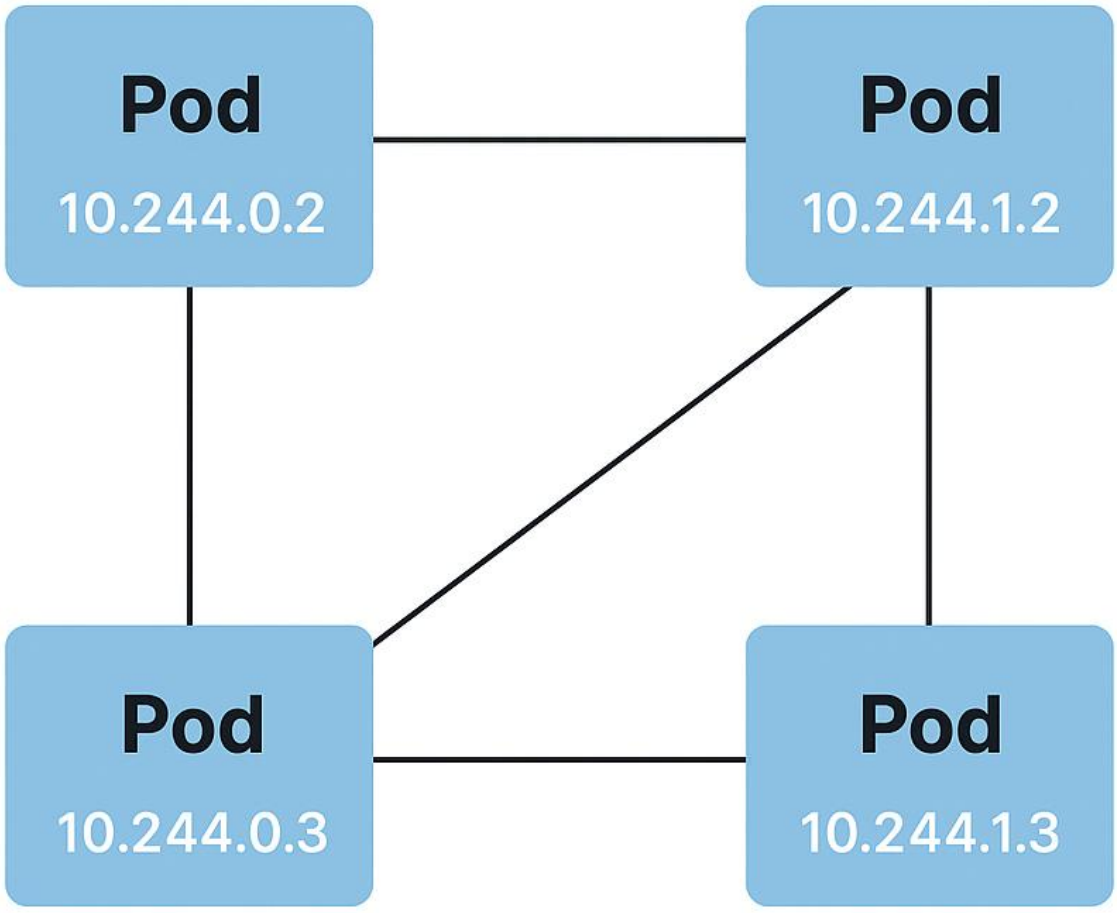
Swipe for complete networking guide →

What's Inside This Guide:

- Kubernetes networking fundamentals
- CNI plugins deep dive
- eBPF implementation secrets
- Real-world troubleshooting
- Production best practices
- Advanced load balancing

The K8s Networking Foundation

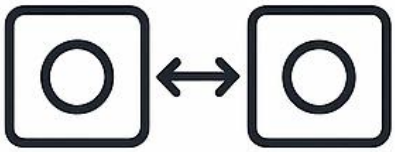
- Flat address space for all pods
- Each pod gets unique IP address
- No NAT required between pods
- Containers share pod IP via localhost



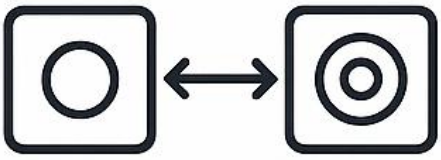
THE FOUR PILLARS OF K8s NETWORKING

4 Core Communication Types:

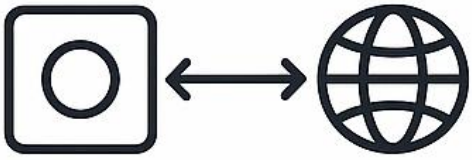
Intra-pod
(container ↔ container)



Pod-to-pod communication



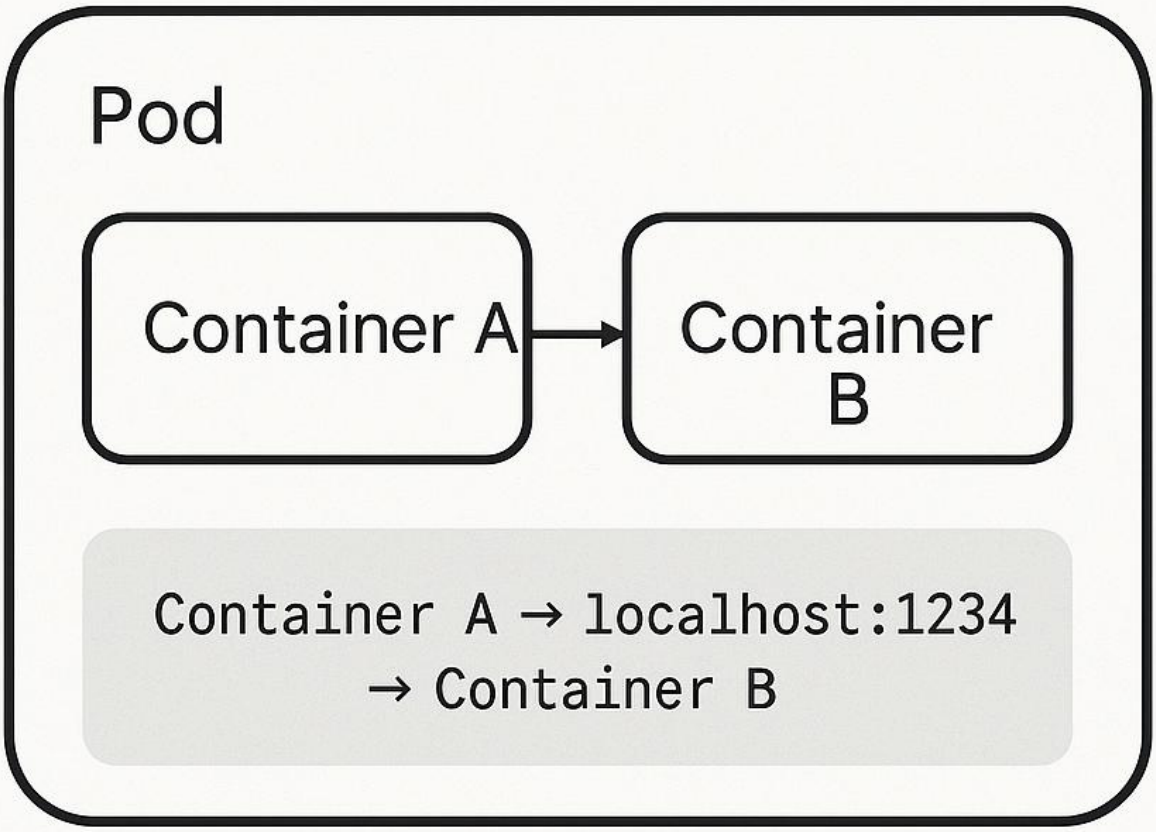
Pod-to-service communication



External access patterns

Master these = Master K8s networking

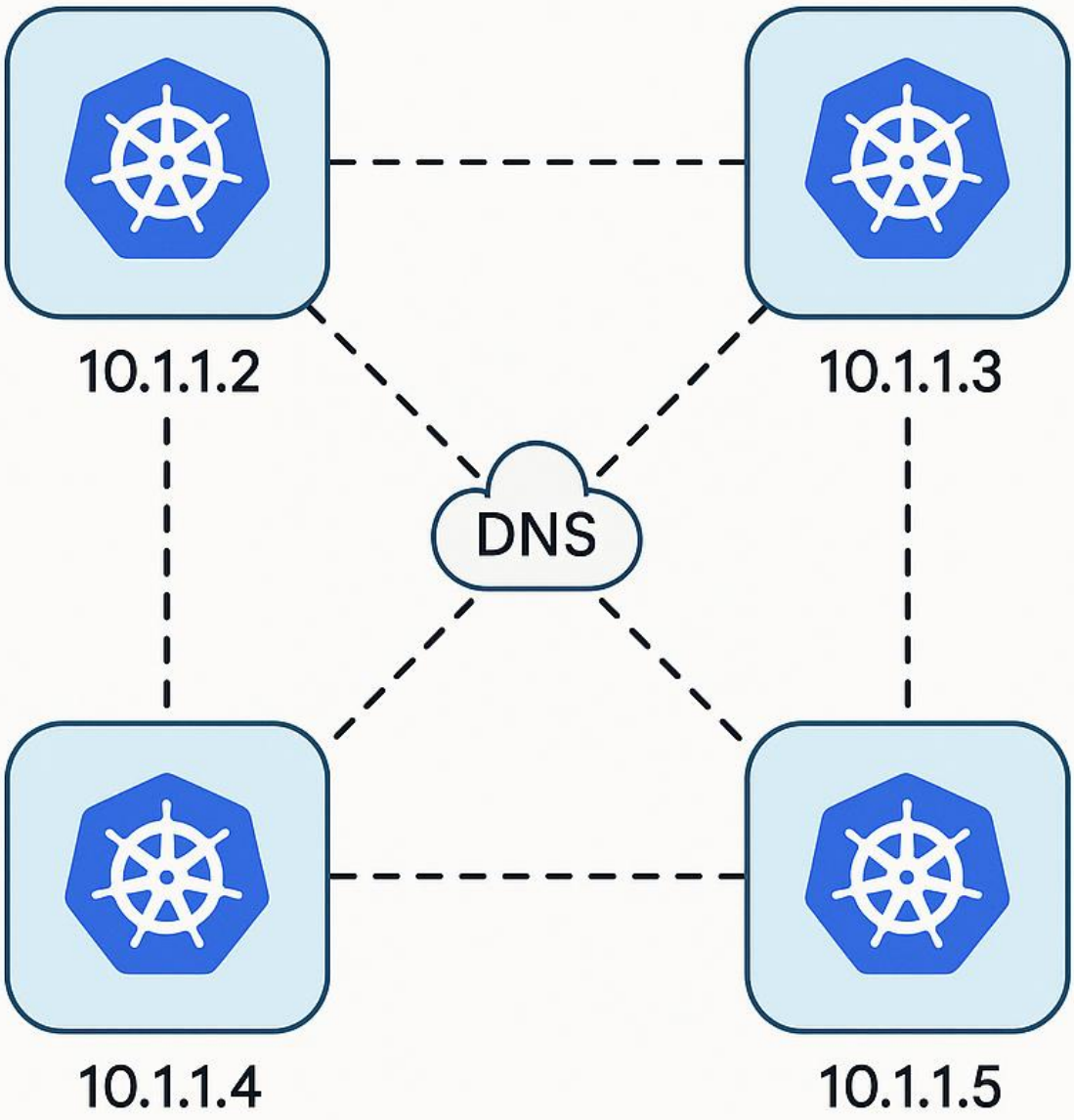
Inside the Pod Network



Containers share
network namespace

Pro Tip:
No port conflicts between pods!

Direct Pod Communication



- Network-visible IP addresses
- No NAT/tunnels/proxies needed
- Standard DNS works out of the box
- Well-known ports for easy config

Seamless app migration

Kubernetes Services Explained

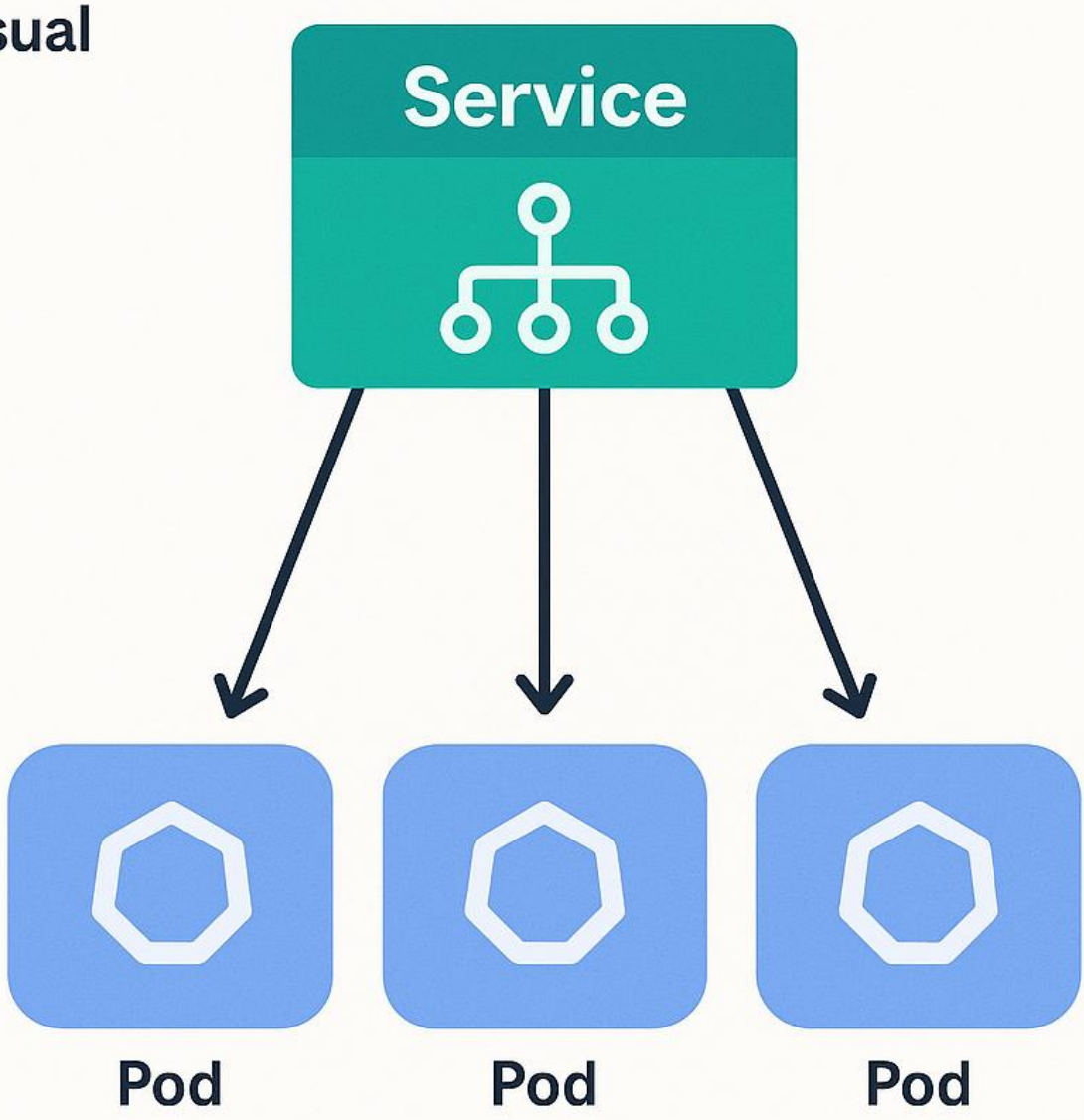
Problem: Pods are ephemeral, IPs change

Solution: Services provide stable endpoints

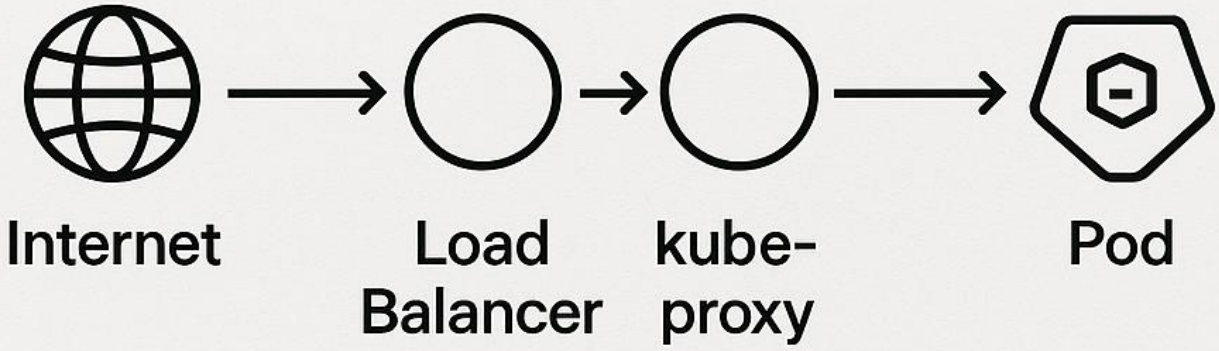
Benefits

- Automatic load balancing
- Service discovery
- Health checking

Visual



Reaching Your Apps

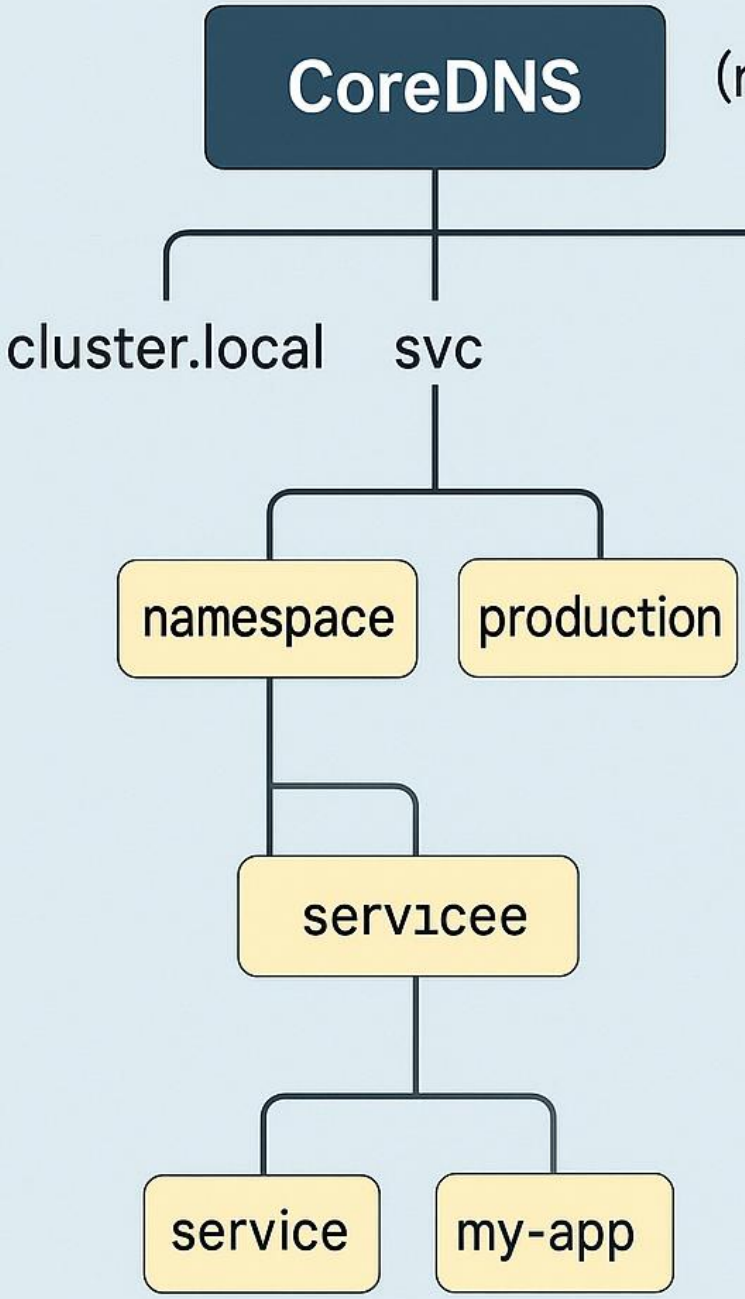


Challenge: Double-hop routing overhead

Solutions: NodePort, LoadBalancer, Ingress

Performance tip: Consider service mesh for optimization

Name Resolution Made Simple



FQDN Format:

`service.namespace.svc.cluster.local`

Example:

`my-app.production svc.cluster.local`

Pro Tip:

“Use short names within namespace”

DNS Setup in Action

- Headless service creation

```
apiVersion: v1
kind: Service
metadata:
 name: my-service
spec:
  clusterIP: None
  ports: 80
  targetPort: 9376
```

- Pod hostname configuration

```
apiVersion: v1
kind: Pod
metadata: name-my-pod
spec:
  hostname: busybox
  containers:
  - name: busybox
  image: busybox
```

- FQDN resolution

```
$ host my-pod.my-servic.default.svc.
cluster.local has address 10.1.0.120
```

Troubleshooting: Check `/etc resolv.conf` in pods

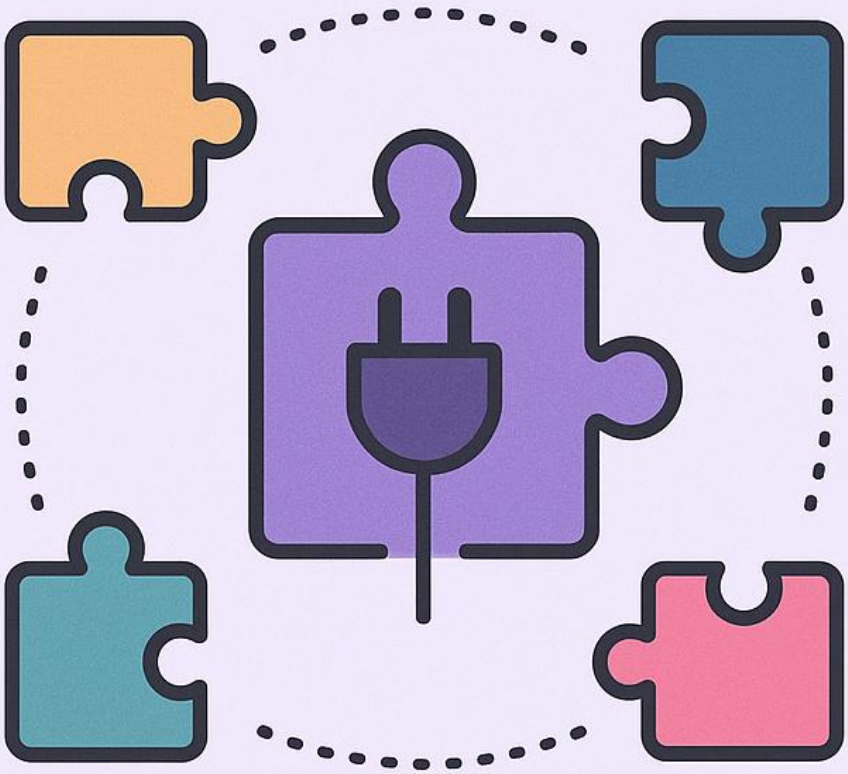
The Plugin Revolution

Why needed:

Diverse networking requirements

Two main types:

- Kubenet (basic, legacy)
- CNI (modern, extensible)



Choose what fits your needs

Built on Linux Networking

- Network namespaces
- Virtual Ethernet (veth) pairs
- Bridges and routing
- IP addresses and ports

Understanding Linux = Understanding K8s

veth: The Virtual Cable

Purpose

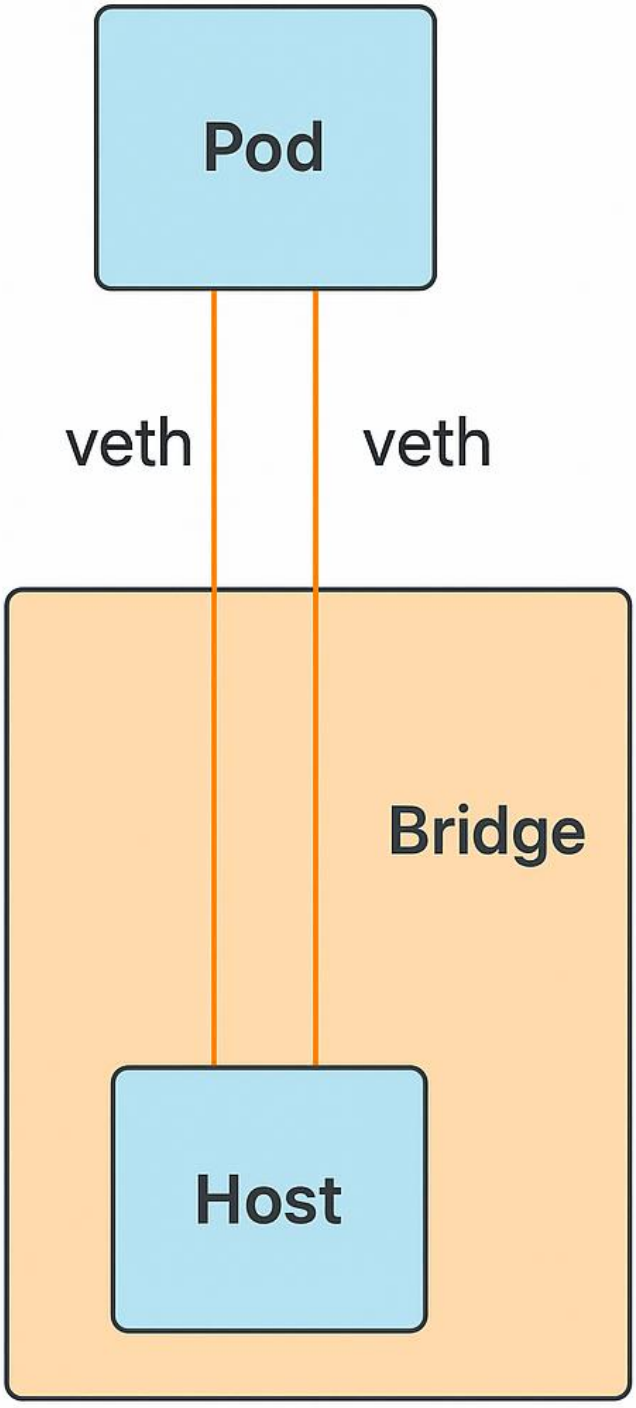
Connect containers to host network

How it works

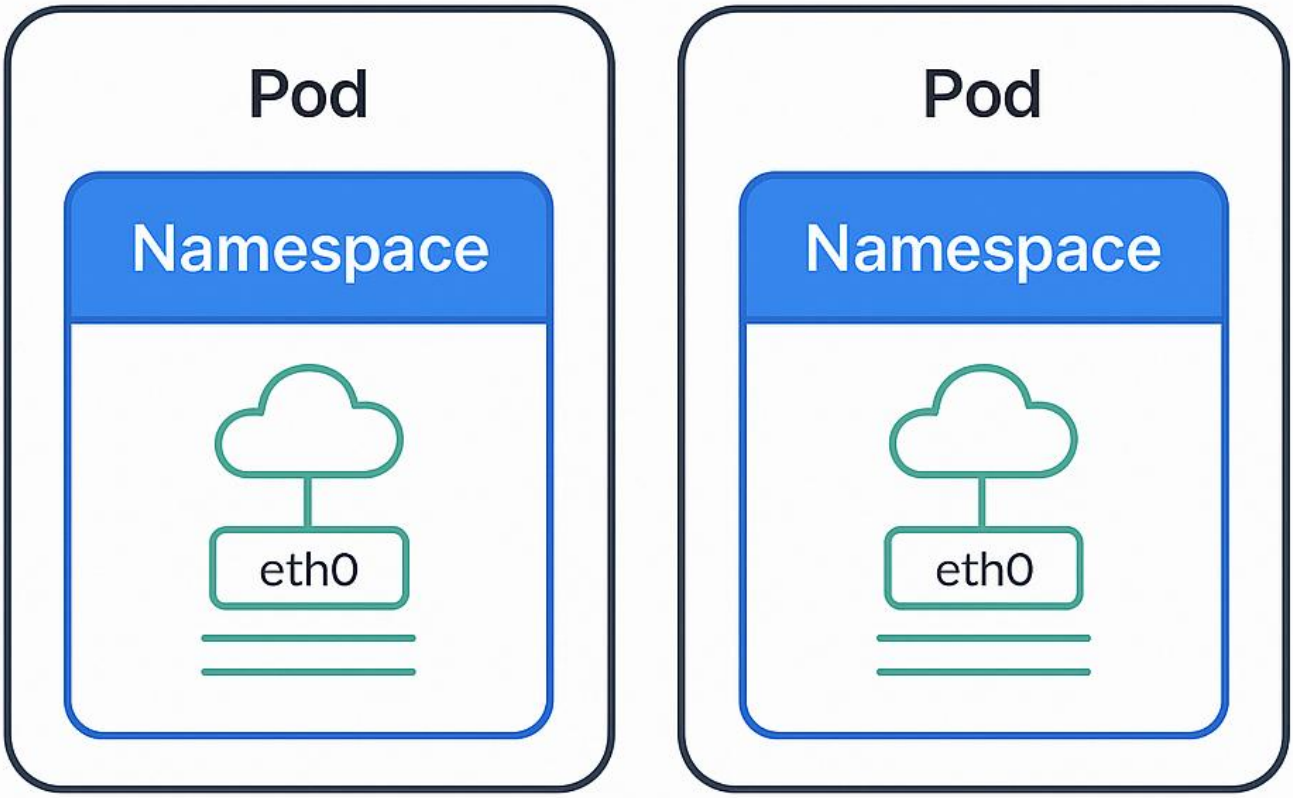
Paired virtual interfaces

Use case

Pod ↔ Host communication



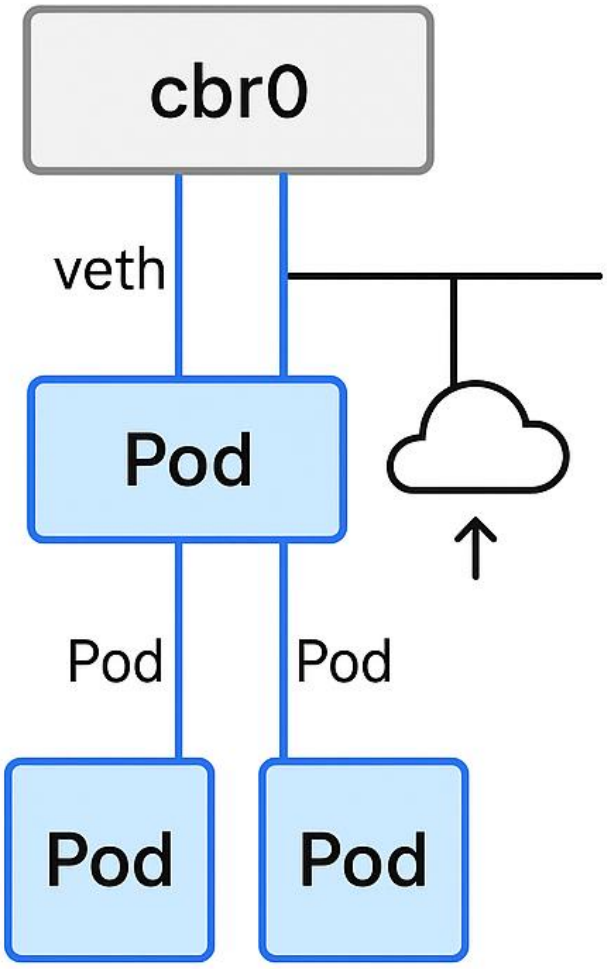
Isolation Through Namespaces



- Network isolation
- No IP conflicts
- Security boundaries

Each pod = own namespace

Kubenet: Keep It Simple



Creates cbr0 bridge + veth pairs

Use cases:

- Single-node environments
- Cloud provider routing
- Learning/ development

Limitation:

“Basic functionality only”

CNI: Container Network Interface

Why it matters

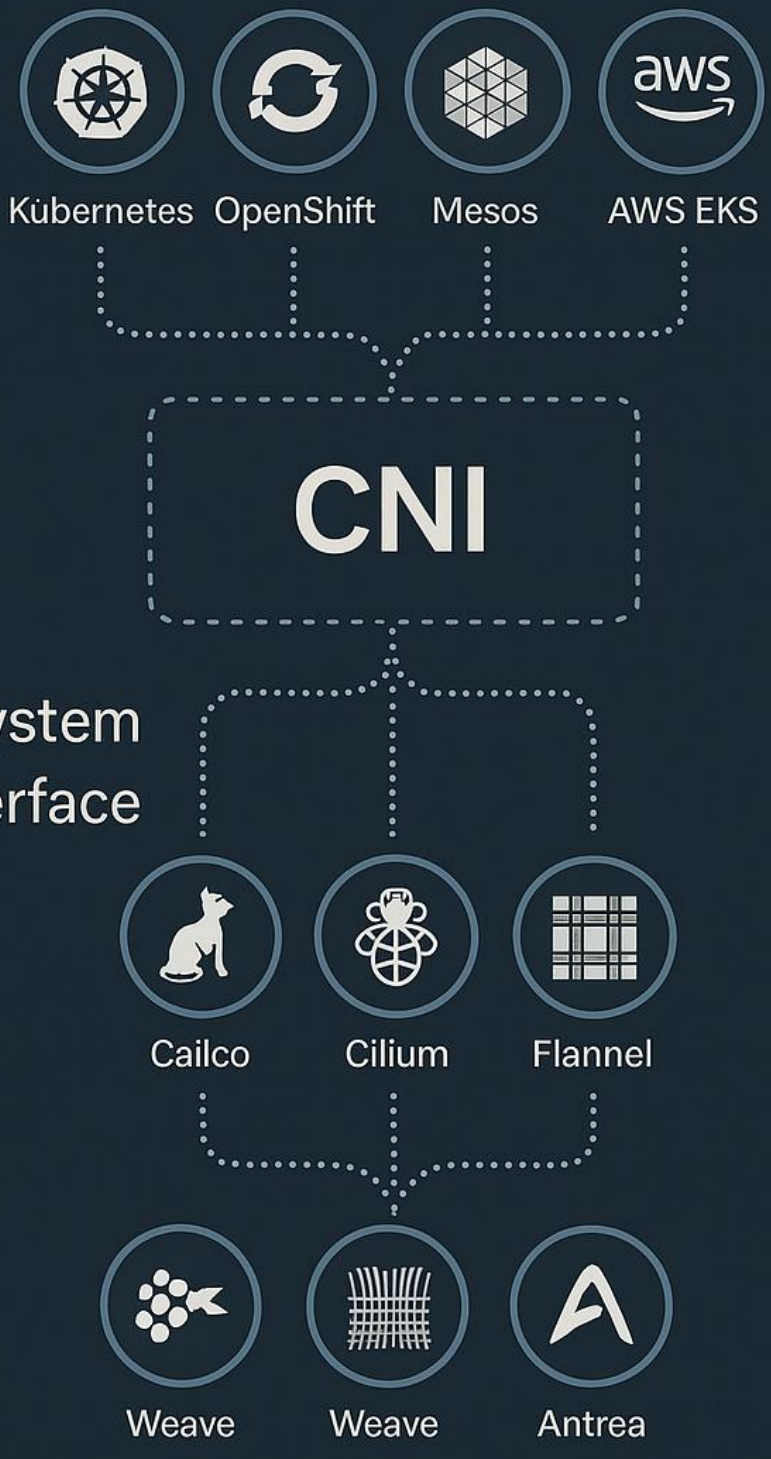
Industry standard

Used by:

Kubernetes
OpenShift
Mesos
AWS EKS

Benefits:

- Vendor flexibility
- Rich plugin ecosystem
- Standardized interface



CNI Plugin Ecosystem

Calico

Layer 3 virtual networking

Flannel

Simple overlay networking

Weave Net

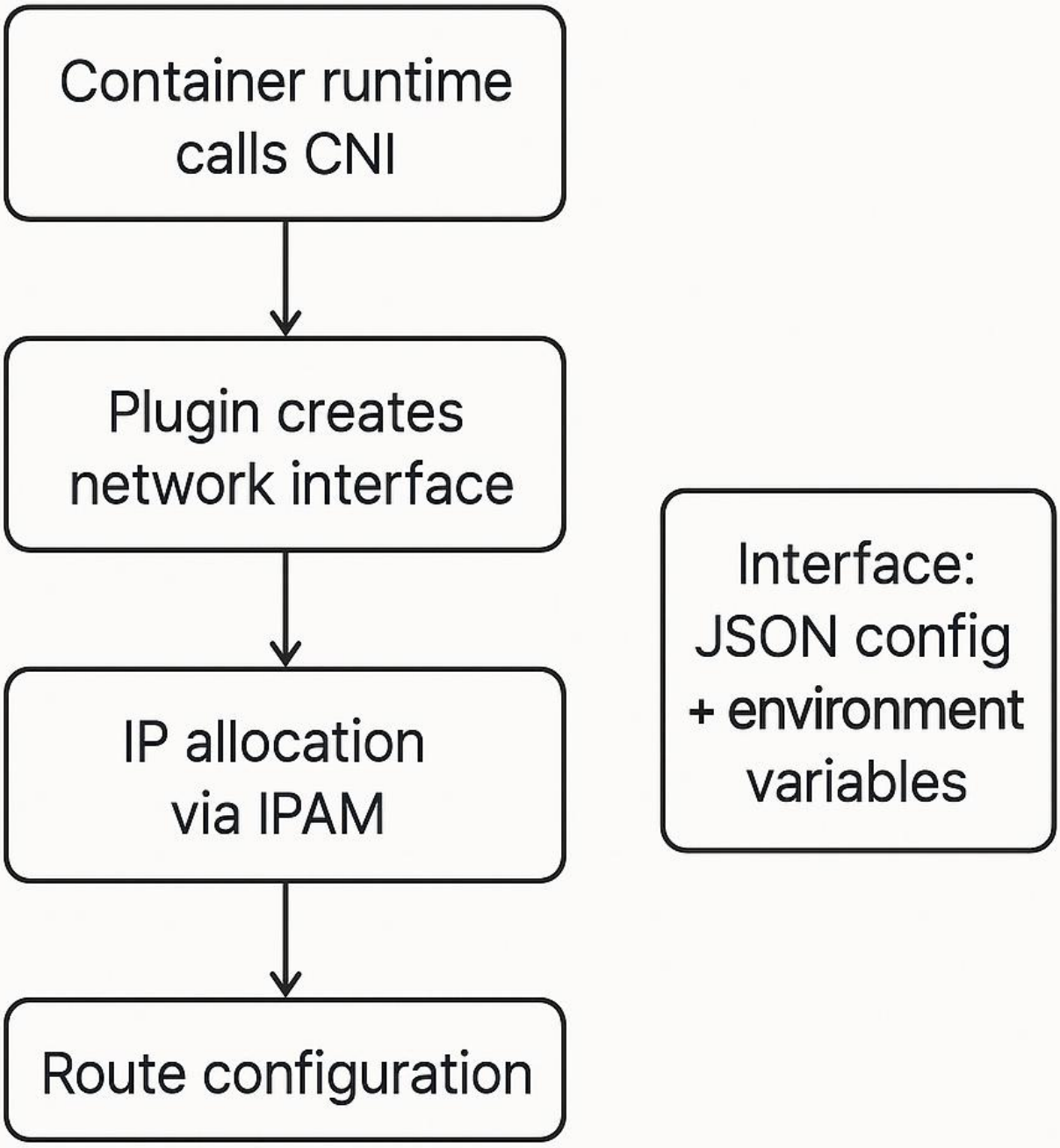
Zero-config networking

Cilium

eBPF-powered networking

Each with specific strengths and use cases

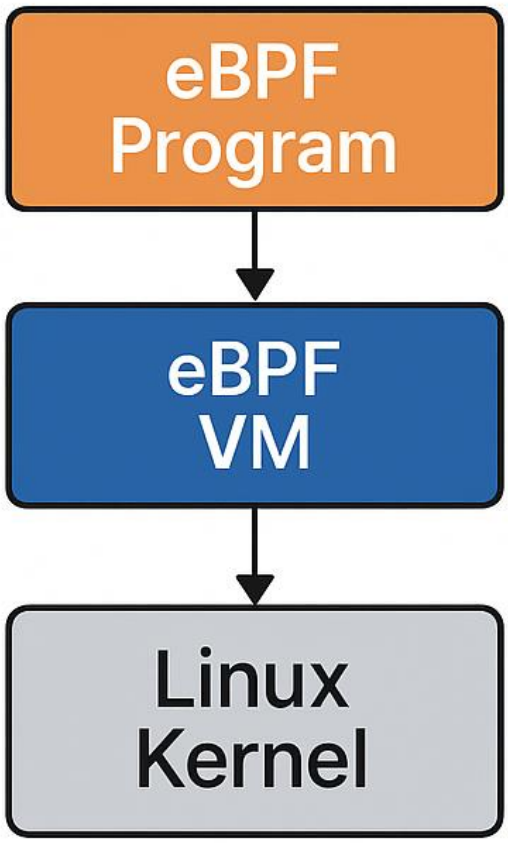
How CNI Plugins Work



eBPF: The Linux Superpower

What it is

In-kernel programmable networking



Benefits:

- No kernel modules needed
- High performance
- Advanced observability

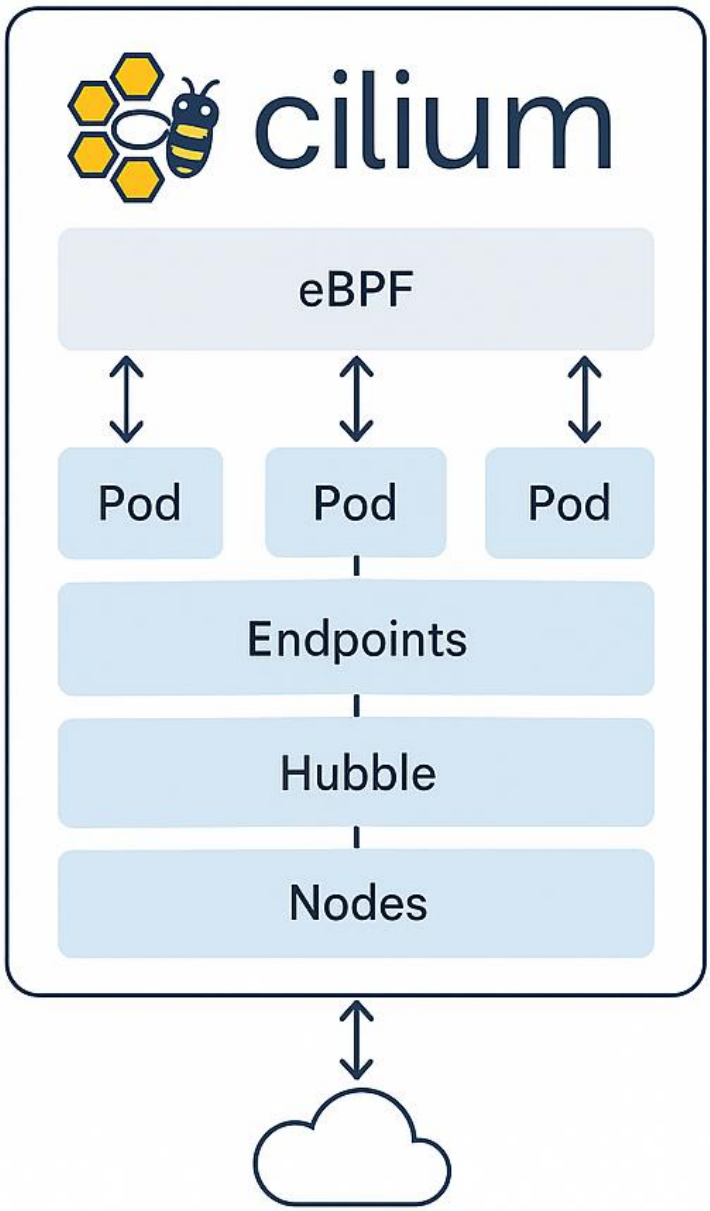
"The Linux superpower"
—Brendan Gregg

Why eBPF Matters

Traditional	eBPF
Networking	User-space → kernel transitions
Performance	In-kernel processing
Use cases	Load balancing, security, observability
Future	The new networking standard

Cilium: eBPF Networking Pioneer

CNCF Project: Production-ready

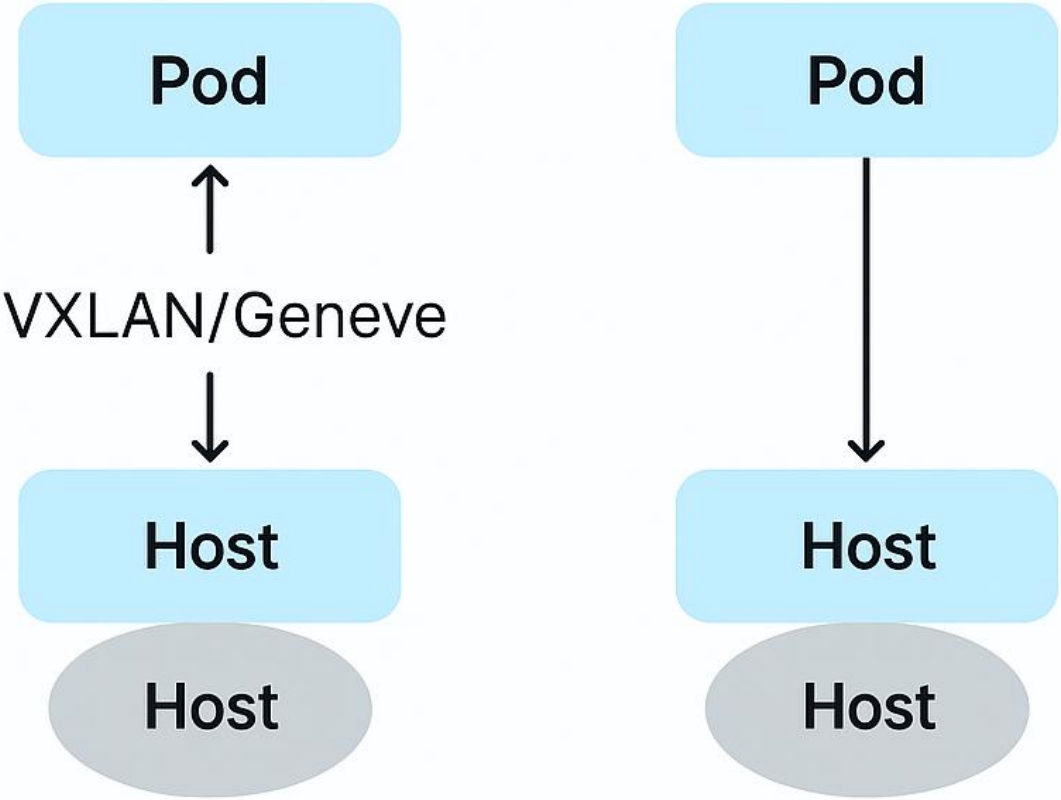


- Identity-based security
- Load balancing without kube-proxy
- Advanced observability (Hubble)
- Multi-cluster networking

Cilium Flexibilitty

Overlay Mode
VXLAN/Geneve encapsulation

Native Routing
Direct host rou-ting



- Choice depends on: Infrastructure capabilities
- Performance: Native > Overlay
- Complexity: Overlay < Native

Load Balancing Reimagined

Traditional

kube-proxy

iptables

Cilium

eBPF hashtables

- Better performance
- Lower CPU usage
- Advanced algorithms (Maglev)

Scale beyond limits

Zero-Trust Networking

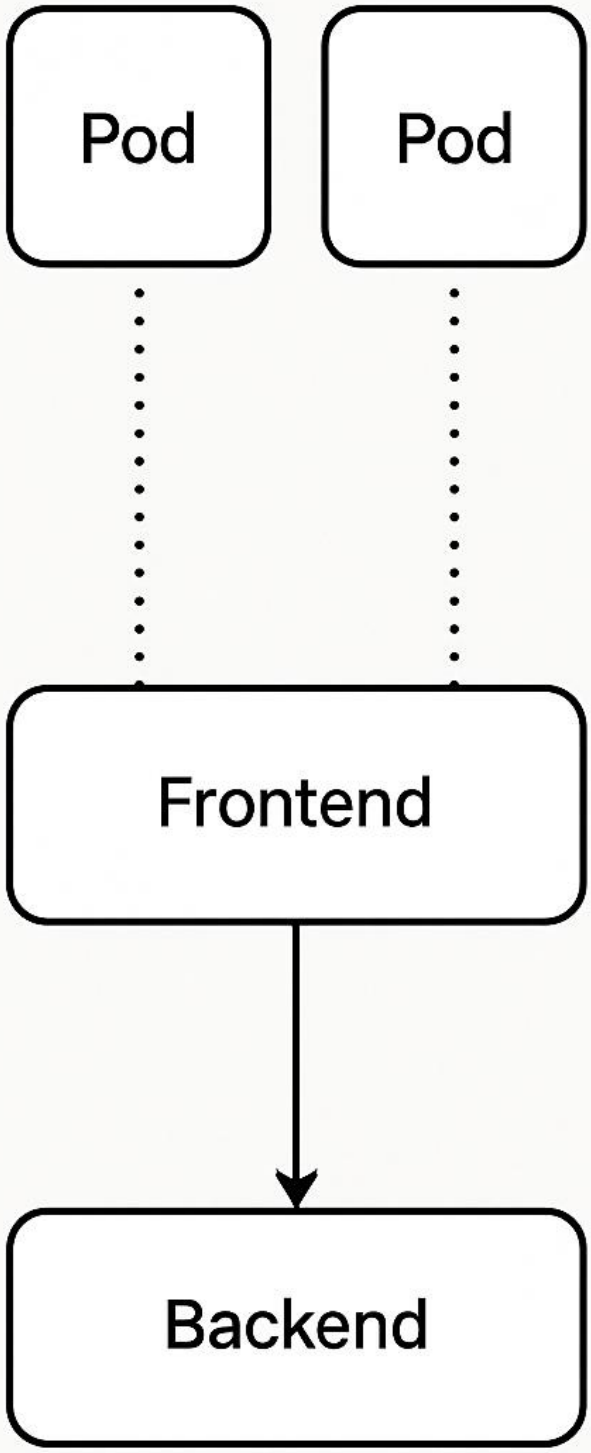
Default: All pods can communicate

Network Policies: Explicit allow rules

Implementation: Calico (reference)

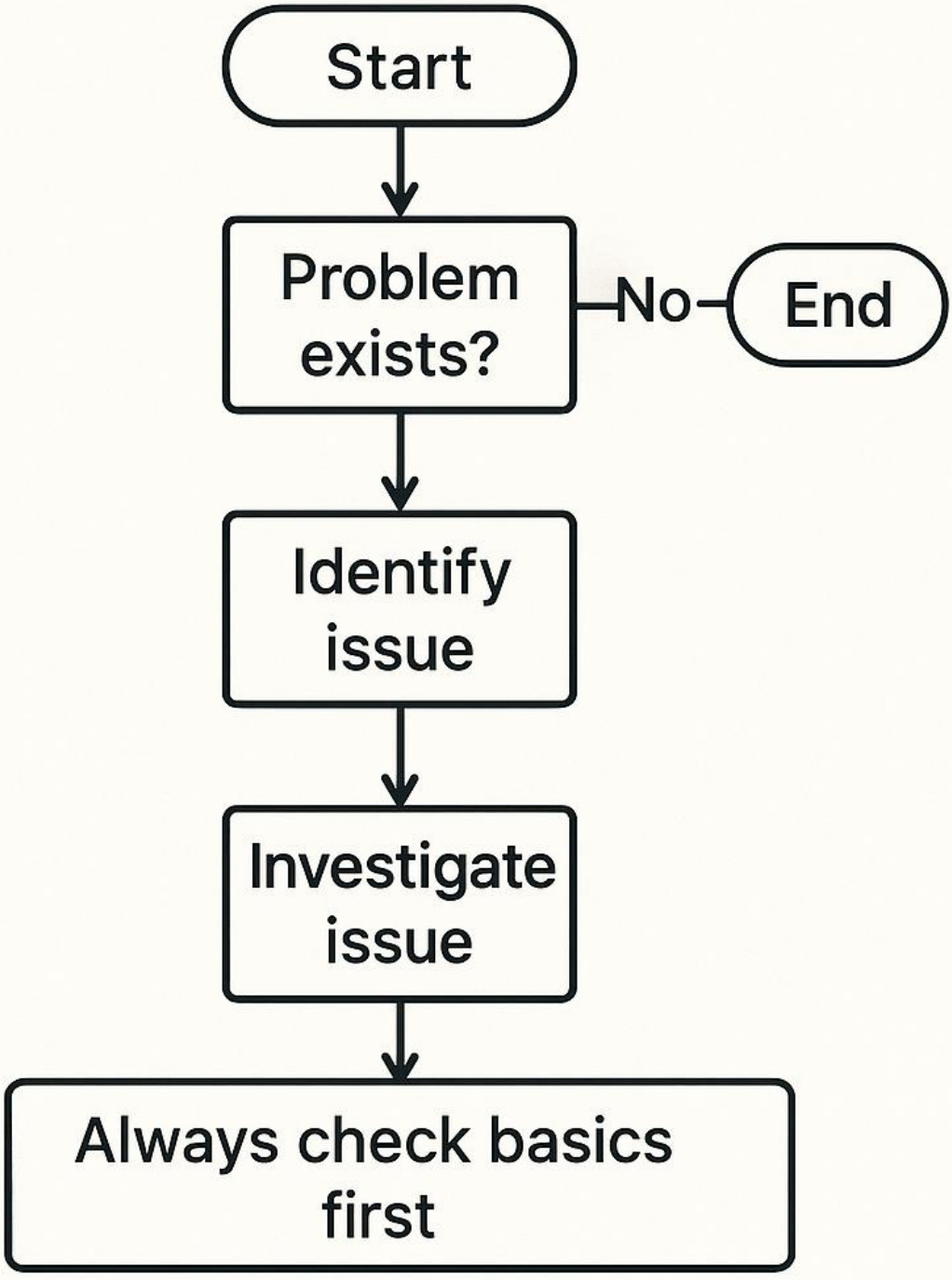
Best Practice: "Start with deny-all"

Example: Frontend → Backend only



Network Debugging Toolkit

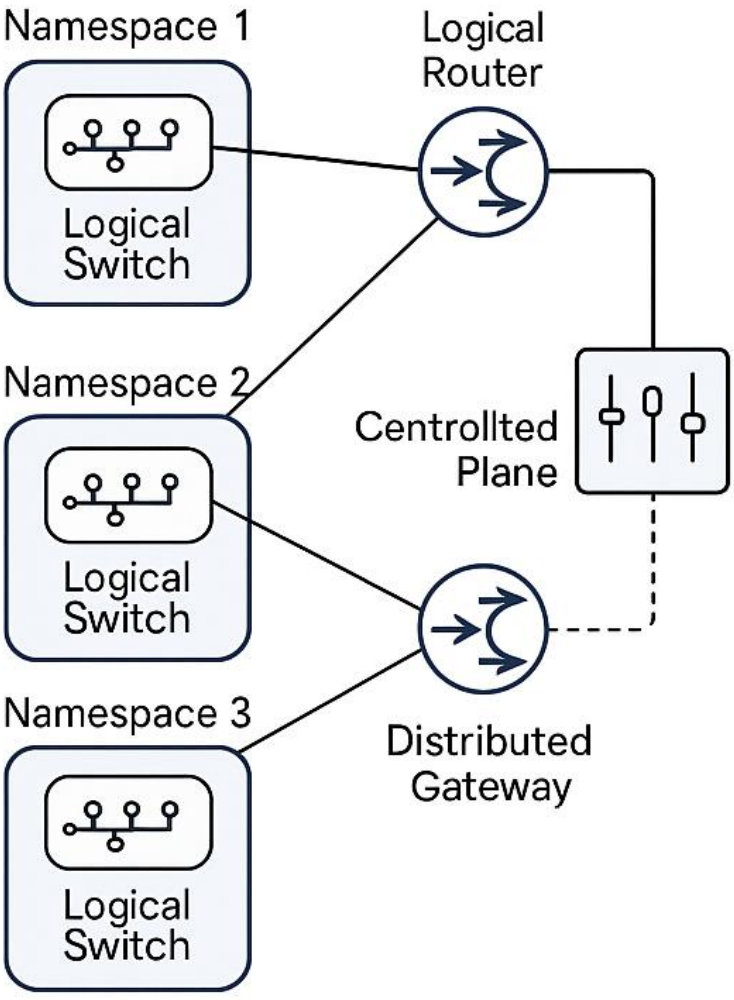
- kubectl exec for pod access
- dig/nslookup for DNS
- netstat/ss for connections
- tcpdump for packet capture



OVN-Kubernetes: Software-Defined Networking

What it is: CNI plugin based on Open Virtual Network (OVN)

Built on: Open vSwitch (OVS) data plane



Key Components

- Logical switchesper namespace
- Logical routers for inter-namespace outing
- Distributed gateway for external laccess
- Network policies via CLs

Architecture Benefits

- True multi-tenancy
- Advanced networking features
- Centralized control plane
- Hardware offioad support

Use Cases

Enterprise environments, multi-tenant clusters, complex networking requirements

OVN-K8s: Advanced Networking Features

Enterprise Features

- Multiple external gateways
- Network segmentation
- Quality of Service (QoS)
- IPv6 dual-stack support
- Hardware acceleration
- DPDK integration

Network Policies

- Default deny-all security
- Granular traffic control
- Stateful connection tracking

Performance

- Hardware offload capabilities
- DPDK for high throughput
- Smart NIC integration

Fix These Common Issues

DNS resolution failures	Check CoreDNS
Pod communication issues	Verify CNI
Service unrearchable	Check endpoints
Slow performance	Profile network path
MTU problems	Check path MTU

Best for: Telecom, financial services, large enterprises with complex security requirements

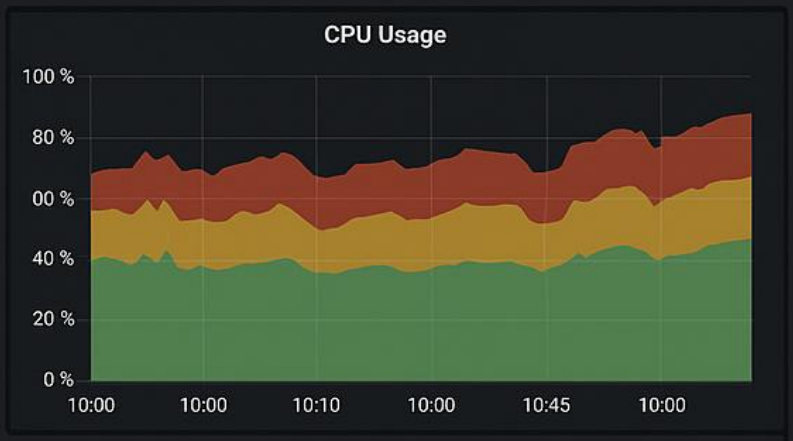
Optimize for Performance

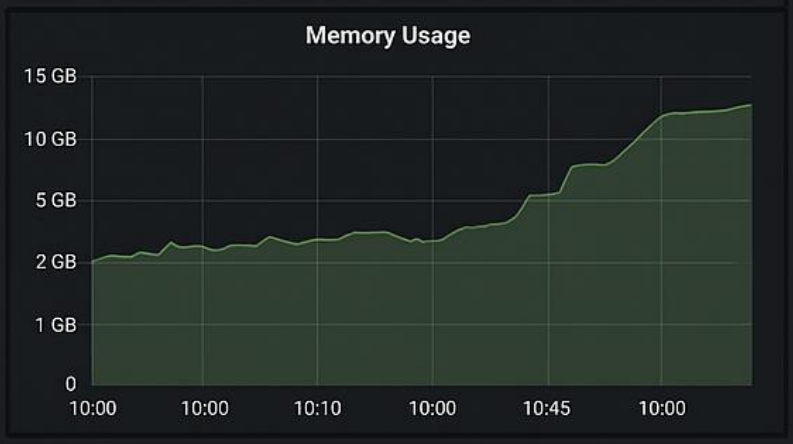
Strategies:

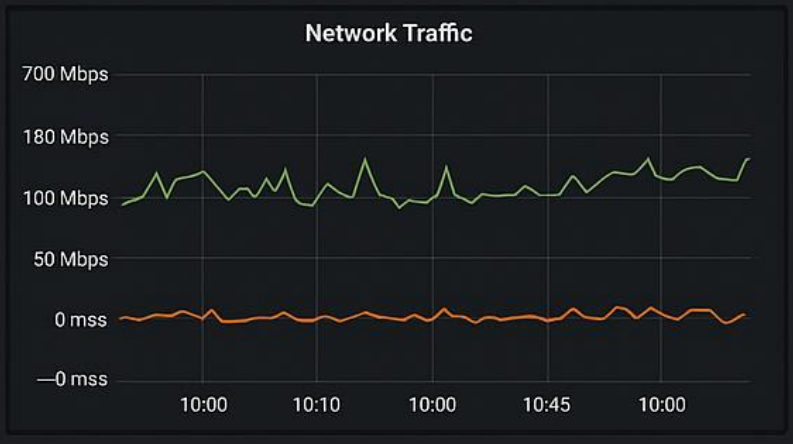
- Choose right CNI plugin
- Tune MTU settings
- Use native routing when possible
- Consider eBPF solutions

Monitoring:

Prometheus + Grafana







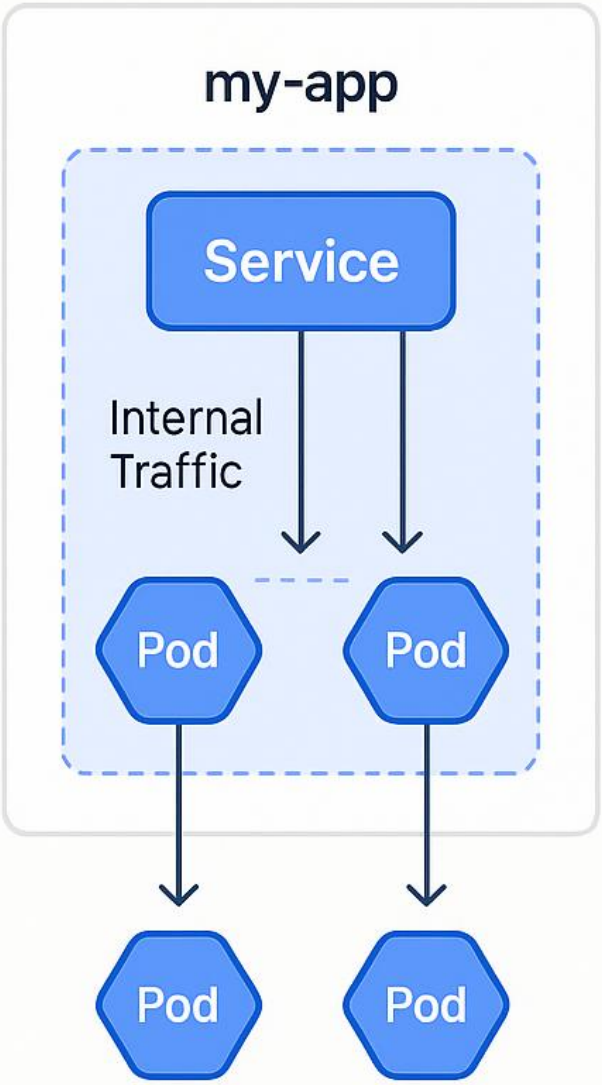
Secure Your Network

- Implement network policies
- Use encrypted communication
- Segment sensitive workloads
- Monitor network traffic
- Regular security audits

Falco for runtime security

ClusterIP: Internal Communication Hub

Default service type for cluster-internal access



Key Features:

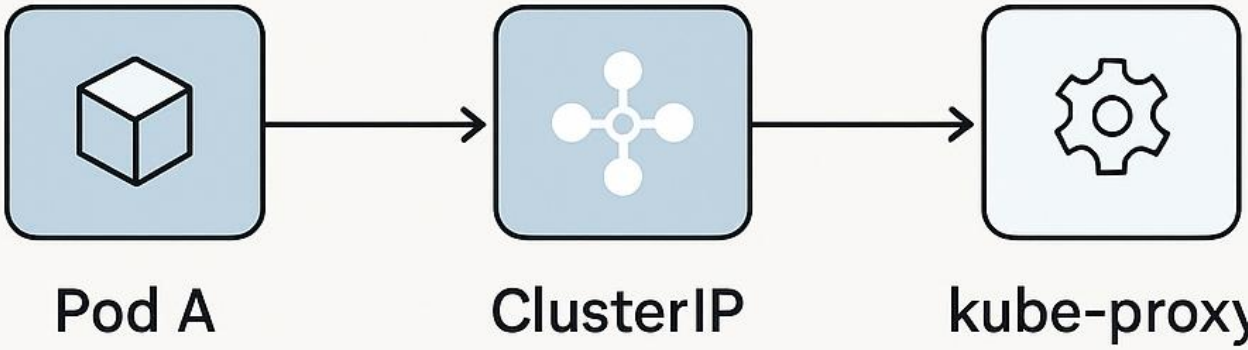
- Virtual IP accessible only within cluster
- Automatic load balancing to healthy pods
- DNS name: service-name.namespace svc.cluster.local
- Port mapping: Service port → Target port

YAML Example:

```
apiVersion: v1
kind: Service
metadata:
  name: my-app
spec:
  type: ClusterIP
  selector:
   app: my-app
  ports
   - port: 80
     targetPort:8080
```

Use Case: Backend services, databases, internal APIs

ClusterIP Traffic Flow



Behind the scenes

- kube-proxy creates iptables rules
- Service IP is virtual (not assigned to any interface)
- Load balancing algorithms: Round-robin, least connections

Troubleshooting

- Check endpoints: `kubectl get endpoints`
- Verify selector labels match
- Test from within cluster: `kubectl exec -it pod --curl service-ip`

Pro Tip: Use service names, not IPs for better portability

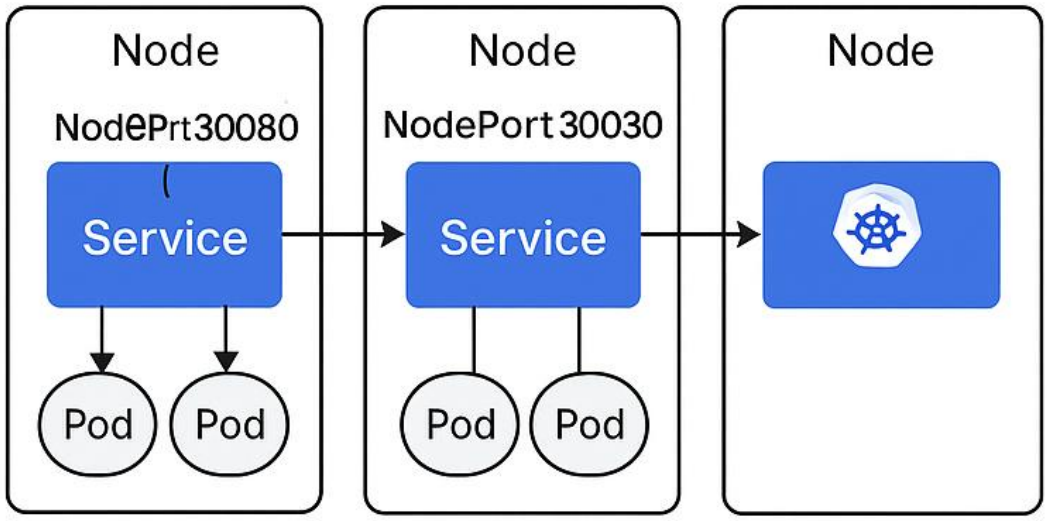
NodePort: External Access Gateway

Exposes service on each node's IP at static port

Port Range: 30000-32767 (configurable)

Access Pattern: NodeIP:NodePort → Service → Pocs

Key Features: External accessibility
High availability across nodes
Built on top of ClusterIP



YAML Example

```
apiVersion: v1
kind: Service
metadata:
 name: my-web-ap
 spec:
 type: NodePort
 selector:
  app: web
  ports: 80
  targetPort: 8
  nodePort: 300
```

- External accessibility
- High availability across nodes
- Built on top of ClusterIP

NodePort Implementation Details

How it works:

- Creates ClusterIP service
- Allocates port on ALL nodes
- Routes traffic from any node to healthy pods

Traffic Flow

Advantages

- Simple external access
- No external load balancer needed

Limitations

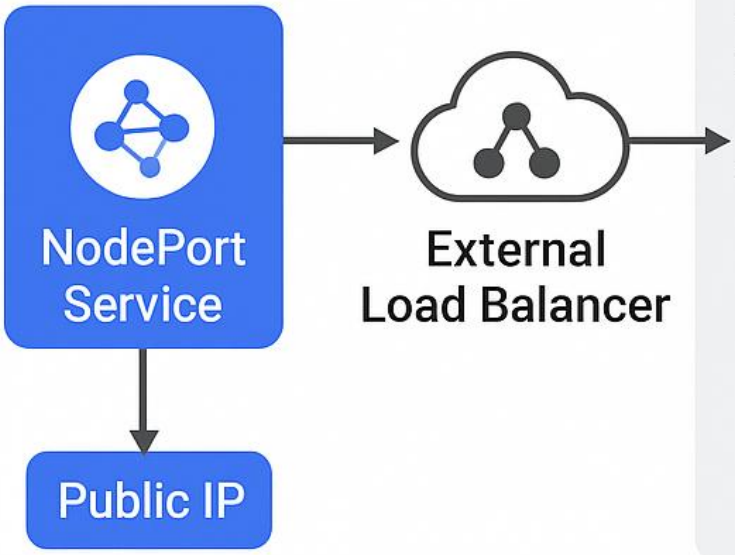
- Limited port range
- Manual port management
- No SSL termination

Best for:

Development, small deployments, cost-conscious setups

LoadBalancer: Cloud-Native External Access

- Cloud provider's load balancer integration
- Creates: NodePort service (autab)
- External load balancer
- Public IP assignment



YAML Example

```
apiVersion: v1
kind: Service
metadata:
   name:web-service
spec:
   type:LoadBälancer
   selector:
   app: web
   ports:
     port:80
   targetPort:  8080
```

Cloud Support: AWS ELB/ALB, GCP Load Balancer, Azure LoadBalancer

Benefits: Production-ready, scalable, managed

ExternalName: DNS Alias Service

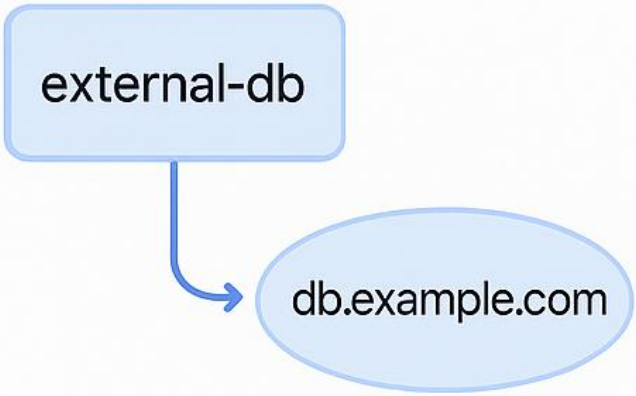
Purpose: Map service to external DNS name

No selectors or endpoints needed

Use cases:

- External database connections
- Third-party API integration
- Service migration scenarios

```
apiVersion: v1
kind: Service
metadata:
 name external-db
spec:
 type:
 ExternalName
 db.example.com
```

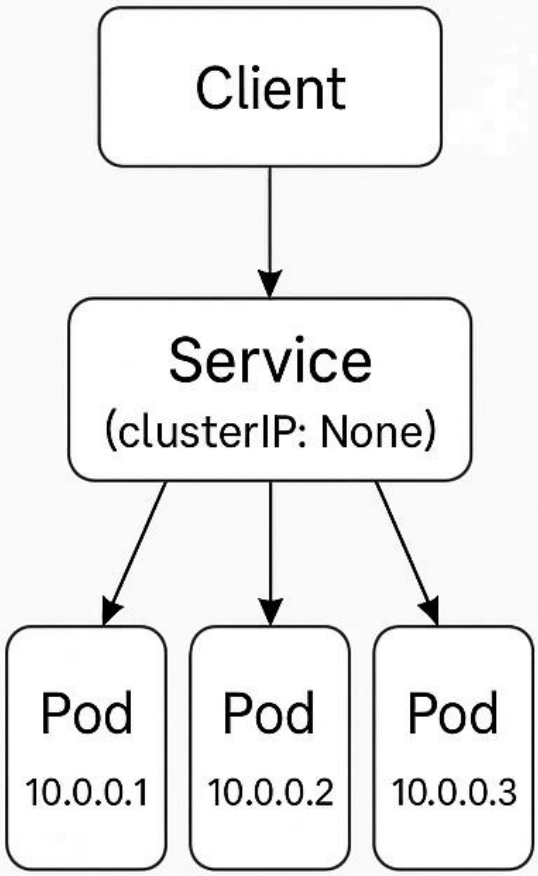



```
external-db.namespace.svc.cluster.local →
db.example.com
```

Pro Tip: Great for abstracting external dependencies

Headless Services: Direct Pod Access

Service with clusterIP: None



Behavior:

- No virtual IP assigned
- DNS returns pod IPs directy
- Client-side load balancing

Use Cases:

- StatefulSets with stable network identities
- Custom load balancing logic
- Service discovery scenarios

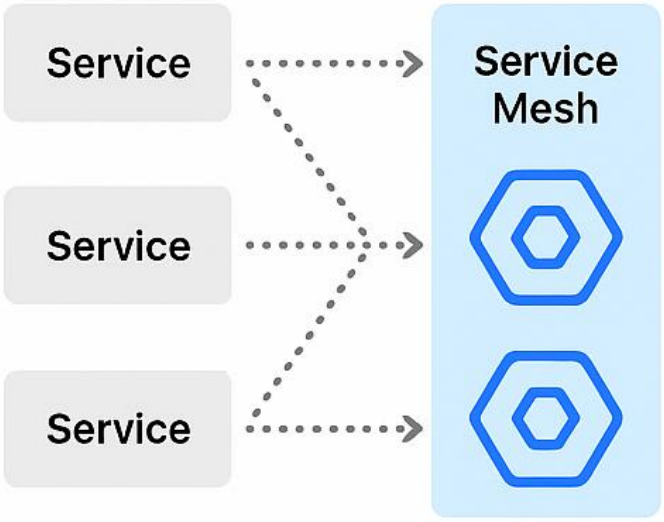
YAML Example:

```
apiVersion: v1
kind: Service
metadata:
  name: headless-svc
spec:
   clusterIP: None
   selector:
     app: stateful-app
   ports
     - port: 80
```

DNS Result:

Multiple A records for each pod

Services + Service Mesh = 🚀



What service mesh adds:

- Advanced traffic management
- Security (mTLS, policies)
- Observability and tracing
- Circuit breaking and retries

Popular solutions:

- Istio (most feature-rich)
- Linkerd (lightweight)
- Consul Connect

Benefits over basic services:

- Zero-trust security
- Traffic splitting
- Traffic splitting/canary deployments
- Distributed tracing

When to use: "Complex microservices architectures"

Optimize Service Performance

Key metrics to monitor

- Connection latency
- Throughput (request/sec)
- Error rates
- Pod health and readiness

Throughput

Connection Latency

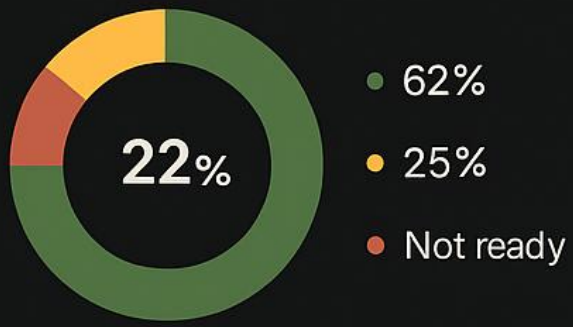
Optimization strategies

- Tune session affinity
- Optimize health checks
- Use appropriate service
- Consider connection po-

Tools

- Prometheus for metrics
- Jaeger for tracing
- Load testing with k6

Pod Health and Rediness



Goal: Sub-100ms service response times

Optimize Service Performance

Key metrics to monitor

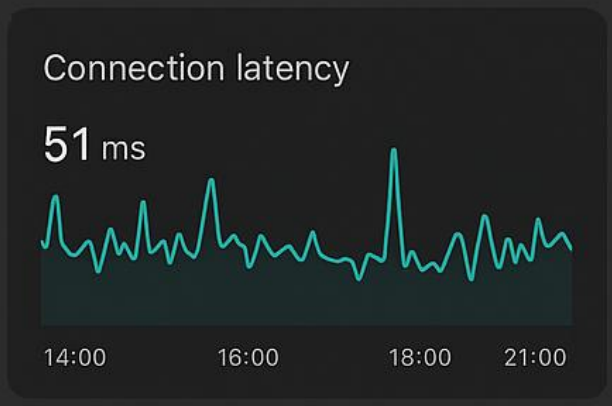
- Connection latency
- Throughput (requests/sec)
- Error rates
- Pod health and readiness

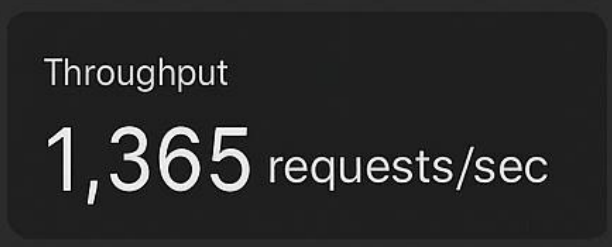
Optimization strategies

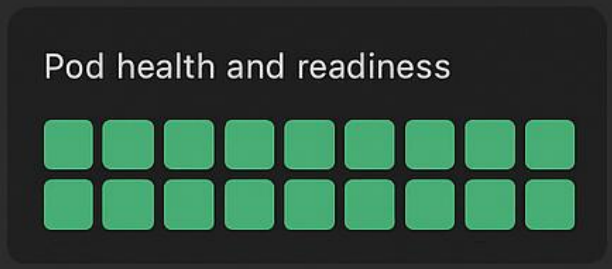
- Tune session affinity
- Optimize health checks
- Use appropriate service type

Tools

- Prometheus for metrics
- Jaeger for tracing
- Load testing with k6

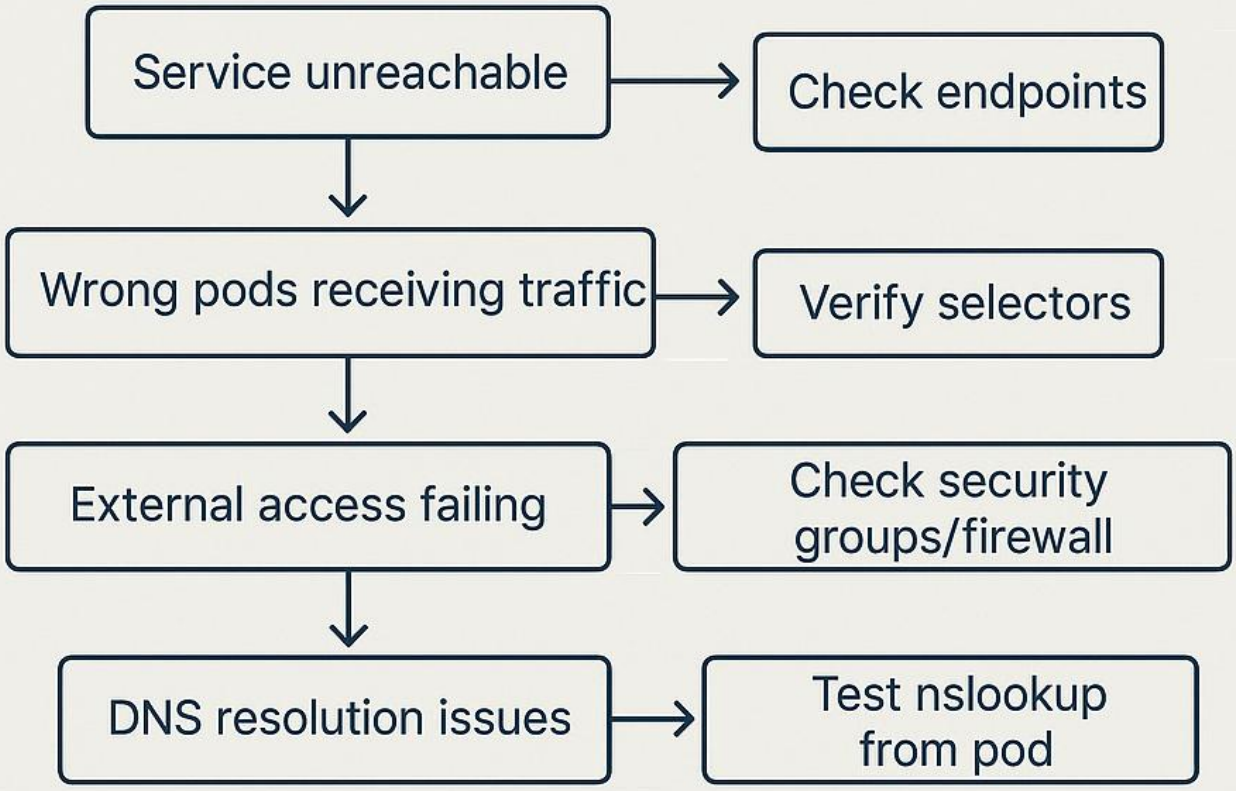






Sub-100ms service response times

Debug Service Issues Like a Pro



Debug commands:

```
bashkubectl get svc,endpoints
kubectl describe·service my-service
kubectl logs -l app=my-app
nslookup my-service.default.svc.cluster
```

Pro tip:

```
Always verify pod labels match
service selectors
```

Production Readiness

- [x] CNI plugin selected and tested
- [x] Network policies implemented
- [x] Service types chosen appropriately
- [x] Load balancing strategy defined
- [x] Monitoring and alerting setup
- [x] Disaster recovery tested
- [x] Performance baselines established
- [x] Security scanning automated
- [x] Service mesh evaluated (if needed)

Ready to Go Deeper? 🚀

This was just the beginning of your K8s networking journey!

📖 Read my complete guide on Medium

https://medium.com/@salwan.mohamed/the-complete-kubernetes-networking-mastery-guide-from-basics-to-advanced-ebof-implementation-ebfddab65b2b

What you'll get in the full guide:

- Step-by-step CNI plugin configurations
- Advanced eBPF implementation examples
- Production troubleshooting playbooks
- OVN-Kubernetes deployment guides
- Real-world case studies

Join 10,000+ engineers mastering K8s networking

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Questions about your setup? Drop them in comments! 👇

Save this post for your next K8s project 📌