✨ Kubernetes Services Deep Dive (CKA 2024) ✨

🎯 What Are Kubernetes Services?

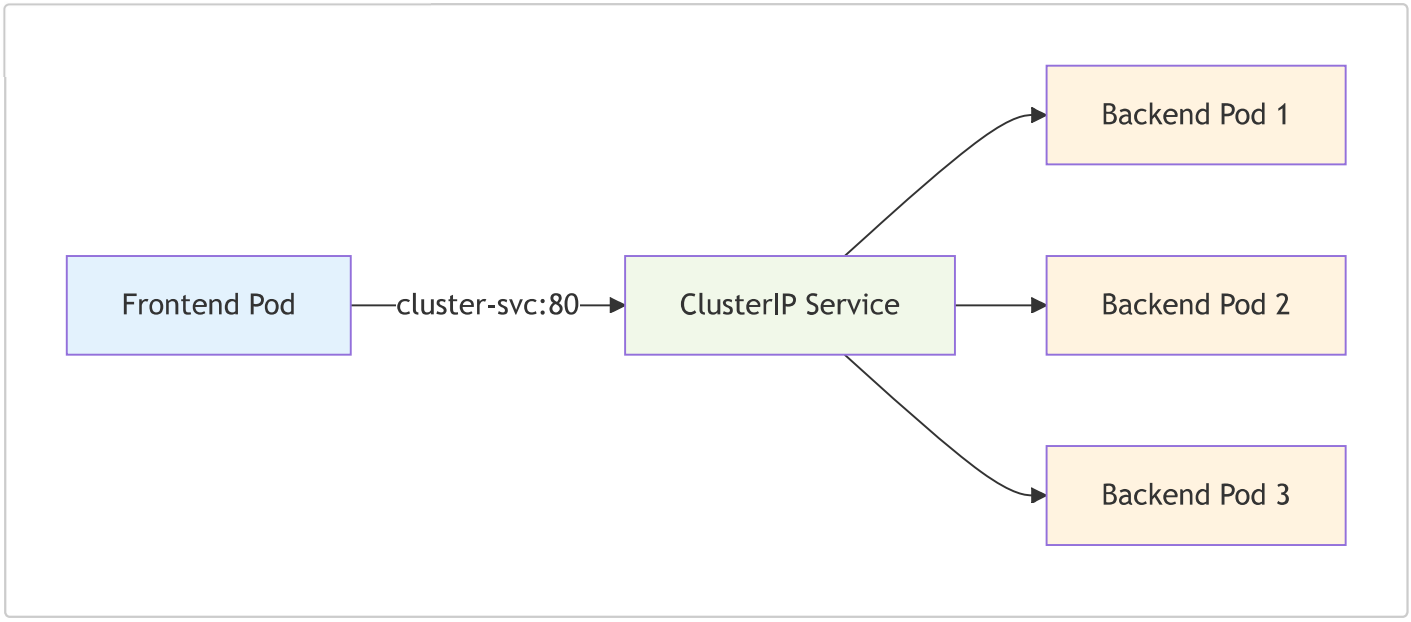
Kubernetes Services are an **abstraction layer** that provides a stable network endpoint for accessing pods. They solve the fundamental problem of pod networking in dynamic environments where pods are constantly created, destroyed, and rescheduled.

1️⃣ ClusterIP Service - Internal Cluster Communication 🔒

🎯 Purpose & Use Cases:

- **Default service type** (when no type is specified)
- Provides **internal-only** communication within the cluster
- Perfect for **backend services**, **databases**, **APIs** that don't need external access
- Enables **service discovery** through DNS names

🔧 How It Works:



📝 Complete YAML Example:

```yaml
apiVersion: v1
kind: Service
metadata:
  name: backend-service
  labels:
    app: backend
    tier: api
spec:
  type: ClusterIP  # Optional - this is default
```

```
  ports:
    - name: http           # Optional port name
      port: 80             # Port exposed by service
      targetPort: 8080     # Port on pod where app listens
      protocol: TCP        # Default is TCP
  selector:
    app: backend           # Matches pods with this label
    version: v1
```

🚀 Creating & Testing:

```
# Create the service
kubectl apply -f clusterip.yaml

# Verify service creation
kubectl get svc backend-service
kubectl describe svc backend-service

# Check endpoints (pod IPs behind the service)
kubectl get endpoints backend-service

# Test from another pod
kubectl run test-pod --image=busybox --rm -it -- sh
# Inside the pod:
wget -qO- http://backend-service:80
# Or use full DNS name:
wget -qO- http://backend-service.default.svc.cluster.local:80
```

🔍 Key Features:

- **Virtual IP (VIP)**: Service gets a stable cluster IP
- **DNS Resolution**: Service accessible via `..svc.cluster.local`
- **Load Balancing**: Distributes traffic across healthy pods
- **Health Checks**: Only routes to ready pods

💡 Best Practices:

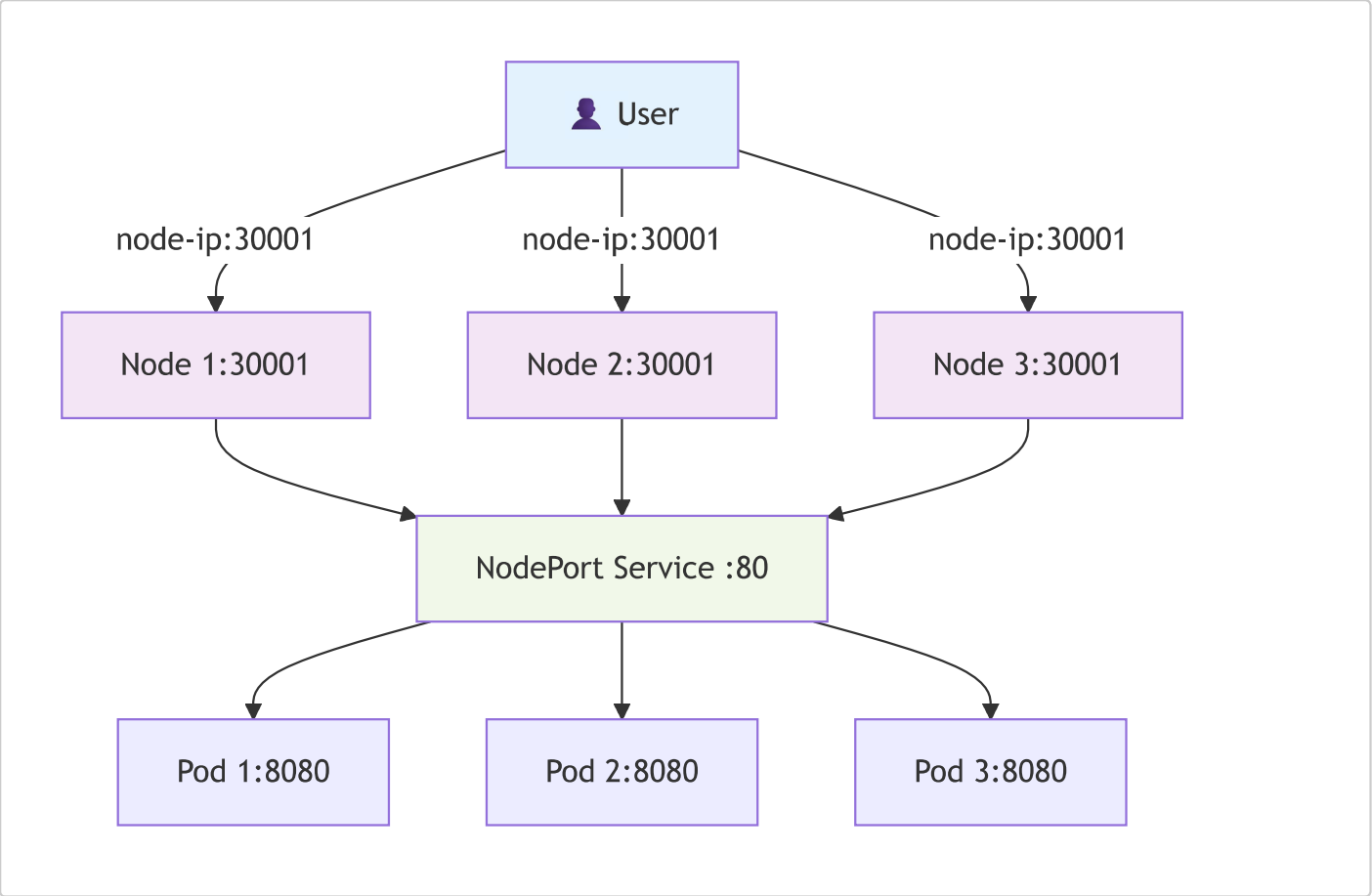
- Use meaningful service names (becomes DNS name)
- Always use labels for pod selection
- Consider port naming for multi-port services
- Use different ports for different protocols (HTTP, gRPC, etc.)

2️⃣ NodePort Service - External Access Through Node Ports 🌐

🎯 Purpose & Use Cases:

- Provides **external access** to cluster services
- Exposes service on a **static port** on each node
- Good for **development**, **testing**, or **small deployments**
- **Not recommended** for production (security concerns, port management)

🔧 How It Works:



📝 Complete YAML Example:

```yaml
apiVersion: v1
kind: Service
metadata:
  name: frontend-nodeport
  labels:
    app: frontend
    service-type: nodeport
spec:
  type: NodePort
  ports:
    - name: http
      port: 80              # ClusterIP port (internal)
      targetPort: 8080      # Pod port
      nodePort: 30001       # External port (30000-32767)
      protocol: TCP
```

```
  selector:
    app: frontend
    tier: web
```

🚀 Creating & Testing:

```
# Create NodePort service
kubectl apply -f nodeport.yaml

# Check service details
kubectl get svc frontend-nodeport
kubectl describe svc frontend-nodeport

# Get node IPs
kubectl get nodes -o wide

# Access externally (replace with actual node IP)
curl http://:30001
curl http://172.18.0.2:30001

# For kind clusters (after port mapping):
curl http://localhost:30001
```

🔍 Port Types Explained:

- **NodePort (30001)**: External port accessible from outside cluster
- **Port (80)**: Internal cluster port for pod-to-pod communication
- **TargetPort (8080)**: Actual port where application listens in pod

⚙️ NodePort Range & Allocation:

- **Default range**: 30000-32767
- **Random allocation**: If nodePort not specified, Kubernetes assigns randomly
- **Manual specification**: Can specify specific port within range
- **Firewall considerations**: Ensure NodePort range is open in firewalls

🔐 Security Considerations:

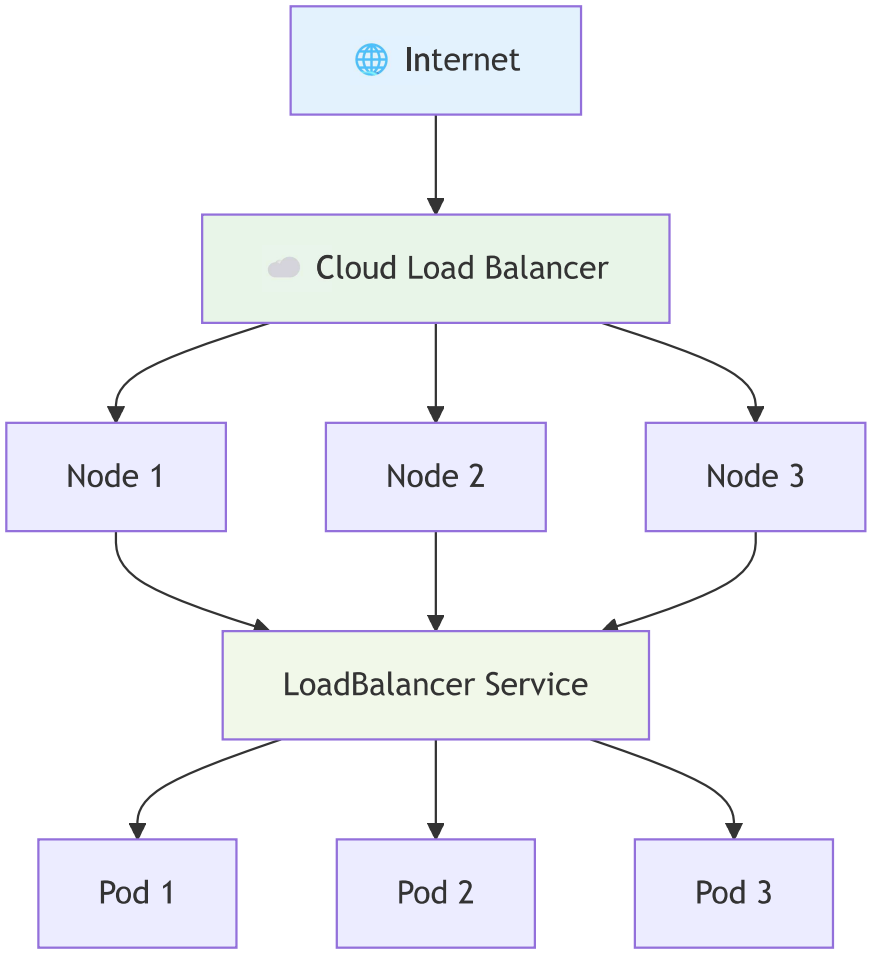
- Exposes services on all nodes
- Requires firewall rules for NodePort range
- No built-in SSL termination
- Consider using ingress controllers instead for production

3️⃣ LoadBalancer Service - Cloud Provider Integration ☁️

🎯 Purpose & Use Cases:

- **Production-grade** external access
- Integrates with **cloud provider load balancers** (AWS ALB/NLB, Azure LB, GCP LB)
- Provides **high availability** and **SSL termination**
- Handles **traffic distribution** and **health checks**

🔧 How It Works:



📝 Complete YAML Example:

```yaml
apiVersion: v1
kind: Service
metadata:
  name: web-loadbalancer
  labels:
    app: web
    service-type: loadbalancer
  annotations:
    # AWS specific annotations
    service.beta.kubernetes.io/aws-load-balancer-type: "nlb"
    service.beta.kubernetes.io/aws-load-balancer-ssl-cert:
```

```
    "arn:aws:acm:region:account:certificate/cert-id"
    # Azure specific annotations
    service.beta.kubernetes.io/azure-load-balancer-internal: "false"
spec:
  type: LoadBalancer
  ports:
    - name: http
      port: 80
      targetPort: 8080
      protocol: TCP
    - name: https
      port: 443
      targetPort: 8080
      protocol: TCP
  selector:
    app: web
    tier: frontend
  # Optional: Restrict source IPs
  loadBalancerSourceRanges:
    - "10.0.0.0/8"
    - "192.168.0.0/16"
```

🚀 Creating & Testing:

```
# Create LoadBalancer service
kubectl apply -f loadbalancer.yaml

# Check service status (wait for EXTERNAL-IP)
kubectl get svc web-loadbalancer -w

# Check cloud provider load balancer details
kubectl describe svc web-loadbalancer

# Access via external IP (once provisioned)
curl http://
curl https://
```

☁️ Cloud Provider Specifics:

AWS Integration:

- Creates Application Load Balancer (ALB) or Network Load Balancer (NLB)
- Supports SSL certificates from ACM
- Integrates with Route 53 for DNS
- Security groups automatically configured

Azure Integration:

- Creates Azure Load Balancer
- Supports internal and external load balancers
- Integrates with Azure DNS
- Network security groups configured

GCP Integration:

- Creates Google Cloud Load Balancer
- Supports HTTP(S) and TCP load balancing
- Integrates with Cloud DNS
- Firewall rules automatically created

⏱️ Behavior in Different Environments:

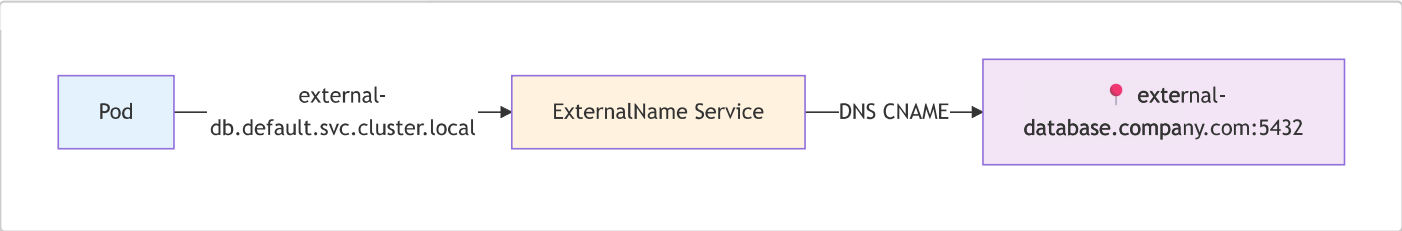
- **Cloud platforms**: Provisions actual external load balancer
- **Local clusters** (kind, minikube): Shows `` status, falls back to NodePort
- **On-premises**: Requires MetalLB or similar load balancer implementation

4️⃣ ExternalName Service - DNS Aliasing & Service Mesh 🔗

🎯 Purpose & Use Cases:

- **DNS aliasing** for external services
- **Service mesh integration** patterns
- **Migration scenarios** (gradual move from external to internal services)
- **Multi-cluster** service discovery
- **Legacy system** integration

🔧 How It Works:



📝 Complete YAML Examples:

Database Connection Example:

```yaml
apiVersion: v1
kind: Service
metadata:
  name: external-database
  labels:
    app: database
```

```
    type: external
spec:
  type: ExternalName
  externalName: prod-db.company.com  # External FQDN
  ports:
    - name: postgres
      port: 5432
      protocol: TCP
```

API Gateway Example:

```
apiVersion: v1
kind: Service
metadata:
  name: payment-api
  labels:
    app: payment
    type: external
spec:
  type: ExternalName
  externalName: api.payment-provider.com
  ports:
    - name: https
      port: 443
      protocol: TCP
```

🚀 Creating & Testing:

```
# Create ExternalName service
kubectl apply -f externalname.yaml

# Verify service creation
kubectl get svc external-database
kubectl describe svc external-database

# Test DNS resolution from pod
kubectl run test-pod --image=busybox --rm -it -- sh
# Inside pod:
nslookup external-database.default.svc.cluster.local
# Should resolve to external-database.company.com

# Test connection (if external service is accessible)
telnet external-database.default.svc.cluster.local 5432
```

🔍 Advanced Use Cases:

Migration Pattern:

```
# Phase 1: Point to external service
apiVersion: v1
kind: Service
metadata:
  name: user-service
spec:
  type: ExternalName
  externalName: legacy-users.company.com

---
# Phase 2: Gradually move to internal service
apiVersion: v1
kind: Service
metadata:
  name: user-service
spec:
  type: ClusterIP
  ports:
    - port: 80
      targetPort: 8080
  selector:
    app: user-service-v2
```

Multi-Environment Configuration:

```
# Development environment
apiVersion: v1
kind: Service
metadata:
  name: payment-service
spec:
  type: ExternalName
  externalName: payment-dev.company.com

---
# Production environment
apiVersion: v1
kind: Service
metadata:
  name: payment-service
spec:
  type: ExternalName
  externalName: payment-prod.company.com
```

🔧 DNS Behavior:

- **CNAME record**: ExternalName creates DNS CNAME pointing to external FQDN
- **No proxy**: Traffic goes directly from pod to external service
- **No load balancing**: Kubernetes doesn't handle external service load balancing
- **No health checks**: External service health not monitored by Kubernetes

⚠️ Limitations:

- No built-in load balancing for external services
- No health checking of external endpoints
- Requires external service to be accessible from cluster
- DNS-only solution (no IP-based routing)

🎛️ Service Creation Methods Comparison

📝 Declarative (YAML) - Recommended for Production:

```
# Create from YAML file
kubectl apply -f service.yaml

# Update service
kubectl apply -f service.yaml

# Benefits: Version control, repeatability, complex configurations
```

⚡ Imperative (CLI) - Quick Testing & Exam:

```
# Expose deployment as ClusterIP
kubectl expose deployment app --port=80 --target-port=8080

# Expose as NodePort
kubectl expose deployment app --type=NodePort --port=80

# Expose as LoadBalancer
kubectl expose deployment app --type=LoadBalancer --port=80

# Generate YAML from imperative command
kubectl expose deployment app --port=80 --dry-run=client -o yaml > service.yaml
```

🔧 Advanced Service Features

🎯 Multi-Port Services:

```yaml
apiVersion: v1
kind: Service
metadata:
  name: multi-port-service
spec:
  type: ClusterIP
  ports:
    - name: http
      port: 80
      targetPort: 8080
    - name: https
      port: 443
      targetPort: 8443
    - name: metrics
      port: 9090
      targetPort: 9090
  selector:
    app: web-server
```

🔒 Session Affinity:

```yaml
apiVersion: v1
kind: Service
metadata:
  name: sticky-service
spec:
  type: ClusterIP
  sessionAffinity: ClientIP  # Routes same client to same pod
  sessionAffinityConfig:
    clientIP:
      timeoutSeconds: 3600   # Session timeout
  ports:
    - port: 80
      targetPort: 8080
  selector:
    app: stateful-app
```

🌐 Headless Services (No ClusterIP):

```yaml
apiVersion: v1
kind: Service
metadata:
  name: headless-service
spec:
  clusterIP: None  # No cluster IP assigned
```

```
  ports:
    - port: 80
      targetPort: 8080
  selector:
    app: database
# Use case: StatefulSets, direct pod access via DNS
```

🛠️ Troubleshooting Services

🔍 Common Debugging Commands:

```
# Check service status
kubectl get svc
kubectl describe svc

# Check endpoints
kubectl get endpoints
kubectl describe endpoints

# Check pod labels match service selector
kubectl get pods --show-labels
kubectl get pods -l app=frontend

# Test service connectivity
kubectl run debug --image=busybox --rm -it -- sh
# Inside pod: wget -qO- http://service-name:port

# Port forward for local testing
kubectl port-forward svc/my-service 8080:80
```

🚨 Common Issues & Solutions:

Issue	Symptoms	Solution
No endpoints	Service exists but no pods behind it	Check pod labels match service selector
Connection refused	Can't connect to service	Verify targetPort matches pod's listening port
External IP pending	LoadBalancer shows ``	Check cloud provider integration/credentials
NodePort not accessible	Can't reach via node IP:port	Check firewall rules, security groups
DNS not resolving	Service name doesn't resolve	Check CoreDNS pods, namespace spelling

📊 Service Types Comparison Table

Feature	ClusterIP	NodePort	LoadBalancer	ExternalName
External Access	❌	✅	✅	✅
Load Balancing	✅	✅	✅	❌
Cloud Integration	❌	❌	✅	❌
Port Range	Any	30000-32767	Any	Any
Production Ready	✅	⚠️	✅	✅
SSL Termination	❌	❌	✅ (cloud)	❌
Cost	Free	Free	Cloud charges	Free
Use Case	Internal APIs	Dev/Test	Production web apps	External services

🎯 Best Practices Summary

🏗️ Architecture:

- Use **ClusterIP** for internal service communication
- Use **LoadBalancer** for production external access
- Avoid **NodePort** in production (use Ingress instead)
- Use **ExternalName** for external service integration

🔧 Configuration:

- Always use meaningful service and port names
- Match service selectors with pod labels carefully
- Use health checks and readiness probes
- Consider session affinity for stateful applications

🔒 Security:

- Restrict LoadBalancer source ranges when needed
- Use network policies to control service access
- Implement proper authentication/authorization
- Regular security scanning of exposed services

📈 Monitoring:

- Monitor service endpoints health
- Track service response times and errors
- Alert on service discovery issues
- Monitor cloud load balancer costs and usage

🎯 Exam Tips

- ✅ **Know the port types**: NodePort vs Port vs TargetPort
- ✅ **Service selector**: Must match pod labels exactly
- ✅ **Default behavior**: ClusterIP is default service type
- ✅ **Imperative commands**: `kubectl expose` for quick service creation
- ✅ **Troubleshooting**: Use `kubectl get endpoints` to verify pod selection
- ✅ **DNS names**: `service-name.namespace.svc.cluster.local`

🚀 **Practice all service types in your lab environment!**