RH OVE Multi-Cluster Ecosystem Documentation

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# 1 RH OVE Multi-Cluster Ecosystem

## 1.1 Complete Documentation Export

*Generated from MkDocs documentation*

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# 3 Home

## 3.1 RH OVE Ecosystem Design and Management

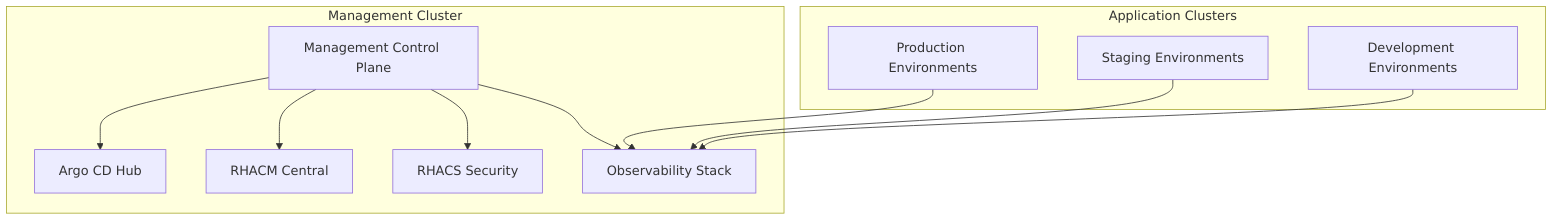
Welcome to the comprehensive guide for designing, deploying, and managing the multi-cluster RH OVE ecosystem.

### 3.1.1 Solution Overview

This documentation covers a complete multi-cluster RH OVE implementation consisting of:

* **1 Management Cluster**: Centralized control plane for governance, policy, monitoring, and GitOps
* **N Application Clusters**: Dedicated workload execution environments for virtual machines and containers

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 3.1.2 Key Features

#### 3.1.2.1 1. Design Phase

* **Multi-cluster topology** for separation of management and workloads
* **Centralized governance** through the management cluster
* **Consistent security** using RHACS and Kyverno policies

#### 3.1.2.2 2. Deployment Phase

* **Rubrik integration** for enterprise backup and recovery
* **Dynatrace monitoring** for comprehensive observability
* **GitOps methodology** using Argo CD for declarative management

#### 3.1.2.3 3. Management Phase

* **Enhanced admission control** with OpenShift defaults plus Kyverno policies
* **CRD-based management** leveraging KubeVirt resources
* **Event-driven integrations** with CMDB systems

#### 3.1.2.4 4. Best Practices

* Resource management and multi-tenancy
* Security and isolation enforcement
* Continuous improvement through monitoring

#### 3.1.2.5 5. References

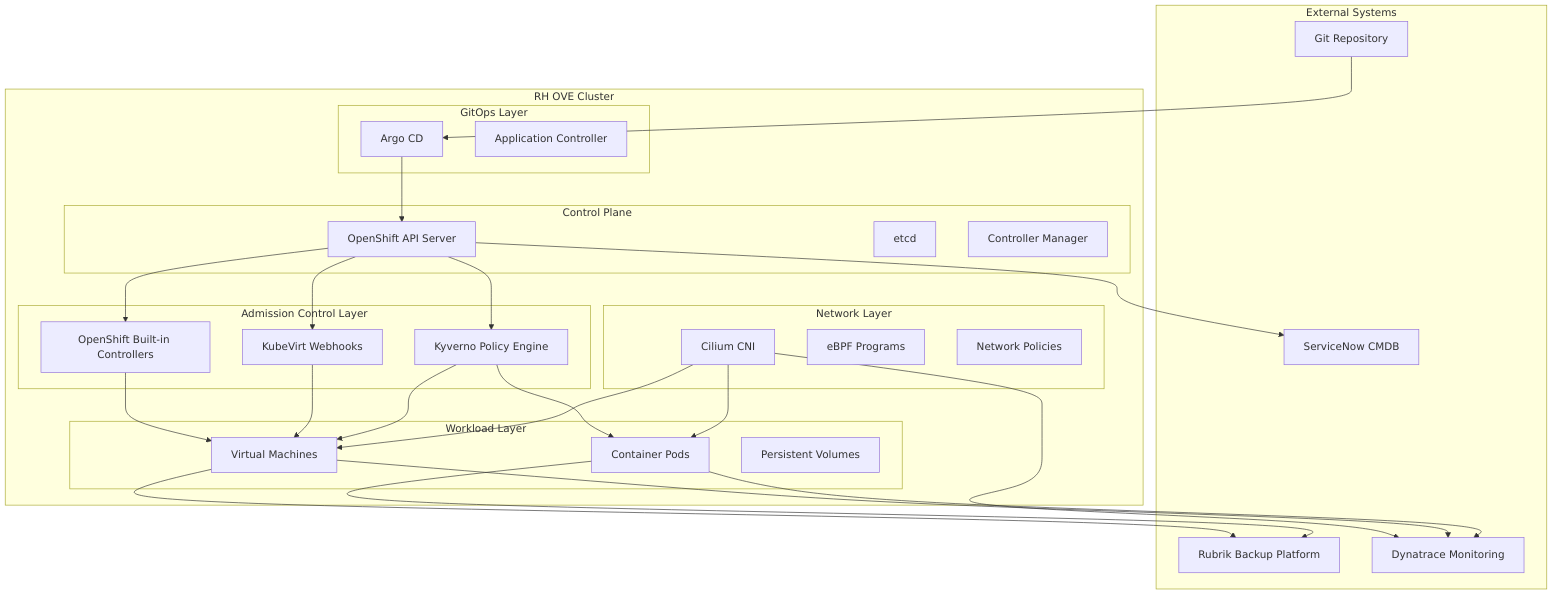
Comprehensive product documentation and URIs for all integrated components.

### 3.1.3 Getting Started

1. Review the [Architecture Overview](architecture/overview.md)
2. Follow the [Installation Guide](deployment/installation.md)
3. Configure [Admission Control](management/admission-control.md)
4. Set up [Monitoring](management/monitoring.md)

### 3.1.4 Architecture Diagram

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

This solution provides a modern, secure, and scalable approach to managing virtualized workloads alongside containerized applications in a unified OpenShift platform.

# 4 Global Overview

## 4.1 Global Architecture Overview

### 4.1.1 Overview

The RH OVE ecosystem is designed as a multi-cluster architecture that separates concerns between management operations and application workloads. This design provides scalability, security, and operational efficiency by dedicating specialized clusters for different purposes while maintaining centralized governance and oversight.

### 4.1.2 Architecture Principles

#### 4.1.2.1 Separation of Concerns

* **Management Cluster**: Centralized control plane for governance, policy, monitoring, and operations
* **Application Clusters**: Dedicated workload execution environments for virtual machines and containers
* **Clear Boundaries**: Well-defined interfaces and responsibilities between cluster types

#### 4.1.2.2 Scalability and Growth

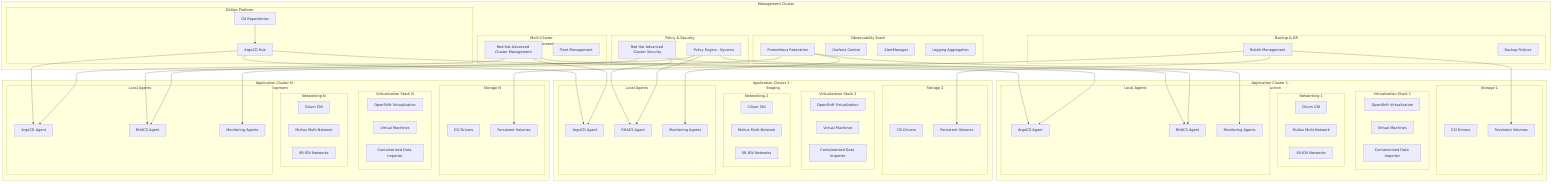
* **Horizontal Scaling**: Add application clusters as demand grows
* **Regional Distribution**: Deploy clusters across different geographic locations
* **Resource Optimization**: Right-size clusters based on workload requirements

#### 4.1.2.3 Security and Compliance

* **Zero Trust Architecture**: Network-level security between clusters
* **Centralized Policy Management**: Consistent security policies across all clusters
* **Compliance Monitoring**: Unified compliance reporting and auditing

### 4.1.3 Multi-Cluster Topology

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 4.1.4 Management Cluster Components

#### 4.1.4.1 Core Management Services

##### 4.1.4.1.1 Red Hat Advanced Cluster Management (RHACM)

apiVersion: operator.open-cluster-management.io/v1  
kind: MultiClusterHub  
metadata:  
 name: multiclusterhub  
 namespace: open-cluster-management  
spec:  
 availabilityConfig: High  
 enableClusterBackup: true  
 overrides:  
 components:  
 - name: multicluster-observability-operator  
 enabled: true  
 - name: cluster-lifecycle  
 enabled: true  
 - name: cluster-permission  
 enabled: true

**Responsibilities:** - Cluster lifecycle management - Policy distribution and compliance - Application deployment coordination - Resource optimization across clusters

##### 4.1.4.1.2 ArgoCD Hub Configuration

apiVersion: argoproj.io/v1alpha1  
kind: ArgoCD  
metadata:  
 name: argocd-hub  
 namespace: argocd  
spec:  
 server:  
 route:  
 enabled: true  
 tls:  
 termination: reencrypt  
 replicas: 3  
 controller:  
 resources:  
 requests:  
 cpu: 500m  
 memory: 1Gi  
 limits:  
 cpu: 2  
 memory: 4Gi  
 dex:  
 openShiftOAuth: true  
 ha:  
 enabled: true  
 rbac:  
 defaultPolicy: 'role:readonly'  
 policy: |  
 p, role:admin, applications, \*, \*/\*, allow  
 p, role:admin, clusters, \*, \*, allow  
 p, role:admin, repositories, \*, \*, allow  
 g, argocd-admins, role:admin

**Responsibilities:** - GitOps workflow orchestration - Application deployment to target clusters - Configuration drift detection and remediation - Multi-cluster application synchronization

#### 4.1.4.2 Security and Compliance

##### 4.1.4.2.1 Red Hat Advanced Cluster Security (RHACS)

apiVersion: platform.stackrox.io/v1alpha1  
kind: Central  
metadata:  
 name: stackrox-central-services  
 namespace: stackrox  
spec:  
 central:  
 exposure:  
 loadBalancer:  
 enabled: true  
 persistence:  
 persistentVolumeClaim:  
 claimName: central-db  
 resources:  
 requests:  
 cpu: 1500m  
 memory: 4Gi  
 limits:  
 cpu: 4000m  
 memory: 8Gi  
 scanner:  
 resources:  
 requests:  
 cpu: 200m  
 memory: 200Mi  
 limits:  
 cpu: 2000m  
 memory: 4Gi

**Responsibilities:** - Centralized security policy management - Vulnerability scanning across clusters - Runtime threat detection - Compliance reporting and audit trails

##### 4.1.4.2.2 Policy Engine (Kyverno)

apiVersion: kyverno.io/v1  
kind: ClusterPolicy  
metadata:  
 name: multi-cluster-vm-policy  
spec:  
 validationFailureAction: enforce  
 background: true  
 rules:  
 - name: require-vm-labels  
 match:  
 any:  
 - resources:  
 kinds:  
 - VirtualMachine  
 validate:  
 message: "VMs must have required labels: environment, owner, backup-policy"  
 pattern:  
 metadata:  
 labels:  
 environment: "?\*"  
 owner: "?\*"  
 backup-policy: "?\*"

#### 4.1.4.3 Observability and Monitoring

##### 4.1.4.3.1 Federated Prometheus Configuration

apiVersion: monitoring.coreos.com/v1  
kind: Prometheus  
metadata:  
 name: prometheus-federation  
 namespace: monitoring  
spec:  
 replicas: 3  
 retention: 30d  
 storage:  
 volumeClaimTemplate:  
 spec:  
 accessModes: ["ReadWriteOnce"]  
 resources:  
 requests:  
 storage: 500Gi  
 serviceAccountName: prometheus  
 serviceMonitorSelector:  
 matchLabels:  
 prometheus: federation  
 additionalScrapeConfigs:  
 name: additional-scrape-configs  
 key: prometheus-additional.yaml

**Federation Configuration:**

- job\_name: 'federate-app-clusters'  
 scrape\_interval: 15s  
 honor\_labels: true  
 metrics\_path: '/federate'  
 params:  
 'match[]':  
 - '{job=~"kubernetes-.\*"}'  
 - '{job=~"node-.\*"}'  
 - '{job=~"kubevirt-.\*"}'  
 static\_configs:  
 - targets:  
 - 'prometheus-app-cluster-1.monitoring.svc.cluster.local:9090'  
 - 'prometheus-app-cluster-2.monitoring.svc.cluster.local:9090'  
 - 'prometheus-app-cluster-n.monitoring.svc.cluster.local:9090'

##### 4.1.4.3.2 Centralized Logging

apiVersion: logging.openshift.io/v1  
kind: ClusterLogForwarder  
metadata:  
 name: central-log-forwarder  
 namespace: openshift-logging  
spec:  
 outputs:  
 - name: central-elasticsearch  
 type: elasticsearch  
 url: https://elasticsearch-central.logging.svc.cluster.local:9200  
 secret:  
 name: elasticsearch-central-secret  
 pipelines:  
 - name: forward-app-logs  
 inputRefs:  
 - application  
 - infrastructure  
 - audit  
 outputRefs:  
 - central-elasticsearch

### 4.1.5 Application Cluster Architecture

#### 4.1.5.1 Cluster Sizing and Resource Allocation

##### 4.1.5.1.1 Production Cluster Profile

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cluster-profile-production  
data:  
 profile: |  
 cluster\_type: production  
 node\_count: 12  
 master\_nodes: 3  
 worker\_nodes: 9  
 storage\_nodes: 3  
   
 node\_specifications:  
 master:  
 cpu: 16  
 memory: 64Gi  
 storage: 500Gi SSD  
 worker:  
 cpu: 32  
 memory: 128Gi  
 storage: 1Ti NVMe  
 storage:  
 cpu: 8  
 memory: 32Gi  
 storage: 4Ti SSD  
   
 network\_configuration:  
 cni: cilium  
 multi\_network: multus  
 sr\_iov: enabled  
 encryption: wireguard  
   
 virtualization:  
 kubevirt\_version: "v1.1.0"  
 nested\_virtualization: true  
 hugepages: 1Gi  
 cpu\_pinning: enabled

##### 4.1.5.1.2 Staging/Development Cluster Profile

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cluster-profile-staging  
data:  
 profile: |  
 cluster\_type: staging  
 node\_count: 6  
 master\_nodes: 3  
 worker\_nodes: 3  
   
 node\_specifications:  
 master:  
 cpu: 8  
 memory: 32Gi  
 storage: 200Gi SSD  
 worker:  
 cpu: 16  
 memory: 64Gi  
 storage: 500Gi SSD  
   
 network\_configuration:  
 cni: cilium  
 multi\_network: multus  
 sr\_iov: optional  
 encryption: ipsec  
   
 virtualization:  
 kubevirt\_version: "v1.1.0"  
 nested\_virtualization: false  
 hugepages: optional  
 cpu\_pinning: disabled

#### 4.1.5.2 Virtualization Stack Configuration

##### 4.1.5.2.1 OpenShift Virtualization Deployment

apiVersion: hco.kubevirt.io/v1beta1  
kind: HyperConverged  
metadata:  
 name: kubevirt-hyperconverged  
 namespace: openshift-cnv  
spec:  
 infra:  
 nodePlacement:  
 nodeSelector:  
 node-role.kubernetes.io/worker: ""  
 workloads:  
 nodePlacement:  
 nodeSelector:  
 node-role.kubernetes.io/worker: ""  
 featureGates:  
 enableCommonBootImageImport: true  
 deployTektonTaskResources: true  
 enableApplicationAwareQuota: true  
 configuration:  
 network:  
 networkBinding:  
 plugins:  
 macvtap: {}  
 passt: {}  
 virtualMachineOptions:  
 disableFreePageReporting: false  
 disableSerialConsoleLog: false

#### 4.1.5.3 Multi-Network Configuration

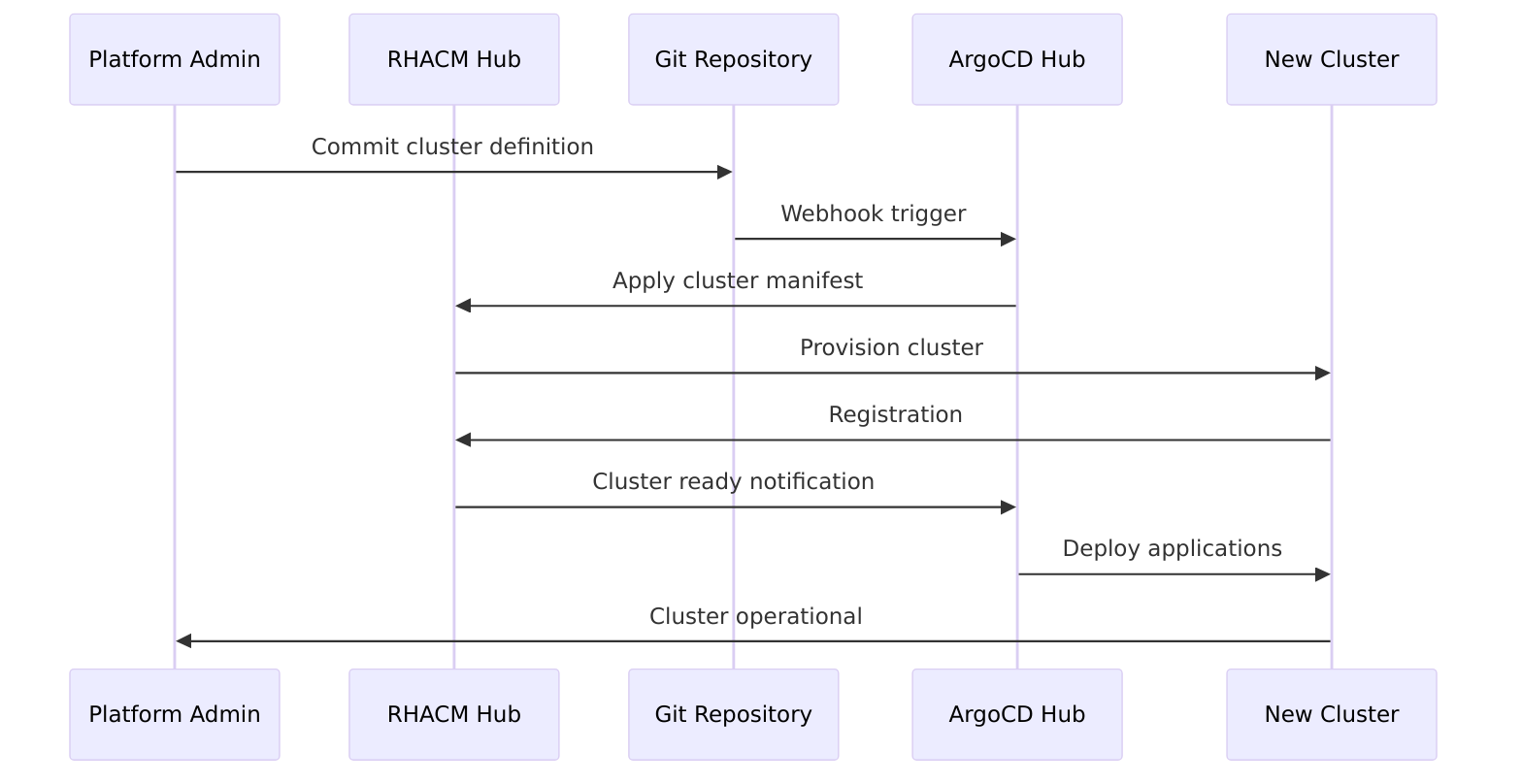
##### 4.1.5.3.1 Network Attachment Definitions for Different Environments

## Production Network Configuration  
apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: prod-management-network  
 namespace: vm-production  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "prod-management-network",  
 "type": "macvlan",  
 "master": "ens192",  
 "mode": "bridge",  
 "ipam": {  
 "type": "static"  
 }  
 }  
---  
## Staging Network Configuration  
apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: staging-management-network  
 namespace: vm-staging  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "staging-management-network",  
 "type": "macvlan",  
 "master": "ens192",  
 "mode": "bridge",  
 "vlan": 100,  
 "ipam": {  
 "type": "dhcp"  
 }  
 }

### 4.1.6 Cluster Lifecycle Management

#### 4.1.6.1 Cluster Provisioning Workflow

**Sequence Diagram**



Sequence Diagram

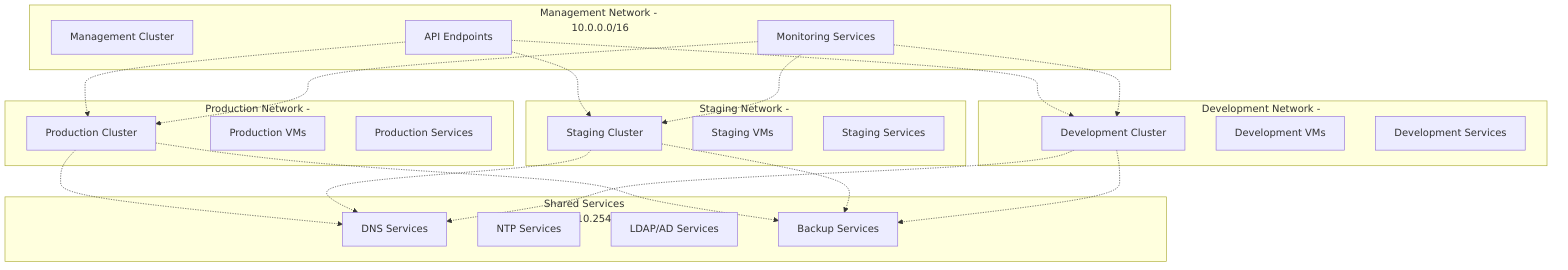
#### 4.1.6.2 Cluster Template

apiVersion: cluster.open-cluster-management.io/v1  
kind: ManagedCluster  
metadata:  
 name: app-cluster-{{ .Values.environment }}-{{ .Values.region }}  
 labels:  
 environment: {{ .Values.environment }}  
 region: {{ .Values.region }}  
 cluster.open-cluster-management.io/clusterset: {{ .Values.clusterset }}  
spec:  
 hubAcceptsClient: true  
 leaseDurationSeconds: 60  
---  
apiVersion: agent.open-cluster-management.io/v1  
kind: KlusterletAddonConfig  
metadata:  
 name: app-cluster-{{ .Values.environment }}-{{ .Values.region }}  
 namespace: app-cluster-{{ .Values.environment }}-{{ .Values.region }}  
spec:  
 clusterName: app-cluster-{{ .Values.environment }}-{{ .Values.region }}  
 clusterNamespace: app-cluster-{{ .Values.environment }}-{{ .Values.region }}  
 clusterLabels:  
 environment: {{ .Values.environment }}  
 region: {{ .Values.region }}  
 applicationManager:  
 enabled: true  
 policyController:  
 enabled: true  
 searchCollector:  
 enabled: true  
 certPolicyController:  
 enabled: true

### 4.1.7 Multi-Cluster Networking

#### 4.1.7.1 Cluster Network Isolation

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

#### 4.1.7.2 Service Mesh Integration

apiVersion: networking.istio.io/v1beta1  
kind: VirtualService  
metadata:  
 name: cross-cluster-vm-service  
spec:  
 hosts:  
 - vm-service.production.svc.cluster.local  
 gateways:  
 - mesh  
 - cross-cluster-gateway  
 http:  
 - match:  
 - headers:  
 cluster:  
 exact: staging  
 route:  
 - destination:  
 host: vm-service.staging.svc.cluster.local  
 - route:  
 - destination:  
 host: vm-service.production.svc.cluster.local

### 4.1.8 Disaster Recovery and Business Continuity

#### 4.1.8.1 Multi-Cluster Backup Strategy

apiVersion: velero.io/v1  
kind: Schedule  
metadata:  
 name: multi-cluster-backup  
 namespace: velero  
spec:  
 schedule: "0 2 \* \* \*" # Daily at 2 AM  
 template:  
 includedNamespaces:  
 - vm-production  
 - vm-staging  
 - openshift-cnv  
 excludedResources:  
 - pods  
 - replicasets  
 snapshotVolumes: true  
 ttl: 720h # 30 days  
 hooks:  
 resources:  
 - name: vm-backup-hook  
 includedNamespaces:  
 - vm-production  
 - vm-staging  
 labelSelector:  
 matchLabels:  
 backup.kubevirt.io/enable: "true"  
 pre:  
 - exec:  
 container: virt-launcher  
 command:  
 - /bin/bash  
 - -c  
 - "virtctl freeze --namespace $NAMESPACE $VM\_NAME"  
 post:  
 - exec:  
 container: virt-launcher  
 command:  
 - /bin/bash  
 - -c  
 - "virtctl unfreeze --namespace $NAMESPACE $VM\_NAME"

#### 4.1.8.2 Cross-Cluster Failover

apiVersion: cluster.open-cluster-management.io/v1beta1  
kind: Placement  
metadata:  
 name: vm-workload-placement  
 namespace: vm-production  
spec:  
 predicates:  
 - requiredClusterSelector:  
 labelSelector:  
 matchLabels:  
 environment: production  
 region: primary  
 - requiredClusterSelector:  
 labelSelector:  
 matchLabels:  
 environment: production  
 region: secondary  
 numberOfClusters: 2  
 prioritizerPolicy:  
 mode: Additive  
 configurations:  
 - scoreCoordinate:  
 type: BuiltIn  
 builtIn: Steady  
 weight: 1  
 - scoreCoordinate:  
 type: BuiltIn  
 builtIn: ResourceAllocatableCPU  
 weight: 1

### 4.1.9 Scalability and Performance

#### 4.1.9.1 Cluster Auto-Scaling

apiVersion: machine.openshift.io/v1beta1  
kind: MachineAutoscaler  
metadata:  
 name: worker-autoscaler  
 namespace: openshift-machine-api  
spec:  
 minReplicas: 3  
 maxReplicas: 20  
 scaleTargetRef:  
 apiVersion: machine.openshift.io/v1beta1  
 kind: MachineSet  
 name: worker-machineset  
---  
apiVersion: autoscaling.openshift.io/v1  
kind: ClusterAutoscaler  
metadata:  
 name: default  
spec:  
 podPriorityThreshold: -10  
 resourceLimits:  
 maxNodesTotal: 50  
 cores:  
 min: 16  
 max: 1000  
 memory:  
 min: 64Gi  
 max: 4000Gi  
 scaleDown:  
 enabled: true  
 delayAfterAdd: 10m  
 delayAfterDelete: 10s  
 delayAfterFailure: 30s  
 unneededTime: 60s

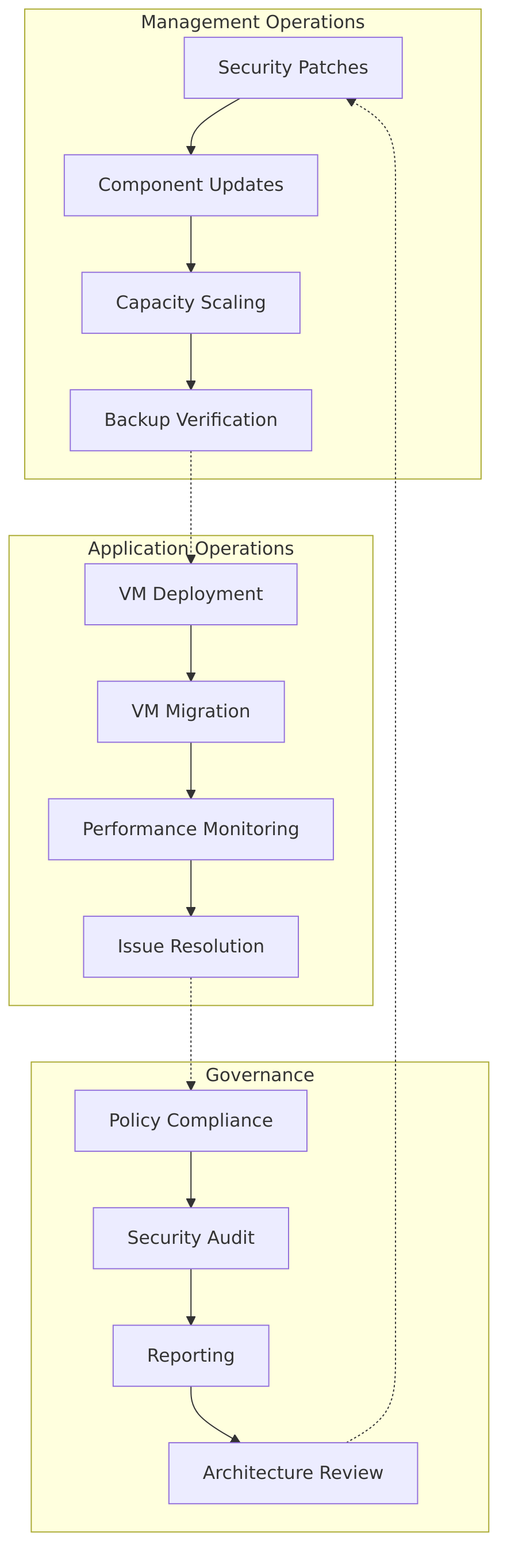
#### 4.1.9.2 VM Resource Management

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: scalable-vm-template  
 namespace: vm-production  
spec:  
 template:  
 spec:  
 domain:  
 cpu:  
 cores: 4  
 sockets: 1  
 threads: 1  
 memory:  
 guest: 8Gi  
 resources:  
 requests:  
 cpu: 2  
 memory: 4Gi  
 limits:  
 cpu: 4  
 memory: 8Gi  
 devices:  
 autoattachPodInterface: false  
 autoattachSerialConsole: true  
 autoattachGraphicsDevice: true  
 evictionStrategy: LiveMigrate  
 terminationGracePeriodSeconds: 180  
 nodeSelector:  
 node-role.kubernetes.io/worker: ""  
 vm-workload: "true"  
 affinity:  
 podAntiAffinity:  
 preferredDuringSchedulingIgnoredDuringExecution:  
 - weight: 100  
 podAffinityTerm:  
 labelSelector:  
 matchExpressions:  
 - key: vm.kubevirt.io/name  
 operator: Exists  
 topologyKey: kubernetes.io/hostname

### 4.1.10 Operational Procedures

#### 4.1.10.1 Day-2 Operations Workflow

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

#### 4.1.10.2 Monitoring and Alerting

apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: multi-cluster-alerts  
 namespace: monitoring  
spec:  
 groups:  
 - name: cluster.health  
 rules:  
 - alert: ClusterDown  
 expr: up{job="kubernetes-apiservers"} == 0  
 for: 5m  
 labels:  
 severity: critical  
 annotations:  
 summary: "Cluster {{ $labels.cluster }} is down"  
 description: "Cluster {{ $labels.cluster }} has been down for more than 5 minutes"  
   
 - alert: VMHighMemory  
 expr: kubevirt\_vm\_memory\_usage\_bytes / kubevirt\_vm\_memory\_available\_bytes > 0.9  
 for: 10m  
 labels:  
 severity: warning  
 annotations:  
 summary: "VM {{ $labels.name }} high memory usage"  
 description: "VM {{ $labels.name }} in cluster {{ $labels.cluster }} has high memory usage"  
   
 - alert: VMMigrationFailed  
 expr: increase(kubevirt\_vm\_migration\_failed\_total[5m]) > 0  
 labels:  
 severity: critical  
 annotations:  
 summary: "VM migration failed"  
 description: "VM migration failed in cluster {{ $labels.cluster }}"

### 4.1.11 Best Practices and Recommendations

#### 4.1.11.1 Cluster Design Guidelines

1. **Resource Planning**
   * Size clusters based on workload requirements
   * Plan for 20-30% overhead for system components
   * Consider NUMA topology for high-performance VMs
2. **Network Segmentation**
   * Isolate management and data plane traffic
   * Use VLANs for multi-tenant environments
   * Implement east-west encryption
3. **Storage Strategy**
   * Use local storage for high-performance workloads
   * Implement storage classes for different performance tiers
   * Plan for backup and disaster recovery
4. **Security Architecture**
   * Implement pod security standards
   * Use network policies for microsegmentation
   * Regular security scanning and compliance checks

#### 4.1.11.2 Operational Excellence

1. **GitOps Workflow**
   * All changes through version control
   * Automated testing and validation
   * Rollback capabilities
2. **Monitoring Strategy**
   * Proactive alerting and monitoring
   * Centralized logging and metrics
   * Regular performance reviews
3. **Disaster Recovery**
   * Regular backup testing
   * Cross-region replication
   * Documented recovery procedures

This global architecture overview provides a comprehensive foundation for understanding how the RH OVE ecosystem scales across multiple clusters while maintaining centralized governance, security, and operational efficiency. The architecture supports growth from small deployments to large-scale multi-region installations while preserving consistent management and security practices.

# 5 Single Cluster Overview

## 5.1 RH OVE Solution Design and Architecture

### 5.1.1 Overview

This document provides an overview of the RH OVE solution, detailing the architecture, deployment, and management strategies.

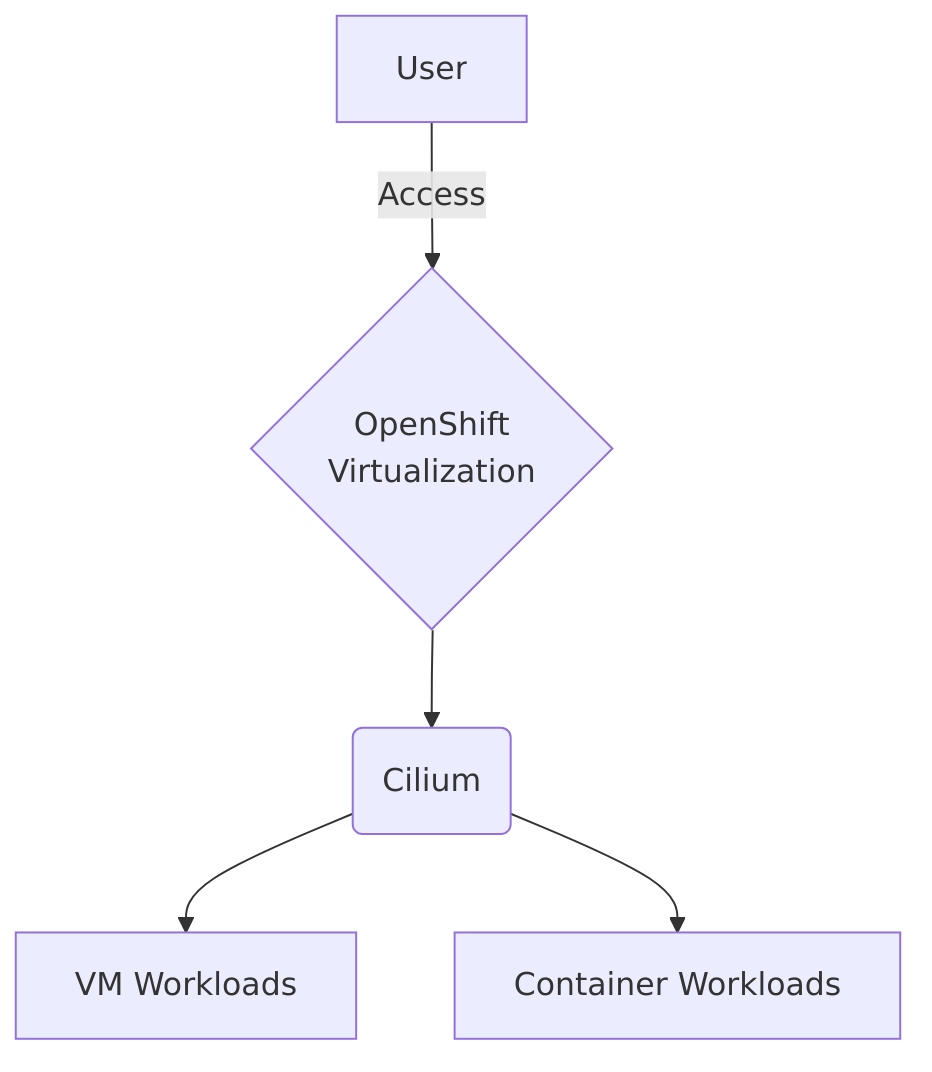
### 5.1.2 Design Principles

* Utilize a namespace-based topology for isolation and security.
* Implement Cilium for network security using eBPF.
* Integrate multiplex workloads to optimize resource utilization.

### 5.1.3 Network Architecture

Mermaid diagram for network architecture:

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 5.1.4 Storage Architecture

Include storage considerations and architecture here.

# 6 Design Principles

## 6.1 Design Principles

### 6.1.1 Overview

The RH OVE solution is built on fundamental design principles that ensure scalability, security, and operational efficiency for hybrid container and VM workloads.

### 6.1.2 Core Principles

#### 6.1.2.1 1. Application Namespace-Based Topology

Based on the analysis from our research, using an application namespace-based topology is considered a best practice for RH OVE clusters.

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Cluster Level"  
 A[RH OVE Cluster]  
 end  
   
 subgraph "Application Namespaces"  
 B[app-web]  
 C[app-database]  
 D[app-analytics]  
 E[app-monitoring]  
 end  
   
 subgraph "Resources per Namespace"  
 B --> F[VMs + Containers + Storage + Network]  
 C --> G[VMs + Containers + Storage + Network]  
 D --> H[VMs + Containers + Storage + Network]  
 E --> I[VMs + Containers + Storage + Network]  
 end

*Note: Diagram rendering failed, showing code instead.*

**Benefits:** - **Isolation and Security**: Strong RBAC and network policy enforcement - **Operational Efficiency**: Simplified management and troubleshooting - **Network Segregation**: Namespace-scoped NetworkAttachmentDefinitions - **Scalability**: Prevents resource clutter and performance bottlenecks - **Policy Management**: Granular security policies and quotas

**Implementation:** - Group related VMs and Kubernetes resources by application or business domain - Apply consistent labeling for automation and cost management - Combine with network policies and RBAC rules - Designate separate namespaces for dev, test, and prod environments

#### 6.1.2.2 2. Mixed Workload Strategy

Multiplexing Kubernetes container workloads and VM workloads on the same RH OVE cluster is highly advantageous:

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph LR  
 subgraph "RH OVE Cluster"  
 A[Unified Management Platform]  
   
 subgraph "Container Workloads"  
 B[Microservices]  
 C[Cloud-Native Apps]  
 D[API Gateways]  
 end  
   
 subgraph "VM Workloads"  
 E[Legacy Applications]  
 F[Windows Workloads]  
 G[Databases]  
 H[Monolithic Applications]  
 end  
 end  
   
 A --> B  
 A --> C  
 A --> D  
 A --> E  
 A --> F  
 A --> G  
 A --> H

*Note: Diagram rendering failed, showing code instead.*

**Advantages:** - **Unified Management**: Same Kubernetes-native interface for all workloads - **Resource Optimization**: Better hardware consolidation - **Flexibility**: Gradual modernization path for legacy applications - **Streamlined DevOps**: Integrated CI/CD pipelines for all workload types - **Advanced Platform Features**: HA, storage provisioning, monitoring for all

#### 6.1.2.3 3. Security-First Design

Implement defense-in-depth security across all layers:

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 A[Security Layers] --> B[Network Security]  
 A --> C[Admission Control]  
 A --> D[RBAC & SCC]  
 A --> E[Pod Security Standards]  
 A --> F[Image Security]  
   
 B --> G[Cilium CNI with eBPF]  
 B --> H[Network Policies]  
 B --> I[Microsegmentation]  
   
 C --> J[OpenShift Built-in]  
 C --> K[KubeVirt Webhooks]  
 C --> L[Kyverno Policies]  
   
 D --> M[Role-Based Access Control]  
 D --> N[Security Context Constraints]  
   
 E --> O[Pod Security Standards]  
 E --> P[Workload Isolation]  
   
 F --> Q[Image Scanning]  
 F --> R[Registry Security]

*Note: Diagram rendering failed, showing code instead.*

#### 6.1.2.4 4. GitOps-Driven Operations

Implement infrastructure and application management through GitOps principles:

**Benefits:** - **Single Source of Truth**: All configurations version-controlled in Git - **Declarative Management**: Infrastructure as Code for VMs and containers - **Automation**: Reduced human error through automated deployments - **Auditability**: Complete change tracking and rollback capabilities - **Collaboration**: Peer review through pull requests

#### 6.1.2.5 5. Observability and Monitoring

Comprehensive monitoring strategy across all workload types:

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Monitoring Stack"  
 A[Dynatrace] --> B[Full-Stack Monitoring]  
 A --> C[AI-Powered Analytics]  
 A --> D[Application Performance]  
   
 E[Prometheus] --> F[Metrics Collection]  
 E --> G[Custom Metrics]  
   
 H[OpenShift Monitoring] --> I[Cluster Health]  
 H --> J[Platform Metrics]  
 end  
   
 subgraph "Workloads"  
 K[VMs]  
 L[Containers]  
 M[Infrastructure]  
 end  
   
 B --> K  
 B --> L  
 B --> M  
 F --> K  
 F --> L  
 I --> M

*Note: Diagram rendering failed, showing code instead.*

### 6.1.3 Implementation Guidelines

#### 6.1.3.1 Namespace Design

## Example namespace structure  
apiVersion: v1  
kind: Namespace  
metadata:  
 name: app-web-prod  
 labels:  
 app: web  
 environment: production  
 tier: frontend  
 annotations:  
 network-policy: strict  
 backup-policy: daily

#### 6.1.3.2 Resource Quotas

apiVersion: v1  
kind: ResourceQuota  
metadata:  
 name: compute-quota  
 namespace: app-web-prod  
spec:  
 hard:  
 requests.cpu: "10"  
 requests.memory: 20Gi  
 limits.cpu: "20"  
 limits.memory: 40Gi  
 persistentvolumeclaims: "10"

#### 6.1.3.3 Network Policies

apiVersion: networking.k8s.io/v1  
kind: NetworkPolicy  
metadata:  
 name: app-web-netpol  
 namespace: app-web-prod  
spec:  
 podSelector:  
 matchLabels:  
 app: web  
 policyTypes:  
 - Ingress  
 - Egress  
 ingress:  
 - from:  
 - namespaceSelector:  
 matchLabels:  
 name: app-gateway-prod

### 6.1.4 Best Practices

#### 6.1.4.1 Design Decisions

1. **Plan namespace strategy early**: Define naming conventions and access hierarchies
2. **Implement least privilege**: Use RBAC and network policies consistently
3. **Design for scale**: Consider resource limits and node capacity planning
4. **Plan for disaster recovery**: Include backup and restoration strategies

#### 6.1.4.2 Operational Considerations

1. **Monitor resource utilization**: Prevent resource contention between workload types
2. **Implement proper logging**: Centralized logging for both VMs and containers
3. **Regular security assessments**: Continuous compliance and vulnerability management
4. **Performance testing**: Regular load testing for mixed workload scenarios

These design principles ensure that the RH OVE solution provides a robust, secure, and scalable platform for modern hybrid workloads while supporting organizational transformation initiatives.

# 7 Network Architecture

## 7.1 Network Architecture

### 7.1.1 Overview

The RH OVE network architecture leverages Cilium CNI for enhanced security and observability, providing advanced network capabilities through eBPF technology for both container and VM workloads.

### 7.1.2 Cilium CNI Integration

Based on our research, using Cilium for RH OVE is widely regarded as a strong, future-proof approach with several key advantages:

#### 7.1.2.1 Benefits

* **Red Hat Certification**: Cilium is a certified CNI plugin for OpenShift
* **eBPF-Powered Enforcement**: Advanced security, visibility, and traffic control
* **Multi-platform Support**: Works for both containers and VMs in hybrid environments
* **High Performance**: Superior performance compared to traditional iptables-based CNIs
* **Service Mesh Capabilities**: L7 security and observability without sidecar proxies

### 7.1.3 Network Architecture Diagram

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "External Networks"  
 EXT[External Networks]  
 LB[Load Balancers]  
 end  
   
 subgraph "OpenShift Cluster"  
 subgraph "Control Plane"  
 API[API Server]  
 ETCD[etcd]  
 end  
   
 subgraph "Cilium Control Plane"  
 CA[Cilium Agent]  
 CO[Cilium Operator]  
 HUB[Hubble Relay]  
 end  
   
 subgraph "Multus Control Plane"  
 MDS[Multus DaemonSet]  
 NADAPI[NAD API Server]  
 end  
   
 subgraph "Node 1"  
 subgraph "Cilium Agent 1"  
 EBPF1[eBPF Programs]  
 POL1[Policy Engine]  
 ENC1[Encryption]  
 end  
   
 subgraph "Multus CNI 1"  
 MCNI1[Multus CNI]  
 NAD1[Network Attachments]  
 SRIOV1[SR-IOV CNI]  
 MACVLAN1[MacVLAN CNI]  
 end  
   
 subgraph "Workloads 1"  
 POD1[Container Pods]  
 VM1[Virtual Machines]  
 MVMI1[Multi-NIC VMs]  
 end  
 end  
   
 subgraph "Node 2"  
 subgraph "Cilium Agent 2"  
 EBPF2[eBPF Programs]  
 POL2[Policy Engine]  
 ENC2[Encryption]  
 end  
   
 subgraph "Multus CNI 2"  
 MCNI2[Multus CNI]  
 NAD2[Network Attachments]  
 SRIOV2[SR-IOV CNI]  
 MACVLAN2[MacVLAN CNI]  
 end  
   
 subgraph "Workloads 2"  
 POD2[Container Pods]  
 VM2[Virtual Machines]  
 MVMI2[Multi-NIC VMs]  
 end  
 end  
 end  
   
 EXT --> LB  
 LB --> API  
 API --> CA  
 API --> MDS  
 CA --> CO  
 CO --> HUB  
   
 NADAPI --> NAD1  
 NADAPI --> NAD2  
   
 EBPF1 --> POD1  
 EBPF1 --> VM1  
 EBPF2 --> POD2  
 EBPF2 --> VM2  
   
 MCNI1 --> MVMI1  
 MCNI2 --> MVMI2  
 NAD1 --> SRIOV1  
 NAD1 --> MACVLAN1  
 NAD2 --> SRIOV2  
 NAD2 --> MACVLAN2  
   
 SRIOV1 --> MVMI1  
 MACVLAN1 --> MVMI1  
 SRIOV2 --> MVMI2  
 MACVLAN2 --> MVMI2  
   
 POL1 --> EBPF1  
 POL2 --> EBPF2  
 ENC1 --> EBPF1  
 ENC2 --> EBPF2

*Note: Diagram rendering failed, showing code instead.*

### 7.1.4 Network Security Features

#### 7.1.4.1 Identity-Aware Security

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph LR  
 subgraph "Traditional Security"  
 A[IP-based Rules]  
 B[Port-based Rules]  
 end  
   
 subgraph "Cilium Identity-Aware"  
 C[Label-based Identity]  
 D[Service Identity]  
 E[Namespace Identity]  
 F[Application Identity]  
 end  
   
 A --> G[Limited Flexibility]  
 B --> G  
   
 C --> H[Zero Trust Architecture]  
 D --> H  
 E --> H  
 F --> H

*Note: Diagram rendering failed, showing code instead.*

#### 7.1.4.2 Network Policies

##### 7.1.4.2.1 Basic Network Policy for VMs

apiVersion: cilium.io/v2  
kind: CiliumNetworkPolicy  
metadata:  
 name: vm-web-policy  
 namespace: app-web-prod  
spec:  
 endpointSelector:  
 matchLabels:  
 app: web-vm  
 ingress:  
 - fromEndpoints:  
 - matchLabels:  
 app: api-gateway  
 toPorts:  
 - ports:  
 - port: "80"  
 protocol: TCP  
 - port: "443"  
 protocol: TCP  
 egress:  
 - toEndpoints:  
 - matchLabels:  
 app: database-vm  
 toPorts:  
 - ports:  
 - port: "5432"  
 protocol: TCP

##### 7.1.4.2.2 L7 HTTP Policy

apiVersion: cilium.io/v2  
kind: CiliumNetworkPolicy  
metadata:  
 name: l7-http-policy  
spec:  
 endpointSelector:  
 matchLabels:  
 app: web-api  
 ingress:  
 - fromEndpoints:  
 - matchLabels:  
 app: frontend  
 toPorts:  
 - ports:  
 - port: "80"  
 protocol: TCP  
 rules:  
 http:  
 - method: "GET"  
 path: "/api/v1/.\*"  
 - method: "POST"  
 path: "/api/v1/users"

### 7.1.5 Multi-Tenant Networking

#### 7.1.5.1 Namespace Isolation

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Tenant A Namespace"  
 A1[VM Workloads A]  
 A2[Container Workloads A]  
 A3[Network Policies A]  
 end  
   
 subgraph "Tenant B Namespace"  
 B1[VM Workloads B]  
 B2[Container Workloads B]  
 B3[Network Policies B]  
 end  
   
 subgraph "Shared Services"  
 S1[DNS]  
 S2[Monitoring]  
 S3[Logging]  
 end  
   
 A3 --> A1  
 A3 --> A2  
 B3 --> B1  
 B3 --> B2  
   
 A1 -.-> S1  
 A2 -.-> S2  
 B1 -.-> S1  
 B2 -.-> S3

*Note: Diagram rendering failed, showing code instead.*

#### 7.1.5.2 NetworkAttachmentDefinition for VMs

apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: vm-network  
 namespace: app-database-prod  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "vm-network",  
 "type": "cilium-cni",  
 "ipam": {  
 "type": "cilium"  
 }  
 }

### 7.1.6 Multus Multi-Network Configuration

#### 7.1.6.1 Overview

Multus CNI enables attaching multiple network interfaces to pods and VMs, allowing for complex networking scenarios such as: - Separation of management and data traffic - VLAN-based network segmentation - High-performance networking with SR-IOV - Legacy application networking requirements

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "VM with Multiple Network Interfaces"  
 A[Virtual Machine]  
 B[eth0 - Default Network]  
 C[eth1 - Management Network]  
 D[eth2 - Storage Network]  
 E[eth3 - SR-IOV Network]  
 end  
   
 subgraph "Network Attachments"  
 F[Default CNI - Cilium]  
 G[Management NAD]  
 H[Storage NAD]  
 I[SR-IOV NAD]  
 end  
   
 A --> B  
 A --> C  
 A --> D  
 A --> E  
   
 B --> F  
 C --> G  
 D --> H  
 E --> I

*Note: Diagram rendering failed, showing code instead.*

#### 7.1.6.2 Multus Installation

Multus is typically installed as part of OpenShift Container Platform:

## Verify Multus is installed  
oc get network.operator.openshift.io cluster -o yaml  
  
## Check Multus DaemonSet  
oc get ds multus -n openshift-multus

#### 7.1.6.3 Network Attachment Definitions (NADs)

##### 7.1.6.3.1 Management Network NAD

apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: management-network  
 namespace: vm-infrastructure  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "management-network",  
 "type": "macvlan",  
 "master": "ens192",  
 "mode": "bridge",  
 "ipam": {  
 "type": "static",  
 "addresses": [  
 {  
 "address": "192.168.100.0/24",  
 "gateway": "192.168.100.1"  
 }  
 ],  
 "dns": {  
 "nameservers": ["192.168.100.10", "8.8.8.8"]  
 }  
 }  
 }

##### 7.1.6.3.2 Storage Network NAD

apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: storage-network  
 namespace: vm-infrastructure  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "storage-network",  
 "type": "macvlan",  
 "master": "ens224",  
 "mode": "bridge",  
 "ipam": {  
 "type": "static",  
 "addresses": [  
 {  
 "address": "10.0.200.0/24"  
 }  
 ]  
 }  
 }

##### 7.1.6.3.3 VLAN-based Network NAD

apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: vlan-100-network  
 namespace: vm-production  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "vlan-100-network",  
 "type": "macvlan",  
 "master": "ens192.100",  
 "mode": "bridge",  
 "ipam": {  
 "type": "dhcp"  
 }  
 }

##### 7.1.6.3.4 SR-IOV Network NAD

apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: sriov-high-performance  
 namespace: vm-production  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "sriov-high-performance",  
 "type": "sriov",  
 "deviceID": "1017",  
 "vf": 0,  
 "ipam": {  
 "type": "static",  
 "addresses": [  
 {  
 "address": "10.0.50.0/24"  
 }  
 ]  
 }  
 }

#### 7.1.6.4 VM Configuration with Multiple Network Cards

##### 7.1.6.4.1 VM with Multiple Interfaces

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: multi-network-vm  
 namespace: vm-infrastructure  
 annotations:  
 k8s.v1.cni.cncf.io/networks: |  
 [  
 {  
 "name": "management-network",  
 "ips": ["192.168.100.50/24"]  
 },  
 {  
 "name": "storage-network",  
 "ips": ["10.0.200.50/24"]  
 },  
 {  
 "name": "vlan-100-network"  
 }  
 ]  
spec:  
 running: true  
 template:  
 metadata:  
 labels:  
 app: multi-network-app  
 spec:  
 domain:  
 cpu:  
 cores: 4  
 memory:  
 guest: 8Gi  
 devices:  
 interfaces:  
 - name: default  
 masquerade: {}  
 - name: management  
 bridge: {}  
 - name: storage  
 bridge: {}  
 - name: vlan-network  
 bridge: {}  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 resources:  
 requests:  
 cpu: 4  
 memory: 8Gi  
 networks:  
 - name: default  
 pod: {}  
 - name: management  
 multus:  
 networkName: management-network  
 - name: storage  
 multus:  
 networkName: storage-network  
 - name: vlan-network  
 multus:  
 networkName: vlan-100-network  
 volumes:  
 - name: rootdisk  
 dataVolume:  
 name: multi-network-vm-root

##### 7.1.6.4.2 High-Performance VM with SR-IOV

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: high-perf-vm  
 namespace: vm-production  
 annotations:  
 k8s.v1.cni.cncf.io/networks: |  
 [  
 {  
 "name": "management-network",  
 "ips": ["192.168.100.100/24"]  
 },  
 {  
 "name": "sriov-high-performance",  
 "ips": ["10.0.50.100/24"]  
 }  
 ]  
spec:  
 running: true  
 template:  
 metadata:  
 labels:  
 app: high-performance-app  
 spec:  
 domain:  
 cpu:  
 cores: 8  
 dedicatedCpuPlacement: true  
 memory:  
 guest: 16Gi  
 hugepages:  
 pageSize: 1Gi  
 devices:  
 interfaces:  
 - name: default  
 masquerade: {}  
 - name: management  
 bridge: {}  
 - name: sriov-net  
 sriov: {}  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 resources:  
 requests:  
 cpu: 8  
 memory: 16Gi  
 hugepages-1Gi: 16Gi  
 networks:  
 - name: default  
 pod: {}  
 - name: management  
 multus:  
 networkName: management-network  
 - name: sriov-net  
 multus:  
 networkName: sriov-high-performance  
 volumes:  
 - name: rootdisk  
 dataVolume:  
 name: high-perf-vm-root

#### 7.1.6.5 Advanced Multus Configurations

##### 7.1.6.5.1 Bond Network Interface

apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: bond-network  
 namespace: vm-infrastructure  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "bond-network",  
 "type": "bond",  
 "mode": "active-backup",  
 "miimon": "100",  
 "links": [  
 {"name": "ens192"},  
 {"name": "ens224"}  
 ],  
 "ipam": {  
 "type": "static",  
 "addresses": [  
 {  
 "address": "10.0.100.0/24",  
 "gateway": "10.0.100.1"  
 }  
 ]  
 }  
 }

##### 7.1.6.5.2 OVS Bridge Network

apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: ovs-bridge-network  
 namespace: vm-infrastructure  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "ovs-bridge-network",  
 "type": "ovs",  
 "bridge": "br-data",  
 "vlan": 200,  
 "ipam": {  
 "type": "static",  
 "addresses": [  
 {  
 "address": "10.0.200.0/24"  
 }  
 ]  
 }  
 }

### 7.1.7 Encryption and Security

#### 7.1.7.1 Transparent Encryption

Cilium supports both IPsec and WireGuard for transparent encryption:

## Cilium ConfigMap for WireGuard encryption  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cilium-config  
 namespace: kube-system  
data:  
 enable-wireguard: "true"  
 wireguard-userspace-fallback: "true"

#### 7.1.7.2 Service Mesh without Sidecars

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph LR  
 subgraph "Traditional Service Mesh"  
 A[Application Pod]  
 B[Sidecar Proxy]  
 C[Network]  
 end  
   
 subgraph "Cilium Service Mesh"  
 D[Application Pod]  
 E[eBPF in Kernel]  
 F[Network]  
 end  
   
 A --> B  
 B --> C  
   
 D --> E  
 E --> F  
   
 G[Higher Resource Usage] --> A  
 H[Lower Latency] --> D  
 I[Better Performance] --> D

*Note: Diagram rendering failed, showing code instead.*

### 7.1.8 Observability with Hubble

#### 7.1.8.1 Network Visibility

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Hubble Observability"  
 A[Hubble Agent]  
 B[Hubble Relay]  
 C[Hubble UI]  
 D[Hubble CLI]  
 end  
   
 subgraph "Data Sources"  
 E[Network Flows]  
 F[Service Dependencies]  
 G[Security Events]  
 H[Performance Metrics]  
 end  
   
 E --> A  
 F --> A  
 G --> A  
 H --> A  
   
 A --> B  
 B --> C  
 B --> D

*Note: Diagram rendering failed, showing code instead.*

#### 7.1.8.2 Hubble Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cilium-config  
 namespace: kube-system  
data:  
 enable-hubble: "true"  
 hubble-listen-address: ":4244"  
 hubble-socket-path: "/var/run/cilium/hubble.sock"  
 hubble-metrics-server: ":9091"  
 hubble-metrics: >-  
 dns:query;ignoreAAAA  
 drop  
 tcp  
 flow  
 icmp  
 http

### 7.1.9 VM-Specific Networking

#### 7.1.9.1 VM Network Integration

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: database-vm  
 namespace: app-database-prod  
spec:  
 template:  
 spec:  
 networks:  
 - name: default  
 pod: {}  
 - name: vm-network  
 multus:  
 networkName: vm-network  
 domain:  
 devices:  
 interfaces:  
 - name: default  
 masquerade: {}  
 - name: vm-network  
 bridge: {}

### 7.1.10 Performance Optimization

#### 7.1.10.1 eBPF Performance Benefits

1. **Bypass iptables overhead**: Direct kernel-space processing
2. **Reduced context switches**: Fewer user-space to kernel-space transitions
3. **Optimized packet processing**: Custom eBPF programs for specific workloads
4. **Hardware acceleration**: Support for XDP (eXpress Data Path)

#### 7.1.10.2 Network Performance Tuning

## Cilium DaemonSet configuration for performance  
apiVersion: apps/v1  
kind: DaemonSet  
metadata:  
 name: cilium  
spec:  
 template:  
 spec:  
 containers:  
 - name: cilium-agent  
 args:  
 - --enable-bandwidth-manager=true  
 - --enable-local-redirect-policy=true  
 - --kube-proxy-replacement=strict  
 resources:  
 requests:  
 cpu: 100m  
 memory: 128Mi  
 limits:  
 cpu: 500m  
 memory: 512Mi

### 7.1.11 Integration with External Systems

#### 7.1.11.1 Load Balancer Integration

apiVersion: cilium.io/v2alpha1  
kind: CiliumLoadBalancerIPPool  
metadata:  
 name: vm-pool  
spec:  
 cidrs:  
 - cidr: "10.100.0.0/24"  
---  
apiVersion: v1  
kind: Service  
metadata:  
 name: vm-web-service  
 annotations:  
 io.cilium/lb-ipam-ips: "10.100.0.10"  
spec:  
 type: LoadBalancer  
 selector:  
 app: web-vm  
 ports:  
 - port: 80  
 targetPort: 8080

### 7.1.12 Troubleshooting and Monitoring

#### 7.1.12.1 Network Flow Monitoring

## Monitor network flows  
hubble observe --namespace app-web-prod  
  
## Check policy violations  
hubble observe --verdict DENIED  
  
## Monitor specific VM traffic  
hubble observe --pod vm-database-vm-xxx

#### 7.1.12.2 Performance Metrics

Key metrics to monitor: - Network throughput per VM/pod - Policy enforcement latency - eBPF program execution time - Hubble flow processing rate

This network architecture provides enterprise-grade security, performance, and observability for mixed VM and container workloads in the RH OVE environment.

# 8 Storage Architecture

## 8.1 Storage Architecture

### 8.1.1 Overview

The RH OVE storage architecture provides unified storage management for both container and VM workloads, leveraging Kubernetes-native storage concepts while supporting traditional VM storage requirements.

### 8.1.2 Storage Components

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Storage Infrastructure"  
 A[Storage Classes]  
 B[Persistent Volumes]  
 C[Container Storage Interface]  
 D[Storage Backends]  
 end  
   
 subgraph "VM Storage"  
 E[DataVolumes]  
 F[VM Disks]  
 G[CDI - Containerized Data Importer]  
 H[VM Templates]  
 end  
   
 subgraph "Container Storage"  
 I[Persistent Volume Claims]  
 J[ConfigMaps]  
 K[Secrets]  
 end  
   
 A --> B  
 B --> C  
 C --> D  
   
 E --> G  
 F --> E  
 H --> E  
   
 I --> B  
 J --> K  
   
 B --> E  
 B --> I

*Note: Diagram rendering failed, showing code instead.*

### 8.1.3 DataVolume Management

#### 8.1.3.1 DataVolume CRD

DataVolumes are the primary mechanism for managing VM storage in RH OVE:

apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: web-vm-disk  
 namespace: app-web-prod  
spec:  
 pvc:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 50Gi  
 storageClassName: fast-ssd  
 source:  
 registry:  
 url: "docker://registry.redhat.io/rhel8/rhel:latest"

#### 8.1.3.2 Storage Import Patterns

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph LR  
 subgraph "Data Sources"  
 A[Container Registry]  
 B[HTTP Server]  
 C[S3 Bucket]  
 D[Existing PVC]  
 end  
   
 subgraph "CDI Processing"  
 E[Import Pod]  
 F[Data Processing]  
 G[Format Conversion]  
 end  
   
 subgraph "Target Storage"  
 H[DataVolume]  
 I[PVC]  
 J[VM Disk]  
 end  
   
 A --> E  
 B --> E  
 C --> E  
 D --> E  
   
 E --> F  
 F --> G  
 G --> H  
 H --> I  
 I --> J

*Note: Diagram rendering failed, showing code instead.*

### 8.1.4 Storage Classes and Performance Tiers

#### 8.1.4.1 Performance Tiers

## High Performance SSD Storage Class  
apiVersion: storage.k8s.io/v1  
kind: StorageClass  
metadata:  
 name: high-performance-ssd  
provisioner: kubernetes.io/no-provisioner  
parameters:  
 type: ssd  
 iops: "10000"  
 throughput: "500Mi"  
reclaimPolicy: Delete  
volumeBindingMode: WaitForFirstConsumer  
---  
## Standard HDD Storage Class  
apiVersion: storage.k8s.io/v1  
kind: StorageClass  
metadata:  
 name: standard-hdd  
provisioner: kubernetes.io/no-provisioner  
parameters:  
 type: hdd  
 iops: "1000"  
 throughput: "100Mi"  
reclaimPolicy: Retain  
volumeBindingMode: WaitForFirstConsumer  
---  
## Archive Storage Class  
apiVersion: storage.k8s.io/v1  
kind: StorageClass  
metadata:  
 name: archive-storage  
provisioner: kubernetes.io/no-provisioner  
parameters:  
 type: archive  
 iops: "100"  
 throughput: "50Mi"  
reclaimPolicy: Retain  
volumeBindingMode: WaitForFirstConsumer

### 8.1.5 VM Disk Configuration

#### 8.1.5.1 VM with Multiple Disks

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: database-vm  
 namespace: app-database-prod  
spec:  
 template:  
 spec:  
 domain:  
 devices:  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 - name: datadisk  
 disk:  
 bus: virtio  
 - name: logdisk  
 disk:  
 bus: virtio  
 resources:  
 requests:  
 memory: 8Gi  
 cpu: 4  
 volumes:  
 - name: rootdisk  
 dataVolume:  
 name: db-vm-root  
 - name: datadisk  
 dataVolume:  
 name: db-vm-data  
 - name: logdisk  
 dataVolume:  
 name: db-vm-logs

#### 8.1.5.2 DataVolume for Different Use Cases

## Boot disk from registry  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: db-vm-root  
spec:  
 pvc:  
 accessModes: [ReadWriteOnce]  
 resources:  
 requests:  
 storage: 30Gi  
 storageClassName: high-performance-ssd  
 source:  
 registry:  
 url: "docker://registry.access.redhat.com/rhel8/rhel:latest"  
---  
## Data disk - blank  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: db-vm-data  
spec:  
 pvc:  
 accessModes: [ReadWriteOnce]  
 resources:  
 requests:  
 storage: 500Gi  
 storageClassName: standard-hdd  
 source:  
 blank: {}  
---  
## Log disk - blank  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: db-vm-logs  
spec:  
 pvc:  
 accessModes: [ReadWriteOnce]  
 resources:  
 requests:  
 storage: 100Gi  
 storageClassName: standard-hdd  
 source:  
 blank: {}

### 8.1.6 Storage Backup Integration

#### 8.1.6.1 Rubrik Integration for VM Storage

Based on our research, Rubrik provides certified integration with RH OVE for VM backup:

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "RH OVE Cluster"  
 A[Virtual Machines]  
 B[DataVolumes]  
 C[Persistent Volumes]  
 D[Rubrik Agent]  
 end  
   
 subgraph "Rubrik Platform"  
 E[Rubrik Cluster]  
 F[Backup Policies]  
 G[Recovery Points]  
 H[Immutable Storage]  
 end  
   
 A --> D  
 B --> D  
 C --> D  
 D --> E  
 E --> F  
 F --> G  
 G --> H

*Note: Diagram rendering failed, showing code instead.*

#### 8.1.6.2 Backup Policy Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: rubrik-backup-policy  
 namespace: app-database-prod  
data:  
 policy.yaml: |  
 vm\_backup\_policy:  
 name: "database-vm-backup"  
 frequency: "daily"  
 retention: "30d"  
 snapshot\_consistency: "crash-consistent"  
 backup\_window: "02:00-06:00"  
 exclude\_disks:  
 - "temp-disk"  
 - "swap-disk"

### 8.1.7 Storage Monitoring and Performance

#### 8.1.7.1 Storage Metrics

Key storage metrics to monitor:

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: storage-metrics  
spec:  
 selector:  
 matchLabels:  
 app: cdi-controller  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics

#### 8.1.7.2 Performance Monitoring

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph LR  
 subgraph "Storage Metrics"  
 A[IOPS per VM]  
 B[Throughput per Volume]  
 C[Latency Metrics]  
 D[Storage Utilization]  
 end  
   
 subgraph "Monitoring Stack"  
 E[Prometheus]  
 F[Grafana]  
 G[Alert Manager]  
 end  
   
 A --> E  
 B --> E  
 C --> E  
 D --> E  
   
 E --> F  
 E --> G

*Note: Diagram rendering failed, showing code instead.*

### 8.1.8 Storage Operations

#### 8.1.8.1 Volume Expansion

## Expand a DataVolume  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: web-vm-disk  
 namespace: app-web-prod  
spec:  
 pvc:  
 accessModes: [ReadWriteOnce]  
 resources:  
 requests:  
 storage: 100Gi # Increased from 50Gi  
 storageClassName: fast-ssd  
 source:  
 pvc:  
 name: web-vm-disk  
 namespace: app-web-prod

#### 8.1.8.2 Volume Cloning

## Clone a DataVolume for VM template  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: web-vm-template-clone  
 namespace: vm-templates  
spec:  
 pvc:  
 accessModes: [ReadWriteOnce]  
 resources:  
 requests:  
 storage: 50Gi  
 storageClassName: fast-ssd  
 source:  
 pvc:  
 name: web-vm-golden-image  
 namespace: vm-templates

#### 8.1.8.3 Snapshot Management

apiVersion: snapshot.storage.k8s.io/v1  
kind: VolumeSnapshot  
metadata:  
 name: db-vm-snapshot-pre-upgrade  
 namespace: app-database-prod  
spec:  
 volumeSnapshotClassName: csi-snapshotter  
 source:  
 persistentVolumeClaimName: db-vm-data

### 8.1.9 Storage Security

#### 8.1.9.1 Encryption at Rest

apiVersion: storage.k8s.io/v1  
kind: StorageClass  
metadata:  
 name: encrypted-storage  
provisioner: ebs.csi.aws.com  
parameters:  
 type: gp3  
 encrypted: "true"  
 kmsKeyId: "arn:aws:kms:region:account:key/key-id"  
reclaimPolicy: Delete  
volumeBindingMode: WaitForFirstConsumer

#### 8.1.9.2 Access Control

apiVersion: rbac.authorization.k8s.io/v1  
kind: Role  
metadata:  
 namespace: app-database-prod  
 name: storage-admin  
rules:  
- apiGroups: [""]  
 resources: ["persistentvolumeclaims"]  
 verbs: ["get", "list", "create", "update", "patch", "delete"]  
- apiGroups: ["cdi.kubevirt.io"]  
 resources: ["datavolumes"]  
 verbs: ["get", "list", "create", "update", "patch", "delete"]  
- apiGroups: ["snapshot.storage.k8s.io"]  
 resources: ["volumesnapshots"]  
 verbs: ["get", "list", "create", "delete"]

### 8.1.10 Best Practices

#### 8.1.10.1 Storage Planning

1. **Right-size storage**: Match storage performance to workload requirements
2. **Use appropriate storage classes**: Different tiers for different use cases
3. **Plan for growth**: Consider volume expansion capabilities
4. **Backup strategy**: Regular snapshots and external backups

#### 8.1.10.2 Performance Optimization

1. **Use SSD for high-IOPS workloads**: Database and application storage
2. **Separate storage by function**: OS, data, logs, and temp on different volumes
3. **Monitor storage metrics**: Track IOPS, throughput, and latency
4. **Implement storage quotas**: Prevent storage exhaustion

#### 8.1.10.3 Security Considerations

1. **Enable encryption at rest**: For sensitive data storage
2. **Implement access controls**: RBAC for storage resources
3. **Regular security scanning**: Check for storage-related vulnerabilities
4. **Audit storage access**: Monitor who accesses what storage

This storage architecture ensures reliable, performant, and secure storage management for the hybrid VM and container workloads in the RH OVE environment.

# 9 IAM Strategy

## 9.1 Identity and Access Management (IAM) Strategy

### 9.1.1 Overview

This document outlines the comprehensive Identity and Access Management (IAM) strategy for the RH OVE multi-cluster ecosystem, implementing authentication and authorization using OpenID Connect (OIDC) providers with enterprise-grade security controls.

### 9.1.2 Executive Summary

The IAM strategy for the RH OVE multi-cluster ecosystem provides enterprise-grade identity and access management through a comprehensive OIDC-based approach that ensures security, compliance, and operational efficiency across all clusters and services.

#### 9.1.2.1 Key Components

##### 9.1.2.1.1 1. **Architecture Components**

* **Mermaid diagram** showing OIDC provider integration across management and application clusters
* **Identity Provider selection** with Keycloak as the recommended solution (Red Hat SSO)
* **Service integration** with ArgoCD, Grafana, Prometheus, and Kubernetes Dashboard
* **Dex OIDC Proxy** deployment for centralized authentication

##### 9.1.2.1.2 2. **Authentication Implementation**

* **OpenShift OAuth configuration** with native OIDC integration
* **Dex OIDC Proxy** for service-to-service authentication
* **Multi-Factor Authentication** using Keycloak authentication flows with mandatory MFA for admin accounts
* **JWT token management** with proper security controls and time-limited tokens
* **Single Sign-On (SSO)** seamless access across all clusters and services

##### 9.1.2.1.3 3. **Authorization Implementation**

* **Kubernetes RBAC integration** with OIDC groups mapping
* **ArgoCD RBAC configuration** for GitOps access control with application-specific permissions
* **Service Account token management** with time-limited tokens and projected volumes
* **Namespace-scoped permissions** aligned with application teams and business units
* **Role-Based Access Control** with predefined organizational roles

##### 9.1.2.1.4 4. **User Lifecycle Management**

* **SCIM integration** for automated user provisioning and deprovisioning
* **Group-based access control** with predefined roles (platform-admins, web-developers, database-admins, security-auditors)
* **Python automation examples** for user management workflows
* **Self-service capabilities** for password reset and account recovery

##### 9.1.2.1.5 5. **Security Controls**

* **Token security** with JWT validation rules and proper expiration policies
* **Network security** policies for authentication services with ingress/egress controls
* **Encryption and key management** with AES-256 and regular key rotation
* **Zero Trust Principles** implementation with least-privilege access patterns

##### 9.1.2.1.6 6. **Monitoring and Audit**

* **Prometheus metrics** for authentication monitoring and alerting
* **Grafana dashboards** for IAM visibility and operational insights
* **Kubernetes audit policies** for compliance logging and security tracking
* **Automated access reviews** and compliance reporting for SOC 2, GDPR, HIPAA
* **Failed authentication tracking** and security incident response

##### 9.1.2.1.7 7. **Disaster Recovery**

* **Identity provider backup** strategies with automated daily backups
* **Multi-region failover** configuration for high availability
* **High availability** for authentication services with automated health checks

#### 9.1.2.2 Technical Implementation Highlights

* **OIDC Provider Integration**: Keycloak (Red Hat SSO) as primary, with Auth0/Okta alternatives
* **Multi-Factor Authentication**: Mandatory for administrative accounts with TOTP/SMS support
* **Service Account Automation**: Time-limited tokens (15min-2hours) with proper lifecycle management
* **Audit and Compliance**: Complete alignment with SOC 2, GDPR, and HIPAA requirements
* **Enterprise Integration**: LDAP/Active Directory federation for existing identity infrastructure

#### 9.1.2.3 Business Benefits

* **Enhanced Security Posture**: Zero trust principles with identity-aware access controls
* **Operational Efficiency**: Centralized identity management across all clusters and services
* **Compliance Readiness**: Automated audit trails and regulatory framework alignment
* **Developer Experience**: Single sign-on with self-service capabilities
* **Cost Optimization**: Reduced operational overhead through automation

#### 9.1.2.4 Implementation Phases

1. **Phase 1**: Design and Planning (Identity provider selection, architecture design)
2. **Phase 2**: Deployment and Configuration (OIDC integration, RBAC implementation)
3. **Phase 3**: Testing and Validation (Security testing, SSO validation, user acceptance)
4. **Phase 4**: Monitoring and Maintenance (Metrics setup, audit automation, user training)

This IAM strategy ensures robust and flexible identity management, leveraging existing enterprise IAM solutions for seamless integration and compliance within the RH OVE multi-cluster ecosystem while providing a foundation for future growth and regulatory requirements.

### 9.1.3 Architecture Components

#### 9.1.3.1 OIDC Provider Integration

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "External Identity Provider"  
 OIDC["OIDC Provider<br/>(Keycloak/Auth0/Okta)"]  
 AD["Active Directory/LDAP"]  
 MFA["MFA Service"]  
 end  
   
 subgraph "Management Cluster"  
 DEXM["Dex OIDC Proxy"]  
 OAUTHM["OAuth2 Proxy"]  
 APIM["Kubernetes API Server"]  
 end  
   
 subgraph "Application Clusters"  
 DEXA["Dex OIDC Proxy"]  
 OAUTHA["OAuth2 Proxy"]  
 APIA["Kubernetes API Server"]  
 end  
   
 subgraph "Services"  
 ARGO["ArgoCD"]  
 GRAF["Grafana"]  
 PROM["Prometheus"]  
 KUBE["Kubernetes Dashboard"]  
 end  
   
 OIDC --> DEXM  
 OIDC --> DEXA  
 AD --> OIDC  
 MFA --> OIDC  
   
 DEXM --> APIM  
 DEXM --> OAUTHM  
 DEXA --> APIA  
 DEXA --> OAUTHA  
   
 OAUTHM --> ARGO  
 OAUTHM --> GRAF  
 OAUTHM --> PROM  
 OAUTHA --> KUBE

*Note: Diagram rendering failed, showing code instead.*

#### 9.1.3.2 Identity Provider Selection

##### 9.1.3.2.1 Recommended: Keycloak (Red Hat SSO)

* **Advantages**: Open source, Red Hat supported, full OIDC compliance
* **Features**: User federation, social login, fine-grained authorization
* **Integration**: Native OpenShift integration, Kubernetes RBAC mapping

##### 9.1.3.2.2 Alternative: Enterprise Solutions

* **Auth0**: SaaS solution with extensive integrations
* **Okta**: Enterprise-grade with advanced security features
* **Azure AD**: Microsoft ecosystem integration

### 9.1.4 Authentication Implementation

#### 9.1.4.1 OpenShift OAuth Configuration

apiVersion: config.openshift.io/v1  
kind: OAuth  
metadata:  
 name: cluster  
spec:  
 identityProviders:  
 - name: keycloak-oidc  
 mappingMethod: claim  
 type: OpenID  
 openID:  
 clientID: openshift-cluster  
 clientSecret:  
 name: oidc-client-secret  
 issuer: https://keycloak.company.com/auth/realms/openshift  
 claims:  
 preferredUsername:  
 - preferred\_username  
 name:  
 - name  
 email:  
 - email  
 groups:  
 - groups

#### 9.1.4.2 Dex OIDC Proxy Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: dex-config  
 namespace: auth-system  
data:  
 config.yaml: |  
 issuer: https://dex.company.com  
 storage:  
 type: kubernetes  
 config:  
 inCluster: true  
 web:  
 https: 0.0.0.0:5556  
 tlsCert: /etc/dex/tls/tls.crt  
 tlsKey: /etc/dex/tls/tls.key  
 connectors:  
 - type: oidc  
 id: keycloak  
 name: Keycloak  
 config:  
 issuer: https://keycloak.company.com/auth/realms/company  
 clientID: dex-client  
 clientSecret: $DEX\_CLIENT\_SECRET  
 redirectURI: https://dex.company.com/callback  
 scopes:  
 - openid  
 - profile  
 - email  
 - groups  
 staticClients:  
 - id: kubernetes  
 redirectURIs:  
 - https://kubectl.company.com/callback  
 name: 'Kubernetes CLI'  
 secret: $KUBERNETES\_CLIENT\_SECRET  
 - id: argocd  
 redirectURIs:  
 - https://argocd.company.com/auth/callback  
 name: 'ArgoCD'  
 secret: $ARGOCD\_CLIENT\_SECRET

#### 9.1.4.3 Multi-Factor Authentication

## Keycloak Authentication Flow  
authenticationFlows:  
 - alias: "browser-with-mfa"  
 description: "Browser flow with mandatory MFA"  
 providerId: "basic-flow"  
 topLevel: true  
 builtIn: false  
 authenticationExecutions:  
 - authenticator: "auth-cookie"  
 requirement: "ALTERNATIVE"  
 - authenticator: "auth-spnego"  
 requirement: "DISABLED"  
 - authenticator: "identity-provider-redirector"  
 requirement: "ALTERNATIVE"  
 - flowAlias: "forms"  
 requirement: "ALTERNATIVE"  
 - alias: "forms"  
 description: "Username, password, otp and other auth forms."  
 providerId: "basic-flow"  
 topLevel: false  
 builtIn: false  
 authenticationExecutions:  
 - authenticator: "auth-username-password-form"  
 requirement: "REQUIRED"  
 - authenticator: "auth-otp-form"  
 requirement: "REQUIRED"

### 9.1.5 Authorization Implementation

#### 9.1.5.1 Kubernetes RBAC Integration

## ClusterRole for Platform Administrators  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRole  
metadata:  
 name: platform-admin  
rules:  
- apiGroups: ["\*"]  
 resources: ["\*"]  
 verbs: ["\*"]  
---  
## ClusterRoleBinding with OIDC Groups  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRoleBinding  
metadata:  
 name: platform-admin-binding  
subjects:  
- kind: Group  
 name: "platform-admins"  
 apiGroup: rbac.authorization.k8s.io  
roleRef:  
 kind: ClusterRole  
 name: platform-admin  
 apiGroup: rbac.authorization.k8s.io  
---  
## Namespace-scoped Role for Application Teams  
apiVersion: rbac.authorization.k8s.io/v1  
kind: Role  
metadata:  
 namespace: app-web-prod  
 name: app-developer  
rules:  
- apiGroups: [""]  
 resources: ["pods", "services", "configmaps", "secrets"]  
 verbs: ["get", "list", "create", "update", "patch", "delete"]  
- apiGroups: ["apps"]  
 resources: ["deployments", "replicasets"]  
 verbs: ["get", "list", "create", "update", "patch", "delete"]  
- apiGroups: ["kubevirt.io"]  
 resources: ["virtualmachines", "virtualmachineinstances"]  
 verbs: ["get", "list", "create", "update", "patch", "delete"]  
---  
## RoleBinding with OIDC Groups  
apiVersion: rbac.authorization.k8s.io/v1  
kind: RoleBinding  
metadata:  
 name: app-developer-binding  
 namespace: app-web-prod  
subjects:  
- kind: Group  
 name: "web-developers"  
 apiGroup: rbac.authorization.k8s.io  
roleRef:  
 kind: Role  
 name: app-developer  
 apiGroup: rbac.authorization.k8s.io

#### 9.1.5.2 ArgoCD RBAC Integration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: argocd-rbac-cm  
 namespace: argocd  
data:  
 policy.default: role:readonly  
 policy.csv: |  
 # Platform Administrators  
 g, platform-admins, role:admin  
   
 # Application Teams  
 g, web-developers, role:web-app-admin  
 g, database-admins, role:database-admin  
   
 # Custom Roles  
 role:web-app-admin, applications, \*, app-web-\*/\*, allow  
 role:web-app-admin, repositories, \*, \*, allow  
 role:web-app-admin, certificates, \*, \*, deny  
   
 role:database-admin, applications, \*, app-database-\*/\*, allow  
 role:database-admin, repositories, \*, \*, allow  
 role:database-admin, certificates, \*, \*, deny

#### 9.1.5.3 Service Account Token Management

## Time-limited Service Account Tokens  
apiVersion: v1  
kind: Secret  
metadata:  
 name: build-robot-secret  
 annotations:  
 kubernetes.io/service-account.name: build-robot  
 kubernetes.io/service-account.token-ttl: "3600" # 1 hour  
type: kubernetes.io/service-account-token  
---  
## Projected Service Account Token (Preferred)  
apiVersion: v1  
kind: Pod  
metadata:  
 name: nginx  
spec:  
 serviceAccountName: build-robot  
 containers:  
 - image: nginx  
 name: nginx  
 volumeMounts:  
 - mountPath: /var/run/secrets/tokens  
 name: vault-token  
 volumes:  
 - name: vault-token  
 projected:  
 sources:  
 - serviceAccountToken:  
 path: vault-token  
 expirationSeconds: 7200 # 2 hours  
 audience: vault

### 9.1.6 User Lifecycle Management

#### 9.1.6.1 Automated User Provisioning

## SCIM Integration Example  
class SCIMUserProvisioning:  
 def \_\_init\_\_(self, keycloak\_client, kubernetes\_client):  
 self.keycloak = keycloak\_client  
 self.k8s = kubernetes\_client  
   
 def provision\_user(self, user\_data):  
 # Create user in Keycloak  
 user = self.keycloak.create\_user({  
 "username": user\_data["username"],  
 "email": user\_data["email"],  
 "firstName": user\_data["firstName"],  
 "lastName": user\_data["lastName"],  
 "enabled": True,  
 "groups": user\_data["groups"]  
 })  
   
 # Assign groups based on role  
 for group in user\_data["groups"]:  
 self.keycloak.assign\_group\_to\_user(user["id"], group)  
   
 # Create ServiceAccount if needed  
 if user\_data.get("service\_account"):  
 self.create\_service\_account(user\_data["username"])  
   
 def deprovision\_user(self, username):  
 # Remove from Keycloak  
 user = self.keycloak.get\_user\_by\_username(username)  
 self.keycloak.delete\_user(user["id"])  
   
 # Clean up Kubernetes resources  
 self.cleanup\_user\_resources(username)

#### 9.1.6.2 Group-Based Access Control

## Keycloak Group Configuration  
groups:  
 - name: "platform-admins"  
 description: "Platform administrators with full cluster access"  
 attributes:  
 kubernetes-role: ["cluster-admin"]  
 argocd-role: ["admin"]  
   
 - name: "web-developers"  
 description: "Web application developers"  
 attributes:  
 kubernetes-role: ["app-developer"]  
 kubernetes-namespaces: ["app-web-prod", "app-web-staging", "app-web-dev"]  
 argocd-role: ["web-app-admin"]  
   
 - name: "database-admins"  
 description: "Database administrators"  
 attributes:  
 kubernetes-role: ["app-developer"]  
 kubernetes-namespaces: ["app-database-prod", "app-database-staging"]  
 argocd-role: ["database-admin"]  
   
 - name: "security-auditors"  
 description: "Security team with read-only access"  
 attributes:  
 kubernetes-role: ["view"]  
 argocd-role: ["readonly"]

### 9.1.7 Security Controls

#### 9.1.7.1 Token Security

## JWT Token Configuration  
jwtPolicy:  
 issuer: "https://keycloak.company.com/auth/realms/company"  
 audiences:  
 - "kubernetes"  
 - "argocd"  
 - "grafana"  
 jwksUri: "https://keycloak.company.com/auth/realms/company/protocol/openid\_connect/certs"  
   
## Token Validation Rules  
tokenValidation:  
 expiration:  
 accessToken: 900 # 15 minutes  
 refreshToken: 3600 # 1 hour  
 idToken: 300 # 5 minutes  
   
 claims:  
 required:  
 - "iss"  
 - "aud"  
 - "exp"  
 - "iat"  
 - "sub"  
 groups: "groups"  
 email: "email"  
 name: "name"

#### 9.1.7.2 Network Security

## Network Policy for Auth Services  
apiVersion: networking.k8s.io/v1  
kind: NetworkPolicy  
metadata:  
 name: auth-system-netpol  
 namespace: auth-system  
spec:  
 podSelector:  
 matchLabels:  
 app: dex  
 policyTypes:  
 - Ingress  
 - Egress  
 ingress:  
 - from:  
 - namespaceSelector:  
 matchLabels:  
 name: ingress-nginx  
 ports:  
 - protocol: TCP  
 port: 5556  
 egress:  
 - to: []  
 ports:  
 - protocol: TCP  
 port: 443 # HTTPS to external OIDC provider  
 - to:  
 - namespaceSelector:  
 matchLabels:  
 name: kube-system  
 ports:  
 - protocol: TCP  
 port: 443 # Kubernetes API

### 9.1.8 Monitoring and Audit

#### 9.1.8.1 Authentication Metrics

## Prometheus ServiceMonitor for Dex  
apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: dex-metrics  
 namespace: auth-system  
spec:  
 selector:  
 matchLabels:  
 app: dex  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics  
---  
## Grafana Dashboard Configuration  
dashboard:  
 title: "IAM Authentication Metrics"  
 panels:  
 - title: "Authentication Requests"  
 type: "graph"  
 targets:  
 - expr: "rate(dex\_requests\_total[5m])"  
 legendFormat: "{{method}} {{code}}"  
   
 - title: "Active Sessions"  
 type: "stat"  
 targets:  
 - expr: "dex\_sessions\_active"  
   
 - title: "Failed Logins"  
 type: "graph"  
 targets:  
 - expr: "rate(dex\_requests\_total{code!~"2.."}[5m])"  
 legendFormat: "Failed Authentications"

#### 9.1.8.2 Audit Logging

## Kubernetes Audit Policy  
apiVersion: audit.k8s.io/v1  
kind: Policy  
rules:  
## Log authentication events  
- level: Request  
 namespaces: ["kube-system", "auth-system"]  
 verbs: ["create", "update", "delete"]  
 resources:  
 - group: ""  
 resources: ["secrets", "serviceaccounts"]  
 - group: "rbac.authorization.k8s.io"  
 resources: ["roles", "rolebindings", "clusterroles", "clusterrolebindings"]  
  
## Log user actions in application namespaces  
- level: Metadata  
 namespaces: ["app-web-prod", "app-database-prod"]  
 verbs: ["create", "update", "delete"]  
 users: ["system:serviceaccount:\*"]  
 omitStages:  
 - RequestReceived

#### 9.1.8.3 Compliance Reporting

## Automated Access Review  
class AccessReviewAutomation:  
 def \_\_init\_\_(self, k8s\_client, keycloak\_client):  
 self.k8s = k8s\_client  
 self.keycloak = keycloak\_client  
   
 def generate\_access\_report(self):  
 report = {  
 "timestamp": datetime.now().isoformat(),  
 "users": [],  
 "service\_accounts": [],  
 "orphaned\_resources": []  
 }  
   
 # Get all users from Keycloak  
 keycloak\_users = self.keycloak.get\_all\_users()  
   
 for user in keycloak\_users:  
 user\_report = {  
 "username": user["username"],  
 "email": user["email"],  
 "groups": self.keycloak.get\_user\_groups(user["id"]),  
 "last\_login": user.get("lastAccess"),  
 "kubernetes\_access": self.get\_k8s\_user\_access(user["username"])  
 }  
 report["users"].append(user\_report)  
   
 return report  
   
 def get\_k8s\_user\_access(self, username):  
 # Get user's effective permissions  
 access = []  
   
 # Check ClusterRoleBindings  
 cluster\_bindings = self.k8s.list\_cluster\_role\_binding()  
 for binding in cluster\_bindings.items:  
 if self.user\_in\_binding(username, binding):  
 access.append({  
 "type": "cluster",  
 "role": binding.role\_ref.name,  
 "binding": binding.metadata.name  
 })  
   
 # Check RoleBindings per namespace  
 for namespace in self.get\_user\_namespaces(username):  
 role\_bindings = self.k8s.list\_namespaced\_role\_binding(namespace)  
 for binding in role\_bindings.items:  
 if self.user\_in\_binding(username, binding):  
 access.append({  
 "type": "namespace",  
 "namespace": namespace,  
 "role": binding.role\_ref.name,  
 "binding": binding.metadata.name  
 })  
   
 return access

### 9.1.9 Disaster Recovery

#### 9.1.9.1 Identity Provider Backup

## Keycloak Backup Configuration  
apiVersion: batch/v1  
kind: CronJob  
metadata:  
 name: keycloak-backup  
 namespace: auth-system  
spec:  
 schedule: "0 2 \* \* \*" # Daily at 2 AM  
 jobTemplate:  
 spec:  
 template:  
 spec:  
 containers:  
 - name: backup  
 image: postgres:13  
 command:  
 - /bin/bash  
 - -c  
 - |  
 pg\_dump -h keycloak-db -U keycloak keycloak > /backup/keycloak-$(date +%Y%m%d).sql  
 aws s3 cp /backup/keycloak-$(date +%Y%m%d).sql s3://iam-backups/  
 env:  
 - name: PGPASSWORD  
 valueFrom:  
 secretKeyRef:  
 name: keycloak-db-secret  
 key: password  
 volumeMounts:  
 - name: backup-volume  
 mountPath: /backup  
 volumes:  
 - name: backup-volume  
 emptyDir: {}  
 restartPolicy: OnFailure

#### 9.1.9.2 Failover Configuration

## Multi-Region OIDC Provider Setup  
regions:  
 primary:  
 region: "us-east-1"  
 keycloak\_url: "https://keycloak-primary.company.com"  
 dex\_url: "https://dex-primary.company.com"  
   
 secondary:  
 region: "us-west-2"  
 keycloak\_url: "https://keycloak-secondary.company.com"  
 dex\_url: "https://dex-secondary.company.com"  
  
## Automated Failover Logic  
failover:  
 health\_check\_interval: 30s  
 failure\_threshold: 3  
 recovery\_threshold: 2  
 dns\_ttl: 60 # Low TTL for quick failover

This comprehensive IAM strategy provides enterprise-grade identity and access management for the RH OVE multi-cluster ecosystem, ensuring security, compliance, and operational efficiency through OIDC-based authentication and Kubernetes-native authorization.

# 10 ADR Table

## 10.1 Architecture Decision Records (ADR) Table

This document provides a comprehensive overview of all architectural decisions made for the RH OVE multi-cluster ecosystem.

### 10.1.1 ADR Summary Table

| ADR | Title | Status | Date | Context | Decision |
| --- | --- | --- | --- | --- | --- |
| [ADR-001](adr-001-multi-cluster-pattern.md) | Multi-Cluster Architecture Pattern | Accepted | 2024-12-01 | Need to support multiple environments with centralized governance and scalable infrastructure | Implement multi-cluster pattern with one management cluster and multiple application clusters |
| [ADR-002](adr-002-gitops-argocd.md) | GitOps with ArgoCD Hub Architecture | Accepted | 2024-12-01 | Require consistent, auditable, scalable deployment approach across multiple clusters | Implement GitOps using ArgoCD in hub-spoke pattern with Git-based configuration |
| [ADR-003](adr-003-cluster-topology.md) | Namespace-Based Cluster Topology | Accepted | 2024-12-01 | Need efficient organizational strategy for mixed VM and container workloads with isolation and security | Implement application namespace-based topology organized by business application |
| [ADR-004](adr-004-admission-controller.md) | Admission Controller Strategy | Accepted | 2024-12-01 | Require flexible, secure, policy-driven approach for resource admission and validation | Implement layered admission control using OpenShift built-in controllers, KubeVirt webhooks, and Kyverno policies |
| [ADR-005](adr-005-network-cni.md) | Cilium CNI with Multus Multi-Network Strategy | Accepted | 2024-12-01 | Need advanced networking for container and VM workloads with enterprise-grade security and performance | Implement Cilium as primary CNI with Multus for multi-network support using eBPF-powered networking |
| [ADR-006](adr-006-backup-strategy.md) | Backup Strategy for RH OVE Ecosystem | Accepted | 2024-12-01 | Ensure data protection and recovery across multi-cluster environment with business continuity requirements | Adopt centralized backup strategy using Rubrik for VM and containerized workloads |
| [ADR-007](adr-007-monitoring-strategy.md) | Monitoring Strategy for RH OVE Ecosystem | Accepted | 2024-12-01 | Need comprehensive monitoring for operational visibility, performance management, and incident response | Implement integrated monitoring using Prometheus/Grafana, Dynatrace, and Hubble |
| [ADR-008](adr-008-iam-strategy.md) | Identity and Access Management (IAM) Strategy | Accepted | 2024-12-01 | Need enterprise-grade identity and access management across multi-cluster ecosystem | Implement comprehensive IAM using OIDC providers with Keycloak, integrated with Kubernetes RBAC |

### 10.1.2 Detailed ADR Information

#### 10.1.2.1 ADR-001: Multi-Cluster Architecture Pattern

**Key Components:** - **Management Cluster**: RHACM, ArgoCD Hub, RHACS, Federated Prometheus, Centralized logging, Rubrik backup management - **Application Clusters**: Production (HA, performance-optimized), Staging (production-like), Development (resource-optimized) - **Network Architecture**: Dedicated segments per cluster, VPN/private connectivity, zero-trust principles

**Benefits:** Separation of concerns, horizontal scalability, security isolation, operational efficiency, fault isolation, resource optimization

**Trade-offs:** Increased network complexity, additional operational overhead, potential data sync challenges

#### 10.1.2.2 ADR-002: GitOps with ArgoCD Hub Architecture

**Key Components:** - **ArgoCD Hub**: Centralized instance in management cluster with HA (3 replicas) - **ArgoCD Agents**: Lightweight agents in application clusters - **Repository Structure**: Clusters, applications (base/overlays), infrastructure (networking/storage/monitoring) - **Application of Applications Pattern**: Root ArgoCD app manages cluster-specific applications

**Benefits:** Declarative configuration, complete audit trail, pull-based security, consistency, easy rollbacks, self-healing

**Trade-offs:** Learning curve for GitOps workflows, Git repository complexity, network dependencies, secret management complexity

#### 10.1.2.3 ADR-003: Namespace-Based Cluster Topology

**Key Components:** - **Naming Convention**: {app-name}-{environment} (e.g., app-web-prod, app-database-staging) - **Standard Templates**: Namespace with labels, ResourceQuota, LimitRange, NetworkPolicies - **Cross-Namespace Communication**: Controlled via NetworkPolicies with explicit allow rules - **RBAC Integration**: Namespace-level roles aligned with application teams

**Benefits:** Strong isolation, simplified RBAC, clear resource attribution, network microsegmentation, operational clarity, compliance alignment

**Trade-offs:** Initial complexity in planning boundaries, cross-app dependency management, shared services challenges

#### 10.1.2.4 ADR-004: Admission Controller Strategy

**Key Components:** - **OpenShift Built-in**: Security Context Constraints, RBAC enforcement, quotas and limits - **KubeVirt Webhooks**: Validation and mutation webhooks for VM specifications - **Kyverno Policies**: Configuration validation, resource constraints, dynamic policy application

**Benefits:** Centralized policy management, dynamic policy application, security enforcement, misconfiguration prevention, extensibility

**Trade-offs:** Complex rule management, performance overhead, learning curve for policy authors

#### 10.1.2.5 ADR-005: Cilium CNI with Multus Multi-Network Strategy

**Key Components:** - **Cilium Features**: eBPF performance, identity-aware security, L7 security, service mesh capabilities, WireGuard encryption - **Multus Integration**: Multi-network support, legacy network integration, SR-IOV for high performance, network segmentation - **Hubble Observability**: Network flow monitoring, policy violation detection, security auditing - **NetworkAttachmentDefinitions**: Management, storage, and data networks with VLAN support

**Benefits:** Superior eBPF performance (10-100x better than iptables), identity-aware policies, L7 security without sidecars, deep observability, multi-network support

**Trade-offs:** Learning curve for eBPF concepts, debugging complexity, higher memory usage, potential compatibility issues

#### 10.1.2.6 ADR-006: Backup Strategy for RH OVE Ecosystem

**Key Components:** - **Rubrik Management**: Centralized in management cluster with unified policy management - **Backup Architecture**: Management cluster (Rubrik node), Application clusters (Edge devices, agents), Cloud archive (long-term retention) - **Policy Configuration**: Daily backups (24h RPO), weekly full with daily incrementals, AES-256 encryption, cloud replication - **Compliance**: GDPR, HIPAA, SOC 2 alignment with audit trails and access control

**Benefits:** Unified management, policy-driven, deduplication/compression, cloud integration, application consistency

**Trade-offs:** Higher upfront costs than open-source alternatives, training requirements for administrators

#### 10.1.2.7 ADR-007: Monitoring Strategy for RH OVE Ecosystem

**Key Components:** - **Prometheus/Grafana**: Scalable metrics collection, customizable dashboards, real-time metrics, integrated alerting - **Dynatrace**: Full-stack monitoring, AI-powered analytics, cloud-native support, unified observability - **Hubble**: eBPF-powered network insights, high throughput flow capture, Cilium integration - **Integration**: Federated Prometheus (3 replicas, 500Gi storage), OAuth SSO, automated tagging

**Benefits:** Operational efficiency with reduced MTTR, proactive performance management, unified observability across clusters

**Trade-offs:** Integration complexity, resource overhead, training requirements for multiple tools

#### 10.1.2.8 ADR-008: Identity and Access Management (IAM) Strategy

**Key Components:** - **Keycloak (Red Hat SSO)**: Primary OIDC provider with LDAP/AD integration, MFA support, group-based access control - **Dex OIDC Proxy**: Service authentication across clusters with static client configuration - **OpenShift OAuth Integration**: Native cluster authentication with OIDC claims mapping - **RBAC Integration**: Kubernetes-native authorization with group-based role assignments - **Service Account Management**: Time-limited tokens with projected volumes and automated lifecycle

**Benefits:** Centralized identity management, single sign-on across all services, enterprise LDAP/AD integration, MFA enforcement, zero trust security, complete audit trails, compliance ready (SOC 2, GDPR, HIPAA)

**Trade-offs:** Initial setup complexity, additional infrastructure dependencies, OIDC/Keycloak learning curve, identity provider availability critical, token lifecycle management complexity

### 10.1.3 Cross-ADR Dependencies

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 ADR001[ADR-001: Multi-Cluster] --> ADR002[ADR-002: GitOps ArgoCD]  
 ADR001 --> ADR003[ADR-003: Namespace Topology]  
 ADR001 --> ADR006[ADR-006: Backup Strategy]  
 ADR001 --> ADR007[ADR-007: Monitoring]  
 ADR001 --> ADR008[ADR-008: IAM Strategy]  
   
 ADR003 --> ADR004[ADR-004: Admission Control]  
 ADR003 --> ADR005[ADR-005: Network CNI]  
 ADR003 --> ADR008  
   
 ADR008 --> ADR002  
 ADR008 --> ADR004  
 ADR008 --> ADR007  
   
 ADR005 --> ADR007  
 ADR002 --> ADR004  
   
 style ADR001 fill:#ff9999  
 style ADR002 fill:#99ccff  
 style ADR003 fill:#99ff99  
 style ADR004 fill:#ffcc99  
 style ADR005 fill:#cc99ff  
 style ADR006 fill:#ffff99  
 style ADR007 fill:#ff99cc  
 style ADR008 fill:#99ffcc

*Note: Diagram rendering failed, showing code instead.*

### 10.1.4 Implementation Timeline

| Phase | ADRs | Duration | Dependencies | Key Deliverables |
| --- | --- | --- | --- | --- |
| **Phase 1: Foundation** | ADR-001, ADR-003 | 4-6 weeks | Infrastructure setup | Multi-cluster setup, namespace topology |
| **Phase 2: Identity & Access** | ADR-008 | 3-4 weeks | Foundation complete | Keycloak deployment, OIDC integration, MFA setup |
| **Phase 3: GitOps & Policy** | ADR-002, ADR-004 | 3-4 weeks | Foundation + IAM complete | ArgoCD hub with OIDC auth, admission controllers |
| **Phase 4: Networking** | ADR-005 | 2-3 weeks | Foundation complete | Cilium CNI, Multus, network policies |
| **Phase 5: Operations** | ADR-006, ADR-007 | 4-5 weeks | All previous phases | Backup strategy, monitoring with IAM integration |

#### 10.1.4.1 Detailed Phase Dependencies

**[Mermaid Gantt Chart - Rendering Failed]**

gantt  
 title ADR Implementation Timeline  
 dateFormat YYYY-MM-DD  
 section Phase 1: Foundation  
 ADR-001 Multi-Cluster :done, foundation1, 2024-01-01, 4w  
 ADR-003 Namespace Topology :done, foundation2, 2024-01-15, 3w  
   
 section Phase 2: Identity  
 ADR-008 IAM Strategy :active, iam, after foundation1, 4w  
   
 section Phase 3: GitOps  
 ADR-002 GitOps ArgoCD :gitops, after iam, 3w  
 ADR-004 Admission Control :admission, after iam, 3w  
   
 section Phase 4: Network  
 ADR-005 Network CNI :network, after foundation2, 3w  
   
 section Phase 5: Operations  
 ADR-006 Backup Strategy :backup, after gitops, 4w  
 ADR-007 Monitoring :monitoring, after network, 4w

*Note: Diagram rendering failed, showing code instead.*

#### 10.1.4.2 Critical Path Analysis

**Critical Dependencies:** - **ADR-008 (IAM)** must be completed before GitOps and Admission Control implementation - **ADR-003 (Namespace Topology)** enables proper RBAC integration with IAM - **ADR-007 (Monitoring)** requires IAM integration for authentication and authorization - **ADR-002 (GitOps)** requires IAM for secure access control and audit trails

**Parallel Implementation Opportunities:** - ADR-005 (Network CNI) can be implemented in parallel with IAM setup - ADR-006 (Backup) and ADR-007 (Monitoring) can be implemented concurrently in final phase

This comprehensive table provides a complete overview of all architectural decisions, their relationships, and implementation considerations for the RH OVE multi-cluster ecosystem.

# 11 ADR-001 Multi-Cluster Pattern

## 11.1 ADR-001: Multi-Cluster Architecture Pattern

### 11.1.1 Status

Accepted

### 11.1.2 Date

2024-12-01

### 11.1.3 Context

The RH OVE ecosystem needs to support multiple environments (production, staging, development) while maintaining centralized governance, security, and operational oversight. The organization requires scalable infrastructure that can grow horizontally and support geographic distribution.

### 11.1.4 Decision

We will implement a multi-cluster architecture pattern with: - **One Management Cluster**: Centralized control plane for governance, GitOps, security, and monitoring - **Multiple Application Clusters**: Dedicated workload execution environments per environment type

### 11.1.5 Rationale

#### 11.1.5.1 Advantages

1. **Separation of Concerns**: Clear boundaries between management and workload execution
2. **Scalability**: Horizontal scaling by adding application clusters as needed
3. **Security**: Network-level isolation between environments
4. **Operational Efficiency**: Centralized management reduces operational overhead
5. **Fault Isolation**: Issues in one cluster don’t affect others
6. **Resource Optimization**: Right-size clusters based on workload requirements

#### 11.1.5.2 Alternatives Considered

1. **Single Large Cluster**: Rejected due to blast radius and resource contention
2. **Completely Separate Clusters**: Rejected due to operational complexity and lack of centralized governance
3. **Namespace-based Multi-tenancy**: Rejected due to insufficient isolation for production workloads

### 11.1.6 Implementation Details

#### 11.1.6.1 Management Cluster Components

* Red Hat Advanced Cluster Management (RHACM)
* ArgoCD Hub for GitOps
* Red Hat Advanced Cluster Security (RHACS)
* Federated Prometheus for monitoring
* Centralized logging aggregation
* Rubrik backup management

#### 11.1.6.2 Application Cluster Types

* **Production**: High-availability, performance-optimized
* **Staging**: Production-like for testing
* **Development**: Resource-optimized for development workflows

#### 11.1.6.3 Network Architecture

* Dedicated network segments per cluster type
* VPN/Private connectivity between management and application clusters
* Zero-trust network principles

### 11.1.7 Consequences

#### 11.1.7.1 Positive

* Improved security posture through cluster-level isolation
* Simplified compliance and audit processes
* Better resource utilization and cost optimization
* Enhanced disaster recovery capabilities
* Reduced blast radius for security incidents

#### 11.1.7.2 Negative

* Increased network complexity
* Additional operational overhead for cluster lifecycle management
* Potential data synchronization challenges
* Learning curve for multi-cluster operations

### 11.1.8 Compliance Considerations

* Meets enterprise security requirements for environment isolation
* Supports regulatory compliance through audit trail separation
* Enables data residency requirements through geographic cluster placement

### 11.1.9 Monitoring and Observability

* Centralized metrics collection via Prometheus federation
* Unified logging through log forwarding to management cluster
* Cross-cluster distributed tracing capabilities
* Centralized alerting and incident management

# 12 ADR-002 GitOps ArgoCD

## 12.1 ADR-002: GitOps with ArgoCD Hub Architecture

### 12.1.1 Status

Accepted

### 12.1.2 Date

2024-12-01

### 12.1.3 Context

The multi-cluster RH OVE ecosystem requires a consistent, auditable, and scalable approach to application deployment and configuration management across multiple clusters. Traditional CI/CD approaches with push-based deployments create security concerns and operational complexity in multi-cluster environments.

### 12.1.4 Decision

We will implement GitOps using ArgoCD in a hub-spoke pattern: - **ArgoCD Hub**: Centralized ArgoCD instance in the management cluster - **ArgoCD Agents**: Lightweight agents in each application cluster - **Git-based Configuration**: All infrastructure and application configurations stored in Git repositories

### 12.1.5 Rationale

#### 12.1.5.1 Advantages

1. **Declarative Configuration**: Infrastructure and applications defined as code
2. **Audit Trail**: Complete Git history of all changes
3. **Security**: Pull-based model eliminates need for external access to clusters
4. **Consistency**: Identical deployment processes across all environments
5. **Rollback Capability**: Easy rollback using Git revert operations
6. **Self-Healing**: Automatic drift correction and reconciliation

#### 12.1.5.2 Alternatives Considered

1. **Jenkins-based CI/CD**: Rejected due to security concerns with push-based deployments
2. **Tekton Pipelines**: Rejected due to complexity in multi-cluster scenarios
3. **Fleet by Rancher**: Rejected due to vendor lock-in concerns
4. **Flux**: Rejected due to preference for ArgoCD’s UI and workflow capabilities

### 12.1.6 Implementation Details

#### 12.1.6.1 ArgoCD Hub Configuration

apiVersion: argoproj.io/v1alpha1  
kind: ArgoCD  
metadata:  
 name: argocd-hub  
 namespace: argocd  
spec:  
 server:  
 replicas: 3  
 route:  
 enabled: true  
 tls:  
 termination: reencrypt  
 ha:  
 enabled: true  
 dex:  
 openShiftOAuth: true  
 rbac:  
 defaultPolicy: 'role:readonly'

#### 12.1.6.2 Repository Structure

gitops-repo/  
├── clusters/  
│ ├── management/  
│ ├── production/  
│ ├── staging/  
│ └── development/  
├── applications/  
│ ├── base/  
│ └── overlays/  
└── infrastructure/  
 ├── networking/  
 ├── storage/  
 └── monitoring/

#### 12.1.6.3 Application of Applications Pattern

* Root ArgoCD Application manages cluster-specific applications
* Environment-specific overlays using Kustomize
* Automated sync policies for non-production environments
* Manual sync for production deployments

### 12.1.7 Consequences

#### 12.1.7.1 Positive

* **Enhanced Security**: No direct cluster access required for deployments
* **Improved Compliance**: Complete audit trail through Git history
* **Reduced Operational Overhead**: Automated deployment and drift correction
* **Better Collaboration**: Git-based workflows familiar to development teams
* **Disaster Recovery**: Easy recreation of cluster state from Git

#### 12.1.7.2 Negative

* **Learning Curve**: Teams need to adapt to GitOps workflows
* **Git Repository Complexity**: Large repositories can become difficult to manage
* **Network Dependencies**: Requires reliable connectivity to Git repositories
* **Secret Management**: Additional complexity for managing sensitive data

### 12.1.8 Security Considerations

* ArgoCD service accounts use minimal required permissions
* Private Git repositories with SSH key authentication
* RBAC integration with OpenShift OAuth
* Secret management through External Secrets Operator
* Network policies restrict ArgoCD communication

### 12.1.9 Monitoring and Alerting

* ArgoCD application health monitoring
* Git repository sync status tracking
* Deployment success/failure notifications
* Performance metrics for sync operations
* Custom dashboards for GitOps workflows

### 12.1.10 Migration Strategy

1. **Phase 1**: Deploy ArgoCD hub in management cluster
2. **Phase 2**: Migrate existing applications to Git repositories
3. **Phase 3**: Configure ArgoCD applications for each cluster
4. **Phase 4**: Implement automated sync for non-production
5. **Phase 5**: Train teams on GitOps workflows

# 13 ADR-003 Cluster Topology

## 13.1 ADR-003: Namespace-Based Cluster Topology

### 13.1.1 Status

Accepted

### 13.1.2 Date

2024-12-01

### 13.1.3 Context

The RH OVE ecosystem requires an efficient organizational strategy for managing mixed VM and container workloads within clusters. We need to balance isolation, security, resource management, and operational simplicity while supporting multi-tenant use cases.

### 13.1.4 Decision

We will implement an **application namespace-based topology** where resources are organized by business application or domain rather than by resource type or technology stack.

#### 13.1.4.1 Topology Structure

Cluster  
├── app-web-prod (namespace)  
│ ├── VMs (web servers)  
│ ├── Containers (microservices)  
│ ├── Storage (PVCs, DataVolumes)  
│ └── Network (NetworkPolicies, NADs)  
├── app-database-prod (namespace)  
│ ├── VMs (database servers)  
│ ├── Containers (database operators)  
│ ├── Storage (high-performance storage)  
│ └── Network (isolated database networks)  
└── app-monitoring-prod (namespace)  
 ├── VMs (legacy monitoring tools)  
 ├── Containers (modern observability stack)  
 ├── Storage (metrics and logs storage)  
 └── Network (monitoring networks)

### 13.1.5 Rationale

#### 13.1.5.1 Advantages

1. **Strong Isolation**: Each application has its own security boundary
2. **Simplified RBAC**: Teams get namespace-level access aligned with their applications
3. **Clear Resource Attribution**: Easy to track costs and resource usage per application
4. **Network Microsegmentation**: Network policies can be application-specific
5. **Operational Clarity**: Troubleshooting and maintenance scoped to business context
6. **Compliance Alignment**: Audit boundaries match business applications

#### 13.1.5.2 Alternatives Considered

##### 13.1.5.2.1 1. Technology-Based Topology

* **Structure**: Separate namespaces for VMs vs containers
* **Rejected**: Creates artificial barriers between related workloads
* **Issues**: Complex cross-namespace communication, unclear ownership

##### 13.1.5.2.2 2. Environment-Based Topology Only

* **Structure**: Single namespace per environment (prod, staging, dev)
* **Rejected**: Poor isolation between different applications
* **Issues**: Resource contention, security boundary concerns

##### 13.1.5.2.3 3. Team-Based Topology

* **Structure**: Namespaces per team/department
* **Rejected**: Teams often work on multiple applications
* **Issues**: Unclear application boundaries, resource conflicts

### 13.1.6 Implementation Details

#### 13.1.6.1 Namespace Naming Convention

## Pattern: {app-name}-{environment}  
## Examples:  
- app-web-prod  
- app-web-staging   
- app-web-dev  
- app-database-prod  
- app-analytics-prod  
- shared-monitoring-prod  
- shared-storage-prod

#### 13.1.6.2 Standard Namespace Template

apiVersion: v1  
kind: Namespace  
metadata:  
 name: app-web-prod  
 labels:  
 application: web  
 environment: production  
 tier: frontend  
 cost-center: "12345"  
 owner: web-team  
 annotations:  
 backup-policy: "daily"  
 monitoring-enabled: "true"  
 network-policy: "strict"  
 compliance-level: "high"  
spec:  
 finalizers:  
 - kubernetes  
---  
## Resource Quota per namespace  
apiVersion: v1  
kind: ResourceQuota  
metadata:  
 name: compute-quota  
 namespace: app-web-prod  
spec:  
 hard:  
 requests.cpu: "20"  
 requests.memory: 40Gi  
 limits.cpu: "40"  
 limits.memory: 80Gi  
 persistentvolumeclaims: "20"  
 services: "10"  
 secrets: "20"  
 configmaps: "20"  
---  
## Limit Range per namespace  
apiVersion: v1  
kind: LimitRange  
metadata:  
 name: resource-limits  
 namespace: app-web-prod  
spec:  
 limits:  
 - default:  
 cpu: "2"  
 memory: 4Gi  
 defaultRequest:  
 cpu: 100m  
 memory: 128Mi  
 type: Container  
 - default:  
 cpu: "8"  
 memory: 16Gi  
 defaultRequest:  
 cpu: "2"  
 memory: 4Gi  
 type: PersistentVolumeClaim

#### 13.1.6.3 Cross-Namespace Communication Policy

apiVersion: networking.k8s.io/v1  
kind: NetworkPolicy  
metadata:  
 name: allow-app-communication  
 namespace: app-web-prod  
spec:  
 podSelector: {}  
 policyTypes:  
 - Ingress  
 - Egress  
 ingress:  
 # Allow ingress from gateway namespace  
 - from:  
 - namespaceSelector:  
 matchLabels:  
 name: shared-gateway-prod  
 egress:  
 # Allow egress to database namespace  
 - to:  
 - namespaceSelector:  
 matchLabels:  
 application: database  
 environment: production  
 ports:  
 - protocol: TCP  
 port: 5432  
 # Allow egress to shared services  
 - to:  
 - namespaceSelector:  
 matchLabels:  
 tier: shared-services

### 13.1.7 Governance and Management

#### 13.1.7.1 Namespace Lifecycle Management

apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: namespace-manager  
 namespace: argocd  
spec:  
 project: infrastructure  
 source:  
 repoURL: https://git.company.com/infrastructure/namespaces  
 targetRevision: HEAD  
 path: namespaces  
 destination:  
 server: https://kubernetes.default.svc  
 syncPolicy:  
 automated:  
 prune: false  
 selfHeal: true  
 syncOptions:  
 - CreateNamespace=true

#### 13.1.7.2 RBAC Template per Namespace

apiVersion: rbac.authorization.k8s.io/v1  
kind: Role  
metadata:  
 namespace: app-web-prod  
 name: app-admin  
rules:  
- apiGroups: [""]  
 resources: ["\*"]  
 verbs: ["\*"]  
- apiGroups: ["apps", "extensions"]  
 resources: ["\*"]  
 verbs: ["\*"]  
- apiGroups: ["kubevirt.io"]  
 resources: ["\*"]  
 verbs: ["\*"]  
- apiGroups: ["cdi.kubevirt.io"]  
 resources: ["\*"]  
 verbs: ["\*"]  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: RoleBinding  
metadata:  
 name: app-admin-binding  
 namespace: app-web-prod  
subjects:  
- kind: Group  
 name: web-team  
 apiGroup: rbac.authorization.k8s.io  
roleRef:  
 kind: Role  
 name: app-admin  
 apiGroup: rbac.authorization.k8s.io

### 13.1.8 Consequences

#### 13.1.8.1 Positive

* **Clear Ownership**: Each namespace has a clear business owner
* **Improved Security**: Strong isolation boundaries between applications
* **Simplified Operations**: Easier to manage, monitor, and troubleshoot
* **Better Resource Management**: Clear resource attribution and quota management
* **Compliance Ready**: Audit boundaries align with business applications

#### 13.1.8.2 Negative

* **Initial Complexity**: Requires careful planning of namespace boundaries
* **Cross-App Dependencies**: Need clear policies for inter-namespace communication
* **Shared Services Challenge**: Need strategy for common services (monitoring, logging)
* **Learning Curve**: Teams need to understand namespace-based organization

### 13.1.9 Migration Strategy

#### 13.1.9.1 Phase 1: Planning and Design

1. Inventory existing applications and their dependencies
2. Define namespace naming conventions and standards
3. Create RBAC and network policy templates

#### 13.1.9.2 Phase 2: Shared Services Migration

1. Create shared services namespaces (monitoring, logging, gateway)
2. Migrate common infrastructure components
3. Establish cross-namespace communication patterns

#### 13.1.9.3 Phase 3: Application Migration

1. Start with least critical applications
2. Create application-specific namespaces with proper quotas and policies
3. Migrate workloads and validate functionality

#### 13.1.9.4 Phase 4: Governance Implementation

1. Implement automated namespace provisioning
2. Enable monitoring and alerting per namespace
3. Create operational runbooks for namespace management

### 13.1.10 Monitoring and Compliance

#### 13.1.10.1 Namespace-Level Metrics

* Resource utilization per namespace
* Cost attribution per application
* Security policy violations
* Cross-namespace communication patterns

#### 13.1.10.2 Compliance Reporting

* Resource usage reports per business unit
* Security posture per application
* Audit logs scoped to business context
* Data residency compliance per namespace

This topology provides a solid foundation for managing complex multi-tenant RH OVE environments while maintaining security, operational clarity, and business alignment.

# 14 ADR-004 Admission Controller

## 14.1 ADR-004: Admission Controller Strategy

### 14.1.1 Status

Accepted

### 14.1.2 Date

2024-12-01

### 14.1.3 Context

The RH OVE ecosystem requires a flexible, secure, and policy-driven approach for managing resource admission and validation within clusters. Implementing appropriate admission control policies ensures compliance, security, and operational consistency.

### 14.1.4 Decision

We will implement a layered admission control strategy utilizing OpenShift’s built-in admission controllers, KubeVirt webhooks, Kyverno policies, and OIDC-integrated RBAC enforcement via Keycloak.

### 14.1.5 Rationale

#### 14.1.5.1 Advantages

1. **Centralized Policy Management**: Simplify governance with cluster-wide policies
2. **Dynamic Policy Application**: Adjust policies without redeploying cluster components
3. **Security Enforcement**: Validate resource configurations before persistence
4. **Prevention of Misconfiguration**: Guard against policy violations
5. **Identity-based Access Management**: Integration with OIDC providers for enhanced user identity verification
6. **Extensibility**: Easy to introduce new policies as needs evolve

#### 14.1.5.2 Alternatives Considered

1. **Legacy Admission Controllers**: Rejected due to limited flexibility and poor integration
2. **Custom Webhooks**: Rejected due to complexity in management and maintenance
3. **Third-Party Solutions**: Rejected due to integration difficulties and vendor lock-in

### 14.1.6 Implementation Details

#### 14.1.6.1 OpenShift Built-in Admission

* **Security Context Constraints**: Default and custom SCCs for VM and container workloads
* **RBAC Enforcements**: Actionable role- and label-based access controls
* **Quotas and Limit Ranges**: Ensuring fair resource allocation per team

#### 14.1.6.2 KubeVirt Webhooks

* **Validation Webhooks**: Enforce configuration standards for VM specs
* **Mutation Webhooks**: Apply defaults and constraints to VM definitions

#### 14.1.6.3 Kyverno Policies

* **Configuration Validation**: Ensure compliance with organization best practices
* **Resource Constraints**: Limit what configurations may be used / deployed
* **Dynamic Policies**: Automate policy reapplication based on changes

### 14.1.7 Compliance Considerations

* **Auditability**: Policy applications and violation logging
* **Policy-as-Code**: Centralized version control and history of policy changes
* **Enforcement vs Warning**: Progressive policy application based on audit

### 14.1.8 Consequences

#### 14.1.8.1 Positive

* **Improved Security Posture**: Clusters protected from non-compliant configurations
* **Enhanced Compliance Auditability**: Documentation and reporting of policy compliance
* **Reduced Operational Risk**: Guard against human error and unsafe configurations

#### 14.1.8.2 Negative

* **Complex Rule Management**: Need mature processes to handle policy lifecycle
* **Performance Overhead**: May introduce latency to resource creation/update
* **Learning Curve**: Required training for policy authors

### 14.1.9 Implementation Plan

#### 14.1.9.1 Phase 1: Planning

1. Identify key compliance and security requirements
2. Design initial policy set and test environment
3. Engage stakeholders to define policy boundaries

#### 14.1.9.2 Phase 2: Rollout

1. Deploy core admission controllers with policy-as-code principles, leveraging IAM for authentication and authorization
2. Begin enforcement in non-production environments
3. Gradually extend to production with monitoring and logging

#### 14.1.9.3 Phase 3: Monitoring and Adjustment

1. Enable continuous policy evaluation and audit logging
2. Conduct regular policy reviews and updates
3. Train teams on policy creation and maintenance

### 14.1.10 Compliance and Observability

#### 14.1.10.1 Monitoring

* Policy applicability and compliance dashboards
* Alerts for policy violations and enforcement actions

#### 14.1.10.2 Logging and Reporting

* Centralized logging of admission requests and results
* Automated compliance reports tied to policy adherence

# 15 ADR-005 Network CNI

## 15.1 ADR-005: Cilium CNI with Multus Multi-Network Strategy

### 15.1.1 Status

Accepted

### 15.1.2 Date

2024-12-01

### 15.1.3 Context

The RH OVE ecosystem requires advanced networking capabilities to support both container and VM workloads with enterprise-grade security, performance, and observability. Traditional iptables-based CNI solutions lack the performance and security features needed for modern hybrid workloads.

### 15.1.4 Decision

We will implement **Cilium as the primary CNI** with **Multus for multi-network support**, providing eBPF-powered networking with advanced security and observability capabilities.

### 15.1.5 Rationale

#### 15.1.5.1 Advantages of Cilium

1. **eBPF Performance**: Superior performance compared to iptables-based solutions
2. **Identity-Aware Security**: Security policies based on workload identity, not IP addresses
3. **L7 Security**: Application-layer security without sidecar proxies
4. **Service Mesh Capabilities**: Built-in service mesh functionality
5. **Red Hat Certification**: Certified CNI plugin for OpenShift
6. **Hubble Observability**: Deep network visibility and monitoring
7. **Transparent Encryption**: Built-in WireGuard and IPsec support

#### 15.1.5.2 Advantages of Multus Integration

1. **Multi-Network Support**: Attach multiple network interfaces to VMs
2. **Legacy Network Integration**: Support for existing VLAN-based networks
3. **Performance Networks**: SR-IOV for high-performance workloads
4. **Network Segmentation**: Separate management, storage, and data networks

#### 15.1.5.3 Alternatives Considered

##### 15.1.5.3.1 1. OVN-Kubernetes (OpenShift Default)

* **Pros**: Native OpenShift integration, mature
* **Cons**: Limited eBPF features, performance overhead
* **Rejected**: Cilium provides superior performance and security

##### 15.1.5.3.2 2. Calico

* **Pros**: Strong network policies, eBPF support
* **Cons**: No built-in service mesh, complex multi-network setup
* **Rejected**: Cilium offers better integrated solution

##### 15.1.5.3.3 3. Flannel

* **Pros**: Simple, lightweight
* **Cons**: Limited security features, no eBPF support
* **Rejected**: Insufficient for enterprise requirements

### 15.1.6 Implementation Details

#### 15.1.6.1 Cilium Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cilium-config  
 namespace: kube-system  
data:  
 # Enable Cilium features  
 enable-ipv4: "true"  
 enable-ipv6: "false"  
   
 # eBPF configuration  
 enable-bpf-masquerade: "true"  
 enable-host-reachable-services: "true"  
   
 # Security features  
 enable-l7-proxy: "true"  
 enable-policy: "default"  
 policy-enforcement-mode: "default"  
   
 # Service mesh capabilities  
 enable-envoy-config: "true"  
   
 # Encryption  
 enable-wireguard: "true"  
 wireguard-userspace-fallback: "true"  
   
 # Observability  
 enable-hubble: "true"  
 hubble-listen-address: ":4244"  
 hubble-metrics-server: ":9091"  
 hubble-metrics: |  
 dns:query;ignoreAAAA  
 drop  
 tcp  
 flow  
 icmp  
 http  
   
 # Performance optimizations  
 enable-bandwidth-manager: "true"  
 enable-local-redirect-policy: "true"  
 kube-proxy-replacement: "strict"

#### 15.1.6.2 Multus Installation

apiVersion: operator.openshift.io/v1  
kind: Network  
metadata:  
 name: cluster  
spec:  
 additionalNetworks:  
 - name: management-network  
 namespace: default  
 type: Raw  
 rawCNIConfig: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "management-network",  
 "type": "macvlan",  
 "master": "ens192",  
 "mode": "bridge",  
 "ipam": {  
 "type": "static"  
 }  
 }

#### 15.1.6.3 Network Attachment Definitions

## Management Network  
apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: management-net  
 namespace: vm-infrastructure  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "management-net",  
 "type": "macvlan",  
 "master": "ens192",  
 "mode": "bridge",  
 "ipam": {  
 "type": "static",  
 "addresses": [  
 {  
 "address": "192.168.100.0/24",  
 "gateway": "192.168.100.1"  
 }  
 ]  
 }  
 }  
---  
## High-Performance SR-IOV Network  
apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: sriov-net  
 namespace: vm-production  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "sriov-net",  
 "type": "sriov",  
 "deviceID": "1017",  
 "vf": 0,  
 "ipam": {  
 "type": "static"  
 }  
 }

#### 15.1.6.4 Identity-Aware Network Policies

apiVersion: cilium.io/v2  
kind: CiliumNetworkPolicy  
metadata:  
 name: web-to-database-policy  
 namespace: app-web-prod  
spec:  
 endpointSelector:  
 matchLabels:  
 app: web-frontend  
 egress:  
 - toEndpoints:  
 - matchLabels:  
 app: database  
 environment: production  
 toPorts:  
 - ports:  
 - port: "5432"  
 protocol: TCP  
 rules:  
 http:  
 - method: "GET"  
 path: "/health"

#### 15.1.6.5 L7 Security Policies

apiVersion: cilium.io/v2  
kind: CiliumNetworkPolicy  
metadata:  
 name: api-security-policy  
 namespace: app-api-prod  
spec:  
 endpointSelector:  
 matchLabels:  
 app: api-server  
 ingress:  
 - fromEndpoints:  
 - matchLabels:  
 app: web-frontend  
 toPorts:  
 - ports:  
 - port: "8080"  
 protocol: TCP  
 rules:  
 http:  
 - method: "GET"  
 path: "/api/v1/.\*"  
 - method: "POST"  
 path: "/api/v1/users"  
 headers:  
 - "Content-Type: application/json"

#### 15.1.6.6 VM Multi-Network Configuration

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: multi-network-vm  
 namespace: vm-infrastructure  
 annotations:  
 k8s.v1.cni.cncf.io/networks: |  
 [  
 {  
 "name": "management-net",  
 "ips": ["192.168.100.10/24"]  
 },  
 {  
 "name": "storage-net",  
 "ips": ["10.0.1.10/24"]  
 }  
 ]  
spec:  
 running: true  
 template:  
 spec:  
 domain:  
 devices:  
 interfaces:  
 - name: default  
 masquerade: {}  
 - name: management  
 bridge: {}  
 - name: storage  
 bridge: {}  
 networks:  
 - name: default  
 pod: {}  
 - name: management  
 multus:  
 networkName: management-net  
 - name: storage  
 multus:  
 networkName: storage-net

### 15.1.7 Security Implementation

#### 15.1.7.1 Transparent Encryption

## WireGuard encryption configuration  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cilium-config  
 namespace: kube-system  
data:  
 enable-wireguard: "true"  
 wireguard-userspace-fallback: "true"  
 encryption-node: "true"

#### 15.1.7.2 Zero Trust Network Policies

apiVersion: cilium.io/v2  
kind: CiliumNetworkPolicy  
metadata:  
 name: default-deny-all  
 namespace: app-web-prod  
spec:  
 endpointSelector: {}  
 ingress: []  
 egress:  
 # Allow DNS  
 - toEndpoints:  
 - matchLabels:  
 k8s:io.kubernetes.pod.namespace: kube-system  
 k8s:k8s-app: kube-dns  
 toPorts:  
 - ports:  
 - port: "53"  
 protocol: UDP

### 15.1.8 Observability with Hubble

#### 15.1.8.1 Hubble Relay Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: hubble-config  
 namespace: kube-system  
data:  
 config.yaml: |  
 server:  
 address: 0.0.0.0:4245  
 relay:  
 address: hubble-relay.kube-system.svc.cluster.local:80  
 tls:  
 enabled: false

#### 15.1.8.2 Network Flow Monitoring

## Monitor network flows  
hubble observe --namespace app-web-prod  
  
## Check policy violations  
hubble observe --verdict DENIED  
  
## Monitor specific VM traffic  
hubble observe --pod vm-database-xxx

### 15.1.9 Performance Optimization

#### 15.1.9.1 eBPF Host Routing

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cilium-config  
 namespace: kube-system  
data:  
 enable-host-routing: "true"  
 enable-external-ips: "true"  
 enable-node-port: "true"  
 enable-host-port: "true"

#### 15.1.9.2 Bandwidth Management

apiVersion: cilium.io/v2  
kind: CiliumBandwidthPolicy  
metadata:  
 name: bandwidth-limit  
 namespace: app-web-prod  
spec:  
 endpointSelector:  
 matchLabels:  
 app: web-frontend  
 egress:  
 - bandwidth: "100M"  
 - bandwidth: "1G"  
 dscp: 46 # High priority traffic

### 15.1.10 Consequences

#### 15.1.10.1 Positive

* **Superior Performance**: eBPF provides 10-100x better performance than iptables
* **Enhanced Security**: Identity-aware policies and L7 security without sidecars
* **Deep Observability**: Hubble provides comprehensive network visibility
* **Future-Proof**: eBPF is the future of Linux networking
* **Multi-Network Support**: Seamless integration with legacy and high-performance networks

#### 15.1.10.2 Negative

* **Learning Curve**: Teams need to learn eBPF concepts and Cilium specifics
* **Debugging Complexity**: eBPF programs can be harder to debug than traditional networking
* **Resource Requirements**: Higher memory usage compared to simpler CNI solutions
* **Compatibility Concerns**: Some legacy applications may need network policy adjustments

### 15.1.11 Migration Strategy

#### 15.1.11.1 Phase 1: Preparation

1. Audit existing network policies and requirements
2. Set up test clusters with Cilium/Multus
3. Train operations team on eBPF and Cilium concepts

#### 15.1.11.2 Phase 2: Non-Production Deployment

1. Deploy Cilium in development and staging clusters
2. Migrate network policies to Cilium format
3. Implement Hubble monitoring and alerting

#### 15.1.11.3 Phase 3: Production Migration

1. Schedule maintenance window for CNI migration
2. Deploy Cilium with careful monitoring
3. Gradually enable advanced features (encryption, L7 policies)

#### 15.1.11.4 Phase 4: Advanced Features

1. Enable service mesh capabilities
2. Implement advanced security policies
3. Optimize performance settings based on workload patterns

### 15.1.12 Monitoring and Alerting

#### 15.1.12.1 Key Metrics

* Network throughput per namespace/pod
* Policy enforcement latency
* eBPF program load and execution time
* Hubble flow processing rate
* Encryption overhead metrics

#### 15.1.12.2 Alerting Rules

groups:  
- name: cilium-alerts  
 rules:  
 - alert: CiliumAgentDown  
 expr: up{job="cilium-agent"} == 0  
 for: 5m  
 labels:  
 severity: critical  
 - alert: NetworkPolicyViolation  
 expr: increase(cilium\_policy\_verdicts\_total{verdict="DENIED"}[5m]) > 10  
 labels:  
 severity: warning

This network architecture provides enterprise-grade performance, security, and observability for the RH OVE ecosystem while supporting both modern cloud-native applications and traditional VM workloads.

# 16 ADR-006 Backup Strategy

## 16.1 ADR-006: Backup Strategy for RH OVE Ecosystem

### 16.1.1 Status

Accepted

### 16.1.2 Date

2024-12-01

### 16.1.3 Context

Ensuring data protection and recovery is crucial for the RH OVE multi-cluster environment. The solution must support frequent, secure, and efficient backups across clusters, aligning with business continuity and compliance requirements.

### 16.1.4 Decision

Adopt a centralized backup strategy using **Rubrik** for VM and containerized workloads, providing consistency, compliance, and ease of management.

### 16.1.5 Rationale

#### 16.1.5.1 Advantages

1. **Unified Management**: Single pane of glass for managing backups across clusters
2. **Policy-Driven**: Flexibility in configuring backup policies per application/business need
3. **Deduplication and Compression**: Reduce storage costs by minimizing redundant data
4. **Cloud Integration**: Support for hybrid cloud scenarios and long-term data retention
5. **Application Consistency**: Automated application-aware snapshot management

#### 16.1.5.2 Alternatives Considered

1. **Velero**: Open-source alternative
   * **Pros**: Strong integration with Kubernetes ecosystems
   * **Cons**: Complexity in VM integration and limited cloud support
   * **Rejected**: Difficulties in ensuring VM workload consistency and enterprise support
2. **DIY Scripting Solutions**: Custom in-house scripts
   * **Pros**: Potentially customizable
   * **Cons**: Highly error-prone, difficult to manage at scale
   * **Rejected**: Lack of enterprise features, consistency guarantees, and support

### 16.1.6 Implementation Details

#### 16.1.6.1 Backup Policy Design

* **Daily Backups**: RPO of 24 hours for critical workloads
* **Weekly Full Backup with Daily Incrementals**: Optimizes storage usage
* **Data Encryption**: Both in transit and at rest using AES-256

#### 16.1.6.2 Backup Architecture

Backup Architecture  
├── Management Cluster  
│ ├── Rubrik Management Node  
│ └── Centralized Backup Policy Management  
├── Application Clusters  
│ ├── Rubrik Edge Devices  
│ ├── Local Snapshot Agents  
│ └── Data Replica Agents  
└── Cloud Archive  
 ├── Long Term Retention Storage  
 └── Cross-Region DR Copies

#### 16.1.6.3 Configuration Example

apiVersion: backup.rubrik.com/v1alpha1  
kind: BackupPolicy  
metadata:  
 name: application-backup-policy  
 namespace: backup  
spec:  
 frequency: "24h"  
 retention:  
 local: "30d"  
 cloud: "365d"  
 snapshotConsistency: "crash-consistent"  
 includeVolumes: "all"  
 excludeVolumes:  
 - "scratch"  
 encryption: enabled  
 replication:  
 target: cloud-archive  
 frequency: "12h"

### 16.1.7 Security and Compliance Considerations

* **Data Encryption**: All backup data encrypted with AES-256
* **Access Control**: Role-based access for backup management and retrieval
* **Audit Trails**: Detailed logging of backup and restore operations
* **Compliance Alignment**: Meets GDPR, HIPAA, and SOC 2 requirements

### 16.1.8 Consequences

#### 16.1.8.1 Positive

* **Reduced Risk**: Comprehensive DR strategy minimizes impact of data loss events
* **Operational Visibility**: Centralized monitoring and alerting of backup status
* **Strategic Flexibility**: Support for hybrid cloud and multi-region deployments

#### 16.1.8.2 Negative

* **Cost Considerations**: Could incur higher upfront Costa than open-source alternatives
* **Training Requirement**: Backup administrators require training in Rubrik solutions

### 16.1.9 Migration Strategy

#### 16.1.9.1 Phase 1: Planning

1. Define business-critical systems and RPO/RTO requirements
2. Design initial backup policy and architecture
3. Identify data sovereignty and compliance requirements

#### 16.1.9.2 Phase 2: Non-Production Deployment

1. Pilot Rubrik deployment in development environment
2. Test backup and restore operations thoroughly
3. Validate compliance alignment with internal and external audits

#### 16.1.9.3 Phase 3: Production Rollout

1. Deploy Rubrik management in the production environment
2. Migrate to production backup policies with minimal downtime
3. Enable monitoring and alerting on backup status

#### 16.1.9.4 Phase 4: Continuous Improvement

1. Regular policy reviews to adapt to changing business needs
2. Leverage Rubrik analytics for optimizations and reporting
3. Update DR plans based on lessons learned and testing

### 16.1.10 Monitoring and Metrics

#### 16.1.10.1 Key Monitoring Metrics

* Backup success/failure rates
* Storage consumption over time
* Deduplication and compression efficiency
* RPO and RTO performance

#### 16.1.10.2 Alerting Setup

groups:  
- name: backup-alerts  
 rules:  
 - alert: BackupFailure  
 expr: rubrik\_backup\_failed{job="rubrik-agent"}  0  
 for: 10m  
 labels:  
 severity: critical  
 - alert: RPOViolation  
 expr: rubrik\_backup\_rpo{target="24h"} =r 24 \* 60 \* 60  
 labels:  
 severity: warning

This comprehensive backup strategy ensures that RH OVE can achieve high data availability, integrity, and compliance, aligning with enterprise best practices for data protection and disaster recovery.

# 17 ADR-007 Monitoring Strategy

## 17.1 ADR-007: Monitoring Strategy for RH OVE Ecosystem

### 17.1.1 Status

Accepted

### 17.1.2 Date

2024-12-01

### 17.1.3 Context

For the RH OVE multi-cluster setup, a comprehensive monitoring solution is necessary to ensure operational visibility, performance management, and incident response capability for both containerized and VM-based workloads.

### 17.1.4 Decision

Implement an integrated monitoring solution using **Prometheus and Grafana** for metrics collection and visualization, enhanced by **Dynatrace** for application performance monitoring and **Hubble** for network observability.

### 17.1.5 Rationale

#### 17.1.5.1 Prometheus & Grafana

1. **Scalability**: Native Kubernetes support, able to scale for large environments
2. **Flexibility**: Customizable dashboards and extensibility with plugins
3. **Community Support**: Active ecosystem with numerous exporters and integrations
4. **Real-time Metrics**: Capable of handling thousands of unique time-series metrics
5. **Alerting**: Integrated alert management with Prometheus Alertmanager

#### 17.1.5.2 Dynatrace

1. **Full-Stack Monitoring**: Covers both infrastructure and application layers
2. **AI-Powered Analytics**: Automated anomaly detection and root cause analysis
3. **Cloud-Native Support**: Strong support for Kubernetes and container environments
4. **Unified Observability**: Centralized insights across microservices and legacy apps

#### 17.1.5.3 Hubble

1. **eBPF-powered Network Insights**: Detailed flow visibility and security audits
2. **High Throughput**: Capable of capturing thousands of network flows per second
3. **Deployment Simplicity**: Out-of-the-box integration with Cilium

#### 17.1.5.4 Alternatives Considered

1. **OpenShift Monitoring Stack**
   * **Pros**: Native solution, well-integrated
   * **Cons**: Lacks depth in application performance monitoring
   * **Rejected**: Chosen instead for basic cluster health visibility
2. **Elastic Stack**
   * **Pros**: Full-text search capabilities
   * **Cons**: Complexity and resource consumption
   * **Rejected**: Simplified requirements focused on metrics
3. **DataDog**
   * **Pros**: Comprehensive feature set, SaaS model
   * **Cons**: Cost concerns for large-scale deployment
   * **Rejected**: Cost prohibitive compared to chosen solutions

### 17.1.6 Implementation Details

#### 17.1.6.1 Prometheus Configuration

apiVersion: monitoring.coreos.com/v1  
kind: Prometheus  
metadata:  
 name: global-prometheus  
 namespace: monitoring  
spec:  
 replicas: 3  
 serviceAccountName: prometheus  
 serviceMonitorSelector:  
 matchLabels:  
 team: observability  
 storage:  
 volumeClaimTemplate:  
 spec:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 500Gi

#### 17.1.6.2 Grafana Setup

* **Dashboards**: Pre-configured dashboards for cluster health, application performance, VM metrics
* **Themes**: Custom theming for alignment with corporate branding
* **User Access Control**: Integrated with OAuth for SSO

#### 17.1.6.3 Dynatrace Integration

* Deployment of OneAgent across clusters for full-stack visibility
* Integration with CI/CD pipelines for real-time performance feedback
* Automated tagging for dynamic cloud workloads

#### 17.1.6.4 Hubble Configuration

* Enable flow aggregation and analysis for detailed network observability
* Real-time flow filtering and visualization of network policies

### 17.1.7 Security and Compliance Considerations

* **Data Encryption**: All telemetry data encrypted in transit
* **Role-Based Access Control**: Segmented access to monitoring data
* **Compliance Monitoring**: Automated checks for regulatory compliance
* **Audit Logging**: Capture all configuration and access attempts

### 17.1.8 Consequences

#### 17.1.8.1 Positive

* **Operational Efficiency**: Reduce MTTR with real-time insights and alerting
* **Proactive Performance Management**: Identify and resolve issues before impacting users
* **Unified Observability**: Single-pane monitoring across clusters and applications

#### 17.1.8.2 Negative

* **Complexity of Integration**: Requires coordination across multiple tools
* **Resource Overhead**: Higher costs in terms of storage and compute resources
* **Training Requirements**: Teams need to become familiar with monitoring tools

### 17.1.9 Migration Strategy

#### 17.1.9.1 Phase 1: Initial Setup and Configuration

1. Deploy base Prometheus and Grafana setup in the management cluster
2. Establish Dynatrace integration for application monitoring
3. Enable Hubble for network flow visibility

#### 17.1.9.2 Phase 2: Metrics and Dashboard Customization

1. Design and implement custom dashboards for key performance indicators
2. Configure alerting thresholds and incident response playbooks
3. Integrate monitoring data with existing ITSM tools

#### 17.1.9.3 Phase 3: Continuous Optimization

1. Conduct regular review of metrics and dashboards for continuous improvement
2. Leverage Dynatrace AI insights for proactive tuning and capacity planning
3. Regularly assess network flow policies for efficiency and security

### 17.1.10 Monitoring and Metrics

#### 17.1.10.1 Key Performance Indicators

* CPU, memory, and storage utilization
* Network latency and throughput
* Application response times and error rates
* VM and container health

#### 17.1.10.2 Alerting Rules

* Resource exhaustion (CPU, Memory, Storage)
* Network policy violations
* Anomalous application behavior

This robust monitoring strategy ensures RH OVE achieves operational excellence, rapid issue resolution, and strategic insight into both infrastructure performance and applications across the multi-cluster environment.

# 18 ADR-008 IAM Strategy

## 18.1 ADR-008: Identity and Access Management (IAM) Strategy

### 18.1.1 Status

Accepted

### 18.1.2 Date

2024-12-01

### 18.1.3 Context

The RH OVE multi-cluster ecosystem requires enterprise-grade identity and access management to ensure secure authentication and authorization across all clusters and services. Traditional cluster-specific authentication creates operational complexity and security risks in multi-cluster environments.

### 18.1.4 Decision

We will implement a comprehensive IAM strategy using OpenID Connect (OIDC) providers with Keycloak as the primary identity provider, integrated with Kubernetes-native RBAC and service mesh authentication.

### 18.1.5 Rationale

#### 18.1.5.1 Advantages

1. **Centralized Identity Management**: Single source of truth for user identities across all clusters
2. **Single Sign-On (SSO)**: Seamless authentication across all services and clusters
3. **Enterprise Integration**: Native integration with existing LDAP/Active Directory infrastructure
4. **Multi-Factor Authentication**: Enhanced security with mandatory MFA for administrative accounts
5. **Audit and Compliance**: Complete audit trail for SOC 2, GDPR, and HIPAA compliance
6. **Zero Trust Security**: Identity-aware access controls with least-privilege principles
7. **Scalability**: Supports horizontal scaling across multiple clusters and regions

#### 18.1.5.2 Alternatives Considered

##### 18.1.5.2.1 1. Basic Kubernetes ServiceAccount Authentication

* **Pros**: Simple, native Kubernetes integration
* **Cons**: No centralized management, limited audit capabilities, poor user experience
* **Rejected**: Insufficient for enterprise requirements

##### 18.1.5.2.2 2. LDAP Direct Integration

* **Pros**: Direct integration with existing directory services
* **Cons**: No OIDC compliance, limited multi-cluster support, poor web service integration
* **Rejected**: Limited modern authentication capabilities

##### 18.1.5.2.3 3. Commercial Solutions (Auth0, Okta)

* **Pros**: Feature-rich, managed service
* **Cons**: Vendor lock-in, higher costs, limited customization
* **Alternative**: Considered for specific use cases but Keycloak preferred for primary solution

### 18.1.6 Implementation Details

#### 18.1.6.1 Core Components

##### 18.1.6.1.1 Identity Provider: Keycloak (Red Hat SSO)

## Keycloak Deployment Configuration  
apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: keycloak  
 namespace: auth-system  
spec:  
 replicas: 3  
 selector:  
 matchLabels:  
 app: keycloak  
 template:  
 spec:  
 containers:  
 - name: keycloak  
 image: quay.io/keycloak/keycloak:20.0  
 env:  
 - name: KC\_DB  
 value: postgres  
 - name: KC\_DB\_URL  
 value: jdbc:postgresql://postgres:5432/keycloak  
 - name: KC\_HOSTNAME\_STRICT  
 value: "false"  
 - name: KC\_HTTP\_ENABLED  
 value: "true"  
 - name: KC\_PROXY  
 value: edge

##### 18.1.6.1.2 OIDC Integration with OpenShift

apiVersion: config.openshift.io/v1  
kind: OAuth  
metadata:  
 name: cluster  
spec:  
 identityProviders:  
 - name: keycloak-oidc  
 mappingMethod: claim  
 type: OpenID  
 openID:  
 clientID: openshift-cluster  
 clientSecret:  
 name: oidc-client-secret  
 issuer: https://keycloak.company.com/auth/realms/openshift  
 claims:  
 preferredUsername: [preferred\_username]  
 name: [name]  
 email: [email]  
 groups: [groups]

##### 18.1.6.1.3 Dex OIDC Proxy for Service Authentication

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: dex-config  
 namespace: auth-system  
data:  
 config.yaml: |  
 issuer: https://dex.company.com  
 storage:  
 type: kubernetes  
 config:  
 inCluster: true  
 connectors:  
 - type: oidc  
 id: keycloak  
 name: Keycloak  
 config:  
 issuer: https://keycloak.company.com/auth/realms/company  
 clientID: dex-client  
 clientSecret: $DEX\_CLIENT\_SECRET  
 scopes: [openid, profile, email, groups]

#### 18.1.6.2 Authentication Flow

**[Mermaid Sequence Diagram - Rendering Failed]**

sequenceDiagram  
 participant User  
 participant Browser  
 participant Dex  
 participant Keycloak  
 participant K8s API  
 participant ArgoCD  
  
 User->>Browser: Access ArgoCD  
 Browser->>ArgoCD: Request access  
 ArgoCD->>Dex: Redirect to OIDC  
 Dex->>Keycloak: Authentication request  
 Keycloak->>User: MFA challenge  
 User->>Keycloak: Credentials + MFA  
 Keycloak->>Dex: ID Token + Access Token  
 Dex->>ArgoCD: Authorization code  
 ArgoCD->>Dex: Exchange for tokens  
 ArgoCD->>K8s API: API calls with user context  
 K8s API->>ArgoCD: Authorized response  
 ArgoCD->>Browser: Application access granted

*Note: Diagram rendering failed, showing code instead.*

#### 18.1.6.3 Authorization Model

##### 18.1.6.3.1 Group-Based RBAC

## Keycloak Groups mapped to Kubernetes RBAC  
groups:  
 platform-admins:  
 kubernetes-role: cluster-admin  
 argocd-role: admin  
 web-developers:  
 kubernetes-role: developer  
 kubernetes-namespaces: [app-web-prod, app-web-staging, app-web-dev]  
 argocd-role: web-app-admin  
 database-admins:  
 kubernetes-role: developer  
 kubernetes-namespaces: [app-database-prod, app-database-staging]  
 argocd-role: database-admin  
 security-auditors:  
 kubernetes-role: view  
 argocd-role: readonly

##### 18.1.6.3.2 Kubernetes RBAC Integration

apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRoleBinding  
metadata:  
 name: platform-admin-binding  
subjects:  
- kind: Group  
 name: "platform-admins"  
 apiGroup: rbac.authorization.k8s.io  
roleRef:  
 kind: ClusterRole  
 name: cluster-admin  
 apiGroup: rbac.authorization.k8s.io

#### 18.1.6.4 Security Controls

##### 18.1.6.4.1 Token Management

* **Access Tokens**: 15-minute expiration
* **Refresh Tokens**: 1-hour expiration
* **ID Tokens**: 5-minute expiration
* **Service Account Tokens**: 2-hour expiration with projected volumes

##### 18.1.6.4.2 Multi-Factor Authentication

## Mandatory MFA Flow in Keycloak  
authenticationFlows:  
 - alias: "browser-with-mfa"  
 description: "Browser flow with mandatory MFA"  
 authenticationExecutions:  
 - authenticator: "auth-username-password-form"  
 requirement: "REQUIRED"  
 - authenticator: "auth-otp-form"  
 requirement: "REQUIRED"

##### 18.1.6.4.3 Network Security

* Network policies restricting authentication service communication
* TLS 1.3 encryption for all authentication traffic
* Certificate-based mutual TLS for service-to-service communication

### 18.1.7 User Lifecycle Management

#### 18.1.7.1 Automated Provisioning

* SCIM integration for user provisioning/deprovisioning
* Automated group assignment based on organizational roles
* ServiceAccount creation for automated systems

#### 18.1.7.2 Self-Service Capabilities

* Password reset and account recovery
* MFA device management
* Access request workflows

### 18.1.8 Monitoring and Audit

#### 18.1.8.1 Metrics and Monitoring

## Prometheus ServiceMonitor for Authentication Metrics  
apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: dex-metrics  
 namespace: auth-system  
spec:  
 selector:  
 matchLabels:  
 app: dex  
 endpoints:  
 - port: metrics  
 interval: 30s

#### 18.1.8.2 Audit Logging

* Complete authentication audit trail
* RBAC change tracking
* Failed authentication monitoring
* Compliance reporting automation

#### 18.1.8.3 Key Metrics

* Authentication success/failure rates
* Active user sessions
* Token expiration and renewal rates
* MFA adoption rates
* Policy violation incidents

### 18.1.9 Disaster Recovery

#### 18.1.9.1 High Availability

* Multi-replica Keycloak deployment with database clustering
* Cross-region identity provider replication
* Automated failover with health checks

#### 18.1.9.2 Backup Strategy

## Daily Keycloak Database Backup  
apiVersion: batch/v1  
kind: CronJob  
metadata:  
 name: keycloak-backup  
 namespace: auth-system  
spec:  
 schedule: "0 2 \* \* \*"  
 jobTemplate:  
 spec:  
 template:  
 spec:  
 containers:  
 - name: backup  
 image: postgres:13  
 command: ["/bin/bash", "-c"]  
 args:  
 - pg\_dump -h keycloak-db -U keycloak keycloak > /backup/keycloak-$(date +%Y%m%d).sql && aws s3 cp /backup/keycloak-$(date +%Y%m%d).sql s3://iam-backups/

### 18.1.10 Consequences

#### 18.1.10.1 Positive

* **Enhanced Security**: Zero trust identity-aware access controls
* **Operational Efficiency**: Centralized identity management reduces operational overhead
* **Compliance Ready**: Built-in audit trails and regulatory framework alignment
* **Developer Experience**: Single sign-on with self-service capabilities
* **Scalability**: Supports multi-cluster and multi-region deployments
* **Cost Optimization**: Reduced manual identity management tasks

#### 18.1.10.2 Negative

* **Initial Complexity**: Setup and configuration require specialized knowledge
* **Dependencies**: Additional infrastructure components to manage and monitor
* **Learning Curve**: Teams need training on OIDC and Keycloak administration
* **Single Point of Failure**: Identity provider availability critical for system access
* **Token Management**: Requires careful handling of token lifecycle and security

### 18.1.11 Migration Strategy

#### 18.1.11.1 Phase 1: Infrastructure Setup (2-3 weeks)

1. Deploy Keycloak in management cluster with HA configuration
2. Configure LDAP/AD integration and user federation
3. Set up Dex OIDC proxy in all clusters
4. Implement network policies and security controls

#### 18.1.11.2 Phase 2: Service Integration (3-4 weeks)

1. Configure OpenShift OAuth with OIDC
2. Integrate ArgoCD with OIDC authentication
3. Configure Grafana and Prometheus with OIDC
4. Set up RBAC mappings and group assignments

#### 18.1.11.3 Phase 3: User Migration (2-3 weeks)

1. Migrate existing users to new identity system
2. Configure MFA for all administrative accounts
3. Test authentication flows and access controls
4. Train users on new authentication experience

#### 18.1.11.4 Phase 4: Monitoring and Optimization (1-2 weeks)

1. Deploy monitoring and alerting for authentication services
2. Configure audit logging and compliance reporting
3. Optimize token lifecycle and security policies
4. Document operational procedures and runbooks

### 18.1.12 Compliance Considerations

#### 18.1.12.1 Regulatory Alignment

* **SOC 2 Type II**: Automated audit trails and access controls
* **GDPR**: Right to be forgotten and data minimization
* **HIPAA**: PHI access controls and audit logging
* **SOX**: Financial system access controls and separation of duties

#### 18.1.12.2 Audit Requirements

* All authentication events logged with timestamps
* RBAC changes tracked with user attribution
* Failed authentication attempts monitored and alerted
* Regular access reviews automated with reporting

This IAM strategy provides enterprise-grade identity and access management for the RH OVE multi-cluster ecosystem, ensuring security, compliance, and operational efficiency through modern OIDC-based authentication and Kubernetes-native authorization.

# 19 Requirements Table

## 19.1 Requirements Summary Table

This document provides a comprehensive overview of all functional and non-functional requirements for the RH OVE multi-cluster ecosystem.

### 19.1.1 Functional Requirements Summary

| Requirement ID | Category | Title | ADR Reference | Acceptance Criteria Summary |
| --- | --- | --- | --- | --- |
| [FR-001.1](fr.md#fr-0011-cluster-topology-management) | Multi-Cluster Management | Cluster Topology Management | ADR-003 | Namespace patterns {app-name}-{environment}, cross-namespace policies, resource quotas |
| [FR-001.2](fr.md#fr-0012-multi-cluster-governance) | Multi-Cluster Management | Multi-Cluster Governance | ADR-001 | RHACM cluster lifecycle, centralized policies, monitoring aggregation |
| [FR-002.1](fr.md#fr-0021-argocd-hub-architecture) | GitOps Integration | ArgoCD Hub Architecture | ADR-002 | HA ArgoCD Hub, Application of Applications, automated/manual sync |
| [FR-002.2](fr.md#fr-0022-configuration-management) | GitOps Integration | Configuration Management | ADR-002 | Git-based config, Kustomize overlays, drift detection |
| [FR-003.1](fr.md#fr-0031-layered-admission-control) | Policy Management | Layered Admission Control | ADR-004 | Kyverno, Security Context Constraints, policy-as-code |
| [FR-003.2](fr.md#fr-0032-security-policy-enforcement) | Policy Management | Security Policy Enforcement | ADR-004 | Blocking/warning modes, violation reporting, exemption workflows |
| [FR-004.1](fr.md#fr-0041-cilium-cni-implementation) | Networking | Cilium CNI Implementation | ADR-005 | Cilium with Hubble, identity-aware policies, WireGuard encryption |
| [FR-004.2](fr.md#fr-0042-multi-network-support) | Networking | Multi-Network Support | ADR-005 | Multus NADs, multiple VM interfaces, VLAN segmentation, SR-IOV |
| [FR-004.3](fr.md#fr-0043-zero-trust-security) | Networking | Zero Trust Security | ADR-005 | Default-deny policies, L7 enforcement, flow monitoring |
| [FR-005.1](fr.md#fr-0051-centralized-backup-management) | Backup & DR | Centralized Backup Management | ADR-006 | Rubrik management, policy-driven scheduling, VM snapshots |
| [FR-005.2](fr.md#fr-0052-disaster-recovery-capabilities) | Backup & DR | Disaster Recovery Capabilities | ADR-006 | Cloud replication, point-in-time recovery, cross-cluster failover |
| [FR-006.1](fr.md#fr-0061-integrated-monitoring-stack) | Monitoring | Integrated Monitoring Stack | ADR-007 | Federated Prometheus, Grafana, Dynatrace, Hubble integration |
| [FR-006.2](fr.md#fr-0062-proactive-monitoring-and-alerting) | Monitoring | Proactive Monitoring and Alerting | ADR-007 | Threshold/anomaly detection, ITSM integration, runbook automation |
| [FR-007.1](fr.md#fr-0071-vm-lifecycle-management) | VM Management | VM Lifecycle Management | KubeVirt | VM CRUD operations, live migration, template management |
| [FR-007.2](fr.md#fr-0072-storage-management) | VM Management | Storage Management | KubeVirt | Multiple storage classes, volume expansion, image import |
| [FR-008.1](fr.md#fr-0081-identity-and-access-management) | Security | Identity and Access Management | ADR-008 | Keycloak OIDC, LDAP/AD federation, SSO, Dex proxy, OAuth integration, RBAC |
| [FR-008.2](fr.md#fr-0082-multi-factor-authentication-and-security-controls) | Security | Multi-Factor Authentication and Security Controls | ADR-008 | Mandatory MFA, token security, TLS 1.3, mutual TLS, SCIM automation |
| [FR-008.3](fr.md#fr-0083-compliance-management) | Security | Compliance Management | ADR-008 | SOC 2/GDPR/HIPAA with IAM, automated access reviews, incident tracking |
| [FR-009.1](fr.md#fr-0091-self-service-capabilities) | Developer Experience | Self-Service Capabilities | DevEx | Web interfaces, CLI tools, template provisioning |
| [FR-009.2](fr.md#fr-0092-cicd-integration) | Developer Experience | CI/CD Integration | DevOps | Git webhooks, image building, deployment strategies |

### 19.1.2 Non-Functional Requirements Summary

#### 19.1.2.1 Performance Requirements

| Requirement ID | Category | Metric | Target Value | Rationale |
| --- | --- | --- | --- | --- |
| FR-NFR-001 | Latency | API Response Time | < 200ms (95th percentile) | User experience optimization |
| FR-NFR-002 | Latency | Cross-Cluster Communication | < 50ms | Real-time data synchronization |
| FR-NFR-003 | Latency | VM Startup Time | < 60 seconds | Rapid workload provisioning |
| FR-NFR-004 | Throughput | VM Deployment Rate | 100+ VMs/hour/cluster | Support for scaling events |
| FR-NFR-005 | Throughput | Monitoring Metrics | 10,000+ metrics/second | Comprehensive observability |
| FR-NFR-006 | Throughput | Log Processing | 1GB+ logs/hour | Adequate logging capacity |
| FR-NFR-007 | Resource Utilization | CPU Usage | ≤ 80% under normal load | Performance headroom |
| FR-NFR-008 | Resource Utilization | Memory Usage | ≤ 85% under normal load | Stability margin |
| FR-NFR-009 | Resource Utilization | Storage Usage | ≤ 90% capacity | Growth accommodation |

#### 19.1.2.2 Availability Requirements

| Requirement ID | Category | Metric | Target Value | Business Impact |
| --- | --- | --- | --- | --- |
| FR-NFR-010 | Uptime | Production Clusters | 99.9% (< 8.77 hours/year downtime) | Business continuity |
| FR-NFR-011 | Uptime | Management Cluster | 99.95% (< 4.38 hours/year downtime) | Central control availability |
| FR-NFR-012 | Failover | Critical Services | < 30 seconds failover time | Minimal service disruption |
| FR-NFR-013 | Disaster Recovery | RPO (Recovery Point Objective) | < 4 hours | Data loss tolerance |
| FR-NFR-014 | Disaster Recovery | RTO (Recovery Time Objective) | < 8 hours | Recovery time tolerance |
| FR-NFR-015 | Disaster Recovery | Cross-Region Failover | < 15 minutes | Geographic resilience |

#### 19.1.2.3 Scalability Requirements

| Requirement ID | Category | Metric | Target Value | Scalability Dimension |
| --- | --- | --- | --- | --- |
| FR-NFR-016 | Horizontal Scaling | Application Clusters | Minimum 10 clusters | Multi-environment support |
| FR-NFR-017 | Horizontal Scaling | Pods per Cluster | 1000+ pods | Workload density |
| FR-NFR-018 | Horizontal Scaling | Total Containers | 50,000+ across all clusters | Enterprise scale |
| FR-NFR-019 | Vertical Scaling | VM Resources | Up to 64 vCPUs, 512GB RAM | Large workload support |
| FR-NFR-020 | Vertical Scaling | Storage Volumes | Up to 100TB per volume | Big data capabilities |
| FR-NFR-021 | Vertical Scaling | Network Bandwidth | Up to 25Gbps per node | High-performance networking |

#### 19.1.2.4 Security Requirements

| Requirement ID | Category | Requirement | Implementation | Compliance Impact |
| --- | --- | --- | --- | --- |
| FR-NFR-022 | Authentication | Multi-Factor Authentication | All API access | Enhanced security posture |
| FR-NFR-023 | Authorization | RBAC Enforcement | All cluster components | Access control consistency |
| FR-NFR-024 | Authentication | Service Account Tokens | Time-limited tokens | Reduced credential exposure |
| FR-NFR-025 | Data Protection | Encryption in Transit | TLS 1.3+ | Data confidentiality |
| FR-NFR-026 | Data Protection | Encryption at Rest | AES-256 | Data protection compliance |
| FR-NFR-027 | Key Management | Key Rotation | Every 90 days | Security best practices |
| FR-NFR-028 | Network Security | Inter-Cluster Encryption | All communications | End-to-end security |
| FR-NFR-029 | Network Security | Network Policies | Deny by default | Zero trust implementation |
| FR-NFR-030 | Network Security | Environment Isolation | Network segmentation | Security boundaries |
| FR-NFR-031 | Compliance | SOC 2 Compliance | Type II certification | Regulatory adherence |
| FR-NFR-032 | Audit | Log Retention | 7 years | Compliance requirements |
| FR-NFR-033 | Security | Vulnerability Scanning | Daily scans | Proactive security |

#### 19.1.2.5 Reliability Requirements

| Requirement ID | Category | Requirement | Target | Reliability Impact |
| --- | --- | --- | --- | --- |
| FR-NFR-034 | Fault Tolerance | Single Node Failure | No service interruption | High availability |
| FR-NFR-035 | Fault Tolerance | Single AZ Failure | Continued operation | Geographic resilience |
| FR-NFR-036 | Data Replication | Minimum Replicas | 3 nodes | Data durability |
| FR-NFR-037 | Error Handling | Error Logging | All errors with severity | Operational visibility |
| FR-NFR-038 | Error Handling | Retry Logic | Exponential backoff | Resilient operations |
| FR-NFR-039 | Error Handling | Critical Error Alerting | Automated notifications | Rapid incident response |
| FR-NFR-040 | Monitoring | Health Coverage | 99% system coverage | Comprehensive monitoring |
| FR-NFR-041 | Monitoring | Metrics Retention | Minimum 1 year | Historical analysis |
| FR-NFR-042 | Observability | Distributed Tracing | All services | End-to-end visibility |

#### 19.1.2.6 Maintainability Requirements

| Requirement ID | Category | Requirement | Implementation | Operational Impact |
| --- | --- | --- | --- | --- |
| FR-NFR-043 | Deployment | Zero-Downtime Updates | Rolling deployments | Service continuity |
| FR-NFR-044 | Deployment | Rollback Capability | < 5 minutes | Rapid recovery |
| FR-NFR-045 | Testing | Automated Test Coverage | 90%+ functionality | Quality assurance |
| FR-NFR-046 | Configuration | Version Control | All configuration | Change management |
| FR-NFR-047 | Configuration | Change Auditability | All changes tracked | Compliance and debugging |
| FR-NFR-048 | Infrastructure | Infrastructure as Code | All deployments | Consistency and repeatability |
| FR-NFR-049 | Documentation | API Specifications | OpenAPI for all APIs | Developer experience |
| FR-NFR-050 | Documentation | Operational Runbooks | All procedures | Operational consistency |
| FR-NFR-051 | Documentation | Architecture Decisions | ADR documentation | Knowledge management |

#### 19.1.2.7 Usability Requirements

| Requirement ID | Category | Requirement | Standard/Implementation | User Impact |
| --- | --- | --- | --- | --- |
| FR-NFR-052 | User Interface | Responsive Design | Mobile-friendly web UI | Multi-device access |
| FR-NFR-053 | API Design | RESTful Principles | Standard REST API | Developer experience |
| FR-NFR-054 | CLI Tools | Help Documentation | Comprehensive help | User self-service |
| FR-NFR-055 | Accessibility | WCAG Compliance | 2.1 AA standards | Inclusive design |
| FR-NFR-056 | Localization | Multi-Language Support | International users | Global accessibility |
| FR-NFR-057 | Accessibility | High Contrast Mode | Visual accessibility | Enhanced usability |

#### 19.1.2.8 Capacity Requirements

| Requirement ID | Category | Resource | Minimum Capacity | Scaling Consideration |
| --- | --- | --- | --- | --- |
| FR-NFR-058 | Storage | Usable Storage | 100TB per production cluster | Data growth accommodation |
| FR-NFR-059 | Storage | IOPS Performance | 10,000+ IOPS per cluster | High-performance workloads |
| FR-NFR-060 | Storage | Backup Retention | 5 years | Compliance and recovery |
| FR-NFR-061 | Network | Inter-Cluster Connectivity | 10Gbps minimum | High-bandwidth applications |
| FR-NFR-062 | Network | Intra-Cluster Latency | ≤ 5ms maximum | Real-time applications |
| FR-NFR-063 | Network | MTU Support | 9000 bytes (jumbo frames) | Network optimization |
| FR-NFR-064 | Compute | CPU Capacity | 1000 vCPUs per production cluster | Computational workloads |
| FR-NFR-065 | Compute | Memory Capacity | 4TB RAM per production cluster | Memory-intensive applications |
| FR-NFR-066 | Compute | GPU Support | 8+ GPUs per cluster | AI/ML workloads |

#### 19.1.2.9 Compliance & Regulatory Requirements

| Requirement ID | Category | Requirement | Implementation | Regulatory Framework |
| --- | --- | --- | --- | --- |
| FR-NFR-067 | Data Governance | Data Classification | Automated labeling | Privacy regulations |
| FR-NFR-068 | Data Protection | PII Handling | Encryption and access control | GDPR, HIPAA |
| FR-NFR-069 | Data Governance | Retention Policies | Automated enforcement | Legal requirements |
| FR-NFR-070 | Audit | Administrative Logging | All admin actions | SOX, SOC 2 |
| FR-NFR-071 | Audit | Log Integrity | Tamper-proof, timestamped | Legal evidence |
| FR-NFR-072 | Compliance | Automated Reporting | Compliance dashboards | Regulatory reporting |
| FR-NFR-073 | Privacy | Right to be Forgotten | Data deletion capability | GDPR Article 17 |
| FR-NFR-074 | Privacy | Data Minimization | Principle enforcement | Privacy by design |
| FR-NFR-075 | Privacy | Privacy by Design | Built-in privacy controls | Proactive compliance |

### 19.1.3 Requirements Traceability Matrix

#### 19.1.3.1 ADR to Requirements Mapping

| ADR | Related Functional Requirements | Related Non-Functional Requirements |
| --- | --- | --- |
| ADR-001: Multi-Cluster Pattern | FR-001.1, FR-001.2 | FR-NFR-010, FR-NFR-011, FR-NFR-016, FR-NFR-034, FR-NFR-035 |
| ADR-002: GitOps ArgoCD | FR-002.1, FR-002.2 | FR-NFR-043, FR-NFR-044, FR-NFR-046, FR-NFR-047, FR-NFR-048 |
| ADR-003: Namespace Topology | FR-001.1, FR-008.1 | FR-NFR-023, FR-NFR-030, FR-NFR-067, FR-NFR-068 |
| ADR-004: Admission Controller | FR-003.1, FR-003.2 | FR-NFR-022, FR-NFR-023, FR-NFR-031, FR-NFR-037, FR-NFR-070 |
| ADR-005: Cilium CNI | FR-004.1, FR-004.2, FR-004.3 | FR-NFR-002, FR-NFR-021, FR-NFR-028, FR-NFR-029, FR-NFR-061, FR-NFR-062 |
| ADR-006: Backup Strategy | FR-005.1, FR-005.2 | FR-NFR-013, FR-NFR-014, FR-NFR-015, FR-NFR-032, FR-NFR-060 |
| ADR-007: Monitoring Strategy | FR-006.1, FR-006.2 | FR-NFR-005, FR-NFR-040, FR-NFR-041, FR-NFR-042, FR-NFR-072 |
| ADR-008: IAM Strategy | FR-008.1, FR-008.2, FR-008.3 | FR-NFR-022, FR-NFR-023, FR-NFR-024, FR-NFR-025, FR-NFR-031, FR-NFR-070, FR-NFR-073 |

#### 19.1.3.2 Requirements Coverage Analysis

| Category | Total Requirements | Critical Requirements | Implementation Status |
| --- | --- | --- | --- |
| Functional Requirements | 19 sub-requirements | 12 critical | Architecture defined |
| Performance Requirements | 9 requirements | 6 critical | Targets established |
| Availability Requirements | 6 requirements | 6 critical | SLAs defined |
| Scalability Requirements | 6 requirements | 4 critical | Capacity planned |
| Security Requirements | 12 requirements | 12 critical | Controls specified |
| Reliability Requirements | 9 requirements | 6 critical | Patterns established |
| Maintainability Requirements | 9 requirements | 5 critical | Processes defined |
| Usability Requirements | 6 requirements | 2 critical | Standards adopted |
| Capacity Requirements | 9 requirements | 6 critical | Minimums established |
| Compliance Requirements | 9 requirements | 9 critical | Frameworks aligned |

### 19.1.4 Requirements Validation Criteria

#### 19.1.4.1 Functional Requirements Validation

* **FR Validation Method**: Acceptance criteria testing, integration testing, user acceptance testing
* **FR Success Metrics**: All acceptance criteria met, integration tests pass, user stories completed
* **FR Review Frequency**: Sprint reviews, milestone assessments, release validation

#### 19.1.4.2 Non-Functional Requirements Validation

* **NFR Validation Method**: Performance testing, load testing, security testing, compliance auditing
* **NFR Success Metrics**: All targets met or exceeded, benchmarks achieved, compliance verified
* **NFR Review Frequency**: Continuous monitoring, quarterly assessments, annual compliance reviews

This comprehensive requirements table provides complete traceability from high-level business needs through detailed technical requirements, enabling effective validation and implementation tracking for the RH OVE multi-cluster ecosystem.

# 20 Functional Requirements

## 20.1 Functional Requirements

### 20.1.1 Overview

This document outlines the functional requirements for the RH OVE multi-cluster ecosystem, derived from the architectural decisions documented in our ADRs.

### 20.1.2 FR-001: Multi-Cluster Management

#### 20.1.2.1 FR-001.1: Cluster Topology Management

* **Requirement**: The system must implement application namespace-based topology for workload organization
* **Rationale**: Based on ADR-003, ensures strong isolation, simplified RBAC, and clear resource attribution
* **Acceptance Criteria**:
  + Support namespace patterns: {app-name}-{environment}
  + Implement cross-namespace communication policies
  + Enable namespace-level resource quotas and limits

#### 20.1.2.2 FR-001.2: Multi-Cluster Governance

* **Requirement**: The system must support centralized governance across multiple application clusters from a management cluster
* **Rationale**: Based on ADR-001, provides separation of concerns and operational efficiency
* **Acceptance Criteria**:
  + Deploy and manage policies from management cluster to application clusters
  + Support cluster lifecycle management through RHACM
  + Enable centralized monitoring and logging aggregation

### 20.1.3 FR-002: GitOps Integration

#### 20.1.3.1 FR-002.1: ArgoCD Hub Architecture

* **Requirement**: The system must implement GitOps using ArgoCD in a hub-spoke pattern
* **Rationale**: Based on ADR-002, provides declarative configuration and audit trails
* **Acceptance Criteria**:
  + Deploy ArgoCD Hub in management cluster with high availability
  + Support Application of Applications pattern
  + Enable automated sync for non-production, manual sync for production
  + Integrate with Git repositories for all infrastructure and application configurations

#### 20.1.3.2 FR-002.2: Configuration Management

* **Requirement**: All infrastructure and application configurations must be stored in Git repositories
* **Rationale**: Ensures version control, auditability, and rollback capabilities
* **Acceptance Criteria**:
  + Support environment-specific overlays using Kustomize
  + Enable automated deployment pipeline with proper approval workflows
  + Provide drift detection and automatic remediation

### 20.1.4 FR-003: Admission Control and Policy Management

#### 20.1.4.1 FR-003.1: Layered Admission Control

* **Requirement**: The system must implement layered admission control using OpenShift built-in controllers, KubeVirt webhooks, and Kyverno policies
* **Rationale**: Based on ADR-004, provides flexible, secure, and policy-driven resource validation
* **Acceptance Criteria**:
  + Deploy Kyverno for custom policy management
  + Implement Security Context Constraints for VM and container workloads
  + Support policy-as-code with version control and automated deployment

#### 20.1.4.2 FR-003.2: Security Policy Enforcement

* **Requirement**: The system must validate and enforce security policies before resource persistence
* **Rationale**: Prevents misconfiguration and ensures compliance
* **Acceptance Criteria**:
  + Support both blocking and warning policy modes
  + Provide detailed policy violation reporting
  + Enable policy exemptions with proper approval workflows

### 20.1.5 FR-004: Networking and Connectivity

#### 20.1.5.1 FR-004.1: Cilium CNI Implementation

* **Requirement**: The system must use Cilium as the primary CNI with eBPF-powered networking
* **Rationale**: Based on ADR-005, provides superior performance, identity-aware security, and L7 capabilities
* **Acceptance Criteria**:
  + Deploy Cilium with Hubble for network observability
  + Implement identity-aware network policies
  + Support transparent encryption using WireGuard
  + Enable service mesh capabilities without sidecar proxies

#### 20.1.5.2 FR-004.2: Multi-Network Support

* **Requirement**: The system must support Multus for multi-network configurations
* **Rationale**: Enables legacy network integration, SR-IOV, and network segmentation
* **Acceptance Criteria**:
  + Support NetworkAttachmentDefinitions for management, storage, and data networks
  + Enable multiple network interfaces for VMs
  + Support VLAN-based network segmentation
  + Provide high-performance networking with SR-IOV

#### 20.1.5.3 FR-004.3: Zero Trust Security

* **Requirement**: The system must implement zero trust network principles
* **Rationale**: Ensures security by default with explicit allow policies
* **Acceptance Criteria**:
  + Implement default-deny network policies
  + Support L7 HTTP/HTTPS policy enforcement
  + Enable network flow monitoring and policy violation alerting

### 20.1.6 FR-005: Backup and Disaster Recovery

#### 20.1.6.1 FR-005.1: Centralized Backup Management

* **Requirement**: The system must implement centralized backup using Rubrik for unified VM and container workload protection
* **Rationale**: Based on ADR-006, provides consistency, compliance, and operational efficiency
* **Acceptance Criteria**:
  + Deploy Rubrik management in management cluster
  + Support policy-driven backup scheduling and retention
  + Enable application-consistent snapshots for VMs
  + Provide deduplication and compression for storage optimization

#### 20.1.6.2 FR-005.2: Disaster Recovery Capabilities

* **Requirement**: The system must support cross-region disaster recovery and failover
* **Rationale**: Ensures business continuity and meets compliance requirements
* **Acceptance Criteria**:
  + Support automated backup replication to cloud storage
  + Enable point-in-time recovery for critical workloads
  + Provide recovery testing and validation capabilities
  + Support cross-cluster failover scenarios

### 20.1.7 FR-006: Monitoring and Observability

#### 20.1.7.1 FR-006.1: Integrated Monitoring Stack

* **Requirement**: The system must implement integrated monitoring using Prometheus, Grafana, Dynatrace, and Hubble
* **Rationale**: Based on ADR-007, provides comprehensive observability across infrastructure and applications
* **Acceptance Criteria**:
  + Deploy federated Prometheus for metrics collection across clusters
  + Implement custom Grafana dashboards for infrastructure and application metrics
  + Integrate Dynatrace for full-stack application performance monitoring
  + Enable Hubble for network flow visibility and security monitoring

#### 20.1.7.2 FR-006.2: Proactive Monitoring and Alerting

* **Requirement**: The system must provide proactive monitoring with intelligent alerting
* **Rationale**: Enables early detection and resolution of issues
* **Acceptance Criteria**:
  + Support threshold-based and anomaly detection alerting
  + Integrate with incident management systems
  + Provide runbook automation for common issues
  + Enable custom alerting rules per application namespace

### 20.1.8 FR-007: Virtual Machine Management

#### 20.1.8.1 FR-007.1: VM Lifecycle Management

* **Requirement**: The system must support complete VM lifecycle management using KubeVirt
* **Rationale**: Provides unified management of VMs and containers
* **Acceptance Criteria**:
  + Support VM creation, scaling, and termination
  + Enable VM live migration for maintenance
  + Provide VM template management and cloning
  + Support both Windows and Linux guest operating systems

#### 20.1.8.2 FR-007.2: Storage Management

* **Requirement**: The system must provide flexible storage management for VMs using DataVolumes and CDI
* **Rationale**: Enables efficient storage provisioning and management
* **Acceptance Criteria**:
  + Support multiple storage classes for different performance tiers
  + Enable volume expansion and snapshotting
  + Provide image import from registries, HTTP, and S3 sources
  + Support persistent volume cloning for template workflows

### 20.1.9 FR-008: Security and Compliance

#### 20.1.9.1 FR-008.1: Identity and Access Management

* **Requirement**: The system must integrate with enterprise identity providers using OIDC for centralized authentication and authorization
* **Rationale**: Based on ADR-008, ensures consistent security policies, audit trails, and enterprise integration
* **Acceptance Criteria**:
  + Deploy Keycloak (Red Hat SSO) as primary OIDC provider with HA configuration
  + Support LDAP/Active Directory federation for existing user directories
  + Implement Single Sign-On (SSO) across all clusters and services
  + Deploy Dex OIDC proxy for service authentication
  + Integrate OpenShift OAuth with OIDC claims mapping
  + Implement namespace-based RBAC with OIDC group delegation
  + Enable service account automation with time-limited tokens (15min-2hours)
  + Provide comprehensive audit logging for all authentication and authorization events

#### 20.1.9.2 FR-008.2: Multi-Factor Authentication and Security Controls

* **Requirement**: The system must enforce multi-factor authentication and implement comprehensive security controls
* **Rationale**: Based on ADR-008, ensures zero trust security principles and enhanced threat protection
* **Acceptance Criteria**:
  + Enforce mandatory MFA for all administrative accounts using TOTP/SMS
  + Implement token security with proper expiration policies (access: 15min, refresh: 1hour, ID: 5min)
  + Deploy network policies restricting authentication service communication
  + Support TLS 1.3 encryption for all authentication traffic
  + Enable certificate-based mutual TLS for service-to-service communication
  + Implement automated user provisioning/deprovisioning via SCIM integration
  + Support self-service password reset and MFA device management

#### 20.1.9.3 FR-008.3: Compliance Management

* **Requirement**: The system must support automated compliance checking and reporting with IAM integration
* **Rationale**: Ensures adherence to regulatory requirements with comprehensive identity audit trails
* **Acceptance Criteria**:
  + Support SOC 2, GDPR, and HIPAA compliance frameworks with identity-aware controls
  + Enable automated compliance scanning and reporting with authentication metrics
  + Provide policy violation tracking and remediation workflows
  + Support data classification and handling policies
  + Generate automated access review reports with RBAC analysis
  + Track failed authentication attempts and security incidents
  + Support “right to be forgotten” with automated user data deletion

### 20.1.10 FR-009: Developer Experience

#### 20.1.10.1 FR-009.1: Self-Service Capabilities

* **Requirement**: The system must provide self-service capabilities for development teams
* **Rationale**: Improves developer productivity and reduces operational overhead
* **Acceptance Criteria**:
  + Provide web-based interfaces for resource management
  + Support CLI tools for automation and scripting
  + Enable template-based resource provisioning
  + Provide comprehensive documentation and tutorials

#### 20.1.10.2 FR-009.2: CI/CD Integration

* **Requirement**: The system must integrate with existing CI/CD pipelines
* **Rationale**: Enables automated testing and deployment workflows
* **Acceptance Criteria**:
  + Support webhook integration with Git repositories
  + Enable automated image building and scanning
  + Provide integration with popular CI/CD tools (Jenkins, GitLab CI, etc.)
  + Support blue-green and canary deployment strategies

# 21 Non-Functional Requirements

## 21.1 Non-Functional Requirements

### 21.1.1 Overview

This document outlines the non-functional requirements for the RH OVE multi-cluster ecosystem, defining quality attributes and constraints.

### 21.1.2 Performance Requirements

#### 21.1.2.1 Latency

* **FR-NFR-001**: API response time must be < 200ms for 95% of requests
* **FR-NFR-002**: Cross-cluster communication latency must be < 50ms
* **FR-NFR-003**: VM startup time must be < 60 seconds for standard workloads

#### 21.1.2.2 Throughput

* **FR-NFR-004**: System must support deployment of 100+ VMs per hour per cluster
* **FR-NFR-005**: Monitoring system must handle 10,000+ metrics per second
* **FR-NFR-006**: Log aggregation must process 1GB+ of logs per hour

#### 21.1.2.3 Resource Utilization

* **FR-NFR-007**: CPU utilization must not exceed 80% under normal load
* **FR-NFR-008**: Memory utilization must not exceed 85% under normal load
* **FR-NFR-009**: Storage utilization must not exceed 90% capacity

### 21.1.3 Availability Requirements

#### 21.1.3.1 Uptime

* **FR-NFR-010**: Production clusters must achieve 99.9% uptime (< 8.77 hours downtime/year)
* **FR-NFR-011**: Management cluster must achieve 99.95% uptime (< 4.38 hours downtime/year)
* **FR-NFR-012**: Critical services must have < 30 seconds failover time

#### 21.1.3.2 Disaster Recovery

* **FR-NFR-013**: RPO (Recovery Point Objective) must be < 4 hours
* **FR-NFR-014**: RTO (Recovery Time Objective) must be < 8 hours
* **FR-NFR-015**: Cross-region failover must complete within 15 minutes

### 21.1.4 Scalability Requirements

#### 21.1.4.1 Horizontal Scaling

* **FR-NFR-016**: System must support minimum 10 application clusters
* **FR-NFR-017**: Each cluster must support 1000+ pods
* **FR-NFR-018**: System must scale to 50,000+ containers across all clusters

#### 21.1.4.2 Vertical Scaling

* **FR-NFR-019**: Individual VMs must scale up to 64 vCPUs and 512GB RAM
* **FR-NFR-020**: Storage volumes must scale up to 100TB per volume
* **FR-NFR-021**: Network bandwidth must scale to 25Gbps per node

### 21.1.5 Security Requirements

#### 21.1.5.1 Authentication & Authorization

* **FR-NFR-022**: All API access must use multi-factor authentication
* **FR-NFR-023**: RBAC must be enforced across all cluster components
* **FR-NFR-024**: Service accounts must use time-limited tokens

#### 21.1.5.2 Data Protection

* **FR-NFR-025**: All data in transit must be encrypted (TLS 1.3+)
* **FR-NFR-026**: All data at rest must be encrypted (AES-256)
* **FR-NFR-027**: Encryption keys must be rotated every 90 days

#### 21.1.5.3 Network Security

* **FR-NFR-028**: All inter-cluster communication must be encrypted
* **FR-NFR-029**: Network policies must deny by default
* **FR-NFR-030**: Network segmentation must isolate environments

#### 21.1.5.4 Compliance

* **FR-NFR-031**: System must maintain SOC 2 Type II compliance
* **FR-NFR-032**: Audit logs must be retained for 7 years
* **FR-NFR-033**: Security scanning must occur daily

### 21.1.6 Reliability Requirements

#### 21.1.6.1 Fault Tolerance

* **FR-NFR-034**: System must survive single node failures without service interruption
* **FR-NFR-035**: System must survive single AZ failures in multi-AZ deployments
* **FR-NFR-036**: Data must be replicated across minimum 3 nodes

#### 21.1.6.2 Error Handling

* **FR-NFR-037**: All errors must be logged with appropriate severity levels
* **FR-NFR-038**: Transient errors must be retried with exponential backoff
* **FR-NFR-039**: Critical errors must trigger automated alerting

#### 21.1.6.3 Monitoring & Observability

* **FR-NFR-040**: System health must be monitored with 99% coverage
* **FR-NFR-041**: Metrics retention must be minimum 1 year
* **FR-NFR-042**: Distributed tracing must be enabled for all services

### 21.1.7 Maintainability Requirements

#### 21.1.7.1 Deployment & Updates

* **FR-NFR-043**: Zero-downtime deployments must be supported
* **FR-NFR-044**: Rollback capability must be available within 5 minutes
* **FR-NFR-045**: Automated testing must cover 90%+ of functionality

#### 21.1.7.2 Configuration Management

* **FR-NFR-046**: All configuration must be version controlled
* **FR-NFR-047**: Configuration changes must be auditable
* **FR-NFR-048**: Infrastructure as Code must be used for all deployments

#### 21.1.7.3 Documentation

* **FR-NFR-049**: All APIs must have OpenAPI specifications
* **FR-NFR-050**: Runbooks must be available for all operational procedures
* **FR-NFR-051**: Architecture decisions must be documented in ADRs

### 21.1.8 Usability Requirements

#### 21.1.8.1 User Interface

* **FR-NFR-052**: Web UI must be responsive and mobile-friendly
* **FR-NFR-053**: API must follow RESTful design principles
* **FR-NFR-054**: CLI tools must provide comprehensive help documentation

#### 21.1.8.2 Accessibility

* **FR-NFR-055**: Web interfaces must meet WCAG 2.1 AA standards
* **FR-NFR-056**: Multi-language support must be available
* **FR-NFR-057**: High contrast mode must be supported

### 21.1.9 Capacity Requirements

#### 21.1.9.1 Storage

* **FR-NFR-058**: Minimum 100TB usable storage per production cluster
* **FR-NFR-059**: Storage must support 10,000+ IOPS per cluster
* **FR-NFR-060**: Backup storage must retain data for 5 years

#### 21.1.9.2 Network

* **FR-NFR-061**: Minimum 10Gbps connectivity between clusters
* **FR-NFR-062**: Maximum 5ms latency within cluster networks
* **FR-NFR-063**: Network must support jumbo frames (9000 MTU)

#### 21.1.9.3 Compute

* **FR-NFR-064**: Minimum 1000 vCPUs available per production cluster
* **FR-NFR-065**: Minimum 4TB RAM available per production cluster
* **FR-NFR-066**: Support for GPU workloads (minimum 8 GPUs per cluster)

### 21.1.10 Compliance & Regulatory Requirements

#### 21.1.10.1 Data Governance

* **FR-NFR-067**: Data must be classified and labeled appropriately
* **FR-NFR-068**: PII data must be encrypted and access-controlled
* **FR-NFR-069**: Data retention policies must be automatically enforced

#### 21.1.10.2 Audit & Logging

* **FR-NFR-070**: All administrative actions must be logged
* **FR-NFR-071**: Logs must be tamper-proof and timestamped
* **FR-NFR-072**: Compliance reports must be generated automatically

#### 21.1.10.3 Privacy

* **FR-NFR-073**: Right to be forgotten must be supported
* **FR-NFR-074**: Data minimization principles must be enforced
* **FR-NFR-075**: Privacy by design must be implemented

# 22 Prerequisites

## 22.1 Prerequisites

### 22.1.1 Overview

This document outlines the prerequisites for deploying the RH OVE ecosystem, including infrastructure requirements, software dependencies, and configuration prerequisites.

### 22.1.2 Infrastructure Requirements

#### 22.1.2.1 Hardware Requirements

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Master Nodes (3 minimum)"  
 A[CPU: 4+ cores per node]  
 B[Memory: 16GB+ per node]  
 C[Storage: 120GB+ per node]  
 D[Network: 1Gbps+]  
 end  
   
 subgraph "Worker Nodes (3+ minimum)"  
 E[CPU: 8+ cores per node]  
 F[Memory: 32GB+ per node]  
 G[Storage: 500GB+ per node]  
 H[Network: 10Gbps+]  
 I[Virtualization: Intel VT-x/AMD-V]  
 end  
   
 subgraph "Storage Backend"  
 J[High-performance SSD]  
 K[Network-attached storage]  
 L[Block storage support]  
 end

*Note: Diagram rendering failed, showing code instead.*

#### 22.1.2.2 Virtualization Support

Ensure hardware virtualization is enabled:

## Check for Intel VT-x  
grep -E "(vmx|svm)" /proc/cpuinfo  
  
## Check if virtualization is enabled in BIOS  
lscpu | grep Virtualization  
  
## Verify KVM modules are loaded  
lsmod | grep kvm

#### 22.1.2.3 Network Requirements

* **Cluster Network**: Internal cluster communication
* **Service Network**: Service-to-service communication
* **Pod Network**: Pod-to-pod communication
* **External Access**: Load balancer and ingress traffic

## Network configuration example  
cluster\_network:  
 cidr: "10.128.0.0/14"  
 host\_prefix: 23  
  
service\_network:  
 - "172.30.0.0/16"  
  
machine\_networks:  
 - cidr: "192.168.1.0/24"

### 22.1.3 Software Prerequisites

#### 22.1.3.1 OpenShift Container Platform

* **Version**: OpenShift 4.12+ (recommended 4.14+)
* **Installation Method**: IPI (Installer Provisioned Infrastructure) or UPI (User Provisioned Infrastructure)
* **Cluster Admin Access**: Required for operator installation

#### 22.1.3.2 Required Operators

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Core Operators"  
 A[OpenShift Virtualization Operator]  
 B[Red Hat OpenShift GitOps]  
 C[Web Terminal Operator]  
 end  
   
 subgraph "Networking"  
 D[Cilium CNI Operator]  
 E[Multus CNI]  
 end  
   
 subgraph "Security & Policy"  
 F[Kyverno Operator]  
 G[Compliance Operator]  
 end  
   
 subgraph "Monitoring & Observability"  
 H[Dynatrace Operator]  
 I[Prometheus Operator]  
 end  
   
 subgraph "Backup & Storage"  
 J[Rubrik Operator]  
 K[CSI Operators]  
 end

*Note: Diagram rendering failed, showing code instead.*

#### 22.1.3.3 Storage Requirements

##### 22.1.3.3.1 Container Storage Interface (CSI) Drivers

## Example CSI StorageClass  
apiVersion: storage.k8s.io/v1  
kind: StorageClass  
metadata:  
 name: rh-ove-ssd  
provisioner: ebs.csi.aws.com  
parameters:  
 type: gp3  
 encrypted: "true"  
reclaimPolicy: Delete  
volumeBindingMode: WaitForFirstConsumer  
allowVolumeExpansion: true

##### 22.1.3.3.2 Storage Classes Required

* **Fast SSD**: For VM boot disks and high-IOPS workloads
* **Standard HDD**: For data storage and backup
* **Archive**: For long-term storage and compliance

### 22.1.4 Network Prerequisites

#### 22.1.4.1 DNS Configuration

## DNS configuration for cluster  
dns:  
 base\_domain: "ove.example.com"  
 cluster\_domain: "cluster.local"  
metadata:  
 name: "rh-ove-cluster"

#### 22.1.4.2 Load Balancer Configuration

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph LR  
 subgraph "External Load Balancer"  
 A[API Load Balancer]  
 B[Ingress Load Balancer]  
 end  
   
 subgraph "OpenShift Cluster"  
 C[Master Nodes]  
 D[Worker Nodes]  
 E[Ingress Controllers]  
 end  
   
 A --> C  
 B --> E  
 E --> D

*Note: Diagram rendering failed, showing code instead.*

#### 22.1.4.3 Firewall Rules

Required ports for RH OVE:

| Port Range | Protocol | Purpose |
| --- | --- | --- |
| 6443 | TCP | Kubernetes API server |
| 22623 | TCP | Machine config server |
| 80/443 | TCP | HTTP/HTTPS ingress |
| 9000-9999 | TCP | Host level services |
| 10250-10259 | TCP | Kubernetes node ports |
| 30000-32767 | TCP | NodePort services |

### 22.1.5 Security Prerequisites

#### 22.1.5.1 Certificate Management

## TLS certificate configuration  
tls:  
 ca\_cert: |  
 -----BEGIN CERTIFICATE-----  
 # CA certificate content  
 -----END CERTIFICATE-----  
   
 api\_cert: |  
 -----BEGIN CERTIFICATE-----  
 # API server certificate  
 -----END CERTIFICATE-----

#### 22.1.5.2 RBAC Configuration

Prepare service accounts and roles:

apiVersion: v1  
kind: ServiceAccount  
metadata:  
 name: rh-ove-admin  
 namespace: openshift-cnv  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRoleBinding  
metadata:  
 name: rh-ove-admin-binding  
roleRef:  
 apiGroup: rbac.authorization.k8s.io  
 kind: ClusterRole  
 name: cluster-admin  
subjects:  
- kind: ServiceAccount  
 name: rh-ove-admin  
 namespace: openshift-cnv

### 22.1.6 External System Prerequisites

#### 22.1.6.1 Git Repository Setup

For GitOps implementation:

## Create GitOps repository structure  
mkdir -p rh-ove-gitops/{applications,infrastructure,policies}  
  
## Initialize Git repository  
cd rh-ove-gitops  
git init  
git remote add origin https://git.example.com/rh-ove-gitops.git

#### 22.1.6.2 Rubrik Backup System

Prerequisites for Rubrik integration:

* **Rubrik cluster**: Version 5.0+
* **Network connectivity**: Cluster to Rubrik management network
* **Service account**: With backup and restore permissions
* **API access**: Rubrik REST API credentials

## Rubrik connection configuration  
apiVersion: v1  
kind: Secret  
metadata:  
 name: rubrik-credentials  
 namespace: rubrik-system  
type: Opaque  
stringData:  
 username: "rubrik-service-account"  
 password: "secure-password"  
 cluster-address: "rubrik.example.com"

#### 22.1.6.3 Dynatrace Monitoring

Prerequisites for Dynatrace integration:

* **Dynatrace tenant**: SaaS or Managed
* **API tokens**: With required permissions
* **Network access**: Cluster to Dynatrace endpoints

## Dynatrace API token secret  
apiVersion: v1  
kind: Secret  
metadata:  
 name: dynakube  
 namespace: dynatrace  
type: Opaque  
stringData:  
 apiToken: "dt0c01.xxxxx"  
 dataIngestToken: "dt0c01.yyyyy"

#### 22.1.6.4 ServiceNow CMDB

For CMDB integration:

* **ServiceNow instance**: With CMDB module
* **Service account**: With CMDB read/write permissions
* **API access**: REST API and webhooks configured

### 22.1.7 Validation Checklist

#### 22.1.7.1 Pre-Installation Checks

## Validation script example  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: pre-install-checks  
data:  
 validate.sh: |  
 #!/bin/bash  
   
 # Check OpenShift version  
 oc version  
   
 # Verify cluster resources  
 oc get nodes  
 oc get storageclass  
   
 # Check virtualization support  
 oc get nodes -o json | jq '.items[].status.allocatable'  
   
 # Validate network connectivity  
 curl -k https://registry.redhat.io/health

#### 22.1.7.2 Resource Verification

## Check available resources  
oc adm top nodes  
  
## Verify storage classes  
oc get storageclass  
  
## Check network plugins  
oc get network.config/cluster -o yaml  
  
## Validate image registry access  
oc get imagestreams -n openshift

### 22.1.8 Installation Timeline

**[Mermaid Gantt Chart - Rendering Failed]**

gantt  
 title RH OVE Deployment Timeline  
 dateFormat YYYY-MM-DD  
 section Infrastructure  
 Hardware Setup :done, infra1, 2024-01-01, 2024-01-07  
 OpenShift Installation :done, infra2, 2024-01-08, 2024-01-14  
   
 section Core Components  
 Virtualization Operator :active, core1, 2024-01-15, 2024-01-21  
 Cilium CNI :core2, 2024-01-22, 2024-01-28  
   
 section Security & Policy  
 Kyverno Installation :policy1, 2024-01-29, 2024-02-04  
 Security Policies :policy2, 2024-02-05, 2024-02-11  
   
 section Monitoring  
 Dynatrace Setup :monitor1, 2024-02-12, 2024-02-18  
 Backup Configuration :backup1, 2024-02-19, 2024-02-25  
   
 section GitOps  
 Argo CD Setup :gitops1, 2024-02-26, 2024-03-04  
 Application Deployment :gitops2, 2024-03-05, 2024-03-11

*Note: Diagram rendering failed, showing code instead.*

This comprehensive prerequisites guide ensures all necessary components and configurations are in place before beginning the RH OVE deployment process.

# 23 Installation Guide

## 23.1 Installation Guide

### 23.1.1 Overview

This installation guide provides step-by-step instructions to deploy the RH OVE ecosystem using a multi-cluster architecture. The deployment follows a hub-and-spoke pattern with one management cluster and multiple application clusters for different environments (production, staging, development).

### 23.1.2 Multi-Cluster Architecture

The RH OVE ecosystem consists of:

* **1 Management Cluster**: Centralized control plane for governance, policy, monitoring, and GitOps
* **N Application Clusters**: Dedicated workload execution environments for virtual machines and containers

### 23.1.3 Installation Flow

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 A[Prerequisites Check] --> B[Management Cluster Setup]  
 B --> C[Install RHACM Hub]  
 C --> D[Deploy ArgoCD Hub]  
 D --> E[Setup RHACS Central]  
 E --> F[Configure Observability Stack]  
 F --> G[Application Cluster Provisioning]  
 G --> H[Deploy RH OVE to App Clusters]  
 H --> I[Configure Multi-Network]  
 I --> J[Setup Backup & DR]  
 J --> K[Validation & Testing]

*Note: Diagram rendering failed, showing code instead.*

### 23.1.4 Core Component Installation

#### 23.1.4.1 OpenShift Cluster Setup

1. **Install OpenShift**
   * Follow [OpenShift Installation Docs](https://docs.openshift.com/) to set up the cluster.
   * Choose between IPI or UPI depending on your infrastructure.
2. **Verify Cluster Health**

* oc get nodes  
  oc get pods -n openshift-apiserver

#### 23.1.4.2 Virtualization Operator

1. **Install OpenShift Virtualization**

* oc apply -f https://path/to/virtualization-operator.yaml

1. **Verify Installation**

* oc get pods -n openshift-cnv  
  oc get kubevirt.kubevirt.io/kubevirt -n openshift-cnv

#### 23.1.4.3 Cilium CNI

1. **Install Cilium**

* helm repo add cilium https://helm.cilium.io/  
  helm install cilium cilium/cilium --namespace kube-system

1. **Verify Cilium Status**

* cilium status

#### 23.1.4.4 Kyverno Policy Engine

1. **Install Kyverno**

* kubectl create -f https://github.com/kyverno/kyverno/releases/download/v1.5.2/install.yaml

1. **Apply Policies**

* kubectl apply -f /path/to/policy-files

### 23.1.5 Monitoring Setup

#### 23.1.5.1 Dynatrace Integration

1. **Install Dynatrace Operator**

* oc apply -f https://path/to/dynatrace-operator.yaml

1. **Configure DynaKube**

* oc apply -f /path/to/dynakube-config.yaml

1. **Verify Monitoring**

* oc get pods -n dynatrace

#### 23.1.5.2 Prometheus and Grafana

1. **Install Prometheus Operator**

* oc apply -f https://path/to/prometheus-operator.yaml

1. **Setup Grafana**

* oc apply -f https://path/to/grafana-deployment.yaml

### 23.1.6 Backup Configuration

#### 23.1.6.1 Rubrik Integration

1. **Install Rubrik Operator**

* oc apply -f https://path/to/rubrik-operator.yaml

1. **Verify Backup**

* oc get pods -n rubrik

### 23.1.7 GitOps Setup

#### 23.1.7.1 Argo CD Installation

1. **Install Argo CD**

* oc apply -n argocd -f https://path/to/argocd-install.yaml

1. **Access Argo CD UI**
   * Forward Argo CD API server port:
   * oc port-forward svc/argocd-server -n argocd 8080:443
2. **Login to Argo CD**
   * Open <https://localhost:8080> in your browser.
3. **Deploy Applications**

* argocd app create my-app --repo https://git.example.com/my-app --path ./  
  argocd app sync my-app

### 23.1.8 Security Hardening

1. **Configure RBAC**

* oc apply -f /path/to/rbac-config.yaml

1. **Enable Pod Security**

* oc apply -f /path/to/pod-security.yaml

1. **Firewall Adjustments**
   * Ensure only necessary ports are open (refer to [prerequisites](prerequisites.md)).

### 23.1.9 Validation Steps

#### 23.1.9.1 Verify All Deployments

oc get all --all-namespaces

#### 23.1.9.2 Check Monitoring Dashboards

* Confirm metrics collection in Grafana and Dynatrace.

### 23.1.10 Post-Installation Tasks

#### 23.1.10.1 Documentation

* Update [MkDocs](../mkdocs.yml) with new components.

#### 23.1.10.2 Backup Verification

* Test Rubrik backups for VM and container data.

### 23.1.11 Conclusion

This guide ensures a smooth installation process for RH OVE, covering all critical steps and components necessary for successful deployment and operation. Follow each section carefully to complete the installation.

# 24 Configuration

## 24.1 Deployment Configuration

### 24.1.1 Overview

This document provides configuration guidelines for the RH OVE deployment, focusing on customization and parameters essential for adapting the solution to your specific environment.

### 24.1.2 OpenShift Configuration

#### 24.1.2.1 Cluster Configuration

Customize your OpenShift cluster with the necessary configurations to optimize performance and security:

apiVersion: config.openshift.io/v1  
kind: ClusterVersion  
metadata:  
 name: version  
spec:  
 channel: stable  
 upstream: https://api.openshift.com/api/upgrades\_info/v1/graph  
  
## Customization to networking  
apiVersion: operator.openshift.io/v1  
kind: Network  
metadata:  
 name: cluster  
spec:  
 clusterNetwork:  
 - cidr: 10.128.0.0/14  
 hostPrefix: 23  
 serviceNetwork:  
 - 172.30.0.0/16

#### 24.1.2.2 Node Configuration

Optimize your nodes for workload management:

apiVersion: machineconfiguration.openshift.io/v1  
kind: MachineConfigPool  
metadata:  
 name: worker  
spec:  
 machineConfigSelector:  
 matchExpressions:  
 - key: machineconfiguration.openshift.io/role  
 operator: In  
 values:  
 - worker  
 nodeSelector:  
 matchLabels:  
 node-role.kubernetes.io/worker: ""  
  
## Taints to manage workloads effectively.  
apiVersion: v1  
kind: Node  
metadata:  
 name: node-1  
spec:  
 taints:  
 - key: app  
 value: high-performing  
 effect: NoSchedule

### 24.1.3 Network Configuration

Customize your Cilium CNI settings:

apiVersion: cilium.io/v2  
kind: CiliumNetworkConfig  
metadata:  
 name: cilium-config  
spec:  
 endpointRoutes: true  
 devices:  
 - eth0  
 autoDirectNodeRoutes: true  
  
## Policy for specific namespace isolation requirements  
apiVersion: cilium.io/v2  
kind: CiliumNetworkPolicy  
metadata:  
 name: namespace-isolation-policy  
 namespace: critical-apps  
spec:  
 endpointSelector:  
 matchLabels:  
 app: critical-environment  
 ingress:  
 fromEndpoints:  
 - matchLabels:  
 access: dedicated

### 24.1.4 Storage Configuration

Manage your storage setups efficiently:

apiVersion: storage.k8s.io/v1  
kind: StorageClass  
metadata:  
 name: performance-storage  
provisioner: ebs.csi.aws.com  
parameters:  
 type: io1  
 iopsPerGB: "50"  
 encrypted: "true"  
reclaimPolicy: Retain  
volumeBindingMode: WaitForFirstConsumer  
  
## PVC for critical workloads needing high IOPS  
apiVersion: v1  
kind: PersistentVolumeClaim  
metadata:  
 name: critical-workload-pvc  
spec:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 100Gi  
 storageClassName: performance-storage

### 24.1.5 Security Configuration

Strengthen the security of your deployment:

## Role-based access control  
apiVersion: rbac.authorization.k8s.io/v1  
kind: Role  
metadata:  
 namespace: secure-namespace  
 name: critical-role  
rules:  
- apiGroups:  
 - ""  
 resources:  
 - pods  
 - services  
 verbs:  
 - get  
 - list  
 - watch  
  
## Pod Security Policies  
apiVersion: policy/v1beta1  
kind: PodSecurityPolicy  
metadata:  
 name: restricted-psp  
spec:  
 privileged: false  
 allowPrivilegeEscalation: false  
 requiredDropCapabilities:  
 - ALL  
 volumes:  
 - 'configMap'  
 - 'emptyDir'  
 - 'persistentVolumeClaim'

### 24.1.6 Conclusion

By properly configuring these parameters, you can ensure that your RH OVE deployment is optimized for performance, security, and operational effectiveness. Adjust configurations based on specific organizational policies and workload demands.

# 25 Admission Control

## 25.1 Admission Control Strategy

### 25.1.1 Overview

The RH OVE solution implements a comprehensive admission control strategy that combines OpenShift’s built-in controllers with KubeVirt-specific webhooks and Kyverno policy engine for enhanced security and governance.

### 25.1.2 Architecture

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 A[API Request] --> B{Admission Control Pipeline}  
 B --> C[OpenShift Built-in Controllers]  
 B --> D[KubeVirt Webhooks]  
 B --> E[Kyverno Policy Engine]  
   
 C --> F[Mutating Admission]  
 D --> F  
 E --> F  
   
 F --> G[Validating Admission]  
 C --> G  
 D --> G  
 E --> G  
   
 G --> H[etcd Storage]  
 G --> I[Denied Request]

*Note: Diagram rendering failed, showing code instead.*

### 25.1.3 Default OpenShift Admission Controllers

RH OVE inherits all standard OpenShift admission controllers including:

* **LimitRanger**: Enforces resource limits and requests
* **ServiceAccount**: Manages service account tokens
* **PodNodeSelector**: Controls node placement
* **SecurityContextConstraint (SCC)**: Enforces security policies
* **ResourceQuota**: Manages namespace-level resource limits
* **MutatingAdmissionWebhook**: Allows custom mutation logic
* **ValidatingAdmissionWebhook**: Allows custom validation logic

### 25.1.4 KubeVirt-Specific Admission Webhooks

KubeVirt automatically registers webhooks for virtualization resources:

* **VirtualMachine validation**: Ensures VM configurations are valid
* **VirtualMachineInstance validation**: Validates running VM instances
* **DataVolume validation**: Verifies storage configurations
* **Migration validation**: Checks migration prerequisites

### 25.1.5 Kyverno Policy Engine Integration

#### 25.1.5.1 Installation

Deploy Kyverno via Helm or manifests:

apiVersion: v1  
kind: Namespace  
metadata:  
 name: kyverno  
---  
apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: kyverno  
 namespace: kyverno  
spec:  
 replicas: 1  
 selector:  
 matchLabels:  
 app: kyverno  
 template:  
 metadata:  
 labels:  
 app: kyverno  
 spec:  
 containers:  
 - name: kyverno  
 image: ghcr.io/kyverno/kyverno:latest

#### 25.1.5.2 VM-Specific Policies

##### 25.1.5.2.1 Resource Limits Policy

apiVersion: kyverno.io/v1  
kind: ClusterPolicy  
metadata:  
 name: vm-resource-limits  
spec:  
 validationFailureAction: enforce  
 background: true  
 rules:  
 - name: require-vm-resource-limits  
 match:  
 any:  
 - resources:  
 kinds:  
 - VirtualMachine  
 validate:  
 message: "VirtualMachine must have CPU and memory limits defined"  
 pattern:  
 spec:  
 template:  
 spec:  
 domain:  
 cpu:  
 cores: ">0"  
 memory:  
 guest: ">0"

##### 25.1.5.2.2 VM Security Policy

apiVersion: kyverno.io/v1  
kind: ClusterPolicy  
metadata:  
 name: vm-security-policy  
spec:  
 validationFailureAction: enforce  
 rules:  
 - name: disallow-privileged-vms  
 match:  
 any:  
 - resources:  
 kinds:  
 - VirtualMachine  
 validate:  
 message: "Privileged VMs are not allowed"  
 pattern:  
 spec:  
 template:  
 spec:  
 domain:  
 features:  
 smm:  
 enabled: "false"

##### 25.1.5.2.3 Namespace Isolation Policy

apiVersion: kyverno.io/v1  
kind: ClusterPolicy  
metadata:  
 name: vm-namespace-isolation  
spec:  
 validationFailureAction: enforce  
 rules:  
 - name: require-namespace-labels  
 match:  
 any:  
 - resources:  
 kinds:  
 - VirtualMachine  
 validate:  
 message: "VirtualMachines must be in properly labeled namespaces"  
 pattern:  
 metadata:  
 namespace: "!default"

#### 25.1.5.3 Multi-Tenant Policies

##### 25.1.5.3.1 Application-Based Namespace Policy

apiVersion: kyverno.io/v1  
kind: ClusterPolicy  
metadata:  
 name: application-namespace-policy  
spec:  
 validationFailureAction: enforce  
 rules:  
 - name: enforce-app-namespace-pattern  
 match:  
 any:  
 - resources:  
 kinds:  
 - VirtualMachine  
 - VirtualMachineInstance  
 validate:  
 message: "VMs must be deployed in application-specific namespaces"  
 pattern:  
 metadata:  
 namespace: "app-\*"

### 25.1.6 Policy Enforcement Flow

**[Mermaid Sequence Diagram - Rendering Failed]**

sequenceDiagram  
 participant User  
 participant API as OpenShift API  
 participant OSA as OpenShift Admission  
 participant KVA as KubeVirt Admission  
 participant KYV as Kyverno  
 participant etcd  
  
 User->>API: Create VirtualMachine  
 API->>OSA: Mutating Admission  
 OSA->>KVA: KubeVirt Mutations  
 KVA->>KYV: Kyverno Mutations  
 KYV->>OSA: Validating Admission  
 OSA->>KVA: KubeVirt Validation  
 KVA->>KYV: Kyverno Validation  
 KYV->>etcd: Store Resource  
 etcd->>User: Success Response

*Note: Diagram rendering failed, showing code instead.*

### 25.1.7 Best Practices

#### 25.1.7.1 Policy Development

1. **Start with monitoring mode**: Use validationFailureAction: audit initially
2. **Test thoroughly**: Validate policies in non-production environments
3. **Use exceptions sparingly**: Avoid broad policy exceptions
4. **Version control**: Store policies in Git repositories

#### 25.1.7.2 Performance Considerations

1. **Optimize policy matching**: Use specific resource selectors
2. **Minimize policy overlap**: Avoid redundant validation rules
3. **Monitor admission latency**: Track policy evaluation performance
4. **Use background processing**: Enable background validation where appropriate

#### 25.1.7.3 Monitoring and Troubleshooting

##### 25.1.7.3.1 Policy Violations Dashboard

Monitor policy violations using Prometheus metrics:

apiVersion: v1  
kind: ServiceMonitor  
metadata:  
 name: kyverno-metrics  
spec:  
 selector:  
 matchLabels:  
 app: kyverno  
 endpoints:  
 - port: metrics

##### 25.1.7.3.2 Common Troubleshooting

1. **Policy not applying**: Check policy syntax and matching criteria
2. **Performance issues**: Review policy complexity and scope
3. **Conflicts**: Examine interaction between different admission controllers
4. **Debugging**: Use kubectl describe to view admission controller events

### 25.1.8 Integration with GitOps

Store all policies in Git and deploy via Argo CD:

apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: kyverno-policies  
spec:  
 source:  
 repoURL: https://git.example.com/rh-ove-policies  
 path: policies/  
 targetRevision: main  
 destination:  
 server: https://kubernetes.default.svc  
 syncPolicy:  
 automated:  
 prune: true  
 selfHeal: true

This comprehensive admission control strategy ensures that all workloads, both containers and VMs, comply with organizational security and operational policies while maintaining the flexibility needed for modern application development.

# 26 GitOps Operations

## 26.1 GitOps Operations

### 26.1.1 Overview

This document outlines the GitOps approach for managing the multi-cluster RH OVE ecosystem, providing guidelines for implementing Infrastructure as Code (IaC) and application deployment through Git-based workflows across management and application clusters.

### 26.1.2 Multi-Cluster GitOps Principles

The RH OVE ecosystem implements GitOps across a hub-and-spoke architecture:

* **Centralized Control**: ArgoCD Hub manages deployments to multiple application clusters
* **Single Source of Truth**: All cluster and VM configurations stored in Git repositories
* **Declarative Management**: Infrastructure as Code for clusters, VMs, and containers
* **Multi-Environment Support**: Separate overlays for production, staging, and development clusters
* **Policy Distribution**: Centralized policy management with cluster-specific enforcement
* **Automated Rollbacks**: Complete change tracking and rollback capabilities across clusters

### 26.1.3 Multi-Cluster Architecture

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Git Repository"  
 A[Application Manifests]  
 B[VM Templates]  
 C[Infrastructure Config]  
 D[Policies]  
 end  
   
 subgraph "GitOps Engine"  
 E[Argo CD]  
 F[Application Controller]  
 G[Sync Engine]  
 end  
   
 subgraph "RH OVE Cluster"  
 H[Virtual Machines]  
 I[Container Workloads]  
 J[Storage Resources]  
 K[Network Policies]  
 end  
   
 A --> E  
 B --> E  
 C --> E  
 D --> E  
   
 E --> F  
 F --> G  
 G --> H  
 G --> I  
 G --> J  
 G --> K

*Note: Diagram rendering failed, showing code instead.*

### 26.1.4 Repository Structure

#### 26.1.4.1 Recommended Git Repository Layout

rh-ove-gitops/  
├── applications/  
│ ├── web-app/  
│ │ ├── base/  
│ │ │ ├── kustomization.yaml  
│ │ │ ├── deployment.yaml  
│ │ │ └── service.yaml  
│ │ └── overlays/  
│ │ ├── dev/  
│ │ ├── staging/  
│ │ └── prod/  
│ └── database-vm/  
│ ├── vm-definition.yaml  
│ ├── datavolume.yaml  
│ └── service.yaml  
├── infrastructure/  
│ ├── storage-classes/  
│ ├── network-policies/  
│ └── rbac/  
├── vm-templates/  
│ ├── rhel8-template.yaml  
│ ├── windows-template.yaml  
│ └── ubuntu-template.yaml  
└── policies/  
 ├── kyverno/  
 └── gatekeeper/

### 26.1.5 Argo CD Configuration

#### 26.1.5.1 Application Definition

apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: database-vm-app  
 namespace: argocd  
spec:  
 project: default  
 source:  
 repoURL: https://git.example.com/rh-ove-gitops  
 targetRevision: main  
 path: applications/database-vm  
 destination:  
 server: https://kubernetes.default.svc  
 namespace: app-database-prod  
 syncPolicy:  
 automated:  
 prune: true  
 selfHeal: true  
 syncOptions:  
 - CreateNamespace=true

#### 26.1.5.2 AppProject for VM Workloads

apiVersion: argoproj.io/v1alpha1  
kind: AppProject  
metadata:  
 name: vm-workloads  
 namespace: argocd  
spec:  
 description: Project for VM-based applications  
 sourceRepos:  
 - https://git.example.com/rh-ove-gitops  
 destinations:  
 - namespace: 'app-\*'  
 server: https://kubernetes.default.svc  
 clusterResourceWhitelist:  
 - group: ''  
 kind: Namespace  
 - group: 'kubevirt.io'  
 kind: VirtualMachine  
 - group: 'cdi.kubevirt.io'  
 kind: DataVolume  
 namespaceResourceWhitelist:  
 - group: ''  
 kind: Service  
 - group: ''  
 kind: ConfigMap  
 - group: ''  
 kind: Secret

### 26.1.6 VM Management through GitOps

#### 26.1.6.1 Virtual Machine Definition

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: web-server-vm  
 namespace: app-web-prod  
 labels:  
 app: web-server  
 managed-by: argocd  
spec:  
 running: true  
 template:  
 metadata:  
 labels:  
 app: web-server  
 version: v1.2.0  
 spec:  
 domain:  
 cpu:  
 cores: 2  
 memory:  
 guest: 4Gi  
 devices:  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 - name: datadisk  
 disk:  
 bus: virtio  
 interfaces:  
 - name: default  
 masquerade: {}  
 networks:  
 - name: default  
 pod: {}  
 volumes:  
 - name: rootdisk  
 dataVolume:  
 name: web-server-root  
 - name: datadisk  
 dataVolume:  
 name: web-server-data

#### 26.1.6.2 DataVolume Configuration

apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: web-server-root  
 namespace: app-web-prod  
spec:  
 pvc:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 30Gi  
 storageClassName: fast-ssd  
 source:  
 registry:  
 url: "docker://registry.redhat.io/rhel8/rhel:latest"  
---  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: web-server-data  
 namespace: app-web-prod  
spec:  
 pvc:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 100Gi  
 storageClassName: standard-hdd  
 source:  
 blank: {}

### 26.1.7 Multi-Environment Management

#### 26.1.7.1 Environment-Specific Overlays

## overlays/prod/kustomization.yaml  
apiVersion: kustomize.config.k8s.io/v1beta1  
kind: Kustomization  
  
resources:  
- ../../base  
  
patchesStrategicMerge:  
- vm-resources.yaml  
- storage-config.yaml  
  
patches:  
- target:  
 kind: VirtualMachine  
 name: web-server-vm  
 patch: |-  
 - op: replace  
 path: /spec/template/spec/domain/cpu/cores  
 value: 4  
 - op: replace  
 path: /spec/template/spec/domain/memory/guest  
 value: 8Gi

#### 26.1.7.2 Environment Promotion Workflow

**[Mermaid Sequence Diagram - Rendering Failed]**

sequenceDiagram  
 participant Dev as Developer  
 participant Git as Git Repository  
 participant ArgoCD as Argo CD  
 participant DevCluster as Dev Cluster  
 participant ProdCluster as Prod Cluster  
  
 Dev->>Git: Push changes to dev branch  
 Git->>ArgoCD: Webhook triggers sync  
 ArgoCD->>DevCluster: Deploy to dev environment  
 Dev->>Git: Create PR to main branch  
 Git->>ArgoCD: Merge triggers prod sync  
 ArgoCD->>ProdCluster: Deploy to production

*Note: Diagram rendering failed, showing code instead.*

### 26.1.8 CI/CD Integration

#### 26.1.8.1 GitLab CI Pipeline

## .gitlab-ci.yml  
stages:  
 - validate  
 - test  
 - deploy  
  
validate-manifests:  
 stage: validate  
 script:  
 - kubeval manifests/\*.yaml  
 - kustomize build overlays/dev | kubeval  
  
vm-integration-test:  
 stage: test  
 script:  
 - kubectl apply --dry-run=client -f vm-definitions/  
 - virtctl validate vm-definitions/  
  
deploy-to-dev:  
 stage: deploy  
 script:  
 - argocd app sync dev-environment  
 only:  
 - develop  
  
deploy-to-prod:  
 stage: deploy  
 script:  
 - argocd app sync prod-environment  
 only:  
 - main

### 26.1.9 Security and Compliance

#### 26.1.9.1 Policy as Code

## policies/kyverno/vm-security-policy.yaml  
apiVersion: kyverno.io/v1  
kind: ClusterPolicy  
metadata:  
 name: vm-security-standards  
spec:  
 validationFailureAction: enforce  
 background: true  
 rules:  
 - name: require-vm-labels  
 match:  
 any:  
 - resources:  
 kinds:  
 - VirtualMachine  
 validate:  
 message: "VMs must have required labels"  
 pattern:  
 metadata:  
 labels:  
 app: "?\*"  
 version: "?\*"  
 managed-by: "argocd"

#### 26.1.9.2 RBAC for GitOps

apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRole  
metadata:  
 name: argocd-application-controller  
rules:  
- apiGroups:  
 - ""  
 resources:  
 - "\*"  
 verbs:  
 - "\*"  
- apiGroups:  
 - "kubevirt.io"  
 resources:  
 - "\*"  
 verbs:  
 - "\*"  
- apiGroups:  
 - "cdi.kubevirt.io"  
 resources:  
 - "\*"  
 verbs:  
 - "\*"

### 26.1.10 Monitoring and Observability

#### 26.1.10.1 GitOps Metrics

Key metrics to monitor: - Sync success rate - Deployment frequency - Mean time to recovery - Application health status

#### 26.1.10.2 Dashboard Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: argocd-cm  
data:  
 url: https://argocd.example.com  
 statusbadge.enabled: "true"  
 application.instanceLabelKey: argocd.argoproj.io/instance

### 26.1.11 Disaster Recovery

#### 26.1.11.1 Backup Strategy

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: backup-config  
data:  
 backup-strategy.yaml: |  
 applications:  
 - name: critical-vms  
 backup\_frequency: "daily"  
 retention: "30d"  
 git\_ref: "backup/$(date +%Y%m%d)"  
   
 infrastructure:  
 - name: cluster-config  
 backup\_frequency: "weekly"  
 retention: "12w"

#### 26.1.11.2 Recovery Procedures

1. **Application Recovery**

* # Restore from specific commit  
  argocd app set myapp --revision abc123  
  argocd app sync myapp

1. **Full Environment Recovery**

* # Deploy entire environment from Git  
  argocd app create disaster-recovery \  
   --repo https://git.example.com/rh-ove-gitops \  
   --path recovery/full-environment \  
   --dest-server https://kubernetes.default.svc

### 26.1.12 Best Practices

#### 26.1.12.1 Development Workflow

1. **Feature branches**: Use feature branches for new VM deployments
2. **Pull requests**: Require peer review for all changes
3. **Automated testing**: Validate manifests before merge
4. **Progressive deployment**: Use staging environments before production

#### 26.1.12.2 Operational Guidelines

1. **Secrets management**: Use external secret management (e.g., Vault)
2. **Resource limits**: Define appropriate CPU/memory limits for VMs
3. **Monitoring**: Implement comprehensive monitoring for all deployments
4. **Documentation**: Keep README files updated in each application directory

This GitOps approach ensures consistent, auditable, and automated management of VM and container workloads in the RH OVE environment.

# 27 Monitoring

## 27.1 Monitoring and Observability

### 27.1.1 Overview

This document provides comprehensive monitoring and observability strategies for the RH OVE ecosystem, covering infrastructure, virtual machines, containers, and application performance monitoring using Dynatrace and other monitoring tools.

### 27.1.2 Monitoring Architecture

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Data Sources"  
 A[Virtual Machines]  
 B[Container Workloads]  
 C[OpenShift Platform]  
 D[Cilium Network]  
 E[Storage Systems]  
 end  
   
 subgraph "Collection Layer"  
 F[Dynatrace OneAgent]  
 G[Prometheus]  
 H[Node Exporter]  
 I[Hubble]  
 J[QEMU Guest Agent]  
 end  
   
 subgraph "Processing & Storage"  
 K[Dynatrace Platform]  
 L[Prometheus Server]  
 M[Alert Manager]  
 end  
   
 subgraph "Visualization & Alerting"  
 N[Dynatrace Dashboard]  
 O[Grafana]  
 P[OpenShift Console]  
 Q[Alert Notifications]  
 end  
   
 A --> F  
 A --> J  
 B --> F  
 C --> G  
 C --> H  
 D --> I  
 E --> G  
   
 F --> K  
 G --> L  
 H --> L  
 I --> L  
 J --> G  
   
 K --> N  
 L --> O  
 L --> M  
 M --> Q  
 N --> Q

*Note: Diagram rendering failed, showing code instead.*

### 27.1.3 Dynatrace Integration

Based on our research, integrating RH OVE monitoring stack with Dynatrace provides comprehensive visibility for VMs and Kubernetes workloads.

#### 27.1.3.1 Dynatrace Operator Installation

apiVersion: dynatrace.com/v1beta1  
kind: DynaKube  
metadata:  
 name: dynakube  
 namespace: dynatrace  
spec:  
 apiUrl: https://your-environment-id.live.dynatrace.com/api  
 oneAgent:  
 classicFullStack:  
 tolerations:  
 - key: node-role.kubernetes.io/master  
 operator: Exists  
 effect: NoSchedule  
 resources:  
 requests:  
 cpu: 100m  
 memory: 512Mi  
 limits:  
 cpu: 300m  
 memory: 1Gi  
 activeGate:  
 capabilities:  
 - kubernetes-monitoring  
 - routing  
 resources:  
 requests:  
 cpu: 150m  
 memory: 512Mi  
 limits:  
 cpu: 500m  
 memory: 1Gi

#### 27.1.3.2 VM-Specific Monitoring Configuration

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: monitored-vm  
 namespace: app-prod  
 annotations:  
 dynatrace.com/inject: "true"  
 dynatrace.com/vm-monitoring: "enabled"  
spec:  
 template:  
 metadata:  
 labels:  
 app: web-server  
 monitoring: enabled  
 spec:  
 domain:  
 devices:  
 interfaces:  
 - name: default  
 masquerade: {}  
 resources:  
 requests:  
 memory: 4Gi  
 cpu: 2  
 volumes:  
 - name: qemu-guest-agent  
 serviceAccount:  
 serviceAccountName: qemu-guest-agent

### 27.1.4 Prometheus Configuration

#### 27.1.4.1 ServiceMonitor for VM Metrics

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: vm-metrics  
 namespace: monitoring  
spec:  
 selector:  
 matchLabels:  
 app: kubevirt-prometheus-metrics  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics

#### 27.1.4.2 Custom Metrics for VMs

apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: vm-monitoring-rules  
 namespace: monitoring  
spec:  
 groups:  
 - name: vm.rules  
 rules:  
 - alert: VMHighCPUUsage  
 expr: kubevirt\_vm\_cpu\_usage\_percentage > 80  
 for: 5m  
 labels:  
 severity: warning  
 annotations:  
 summary: "VM {{ $labels.name }} has high CPU usage"  
 description: "VM {{ $labels.name }} in namespace {{ $labels.namespace }} has CPU usage above 80% for more than 5 minutes."  
   
 - alert: VMHighMemoryUsage  
 expr: kubevirt\_vm\_memory\_usage\_percentage > 85  
 for: 5m  
 labels:  
 severity: warning  
 annotations:  
 summary: "VM {{ $labels.name }} has high memory usage"  
 description: "VM {{ $labels.name }} in namespace {{ $labels.namespace }} has memory usage above 85% for more than 5 minutes."

### 27.1.5 Network Monitoring with Hubble

#### 27.1.5.1 Hubble Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cilium-config  
 namespace: kube-system  
data:  
 enable-hubble: "true"  
 hubble-listen-address: ":4244"  
 hubble-metrics-server: ":9091"  
 hubble-metrics: |  
 dns:query;ignoreAAAA  
 drop  
 tcp  
 flow  
 icmp  
 http

#### 27.1.5.2 Network Flow Monitoring

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: hubble-metrics  
spec:  
 selector:  
 matchLabels:  
 k8s-app: hubble  
 endpoints:  
 - port: hubble-metrics  
 interval: 30s

### 27.1.6 Storage Monitoring

#### 27.1.6.1 CDI and Storage Metrics

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: cdi-controller-metrics  
spec:  
 selector:  
 matchLabels:  
 app: cdi-controller  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics

#### 27.1.6.2 Storage Performance Alerts

apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: storage-monitoring-rules  
spec:  
 groups:  
 - name: storage.rules  
 rules:  
 - alert: HighStorageLatency  
 expr: kubelet\_volume\_stats\_available\_bytes / kubelet\_volume\_stats\_capacity\_bytes < 0.1  
 for: 5m  
 labels:  
 severity: critical  
 annotations:  
 summary: "Storage volume {{ $labels.persistentvolumeclaim }} is running out of space"  
   
 - alert: DataVolumeImportFailed  
 expr: increase(cdi\_import\_progress\_total{phase="Failed"}[5m]) > 0  
 labels:  
 severity: warning  
 annotations:  
 summary: "DataVolume import failed"

### 27.1.7 Application Performance Monitoring

#### 27.1.7.1 Guest Agent Installation

For enhanced VM monitoring, install QEMU Guest Agent:

## Inside RHEL/CentOS VM  
sudo yum install qemu-guest-agent  
sudo systemctl enable qemu-guest-agent  
sudo systemctl start qemu-guest-agent  
  
## Inside Ubuntu VM  
sudo apt-get install qemu-guest-agent  
sudo systemctl enable qemu-guest-agent  
sudo systemctl start qemu-guest-agent  
  
## Inside Windows VM  
## Download and install virtio-win guest tools

#### 27.1.7.2 Node Exporter for VM Guests

apiVersion: apps/v1  
kind: DaemonSet  
metadata:  
 name: node-exporter-vm  
spec:  
 selector:  
 matchLabels:  
 app: node-exporter-vm  
 template:  
 metadata:  
 labels:  
 app: node-exporter-vm  
 spec:  
 containers:  
 - name: node-exporter  
 image: prom/node-exporter:latest  
 ports:  
 - containerPort: 9100  
 volumeMounts:  
 - name: proc  
 mountPath: /host/proc  
 readOnly: true  
 - name: sys  
 mountPath: /host/sys  
 readOnly: true  
 volumes:  
 - name: proc  
 hostPath:  
 path: /proc  
 - name: sys  
 hostPath:  
 path: /sys

### 27.1.8 Dashboard Configuration

#### 27.1.8.1 Grafana Dashboard for VMs

{  
 "dashboard": {  
 "title": "RH OVE Virtual Machine Monitoring",  
 "panels": [  
 {  
 "title": "VM CPU Usage",  
 "type": "graph",  
 "targets": [  
 {  
 "expr": "kubevirt\_vm\_cpu\_usage\_percentage",  
 "legendFormat": "{{name}}"  
 }  
 ]  
 },  
 {  
 "title": "VM Memory Usage",  
 "type": "graph",  
 "targets": [  
 {  
 "expr": "kubevirt\_vm\_memory\_usage\_percentage",  
 "legendFormat": "{{name}}"  
 }  
 ]  
 },  
 {  
 "title": "VM Network I/O",  
 "type": "graph",  
 "targets": [  
 {  
 "expr": "rate(kubevirt\_vm\_network\_receive\_bytes\_total[5m])",  
 "legendFormat": "{{name}} - RX"  
 },  
 {  
 "expr": "rate(kubevirt\_vm\_network\_transmit\_bytes\_total[5m])",  
 "legendFormat": "{{name}} - TX"  
 }  
 ]  
 }  
 ]  
 }  
}

#### 27.1.8.2 Dynatrace Dashboard Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: dynatrace-dashboard-config  
data:  
 vm-overview.json: |  
 {  
 "dashboardMetadata": {  
 "name": "RH OVE VM Overview",  
 "shared": true,  
 "tags": ["rh-ove", "virtualization"]  
 },  
 "tiles": [  
 {  
 "name": "VM Performance",  
 "tileType": "CUSTOM\_CHARTING",  
 "configured": true,  
 "queries": [  
 {  
 "metric": "builtin:host.cpu.usage",  
 "aggregation": {  
 "type": "AVG"  
 },  
 "filterBy": {  
 "neType": "HOST",  
 "tags": ["vm:kubevirt"]  
 }  
 }  
 ]  
 }  
 ]  
 }

### 27.1.9 Alerting Strategy

#### 27.1.9.1 Alert Routing Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: alertmanager-config  
data:  
 alertmanager.yml: |  
 global:  
 smtp\_smarthost: 'smtp.example.com:587'  
 smtp\_from: 'alerts@example.com'  
   
 route:  
 group\_by: ['alertname', 'cluster', 'service']  
 group\_wait: 10s  
 group\_interval: 10s  
 repeat\_interval: 1h  
 receiver: 'web.hook'  
 routes:  
 - match:  
 severity: critical  
 receiver: 'critical-alerts'  
 - match:  
 service: vm  
 receiver: 'vm-alerts'  
   
 receivers:  
 - name: 'web.hook'  
 webhook\_configs:  
 - url: 'http://webhook.example.com/alerts'  
   
 - name: 'critical-alerts'  
 email\_configs:  
 - to: 'oncall@example.com'  
 subject: 'CRITICAL: {{ .GroupLabels.alertname }}'  
 body: |  
 {{ range .Alerts }}  
 Alert: {{ .Annotations.summary }}  
 Description: {{ .Annotations.description }}  
 {{ end }}  
   
 - name: 'vm-alerts'  
 slack\_configs:  
 - api\_url: 'https://hooks.slack.com/services/...'  
 channel: '#vm-alerts'  
 title: 'VM Alert: {{ .GroupLabels.alertname }}'

### 27.1.10 Logging Strategy

#### 27.1.10.1 Centralized Logging for VMs

apiVersion: logging.coreos.com/v1  
kind: ClusterLogForwarder  
metadata:  
 name: vm-logs  
 namespace: openshift-logging  
spec:  
 outputs:  
 - name: vm-logs-output  
 type: elasticsearch  
 url: https://elasticsearch.example.com:9200  
 elasticsearch:  
 index: vm-logs-{.log\_type}-{.@timestamp.YYYY.MM.dd}  
 pipelines:  
 - name: vm-logs-pipeline  
 inputRefs:  
 - application  
 filterRefs:  
 - vm-log-filter  
 outputRefs:  
 - vm-logs-output

### 27.1.11 Performance Optimization

#### 27.1.11.1 Monitoring Resource Optimization

apiVersion: v1  
kind: ResourceQuota  
metadata:  
 name: monitoring-quota  
 namespace: monitoring  
spec:  
 hard:  
 requests.cpu: "2"  
 requests.memory: 4Gi  
 limits.cpu: "4"  
 limits.memory: 8Gi  
 persistentvolumeclaims: "5"

#### 27.1.11.2 Metrics Retention Policy

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: prometheus-config  
data:  
 prometheus.yml: |  
 global:  
 scrape\_interval: 30s  
 evaluation\_interval: 30s  
 external\_labels:  
 cluster: 'rh-ove-cluster'  
   
 rule\_files:  
 - "vm-monitoring-rules.yml"  
   
 scrape\_configs:  
 - job\_name: 'kubevirt-vms'  
 kubernetes\_sd\_configs:  
 - role: pod  
 relabel\_configs:  
 - source\_labels: [\_\_meta\_kubernetes\_pod\_label\_kubevirt\_io]  
 target\_label: vm\_name

### 27.1.12 Troubleshooting Monitoring

#### 27.1.12.1 Common Issues and Solutions

1. **OneAgent not reporting VM data**

* # Check OneAgent status  
  oc get pods -n dynatrace  
  oc describe pod dynatrace-oneagent-xxx  
    
  # Verify VM annotations  
  oc get vm -o yaml | grep -A5 annotations

1. **Missing VM metrics in Prometheus**

* # Check ServiceMonitor configuration  
  oc get servicemonitor -n monitoring  
    
  # Verify metrics endpoint  
  oc port-forward svc/kubevirt-prometheus-metrics 8080:8080  
  curl localhost:8080/metrics

1. **Network flow data not appearing**

* # Check Hubble status  
  cilium status  
  hubble status  
    
  # Verify Hubble configuration  
  oc get configmap cilium-config -n kube-system -o yaml

This comprehensive monitoring strategy ensures full visibility into the RH OVE ecosystem, covering infrastructure, virtual machines, containers, and application performance.

# 28 Backup & Recovery

## 28.1 Backup & Recovery

### 28.1.1 Overview

This document outlines the backup and recovery strategies for the RH OVE ecosystem. It highlights the integration with Rubrik, detailing how to efficiently back up and restore both VM and container data.

### 28.1.2 Backup Strategy

#### 28.1.2.1 Rubrik Integration

Utilize Rubrik’s capabilities to ensure robust data protection:

* **Certified Integration**: Rubrik is certified for RH OVE, providing seamless data protection.
* **Immutable Backups**: Ensure data safety with air-gapped, tamper-proof backups.
* **Policy-Driven**: Simplify backup management with declarative policies for VM workloads.

#### 28.1.2.2 Backup Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: rubrik-backup-config  
 namespace: rubrik-system  
data:  
 backupPolicy.yaml: |  
 policies:  
 - name: daily-VM-backup  
 frequency: daily  
 retention: 30d  
 exclude: 'temp-volumes'  
  
 schedules:  
 - name: nightly-backup  
 time: '02:00'  
 days:  
 - Monday  
 - Wednesday  
 - Friday

#### 28.1.2.3 Data Volume Backup

Backup specific DataVolumes using Rubrik advanced features:

apiVersion: rubrik.com/v1  
kind: DataProtectionPolicy  
metadata:  
 name: data-volume-backup  
spec:  
 dataprotection:  
 enable: true  
 rubrikCluster:  
 name: rubrik-cluster1  
 snapshot:  
 schedule: nightly  
 retention: 31  
datavolume:  
 selector:  
 matchLabels:  
 app: production

### 28.1.3 Recovery Strategy

#### 28.1.3.1 Rubrik Recovery

Rubrik’s high-speed recovery ensures minimal downtime for critical workloads:

1. **Instant Restore**: Quickly recover VMs from snapshots directly on RH OVE.
2. **File-Level Restore**: Execute rapid recovery at the file level for broad access needs.
3. **Automated Recovery Paths**: Simplify recovery workflows through automation.

#### 28.1.3.2 Recovery Plan

Define a detailed recovery plan to access Rubrik’s capability.

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: recovery-plan  
 namespace: recovery  
spec:  
 paths:  
 critical-apps:  
 - name: app1  
 vm: app1-vm  
 backup: latest  
 action: restore  
 - name: app2  
 vm: app2-vm  
 backup: nightly  
 action: restore  
 hooks:  
 preRestore:  
 - /scripts/pre-restore.sh  
 postRestore:  
 - /scripts/post-restore.sh

### 28.1.4 Testing and Validation

#### 28.1.4.1 Backup Verification

Regularly test backups to ensure integrity and reliability:

* **Backup Verification Schedules**: Conduct routine checks on backup snapshots for quality assurance.
* **Periodic Restore Drills**: Simulate restore scenarios to assess recovery time objectives.

#### 28.1.4.2 Recovery Assurance

Ensure recovery processes are validated and documented:

* **Recovery Testing**: Periodically execute recovery processes within a non-production environment.
* **Documentation**: Maintain up-to-date recovery documentation with steps, tools, and responsible parties.

### 28.1.5 Monitoring and Alerts

Utilize monitoring tools to track backup and restore activities:

* **Alerting Policies**: Implement alerts for failed backups, missed schedules, or data integrity issues.
* **Monitoring Dashboards**: Use dashboards to visualize backup/recovery activities and efficiency metrics.

### 28.1.6 Conclusion

By following these backup and recovery strategies, organizations can ensure the safety, integrity, and availability of their critical data within the RH OVE ecosystem. Taking advantage of Rubrik’s robust integration further enhances data resilience, minimizing risks associated with data loss.

# 29 Day-2 Operations

## 29.1 Day-2 Operations

### 29.1.1 Overview

This document covers day-2 operational activities essential for maintaining the multi-cluster RH OVE ecosystem. It includes guidelines for managing the management cluster and multiple application clusters, covering ongoing maintenance, upgrades, performance tuning, and operational tasks across the entire fleet.

### 29.1.2 Maintenance Tasks

#### 29.1.2.1 Regular Cluster Health Checks

* **Node Status Monitoring**: Regularly check node health and availability.
* oc get nodes -o wide
* **Resource Usage Monitoring**: Monitor CPU, memory, and storage utilization.
* oc adm top nodes  
  oc adm top pods --all-namespaces

#### 29.1.2.2 Backup Management

* **Review Backup Logs**: Ensure completion and verify logs for any anomalies.
* oc logs -n rubrik rubrik-agent-
* **Data Integrity Checks**: Periodically verify backup integrity and accessibility.

### 29.1.3 Upgrades

#### 29.1.3.1 OpenShift Cluster Upgrades

* **Plan Your Upgrade**: Evaluate impact, and schedule during maintenance windows.
  + Review [OpenShift Upgrade Guide](https://docs.openshift.com/upgrade/)
* **In-place Upgrades**: Use OpenShift’s upgrade capabilities to update cluster components.
* oc adm upgrade

#### 29.1.3.2 Component Upgrades

* **Operator Lifecycle Management (OLM)**: Upgrade operators using OLM.
* oc get clusterserviceversions -n openshift-operators
* **KubeVirt Upgrades**: Follow the KubeVirt upgrade process for virtualization components.
  + Refer to [KubeVirt Upgrade Guide](https://kubevirt.io/upgrade-guide/)

### 29.1.4 Performance Tuning

#### 29.1.4.1 Resource Balancing

* **Node Selector and Affinity Rules**: Ensure workloads are distributed evenly.
* apiVersion: v1  
  kind: Pod  
  metadata:  
   name: example-pod  
  spec:  
   affinity:  
   nodeAffinity:  
   requiredDuringSchedulingIgnoredDuringExecution:  
   nodeSelectorTerms:  
   - matchExpressions:  
   - key: disktype  
   operator: In  
   values:  
   - ssd
* **Vertical and Horizontal Scaling**: Utilize HPA and VPA for scaling applications.

#### 29.1.4.2 Network Optimization

* **Cilium Policy Management**: Optimize and tune Cilium network policies for performance.
* apiVersion: cilium.io/v2  
  kind: CiliumNetworkPolicy  
  metadata:  
   name: optimized-policy  
  spec:  
   endpointSelector:  
   matchLabels:  
   app: myapp  
   ingress:  
   - fromEndpoints:  
   - matchLabels:  
   app: trusted

### 29.1.5 Security and Compliance

#### 29.1.5.1 Regular Security Audits

* **Policy Compliance**: Ensure adherence to Kyverno policies and security standards.
* kubectl get cpol -o yaml
* **Vulnerability Scans**: Run regular vulnerability assessments on container images and hosts.

### 29.1.6 Documentation and Reporting

#### 29.1.6.1 Keeping Documentation Up-to-Date

* **Change Logs**: Maintain a changelog for all configurations and updates.
* **Operational Runbooks**: Create and update runbooks for standard operations.

#### 29.1.6.2 Performance and Utilization Reports

* **Utilize Metrics Dashboards**: Use Grafana and Prometheus to generate reports.

### 29.1.7 Conclusion

Following these day-2 operation guidelines helps maintain a stable, secure, and efficient RH OVE environment. Regular monitoring, updates, optimizations, and documentation ensure long-term success and reliability of the platform.

# 30 Troubleshooting

## 30.1 Troubleshooting Guide

### 30.1.1 Overview

This comprehensive troubleshooting guide addresses common issues in the RH OVE ecosystem, providing systematic approaches to diagnose and resolve problems across virtualization, networking, storage, and monitoring components.

### 30.1.2 General Troubleshooting Approach

#### 30.1.2.1 Diagnostic Flow

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 A[Issue Identified] --> B[Gather Information]  
 B --> C[Check Logs]  
 C --> D[Verify Configuration]  
 D --> E[Test Components]  
 E --> F{Issue Resolved?}  
 F -->|No| G[Escalate/Deep Dive]  
 F -->|Yes| H[Document Solution]  
 G --> I[Advanced Diagnostics]  
 I --> J[Vendor Support]

*Note: Diagram rendering failed, showing code instead.*

#### 30.1.2.2 Essential Commands

## Cluster overview  
oc get nodes  
oc get pods --all-namespaces  
oc get events --all-namespaces --sort-by='.lastTimestamp'  
  
## Resource utilization  
oc adm top nodes  
oc adm top pods --all-namespaces  
  
## Detailed investigation  
oc describe node <node-name>  
oc logs -f <pod-name> -n <namespace>

### 30.1.3 Virtual Machine Issues

#### 30.1.3.1 VM Won’t Start

##### 30.1.3.1.1 Symptoms

* VM remains in “Pending” or “Scheduling” state
* VM fails to boot or crashes during startup

##### 30.1.3.1.2 Troubleshooting Steps

1. **Check VM Definition**

* oc get vm <vm-name> -o yaml  
  oc describe vm <vm-name>

1. **Verify Node Resources**

* oc describe nodes  
  oc adm top nodes

1. **Check DataVolume Status**

* oc get datavolume  
  oc describe datavolume <dv-name>

1. **Review Events**

* oc get events --field-selector involvedObject.name=<vm-name>

##### 30.1.3.1.3 Common Solutions

* **Insufficient Resources**: Scale cluster or adjust VM specs
* **DataVolume Issues**: Check CDI logs and storage classes
* **Node Affinity**: Verify node selector and affinity rules

#### 30.1.3.2 VM Performance Issues

##### 30.1.3.2.1 Symptoms

* Slow VM performance
* High CPU/memory usage
* Network latency

##### 30.1.3.2.2 Troubleshooting Steps

1. **Check VM Resource Allocation**

* oc get vm <vm-name> -o jsonpath='{.spec.template.spec.domain.resources}'

1. **Monitor VM Metrics**

* # Use virtctl to access VM console  
  virtctl console <vm-name>  
    
  # Check VM performance inside guest  
  top  
  iostat  
  iftop

1. **Verify Host Resources**

* oc adm top node <node-name>  
  oc describe node <node-name>

##### 30.1.3.2.3 Solutions

* Adjust VM CPU/memory allocation
* Enable CPU pinning for critical VMs
* Check storage performance and IOPS limits

### 30.1.4 Networking Issues

#### 30.1.4.1 Cilium Network Problems

##### 30.1.4.1.1 Symptoms

* Pods cannot communicate
* Network policies not working
* DNS resolution failures

##### 30.1.4.1.2 Troubleshooting Steps

1. **Check Cilium Status**

* cilium status  
  cilium connectivity test

1. **Verify Network Policies**

* oc get cnp  
  oc describe cnp <policy-name>

1. **Monitor Network Flows**

* hubble observe --pod <pod-name>  
  hubble observe --verdict DENIED

##### 30.1.4.1.3 Common Solutions

## Debug network connectivity  
apiVersion: v1  
kind: Pod  
metadata:  
 name: network-debug  
spec:  
 containers:  
 - name: debug  
 image: nicolaka/netshoot  
 command: ['sleep', '3600']

#### 30.1.4.2 VM Network Connectivity

##### 30.1.4.2.1 Symptoms

* VM cannot reach external networks
* Inter-VM communication failures
* Service discovery issues

##### 30.1.4.2.2 Troubleshooting Steps

1. **Check VM Network Configuration**

* oc get vm <vm-name> -o yaml | grep -A 10 networks

1. **Verify Service Configuration**

* oc get svc  
  oc describe svc <service-name>

1. **Test Connectivity from VM**

* virtctl console <vm-name>  
  # Inside VM:  
  ping <target-ip>  
  nslookup <service-name>

### 30.1.5 Storage Issues

#### 30.1.5.1 DataVolume Problems

##### 30.1.5.1.1 Symptoms

* DataVolume stuck in “Pending” state
* Import/clone operations failing
* Storage quota exceeded

##### 30.1.5.1.2 Troubleshooting Steps

1. **Check DataVolume Status**

* oc get datavolume  
  oc describe datavolume <dv-name>

1. **Review CDI Logs**

* oc logs -n cdi deployment/cdi-controller  
  oc logs -n cdi deployment/cdi-operator

1. **Verify Storage Classes**

* oc get storageclass  
  oc describe storageclass <sc-name>

##### 30.1.5.1.3 Solutions

## Debug DataVolume with verbose logging  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: debug-dv  
 annotations:  
 cdi.kubevirt.io/debug: "true"  
spec:  
 pvc:  
 accessModes: [ReadWriteOnce]  
 resources:  
 requests:  
 storage: 10Gi  
 source:  
 blank: {}

#### 30.1.5.2 Storage Performance Issues

##### 30.1.5.2.1 Symptoms

* Slow disk I/O
* High storage latency
* VM disk full errors

##### 30.1.5.2.2 Troubleshooting Steps

1. **Check Storage Metrics**

* # Prometheus queries  
  kubectl port-forward -n monitoring svc/prometheus 9090:9090  
  # Query: kubelet\_volume\_stats\_used\_bytes

1. **Verify PVC Usage**

* oc get pvc  
  oc describe pvc <pvc-name>

1. **Monitor Storage Node Performance**

* oc adm top nodes  
  iostat -x 1

### 30.1.6 Monitoring Issues

#### 30.1.6.1 Dynatrace Agent Problems

##### 30.1.6.1.1 Symptoms

* Missing VM metrics in Dynatrace
* OneAgent not reporting data
* High resource usage by monitoring

##### 30.1.6.1.2 Troubleshooting Steps

1. **Check OneAgent Status**

* oc get pods -n dynatrace  
  oc describe pod <oneagent-pod>

1. **Verify VM Annotations**

* oc get vm -o yaml | grep -A5 annotations

1. **Review Dynatrace Logs**

* oc logs -n dynatrace <oneagent-pod>

#### 30.1.6.2 Prometheus Metrics Missing

##### 30.1.6.2.1 Symptoms

* Missing metrics in Grafana
* ServiceMonitor not working
* Prometheus targets down

##### 30.1.6.2.2 Troubleshooting Steps

1. **Check ServiceMonitor Configuration**

* oc get servicemonitor  
  oc describe servicemonitor <sm-name>

1. **Verify Metrics Endpoints**

* oc port-forward svc/<service-name> 8080:8080  
  curl localhost:8080/metrics

1. **Check Prometheus Targets**

* # Access Prometheus UI  
  oc port-forward -n monitoring svc/prometheus 9090:9090  
  # Go to Status -> Targets

### 30.1.7 GitOps and Argo CD Issues

#### 30.1.7.1 Application Sync Failures

##### 30.1.7.1.1 Symptoms

* Applications stuck in “OutOfSync” state
* Sync operations failing
* Resource conflicts

##### 30.1.7.1.2 Troubleshooting Steps

1. **Check Application Status**

* argocd app get <app-name>  
  argocd app logs <app-name>

1. **Verify Git Repository Access**

* argocd repo list  
  argocd repo get <repo-url>

1. **Review Resource Conflicts**

* oc get <resource-type> <resource-name> -o yaml

##### 30.1.7.1.3 Solutions

## Force refresh and sync  
argocd app refresh <app-name>  
argocd app sync <app-name> --force  
  
## Reset application state  
argocd app actions run <app-name> restart --kind Deployment

### 30.1.8 Performance Issues

#### 30.1.8.1 Cluster Resource Exhaustion

##### 30.1.8.1.1 Symptoms

* High CPU/memory usage
* Pod evictions
* Slow response times

##### 30.1.8.1.2 Troubleshooting Steps

1. **Identify Resource Consumers**

* oc adm top pods --all-namespaces --sort-by=cpu  
  oc adm top pods --all-namespaces --sort-by=memory

1. **Check Node Capacity**

* oc describe nodes | grep -A5 "Allocated resources"

1. **Review Resource Quotas**

* oc get resourcequota --all-namespaces  
  oc describe resourcequota <quota-name>

#### 30.1.8.2 VM Live Migration Issues

##### 30.1.8.2.1 Symptoms

* Migration fails or takes too long
* VM downtime during migration
* Network connectivity loss

##### 30.1.8.2.2 Troubleshooting Steps

1. **Check Migration Status**

* oc get vmi  
  oc describe virtualmachinmigration <migration-name>

1. **Verify Node Compatibility**

* oc get nodes -o wide  
  oc describe node <target-node>

1. **Monitor Migration Progress**

* oc get events --field-selector reason=LiveMigration

### 30.1.9 Emergency Procedures

#### 30.1.9.1 Cluster Recovery

##### 30.1.9.1.1 When Multiple Nodes Are Down

1. **Check etcd Health**

* oc get etcd -o yaml  
  oc logs -n openshift-etcd <etcd-pod>

1. **Restore from Backup**

* # Follow OpenShift disaster recovery procedures  
  oc adm restore-cluster

#### 30.1.9.2 VM Emergency Access

##### 30.1.9.2.1 When VM Console Is Unresponsive

1. **Use virtctl**

* virtctl console <vm-name>  
  virtctl vnc <vm-name>

1. **Force VM Restart**

* virtctl restart <vm-name>  
  virtctl stop <vm-name> --force

### 30.1.10 Advanced Diagnostics

#### 30.1.10.1 Debug Pod Creation

apiVersion: v1  
kind: Pod  
metadata:  
 name: debug-tools  
spec:  
 containers:  
 - name: debug  
 image: registry.redhat.io/ubi8/ubi:latest  
 command: ['sleep', '3600']  
 securityContext:  
 privileged: true  
 volumeMounts:  
 - name: host  
 mountPath: /host  
 volumes:  
 - name: host  
 hostPath:  
 path: /  
 nodeSelector:  
 kubernetes.io/hostname: <node-name>

#### 30.1.10.2 Log Collection Script

##!/bin/bash  
## Comprehensive log collection script  
  
NAMESPACE=${1:-default}  
OUTPUT\_DIR="troubleshooting-$(date +%Y%m%d-%H%M%S)"  
  
mkdir -p $OUTPUT\_DIR  
  
## Cluster information  
oc cluster-info > $OUTPUT\_DIR/cluster-info.txt  
oc get nodes -o wide > $OUTPUT\_DIR/nodes.txt  
oc get pods --all-namespaces > $OUTPUT\_DIR/all-pods.txt  
  
## VM specific information  
oc get vm --all-namespaces -o yaml > $OUTPUT\_DIR/vms.yaml  
oc get vmi --all-namespaces -o yaml > $OUTPUT\_DIR/vmis.yaml  
oc get datavolume --all-namespaces -o yaml > $OUTPUT\_DIR/datavolumes.yaml  
  
## Events  
oc get events --all-namespaces --sort-by='.lastTimestamp' > $OUTPUT\_DIR/events.txt  
  
## Logs from key components  
oc logs -n openshift-cnv deployment/virt-controller > $OUTPUT\_DIR/virt-controller.log  
oc logs -n openshift-cnv deployment/virt-api > $OUTPUT\_DIR/virt-api.log  
oc logs -n cdi deployment/cdi-controller > $OUTPUT\_DIR/cdi-controller.log  
  
echo "Logs collected in $OUTPUT\_DIR"  
tar -czf $OUTPUT\_DIR.tar.gz $OUTPUT\_DIR

### 30.1.11 Support and Escalation

#### 30.1.11.1 When to Escalate

* Hardware failures
* Data corruption issues
* Security breaches
* Performance degradation > 50%
* Multiple component failures

#### 30.1.11.2 Information to Gather

1. **Environment Details**
   * OpenShift version
   * KubeVirt version
   * Cluster size and configuration
2. **Problem Description**
   * Timeline of events
   * Error messages
   * Impact assessment
3. **Diagnostic Data**
   * Logs (sanitized)
   * Configuration files
   * Resource utilization data

#### 30.1.11.3 Support Contacts

* **Red Hat Support**: <https://access.redhat.com/support/>
* **Community Forums**: <https://commons.openshift.org/>
* **KubeVirt Community**: <https://kubevirt.io/community/>

This troubleshooting guide provides systematic approaches to resolve common issues in the RH OVE ecosystem. Regular review and updates of this guide ensure it remains current with evolving technologies and operational experiences.

# 31 Performance Tuning

## 31.1 Performance Tuning

### 31.1.1 Overview

This document provides comprehensive performance tuning guidelines for the RH OVE ecosystem, covering optimization strategies for virtual machines, networking, storage, and cluster-wide performance enhancements.

### 31.1.2 Performance Optimization Strategy

#### 31.1.2.1 Performance Monitoring Approach

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 A[Baseline Metrics] --> B[Identify Bottlenecks]  
 B --> C[Apply Optimizations]  
 C --> D[Measure Impact]  
 D --> E{Performance Improved?}  
 E -->|Yes| F[Document Changes]  
 E -->|No| G[Try Alternative Approach]  
 G --> C  
 F --> H[Continuous Monitoring]

*Note: Diagram rendering failed, showing code instead.*

#### 31.1.2.2 Key Performance Indicators (KPIs)

* **VM Performance**: CPU utilization, memory usage, disk I/O, network throughput
* **Cluster Performance**: Node utilization, pod scheduling latency, API response times
* **Network Performance**: Latency, packet loss, bandwidth utilization
* **Storage Performance**: IOPS, throughput, latency

### 31.1.3 Virtual Machine Performance Tuning

#### 31.1.3.1 CPU Optimization

##### 31.1.3.1.1 CPU Pinning for High-Performance VMs

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: high-performance-vm  
spec:  
 template:  
 spec:  
 domain:  
 cpu:  
 cores: 4  
 dedicatedCpuPlacement: true  
 isolateEmulatorThread: true  
 resources:  
 requests:  
 cpu: 4  
 memory: 8Gi  
 limits:  
 cpu: 4  
 memory: 8Gi  
 nodeSelector:  
 node-role.kubernetes.io/worker: ""  
 cpumanager: "true"

##### 31.1.3.1.2 CPU Manager Configuration

apiVersion: machineconfiguration.openshift.io/v1  
kind: KubeletConfig  
metadata:  
 name: cpumanager-enabled  
spec:  
 machineConfigPoolSelector:  
 matchLabels:  
 pools.operator.machineconfiguration.openshift.io/worker: ""  
 kubeletConfig:  
 cpuManagerPolicy: static  
 cpuManagerReconcilePeriod: 5s  
 reservedSystemCPUs: "0,1"

##### 31.1.3.1.3 NUMA Topology Awareness

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: numa-optimized-vm  
spec:  
 template:  
 spec:  
 domain:  
 cpu:  
 cores: 8  
 numa:  
 guestMappingPassthrough: {}  
 memory:  
 guest: 16Gi  
 hugepages:  
 pageSize: 1Gi

#### 31.1.3.2 Memory Optimization

##### 31.1.3.2.1 Hugepages Configuration

## Node configuration for hugepages  
apiVersion: machineconfiguration.openshift.io/v1  
kind: MachineConfig  
metadata:  
 name: hugepages-worker  
 labels:  
 machineconfiguration.openshift.io/role: worker  
spec:  
 config:  
 ignition:  
 version: 3.2.0  
 systemd:  
 units:  
 - name: hugepages-1gi.service  
 enabled: true  
 contents: |  
 [Unit]  
 Description=Configure 1Gi hugepages  
 [Service]  
 Type=oneshot  
 ExecStart=/bin/bash -c 'echo 8 > /sys/kernel/mm/hugepages/hugepages-1048576kB/nr\_hugepages'  
 [Install]  
 WantedBy=multi-user.target

##### 31.1.3.2.2 VM Memory Configuration with Hugepages

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: memory-optimized-vm  
spec:  
 template:  
 spec:  
 domain:  
 memory:  
 guest: 8Gi  
 hugepages:  
 pageSize: 1Gi  
 resources:  
 requests:  
 memory: 8Gi  
 hugepages-1Gi: 8Gi  
 limits:  
 memory: 8Gi  
 hugepages-1Gi: 8Gi

#### 31.1.3.3 Storage Performance Optimization

##### 31.1.3.3.1 High-Performance Storage Configuration

apiVersion: storage.k8s.io/v1  
kind: StorageClass  
metadata:  
 name: high-performance-ssd  
provisioner: kubernetes.io/no-provisioner  
parameters:  
 type: ssd  
 fsType: ext4  
 # Optimize for performance  
 mountOptions: "noatime,nodiratime"  
reclaimPolicy: Delete  
volumeBindingMode: WaitForFirstConsumer

##### 31.1.3.3.2 VM Disk Performance Tuning

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: storage-optimized-vm  
spec:  
 template:  
 spec:  
 domain:  
 devices:  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 # Enable disk cache for better performance  
 cache: writeback  
 - name: datadisk  
 disk:  
 bus: virtio  
 cache: none  
 # Use native I/O for better performance  
 io: native  
 resources:  
 requests:  
 cpu: 2  
 memory: 4Gi  
 volumes:  
 - name: rootdisk  
 dataVolume:  
 name: vm-root-disk  
 - name: datadisk  
 dataVolume:  
 name: vm-data-disk

##### 31.1.3.3.3 Storage I/O Optimization

apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: optimized-datavolume  
spec:  
 pvc:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 100Gi  
 storageClassName: high-performance-ssd  
 # Optimize volume for performance  
 volumeMode: Block  
 source:  
 blank: {}

### 31.1.4 Network Performance Tuning

#### 31.1.4.1 Cilium Performance Optimization

##### 31.1.4.1.1 eBPF Optimization Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cilium-config  
 namespace: kube-system  
data:  
 # Enable bandwidth manager for better QoS  
 enable-bandwidth-manager: "true"  
   
 # Enable local redirect policy for better performance  
 enable-local-redirect-policy: "true"  
   
 # Optimize datapath  
 datapath-mode: "veth"  
   
 # Enable XDP acceleration where supported  
 enable-xdp-acceleration: "true"  
   
 # kube-proxy replacement for better performance  
 kube-proxy-replacement: "strict"  
   
 # Optimize for performance  
 enable-cilium-endpoint-slice: "true"

##### 31.1.4.1.2 Network Device Optimization

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cilium-config  
 namespace: kube-system  
data:  
 # Specify devices for optimal performance  
 devices: "eth0"  
   
 # Enable auto direct node routes  
 auto-direct-node-routes: "true"  
   
 # Optimize tunnel protocol  
 tunnel: "disabled"  
   
 # Use native routing when possible  
 enable-ipv4-masquerade: "false"  
 enable-ipv6-masquerade: "false"

#### 31.1.4.2 VM Network Performance

##### 31.1.4.2.1 SR-IOV Configuration for High-Performance Networking

apiVersion: sriovnetwork.openshift.io/v1  
kind: SriovNetworkNodePolicy  
metadata:  
 name: high-performance-network  
 namespace: openshift-sriov-network-operator  
spec:  
 nodeSelector:  
 feature.node.kubernetes.io/network-sriov.capable: "true"  
 nicSelector:  
 vendor: "15b3"  
 deviceID: "1017"  
 numVfs: 8  
 priority: 99  
 resourceName: "high\_perf\_nic"

##### 31.1.4.2.2 VM with SR-IOV Network Attachment

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: sriov-vm  
spec:  
 template:  
 spec:  
 domain:  
 devices:  
 interfaces:  
 - name: default  
 masquerade: {}  
 - name: sriov-network  
 sriov: {}  
 resources:  
 requests:  
 cpu: 4  
 memory: 8Gi  
 networks:  
 - name: default  
 pod: {}  
 - name: sriov-network  
 multus:  
 networkName: high-performance-network

#### 31.1.4.3 Multi-Network Performance with Multus

##### 31.1.4.3.1 Dedicated Network Interfaces for Different Traffic Types

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: multi-interface-performance-vm  
 namespace: high-performance-workloads  
 annotations:  
 k8s.v1.cni.cncf.io/networks: |  
 [  
 {  
 "name": "management-network",  
 "ips": ["192.168.1.5/24"]  
 },  
 {  
 "name": "storage-network",  
 "ips": ["192.168.2.5/24"]  
 },  
 {  
 "name": "sriov-data-network",  
 "ips": ["10.0.0.5/24"]  
 }  
 ]  
spec:  
 running: true  
 template:  
 spec:  
 domain:  
 cpu:  
 cores: 16  
 dedicatedCpuPlacement: true  
 isolateEmulatorThread: true  
 memory:  
 guest: 32Gi  
 hugepages:  
 pageSize: 1Gi  
 devices:  
 interfaces:  
 - name: default  
 masquerade: {}  
 - name: management  
 bridge:  
 port: []  
 - name: storage  
 bridge:  
 port: []  
 - name: sriov-data  
 sriov: {}  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 cache: writeback  
 resources:  
 requests:  
 cpu: 16  
 memory: 32Gi  
 hugepages-1Gi: 32Gi  
 limits:  
 cpu: 16  
 memory: 32Gi  
 hugepages-1Gi: 32Gi  
 networks:  
 - name: default  
 pod: {}  
 - name: management  
 multus:  
 networkName: management-network  
 - name: storage  
 multus:  
 networkName: storage-network  
 - name: sriov-data  
 multus:  
 networkName: sriov-data-network  
 volumes:  
 - name: rootdisk  
 dataVolume:  
 name: multi-interface-vm-root

##### 31.1.4.3.2 High-Performance NAD Configurations

## High-performance management network  
apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: management-network  
 namespace: high-performance-workloads  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "management-network",  
 "type": "macvlan",  
 "master": "ens192",  
 "mode": "bridge",  
 "capabilities": {  
 "ips": true  
 },  
 "ipam": {  
 "type": "static"  
 }  
 }  
---  
## Dedicated storage network with optimized MTU  
apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: storage-network  
 namespace: high-performance-workloads  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "storage-network",  
 "type": "macvlan",  
 "master": "ens224",  
 "mode": "bridge",  
 "mtu": 9000,  
 "capabilities": {  
 "ips": true  
 },  
 "ipam": {  
 "type": "static"  
 }  
 }  
---  
## SR-IOV high-performance data network  
apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: sriov-data-network  
 namespace: high-performance-workloads  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "sriov-data-network",  
 "type": "sriov",  
 "deviceID": "1017",  
 "vf": 0,  
 "spoofchk": "off",  
 "trust": "on",  
 "capabilities": {  
 "ips": true  
 },  
 "ipam": {  
 "type": "static"  
 }  
 }

##### 31.1.4.3.3 Bond Network for High Availability

apiVersion: k8s.cni.cncf.io/v1  
kind: NetworkAttachmentDefinition  
metadata:  
 name: bond-ha-network  
 namespace: high-performance-workloads  
spec:  
 config: |  
 {  
 "cniVersion": "0.3.1",  
 "name": "bond-ha-network",  
 "type": "bond",  
 "mode": "802.3ad",  
 "miimon": "100",  
 "updelay": "200",  
 "downdelay": "200",  
 "links": [  
 {  
 "name": "ens256"  
 },  
 {  
 "name": "ens257"  
 }  
 ],  
 "ipam": {  
 "type": "static"  
 }  
 }

### 31.1.5 Cluster Performance Optimization

#### 31.1.5.1 Node-Level Optimizations

##### 31.1.5.1.1 Performance Profile for Worker Nodes

apiVersion: performance.openshift.io/v2  
kind: PerformanceProfile  
metadata:  
 name: high-performance-worker  
spec:  
 cpu:  
 isolated: "2-47"  
 reserved: "0-1"  
 hugepages:  
 defaultHugepagesSize: 1G  
 pages:  
 - count: 16  
 size: 1G  
 nodeSelector:  
 node-role.kubernetes.io/worker-rt: ""  
 realTimeKernel:  
 enabled: true  
 numa:  
 topologyPolicy: "single-numa-node"

##### 31.1.5.1.2 Machine Config for Kernel Tuning

apiVersion: machineconfiguration.openshift.io/v1  
kind: MachineConfig  
metadata:  
 name: performance-tuning  
 labels:  
 machineconfiguration.openshift.io/role: worker  
spec:  
 config:  
 ignition:  
 version: 3.2.0  
 storage:  
 files:  
 - path: /etc/sysctl.d/99-performance.conf  
 mode: 0644  
 contents:  
 inline: |  
 # Network performance tuning  
 net.core.rmem\_max = 268435456  
 net.core.wmem\_max = 268435456  
 net.ipv4.tcp\_rmem = 4096 131072 268435456  
 net.ipv4.tcp\_wmem = 4096 65536 268435456  
   
 # Virtual memory tuning  
 vm.swappiness = 1  
 vm.dirty\_ratio = 15  
 vm.dirty\_background\_ratio = 5  
   
 # CPU scheduler tuning  
 kernel.sched\_migration\_cost\_ns = 5000000

#### 31.1.5.2 Resource Management Optimization

##### 31.1.5.2.1 Cluster Resource Allocation

apiVersion: v1  
kind: ResourceQuota  
metadata:  
 name: performance-quota  
 namespace: high-performance-workloads  
spec:  
 hard:  
 requests.cpu: "100"  
 requests.memory: 200Gi  
 limits.cpu: "200"  
 limits.memory: 400Gi  
 hugepages-1Gi: 64Gi  
 persistentvolumeclaims: "50"

##### 31.1.5.2.2 Priority Classes for Critical Workloads

apiVersion: scheduling.k8s.io/v1  
kind: PriorityClass  
metadata:  
 name: high-performance-priority  
value: 1000  
globalDefault: false  
description: "Priority class for high-performance VMs"  
---  
apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: critical-vm  
spec:  
 template:  
 spec:  
 priorityClassName: high-performance-priority  
 domain:  
 cpu:  
 cores: 8  
 memory:  
 guest: 16Gi

### 31.1.6 Monitoring Performance Optimizations

#### 31.1.6.1 Efficient Metrics Collection

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: performance-metrics  
spec:  
 selector:  
 matchLabels:  
 app: high-performance-app  
 endpoints:  
 - port: metrics  
 interval: 15s # Reduced interval for better granularity  
 scrapeTimeout: 10s  
 path: /metrics  
 metricRelabelings:  
 - sourceLabels: [\_\_name\_\_]  
 regex: 'go\_.\*|process\_.\*'  
 action: drop # Drop unnecessary metrics

#### 31.1.6.2 Performance Dashboard Configuration

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: performance-dashboard  
data:  
 dashboard.json: |  
 {  
 "dashboard": {  
 "title": "RH OVE Performance Dashboard",  
 "panels": [  
 {  
 "title": "VM CPU Usage",  
 "type": "graph",  
 "targets": [  
 {  
 "expr": "rate(kubevirt\_vm\_cpu\_usage\_seconds\_total[5m]) \* 100",  
 "legendFormat": "{{name}} CPU %"  
 }  
 ]  
 },  
 {  
 "title": "VM Memory Usage",  
 "type": "graph",  
 "targets": [  
 {  
 "expr": "kubevirt\_vm\_memory\_usage\_bytes / kubevirt\_vm\_memory\_available\_bytes \* 100",  
 "legendFormat": "{{name}} Memory %"  
 }  
 ]  
 }  
 ]  
 }  
 }

### 31.1.7 Performance Testing and Benchmarking

#### 31.1.7.1 VM Performance Testing

##!/bin/bash  
## VM Performance Test Script  
  
VM\_NAME="performance-test-vm"  
NAMESPACE="testing"  
  
## CPU Performance Test  
virtctl console $VM\_NAME << EOF  
## Install and run CPU benchmark  
yum install -y stress-ng  
stress-ng --cpu 0 --timeout 60s --metrics-brief  
EOF  
  
## Memory Performance Test  
virtctl console $VM\_NAME << EOF  
## Memory bandwidth test  
stress-ng --vm 1 --vm-bytes 4G --timeout 60s --metrics-brief  
EOF  
  
## Disk I/O Performance Test  
virtctl console $VM\_NAME << EOF  
## Disk performance test  
dd if=/dev/zero of=/tmp/testfile bs=1G count=1 oflag=direct  
dd if=/tmp/testfile of=/dev/null bs=1G count=1 iflag=direct  
rm /tmp/testfile  
EOF

#### 31.1.7.2 Network Performance Testing

apiVersion: v1  
kind: Pod  
metadata:  
 name: network-performance-test  
spec:  
 containers:  
 - name: iperf-server  
 image: networkstatic/iperf3  
 command: ['iperf3', '-s']  
 ports:  
 - containerPort: 5201  
 - name: iperf-client  
 image: networkstatic/iperf3  
 command: ['sleep', '3600']

### 31.1.8 Performance Troubleshooting

#### 31.1.8.1 Common Performance Issues

##### 31.1.8.1.1 High CPU Usage

## Identify CPU-intensive processes  
oc adm top pods --all-namespaces --sort-by=cpu  
  
## Check node CPU utilization  
oc adm top nodes  
  
## Analyze CPU usage patterns  
virtctl console <vm-name>  
top -p 1

##### 31.1.8.1.2 Memory Pressure

## Check memory usage  
oc adm top pods --all-namespaces --sort-by=memory  
  
## Verify hugepages allocation  
oc get nodes -o custom-columns=NAME:.metadata.name,HUGEPAGES:.status.allocatable.hugepages-1Gi  
  
## Check for memory leaks in VM  
virtctl console <vm-name>  
free -h  
cat /proc/meminfo

##### 31.1.8.1.3 Storage Performance Issues

## Check storage performance metrics  
oc get pvc  
oc describe pvc <pvc-name>  
  
## Monitor I/O patterns  
virtctl console <vm-name>  
iostat -x 1  
  
## Check storage backend performance  
oc get nodes -o wide

### 31.1.9 Best Practices Summary

#### 31.1.9.1 VM Performance Best Practices

1. **CPU Optimization**
   * Use CPU pinning for latency-sensitive workloads
   * Enable NUMA topology awareness
   * Configure appropriate CPU limits and requests
2. **Memory Optimization**
   * Use hugepages for memory-intensive applications
   * Configure appropriate memory ballooning
   * Monitor memory usage patterns
3. **Storage Optimization**
   * Use high-performance storage classes for critical workloads
   * Optimize disk cache settings
   * Consider using block storage for high I/O workloads
4. **Network Optimization**
   * Use SR-IOV for high-bandwidth applications
   * Optimize Cilium configuration for performance
   * Consider DPDK for packet processing workloads

#### 31.1.9.2 Monitoring and Maintenance

1. **Regular Performance Reviews**
   * Monitor KPIs continuously
   * Perform regular performance testing
   * Document performance baselines
2. **Capacity Planning**
   * Plan for growth and scaling
   * Monitor resource utilization trends
   * Implement proper resource quotas
3. **Optimization Cycles**
   * Regular performance tuning reviews
   * Test optimizations in non-production environments
   * Document all performance changes

This performance tuning guide provides comprehensive strategies for optimizing the RH OVE ecosystem. Regular application of these practices ensures optimal performance for virtualized workloads while maintaining system stability and reliability.

# 32 Overview

## 32.1 RH OVE Use Cases Overview

### 32.1.1 Introduction

This section provides comprehensive use cases for the Red Hat OpenShift Virtualization Engine (RH OVE) multi-cluster ecosystem, demonstrating real-world scenarios and implementation patterns.

### 32.1.2 📊 [Complete Use Cases Summary Table](use-cases-table.md)

For a comprehensive overview of all use cases with complexity ratings, implementation timelines, and prerequisites, see our [Use Cases Summary Table](use-cases-table.md).

### 32.1.3 Use Case Categories

#### 32.1.3.1 1. VM Lifecycle Management

* **VM Import and Migration**: Importing existing VMs from various sources
* **VM Template Management**: Creating and managing VM templates
* **VM Scaling and Performance**: Dynamic resource allocation and optimization
* **VM Backup and Recovery**: Data protection strategies for virtual machines

#### 32.1.3.2 2. Hybrid Application Deployment

* **VM + Container Integration**: Running legacy VMs alongside containerized services
* **Multi-Tier Applications**: Web, application, and database tiers across different deployment models
* **Service Mesh Integration**: Connecting VMs and containers through service mesh
* **Data Sharing**: Persistent storage sharing between VMs and containers

#### 32.1.3.3 3. Platform-as-a-Service (PaaS) Integration

* **Database Services**: Running databases as VMs with containerized management
* **Middleware Platforms**: Message queues, application servers, and integration platforms
* **Development Environments**: Self-service development platforms
* **CI/CD Pipeline Integration**: Automated deployment across VM and container workloads

#### 32.1.3.4 4. Enterprise Integration Scenarios

* **Legacy Application Modernization**: Gradual migration strategies
* **Disaster Recovery**: Cross-cluster failover and recovery procedures
* **Multi-Cloud Deployment**: Hybrid cloud scenarios with on-premises integration
* **Compliance and Security**: Meeting enterprise security and regulatory requirements

### 32.1.4 Architecture Patterns

#### 32.1.4.1 Hub and Spoke Pattern

* Management cluster orchestrates multiple application clusters
* Centralized policy and governance with distributed execution
* GitOps-driven configuration management

#### 32.1.4.2 Network Integration

* Cilium CNI with Multus multi-network support
* VLAN integration for legacy systems
* Service mesh connectivity between VMs and containers

#### 32.1.4.3 Identity and Access Management

* OIDC-based authentication with Keycloak
* RBAC integration across VM and container environments
* Multi-factor authentication for administrative access

### 32.1.5 Use Case Implementation Guide

#### 32.1.5.1 Prerequisites

* OpenShift 4.12+ clusters with KubeVirt enabled
* Sufficient compute, memory, and storage resources
* Network connectivity between clusters
* Identity provider integration (Keycloak/LDAP/AD)

#### 32.1.5.2 Common Patterns

1. **Resource Provisioning**: Using CDI for VM disk management
2. **Network Configuration**: Multi-network setup with Multus
3. **Storage Management**: Persistent volume strategies for VMs
4. **Monitoring Integration**: Unified monitoring for VMs and containers
5. **Backup Strategies**: Integrated backup solutions for hybrid workloads

### 32.1.6 Getting Started

1. Review the specific use case documentation
2. Understand the architectural requirements
3. Prepare the environment according to prerequisites
4. Follow the step-by-step implementation guide
5. Validate the deployment and test functionality
6. Monitor and maintain the solution

Each use case provides: - **Business Context**: Why this pattern is needed - **Technical Requirements**: Infrastructure and software requirements - **Implementation Steps**: Detailed configuration procedures - **Validation Procedures**: Testing and verification steps - **Troubleshooting Guide**: Common issues and solutions - **Best Practices**: Recommendations for production deployment

# 33 Summary Table

### 33.0.1 Use Cases Dependencies Graph

This diagram shows the logical dependencies and recommended implementation flow between various use cases within the RH OVE ecosystem. The graph illustrates prerequisite relationships - arrows point from foundational capabilities to dependent advanced features.

#### 33.0.1.1 Color Legend

* 🔵 **VM Lifecycle** (Light Blue): Core virtualization capabilities
* 🟣 **Observability** (Purple): Monitoring and insights
* 🟢 **Application Deployment** (Green): Application management and deployment
* 🟠 **Security** (Orange): Security and protection services
* 🔴 **Enterprise Integration** (Pink): Enterprise systems integration
* 🟡 **PaaS Services** (Light Green): Platform-as-a-Service offerings

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 %% VM Lifecycle Foundation  
 VMImport[VM Import and Migration]  
 VMTemplate[VM Template Management]  
 VMScale[VM Scaling and Performance]  
 VMBackup[VM Backup and Recovery]  
   
 %% Observability Foundation  
 Observability[End-to-End Observability]  
   
 %% Application and Platform Services  
 HybridApps[Hybrid Applications]  
 DatabasePaaS[Database Services as PaaS]  
 MultiEnv[Multi-Environment Application Setup]  
   
 %% Security  
 WAF[WAF and Firewalling]  
   
 %% Enterprise Integration  
 EventPublish[Event Publishing to CMDB/SIEM]  
 DisasterRecovery[Disaster Recovery]  
 LegacyMod[Legacy Application Modernization]  
   
 %% VM Lifecycle Dependencies  
 VMImport --> VMTemplate  
 VMTemplate --> VMScale  
 VMTemplate --> VMBackup  
 VMScale --> DisasterRecovery  
 VMBackup --> DisasterRecovery  
   
 %% Platform Dependencies  
 VMTemplate --> MultiEnv  
 VMScale --> HybridApps  
 VMBackup --> HybridApps  
   
 %% Observability Dependencies  
 VMScale --> Observability  
 HybridApps --> Observability  
 Observability --> WAF  
 Observability --> EventPublish  
   
 %% Advanced Services Dependencies  
 HybridApps --> DatabasePaaS  
 MultiEnv --> DatabasePaaS  
 Observability --> DatabasePaaS  
   
 %% Enterprise Integration Dependencies  
 DisasterRecovery --> EventPublish  
 DatabasePaaS --> EventPublish  
   
 %% Legacy Modernization Dependencies  
 HybridApps --> LegacyMod  
 DatabasePaaS --> LegacyMod  
 EventPublish --> LegacyMod  
 DisasterRecovery --> LegacyMod  
   
 %% Styling by Category and Complexity  
 classDef vmLifecycle fill:#e1f5fe,stroke:#01579b,stroke-width:2px,color:#000  
 classDef observability fill:#f3e5f5,stroke:#4a148c,stroke-width:2px,color:#000  
 classDef application fill:#e8f5e8,stroke:#1b5e20,stroke-width:2px,color:#000  
 classDef security fill:#fff3e0,stroke:#e65100,stroke-width:2px,color:#000  
 classDef enterprise fill:#fce4ec,stroke:#880e4f,stroke-width:2px,color:#000  
 classDef paas fill:#f1f8e9,stroke:#33691e,stroke-width:2px,color:#000  
   
 class VMImport,VMTemplate,VMScale,VMBackup vmLifecycle  
 class Observability observability  
 class HybridApps,MultiEnv application  
 class WAF security  
 class DisasterRecovery,EventPublish,LegacyMod enterprise  
 class DatabasePaaS paas

*Note: Diagram rendering failed, showing code instead.*

## 33.1 Use Cases Summary Table

### 33.1.1 Overview

This table provides a comprehensive overview of all use cases documented for the Red Hat OpenShift Virtualization Engine (RH OVE) ecosystem.

### 33.1.2 Use Cases Matrix

| Use Case | Category | Complexity | Key Technologies | Business Value | Implementation Time | Prerequisites |
| --- | --- | --- | --- | --- | --- | --- |
| [VM Import and Migration](vm-importation.md) | VM Lifecycle | Medium | KubeVirt, CDI, MTV | Legacy system modernization | 2-4 weeks | OpenShift 4.12+, Source VM access |
| [VM Template Management](vm-template-management.md) | VM Lifecycle | Low | KubeVirt, CDI | Standardized deployments | 1-2 weeks | OpenShift 4.12+, Template storage |
| [VM Scaling and Performance](vm-scaling-performance.md) | VM Lifecycle | High | HPA, VPA, KubeVirt | Resource optimization | 3-6 weeks | Metrics server, Monitoring stack |
| [VM Backup and Recovery](vm-backup-recovery.md) | VM Lifecycle | Medium | Rubrik CDM, Polaris | Data protection | 2-4 weeks | Rubrik infrastructure |
| [Hybrid Applications](hybrid-applications.md) | Application Deployment | High | Cilium, Service Mesh | Modernization flexibility | 4-8 weeks | Multi-network setup |
| [Database Services as PaaS](database-services-paas.md) | PaaS Integration | High | DB Operators, Helm | Self-service databases | 6-10 weeks | Persistent storage, Operators |
| [Legacy Application Modernization](legacy-modernization.md) | Enterprise Integration | Very High | MTA, Service Mesh, Tekton | Digital transformation | 12-24 weeks | Application analysis |
| [Disaster Recovery](disaster-recovery.md) | Enterprise Integration | High | RHACM, Storage replication | Business continuity | 8-12 weeks | Multi-site infrastructure |
| [End-to-End Observability](end-to-end-observability.md) | Observability | Medium | Prometheus, Jaeger, Dynatrace | Operational insights | 3-6 weeks | Monitoring infrastructure |
| [WAF and Firewalling](waf-firewalling.md) | Security | Medium | Cilium L4-L7, F5 BigIP | Application security | 2-4 weeks | F5 BigIP appliance |
| [Event Publishing to CMDB/SIEM](publishing-events-to-cmdb-siem.md) | Integration | High | Event Bus, Adapters | Enterprise integration | 4-8 weeks | CMDB/SIEM connectivity |
| [Multi-Environment Application Setup](setup-multi-env-application.md) | Application Deployment | Medium | RHACM, ArgoCD, Namespaces | Development workflow | 2-4 weeks | Multi-cluster setup |

### 33.1.3 Complexity Levels

| Level | Description | Skills Required | Timeline |
| --- | --- | --- | --- |
| **Low** | Basic configuration with standard components | Platform administrator | 1-2 weeks |
| **Medium** | Integration of multiple components with custom configuration | Senior platform engineer | 2-6 weeks |
| **High** | Complex multi-component solutions requiring custom development | Solution architect + team | 4-12 weeks |
| **Very High** | Enterprise-wide transformation requiring extensive planning | Enterprise architect + multiple teams | 12+ weeks |

### 33.1.4 Category Breakdown

#### 33.1.4.1 VM Lifecycle Management

* **Purpose**: Managing virtual machine operations and lifecycle
* **Use Cases**: 4 use cases covering import, templates, scaling, and backup
* **Key Benefits**: Infrastructure consolidation, operational efficiency

#### 33.1.4.2 Application Deployment

* **Purpose**: Deploying and managing hybrid application architectures
* **Use Cases**: 1 comprehensive use case for hybrid applications
* **Key Benefits**: Application modernization, deployment flexibility

#### 33.1.4.3 PaaS Integration

* **Purpose**: Providing platform services for development teams
* **Use Cases**: 1 comprehensive database services platform
* **Key Benefits**: Developer productivity, service standardization

#### 33.1.4.4 Enterprise Integration

* **Purpose**: Integrating with existing enterprise systems and processes
* **Use Cases**: 2 use cases covering modernization and disaster recovery
* **Key Benefits**: Risk mitigation, business continuity

#### 33.1.4.5 Observability

* **Purpose**: Monitoring and understanding system behavior
* **Use Cases**: 1 comprehensive observability solution
* **Key Benefits**: Operational visibility, proactive issue resolution

#### 33.1.4.6 Security

* **Purpose**: Protecting applications and infrastructure
* **Use Cases**: 1 WAF and firewalling solution
* **Key Benefits**: Security compliance, threat protection

#### 33.1.4.7 Integration

* **Purpose**: Connecting with external enterprise systems
* **Use Cases**: 1 event publishing integration
* **Key Benefits**: Enterprise integration, compliance reporting

### 33.1.5 Implementation Priority Matrix

#### 33.1.5.1 Phase 1: Foundation (Weeks 1-8)

1. VM Template Management
2. VM Import and Migration
3. End-to-End Observability

#### 33.1.5.2 Phase 2: Core Services (Weeks 9-20)

1. VM Scaling and Performance
2. VM Backup and Recovery
3. WAF and Firewalling

#### 33.1.5.3 Phase 3: Advanced Integration (Weeks 21-36)

1. Hybrid Applications
2. Database Services as PaaS
3. Event Publishing to CMDB/SIEM

#### 33.1.5.4 Phase 4: Enterprise Transformation (Weeks 37+)

1. Legacy Application Modernization
2. Disaster Recovery

### 33.1.6 Prerequisites Summary

#### 33.1.6.1 Common Prerequisites

* OpenShift 4.12+ with KubeVirt enabled
* Sufficient compute, memory, and storage resources
* Network connectivity between components
* Identity provider integration

#### 33.1.6.2 Specialized Prerequisites

* **Rubrik Infrastructure**: For VM backup and recovery
* **F5 BigIP**: For advanced WAF capabilities
* **External Systems**: CMDB, SIEM, legacy systems for integration use cases
* **Multi-site Setup**: For disaster recovery scenarios

### 33.1.7 Success Metrics

| Use Case Category | Key Performance Indicators |
| --- | --- |
| VM Lifecycle | VM provisioning time, resource utilization, backup success rate |
| Application Deployment | Deployment frequency, rollback rate, application performance |
| PaaS Integration | Service provisioning time, developer satisfaction, service availability |
| Enterprise Integration | Integration success rate, compliance score, incident response time |
| Observability | Mean time to detection (MTTD), alert accuracy, dashboard usage |
| Security | Security incident reduction, compliance pass rate, threat detection rate |

### 33.1.8 Getting Started

1. **Assessment**: Review your current infrastructure and identify priority use cases
2. **Planning**: Create implementation roadmap based on complexity and business value
3. **Prerequisites**: Ensure all required infrastructure and tools are available
4. **Pilot**: Start with low-complexity use cases to build expertise
5. **Scale**: Gradually implement more complex use cases as team capabilities grow

For detailed implementation guidance, refer to the individual use case documentation linked in the table above.

# 34 VM Import & Migration

## 34.1 Use Case: VM Importation and Migration

### 34.1.1 Business Context

Organizations often need to migrate existing virtual machines from various virtualization platforms (VMware vSphere, Red Hat Virtualization, Hyper-V, or KVM) to OpenShift Virtualization. This use case demonstrates how to import VMs while maintaining data integrity, minimizing downtime, and ensuring seamless operation in the new environment.

### 34.1.2 Technical Requirements

#### 34.1.2.1 Infrastructure Requirements

* OpenShift 4.12+ cluster with KubeVirt enabled
* Container Data Importer (CDI) operator installed
* Sufficient storage capacity for VM disk images
* Network connectivity to source virtualization platform
* Migration Toolkit for Virtualization (MTV) operator (optional)

#### 34.1.2.2 Resource Requirements

* **CPU**: 2+ cores per VM being imported
* **Memory**: 4GB+ RAM per VM being imported
* **Storage**: 2x the source VM disk size (for staging and final storage)
* **Network**: High-bandwidth connection for large VM transfers

### 34.1.3 Implementation Architecture

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TB  
 subgraph "Source Environment"  
 VS[VMware vSphere]  
 RHV[Red Hat Virtualization]  
 HV[Hyper-V]  
 KVM[KVM/QEMU]  
 end  
   
 subgraph "OpenShift Cluster"  
 MTV[Migration Toolkit for Virtualization]  
 CDI[Container Data Importer]  
 PVC[PersistentVolumeClaim]  
 DV[DataVolume]  
 VM[VirtualMachine]  
 end  
   
 subgraph "Storage"  
 SC[StorageClass]  
 PV[PersistentVolume]  
 CSI[CSI Driver]  
 end  
   
 VS --> MTV  
 RHV --> MTV  
 HV --> MTV  
 KVM --> CDI  
   
 MTV --> DV  
 CDI --> DV  
 DV --> PVC  
 PVC --> PV  
 PV --> CSI  
   
 DV --> VM  
   
 style MTV fill:#99ccff  
 style CDI fill:#99ffcc  
 style VM fill:#ff99cc

*Note: Diagram rendering failed, showing code instead.*

### 34.1.4 Implementation Steps

#### 34.1.4.1 Step 1: Prepare the Source Environment

##### 34.1.4.1.1 For VMware vSphere

## Create a service account for MTV  
## In vSphere Client:  
## 1. Create a dedicated user account  
## 2. Assign minimal required permissions:  
## - Datastore > Browse datastore  
## - Virtual machine > Snapshot management  
## - Virtual machine > Provisioning

##### 34.1.4.1.2 For KVM/QEMU Direct Import

## Prepare VM disk images  
qemu-img convert -f qcow2 -O qcow2 /path/to/source.qcow2 /path/to/optimized.qcow2  
  
## Compress for faster transfer  
gzip /path/to/optimized.qcow2

#### 34.1.4.2 Step 2: Install Migration Tools

##### 34.1.4.2.1 Install Migration Toolkit for Virtualization

apiVersion: operators.coreos.com/v1alpha1  
kind: Subscription  
metadata:  
 name: mtv-operator  
 namespace: openshift-mtv  
spec:  
 channel: release-v2.4  
 installPlanApproval: Automatic  
 name: mtv-operator  
 source: redhat-operators  
 sourceNamespace: openshift-marketplace  
---  
apiVersion: v1  
kind: Namespace  
metadata:  
 name: openshift-mtv

##### 34.1.4.2.2 Install Container Data Importer

apiVersion: operators.coreos.com/v1alpha1  
kind: Subscription  
metadata:  
 name: containerized-data-importer  
 namespace: openshift-cnv  
spec:  
 channel: stable  
 installPlanApproval: Automatic  
 name: containerized-data-importer  
 source: redhat-operators  
 sourceNamespace: openshift-marketplace

#### 34.1.4.3 Step 3: Configure Source Provider (MTV)

apiVersion: forklift.konveyor.io/v1beta1  
kind: Provider  
metadata:  
 name: vmware-source  
 namespace: openshift-mtv  
spec:  
 type: vsphere  
 url: https://vcenter.example.com/sdk  
 secret:  
 name: vmware-credentials  
 namespace: openshift-mtv  
---  
apiVersion: v1  
kind: Secret  
metadata:  
 name: vmware-credentials  
 namespace: openshift-mtv  
type: Opaque  
stringData:  
 user: migration-user@vsphere.local  
 password: "your-secure-password"  
 thumbprint: "AA:BB:CC:DD:EE:FF:00:11:22:33:44:55:66:77:88:99:AA:BB:CC:DD"

#### 34.1.4.4 Step 4: Create Migration Plan

apiVersion: forklift.konveyor.io/v1beta1  
kind: Plan  
metadata:  
 name: webapp-migration-plan  
 namespace: openshift-mtv  
spec:  
 provider:  
 source:  
 name: vmware-source  
 namespace: openshift-mtv  
 destination:  
 name: host  
 namespace: openshift-mtv  
 targetNamespace: app-web-prod  
 vms:  
 - id: vm-12345  
 name: web-server-01  
 - id: vm-12346  
 name: app-server-01  
 map:  
 network:  
 - source:  
 name: "VM Network"  
 destination:  
 name: default  
 type: pod  
 - source:  
 name: "Storage Network"  
 destination:  
 name: storage-net  
 type: multus  
 storage:  
 - source:  
 name: "datastore1"  
 destination:  
 storageClass: ocs-storagecluster-ceph-rbd  
 - source:  
 name: "datastore2"  
 destination:  
 storageClass: ocs-storagecluster-cephfs

#### 34.1.4.5 Step 5: Direct Import Using CDI (Alternative Method)

##### 34.1.4.5.1 Import from HTTP/HTTPS Source

apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: imported-vm-disk  
 namespace: app-web-prod  
spec:  
 source:  
 http:  
 url: "https://storage.example.com/vm-images/web-server.qcow2"  
 secretRef: "image-pull-secret"  
 storage:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 50Gi  
 storageClassName: ocs-storagecluster-ceph-rbd  
---  
apiVersion: v1  
kind: Secret  
metadata:  
 name: image-pull-secret  
 namespace: app-web-prod  
type: kubernetes.io/basic-auth  
stringData:  
 username: "storage-user"  
 password: "storage-password"

##### 34.1.4.5.2 Import from Registry

apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: registry-imported-vm  
 namespace: app-web-prod  
spec:  
 source:  
 registry:  
 url: "docker://quay.io/example/vm-images:web-server-v1.0"  
 pullMethod: pod  
 secretRef: "registry-credentials"  
 storage:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 30Gi  
 storageClassName: ocs-storagecluster-ceph-rbd

#### 34.1.4.6 Step 6: Create Virtual Machine Definition

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: imported-web-server  
 namespace: app-web-prod  
 labels:  
 app: web-server  
 tier: frontend  
 environment: production  
 annotations:  
 description: "Imported web server from VMware vSphere"  
spec:  
 running: false  
 template:  
 metadata:  
 labels:  
 kubevirt.io/vm: imported-web-server  
 spec:  
 domain:  
 cpu:  
 cores: 4  
 sockets: 1  
 threads: 1  
 memory:  
 guest: 8Gi  
 devices:  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 - name: cloudinitdisk  
 disk:  
 bus: virtio  
 interfaces:  
 - name: default  
 masquerade: {}  
 - name: storage-network  
 bridge: {}  
 machine:  
 type: pc-q35-rhel8.6.0  
 resources:  
 requests:  
 memory: 8Gi  
 cpu: 4  
 networks:  
 - name: default  
 pod: {}  
 - name: storage-network  
 multus:  
 networkName: storage-net  
 volumes:  
 - name: rootdisk  
 dataVolume:  
 name: imported-vm-disk  
 - name: cloudinitdisk  
 cloudInitNoCloud:  
 userData: |  
 #cloud-config  
 user: admin  
 password: changeme  
 chpasswd: { expire: False }  
 ssh\_pwauth: True  
 package\_upgrade: true  
 packages:  
 - qemu-guest-agent  
 runcmd:  
 - systemctl enable qemu-guest-agent  
 - systemctl start qemu-guest-agent

#### 34.1.4.7 Step 7: Execute Migration

##### 34.1.4.7.1 Start Migration Plan

## Apply the migration plan  
oc apply -f migration-plan.yaml  
  
## Monitor migration progress  
oc get migration -n openshift-mtv -w  
  
## Check migration status  
oc describe migration webapp-migration -n openshift-mtv

##### 34.1.4.7.2 Monitor Import Progress (CDI)

## Check DataVolume status  
oc get dv imported-vm-disk -n app-web-prod  
  
## Monitor import progress  
oc describe dv imported-vm-disk -n app-web-prod  
  
## Check PVC status  
oc get pvc imported-vm-disk -n app-web-prod

#### 34.1.4.8 Step 8: Post-Migration Validation

##### 34.1.4.8.1 Start and Validate VM

## Start the imported VM  
oc patch vm imported-web-server -n app-web-prod --type merge -p '{"spec":{"running":true}}'  
  
## Check VM status  
oc get vm imported-web-server -n app-web-prod  
  
## Check VMI status  
oc get vmi imported-web-server -n app-web-prod  
  
## Access VM console  
virtctl console imported-web-server -n app-web-prod

##### 34.1.4.8.2 Network Connectivity Test

## Test pod network connectivity  
oc exec -it deployment/test-client -- ping $(oc get vmi imported-web-server -n app-web-prod -o jsonpath='{.status.interfaces[0].ipAddress}')  
  
## Test multus network connectivity  
oc exec -it deployment/storage-client -- ping $(oc get vmi imported-web-server -n app-web-prod -o jsonpath='{.status.interfaces[1].ipAddress}')

### 34.1.5 Troubleshooting Guide

#### 34.1.5.1 Common Issues and Solutions

##### 34.1.5.1.1 1. Import Fails with “Insufficient Storage”

## Check available storage  
oc get pv | grep Available  
  
## Check storage class  
oc describe storageclass ocs-storagecluster-ceph-rbd  
  
## Solution: Request smaller disk or add more storage capacity

##### 34.1.5.1.2 2. Network Import Timeout

## Increase timeout in DataVolume  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: imported-vm-disk  
 annotations:  
 cdi.kubevirt.io/storage.pod.restarts: "10"  
 cdi.kubevirt.io/storage.pod.retries: "4"  
spec:  
 # ... rest of spec

##### 34.1.5.1.3 3. VM Boot Issues After Import

## Check VM events  
oc describe vm imported-web-server -n app-web-prod  
  
## Common fixes:  
## 1. Update machine type  
## 2. Install virtio drivers  
## 3. Adjust memory/CPU allocation

##### 34.1.5.1.4 4. Performance Issues

## Optimize disk performance  
spec:  
 domain:  
 devices:  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 cache: writethrough # Add cache policy  
 io: native # Add I/O policy

### 34.1.6 Best Practices

#### 34.1.6.1 Pre-Migration

1. **Inventory Assessment**: Document all VMs, their dependencies, and resource requirements
2. **Network Planning**: Map source networks to destination networks
3. **Storage Planning**: Choose appropriate storage classes for different workload types
4. **Security Review**: Ensure imported VMs meet security standards

#### 34.1.6.2 During Migration

1. **Batch Processing**: Migrate VMs in small batches to manage resources
2. **Monitoring**: Continuously monitor migration progress and resource utilization
3. **Validation**: Test each migrated VM before proceeding to the next batch
4. **Documentation**: Keep detailed logs of the migration process

#### 34.1.6.3 Post-Migration

1. **Performance Tuning**: Optimize VM configurations for the new environment
2. **Security Hardening**: Apply security policies and configurations
3. **Backup Configuration**: Set up backup strategies for migrated VMs
4. **Monitoring Setup**: Configure monitoring and alerting for new VMs

#### 34.1.6.4 Production Considerations

1. **Resource Quotas**: Implement appropriate resource quotas per namespace
2. **Network Policies**: Apply network segmentation policies
3. **Storage Policies**: Use appropriate storage classes for different tiers
4. **Disaster Recovery**: Plan for cross-cluster failover scenarios

### 34.1.7 Integration with RH OVE Ecosystem

#### 34.1.7.1 GitOps Integration

## ArgoCD Application for VM management  
apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: imported-vms  
 namespace: argocd  
spec:  
 project: production  
 source:  
 repoURL: https://git.company.com/rh-ove/vm-configs  
 targetRevision: HEAD  
 path: imported-vms  
 destination:  
 server: https://kubernetes.default.svc  
 namespace: app-web-prod  
 syncPolicy:  
 automated:  
 prune: false  
 selfHeal: true

#### 34.1.7.2 Monitoring Integration

## ServiceMonitor for VM metrics  
apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: vm-metrics  
 namespace: app-web-prod  
spec:  
 selector:  
 matchLabels:  
 app: kubevirt-vm  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics

This comprehensive guide provides everything needed to successfully import and migrate VMs into the RH OVE multi-cluster ecosystem while maintaining enterprise-grade security, monitoring, and operational standards.

# 35 VM Template Management

## 35.1 Use Case: VM Template Management

### 35.1.1 Business Context

Efficient VM template management is crucial for maintaining consistency, reducing deployment times, and ensuring that VMs adhere to organizational standards. By leveraging templates, organizations can streamline the creation of VMs with predefined configurations that meet specific operational, security, and compliance requirements.

### 35.1.2 Technical Requirements

#### 35.1.2.1 Infrastructure Requirements

* OpenShift 4.12+ with KubeVirt enabled
* Storage solutions for template images (e.g., OpenShift Data Foundation)
* Network connectivity between clusters for template distribution

#### 35.1.2.2 Resource Requirements

* **Storage**: Adequate space for storing multiple VM templates
* **Network**: Fast connectivity for template distribution and deployment

### 35.1.3 Architecture Overview

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 TEMPLATE\_STORE["Template Storage"] -- Distributes --> CLUSTER1["OpenShift Cluster 1"]  
 TEMPLATE\_STORE -- Distributes --> CLUSTER2["OpenShift Cluster 2"]  
 CLUSTER1 -- Deploys --> VM1["VM Instances"]  
 CLUSTER2 -- Deploys --> VM2["VM Instances"]  
  
 style TEMPLATE\_STORE fill:#f9f,stroke:#333

*Note: Diagram rendering failed, showing code instead.*

### 35.1.4 Implementation Steps

#### 35.1.4.1 Step 1: Create VM Templates

##### 35.1.4.1.1 Define Template Specification

apiVersion: kubevirt.io/v1alpha3  
kind: VirtualMachineTemplate  
metadata:  
 name: webserver-template  
spec:  
 domain:  
 cpu:  
 cores: 2  
 devices:  
 disks:  
 - name: rootdisk  
 disk:  
 bus: virtio  
 memory:  
 guest: 4Gi  
 volumes:  
 - name: rootdisk  
 containerDisk:  
 image: kubevirt/cirros-registry-disk-demo

#### 35.1.4.2 Step 2: Store Templates

##### 35.1.4.2.1 Upload Template to Storage

* Use OpenShift Data Foundation or another persistent storage solution to store VM templates.

#### 35.1.4.3 Step 3: Distribute Templates

##### 35.1.4.3.1 Sync Templates Across Clusters

* Ensure templates are replicated to all relevant clusters using synchronized storage.

#### 35.1.4.4 Step 4: Deploy VMs Using Templates

##### 35.1.4.4.1 Create VMs from Templates

apiVersion: kubevirt.io/v1alpha3  
kind: VirtualMachine  
metadata:  
 name: new-webserver  
spec:  
 running: false  
 template:  
 metadata:  
 labels:  
 vm.kubevirt.io/template: webserver-template  
 spec:  
 domain:  
 cpu:  
 cores: 2  
 devices:  
 disks:  
 - disk:  
 bus: virtio  
 name: rootdisk  
 memory:  
 guest: 4Gi

### 35.1.5 Troubleshooting Guide

#### 35.1.5.1 Common Issues and Solutions

##### 35.1.5.1.1 Template Sync Issues

* Verify storage connectivity and check log files for errors.

##### 35.1.5.1.2 Deployment Failures

* Ensure templates are properly defined and contain all necessary configurations.

### 35.1.6 Best Practices

* **Template Versioning**: Keep versions of templates to track changes and rollback if necessary.
* **Regular Audits**: Periodically review and update templates to ensure they meet current security and compliance standards.
* **Backup Templates**: Ensure templates are backed up to prevent loss in case of storage failures.

### 35.1.7 Integration with RH OVE Ecosystem

#### 35.1.7.1 Monitoring Integration

* Set up monitoring for template storage systems to detect and resolve issues promptly.

This guide provides the necessary steps and best practices for efficient VM template management within an RH OVE environment, facilitating faster and more consistent VM deployments.

# 36 VM Scaling & Performance

## 36.1 Use Case: VM Scaling and Performance Optimization

### 36.1.1 Business Context

Dynamic scaling and performance optimization are essential for maintaining optimal VM performance while managing resource costs. This use case demonstrates how to implement auto-scaling, resource optimization, and performance monitoring for virtual machines in the RH OVE ecosystem.

### 36.1.2 Technical Requirements

#### 36.1.2.1 Infrastructure Requirements

* OpenShift 4.12+ with KubeVirt enabled
* Horizontal Pod Autoscaler (HPA) support
* Metrics server and custom metrics API
* Persistent storage with performance monitoring capabilities
* CPU and memory monitoring tools (Prometheus/Grafana)

#### 36.1.2.2 Resource Requirements

* **CPU**: Variable based on workload demands
* **Memory**: Dynamic allocation based on usage patterns
* **Storage**: High-performance storage with IOPS monitoring
* **Network**: Low-latency network for performance-sensitive applications

### 36.1.3 Architecture Overview

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 subgraph "Monitoring Stack"  
 PROMETHEUS["Prometheus"]  
 GRAFANA["Grafana"]  
 ALERTMANAGER["AlertManager"]  
 end  
   
 subgraph "Scaling Infrastructure"  
 HPA["Horizontal Pod Autoscaler"]  
 VPA["Vertical Pod Autoscaler"]  
 METRICS["Metrics Server"]  
 end  
   
 subgraph "VM Workloads"  
 VM1["VM Instance 1"]  
 VM2["VM Instance 2"]  
 VM3["VM Instance 3"]  
 end  
   
 PROMETHEUS --> ALERTMANAGER  
 GRAFANA --> PROMETHEUS  
 METRICS --> HPA  
 METRICS --> VPA  
 HPA --> VM1  
 HPA --> VM2  
 VPA --> VM3  
   
 VM1 --> PROMETHEUS  
 VM2 --> PROMETHEUS  
 VM3 --> PROMETHEUS  
  
 style PROMETHEUS fill:#f9f,stroke:#333  
 style HPA fill:#ff9,stroke:#333

*Note: Diagram rendering failed, showing code instead.*

### 36.1.4 Implementation Steps

#### 36.1.4.1 Step 1: Enable VM Performance Monitoring

##### 36.1.4.1.1 Deploy VM with Performance Monitoring

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: performance-vm  
 namespace: vm-workloads  
spec:  
 running: true  
 template:  
 metadata:  
 labels:  
 app: performance-vm  
 monitoring: "enabled"  
 spec:  
 domain:  
 cpu:  
 cores: 2  
 model: host-passthrough  
 devices:  
 disks:  
 - disk:  
 bus: virtio  
 name: rootdisk  
 interfaces:  
 - name: default  
 bridge: {}  
 memory:  
 guest: 4Gi  
 resources:  
 requests:  
 memory: 4Gi  
 cpu: 2  
 limits:  
 memory: 8Gi  
 cpu: 4  
 networks:  
 - name: default  
 pod: {}  
 volumes:  
 - dataVolume:  
 name: performance-vm-dv  
 name: rootdisk  
---  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: performance-vm-dv  
 namespace: vm-workloads  
spec:  
 source:  
 http:  
 url: "https://vm-images.example.com/performance-vm.img"  
 pvc:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 50Gi  
 storageClassName: fast-ssd

#### 36.1.4.2 Step 2: Configure Horizontal Pod Autoscaler for VMs

##### 36.1.4.2.1 HPA Configuration

apiVersion: autoscaling/v2  
kind: HorizontalPodAutoscaler  
metadata:  
 name: vm-hpa  
 namespace: vm-workloads  
spec:  
 scaleTargetRef:  
 apiVersion: kubevirt.io/v1  
 kind: VirtualMachine  
 name: performance-vm  
 minReplicas: 1  
 maxReplicas: 5  
 metrics:  
 - type: Resource  
 resource:  
 name: cpu  
 target:  
 type: Utilization  
 averageUtilization: 70  
 - type: Resource  
 resource:  
 name: memory  
 target:  
 type: Utilization  
 averageUtilization: 80  
 behavior:  
 scaleUp:  
 stabilizationWindowSeconds: 60  
 policies:  
 - type: Percent  
 value: 50  
 periodSeconds: 60  
 scaleDown:  
 stabilizationWindowSeconds: 300  
 policies:  
 - type: Percent  
 value: 25  
 periodSeconds: 60

#### 36.1.4.3 Step 3: Implement Vertical Pod Autoscaler

##### 36.1.4.3.1 VPA Configuration

apiVersion: autoscaling.k8s.io/v1  
kind: VerticalPodAutoscaler  
metadata:  
 name: vm-vpa  
 namespace: vm-workloads  
spec:  
 targetRef:  
 apiVersion: kubevirt.io/v1  
 kind: VirtualMachine  
 name: performance-vm  
 updatePolicy:  
 updateMode: "Auto"  
 resourcePolicy:  
 containerPolicies:  
 - containerName: compute  
 minAllowed:  
 cpu: 100m  
 memory: 1Gi  
 maxAllowed:  
 cpu: 8  
 memory: 16Gi  
 controlledResources: ["cpu", "memory"]

#### 36.1.4.4 Step 4: Performance Monitoring and Alerting

##### 36.1.4.4.1 ServiceMonitor for VM Metrics

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: vm-performance-monitor  
 namespace: vm-workloads  
 labels:  
 app: vm-monitor  
spec:  
 selector:  
 matchLabels:  
 monitoring: "enabled"  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics  
 honorLabels: true

##### 36.1.4.4.2 Performance Alerting Rules

apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: vm-performance-alerts  
 namespace: vm-workloads  
spec:  
 groups:  
 - name: vm.performance  
 rules:  
 - alert: VMHighCPUUsage  
 expr: kubevirt\_vm\_cpu\_usage > 0.8  
 for: 5m  
 labels:  
 severity: warning  
 annotations:  
 summary: "VM {{ $labels.name }} has high CPU usage"  
 description: "VM {{ $labels.name }} CPU usage is above 80% for more than 5 minutes."  
   
 - alert: VMHighMemoryUsage  
 expr: kubevirt\_vm\_memory\_usage > 0.9  
 for: 5m  
 labels:  
 severity: critical  
 annotations:  
 summary: "VM {{ $labels.name }} has high memory usage"  
 description: "VM {{ $labels.name }} memory usage is above 90% for more than 5 minutes."  
   
 - alert: VMDiskIOHigh  
 expr: kubevirt\_vm\_disk\_iops > 1000  
 for: 10m  
 labels:  
 severity: warning  
 annotations:  
 summary: "VM {{ $labels.name }} has high disk I/O"  
 description: "VM {{ $labels.name }} disk IOPS is above 1000 for more than 10 minutes."

#### 36.1.4.5 Step 5: Performance Optimization Strategies

##### 36.1.4.5.1 CPU Pinning for Performance-Critical VMs

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: high-performance-vm  
 namespace: vm-workloads  
spec:  
 running: true  
 template:  
 metadata:  
 annotations:  
 cpu-load-balancing.crio.io: "disable"  
 cpu-quota.crio.io: "disable"  
 irq-load-balancing.crio.io: "disable"  
 spec:  
 domain:  
 cpu:  
 cores: 4  
 sockets: 1  
 threads: 1  
 dedicatedCpuPlacement: true  
 isolateEmulatorThread: true  
 model: host-passthrough  
 devices:  
 disks:  
 - disk:  
 bus: virtio  
 name: rootdisk  
 memory:  
 guest: 8Gi  
 hugepages:  
 pageSize: 1Gi  
 resources:  
 requests:  
 memory: 8Gi  
 cpu: 4  
 limits:  
 memory: 8Gi  
 cpu: 4  
 nodeSelector:  
 node-role.kubernetes.io/worker: ""  
 performance-node: "true"  
 volumes:  
 - dataVolume:  
 name: high-performance-vm-dv  
 name: rootdisk

#### 36.1.4.6 Step 6: Storage Performance Optimization

##### 36.1.4.6.1 High-Performance Storage Configuration

apiVersion: storage.k8s.io/v1  
kind: StorageClass  
metadata:  
 name: high-performance-ssd  
provisioner: kubernetes.io/csi-driver  
parameters:  
 type: gp3  
 iops: "3000"  
 throughput: "125"  
 fsType: ext4  
reclaimPolicy: Delete  
allowVolumeExpansion: true  
volumeBindingMode: WaitForFirstConsumer

### 36.1.5 Troubleshooting Guide

#### 36.1.5.1 Common Issues and Solutions

##### 36.1.5.1.1 Scaling Not Triggering

* **Issue**: HPA/VPA not scaling VMs as expected
* **Solution**:
  + Check metrics server functionality: kubectl top nodes
  + Verify resource requests are set properly
  + Check HPA status: kubectl describe hpa vm-hpa

##### 36.1.5.1.2 Performance Degradation

* **Issue**: VM performance is not meeting expectations
* **Solution**:
  + Review CPU pinning configuration
  + Check for resource contention on nodes
  + Verify storage performance metrics
  + Analyze network latency and throughput

##### 36.1.5.1.3 Memory Issues

* **Issue**: Out of memory errors or high memory pressure
* **Solution**:
  + Increase memory limits in VM specification
  + Enable hugepages for better memory performance
  + Check for memory leaks in applications

### 36.1.6 Best Practices

#### 36.1.6.1 Resource Management

* **Right-sizing**: Start with conservative resource allocations and scale based on monitoring data
* **Resource Limits**: Always set both requests and limits to prevent resource starvation
* **Node Selection**: Use node selectors and taints to ensure VMs are scheduled on appropriate nodes

#### 36.1.6.2 Performance Tuning

* **CPU Optimization**: Use CPU pinning for performance-critical workloads
* **Memory Optimization**: Configure hugepages for memory-intensive applications
* **Storage Optimization**: Use high-performance storage classes for I/O intensive workloads
* **Network Optimization**: Configure SR-IOV for network-intensive applications

#### 36.1.6.3 Monitoring and Alerting

* **Proactive Monitoring**: Set up comprehensive monitoring for all performance metrics
* **Alert Thresholds**: Configure appropriate alert thresholds to prevent performance issues
* **Capacity Planning**: Use historical data for capacity planning and resource allocation

### 36.1.7 Integration with RH OVE Ecosystem

#### 36.1.7.1 GitOps Integration

apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: vm-performance  
 namespace: argocd  
spec:  
 project: default  
 source:  
 repoURL: https://git.example.com/vm-performance-config  
 targetRevision: HEAD  
 path: performance  
 destination:  
 server: https://kubernetes.default.svc  
 namespace: vm-workloads  
 syncPolicy:  
 automated:  
 prune: false  
 selfHeal: true  
 syncOptions:  
 - CreateNamespace=true

#### 36.1.7.2 Multi-Cluster Performance Management

* **Centralized Monitoring**: Aggregate performance metrics across multiple clusters
* **Cross-Cluster Scaling**: Implement scaling policies that consider cluster resource availability
* **Performance Benchmarking**: Establish performance baselines across different cluster configurations

This comprehensive guide provides the tools and strategies needed to implement effective VM scaling and performance optimization within the RH OVE ecosystem, ensuring optimal resource utilization and application performance.

# 37 VM Backup & Recovery

## 37.1 Use Case: VM Backup and Recovery

### 37.1.1 Business Context

Ensuring data integrity and availability requires effective VM backup and recovery strategies. This use case explores how to implement comprehensive backup solutions and recovery processes to protect critical VM workloads, ensuring minimal downtime and data loss.

### 37.1.2 Technical Requirements

#### 37.1.2.1 Infrastructure Requirements

* OpenShift 4.12+ with KubeVirt enabled
* Rubrik Cloud Data Management for comprehensive backup and recovery
* Network connectivity for Rubrik management and data transfer

#### 37.1.2.2 Resource Requirements

* **Storage**: Adequate space for backup snapshots and archival
* **Network**: Sufficient bandwidth for backup data transfer

### 37.1.3 Architecture Overview

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 subgraph "OpenShift Cluster"  
 VM1["VM Instance 1"]  
 VM2["VM Instance 2"]  
 VM3["VM Instance 3"]  
 end  
   
 subgraph "Rubrik Ecosystem"  
 RUBRIK\_CDM["Rubrik CDM"]  
 RUBRIK\_POLARIS["Rubrik Polaris"]  
 SLA\_DOMAINS["SLA Domains"]  
 end  
   
 subgraph "Storage & Replication"  
 LOCAL\_STORAGE["Local Rubrik Storage"]  
 REMOTE\_RUBRIK["Remote Rubrik Cluster"]  
 CLOUD\_ARCHIVE["Cloud Archive (AWS/Azure)"]  
 end  
   
 VM1 --> RUBRIK\_CDM  
 VM2 --> RUBRIK\_CDM  
 VM3 --> RUBRIK\_CDM  
   
 RUBRIK\_CDM --> SLA\_DOMAINS  
 RUBRIK\_CDM --> LOCAL\_STORAGE  
 LOCAL\_STORAGE --> REMOTE\_RUBRIK  
 LOCAL\_STORAGE --> CLOUD\_ARCHIVE  
   
 RUBRIK\_POLARIS --> RUBRIK\_CDM  
 RUBRIK\_POLARIS --> REMOTE\_RUBRIK  
  
 style RUBRIK\_CDM fill:#f9f,stroke:#333  
 style RUBRIK\_POLARIS fill:#ff9,stroke:#333  
 style SLA\_DOMAINS fill:#9ff,stroke:#333

*Note: Diagram rendering failed, showing code instead.*

### 37.1.4 Implementation Steps

#### 37.1.4.1 Step 1: Setup Backup Infrastructure

##### 37.1.4.1.1 Deploy Rubrik Kubernetes Connector

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: rubrik-connector  
 namespace: rubrik-system  
spec:  
 replicas: 1  
 selector:  
 matchLabels:  
 app: rubrik-connector  
 template:  
 metadata:  
 labels:  
 app: rubrik-connector  
 spec:  
 containers:  
 - name: connector  
 image: rubrik/kubernetes-connector:latest  
 env:  
 - name: RUBRIK\_CDM\_URL  
 valueFrom:  
 secretKeyRef:  
 name: rubrik-credentials  
 key: cdm-url  
 - name: RUBRIK\_USERNAME  
 valueFrom:  
 secretKeyRef:  
 name: rubrik-credentials  
 key: username  
 - name: RUBRIK\_PASSWORD  
 valueFrom:  
 secretKeyRef:  
 name: rubrik-credentials  
 key: password  
 ports:  
 - containerPort: 8080  
 volumeMounts:  
 - name: kubeconfig  
 mountPath: /etc/kubeconfig  
 readOnly: true  
 volumes:  
 - name: kubeconfig  
 secret:  
 secretName: rubrik-kubeconfig  
---  
apiVersion: v1  
kind: Secret  
metadata:  
 name: rubrik-credentials  
 namespace: rubrik-system  
type: Opaque  
data:  
 cdm-url: <base64-encoded-rubrik-cdm-url>  
 username: <base64-encoded-username>  
 password: <base64-encoded-password>

##### 37.1.4.1.2 Configure Rubrik SLA Domains

## Rubrik SLA Domain Configuration  
apiVersion: rubrik.com/v1  
kind: SLADomain  
metadata:  
 name: vm-backup-sla  
 namespace: vm-workloads  
spec:  
 name: "VM Production Backup"  
 frequencies:  
 - timeUnit: "Daily"  
 frequency: 1  
 retention: 30 # days  
 - timeUnit: "Weekly"  
 frequency: 1  
 retention: 12 # weeks  
 - timeUnit: "Monthly"  
 frequency: 1  
 retention: 12 # months  
 archivalSpecs:  
 - locationId: "cloud-archive-location"  
 archivalThreshold: 7 # days  
 replicationSpecs:  
 - locationId: "remote-rubrik-cluster"  
 retentionLimit: 90 # days

#### 37.1.4.2 Step 2: Configure VM Backup Policies

##### 37.1.4.2.1 Assign VMs to SLA Domains

apiVersion: rubrik.com/v1  
kind: VMBackupPolicy  
metadata:  
 name: vm-backup-policy  
 namespace: vm-workloads  
spec:  
 selector:  
 matchLabels:  
 backup: "enabled"  
 slaRef:  
 name: vm-backup-sla  
 backupOptions:  
 consistencyType: "application-consistent"  
 excludedDisks: []  
 includeIndexing: true  
---  
## Apply backup policy to specific VMs  
apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: critical-app-vm  
 namespace: vm-workloads  
 labels:  
 backup: "enabled"  
 tier: "production"  
spec:  
 running: true  
 template:  
 metadata:  
 labels:  
 backup: "enabled"  
 spec:  
 domain:  
 devices:  
 disks:  
 - disk:  
 bus: virtio  
 name: rootdisk  
 memory:  
 guest: 8Gi  
 cpu:  
 cores: 4  
 volumes:  
 - dataVolume:  
 name: critical-app-vm-dv  
 name: rootdisk

##### 37.1.4.2.2 On-Demand Backup Configuration

## Trigger immediate backup using Rubrik CLI  
rubrik backup vm --vm-name "critical-app-vm" --namespace "vm-workloads" --sla "VM Production Backup"  
  
## Schedule backup using Rubrik API  
curl -X POST "https://rubrik-cdm.example.com/api/internal/vmware/vm/{vm-id}/snapshot" \  
 -H "Authorization: Bearer ${RUBRIK\_TOKEN}" \  
 -H "Content-Type: application/json" \  
 -d '{  
 "slaId": "vm-backup-sla-id",  
 "archivalPolicy": {  
 "locationId": "cloud-archive-location",  
 "retentionDays": 2555  
 }  
 }'

#### 37.1.4.3 Step 3: Configure Backup Storage and Replication

##### 37.1.4.3.1 Cloud Archive Configuration

apiVersion: rubrik.com/v1  
kind: CloudArchive  
metadata:  
 name: aws-s3-archive  
 namespace: rubrik-system  
spec:  
 provider: "AWS"  
 bucketName: "rubrik-vm-backups"  
 region: "us-west-2"  
 encryptionType: "AWS\_KMS"  
 credentials:  
 secretRef:  
 name: aws-credentials  
 namespace: rubrik-system  
 storageClass: "GLACIER"  
 retentionLock: true  
 retentionLockDurationDays: 2555 # 7 years  
---  
apiVersion: v1  
kind: Secret  
metadata:  
 name: aws-credentials  
 namespace: rubrik-system  
type: Opaque  
data:  
 access-key-id: <base64-encoded-access-key>  
 secret-access-key: <base64-encoded-secret-key>

##### 37.1.4.3.2 Replication Target Configuration

apiVersion: rubrik.com/v1  
kind: ReplicationTarget  
metadata:  
 name: dr-site-rubrik  
 namespace: rubrik-system  
spec:  
 targetClusterAddress: "rubrik-dr.example.com"  
 credentials:  
 secretRef:  
 name: dr-rubrik-credentials  
 replicationBandwidth: "100 Mbps"  
 encryptionInTransit: true  
 retentionOnTarget: 90 # days

#### 37.1.4.4 Step 4: Implement Recovery Procedures

##### 37.1.4.4.1 Instant Recovery Configuration

apiVersion: rubrik.com/v1  
kind: VMRecovery  
metadata:  
 name: vm-instant-recovery  
 namespace: vm-workloads  
spec:  
 sourceVM:  
 name: "critical-app-vm"  
 namespace: "vm-workloads"  
 recoveryPoint:  
 snapshotId: "snapshot-id-from-rubrik"  
 # or use timestamp  
 # timestamp: "2024-01-15T10:30:00Z"  
 recoveryOptions:  
 type: "instant" # instant, full, or export  
 targetNamespace: "vm-recovery"  
 targetVMName: "critical-app-vm-recovered"  
 powerOn: true  
 preserveMAC: false  
 networkMapping:  
 - sourceNetwork: "production-network"  
 targetNetwork: "recovery-network"  
---  
## Alternative: Full VM Recovery  
apiVersion: rubrik.com/v1  
kind: VMRecovery  
metadata:  
 name: vm-full-recovery  
 namespace: vm-workloads  
spec:  
 sourceVM:  
 name: "critical-app-vm"  
 namespace: "vm-workloads"  
 recoveryPoint:  
 snapshotId: "latest"  
 recoveryOptions:  
 type: "full"  
 targetNamespace: "vm-workloads"  
 targetVMName: "critical-app-vm"  
 powerOn: false  
 overwriteExisting: true

##### 37.1.4.4.2 Granular File Recovery

## Mount VM snapshot for file-level recovery  
rubrik vm mount --vm-name "critical-app-vm" \  
 --snapshot-id "snapshot-id" \  
 --mount-path "/mnt/recovery" \  
 --read-only  
  
## Extract specific files  
cp /mnt/recovery/important-file.txt /recovery/destination/  
  
## Unmount when recovery is complete  
rubrik vm unmount --mount-id "mount-id"

##### 37.1.4.4.3 Cross-Platform Recovery

## Export VM to different platform (e.g., VMware to KubeVirt)  
apiVersion: rubrik.com/v1  
kind: VMExport  
metadata:  
 name: vm-cross-platform-recovery  
 namespace: vm-workloads  
spec:  
 sourceVM:  
 name: "legacy-vmware-vm"  
 platform: "vmware"  
 exportOptions:  
 targetPlatform: "kubevirt"  
 targetNamespace: "migrated-workloads"  
 format: "ova"  
 targetStorage:  
 storageClass: "fast-ssd"  
 size: "100Gi"  
 conversionOptions:  
 optimizeForKubernetes: true  
 removeVMwareTools: true  
 installKubernetesAgents: true

### 37.1.5 Troubleshooting Guide

#### 37.1.5.1 Common Issues and Solutions

##### 37.1.5.1.1 Rubrik Connector Issues

* **Issue**: Rubrik connector cannot communicate with CDM
* **Solution**:
  + Verify network connectivity between OpenShift cluster and Rubrik CDM
  + Check Rubrik credentials in the secret
  + Ensure proper RBAC permissions for the connector service account

##### 37.1.5.1.2 Backup Failures

* **Issue**: VM backups failing or incomplete
* **Solution**:
  + Check VM quiesce settings and ensure VM tools are installed
  + Verify SLA domain configuration and policies
  + Monitor Rubrik cluster storage capacity
  + Review backup logs in Rubrik Polaris dashboard

##### 37.1.5.1.3 Recovery Performance Issues

* **Issue**: Slow recovery or instant recovery not working
* **Solution**:
  + Verify network bandwidth between Rubrik and OpenShift cluster
  + Check storage performance on target environment
  + Use Rubrik’s storage optimization features
  + Consider using local recovery points for faster access

##### 37.1.5.1.4 Replication and Archive Issues

* **Issue**: Replication to remote site or cloud archive failing
* **Solution**:
  + Verify bandwidth allocation and network policies
  + Check cloud credentials and permissions
  + Review replication target configuration
  + Monitor Rubrik cluster bandwidth utilization

### 37.1.6 Best Practices

* **Regular Backups**: Schedule regular backups and snapshots for critical VMs.
* **Test Recovery**: Regularly test recovery procedures using Rubrik capabilities to ensure data integrity.
* **Security and Compliance**: Leverage Rubrik’s built-in encryption and compliance features.

### 37.1.7 Integration with RH OVE Ecosystem

#### 37.1.7.1 Monitoring and Alerting Integration

## Rubrik Metrics ServiceMonitor  
apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: rubrik-metrics  
 namespace: rubrik-system  
spec:  
 selector:  
 matchLabels:  
 app: rubrik-connector  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics  
---  
## Rubrik Backup Alerts  
apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: rubrik-backup-alerts  
 namespace: rubrik-system  
spec:  
 groups:  
 - name: rubrik.backup  
 rules:  
 - alert: RubrikBackupFailure  
 expr: rubrik\_backup\_failures\_total > 0  
 for: 5m  
 labels:  
 severity: critical  
 annotations:  
 summary: "Rubrik backup failure detected"  
 description: "VM backup has failed for {{ $labels.vm\_name }}"  
   
 - alert: RubrikClusterCapacity  
 expr: rubrik\_cluster\_used\_capacity\_percentage > 85  
 for: 10m  
 labels:  
 severity: warning  
 annotations:  
 summary: "Rubrik cluster capacity high"  
 description: "Rubrik cluster is {{ $value }}% full"  
   
 - alert: RubrikReplicationDelay  
 expr: rubrik\_replication\_lag\_minutes > 60  
 for: 15m  
 labels:  
 severity: warning  
 annotations:  
 summary: "Rubrik replication lag detected"  
 description: "Replication is {{ $value }} minutes behind"

#### 37.1.7.2 GitOps Integration

apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: rubrik-backup-policies  
 namespace: argocd  
spec:  
 project: platform-services  
 source:  
 repoURL: https://git.example.com/rubrik-backup-config  
 targetRevision: HEAD  
 path: policies/production  
 destination:  
 server: https://kubernetes.default.svc  
 namespace: vm-workloads  
 syncPolicy:  
 automated:  
 prune: false  
 selfHeal: true  
 syncOptions:  
 - CreateNamespace=true

#### 37.1.7.3 Multi-Cluster Backup Management

* **Centralized Management**: Use Rubrik Polaris to manage backup policies across multiple OpenShift clusters
* **Cross-Cluster Recovery**: Implement recovery procedures that can restore VMs to different clusters
* **Global SLA Management**: Define consistent backup policies across the entire RH OVE ecosystem

This guide provides the necessary steps and best practices for implementing VM backup and recovery processes in the RH OVE environment, ensuring data resilience and availability for enterprise workloads.

# 38 Hybrid Applications

## 38.1 Use Case: Hybrid Application Deployment (VMs, Containers, and PaaS)

### 38.1.1 Business Context

Organizations increasingly adopt hybrid application models involving VMs, containers, and Platform-as-a-Service (PaaS) solutions to streamline operations and leverage the cloud. This use case demonstrates how to integrate these diverse technologies within the RH OVE multi-cluster ecosystem, maximizing flexibility and efficiency.

### 38.1.2 Technical Requirements

#### 38.1.2.1 Infrastructure Requirements

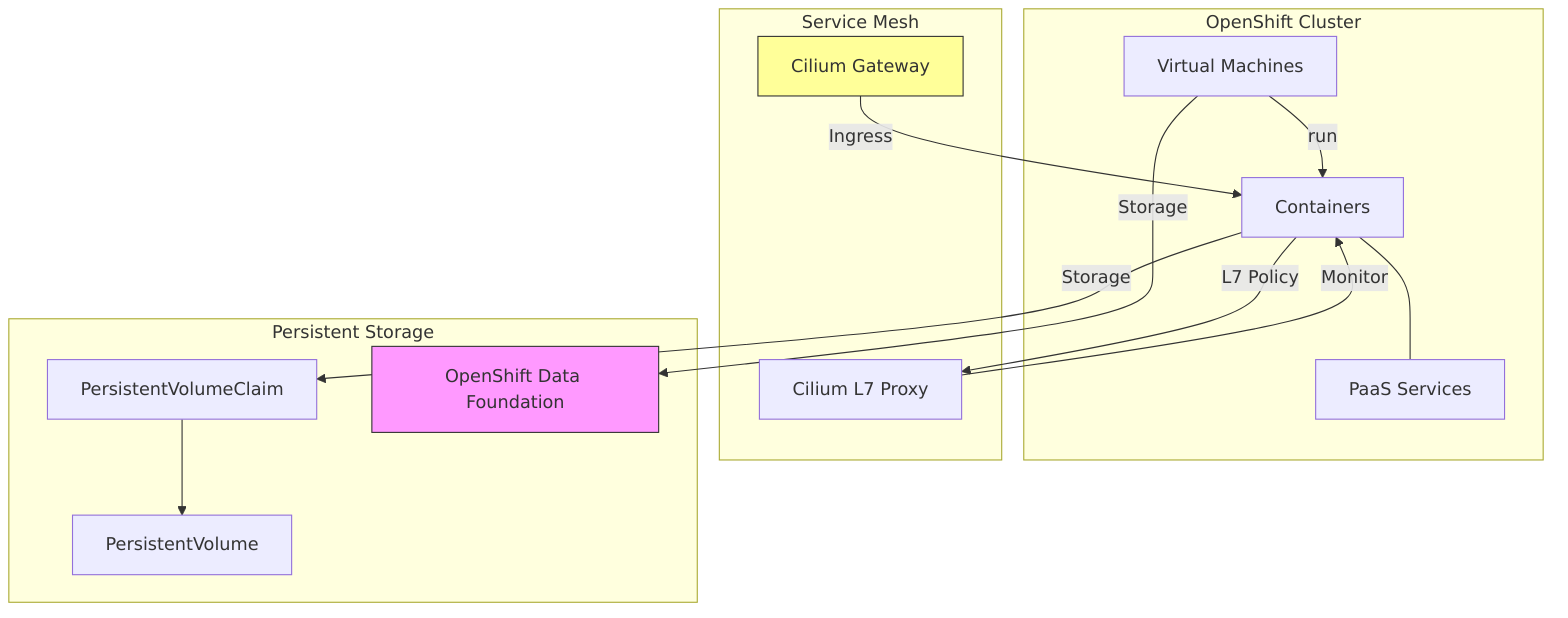
* OpenShift 4.12+ with OpenShift Virtualization enabled
* KubeVirt for VM support
* Cilium CNI with service mesh capabilities
* Persistent storage solution (e.g., OpenShift Data Foundation)
* Multus for multi-network support

#### 38.1.2.2 Resource Requirements

* **CPU**: 2+ cores per microservice or VM
* **Memory**: 4GB+ RAM per microservice or VM
* **Storage**: 20GB+ per microservice, scalable as needed
* **Network**: High throughput, low latency network configuration

### 38.1.3 Architecture Overview

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 38.1.4 Implementation Steps

#### 38.1.4.1 Step 1: VM Integration

##### 38.1.4.1.1 Provision Virtual Machines

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: app-vm  
 namespace: hybrid-app  
spec:  
 running: true  
 template:  
 spec:  
 domain:  
 devices:  
 disks:  
 - disk:  
 bus: virtio  
 name: rootdisk  
 networks:  
 - networkName: default  
 pod: {}  
 volumes:  
 - dataVolume:  
 name: app-vm-dv  
 name: rootdisk  
---  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: app-vm-dv  
 namespace: hybrid-app  
spec:  
 source:  
 http:  
 url: "https://vm-images.example.com/app-vm.img"  
 pvc:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 50Gi

#### 38.1.4.2 Step 2: Container Integration

##### 38.1.4.2.1 Deploy Containerized Services

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: app-container  
 namespace: hybrid-app  
spec:  
 replicas: 3  
 selector:  
 matchLabels:  
 app: app-container  
 template:  
 metadata:  
 labels:  
 app: app-container  
 spec:  
 containers:  
 - name: app  
 image: quay.io/example/app-image:latest  
 ports:  
 - containerPort: 8080  
 volumes:  
 - name: app-storage  
 persistentVolumeClaim:  
 claimName: app-pvc  
---  
apiVersion: v1  
kind: PersistentVolumeClaim  
metadata:  
 name: app-pvc  
 namespace: hybrid-app  
spec:  
 accessModes:  
 - ReadWriteMany  
 resources:  
 requests:  
 storage: 100Gi

#### 38.1.4.3 Step 3: Service Mesh Enablement

##### 38.1.4.3.1 Configure Cilium Gateway API and L7 Policies

apiVersion: gateway.networking.k8s.io/v1beta1  
kind: Gateway  
metadata:  
 name: app-gateway  
 namespace: hybrid-app  
spec:  
 gatewayClassName: cilium  
 listeners:  
 - name: http  
 port: 80  
 protocol: HTTP  
 hostname: "app.example.com"  
---  
apiVersion: gateway.networking.k8s.io/v1beta1  
kind: HTTPRoute  
metadata:  
 name: app-routing  
 namespace: hybrid-app  
spec:  
 parentRefs:  
 - name: app-gateway  
 hostnames:  
 - "app.example.com"  
 rules:  
 - matches:  
 - path:  
 type: PathPrefix  
 value: "/"  
 backendRefs:  
 - name: app-container  
 port: 8080  
---  
apiVersion: "cilium.io/v2"  
kind: CiliumNetworkPolicy  
metadata:  
 name: app-l7-policy  
 namespace: hybrid-app  
spec:  
 endpointSelector:  
 matchLabels:  
 app: app-container  
 ingress:  
 - fromEndpoints:  
 - matchLabels:  
 "k8s:io.cilium.k8s.policy.cluster": "default"  
 toPorts:  
 - ports:  
 - port: "8080"  
 protocol: TCP  
 rules:  
 http:  
 - method: "GET"  
 - method: "POST"  
 - method: "PUT"  
 - method: "DELETE"  
  
#### Step 4: PaaS Integration  
  
##### Deploy Middleware and Database Services  
```yaml  
apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: middleware  
 namespace: hybrid-app  
spec:  
 replicas: 2  
 selector:  
 matchLabels:  
 app: middleware  
 template:  
 metadata:  
 labels:  
 app: middleware  
 spec:  
 containers:  
 - name: middleware  
 image: quay.io/example/middleware-image:latest  
 env:  
 - name: DB\_HOST  
 value: db.example.com  
 - name: DB\_USER  
 valueFrom:  
 secretKeyRef:  
 name: db-secrets  
 key: username  
---  
apiVersion: v1  
kind: Service  
metadata:  
 name: middleware-service  
 namespace: hybrid-app  
spec:  
 selector:  
 app: middleware  
 ports:  
 - protocol: TCP  
 port: 8080  
 targetPort: 8080  
 type: ClusterIP

#### 38.1.4.4 Step 5: Continuous Integration/Continuous Deployment (CI/CD)

##### 38.1.4.4.1 Integrate with ArgoCD

apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: hybrid-app  
 namespace: argocd  
spec:  
 project: default  
 source:  
 repoURL: https://git.example.com/hybrid-app-config  
 targetRevision: HEAD  
 path: hybrid  
 destination:  
 server: https://kubernetes.default.svc  
 namespace: hybrid-app  
 syncPolicy:  
 automated:  
 prune: false  
 selfHeal: true

### 38.1.5 Troubleshooting Guide

#### 38.1.5.1 Common Issues and Solutions

##### 38.1.5.1.1 VM Performance Degradation

* Check resource allocation and adjust CPU/RAM as needed.
* Ensure the underlying storage is not a bottleneck.

##### 38.1.5.1.2 Service Mesh Connectivity Issues

* Validate Cilium Gateway API configurations and ensure L7 policies are applied.
* Check Cilium network policies and ensure proper endpoint selection.

##### 38.1.5.1.3 Storage Access Issues

* Verify PVC binding and ensure correct storage class is applied.
* Check application logs for connectivity and permission errors.

### 38.1.6 Best Practices

* **Resource Management**: Dynamic scaling policies for both VMs and containers.
* **Network Policies**: Zero-trust approach with Cilium network policies for clear segmentation.
* **Security Hardening**: Apply security best practices for VM and container images with Cilium L7 policies.
* **Monitoring and Logging**: Unified logging solutions using Fluentd or Logstash with direct integration to Prometheus and Cilium Hubble for network observability.

### 38.1.7 Integration with RH OVE Ecosystem

#### 38.1.7.1 Monitoring Integration

## Monitoring and alerting configuration  
apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: hybrid-app-monitor  
 namespace: hybrid-app  
spec:  
 selector:  
 matchLabels:  
 app: app-container  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics

This comprehensive guide provides everything needed to deploy and manage hybrid applications within the RH OVE multi-cluster ecosystem while adhering to enterprise-grade security, monitoring, and operational standards.

# 39 Multi-Environment Setup

## 39.1 Use Case: Setup a New Application with 3 Environments (Dev, Lat, Prod)

### 39.1.1 Business Context

Setting up distinct environments for development, testing (LAT - User Acceptance Testing level), and production is crucial for ensuring software quality and stability. This use case demonstrates deploying applications across multiple clusters and namespaces, with development running on a separate cluster for enhanced isolation, while LAT and production environments share a cluster but use different namespaces.

**Key Focus: Label-Based Application Management** This use case emphasizes the strategic use of Kubernetes labels for effective application lifecycle management, environment identification, resource organization, and automated operations across multi-cluster deployments.

### 39.1.2 Label Management Strategy

#### 39.1.2.1 Core Labeling Standards

This implementation follows a comprehensive labeling strategy for consistent resource management:

##### 39.1.2.1.1 Standard Label Schema

## Application identification labels  
app.kubernetes.io/name: <application-name> # Application name  
app.kubernetes.io/version: <version> # Application version  
app.kubernetes.io/component: <component> # Component type (frontend, backend, database)  
app.kubernetes.io/part-of: <system> # Higher-level application/system  
app.kubernetes.io/managed-by: <tool> # Management tool (argocd, helm, etc.)  
  
## Environment and deployment labels  
environment: <env> # Environment (dev, lat, prod)   
tier: <tier> # Tier (production, non-production)  
cluster: <cluster-name> # Target cluster identifier  
region: <region> # Geographic region  
  
## Operational labels  
owner: <team> # Owning team  
cost-center: <code> # Cost allocation  
monitoring: <enabled/disabled> # Monitoring status  
backup: <policy> # Backup policy

##### 39.1.2.1.2 Label Selection and Filtering Examples

## Select all resources for a specific application  
kubectl get all -l app.kubernetes.io/name=sample-app  
  
## Select resources by environment  
kubectl get pods -l environment=prod  
  
## Select resources by cluster and environment  
kubectl get deployments -l cluster=prod-cluster,environment=lat  
  
## Select all production tier resources  
kubectl get services -l tier=production  
  
## Select resources managed by ArgoCD  
kubectl get all -l app.kubernetes.io/managed-by=argocd

### 39.1.3 Technical Requirements

#### 39.1.3.1 Infrastructure Requirements

* **Development Cluster**: Dedicated OpenShift 4.12+ cluster for development workloads
* **Production Cluster**: OpenShift 4.12+ cluster hosting LAT and Production environments
* Red Hat Advanced Cluster Management (RHACM) for multi-cluster management
* Network connectivity between clusters for GitOps and management operations
* Shared container registry accessible by both clusters

#### 39.1.3.2 Resource Requirements

##### 39.1.3.2.1 Development Cluster

* **CPU**: 4-8 cores for development workloads
* **Memory**: 16-32GB RAM for development environments
* **Storage**: Fast local storage for rapid development cycles
* **Network**: Internal network access, limited external exposure

##### 39.1.3.2.2 Production Cluster

* **CPU**: 16-32 cores for LAT and Production workloads
* **Memory**: 64-128GB RAM for production-grade environments
* **Storage**: Enterprise-grade persistent storage with backup capabilities
* **Network**: Full production network access with security controls

### 39.1.4 Architecture Overview

**[Mermaid Flowchart/Graph Diagram - Rendering Failed]**

graph TD  
 subgraph "Development Cluster"  
 DEV\_NS["Development Namespace"]  
 DEV\_APP["Application: v1.0.0-dev"]  
 DEV\_CONFIG["Dev ConfigMaps/Secrets"]  
 DEV\_STORAGE["Dev Storage"]  
 end  
  
 subgraph "Production Cluster"  
 subgraph "LAT Environment"  
 LAT\_NS["LAT Namespace"]  
 LAT\_APP["Application: v1.0.0-rc"]  
 LAT\_CONFIG["LAT ConfigMaps/Secrets"]  
 LAT\_STORAGE["LAT Storage"]  
 end  
   
 subgraph "Production Environment"  
 PROD\_NS["Production Namespace"]  
 PROD\_APP["Application: v1.0.0"]  
 PROD\_CONFIG["Prod ConfigMaps/Secrets"]  
 PROD\_STORAGE["Prod Storage"]  
 end  
 end  
  
 subgraph "Shared Infrastructure"  
 REGISTRY["Container Registry"]  
 RHACM["Red Hat ACM"]  
 GITOPS["GitOps (ArgoCD)"]  
 end  
  
 DEV\_NS --> DEV\_APP  
 DEV\_APP --> DEV\_CONFIG  
 DEV\_APP --> DEV\_STORAGE  
   
 LAT\_NS --> LAT\_APP  
 LAT\_APP --> LAT\_CONFIG  
 LAT\_APP --> LAT\_STORAGE  
   
 PROD\_NS --> PROD\_APP  
 PROD\_APP --> PROD\_CONFIG  
 PROD\_APP --> PROD\_STORAGE  
  
 REGISTRY --> DEV\_APP  
 REGISTRY --> LAT\_APP  
 REGISTRY --> PROD\_APP  
   
 RHACM --> DEV\_NS  
 RHACM --> LAT\_NS  
 RHACM --> PROD\_NS  
   
 GITOPS --> DEV\_NS  
 GITOPS --> LAT\_NS  
 GITOPS --> PROD\_NS  
  
 style DEV\_NS fill:#ddf,stroke:#333  
 style LAT\_NS fill:#ffd,stroke:#333  
 style PROD\_NS fill:#fdd,stroke:#333  
 style REGISTRY fill:#f9f,stroke:#333  
 style RHACM fill:#9ff,stroke:#333

*Note: Diagram rendering failed, showing code instead.*

### 39.1.5 Implementation Steps

#### 39.1.5.1 Step 1: Setup Multi-Cluster Management with RHACM

##### 39.1.5.1.1 Deploy RHACM Hub Cluster

apiVersion: operator.open-cluster-management.io/v1  
kind: MultiClusterHub  
metadata:  
 name: multiclusterhub  
 namespace: open-cluster-management  
spec:  
 availabilityConfig: High  
 enableClusterBackup: true  
 imagePullSecret: multiclusterhub-operator-pull-secret

##### 39.1.5.1.2 Register Development Cluster as Managed Cluster

apiVersion: cluster.open-cluster-management.io/v1  
kind: ManagedCluster  
metadata:  
 name: dev-cluster  
 labels:  
 # Cluster identification labels  
 cloud: auto-detect  
 vendor: OpenShift  
 environment: development  
 cluster-role: development  
 # Management labels  
 managed-by: rhacm  
 region: us-east-1  
 tier: non-production  
 # Operational labels  
 monitoring: enabled  
 cost-center: dev-ops  
 owner: platform-team  
spec:  
 hubAcceptsClient: true  
---  
apiVersion: agent.open-cluster-management.io/v1  
kind: KlusterletAddonConfig  
metadata:  
 name: dev-cluster  
 namespace: dev-cluster  
spec:  
 clusterName: dev-cluster  
 clusterNamespace: dev-cluster  
 clusterLabels:  
 cloud: auto-detect  
 vendor: OpenShift  
 environment: development  
 cluster-role: development  
 tier: non-production  
 region: us-east-1  
 applicationManager:  
 enabled: true  
 policyController:  
 enabled: true  
 searchCollector:  
 enabled: true  
 certPolicyController:  
 enabled: true  
 iamPolicyController:  
 enabled: true

#### 39.1.5.2 Step 2: Create Namespaces Across Clusters

##### 39.1.5.2.1 Development Cluster - Namespace Configuration

## Apply to Development Cluster  
apiVersion: v1  
kind: Namespace  
metadata:  
 name: development  
 labels:  
 # Standard Kubernetes labels  
 name: development  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/part-of: sample-system  
 app.kubernetes.io/managed-by: argocd  
   
 # Environment and deployment labels  
 environment: dev  
 tier: non-production  
 cluster: dev-cluster  
 region: us-east-1  
   
 # Operational labels  
 owner: dev-team  
 cost-center: engineering  
 monitoring: enabled  
 backup: daily  
   
 # Feature flags for this environment  
 feature.experimental: "true"  
 feature.debug: "true"  
 annotations:  
 openshift.io/description: "Development environment for sample application"  
 openshift.io/display-name: "Sample App - Development"  
 cluster.open-cluster-management.io/managedCluster: "dev-cluster"  
 # Label management annotations  
 label-policy.io/required: "environment,tier,owner"  
 label-policy.io/validation: "strict"

##### 39.1.5.2.2 Production Cluster - LAT and Production Namespaces

## Apply to Production Cluster  
apiVersion: v1  
kind: Namespace  
metadata:  
 name: lat  
 labels:  
 # Standard Kubernetes labels  
 name: lat  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/part-of: sample-system  
 app.kubernetes.io/managed-by: argocd  
   
 # Environment and deployment labels  
 environment: lat  
 tier: non-production  
 cluster: prod-cluster  
 region: us-east-1  
   
 # Operational labels  
 owner: qa-team  
 cost-center: quality-assurance  
 monitoring: enabled  
 backup: weekly  
   
 # Feature flags for LAT environment  
 feature.experimental: "false"  
 feature.debug: "false"  
 feature.performance-testing: "true"  
 annotations:  
 openshift.io/description: "LAT/UAT environment for sample application"  
 openshift.io/display-name: "Sample App - LAT"  
 cluster.open-cluster-management.io/managedCluster: "prod-cluster"  
 label-policy.io/required: "environment,tier,owner"  
 label-policy.io/validation: "strict"  
---  
apiVersion: v1  
kind: Namespace  
metadata:  
 name: production  
 labels:  
 # Standard Kubernetes labels  
 name: production  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/part-of: sample-system  
 app.kubernetes.io/managed-by: argocd  
   
 # Environment and deployment labels  
 environment: prod  
 tier: production  
 cluster: prod-cluster  
 region: us-east-1  
   
 # Operational labels  
 owner: platform-team  
 cost-center: production-ops  
 monitoring: enhanced  
 backup: continuous  
   
 # Production-specific feature flags  
 feature.experimental: "false"  
 feature.debug: "false"  
 feature.high-availability: "true"  
 feature.auto-scaling: "true"  
 annotations:  
 openshift.io/description: "Production environment for sample application"  
 openshift.io/display-name: "Sample App - Production"  
 cluster.open-cluster-management.io/managedCluster: "prod-cluster"  
 label-policy.io/required: "environment,tier,owner,backup"  
 label-policy.io/validation: "strict"

#### 39.1.5.3 Step 3: Configure Cross-Cluster GitOps with ArgoCD

##### 39.1.5.3.1 ArgoCD ApplicationSet for Multi-Cluster Deployment with Label-Based Selection

apiVersion: argoproj.io/v1alpha1  
kind: ApplicationSet  
metadata:  
 name: sample-app-multi-env  
 namespace: argocd  
 labels:  
 # ApplicationSet identification  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: applicationset  
 app.kubernetes.io/managed-by: argocd  
 app.kubernetes.io/part-of: sample-system  
 # Management labels  
 owner: platform-team  
 deployment-strategy: multi-cluster  
spec:  
 generators:  
 # Development cluster selector  
 - clusters:  
 selector:  
 matchLabels:  
 environment: development  
 tier: non-production  
 values:  
 environment: development  
 namespace: development  
 imageTag: "1.0.0-dev"  
 replicas: "2"  
 resources: "small"  
 cluster\_type: "development"  
 # LAT environment selector (on production cluster)  
 - clusters:  
 selector:  
 matchLabels:  
 cluster-role: production  
 tier: production  
 values:  
 environment: lat  
 namespace: lat  
 imageTag: "1.0.0-rc"  
 replicas: "2"  
 resources: "medium"  
 cluster\_type: "production"  
 # Production environment selector  
 - clusters:  
 selector:  
 matchLabels:  
 cluster-role: production  
 tier: production  
 values:  
 environment: production  
 namespace: production  
 imageTag: "1.0.0"  
 replicas: "5"  
 resources: "large"  
 cluster\_type: "production"  
 template:  
 metadata:  
 name: 'sample-app-{{values.environment}}'  
 labels:  
 # Application labels for ArgoCD application  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: application  
 app.kubernetes.io/managed-by: argocd  
 environment: '{{values.environment}}'  
 cluster-type: '{{values.cluster\_type}}'  
 spec:  
 project: default  
 source:  
 repoURL: https://git.example.com/sample-app-config  
 targetRevision: HEAD  
 path: overlays/{{values.environment}}  
 helm:  
 parameters:  
 - name: image.tag  
 value: '{{values.imageTag}}'  
 - name: replicaCount  
 value: '{{values.replicas}}'  
 - name: resources.profile  
 value: '{{values.resources}}'  
 - name: environment  
 value: '{{values.environment}}'  
 - name: cluster\_type  
 value: '{{values.cluster\_type}}'  
 destination:  
 server: '{{server}}'  
 namespace: '{{values.namespace}}'  
 syncPolicy:  
 automated:  
 prune: true  
 selfHeal: true  
 syncOptions:  
 - CreateNamespace=true  
 - RespectIgnoreDifferences=true

#### 39.1.5.4 Step 4: Configure RBAC and Service Accounts

##### 39.1.5.4.1 Development Cluster Service Account with Enhanced Labels

## Apply to Development Cluster  
apiVersion: v1  
kind: ServiceAccount  
metadata:  
 name: sample-app-sa  
 namespace: development  
 labels:  
 # Standard Kubernetes labels  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: serviceaccount  
 app.kubernetes.io/managed-by: kubectl  
 app.kubernetes.io/part-of: sample-system  
   
 # Environment and deployment labels  
 app: sample-app  
 environment: dev  
 cluster: dev-cluster  
 tier: non-production  
   
 # RBAC and security labels  
 security.io/rbac: enabled  
 security.io/scope: namespace  
   
 # Operational labels  
 owner: dev-team  
 managed-by: platform-team  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: Role  
metadata:  
 name: sample-app-role  
 namespace: development  
rules:  
- apiGroups: [""]  
 resources: ["configmaps", "secrets", "pods", "services"]  
 verbs: ["get", "list", "watch"]  
- apiGroups: ["apps"]  
 resources: ["deployments", "replicasets"]  
 verbs: ["get", "list", "watch"]  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: RoleBinding  
metadata:  
 name: sample-app-rolebinding  
 namespace: development  
subjects:  
- kind: ServiceAccount  
 name: sample-app-sa  
 namespace: development  
roleRef:  
 kind: Role  
 name: sample-app-role  
 apiGroup: rbac.authorization.k8s.io

##### 39.1.5.4.2 Production Cluster Service Accounts with Enhanced Labels

## Apply to Production Cluster - LAT Environment  
apiVersion: v1  
kind: ServiceAccount  
metadata:  
 name: sample-app-sa  
 namespace: lat  
 labels:  
 # Standard Kubernetes labels  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: serviceaccount  
 app.kubernetes.io/managed-by: kubectl  
 app.kubernetes.io/part-of: sample-system  
   
 # Environment and deployment labels  
 app: sample-app  
 environment: lat  
 cluster: prod-cluster  
 tier: non-production  
   
 # RBAC and security labels  
 security.io/rbac: enabled  
 security.io/scope: namespace  
 security.io/audit: enabled  
   
 # Operational labels  
 owner: qa-team  
 managed-by: platform-team  
---  
## Apply to Production Cluster - Production Environment  
apiVersion: v1  
kind: ServiceAccount  
metadata:  
 name: sample-app-sa  
 namespace: production  
 labels:  
 # Standard Kubernetes labels  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: serviceaccount  
 app.kubernetes.io/managed-by: kubectl  
 app.kubernetes.io/part-of: sample-system  
   
 # Environment and deployment labels  
 app: sample-app  
 environment: prod  
 cluster: prod-cluster  
 tier: production  
   
 # RBAC and security labels  
 security.io/rbac: enabled  
 security.io/scope: namespace  
 security.io/audit: enhanced  
 security.io/compliance: required  
   
 # Operational labels  
 owner: platform-team  
 managed-by: platform-team  
 criticality: high

#### 39.1.5.5 Step 5: Configure Environment Specific Resources

##### 39.1.5.5.1 Development Environment Configuration (Apply to Development Cluster)

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: app-config  
 namespace: development  
 labels:  
 app: sample-app  
 environment: dev  
 cluster: dev-cluster  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: config  
data:  
 APP\_ENV: "development"  
 LOG\_LEVEL: "debug"  
 DATABASE\_HOST: "dev-postgres.development.svc.cluster.local"  
 DATABASE\_PORT: "5432"  
 DATABASE\_NAME: "sampleapp\_dev"  
 REDIS\_HOST: "dev-redis.development.svc.cluster.local"  
 REDIS\_PORT: "6379"  
 API\_BASE\_URL: "https://api-dev.example.com"  
 FEATURE\_FLAGS: "new-ui:true,beta-features:true"  
 MAX\_CONNECTIONS: "10"  
 CACHE\_TTL: "300"  
 CLUSTER\_NAME: "dev-cluster"  
---  
apiVersion: v1  
kind: Secret  
metadata:  
 name: app-secrets  
 namespace: development  
 labels:  
 app: sample-app  
 environment: dev  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: secrets  
type: Opaque  
stringData:  
 DATABASE\_PASSWORD: "dev\_password\_123"  
 REDIS\_PASSWORD: "dev\_redis\_password"  
 JWT\_SECRET: "dev\_jwt\_secret\_key"  
 API\_KEY: "dev\_api\_key\_12345"  
 ENCRYPTION\_KEY: "dev\_encryption\_key"  
---  
## LAT Environment Configuration (Apply to Production Cluster)  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: app-config  
 namespace: lat  
 labels:  
 app: sample-app  
 environment: lat  
 cluster: prod-cluster  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: config  
data:  
 APP\_ENV: "lat"  
 LOG\_LEVEL: "info"  
 DATABASE\_HOST: "lat-postgres.lat.svc.cluster.local"  
 DATABASE\_PORT: "5432"  
 DATABASE\_NAME: "sampleapp\_lat"  
 REDIS\_HOST: "lat-redis.lat.svc.cluster.local"  
 REDIS\_PORT: "6379"  
 API\_BASE\_URL: "https://api-lat.example.com"  
 FEATURE\_FLAGS: "new-ui:true,beta-features:false"  
 MAX\_CONNECTIONS: "20"  
 CACHE\_TTL: "600"  
 CLUSTER\_NAME: "prod-cluster"  
---  
apiVersion: v1  
kind: Secret  
metadata:  
 name: app-secrets  
 namespace: lat  
 labels:  
 app: sample-app  
 environment: lat  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: secrets  
type: Opaque  
stringData:  
 DATABASE\_PASSWORD: "lat\_password\_456"  
 REDIS\_PASSWORD: "lat\_redis\_password"  
 JWT\_SECRET: "lat\_jwt\_secret\_key"  
 API\_KEY: "lat\_api\_key\_67890"  
 ENCRYPTION\_KEY: "lat\_encryption\_key"  
---  
## Production Environment Configuration (Apply to Production Cluster)  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: app-config  
 namespace: production  
 labels:  
 app: sample-app  
 environment: prod  
 cluster: prod-cluster  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: config  
data:  
 APP\_ENV: "production"  
 LOG\_LEVEL: "warn"  
 DATABASE\_HOST: "prod-postgres.production.svc.cluster.local"  
 DATABASE\_PORT: "5432"  
 DATABASE\_NAME: "sampleapp\_prod"  
 REDIS\_HOST: "prod-redis.production.svc.cluster.local"  
 REDIS\_PORT: "6379"  
 API\_BASE\_URL: "https://api.example.com"  
 FEATURE\_FLAGS: "new-ui:false,beta-features:false"  
 MAX\_CONNECTIONS: "50"  
 CACHE\_TTL: "3600"  
 CLUSTER\_NAME: "prod-cluster"  
---  
apiVersion: v1  
kind: Secret  
metadata:  
 name: app-secrets  
 namespace: production  
 labels:  
 app: sample-app  
 environment: prod  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/component: secrets  
type: Opaque  
stringData:  
 DATABASE\_PASSWORD: "prod\_secure\_password\_789"  
 REDIS\_PASSWORD: "prod\_redis\_secure\_password"  
 JWT\_SECRET: "prod\_jwt\_secret\_key\_secure"  
 API\_KEY: "prod\_api\_key\_secure\_abcdef"  
 ENCRYPTION\_KEY: "prod\_encryption\_key\_secure"

#### 39.1.5.6 Step 6: Deploy Application Across Clusters and Environments

##### 39.1.5.6.1 Development Environment Deployment (Apply to Development Cluster)

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: sample-app  
 namespace: development  
 labels:  
 app: sample-app  
 environment: dev  
 cluster: dev-cluster  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/version: "1.0.0"  
 app.kubernetes.io/component: application  
spec:  
 replicas: 2  
 strategy:  
 type: RollingUpdate  
 rollingUpdate:  
 maxUnavailable: 1  
 maxSurge: 1  
 selector:  
 matchLabels:  
 app: sample-app  
 environment: dev  
 template:  
 metadata:  
 labels:  
 app: sample-app  
 environment: dev  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/version: "1.0.0"  
 spec:  
 serviceAccountName: sample-app-sa  
 containers:  
 - name: sample-app  
 image: quay.io/example/sample-app:1.0.0-dev  
 imagePullPolicy: Always  
 ports:  
 - containerPort: 8080  
 name: http  
 protocol: TCP  
 envFrom:  
 - configMapRef:  
 name: app-config  
 - secretRef:  
 name: app-secrets  
 resources:  
 requests:  
 memory: "256Mi"  
 cpu: "100m"  
 limits:  
 memory: "512Mi"  
 cpu: "200m"  
 livenessProbe:  
 httpGet:  
 path: /health/live  
 port: 8080  
 initialDelaySeconds: 30  
 periodSeconds: 10  
 timeoutSeconds: 5  
 failureThreshold: 3  
 readinessProbe:  
 httpGet:  
 path: /health/ready  
 port: 8080  
 initialDelaySeconds: 5  
 periodSeconds: 5  
 timeoutSeconds: 3  
 failureThreshold: 3  
 volumeMounts:  
 - name: app-data  
 mountPath: /data  
 - name: temp-storage  
 mountPath: /tmp  
 volumes:  
 - name: app-data  
 persistentVolumeClaim:  
 claimName: sample-app-data  
 - name: temp-storage  
 emptyDir: {}  
---  
apiVersion: v1  
kind: Service  
metadata:  
 name: sample-app-service  
 namespace: development  
 labels:  
 app: sample-app  
 environment: dev  
spec:  
 selector:  
 app: sample-app  
 environment: dev  
 ports:  
 - name: http  
 port: 80  
 targetPort: 8080  
 protocol: TCP  
 type: ClusterIP  
---  
## LAT Environment Deployment  
apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: sample-app  
 namespace: lat  
 labels:  
 app: sample-app  
 environment: lat  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/version: "1.0.0"  
 app.kubernetes.io/component: application  
spec:  
 replicas: 2  
 strategy:  
 type: RollingUpdate  
 rollingUpdate:  
 maxUnavailable: 0  
 maxSurge: 1  
 selector:  
 matchLabels:  
 app: sample-app  
 environment: lat  
 template:  
 metadata:  
 labels:  
 app: sample-app  
 environment: lat  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/version: "1.0.0"  
 spec:  
 serviceAccountName: sample-app-sa  
 containers:  
 - name: sample-app  
 image: quay.io/example/sample-app:1.0.0-rc  
 imagePullPolicy: IfNotPresent  
 ports:  
 - containerPort: 8080  
 name: http  
 protocol: TCP  
 envFrom:  
 - configMapRef:  
 name: app-config  
 - secretRef:  
 name: app-secrets  
 resources:  
 requests:  
 memory: "512Mi"  
 cpu: "250m"  
 limits:  
 memory: "1Gi"  
 cpu: "500m"  
 livenessProbe:  
 httpGet:  
 path: /health/live  
 port: 8080  
 initialDelaySeconds: 30  
 periodSeconds: 10  
 timeoutSeconds: 5  
 failureThreshold: 3  
 readinessProbe:  
 httpGet:  
 path: /health/ready  
 port: 8080  
 initialDelaySeconds: 5  
 periodSeconds: 5  
 timeoutSeconds: 3  
 failureThreshold: 3  
 volumeMounts:  
 - name: app-data  
 mountPath: /data  
 - name: temp-storage  
 mountPath: /tmp  
 volumes:  
 - name: app-data  
 persistentVolumeClaim:  
 claimName: sample-app-data  
 - name: temp-storage  
 emptyDir: {}  
---  
## Production Environment Deployment  
apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: sample-app  
 namespace: production  
 labels:  
 app: sample-app  
 environment: prod  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/version: "1.0.0"  
 app.kubernetes.io/component: application  
spec:  
 replicas: 5  
 strategy:  
 type: RollingUpdate  
 rollingUpdate:  
 maxUnavailable: 1  
 maxSurge: 2  
 selector:  
 matchLabels:  
 app: sample-app  
 environment: prod  
 template:  
 metadata:  
 labels:  
 app: sample-app  
 environment: prod  
 app.kubernetes.io/name: sample-app  
 app.kubernetes.io/version: "1.0.0"  
 spec:  
 serviceAccountName: sample-app-sa  
 containers:  
 - name: sample-app  
 image: quay.io/example/sample-app:1.0.0  
 imagePullPolicy: IfNotPresent  
 ports:  
 - containerPort: 8080  
 name: http  
 protocol: TCP  
 envFrom:  
 - configMapRef:  
 name: app-config  
 - secretRef:  
 name: app-secrets  
 resources:  
 requests:  
 memory: "1Gi"  
 cpu: "500m"  
 limits:  
 memory: "2Gi"  
 cpu: "1"  
 livenessProbe:  
 httpGet:  
 path: /health/live  
 port: 8080  
 initialDelaySeconds: 60  
 periodSeconds: 10  
 timeoutSeconds: 5  
 failureThreshold: 3  
 readinessProbe:  
 httpGet:  
 path: /health/ready  
 port: 8080  
 initialDelaySeconds: 10  
 periodSeconds: 5  
 timeoutSeconds: 3  
 failureThreshold: 3  
 volumeMounts:  
 - name: app-data  
 mountPath: /data  
 - name: temp-storage  
 mountPath: /tmp  
 volumes:  
 - name: app-data  
 persistentVolumeClaim:  
 claimName: sample-app-data  
 - name: temp-storage  
 emptyDir: {}  
 affinity:  
 podAntiAffinity:  
 preferredDuringSchedulingIgnoredDuringExecution:  
 - weight: 100  
 podAffinityTerm:  
 labelSelector:  
 matchExpressions:  
 - key: app  
 operator: In  
 values:  
 - sample-app  
 topologyKey: kubernetes.io/hostname

#### 39.1.5.7 Step 5: Configure Persistent Storage

##### 39.1.5.7.1 PersistentVolumeClaims for Each Environment

apiVersion: v1  
kind: PersistentVolumeClaim  
metadata:  
 name: sample-app-data  
 namespace: development  
 labels:  
 app: sample-app  
 environment: dev  
spec:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 5Gi  
 storageClassName: ocs-storagecluster-ceph-rbd  
---  
apiVersion: v1  
kind: PersistentVolumeClaim  
metadata:  
 name: sample-app-data  
 namespace: lat  
 labels:  
 app: sample-app  
 environment: lat  
spec:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 10Gi  
 storageClassName: ocs-storagecluster-ceph-rbd  
---  
apiVersion: v1  
kind: PersistentVolumeClaim  
metadata:  
 name: sample-app-data  
 namespace: production  
 labels:  
 app: sample-app  
 environment: prod  
spec:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 50Gi  
 storageClassName: ocs-storagecluster-ceph-rbd

#### 39.1.5.8 Step 6: Configure Network and Resource Policies

##### 39.1.5.8.1 Network Policies

apiVersion: networking.k8s.io/v1  
kind: NetworkPolicy  
metadata:  
 name: allow-specific  
 namespace: development  
spec:  
 podSelector:  
 matchLabels:  
 app: sample-app  
 policyTypes:  
 - Ingress  
 - Egress  
 ingress:  
 - from:  
 - ipBlock:  
 cidr: 10.0.0.0/8  
 egress:  
 - to:  
 - ipBlock:  
 cidr: 10.0.0.0/8  
---  
## Repeat for LAT and Prod with respective rules

##### 39.1.5.8.2 Resource Quotas

apiVersion: v1  
kind: ResourceQuota  
metadata:  
 name: compute-resources  
 namespace: development  
spec:  
 hard:  
 requests.cpu: "2"  
 requests.memory: 4Gi  
 limits.cpu: "4"  
 limits.memory: 8Gi  
---  
## Repeat for LAT and Prod with tailored allocations

#### 39.1.5.9 Validation and Testing

##### 39.1.5.9.1 Validate Deployments

kubectl get deployments -n development  
kubectl get pods -n development  
kubectl get services -n development

* Verify that all resources are correctly deployed and running.

##### 39.1.5.9.2 Test Application Functionality

* Ensure each environment functions as expected from development to LAT and into production.

#### 39.1.5.10 Label-Based Management Operations

##### 39.1.5.10.1 Advanced Label Queries and Operations

## Application lifecycle management using labels  
  
## Find all resources belonging to sample-app across all environments  
kubectl get all --all-namespaces -l app.kubernetes.io/name=sample-app  
  
## Get all production tier resources  
kubectl get all --all-namespaces -l tier=production  
  
## List all resources managed by ArgoCD  
kubectl get all --all-namespaces -l app.kubernetes.io/managed-by=argocd  
  
## Find resources by owner team  
kubectl get all --all-namespaces -l owner=platform-team  
  
## Get all development environment resources  
kubectl get all --all-namespaces -l environment=dev  
  
## Find all resources with backup enabled  
kubectl get all --all-namespaces -l backup!=none  
  
## Complex queries combining multiple labels  
kubectl get deployments --all-namespaces -l 'app.kubernetes.io/name=sample-app,tier=production'  
  
## Scale all deployments in development environment  
kubectl scale deployments -l environment=dev --replicas=1 --all-namespaces  
  
## Delete all test resources (be careful!)  
kubectl delete all -l environment=test --all-namespaces

##### 39.1.5.10.2 Label-Based Resource Policies

## OPA Gatekeeper policy to enforce required labels  
apiVersion: templates.gatekeeper.sh/v1beta1  
kind: ConstraintTemplate  
metadata:  
 name: k8srequiredlabels  
spec:  
 crd:  
 spec:  
 names:  
 kind: K8sRequiredLabels  
 validation:  
 type: object  
 properties:  
 labels:  
 type: array  
 items:  
 type: string  
 targets:  
 - target: admission.k8s.gatekeeper.sh  
 rego: |  
 package k8srequiredlabels  
   
 violation[{"msg": msg}] {  
 required := input.parameters.labels  
 provided := input.review.object.metadata.labels  
 missing := required[\_]  
 not provided[missing]  
 msg := sprintf("Missing required label: %v", [missing])  
 }  
---  
apiVersion: constraints.gatekeeper.sh/v1beta1  
kind: K8sRequiredLabels  
metadata:  
 name: must-have-environment  
spec:  
 match:  
 kinds:  
 - apiGroups: ["apps"]  
 kinds: ["Deployment"]  
 - apiGroups: [""]  
 kinds: ["Service"]  
 parameters:  
 labels: ["environment", "owner", "app.kubernetes.io/name"]

#### 39.1.5.11 Best Practices for Label Management

##### 39.1.5.11.1 Label Strategy Best Practices

* **Consistent Naming**: Use standardized label keys across all environments
* **Hierarchical Organization**: Implement app.kubernetes.io standard labels
* **Environment Identification**: Always include environment and tier labels
* **Ownership Tracking**: Include owner and cost-center labels for accountability
* **Automation Friendly**: Design labels for automated selection and management
* **Policy Enforcement**: Use admission controllers to enforce required labels

##### 39.1.5.11.2 Configuration Management

* **Consistent Configuration Management**: Use ConfigMaps and Secrets effectively across environments.
* **Isolation**: Ensure namespaces are isolated to prevent cross-environment contamination.
* **Resource Management**: Tailor quotas and limits to reflect environment purposes.
* **Automation**: Implement CI/CD pipelines for streamlined deployments.
* **Monitoring**: Use Prometheus and Grafana for monitoring and alerts.

##### 39.1.5.11.3 Label-Based Monitoring and Alerting

## Prometheus monitoring rules using labels  
apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: sample-app-alerts  
 labels:  
 app.kubernetes.io/name: sample-app  
 monitoring: prometheus  
spec:  
 groups:  
 - name: sample-app  
 rules:  
 - alert: ApplicationDown  
 expr: up{app\_kubernetes\_io\_name="sample-app"} == 0  
 for: 5m  
 labels:  
 severity: critical  
 environment: "{{ $labels.environment }}"  
 owner: "{{ $labels.owner }}"  
 annotations:  
 summary: "Sample app is down in {{ $labels.environment }}"  
 description: "Application {{ $labels.app\_kubernetes\_io\_name }} in {{ $labels.environment }} environment has been down for more than 5 minutes."

### 39.1.6 Integration with RH OVE Ecosystem

* **GitOps Integration**: Use ArgoCD for deploying and managing environment configurations.
* **Policy Automation**: Enforce standards and policies through OPA Gatekeeper.
* **Multi-Cluster Management**: Utilize RHACM for managing environments across multiple clusters.

This guide provides a clear pathway for setting up a robust, multi-environment application deployment workflow within RH OVE using Kubernetes namespaces, ensuring seamless transitions from development through to production.

# 40 Database Services

## 40.1 Use Case: Database Services as Platform-as-a-Service (PaaS)

### 40.1.1 Business Context

Organizations require flexible, scalable database solutions that can support various application needs while minimizing operational overhead. This use case demonstrates how to implement database services as Platform-as-a-Service (PaaS) offerings within the RH OVE ecosystem, providing self-service database provisioning, automated management, and seamless integration with application workloads.

### 40.1.2 Technical Requirements

#### 40.1.2.1 Infrastructure Requirements

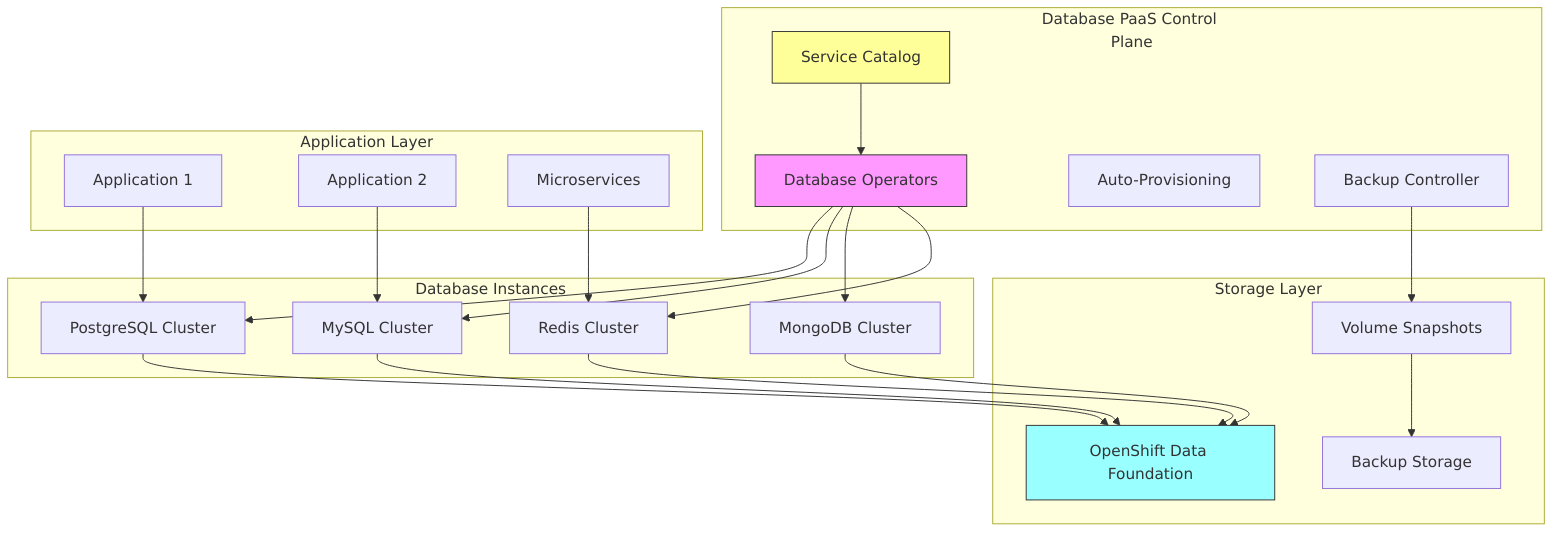
* OpenShift 4.12+ with KubeVirt enabled
* OpenShift Data Foundation for persistent storage
* Database operators (PostgreSQL, MySQL, MongoDB, Redis operators)
* Service mesh for secure communication (OpenShift Service Mesh)
* Monitoring and observability stack (Prometheus, Grafana)
* Backup and disaster recovery solutions (OADP/Velero/Rubrik)

#### 40.1.2.2 Resource Requirements

* **CPU**: Variable based on database workload (2-16 cores per instance)
* **Memory**: 4GB-64GB RAM per database instance
* **Storage**: High-performance persistent storage with snapshot capabilities
* **Network**: Low-latency networking for database replication and client connections

### 40.1.3 Architecture Overview

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 40.1.4 Implementation Steps

#### 40.1.4.1 Step 1: Install Database Operators

##### 40.1.4.1.1 PostgreSQL Operator Deployment

apiVersion: operators.coreos.com/v1alpha1  
kind: Subscription  
metadata:  
 name: postgresql-operator  
 namespace: database-operators  
spec:  
 channel: stable  
 name: postgresql-operator  
 source: certified-operators  
 sourceNamespace: openshift-marketplace  
---  
apiVersion: v1  
kind: Namespace  
metadata:  
 name: database-operators  
 labels:  
 openshift.io/cluster-monitoring: "true"

##### 40.1.4.1.2 MySQL Operator Deployment

apiVersion: operators.coreos.com/v1alpha1  
kind: Subscription  
metadata:  
 name: mysql-operator  
 namespace: database-operators  
spec:  
 channel: stable  
 name: mysql-operator  
 source: certified-operators  
 sourceNamespace: openshift-marketplace

#### 40.1.4.2 Step 2: Create Database Service Templates

##### 40.1.4.2.1 PostgreSQL Service Template

apiVersion: postgresql.cnpg.io/v1  
kind: Cluster  
metadata:  
 name: postgres-template  
 namespace: database-services  
spec:  
 instances: 3  
   
 postgresql:  
 parameters:  
 max\_connections: "200"  
 shared\_buffers: "256MB"  
 effective\_cache\_size: "1GB"  
 work\_mem: "4MB"  
 maintenance\_work\_mem: "64MB"  
   
 bootstrap:  
 initdb:  
 database: app\_db  
 owner: app\_user  
 secret:  
 name: postgres-credentials  
   
 storage:  
 size: 100Gi  
 storageClass: fast-ssd  
   
 resources:  
 requests:  
 memory: "2Gi"  
 cpu: "1"  
 limits:  
 memory: "4Gi"  
 cpu: "2"  
   
 monitoring:  
 enabled: true  
 customQueriesConfigMap:  
 - name: postgres-monitoring  
 key: custom-queries.yaml  
   
 backup:  
 barmanObjectStore:  
 destinationPath: s3://db-backups/postgres  
 s3Credentials:  
 accessKeyId:  
 name: backup-credentials  
 key: ACCESS\_KEY\_ID  
 secretAccessKey:  
 name: backup-credentials  
 key: SECRET\_ACCESS\_KEY  
 wal:  
 retention: "7d"  
 data:  
 retention: "30d"

##### 40.1.4.2.2 MySQL Service Template

apiVersion: mysql.oracle.com/v2  
kind: InnoDBCluster  
metadata:  
 name: mysql-template  
 namespace: database-services  
spec:  
 secretName: mysql-credentials  
 tlsUseSelfSigned: true  
 instances: 3  
 router:  
 instances: 2  
   
 datadirVolumeClaimTemplate:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 100Gi  
 storageClassName: fast-ssd  
   
 mycnf: |  
 [mysqld]  
 max\_connections = 500  
 innodb\_buffer\_pool\_size = 2G  
 innodb\_log\_file\_size = 256M  
 binlog\_expire\_logs\_seconds = 604800  
   
 resources:  
 requests:  
 memory: "2Gi"  
 cpu: "1"  
 limits:  
 memory: "4Gi"  
 cpu: "2"  
   
 backupProfiles:  
 - name: daily-backup  
 dumpInstance:  
 dumpOptions:  
 users: true  
 excludeSchemas: ["information\_schema", "performance\_schema"]  
 schedule: "0 2 \* \* \*"  
 backupRetentionDays: 30

#### 40.1.4.3 Step 3: Implement Self-Service Provisioning

##### 40.1.4.3.1 Service Catalog Integration

apiVersion: servicecatalog.k8s.io/v1beta1  
kind: ServiceClass  
metadata:  
 name: postgresql-service  
spec:  
 clusterServiceBrokerName: database-service-broker  
 externalName: postgresql  
 description: "Managed PostgreSQL Database Service"  
 externalMetadata:  
 displayName: "PostgreSQL Database"  
 imageUrl: "https://example.com/postgresql-icon.png"  
 longDescription: "High-availability PostgreSQL database with automated backups and monitoring"  
 providerDisplayName: "Database Team"  
 supportUrl: "https://example.com/support"  
 plans:  
 - name: small  
 externalID: postgres-small  
 description: "Small PostgreSQL instance (2 CPU, 4GB RAM, 100GB storage)"  
 free: false  
 externalMetadata:  
 displayName: "Small"  
 bullets:  
 - "2 CPU cores"  
 - "4GB RAM"  
 - "100GB storage"  
 - "Daily backups"  
 - name: medium  
 externalID: postgres-medium  
 description: "Medium PostgreSQL instance (4 CPU, 8GB RAM, 500GB storage)"  
 free: false  
 externalMetadata:  
 displayName: "Medium"  
 bullets:  
 - "4 CPU cores"  
 - "8GB RAM"  
 - "500GB storage"  
 - "Daily backups"  
 - "Read replicas"

##### 40.1.4.3.2 Database Provisioning Operator

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: database-provisioning-operator  
 namespace: database-operators  
spec:  
 replicas: 1  
 selector:  
 matchLabels:  
 app: database-provisioning-operator  
 template:  
 metadata:  
 labels:  
 app: database-provisioning-operator  
 spec:  
 containers:  
 - name: operator  
 image: quay.io/example/database-provisioning-operator:latest  
 env:  
 - name: WATCH\_NAMESPACE  
 value: ""  
 - name: POD\_NAME  
 valueFrom:  
 fieldRef:  
 fieldPath: metadata.name  
 - name: OPERATOR\_NAME  
 value: "database-provisioning-operator"  
 ports:  
 - containerPort: 8080  
 name: metrics  
 - containerPort: 8081  
 name: health  
 livenessProbe:  
 httpGet:  
 path: /healthz  
 port: 8081  
 initialDelaySeconds: 15  
 periodSeconds: 20  
 readinessProbe:  
 httpGet:  
 path: /readyz  
 port: 8081  
 initialDelaySeconds: 5  
 periodSeconds: 10  
 resources:  
 limits:  
 cpu: 200m  
 memory: 256Mi  
 requests:  
 cpu: 100m  
 memory: 128Mi

#### 40.1.4.4 Step 4: Configure Automated Backup and Recovery

##### 40.1.4.4.1 Backup Schedule Configuration

apiVersion: batch/v1  
kind: CronJob  
metadata:  
 name: database-backup-scheduler  
 namespace: database-services  
spec:  
 schedule: "0 2 \* \* \*" # Daily at 2 AM  
 jobTemplate:  
 spec:  
 template:  
 spec:  
 containers:  
 - name: backup-job  
 image: quay.io/example/database-backup:latest  
 env:  
 - name: BACKUP\_TYPE  
 value: "full"  
 - name: RETENTION\_DAYS  
 value: "30"  
 - name: S3\_BUCKET  
 value: "database-backups"  
 - name: AWS\_ACCESS\_KEY\_ID  
 valueFrom:  
 secretKeyRef:  
 name: backup-credentials  
 key: access-key-id  
 - name: AWS\_SECRET\_ACCESS\_KEY  
 valueFrom:  
 secretKeyRef:  
 name: backup-credentials  
 key: secret-access-key  
 command:  
 - /bin/bash  
 - -c  
 - |  
 #!/bin/bash  
 set -e  
   
 # Discover all database instances  
 for db in $(kubectl get postgresql,mysql,mongodb -o name --all-namespaces); do  
 echo "Backing up $db"  
 backup-database.sh "$db"  
 done  
 restartPolicy: OnFailure

#### 40.1.4.5 Step 5: Implement Monitoring and Alerting

##### 40.1.4.5.1 Database Monitoring Configuration

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: database-services-monitor  
 namespace: database-services  
 labels:  
 monitoring: database-services  
spec:  
 selector:  
 matchLabels:  
 monitoring: enabled  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics  
 honorLabels: true  
---  
apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: database-services-alerts  
 namespace: database-services  
spec:  
 groups:  
 - name: database.alerts  
 rules:  
 - alert: DatabaseInstanceDown  
 expr: up{job="database-services"} == 0  
 for: 5m  
 labels:  
 severity: critical  
 annotations:  
 summary: "Database instance {{ $labels.instance }} is down"  
 description: "Database instance {{ $labels.instance }} has been down for more than 5 minutes."  
   
 - alert: DatabaseHighConnections  
 expr: database\_connections\_active / database\_connections\_max > 0.8  
 for: 10m  
 labels:  
 severity: warning  
 annotations:  
 summary: "Database {{ $labels.instance }} has high connection usage"  
 description: "Database {{ $labels.instance }} is using {{ $value | humanizePercentage }} of available connections."  
   
 - alert: DatabaseSlowQueries  
 expr: rate(database\_slow\_queries\_total[5m]) > 10  
 for: 5m  
 labels:  
 severity: warning  
 annotations:  
 summary: "Database {{ $labels.instance }} has high slow query rate"  
 description: "Database {{ $labels.instance }} has {{ $value }} slow queries per second."  
   
 - alert: DatabaseBackupFailed  
 expr: database\_backup\_last\_success\_timestamp < (time() - 86400)  
 for: 1m  
 labels:  
 severity: critical  
 annotations:  
 summary: "Database backup failed for {{ $labels.instance }}"  
 description: "Database backup for {{ $labels.instance }} has not succeeded in the last 24 hours."

#### 40.1.4.6 Step 6: Implement Database Security

##### 40.1.4.6.1 Network Policies for Database Isolation

apiVersion: networking.k8s.io/v1  
kind: NetworkPolicy  
metadata:  
 name: database-isolation  
 namespace: database-services  
spec:  
 podSelector:  
 matchLabels:  
 tier: database  
 policyTypes:  
 - Ingress  
 - Egress  
 ingress:  
 - from:  
 - namespaceSelector:  
 matchLabels:  
 name: application-services  
 - podSelector:  
 matchLabels:  
 tier: application  
 ports:  
 - protocol: TCP  
 port: 5432 # PostgreSQL  
 - protocol: TCP  
 port: 3306 # MySQL  
 - protocol: TCP  
 port: 27017 # MongoDB  
 - protocol: TCP  
 port: 6379 # Redis  
 egress:  
 - to: []  
 ports:  
 - protocol: TCP  
 port: 53 # DNS  
 - protocol: UDP  
 port: 53 # DNS  
 - to:  
 - namespaceSelector:  
 matchLabels:  
 name: backup-services  
 ports:  
 - protocol: TCP  
 port: 443 # HTTPS for backup storage

##### 40.1.4.6.2 Database Secret Management

apiVersion: external-secrets.io/v1beta1  
kind: SecretStore  
metadata:  
 name: database-secret-store  
 namespace: database-services  
spec:  
 provider:  
 vault:  
 server: "https://vault.example.com"  
 path: "secret"  
 version: "v2"  
 auth:  
 kubernetes:  
 mountPath: "kubernetes"  
 role: "database-secrets"  
---  
apiVersion: external-secrets.io/v1beta1  
kind: ExternalSecret  
metadata:  
 name: postgres-credentials  
 namespace: database-services  
spec:  
 refreshInterval: 1h  
 secretStoreRef:  
 name: database-secret-store  
 kind: SecretStore  
 target:  
 name: postgres-credentials  
 creationPolicy: Owner  
 template:  
 type: Opaque  
 data:  
 username: "{{ .username }}"  
 password: "{{ .password }}"  
 database: "{{ .database }}"  
 data:  
 - secretKey: username  
 remoteRef:  
 key: database/postgres  
 property: username  
 - secretKey: password  
 remoteRef:  
 key: database/postgres  
 property: password  
 - secretKey: database  
 remoteRef:  
 key: database/postgres  
 property: database

### 40.1.5 Application Integration Examples

#### 40.1.5.1 Spring Boot Application Configuration

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: spring-app  
 namespace: application-services  
spec:  
 replicas: 3  
 selector:  
 matchLabels:  
 app: spring-app  
 template:  
 metadata:  
 labels:  
 app: spring-app  
 tier: application  
 spec:  
 containers:  
 - name: app  
 image: quay.io/example/spring-app:latest  
 env:  
 - name: SPRING\_DATASOURCE\_URL  
 value: "jdbc:postgresql://postgres-service.database-services.svc.cluster.local:5432/app\_db"  
 - name: SPRING\_DATASOURCE\_USERNAME  
 valueFrom:  
 secretKeyRef:  
 name: app-db-credentials  
 key: username  
 - name: SPRING\_DATASOURCE\_PASSWORD  
 valueFrom:  
 secretKeyRef:  
 name: app-db-credentials  
 key: password  
 - name: SPRING\_JPA\_HIBERNATE\_DDL\_AUTO  
 value: "validate"  
 ports:  
 - containerPort: 8080  
 livenessProbe:  
 httpGet:  
 path: /actuator/health  
 port: 8080  
 initialDelaySeconds: 60  
 periodSeconds: 30  
 readinessProbe:  
 httpGet:  
 path: /actuator/health/readiness  
 port: 8080  
 initialDelaySeconds: 30  
 periodSeconds: 10

### 40.1.6 Troubleshooting Guide

#### 40.1.6.1 Common Issues and Solutions

##### 40.1.6.1.1 Database Connection Issues

* **Issue**: Applications cannot connect to database services
* **Solution**:
  + Verify network policies allow traffic between application and database namespaces
  + Check service discovery and DNS resolution
  + Validate database credentials and authentication

##### 40.1.6.1.2 Performance Issues

* **Issue**: Slow database queries and high latency
* **Solution**:
  + Review database configuration parameters
  + Analyze slow query logs and optimize indexes
  + Scale database resources (CPU, memory, storage IOPS)
  + Implement connection pooling

##### 40.1.6.1.3 Backup and Recovery Failures

* **Issue**: Database backups failing or restoration issues
* **Solution**:
  + Verify backup storage credentials and permissions
  + Check backup retention policies and storage quotas
  + Test backup restoration procedures regularly
  + Monitor backup job logs for errors

##### 40.1.6.1.4 Resource Constraints

* **Issue**: Database instances running out of resources
* **Solution**:
  + Implement resource monitoring and alerting
  + Configure horizontal and vertical scaling policies
  + Optimize database configuration for workload patterns
  + Consider database sharding for large datasets

### 40.1.7 Best Practices

#### 40.1.7.1 Database Design and Configuration

* **Resource Planning**: Size database instances based on expected workload patterns
* **Configuration Tuning**: Optimize database parameters for specific use cases
* **Connection Management**: Implement connection pooling and limit concurrent connections
* **Index Strategy**: Create appropriate indexes for query performance

#### 40.1.7.2 Security and Compliance

* **Encryption**: Enable encryption at rest and in transit for all database communications
* **Access Control**: Implement least-privilege access using RBAC and network policies
* **Audit Logging**: Enable database audit logging for compliance requirements
* **Secret Rotation**: Implement automated secret rotation for database credentials

#### 40.1.7.3 Operations and Maintenance

* **Monitoring**: Implement comprehensive monitoring for performance, availability, and capacity
* **Backup Strategy**: Implement automated backups with tested restoration procedures
* **Disaster Recovery**: Plan and test disaster recovery procedures regularly
* **Maintenance Windows**: Schedule regular maintenance windows for updates and optimizations

### 40.1.8 Integration with RH OVE Ecosystem

#### 40.1.8.1 GitOps Integration

apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: database-services  
 namespace: argocd  
spec:  
 project: platform-services  
 source:  
 repoURL: https://git.example.com/database-services-config  
 targetRevision: HEAD  
 path: overlays/production  
 destination:  
 server: https://kubernetes.default.svc  
 namespace: database-services  
 syncPolicy:  
 automated:  
 prune: false  
 selfHeal: true  
 syncOptions:  
 - CreateNamespace=true

#### 40.1.8.2 Multi-Cluster Database Federation

* **Cross-Cluster Replication**: Implement database replication across multiple clusters
* **Global Load Balancing**: Use global load balancers for database read replicas
* **Disaster Recovery**: Maintain database replicas in different geographical regions

This comprehensive guide provides everything needed to implement Database Services as PaaS within the RH OVE ecosystem, enabling self-service database provisioning, automated management, and seamless integration with application workloads while maintaining enterprise-grade security, performance, and reliability.

# 41 Legacy Modernization

## 41.1 Use Case: Legacy Application Modernization

### 41.1.1 Business Context

Legacy application modernization is critical for organizations looking to leverage modern cloud-native technologies while preserving existing business logic and data. This use case demonstrates a phased approach to modernizing legacy applications using the RH OVE ecosystem, enabling gradual transformation with minimal business disruption.

### 41.1.2 Technical Requirements

#### 41.1.2.1 Infrastructure Requirements

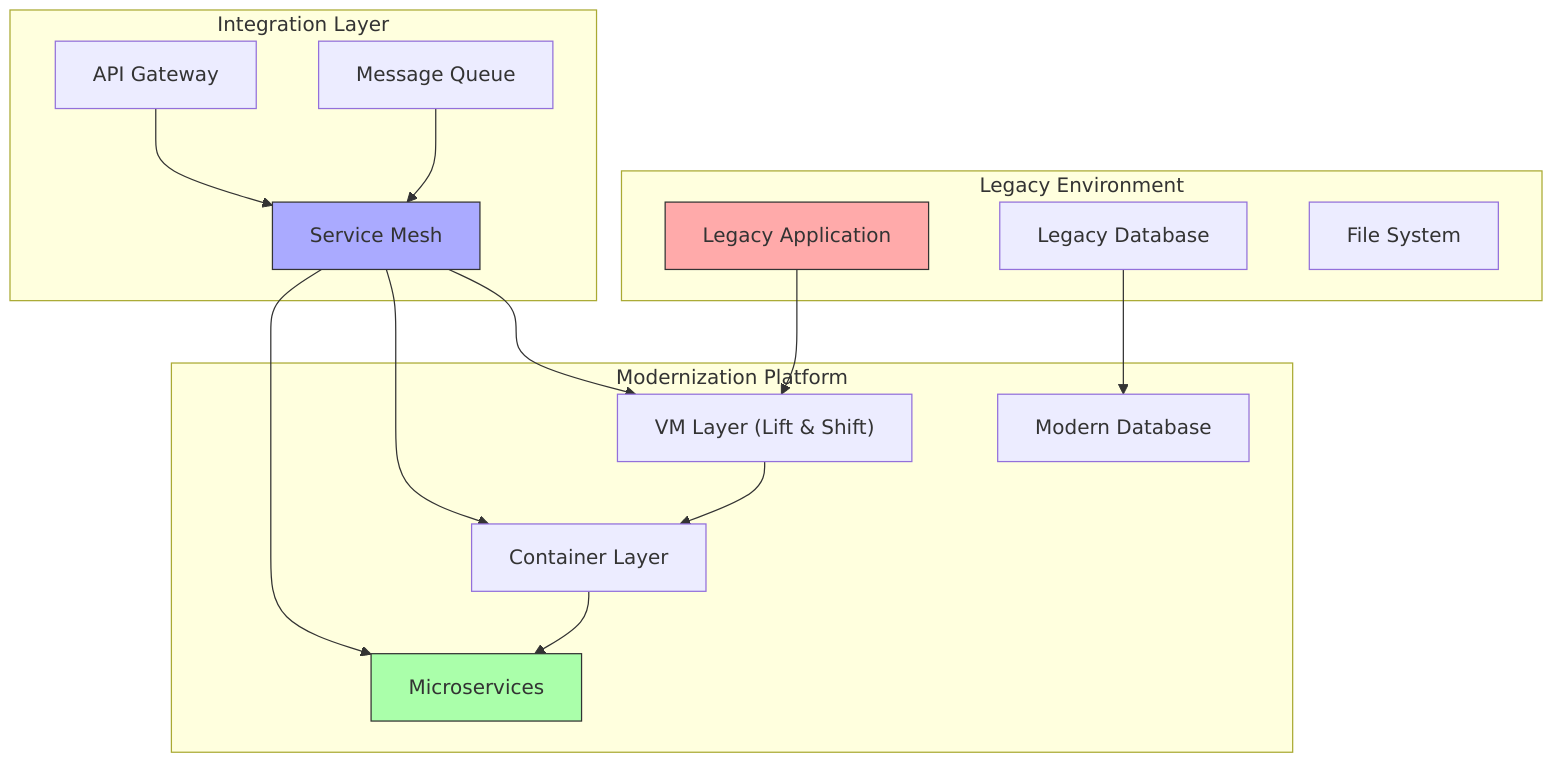
* OpenShift 4.12+ with KubeVirt enabled
* Application migration tools (Migration Toolkit for Applications - MTA)
* Service mesh for hybrid connectivity (OpenShift Service Mesh/Istio)
* CI/CD pipelines (OpenShift Pipelines/Tekton)
* Container registry (Quay.io or OpenShift integrated registry)

#### 41.1.2.2 Resource Requirements

* **Compute**: Sufficient resources for both legacy and modernized components during transition
* **Storage**: Persistent storage for data migration and synchronization
* **Network**: High-bandwidth connectivity for data replication and service communication

### 41.1.3 Architecture Overview

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 41.1.4 Implementation Steps

#### 41.1.4.1 Phase 1: Assessment and Planning

##### 41.1.4.1.1 Application Discovery

## MTA Configuration for Application Analysis  
apiVersion: tackle.konveyor.io/v1alpha1  
kind: Application  
metadata:  
 name: legacy-app-analysis  
 namespace: konveyor-tackle  
spec:  
 name: "Legacy ERP System"  
 description: "Monolithic ERP application requiring modernization"  
 repository:  
 kind: git  
 url: "https://git.example.com/legacy-erp"  
 binary: "erp-application.war"

##### 41.1.4.1.2 Migration Assessment

## Run application analysis using MTA CLI  
konveyor-cli analyze \  
 --input /path/to/legacy-app \  
 --output /path/to/analysis-results \  
 --target cloud-readiness \  
 --target containers

#### 41.1.4.2 Phase 2: Lift and Shift (VM Migration)

##### 41.1.4.2.1 VM-based Legacy Application Deployment

apiVersion: kubevirt.io/v1  
kind: VirtualMachine  
metadata:  
 name: legacy-erp-vm  
 namespace: modernization  
spec:  
 running: true  
 template:  
 metadata:  
 labels:  
 app: legacy-erp  
 tier: application  
 phase: lift-shift  
 spec:  
 domain:  
 cpu:  
 cores: 4  
 devices:  
 disks:  
 - disk:  
 bus: virtio  
 name: rootdisk  
 - disk:  
 bus: virtio  
 name: datadisk  
 interfaces:  
 - name: default  
 bridge: {}  
 memory:  
 guest: 8Gi  
 resources:  
 requests:  
 memory: 8Gi  
 cpu: 4  
 networks:  
 - name: default  
 pod: {}  
 volumes:  
 - dataVolume:  
 name: legacy-erp-root  
 name: rootdisk  
 - dataVolume:  
 name: legacy-erp-data  
 name: datadisk  
---  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: legacy-erp-root  
 namespace: modernization  
spec:  
 source:  
 http:  
 url: "https://vm-images.example.com/legacy-erp-root.img"  
 pvc:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 100Gi  
---  
apiVersion: cdi.kubevirt.io/v1beta1  
kind: DataVolume  
metadata:  
 name: legacy-erp-data  
 namespace: modernization  
spec:  
 source:  
 http:  
 url: "https://vm-images.example.com/legacy-erp-data.img"  
 pvc:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 500Gi

#### 41.1.4.3 Phase 3: Containerization

##### 41.1.4.3.1 Legacy Application Container Deployment

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: legacy-erp-container  
 namespace: modernization  
spec:  
 replicas: 2  
 selector:  
 matchLabels:  
 app: legacy-erp  
 tier: application  
 phase: containerized  
 template:  
 metadata:  
 labels:  
 app: legacy-erp  
 tier: application  
 phase: containerized  
 spec:  
 containers:  
 - name: erp-app  
 image: quay.io/example/legacy-erp:containerized  
 ports:  
 - containerPort: 8080  
 name: http  
 - containerPort: 8443  
 name: https  
 env:  
 - name: DB\_HOST  
 value: "legacy-database-service"  
 - name: DB\_PORT  
 value: "5432"  
 - name: DB\_NAME  
 valueFrom:  
 secretKeyRef:  
 name: db-credentials  
 key: database  
 - name: DB\_USER  
 valueFrom:  
 secretKeyRef:  
 name: db-credentials  
 key: username  
 - name: DB\_PASSWORD  
 valueFrom:  
 secretKeyRef:  
 name: db-credentials  
 key: password  
 volumeMounts:  
 - name: app-data  
 mountPath: /opt/erp/data  
 - name: app-config  
 mountPath: /opt/erp/config  
 volumes:  
 - name: app-data  
 persistentVolumeClaim:  
 claimName: erp-data-pvc  
 - name: app-config  
 configMap:  
 name: erp-config

#### 41.1.4.4 Phase 4: Service Decomposition

##### 41.1.4.4.1 Extract User Management Service

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: user-management-service  
 namespace: modernization  
spec:  
 replicas: 3  
 selector:  
 matchLabels:  
 app: user-management  
 tier: microservice  
 template:  
 metadata:  
 labels:  
 app: user-management  
 tier: microservice  
 version: v1  
 spec:  
 containers:  
 - name: user-management  
 image: quay.io/example/user-management:v1.0.0  
 ports:  
 - containerPort: 8080  
 name: http  
 env:  
 - name: DATABASE\_URL  
 valueFrom:  
 secretKeyRef:  
 name: user-db-credentials  
 key: url  
 - name: REDIS\_URL  
 valueFrom:  
 secretKeyRef:  
 name: redis-credentials  
 key: url  
 livenessProbe:  
 httpGet:  
 path: /health  
 port: 8080  
 initialDelaySeconds: 30  
 periodSeconds: 10  
 readinessProbe:  
 httpGet:  
 path: /ready  
 port: 8080  
 initialDelaySeconds: 5  
 periodSeconds: 5  
---  
apiVersion: v1  
kind: Service  
metadata:  
 name: user-management-service  
 namespace: modernization  
spec:  
 selector:  
 app: user-management  
 ports:  
 - name: http  
 port: 80  
 targetPort: 8080  
 type: ClusterIP

#### 41.1.4.5 Phase 5: Service Mesh Integration

##### 41.1.4.5.1 Istio Service Mesh Configuration

apiVersion: networking.istio.io/v1beta1  
kind: VirtualService  
metadata:  
 name: legacy-erp-routing  
 namespace: modernization  
spec:  
 hosts:  
 - erp.example.com  
 http:  
 - match:  
 - uri:  
 prefix: /api/users  
 route:  
 - destination:  
 host: user-management-service  
 port:  
 number: 80  
 weight: 100  
 - match:  
 - uri:  
 prefix: /  
 route:  
 - destination:  
 host: legacy-erp-container  
 port:  
 number: 8080  
 weight: 90  
 - destination:  
 host: legacy-erp-vm  
 port:  
 number: 8080  
 weight: 10  
---  
apiVersion: networking.istio.io/v1beta1  
kind: DestinationRule  
metadata:  
 name: legacy-erp-destination  
 namespace: modernization  
spec:  
 host: legacy-erp-container  
 trafficPolicy:  
 circuitBreaker:  
 consecutive5xxErrors: 3  
 interval: 30s  
 baseEjectionTime: 30s

#### 41.1.4.6 Phase 6: Data Migration Strategy

##### 41.1.4.6.1 Database Migration Pipeline

apiVersion: tekton.dev/v1beta1  
kind: Pipeline  
metadata:  
 name: data-migration-pipeline  
 namespace: modernization  
spec:  
 params:  
 - name: source-db-url  
 description: Source database connection URL  
 - name: target-db-url  
 description: Target database connection URL  
 - name: migration-batch-size  
 default: "1000"  
 description: Number of records to migrate per batch  
   
 tasks:  
 - name: validate-source  
 taskRef:  
 name: database-validation  
 params:  
 - name: db-url  
 value: $(params.source-db-url)  
   
 - name: create-target-schema  
 taskRef:  
 name: schema-creation  
 params:  
 - name: db-url  
 value: $(params.target-db-url)  
 runAfter:  
 - validate-source  
   
 - name: migrate-data  
 taskRef:  
 name: data-migration  
 params:  
 - name: source-db-url  
 value: $(params.source-db-url)  
 - name: target-db-url  
 value: $(params.target-db-url)  
 - name: batch-size  
 value: $(params.migration-batch-size)  
 runAfter:  
 - create-target-schema  
   
 - name: validate-migration  
 taskRef:  
 name: migration-validation  
 params:  
 - name: source-db-url  
 value: $(params.source-db-url)  
 - name: target-db-url  
 value: $(params.target-db-url)  
 runAfter:  
 - migrate-data

#### 41.1.4.7 Phase 7: Progressive Traffic Migration

##### 41.1.4.7.1 Canary Deployment Strategy

apiVersion: argoproj.io/v1alpha1  
kind: Rollout  
metadata:  
 name: legacy-erp-rollout  
 namespace: modernization  
spec:  
 replicas: 5  
 strategy:  
 canary:  
 steps:  
 - setWeight: 10  
 - pause: {duration: 300s}  
 - setWeight: 25  
 - pause: {duration: 300s}  
 - setWeight: 50  
 - pause: {duration: 300s}  
 - setWeight: 75  
 - pause: {duration: 300s}  
 canaryService: legacy-erp-canary  
 stableService: legacy-erp-stable  
 trafficRouting:  
 istio:  
 virtualService:  
 name: legacy-erp-routing  
 routes:  
 - primary  
 selector:  
 matchLabels:  
 app: legacy-erp  
 template:  
 metadata:  
 labels:  
 app: legacy-erp  
 spec:  
 containers:  
 - name: erp-app  
 image: quay.io/example/legacy-erp:modernized  
 ports:  
 - containerPort: 8080

### 41.1.5 Monitoring and Observability

#### 41.1.5.1 Application Performance Monitoring

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: modernization-monitoring  
 namespace: modernization  
spec:  
 selector:  
 matchLabels:  
 monitoring: enabled  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics  
---  
apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: modernization-alerts  
 namespace: modernization  
spec:  
 groups:  
 - name: modernization.alerts  
 rules:  
 - alert: LegacyAppHighErrorRate  
 expr: rate(http\_requests\_total{status=~"5.."}[5m]) > 0.1  
 for: 5m  
 labels:  
 severity: warning  
 annotations:  
 summary: "High error rate in legacy application"  
   
 - alert: MigrationDataInconsistency  
 expr: migration\_data\_consistency\_check != 1  
 for: 1m  
 labels:  
 severity: critical  
 annotations:  
 summary: "Data inconsistency detected during migration"

### 41.1.6 Troubleshooting Guide

#### 41.1.6.1 Common Issues and Solutions

##### 41.1.6.1.1 Performance Degradation During Migration

* **Issue**: Application performance degrades during data migration
* **Solution**:
  + Implement read replicas for database queries
  + Use incremental migration strategies
  + Schedule heavy migration tasks during off-peak hours

##### 41.1.6.1.2 Service Communication Failures

* **Issue**: Communication failures between legacy and modern components
* **Solution**:
  + Verify service mesh configuration
  + Check network policies and firewall rules
  + Implement circuit breakers and retry mechanisms

##### 41.1.6.1.3 Data Consistency Issues

* **Issue**: Data inconsistencies between old and new systems
* **Solution**:
  + Implement two-phase commit protocols
  + Use event sourcing for critical operations
  + Regular data validation and reconciliation

### 41.1.7 Best Practices

#### 41.1.7.1 Migration Strategy

* **Incremental Approach**: Migrate functionality incrementally to reduce risk
* **Feature Toggles**: Use feature flags to control rollout of new functionality
* **Rollback Plans**: Always have rollback procedures for each migration phase

#### 41.1.7.2 Testing and Validation

* **Automated Testing**: Implement comprehensive test suites for both legacy and modern components
* **Performance Testing**: Conduct load testing throughout the migration process
* **Data Validation**: Implement automated data consistency checks

#### 41.1.7.3 Security Considerations

* **Zero-Trust Architecture**: Implement zero-trust principles across all components
* **Secrets Management**: Use proper secrets management for database credentials and API keys
* **Network Segmentation**: Implement proper network segmentation between components

### 41.1.8 Integration with RH OVE Ecosystem

#### 41.1.8.1 GitOps Integration

apiVersion: argoproj.io/v1alpha1  
kind: Application  
metadata:  
 name: legacy-modernization  
 namespace: argocd  
spec:  
 project: modernization  
 source:  
 repoURL: https://git.example.com/legacy-modernization-config  
 targetRevision: HEAD  
 path: environments/production  
 destination:  
 server: https://kubernetes.default.svc  
 namespace: modernization  
 syncPolicy:  
 automated:  
 prune: false  
 selfHeal: true  
 syncOptions:  
 - CreateNamespace=true

#### 41.1.8.2 Multi-Cluster Deployment

* **Staging Environment**: Use separate clusters for testing and validation
* **Production Rollout**: Implement blue-green deployment across clusters
* **Disaster Recovery**: Maintain legacy systems as backup during transition

This comprehensive guide provides a structured approach to legacy application modernization within the RH OVE ecosystem, enabling organizations to gradually transform their applications while maintaining business continuity and reducing risk.

# 42 Disaster Recovery

## 42.1 Use Case: Disaster Recovery

### 42.1.1 Business Context

Disaster recovery is a crucial aspect of business continuity, ensuring that workloads can be swiftly restored following catastrophic events. This use case outlines strategies and tools for implementing effective disaster recovery plans within the RH OVE ecosystem.

### 42.1.2 Technical Requirements

#### 42.1.2.1 Infrastructure Requirements

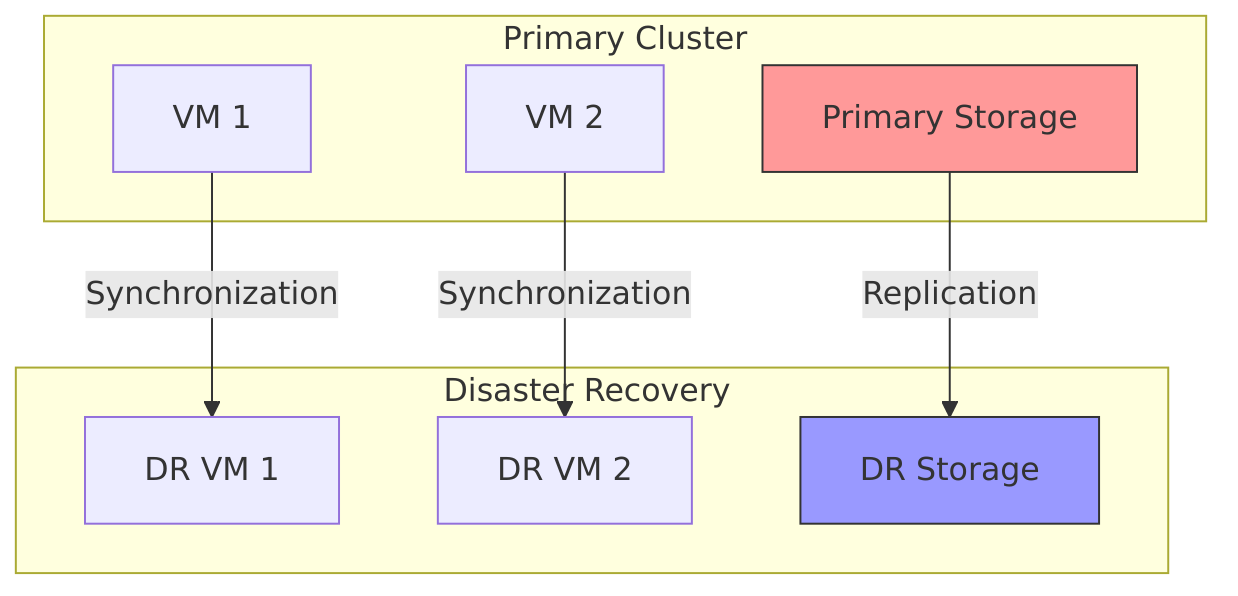
* OpenShift 4.12+ clusters with multi-cluster management enabled
* Cross-cluster networking with VPN or direct connectivity
* Data replication and backup solutions
* Disaster recovery orchestration tools (Red Hat Advanced Cluster Management - RHACM)

#### 42.1.2.2 Resource Requirements

* **Compute**: Sufficient capacity on recovery clusters
* **Storage**: Redundant storage solutions with replication
* **Network**: Reliable, high-speed connections between primary and secondary sites

### 42.1.3 Architecture Overview

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 42.1.4 Implementation Steps

#### 42.1.4.1 Step 1: Plan and Prepare

##### 42.1.4.1.1 Define Disaster Recovery Objectives

* Identify RTO (Recovery Time Objective) and RPO (Recovery Point Objective)

##### 42.1.4.1.2 Inventory Assessment

* Document existing resources and dependencies

#### 42.1.4.2 Step 2: Configure Data Replication

##### 42.1.4.2.1 Persistent Storage Replication

* Configure synchronous or asynchronous replication between primary and DR sites.

apiVersion: apps/v1  
kind: StatefulSet  
metadata:  
 name: dr-replication-demo  
 namespace: storage-replication  
spec:  
 selector:  
 matchLabels:  
 app: replication  
 serviceName: "replication"  
 replicas: 2  
 template:  
 metadata:  
 labels:  
 app: replication  
 spec:  
 containers:  
 - name: replication-agent  
 image: replication-agent:latest  
 args:  
 - --source-pvc  
 - source-storage-pvc  
 - --target-pvc  
 - target-storage-pvc

#### 42.1.4.3 Step 3: Implement Cross-Cluster Networking

##### 42.1.4.3.1 VPN Configuration for Cluster Connectivity

* Set up VPN tunnels or configure direct connectivity between cluster sites.

#### 42.1.4.4 Step 4: Deploy DR Orchestration Tools

##### 42.1.4.4.1 RHACM Configuration

* Deploy Red Hat Advanced Cluster Management for cluster failover management.

apiVersion: cluster.open-cluster-management.io/v1  
kind: ManagedCluster  
metadata:  
 name: disaster-recovery-cluster  
spec:  
 hubAcceptsClient: true  
 managedClusterClientConfigs:  
 - url: https://api.dr-cluster.example.com:6443

#### 42.1.4.5 Step 5: Automate Failover and Recovery

##### 42.1.4.5.1 Failover Scripts and Automation

* Develop scripts to automate the failover process based on RHACM policies.

##!/bin/bash  
## Failover script for disaster recovery activation  
  
## Scale down primary workloads  
kubectl scale deployment --all --replicas=0 -n primary-workloads  
  
## Scale up DR workloads  
kubectl scale deployment --all --replicas=1 -n disaster-recovery-workloads  
  
## Update DNS settings  
update-dns --zone=example.com --record=\*.example.com --new-ip=dr-cluster-ip

#### 42.1.4.6 Step 6: Testing and Validation

##### 42.1.4.6.1 Disaster Recovery Drills

* Conduct regular DR drills to test and validate recovery procedures.

## Trigger disaster recovery drill  
run-drill --cluster=disaster-recovery-cluster --scenario=full-cluster-failure

### 42.1.5 Troubleshooting Guide

#### 42.1.5.1 Common Issues and Solutions

##### 42.1.5.1.1 Replication Lag

* **Issue**: Data replication falls behind
* **Solution**:
  + Increase network bandwidth
  + Optimize replication frequencies
  + Monitor replication service for bottlenecks

##### 42.1.5.1.2 Failover Errors

* **Issue**: Failover task errors or delays
* **Solution**:
  + Verify failover scripts and automation procedures
  + Test DNS updates and propagation
  + Check cluster configuration consistency

##### 42.1.5.1.3 Network Connectivity Issues

* **Issue**: VPN or network interruptions
* **Solution**:
  + Test alternate routes and consider multi-path routing
  + Verify firewall and security group configurations
  + Implement continuous network monitoring

### 42.1.6 Best Practices

#### 42.1.6.1 Strategy and Planning

* **Comprehensive Planning**: Develop detailed DR plans aligned with business priorities
* **Periodic Reviews**: Regularly review DR strategies and update based on changes in infrastructure
* **Stakeholder Engagement**: Involve all relevant stakeholders in DR planning and testing

#### 42.1.6.2 Technology and Tools

* **Automation**: Leverage automation for failover processes to minimize human error
* **Monitoring and Alerts**: Implement monitoring and alerting for quick detection of failures
* **Compliance and Auditing**: Ensure DR plans meet compliance and regulatory requirements

### 42.1.7 Integration with RH OVE Ecosystem

#### 42.1.7.1 Multi-Cluster Management

* Use RHACM for managing multiple clusters, facilitating disaster recovery coordination

#### 42.1.7.2 Environmental Parity

* Ensure consistency in configurations between primary and secondary environments

This guide provides the steps and best practices necessary to establish robust disaster recovery systems within the RH OVE ecosystem, ensuring business continuity and data availability even in the event of a major failure or disaster.

# 43 End-to-End Observability

## 43.1 Use Case: End-to-End Application Observability in RH OVE

### 43.1.1 Business Context

In the Red Hat OpenShift Virtualization Engine (RH OVE) ecosystem, comprehensive observability is essential for monitoring both containerized applications and virtual machines, understanding performance bottlenecks, troubleshooting issues, and ensuring optimal resource utilization across hybrid workloads. This use case demonstrates two complementary approaches: native OpenShift observability tools and integration with Dynatrace for enterprise-grade observability.

### 43.1.2 What Developers Need to Expose

For effective end-to-end observability, developers must instrument their applications to expose:

#### 43.1.2.1 Required Metrics

* **Business Metrics**: Transaction counts, success rates, revenue metrics
* **Application Metrics**: Response times, error rates, throughput
* **Resource Metrics**: CPU, memory, disk I/O, network usage
* **Custom Metrics**: Domain-specific KPIs and performance indicators

#### 43.1.2.2 Required Traces

* **Request Traces**: End-to-end request flow across microservices
* **Database Traces**: SQL queries and database connection metrics
* **External Service Traces**: API calls to third-party services
* **Async Operations**: Message queue operations, background jobs

#### 43.1.2.3 Required Logs

* **Structured Logs**: JSON formatted with consistent fields
* **Error Logs**: Exception details with stack traces
* **Audit Logs**: Security and compliance events
* **Performance Logs**: Slow queries, long-running operations

#### 43.1.2.4 Health Endpoints

* **Liveness Probes**: /health/live - Application is running
* **Readiness Probes**: /health/ready - Application ready to serve traffic
* **Metrics Endpoint**: /metrics - Prometheus-formatted metrics
* **Info Endpoint**: /info - Application version and build information

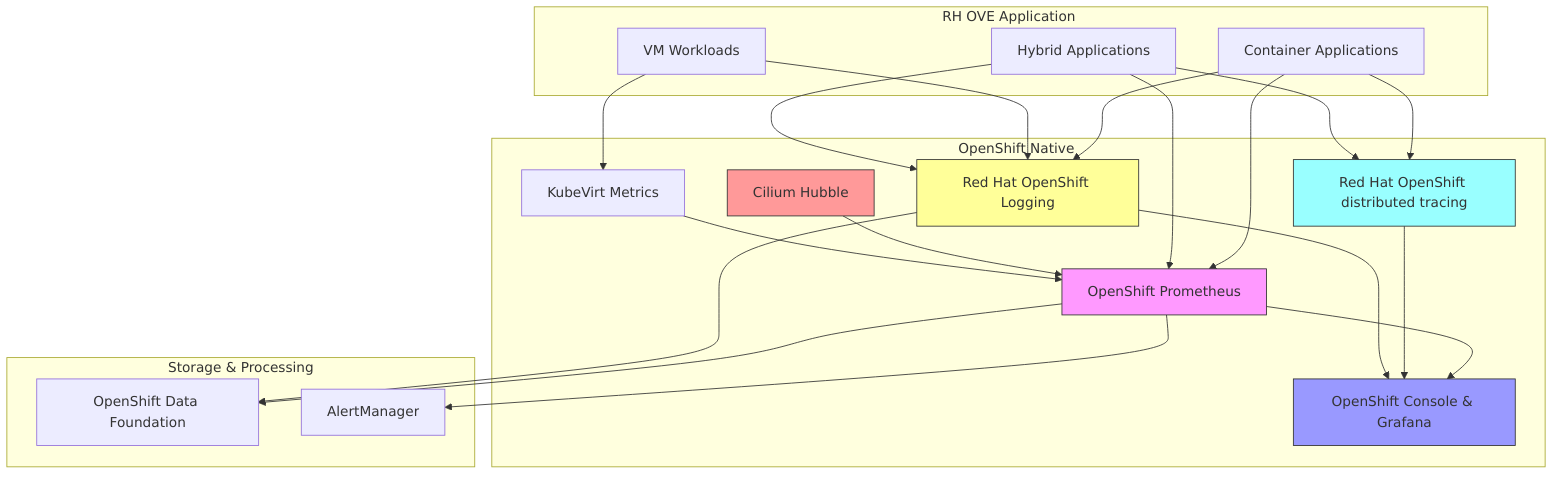
### 43.1.3 1. Native OpenShift Observability

#### 43.1.3.1 Infrastructure Requirements

* OpenShift 4.12+ with built-in monitoring stack
* OpenShift Data Foundation for persistent storage
* Red Hat OpenShift Logging (based on Loki)
* Red Hat OpenShift distributed tracing (Jaeger)
* Cilium Hubble for network observability
* KubeVirt monitoring for VM workloads

#### 43.1.3.2 Architecture Overview

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

#### 43.1.3.3 Implementation Steps

#### 43.1.3.4 Step 1: Enable OpenShift Built-in Monitoring

##### 43.1.3.4.1 Configure User Workload Monitoring

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: cluster-monitoring-config  
 namespace: openshift-monitoring  
data:  
 config.yaml: |  
 enableUserWorkloadMonitoring: true  
 prometheusK8s:  
 retention: 30d  
 volumeClaimTemplate:  
 spec:  
 storageClassName: ocs-storagecluster-ceph-rbd  
 resources:  
 requests:  
 storage: 100Gi

#### 43.1.3.5 Step 2: Application Instrumentation for Container Applications

##### 43.1.3.5.1 Comprehensive Metrics Configuration (Go Example)

package main  
  
import (  
 "context"  
 "net/http"  
 "time"  
   
 "github.com/prometheus/client\_golang/prometheus"  
 "github.com/prometheus/client\_golang/prometheus/promauto"  
 "github.com/prometheus/client\_golang/prometheus/promhttp"  
)  
  
var (  
 // Business metrics  
 httpRequestsTotal = promauto.NewCounterVec(  
 prometheus.CounterOpts{  
 Name: "myapp\_http\_requests\_total",  
 Help: "Total number of HTTP requests by status code and method",  
 },  
 []string{"method", "status\_code", "endpoint"},  
 )  
   
 // Performance metrics  
 httpRequestDuration = promauto.NewHistogramVec(  
 prometheus.HistogramOpts{  
 Name: "myapp\_http\_request\_duration\_seconds",  
 Help: "HTTP request duration in seconds",  
 Buckets: prometheus.DefBuckets,  
 },  
 []string{"method", "endpoint"},  
 )  
   
 // Resource metrics  
 activeConnections = promauto.NewGauge(  
 prometheus.GaugeOpts{  
 Name: "myapp\_active\_connections",  
 Help: "Number of active connections",  
 },  
 )  
   
 // Custom business metrics  
 ordersProcessed = promauto.NewCounterVec(  
 prometheus.CounterOpts{  
 Name: "myapp\_orders\_processed\_total",  
 Help: "Total number of orders processed",  
 },  
 []string{"status"},  
 )  
)  
  
func instrumentHandler(next http.HandlerFunc, endpoint string) http.HandlerFunc {  
 return http.HandlerFunc(func(w http.ResponseWriter, r \*http.Request) {  
 start := time.Now()  
   
 // Process request  
 next.ServeHTTP(w, r)  
   
 // Record metrics  
 duration := time.Since(start).Seconds()  
 httpRequestDuration.WithLabelValues(r.Method, endpoint).Observe(duration)  
 httpRequestsTotal.WithLabelValues(r.Method, "200", endpoint).Inc()  
 })  
}  
  
func main() {  
 // Health endpoints  
 http.HandleFunc("/health/live", func(w http.ResponseWriter, r \*http.Request) {  
 w.WriteHeader(http.StatusOK)  
 w.Write([]byte("alive"))  
 })  
   
 http.HandleFunc("/health/ready", func(w http.ResponseWriter, r \*http.Request) {  
 // Check dependencies (DB, external services)  
 w.WriteHeader(http.StatusOK)  
 w.Write([]byte("ready"))  
 })  
   
 // Metrics endpoint  
 http.Handle("/metrics", promhttp.Handler())  
   
 // Business endpoints with instrumentation  
 http.HandleFunc("/api/orders", instrumentHandler(ordersHandler, "/api/orders"))  
   
 http.ListenAndServe(":8080", nil)  
}

##### 43.1.3.5.2 Distributed Tracing Configuration (Node.js Example)

const { NodeSDK } = require('@opentelemetry/auto-instrumentations-node');  
const { JaegerExporter } = require('@opentelemetry/exporter-jaeger');  
const { Resource } = require('@opentelemetry/resources');  
const { SemanticResourceAttributes } = require('@opentelemetry/semantic-conventions');  
  
// Configure Jaeger exporter for OpenShift distributed tracing  
const jaegerExporter = new JaegerExporter({  
 endpoint: 'http://jaeger-collector.openshift-distributed-tracing-system.svc.cluster.local:14268/api/traces',  
});  
  
// Initialize OpenTelemetry SDK  
const sdk = new NodeSDK({  
 resource: new Resource({  
 [SemanticResourceAttributes.SERVICE\_NAME]: 'myapp-service',  
 [SemanticResourceAttributes.SERVICE\_VERSION]: process.env.APP\_VERSION || '1.0.0',  
 [SemanticResourceAttributes.DEPLOYMENT\_ENVIRONMENT]: process.env.NODE\_ENV || 'development',  
 }),  
 traceExporter: jaegerExporter,  
});  
  
sdk.start();  
  
const express = require('express');  
const { trace, context } = require('@opentelemetry/api');  
const app = express();  
  
// Custom tracing for business operations  
app.get('/api/orders/:id', async (req, res) => {  
 const tracer = trace.getTracer('myapp');  
   
 await tracer.startActiveSpan('process\_order', async (span) => {  
 try {  
 // Add custom attributes  
 span.setAttributes({  
 'order.id': req.params.id,  
 'user.id': req.headers['user-id'],  
 'operation.type': 'order\_processing'  
 });  
   
 // Simulate database call with tracing  
 await tracer.startActiveSpan('database\_query', async (dbSpan) => {  
 // Database operation  
 dbSpan.setAttributes({  
 'db.operation': 'SELECT',  
 'db.table': 'orders'  
 });  
 dbSpan.end();  
 });  
   
 // Simulate external API call  
 await tracer.startActiveSpan('external\_api\_call', async (apiSpan) => {  
 apiSpan.setAttributes({  
 'http.method': 'POST',  
 'http.url': 'https://payment-service/process'  
 });  
 apiSpan.end();  
 });  
   
 res.json({ orderId: req.params.id, status: 'processed' });  
 } catch (error) {  
 span.recordException(error);  
 span.setStatus({ code: trace.SpanStatusCode.ERROR, message: error.message });  
 res.status(500).json({ error: 'Processing failed' });  
 } finally {  
 span.end();  
 }  
 });  
});

##### 43.1.3.5.3 Structured Logging Configuration

## Python example with structured logging for OpenShift Logging  
import logging  
import json  
import sys  
from datetime import datetime  
  
class StructuredLogger:  
 def \_\_init\_\_(self, service\_name):  
 self.service\_name = service\_name  
 self.logger = logging.getLogger(service\_name)  
 self.logger.setLevel(logging.INFO)  
   
 # Configure JSON formatter for OpenShift Logging  
 handler = logging.StreamHandler(sys.stdout)  
 handler.setFormatter(self.JsonFormatter())  
 self.logger.addHandler(handler)  
   
 class JsonFormatter(logging.Formatter):  
 def format(self, record):  
 log\_entry = {  
 'timestamp': datetime.utcnow().isoformat() + 'Z',  
 'level': record.levelname,  
 'service': record.name,  
 'message': record.getMessage(),  
 }  
   
 # Add custom fields if present  
 if hasattr(record, 'user\_id'):  
 log\_entry['user\_id'] = record.user\_id  
 if hasattr(record, 'trace\_id'):  
 log\_entry['trace\_id'] = record.trace\_id  
 if hasattr(record, 'span\_id'):  
 log\_entry['span\_id'] = record.span\_id  
   
 return json.dumps(log\_entry)  
   
 def info(self, message, \*\*kwargs):  
 extra = {k: v for k, v in kwargs.items()}  
 self.logger.info(message, extra=extra)  
   
 def error(self, message, \*\*kwargs):  
 extra = {k: v for k, v in kwargs.items()}  
 self.logger.error(message, extra=extra)  
  
## Usage in application  
logger = StructuredLogger('myapp-service')  
  
def process\_order(order\_id, user\_id):  
 logger.info(  
 "Processing order",  
 user\_id=user\_id,  
 order\_id=order\_id,  
 operation='order\_processing'  
 )  
   
 try:  
 # Business logic  
 result = do\_business\_logic()  
 logger.info(  
 "Order processed successfully",  
 user\_id=user\_id,  
 order\_id=order\_id,  
 result=result  
 )  
 except Exception as e:  
 logger.error(  
 "Order processing failed",  
 user\_id=user\_id,  
 order\_id=order\_id,  
 error=str(e),  
 stack\_trace=traceback.format\_exc()  
 )  
 raise

#### 43.1.3.6 Step 3: Configure OpenShift Native Observability Components

##### 43.1.3.6.1 Enable Red Hat OpenShift Logging

apiVersion: logging.coreos.com/v1  
kind: ClusterLogging  
metadata:  
 name: instance  
 namespace: openshift-logging  
spec:  
 managementState: Managed  
 logStore:  
 type: lokistack  
 lokistack:  
 name: logging-loki  
 collection:  
 type: vector  
 vector:  
 resources:  
 limits:  
 memory: 1Gi  
 requests:  
 memory: 512Mi  
 visualization:  
 type: ocp-console  
---  
apiVersion: loki.grafana.com/v1  
kind: LokiStack  
metadata:  
 name: logging-loki  
 namespace: openshift-logging  
spec:  
 size: 1x.small  
 storage:  
 schemas:  
 - version: v12  
 effectiveDate: '2022-06-01'  
 secret:  
 name: logging-loki-s3  
 type: s3  
 storageClassName: ocs-storagecluster-ceph-rbd  
 tenants:  
 mode: openshift-logging

##### 43.1.3.6.2 Deploy Red Hat OpenShift distributed tracing

apiVersion: jaegertracing.io/v1  
kind: Jaeger  
metadata:  
 name: jaeger-production  
 namespace: openshift-distributed-tracing-system  
spec:  
 strategy: production  
 storage:  
 type: elasticsearch  
 elasticsearch:  
 nodeCount: 3  
 storage:  
 storageClassName: ocs-storagecluster-ceph-rbd  
 size: 100Gi  
 resources:  
 requests:  
 memory: 4Gi  
 cpu: 1  
 limits:  
 memory: 4Gi  
 cpu: 1

#### 43.1.3.7 Step 4: Configure Application Monitoring

##### 43.1.3.7.1 ServiceMonitor for Application Metrics

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: myapp-metrics  
 namespace: myapp-namespace  
 labels:  
 app: myapp  
spec:  
 selector:  
 matchLabels:  
 app: myapp  
 endpoints:  
 - port: metrics  
 interval: 30s  
 path: /metrics  
 honorLabels: true  
---  
apiVersion: v1  
kind: Service  
metadata:  
 name: myapp-metrics  
 namespace: myapp-namespace  
 labels:  
 app: myapp  
spec:  
 ports:  
 - name: metrics  
 port: 8080  
 targetPort: 8080  
 selector:  
 app: myapp

##### 43.1.3.7.2 PrometheusRule for Custom Alerts

apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: myapp-alerts  
 namespace: myapp-namespace  
spec:  
 groups:  
 - name: myapp.rules  
 rules:  
 - alert: MyAppHighErrorRate  
 expr: |  
 (  
 sum(rate(myapp\_http\_requests\_total{status\_code=~"5.."}[5m]))  
 /  
 sum(rate(myapp\_http\_requests\_total[5m]))  
 ) > 0.05  
 for: 5m  
 labels:  
 severity: warning  
 annotations:  
 summary: "High error rate detected in MyApp"  
 description: "Error rate is {{ $value | humanizePercentage }} for the last 5 minutes"  
   
 - alert: MyAppHighLatency  
 expr: |  
 histogram\_quantile(0.95,   
 sum(rate(myapp\_http\_request\_duration\_seconds\_bucket[5m])) by (le)  
 ) > 1.0  
 for: 5m  
 labels:  
 severity: warning  
 annotations:  
 summary: "High latency detected in MyApp"  
 description: "95th percentile latency is {{ $value }}s"  
   
 - alert: MyAppPodCrashLooping  
 expr: rate(kube\_pod\_container\_status\_restarts\_total{namespace="myapp-namespace"}[15m]) > 0  
 for: 5m  
 labels:  
 severity: critical  
 annotations:  
 summary: "MyApp pod is crash looping"  
 description: "Pod {{ $labels.pod }} is restarting frequently"

#### 43.1.3.8 Step 5: VM Workload Monitoring

##### 43.1.3.8.1 KubeVirt VM Monitoring

apiVersion: monitoring.coreos.com/v1  
kind: ServiceMonitor  
metadata:  
 name: kubevirt-vm-metrics  
 namespace: kubevirt-system  
spec:  
 selector:  
 matchLabels:  
 prometheus.kubevirt.io: "true"  
 endpoints:  
 - port: metrics  
 interval: 30s  
 honorLabels: true  
---  
## VM-specific PrometheusRule  
apiVersion: monitoring.coreos.com/v1  
kind: PrometheusRule  
metadata:  
 name: vm-alerts  
 namespace: vm-workloads  
spec:  
 groups:  
 - name: vm.rules  
 rules:  
 - alert: VMHighCPUUsage  
 expr: kubevirt\_vmi\_vcpu\_seconds\_total > 0.8  
 for: 10m  
 labels:  
 severity: warning  
 annotations:  
 summary: "VM {{ $labels.name }} has high CPU usage"  
   
 - alert: VMHighMemoryUsage  
 expr: |  
 (  
 kubevirt\_vmi\_memory\_resident\_bytes  
 /  
 kubevirt\_vmi\_memory\_maximum\_bytes  
 ) > 0.9  
 for: 5m  
 labels:  
 severity: critical  
 annotations:  
 summary: "VM {{ $labels.name }} has high memory usage"

#### 43.1.3.9 Step 6: Network Observability with Cilium Hubble

##### 43.1.3.9.1 Enable Cilium Hubble

apiVersion: cilium.io/v2alpha1  
kind: CiliumConfig  
metadata:  
 name: cilium-config  
 namespace: cilium-system  
spec:  
 hubble:  
 enabled: true  
 metrics:  
 enabled:  
 - dns:query;ignoreAAAA  
 - drop  
 - tcp  
 - flow  
 - icmp  
 - http  
 relay:  
 enabled: true  
 ui:  
 enabled: true

#### 43.1.3.10 Best Practices for Native Observability

* **Consistent Labeling**: Use standardized labels across all metrics (service, version, environment)
* **Cardinality Management**: Avoid high-cardinality labels that can overwhelm Prometheus
* **Sampling Strategy**: Implement trace sampling for high-traffic applications (1-10% sample rate)
* **Log Levels**: Use appropriate log levels and structured logging with consistent fields
* **Resource Limits**: Set appropriate resource limits for observability components
* **Retention Policies**: Configure appropriate retention for metrics (30d) and logs (7d for debug, 30d for info/error)
* **Alert Fatigue**: Create meaningful alerts with proper thresholds and runbooks

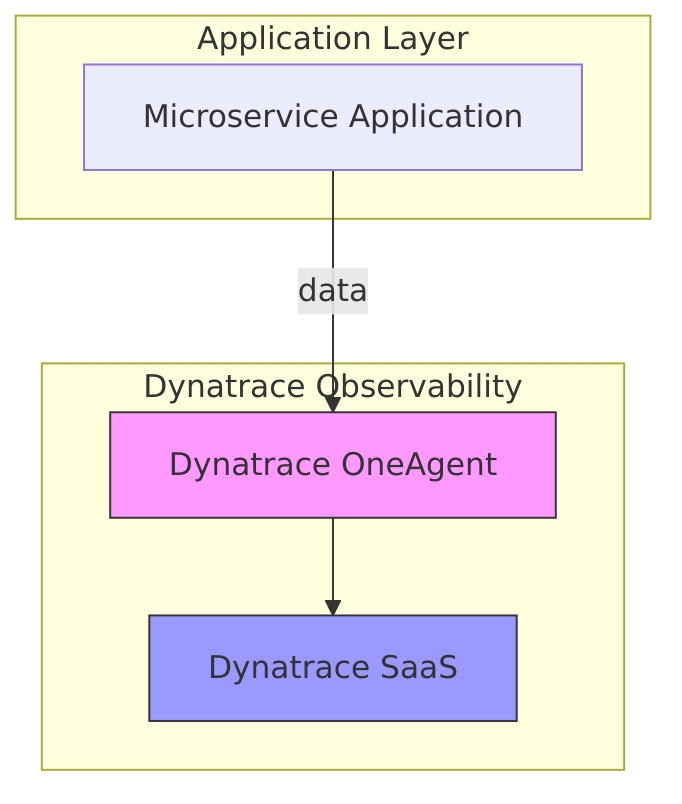
#### 43.1.3.11 2. Observability with Dynatrace

### 43.1.4 Infrastructure Requirements

* Dynatrace OneAgent deployed on OpenShift nodes
* Dynatrace SaaS or Managed account
* Network access to Dynatrace monitoring endpoints

### 43.1.5 Architecture Overview

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 43.1.6 Implementation Steps

#### 43.1.6.1 Step 1: Deploy Dynatrace OneAgent

* Use Dynatrace Operator for OpenShift to deploy OneAgent.

apiVersion: dynatrace.com/v1alpha1  
kind: Dynakube  
metadata:  
 name: dynakube  
 namespace: dynatrace  
spec:  
 oneAgent:  
 classicFullStack: true  
 apiUrl: "https://<environment-id>.live.dynatrace.com/api"  
 tokens: "api-token"

#### 43.1.6.2 Step 2: Application Configuration

* No changes required for application code, as OneAgent will automatically instrument all services.

#### 43.1.6.3 Step 3: Monitor and Analyze

* Use Dynatrace dashboards for comprehensive observability and performance analysis.
* Implement AI-driven alerts for proactive issue detection.

#### 43.1.6.4 Best Practices

* **Ensure Network Connectivity**: Verify network connectivity to Dynatrace endpoints.
* **Optimize Resource Allocation**: Ensure sufficient resources for OneAgent processing.
* **Leverage Dynatrace AI**: Utilize Dynatrace’s AI capabilities for automated root cause analysis.

This comprehensive guide provides both native and third-party observability solutions, enabling holistic insights into application performance and behavior within the RH OVE ecosystem.

# 44 WAF & Firewalling

## 44.1 Use Case: Web Application Firewall (WAF) Firewalling and Integration with F5 BigIP

### 44.1.1 Business Context

As enterprises adopt cloud-native architectures, securing web applications becomes crucial for protecting sensitive data and maintaining business continuity. This use case demonstrates how to implement a robust Web Application Firewall (WAF) using native L4-L7 capabilities and integrate it with F5 BigIP for enhanced security management within the RH OVE ecosystem.

### 44.1.2 Technical Requirements

#### 44.1.2.1 Infrastructure Requirements

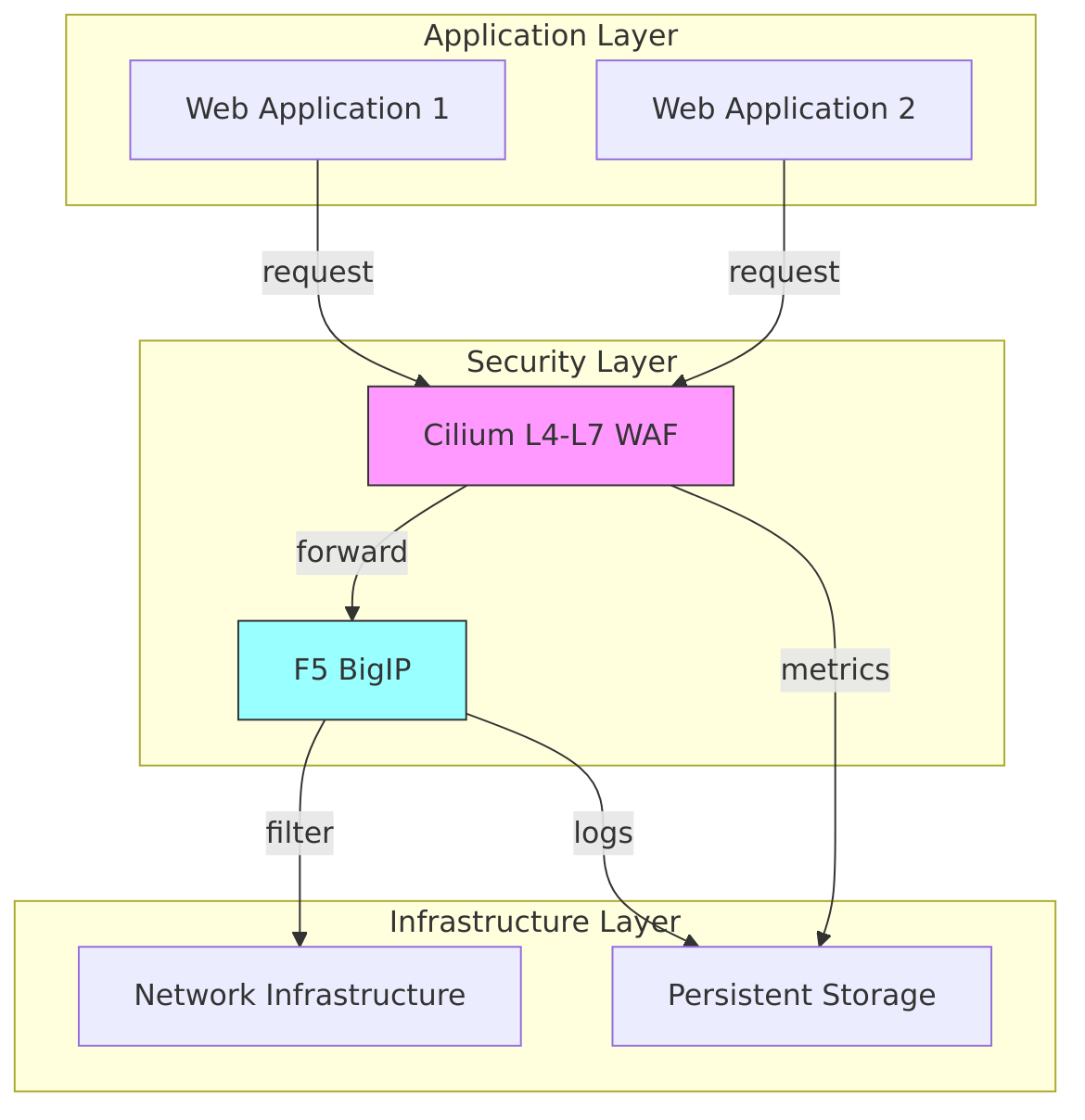
* OpenShift 4.12+ cluster with Multus CNI enabled
* Cilium CNI for L4-L7 Policy Enforcement
* F5 BigIP for advanced traffic management and security policies
* Persistent storage solutions for logs and reports

#### 44.1.2.2 Resource Requirements

* **CPU**: Sufficient compute resources to support firewall processing
* **Memory**: Adequate memory allocation for traffic inspection and logs
* **Storage**: High-performance storage for log retention and reporting
* **Network**: Scalable network infrastructure for seamless traffic flow

### 44.1.3 Architecture Overview

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 44.1.4 Implementation Steps

#### 44.1.4.1 Step 1: Deploy Cilium L4-L7 Firewall

##### 44.1.4.1.1 Cilium Configuration

apiVersion: cilium.io/v2  
kind: CiliumNetworkPolicy  
metadata:  
 name: web-app-waf-policy  
 namespace: infrastructure  
spec:  
 endpointSelector:  
 matchLabels:  
 app.kubernetes.io/name: web  
 ingress:  
 - rules:  
 http:  
 - method: "POST"  
 path: "/api"  
 - method: "GET"  
 path: "/"  
 egress:  
 - toEndpoints:  
 - matchLabels:  
 infrastructure: f5-bigip

#### 44.1.4.2 Step 2: Integrate with F5 BigIP

##### 44.1.4.2.1 F5 BigIP Virtual Server Configuration

* Configure F5 virtual server to handle traffic directed from Cilium WAF.
* Implement F5 policies for SSL termination, traffic redirection, and detailed logging.

## Example F5 BigIP CLI configuration  
create ltm virtual vs-web-app {  
 destination 192.168.1.100:80  
 ip-protocol tcp  
 profiles add { http { context clientside } }  
 pool my-web-app-pool  
 rules { waf-inspection }   
}  
  
## Associate WAF policies  
create ltm policy waf-inspection {  
 rules add {  
 10 { conditions { tcp } actions { forward pool-member my-web-app-pool  
 } }  
 }  
}

#### 44.1.4.3 Step 3: Advanced Traffic Monitoring and Logging

##### 44.1.4.3.1 Persistent Storage Configuration

* Configure persistent volumes for log storage using Cilium and F5 BigIP integrations.

apiVersion: v1  
kind: PersistentVolumeClaim  
metadata:  
 name: storage-logs  
 namespace: infrastructure  
spec:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 500Gi  
 storageClassName: high-performance

#### 44.1.4.4 Step 4: Deploy Monitoring and Analytics Tools

##### 44.1.4.4.1 Monitoring with Grafana and Prometheus

* Use Grafana dashboards to visualize traffic patterns and security metrics.
* Implement Prometheus alerting for suspicious activity detection.

## Grafana Dashboard Configuration  
apiVersion: integreatly.org/v1alpha1  
kind: GrafanaDashboard  
metadata:  
 name: waf-dashboard  
 namespace: monitoring  
spec:  
 json: |  
 {  
 "title": "Web Application Firewall Overview",  
 "panels": [  
 {  
 "type": "graph",  
 "title": "HTTP Requests",  
 "targets": [  
 { "expr": "sum(rate(http\_requests\_total[5m]))", "interval": ",5m" }  
 ]  
 }  
 ]  
 }

#### 44.1.4.5 Troubleshooting and Maintenance

##### 44.1.4.5.1 Common Issues and Solutions

* **Policy Misconfiguration**: Verify Cilium and F5 policy configurations for errors.
* **Performance Degradation**: Ensure adequate resources for Cilium and F5 processing.
* **Logging Failures**: Check storage availability and permissions.

#### 44.1.4.6 Best Practices

* **Regular Audits**: Conduct regular audits of firewall rules and configurations.
* **Security Hardening**: Apply security patches to F5 BigIP and Cilium regularly.
* **Performance Monitoring**: Continuously monitor firewall performance and resource usage.

### 44.1.5 Integration with RH OVE Ecosystem

* **Seamless Traffic Flow**: Ensure smooth integration of traffic between application components and security layers.
* **Consistent Policy Management**: Use GitOps practices to manage and version firewall rules.
* **Network Observability**: Leverage Cilium Hubble for enhanced network observability within the OpenShift clusters.

This comprehensive guide provides the steps and best practices required to deploy and manage an effective Web Application Firewall solution in combination with F5 BigIP, ensuring robust protection for your web applications while seamlessly integrating within the RH OVE multi-cluster ecosystem.

# 45 Events to CMDB/SIEM

## 45.1 Use Case: Publishing Kubernetes Events to CMDB and SIEM Solutions

### 45.1.1 Business Context

Enterprise IT environments require robust integration between Kubernetes events and existing IT service management and security incident management platforms. Integrating Kubernetes events with CMDB (such as ServiceNow or GLPI) and SIEM solutions enhances visibility, compliance, and proactive issue resolution. This use case focuses on using an event-bus to publish infrastructure changes, security issues, and admission control issues from Kubernetes to these platforms.

### 45.1.2 Technical Requirements

#### 45.1.2.1 Infrastructure Requirements

* OpenShift 4.12+ cluster with event capture capabilities
* Event-bus solution such as NATS, Kafka, or RabbitMQ
* Connectivity to CMDB (e.g., ServiceNow, GLPI) and SIEM solutions
* Persistent storage for event retention and replay

#### 45.1.2.2 Resource Requirements

* **CPU**: Adequate resources for handling and processing events
* **Memory**: Sufficient memory for event processing and transformation
* **Storage**: Persistent storage for event logs and audit trails
* **Network**: Reliable connectivity to external platforms

### 45.1.3 Event Categories and Sources

#### 45.1.3.1 Infrastructure Change Events

* **Node Events**: Node ready/not ready, resource pressure, kubelet issues
* **Pod Events**: Pod scheduling, image pulling, container creation/termination
* **Storage Events**: Volume mounting/unmounting, PVC binding issues
* **Network Events**: Service endpoint changes, ingress controller updates
* **Resource Events**: Deployment scaling, ConfigMap/Secret updates

#### 45.1.3.2 Security Events

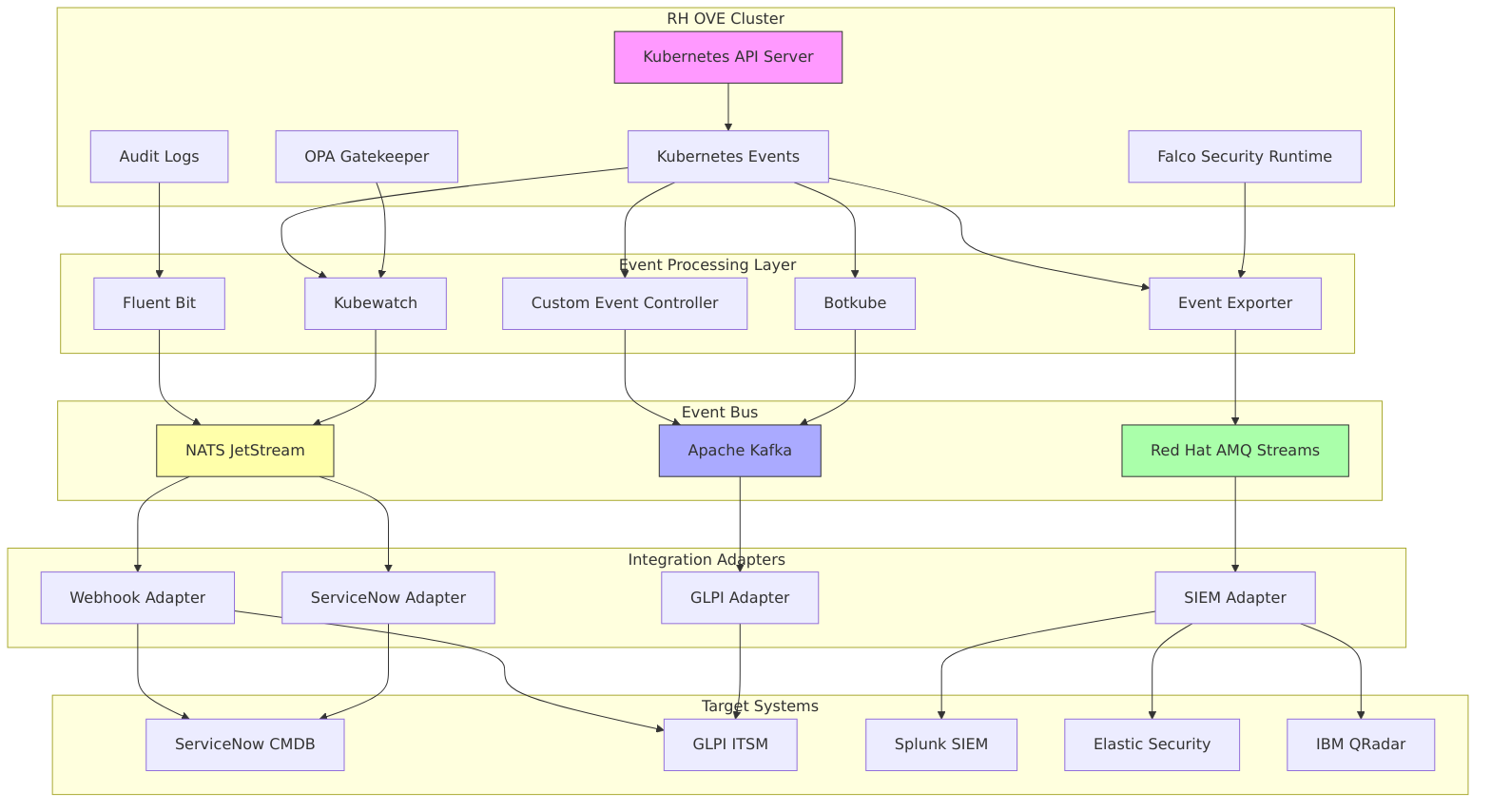
* **RBAC Violations**: Unauthorized access attempts, permission denials
* **Pod Security Policy Violations**: SecurityContext violations, privileged access attempts
* **Image Security Events**: Image scanning failures, vulnerable image deployments
* **Network Policy Violations**: Blocked network connections, policy enforcement
* **Certificate Events**: TLS certificate expiration, rotation failures

#### 45.1.3.3 Admission Control Events

* **ValidatingAdmissionWebhook**: Policy violations, validation failures
* **MutatingAdmissionWebhook**: Resource mutations, injection failures
* **Resource Quota Violations**: Quota exceeded, resource limit breaches
* **LimitRange Violations**: Container resource limit violations

### 45.1.4 Architecture Overview

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

### 45.1.5 Implementation Steps

#### 45.1.5.1 Step 1: Deploy Event Bus Solution

##### 45.1.5.1.1 Deploy NATS Streaming

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: nats-streaming  
 namespace: event-bus  
spec:  
 replicas: 3  
 selector:  
 matchLabels:  
 app: nats-streaming  
 template:  
 metadata:  
 labels:  
 app: nats-streaming  
 spec:  
 containers:  
 - name: nats  
 image: nats-streaming:latest  
 ports:  
 - containerPort: 4222  
 - containerPort: 8222  
 resources:  
 limits:  
 memory: 512Mi  
 cpu: 0.5  
 requests:  
 memory: 256Mi  
 cpu: 0.25

#### 45.1.5.2 Step 2: Configure Event Processing Solutions

##### 45.1.5.2.1 Option 1: Deploy Kubewatch for Event Monitoring

Kubewatch is a Kubernetes watcher that publishes notifications to various channels.

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: kubewatch  
 namespace: event-processing  
spec:  
 replicas: 1  
 selector:  
 matchLabels:  
 app: kubewatch  
 template:  
 metadata:  
 labels:  
 app: kubewatch  
 spec:  
 serviceAccountName: kubewatch  
 containers:  
 - name: kubewatch  
 image: bitnami/kubewatch:latest  
 env:  
 - name: KW\_CONFIG  
 value: /config/kubewatch-config.yaml  
 volumeMounts:  
 - name: config  
 mountPath: /config  
 resources:  
 limits:  
 memory: 256Mi  
 cpu: 100m  
 requests:  
 memory: 128Mi  
 cpu: 50m  
 volumes:  
 - name: config  
 configMap:  
 name: kubewatch-config  
---  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: kubewatch-config  
 namespace: event-processing  
data:  
 kubewatch-config.yaml: |  
 namespace: ""  
 handler:  
 webhook:  
 url: "http://event-router.event-processing.svc.cluster.local:8080/webhook"  
 resource:  
 deployment: true  
 replicationcontroller: false  
 replicaset: false  
 daemonset: true  
 services: true  
 pod: true  
 job: true  
 node: true  
 clusterrole: false  
 serviceaccount: false  
 persistentvolume: true  
 namespace: true  
 secret: false  
 configmap: false  
 ingress: true  
 event: true  
---  
apiVersion: v1  
kind: ServiceAccount  
metadata:  
 name: kubewatch  
 namespace: event-processing  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRole  
metadata:  
 name: kubewatch  
rules:  
- apiGroups: [""]  
 resources: ["pods", "nodes", "namespaces", "events", "services", "persistentvolumes"]  
 verbs: ["list", "watch", "get"]  
- apiGroups: ["apps"]  
 resources: ["deployments", "daemonsets", "replicasets"]  
 verbs: ["list", "watch", "get"]  
- apiGroups: ["extensions"]  
 resources: ["ingresses"]  
 verbs: ["list", "watch", "get"]  
- apiGroups: ["batch"]  
 resources: ["jobs"]  
 verbs: ["list", "watch", "get"]  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRoleBinding  
metadata:  
 name: kubewatch  
roleRef:  
 apiGroup: rbac.authorization.k8s.io  
 kind: ClusterRole  
 name: kubewatch  
subjects:  
- kind: ServiceAccount  
 name: kubewatch  
 namespace: event-processing

##### 45.1.5.2.2 Option 2: Deploy Botkube for Advanced Event Processing

Botkube provides intelligent event filtering and routing capabilities.

apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: botkube-config  
 namespace: event-processing  
data:  
 config.yaml: |  
 settings:  
 clustername: "rh-ove-cluster"  
 kubectl:  
 enabled: false  
 configwatcher: true  
 upgradenotifier: true  
   
 communications:  
 webhook:  
 enabled: true  
 url: "http://event-router.event-processing.svc.cluster.local:8080/botkube"  
   
 resources:  
 - name: "v1/pods"  
 namespaces:  
 include:  
 - "default"  
 - "kube-system"  
 - "openshift-\*"  
 events:  
 - create  
 - delete  
 - error  
 updateSetting:  
 includeDiff: true  
 fields:  
 - "spec.containers[\*].image"  
 - "status.phase"  
   
 - name: "v1/services"  
 namespaces:  
 include:  
 - "default"  
 events:  
 - create  
 - delete  
 - error  
   
 - name: "v1/nodes"  
 events:  
 - create  
 - delete  
 - error  
   
 - name: "v1/events"  
 events:  
 - error  
 - warning  
 filters:  
 objectAnnotations:  
 pattern: ".\*"  
 reason:  
 - "FailedScheduling"  
 - "Unhealthy"  
 - "FailedMount"  
 - "NetworkNotReady"  
 - "NodeNotReady"  
 - "Rebooted"  
 - "SystemOOM"  
---  
apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: botkube  
 namespace: event-processing  
spec:  
 replicas: 1  
 selector:  
 matchLabels:  
 app: botkube  
 template:  
 metadata:  
 labels:  
 app: botkube  
 spec:  
 serviceAccountName: botkube  
 containers:  
 - name: botkube  
 image: infracloudio/botkube:latest  
 env:  
 - name: CONFIG\_PATH  
 value: "/tmp/config/"  
 - name: LOG\_LEVEL  
 value: "info"  
 volumeMounts:  
 - name: config  
 mountPath: "/tmp/config"  
 resources:  
 limits:  
 memory: 256Mi  
 cpu: 100m  
 requests:  
 memory: 128Mi  
 cpu: 50m  
 volumes:  
 - name: config  
 configMap:  
 name: botkube-config  
---  
apiVersion: v1  
kind: ServiceAccount  
metadata:  
 name: botkube  
 namespace: event-processing  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRole  
metadata:  
 name: botkube  
rules:  
- apiGroups: ["\*"]  
 resources: ["\*"]  
 verbs: ["get", "watch", "list"]  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRoleBinding  
metadata:  
 name: botkube  
roleRef:  
 apiGroup: rbac.authorization.k8s.io  
 kind: ClusterRole  
 name: botkube  
subjects:  
- kind: ServiceAccount  
 name: botkube  
 namespace: event-processing

##### 45.1.5.2.3 Option 3: Deploy Kubernetes Event Exporter

For more granular control over event processing and routing.

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: event-exporter  
 namespace: event-processing  
spec:  
 replicas: 1  
 selector:  
 matchLabels:  
 app: event-exporter  
 template:  
 metadata:  
 labels:  
 app: event-exporter  
 spec:  
 serviceAccountName: event-exporter  
 containers:  
 - name: event-exporter  
 image: giantswarm/event-exporter:latest  
 args:  
 - --config-file=/config/config.yaml  
 - --logtostderr  
 - --v=2  
 volumeMounts:  
 - name: config  
 mountPath: /config  
 resources:  
 limits:  
 memory: 256Mi  
 cpu: 100m  
 requests:  
 memory: 128Mi  
 cpu: 50m  
 volumes:  
 - name: config  
 configMap:  
 name: event-exporter-config  
---  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: event-exporter-config  
 namespace: event-processing  
data:  
 config.yaml: |  
 logLevel: 2  
 logFormat: json  
 receivers:  
 - name: "webhook-receiver"  
 webhook:  
 endpoint: "http://event-router.event-processing.svc.cluster.local:8080/events"  
 headers:  
 X-Source: "kubernetes-events"  
 Content-Type: "application/json"  
 - name: "kafka-receiver"  
 kafka:  
 brokers:  
 - "kafka.event-bus.svc.cluster.local:9092"  
 topic: "kubernetes-events"  
   
 route:  
 routes:  
 # Infrastructure change events  
 - match:  
 - receiver: "webhook-receiver"  
 name: "infrastructure-changes"  
 - receiver: "kafka-receiver"  
 name: "infrastructure-changes"  
 groupBy: ["namespace", "reason"]  
 groupWait: 10s  
 groupInterval: 30s  
 repeatInterval: 1h  
 routes:  
 - match:  
 - field: "reason"  
 op: "in"  
 values: ["Scheduled", "Pulled", "Created", "Started"]  
 name: "pod-lifecycle"  
 - match:  
 - field: "reason"  
 op: "in"  
 values: ["NodeReady", "NodeNotReady", "Rebooted"]  
 name: "node-events"  
 - match:  
 - field: "reason"  
 op: "in"  
 values: ["SuccessfulMount", "FailedMount"]  
 name: "storage-events"  
   
 # Security events  
 - match:  
 - receiver: "webhook-receiver"  
 name: "security-events"  
 groupBy: ["namespace", "reason", "involvedObject.kind"]  
 routes:  
 - match:  
 - field: "reason"  
 op: "in"  
 values: ["Forbidden", "Unauthorized", "PolicyViolation"]  
 name: "security-violations"  
 - match:  
 - field: "message"  
 op: "re"  
 values: [".\*security.\*", ".\*violation.\*", ".\*denied.\*"]  
 name: "security-related"  
   
 # Admission control events  
 - match:  
 - receiver: "kafka-receiver"  
 name: "admission-control"  
 routes:  
 - match:  
 - field: "reason"  
 op: "in"  
 values: ["FailedCreate", "AdmissionWebhookDenied"]  
 name: "admission-denied"  
---  
apiVersion: v1  
kind: ServiceAccount  
metadata:  
 name: event-exporter  
 namespace: event-processing  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRole  
metadata:  
 name: event-exporter  
rules:  
- apiGroups: [""]  
 resources: ["events"]  
 verbs: ["get", "watch", "list"]  
---  
apiVersion: rbac.authorization.k8s.io/v1  
kind: ClusterRoleBinding  
metadata:  
 name: event-exporter  
roleRef:  
 apiGroup: rbac.authorization.k8s.io  
 kind: ClusterRole  
 name: event-exporter  
subjects:  
- kind: ServiceAccount  
 name: event-exporter  
 namespace: event-processing

##### 45.1.5.2.4 Option 4: Custom Event Controller with Event Router

For maximum flexibility, deploy a custom event router that can transform and route events.

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: event-router  
 namespace: event-processing  
spec:  
 replicas: 2  
 selector:  
 matchLabels:  
 app: event-router  
 template:  
 metadata:  
 labels:  
 app: event-router  
 spec:  
 containers:  
 - name: event-router  
 image: quay.io/example/event-router:latest  
 ports:  
 - containerPort: 8080  
 env:  
 - name: NATS\_URL  
 value: "nats://nats.event-bus.svc.cluster.local:4222"  
 - name: KAFKA\_BROKERS  
 value: "kafka.event-bus.svc.cluster.local:9092"  
 - name: LOG\_LEVEL  
 value: "info"  
 resources:  
 limits:  
 memory: 512Mi  
 cpu: 200m  
 requests:  
 memory: 256Mi  
 cpu: 100m  
 livenessProbe:  
 httpGet:  
 path: /health  
 port: 8080  
 initialDelaySeconds: 30  
 periodSeconds: 10  
 readinessProbe:  
 httpGet:  
 path: /ready  
 port: 8080  
 initialDelaySeconds: 5  
 periodSeconds: 5  
---  
apiVersion: v1  
kind: Service  
metadata:  
 name: event-router  
 namespace: event-processing  
spec:  
 selector:  
 app: event-router  
 ports:  
 - name: http  
 port: 8080  
 targetPort: 8080  
 type: ClusterIP

#### 45.1.5.3 Step 3: Deploy Event Bus Solutions

##### 45.1.5.3.1 Deploy Red Hat AMQ Streams (Kafka)

apiVersion: kafka.strimzi.io/v1beta2  
kind: Kafka  
metadata:  
 name: event-cluster  
 namespace: event-bus  
spec:  
 kafka:  
 version: 3.4.0  
 replicas: 3  
 listeners:  
 - name: plain  
 port: 9092  
 type: internal  
 tls: false  
 - name: tls  
 port: 9093  
 type: internal  
 tls: true  
 config:  
 offsets.topic.replication.factor: 3  
 transaction.state.log.replication.factor: 3  
 transaction.state.log.min.isr: 2  
 default.replication.factor: 3  
 min.insync.replicas: 2  
 inter.broker.protocol.version: "3.4"  
 log.retention.hours: 168 # 7 days  
 log.segment.bytes: 1073741824 # 1GB  
 storage:  
 type: persistent-claim  
 size: 100Gi  
 class: ocs-storagecluster-ceph-rbd  
 resources:  
 requests:  
 memory: 2Gi  
 cpu: 500m  
 limits:  
 memory: 4Gi  
 cpu: 1  
 zookeeper:  
 replicas: 3  
 storage:  
 type: persistent-claim  
 size: 10Gi  
 class: ocs-storagecluster-ceph-rbd  
 resources:  
 requests:  
 memory: 1Gi  
 cpu: 500m  
 limits:  
 memory: 2Gi  
 cpu: 1  
 entityOperator:  
 topicOperator: {}  
 userOperator: {}  
---  
apiVersion: kafka.strimzi.io/v1beta2  
kind: KafkaTopic  
metadata:  
 name: kubernetes-events  
 namespace: event-bus  
 labels:  
 strimzi.io/cluster: event-cluster  
spec:  
 partitions: 12  
 replicas: 3  
 config:  
 retention.ms: 604800000 # 7 days  
 segment.ms: 3600000 # 1 hour  
---  
apiVersion: kafka.strimzi.io/v1beta2  
kind: KafkaTopic  
metadata:  
 name: security-events  
 namespace: event-bus  
 labels:  
 strimzi.io/cluster: event-cluster  
spec:  
 partitions: 6  
 replicas: 3  
 config:  
 retention.ms: 2592000000 # 30 days  
 segment.ms: 3600000 # 1 hour  
---  
apiVersion: kafka.strimzi.io/v1beta2  
kind: KafkaTopic  
metadata:  
 name: infrastructure-changes  
 namespace: event-bus  
 labels:  
 strimzi.io/cluster: event-cluster  
spec:  
 partitions: 6  
 replicas: 3  
 config:  
 retention.ms: 1209600000 # 14 days  
 segment.ms: 3600000 # 1 hour

##### 45.1.5.3.2 Deploy NATS JetStream

apiVersion: apps/v1  
kind: StatefulSet  
metadata:  
 name: nats  
 namespace: event-bus  
spec:  
 serviceName: nats  
 replicas: 3  
 selector:  
 matchLabels:  
 app: nats  
 template:  
 metadata:  
 labels:  
 app: nats  
 spec:  
 containers:  
 - name: nats  
 image: nats:alpine  
 ports:  
 - containerPort: 4222  
 name: client  
 - containerPort: 7422  
 name: leafnodes  
 - containerPort: 6222  
 name: cluster  
 - containerPort: 8222  
 name: monitor  
 - containerPort: 7777  
 name: metrics  
 args:  
 - --config  
 - /etc/nats-config/nats.conf  
 volumeMounts:  
 - name: config-volume  
 mountPath: /etc/nats-config  
 - name: data  
 mountPath: /data  
 resources:  
 requests:  
 memory: 512Mi  
 cpu: 200m  
 limits:  
 memory: 1Gi  
 cpu: 500m  
 livenessProbe:  
 httpGet:  
 path: /healthz  
 port: 8222  
 initialDelaySeconds: 10  
 timeoutSeconds: 5  
 readinessProbe:  
 httpGet:  
 path: /healthz  
 port: 8222  
 initialDelaySeconds: 10  
 timeoutSeconds: 5  
 volumes:  
 - name: config-volume  
 configMap:  
 name: nats-config  
 volumeClaimTemplates:  
 - metadata:  
 name: data  
 spec:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 10Gi  
 storageClassName: ocs-storagecluster-ceph-rbd  
---  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: nats-config  
 namespace: event-bus  
data:  
 nats.conf: |  
 port: 4222  
 http\_port: 8222  
   
 cluster {  
 name: nats-cluster  
 port: 6222  
 routes = [  
 nats://nats-0.nats.event-bus.svc.cluster.local:6222  
 nats://nats-1.nats.event-bus.svc.cluster.local:6222  
 nats://nats-2.nats.event-bus.svc.cluster.local:6222  
 ]  
 }  
   
 jetstream {  
 store\_dir: "/data"  
 max\_memory\_store: 256MB  
 max\_file\_store: 2GB  
 }  
   
 accounts {  
 $SYS { users = [ { user: "admin", pass: "password" } ] }  
 events {  
 jetstream: enabled  
 users = [  
 { user: "event-publisher", pass: "publisher-secret" }  
 { user: "event-consumer", pass: "consumer-secret" }  
 ]  
 }  
 }  
---  
apiVersion: v1  
kind: Service  
metadata:  
 name: nats  
 namespace: event-bus  
spec:  
 selector:  
 app: nats  
 clusterIP: None  
 ports:  
 - name: client  
 port: 4222  
 - name: cluster  
 port: 6222  
 - name: monitor  
 port: 8222

#### 45.1.5.4 Step 4: Configure Integration Adapters

##### 45.1.5.4.1 ServiceNow Integration Adapter

apiVersion: apps/v1  
kind: Deployment  
metadata:  
 name: servicenow-adapter  
 namespace: integration  
spec:  
 replicas: 2  
 selector:  
 matchLabels:  
 app: servicenow-adapter  
 template:  
 metadata:  
 labels:  
 app: servicenow-adapter  
 spec:  
 containers:  
 - name: adapter  
 image: quay.io/example/servicenow-adapter:latest  
 env:  
 - name: SERVICENOW\_INSTANCE  
 value: "https://dev12345.service-now.com"  
 - name: SERVICENOW\_USERNAME  
 valueFrom:  
 secretKeyRef:  
 name: servicenow-credentials  
 key: username  
 - name: SERVICENOW\_PASSWORD  
 valueFrom:  
 secretKeyRef:  
 name: servicenow-credentials  
 key: password  
 - name: KAFKA\_BROKERS  
 value: "event-cluster-kafka-bootstrap.event-bus.svc.cluster.local:9092"  
 - name: KAFKA\_TOPICS  
 value: "kubernetes-events,infrastructure-changes,security-events"  
 - name: SERVICENOW\_TABLE\_MAPPING  
 value: |  
 {  
 "kubernetes-events": "incident",  
 "infrastructure-changes": "change\_request",  
 "security-events": "sn\_si\_incident"  
 }  
 resources:  
 requests:  
 memory: 256Mi  
 cpu: 100m  
 limits:  
 memory: 512Mi  
 cpu: 200m  
 livenessProbe:  
 httpGet:  
 path: /health  
 port: 8080  
 initialDelaySeconds: 30  
 periodSeconds: 10  
 readinessProbe:  
 httpGet:  
 path: /ready  
 port: 8080  
 initialDelaySeconds: 5  
 periodSeconds: 5  
---  
apiVersion: v1  
kind: Secret  
metadata:  
 name: servicenow-credentials  
 namespace: integration  
type: Opaque  
data:  
 username: <base64-encoded-username>  
 password: <base64-encoded-password>  
---  
apiVersion: v1  
kind: ConfigMap  
metadata:  
 name: servicenow-field-mapping  
 namespace: integration  
data:  
 mapping.json: |  
 {  
 "incident": {  
 "short\_description": "{{ .reason }}: {{ .message | truncate 100 }}",  
 "description": "Kubernetes Event Details:\n\nNamespace: {{ .namespace }}\nObject: {{ .involvedObject.kind }}/{{ .involvedObject.name }}\nReason: {{ .reason }}\nMessage: {{ .message }}\nFirst Seen: {{ .firstTimestamp }}\nLast Seen: {{ .lastTimestamp }}\nCount: {{ .count }}",  
 "category": "Software",  
 "subcategory": "Kubernetes",  
 "urgency": "{{ if eq .type \"Warning\" }}2{{ else }}3{{ end }}",  
 "impact": "{{ if contains .reason \"Failed\" }}2{{ else }}3{{ end }}",  
 "assignment\_group": "Platform Engineering",  
 "caller\_id": "kubernetes-system",  
 "u\_kubernetes\_cluster": "{{ .clusterName }}",  
 "u\_kubernetes\_namespace": "{{ .namespace }}",  
 "u\_kubernetes\_object": "{{ .involvedObject.kind }}/{{ .involvedObject.name }}"  
 },  
 "change\_request": {  
 "short\_description": "Infrastructure Change: {{ .reason }}",  
 "description": "{{ .message }}",  
 "category": "Standard",  
 "type": "Normal",  
 "risk": "Low",  
 "impact": "3",  
 "priority": "4",  
 "assignment\_group": "Platform Engineering"  
 }  
 }

##### 45.1.5.4.2 Publish Events to SIEM

* Configure integration using SIEM platform’s ingress mechanisms.
* Example for Splunk:

apiVersion: batch/v1beta1  
kind: CronJob  
metadata:  
 name: publish-events-splunk  
 namespace: integration  
spec:  
 schedule: "\*/5 \* \* \* \*"  
 jobTemplate:  
 spec:  
 template:  
 spec:  
 containers:  
 - name: splunk-publisher  
 image: splunk-integration:latest  
 env:  
 - name: SPLUNK\_HEC\_URL  
 value: "https://splunk-hec.local/services/collector"  
 - name: SPLUNK\_TOKEN  
 valueFrom:  
 secretKeyRef:  
 name: splunk-credentials  
 key: hec\_token  
 command: ["publish", "--source=nats", "--target=splunk"]

#### 45.1.5.5 Step 4: Persistent Storage for Event Retention

##### 45.1.5.5.1 Storage Configuration

* Use OpenShift Data Foundation for persistent storage.

apiVersion: v1  
kind: PersistentVolumeClaim  
metadata:  
 name: events-storage  
 namespace: event-bus  
spec:  
 accessModes:  
 - ReadWriteOnce  
 resources:  
 requests:  
 storage: 100Gi  
 storageClassName: ocs-storagecluster-ceph-rbd

#### 45.1.5.6 Troubleshooting

##### 45.1.5.6.1 Common Issues and Solutions

* **Connectivity Issues**: Verify network policies and DNS resolution to external CMDB and SIEM platforms.
* **Event Capture Failures**: Ensure event-controller configurations are correct and have appropriate RBAC permissions.
* **Performance Bottlenecks**: Scale event-bus components and monitor resource utilization.

#### 45.1.5.7 Best Practices

* **Secure Integration**: Use secure channels (TLS) for communication with external platforms.
* **Scalable Event Processing**: Implement horizontal scaling for event-bus solutions.
* **Audit and Compliance**: Maintain detailed logs and audit trails for event processing.

### 45.1.6 Integration with RH OVE Ecosystem

* **Automation and Policy Enforcement**: Use event-driven automation for rapid remediation and policy enforcement.
* **Proactive Monitoring**: Enhance monitoring and observability for real-time insights into infrastructure and application changes.

This use case guides implementing a scalable and flexible solution to publish vital Kubernetes events to enterprise IT management and security platforms, enhancing operational visibility and control.

# 46 Overview

## 46.1 RH OVE Ecosystem Project Plan

### 46.1.1 Executive Summary

This document outlines a comprehensive project plan for implementing the Red Hat OpenShift Virtualization Engine (RH OVE) Multi-Cluster Ecosystem. The project is divided into three strategic sub-projects, each focusing on specific aspects of the ecosystem implementation and operation.

### 46.1.2 Project Structure Overview

The RH OVE Ecosystem implementation is organized into three complementary sub-projects:

1. **RH OVE Infrastructure Project** - Core platform setup and operations
2. **Use-Cases Implementation Project** - Application scenarios and demonstrations
3. **Migration Workload from VMware Project** - Legacy workload migration

### 46.1.3 Sub-Project 1: RH OVE Infrastructure Project

#### 46.1.3.1 Scope

Focus on the complete lifecycle of infrastructure setup and operations, including study, High-Level Design (HLD), Low-Level Design (LLD), implementation, testing, and Day-2 operations for the core RH OVE multi-cluster infrastructure components.

#### 46.1.3.2 Documentation Areas Covered

* **Architecture**:
  + Global Overview (global-overview.md)
  + Single Cluster Overview (overview.md)
  + Design Principles (design-principles.md)
  + Network Architecture (network.md)
  + Storage Architecture (storage.md)
  + IAM Strategy (iam.md)
* **Architecture Decision Records (ADRs)**:
  + Multi-cluster patterns
  + GitOps with ArgoCD
  + Cluster topology
  + Admission control strategies
  + Network CNI implementation
  + Backup strategies
  + Monitoring approaches
  + IAM implementation
* **Deployment**:
  + Prerequisites (prerequisites.md)
  + Installation procedures (installation.md)
  + Configuration management (configuration.md)
* **Management**:
  + Admission control (admission-control.md)
  + GitOps operations (gitops.md)
  + Monitoring systems (monitoring.md)
  + Backup and recovery (backup.md)
* **Operations**:
  + Day-2 operations (day2-ops.md)
  + Troubleshooting procedures (troubleshooting.md)
  + Performance tuning (performance.md)

#### 46.1.3.3 Work Phases

1. **Study Phase**: Detailed understanding of RH OVE architecture and components
2. **Design Phase**: Create and validate HLD and LLD documents
3. **Implementation Phase**: Deploy infrastructure components following established practices
4. **Testing Phase**: Verify infrastructure robustness, security, and performance
5. **Day-2 Operations Phase**: Establish ongoing monitoring, troubleshooting, and tuning

#### 46.1.3.4 Required Personas

* **Infrastructure Architect**: Designs overall infrastructure architecture and integration patterns
* **DevOps Engineer**: Implements automation, CI/CD pipelines, and GitOps workflows
* **System Administrator**: Manages day-to-day operations, monitoring, and maintenance
* **Security Engineer**: Ensures security compliance and implements security controls
* **Network Engineer**: Designs and implements network architecture and policies

### 46.1.4 Sub-Project 2: Use-Cases Implementation Project

#### 46.1.4.1 Scope

Study, design, implement, test, and operate comprehensive use-cases demonstrating RH OVE capabilities for applications and services. Each use-case highlights unique features and integrations within RH OVE, showcasing multi-cluster deployment benefits.

#### 46.1.4.2 Documentation Areas Covered

* **Use Cases Overview**: Comprehensive introduction to all use-cases, relevance, and expected outcomes
* **VM Lifecycle Management**:
  + VM Import & Migration (vm-importation.md)
  + VM Template Management (vm-template-management.md)
  + VM Scaling & Performance (vm-scaling-performance.md)
  + VM Backup & Recovery (vm-backup-recovery.md)
* **Application Deployment**:
  + Hybrid Applications (hybrid-applications.md) - Integration of legacy VMs, containers, and microservices
  + Multi-Environment Setup (setup-multi-env-application.md) - Dev, staging, and production environments
* **PaaS Integration**:
  + Database Services (database-services-paas.md) - Multi-cloud deployment with automated backups
* **Enterprise Integration**:
  + Legacy Modernization (legacy-modernization.md) - Containerization and orchestration strategies
  + Disaster Recovery (disaster-recovery.md) - Comprehensive DR plans and procedures
* **Summary Table**:
  + Use-Cases Summary (use-cases-table.md) - Provides an overview of all use-cases
* **Observability**:
  + End-to-End Observability (end-to-end-observability.md) - Monitoring, tracing, and logging
* **Security**:
  + WAF 026 Firewalling (waf-firewalling.md) - Security controls and compliance
* **Integration**:
  + Events to CMDB/SIEM (publishing-events-to-cmdb-siem.md) - Enterprise integration patterns
* **References**: Best practices and glossary

#### 46.1.4.3 Work Phases

1. **Study Phase**: Gather requirements and analyze use-case scenarios specific to organizational goals
2. **Design Phase**: Develop HLD and LLD for each use-case, ensuring alignment with strategic objectives
3. **Implementation Phase**: Configure infrastructure and deploy components, including pipelines
4. **Testing Phase**: Perform functional and integration testing against business requirements
5. **Day-2 Operations Phase**: Create runbooks and SOPs for ongoing support and improvement

#### 46.1.4.4 Required Personas

* **Solution Architect**: Designs use-case architecture and ensures business alignment
* **Application Developer**: Implements code and configuration changes for each use-case
* **Testing Specialist**: Conducts rigorous testing to validate functionality
* **DevOps Engineer**: Automates deployment and integration processes
* **Security Specialist**: Ensures compliance and security measures
* **Business Analyst**: Defines requirements and validates business outcomes

### 46.1.5 Sub-Project 3: Migration Workload from VMware Project

#### 46.1.5.1 Scope

Plan and execute migration of workloads from VMware environments to RH OVE, including study of current workloads, design of migration strategy, implementation, testing, and operation of migrated workloads.

#### 46.1.5.2 Documentation Areas Covered

* **VM Lifecycle Specific Documentation**:
  + VM importation procedures and best practices
  + VM template management and standardization
  + VM scaling and performance optimization
  + VM backup and recovery strategies
* **Migration-Specific ADRs**:
  + Migration strategy decisions
  + Compatibility and interoperability considerations
  + Performance and resource optimization
* **Migration Planning**:
  + Assessment and inventory procedures
  + Migration waves and prioritization
  + Risk mitigation strategies
  + Rollback procedures

#### 46.1.5.3 Work Phases

1. **Study Phase**: Inventory and analyze existing VMware workloads and requirements
2. **Design Phase**: Create migration strategies with comprehensive HLD and LLD documentation
3. **Implementation Phase**: Execute migration workflows, import VMs, configure templates
4. **Testing Phase**: Validate workload functionality and performance post-migration
5. **Day-2 Operations Phase**: Develop monitoring, backup, and disaster recovery procedures

#### 46.1.5.4 Required Personas

* **Migration Specialist**: Leads migration strategy and execution
* **VMware Administrator**: Provides expertise on source environment
* **RH OVE Engineer**: Implements target environment configurations
* **Application Owner**: Validates business functionality post-migration
* **Performance Engineer**: Ensures performance requirements are met
* **Backup Administrator**: Implements backup and recovery procedures

### 46.1.6 Project Dependencies and Integration Points

#### 46.1.6.1 Inter-Project Dependencies

1. **Infrastructure → Use-Cases**: Core infrastructure must be operational before use-case implementation
2. **Infrastructure → Migration**: Target infrastructure must be ready before migration activities
3. **Use-Cases ↔ Migration**: Some use-cases may serve as migration validation scenarios

#### 46.1.6.2 Shared Resources

* **Documentation Standards**: Common templates and style guides
* **Testing Framework**: Shared testing methodologies and tools
* **Monitoring and Observability**: Common monitoring stack across all projects
* **Security Policies**: Unified security standards and compliance requirements

### 46.1.7 Success Criteria

#### 46.1.7.1 Sub-Project 1: Infrastructure

* ✅ Multi-cluster RH OVE environment deployed and operational
* ✅ All ADRs implemented and validated
* ✅ Monitoring and alerting systems operational
* ✅ Backup and disaster recovery procedures tested
* ✅ Day-2 operations runbooks completed and validated

#### 46.1.7.2 Sub-Project 2: Use-Cases

* ✅ All documented use-cases successfully implemented
* ✅ Use-cases demonstrate business value and ROI
* ✅ Integration patterns validated and documented
* ✅ Performance benchmarks established
* ✅ Operational procedures for each use-case documented

#### 46.1.7.3 Sub-Project 3: Migration

* ✅ VMware workload inventory completed
* ✅ Migration strategy validated through pilot migrations
* ✅ Production workloads successfully migrated
* ✅ Performance parity or improvement achieved
* ✅ Decommissioning of legacy VMware infrastructure completed

### 46.1.8 Risk Mitigation

#### 46.1.8.1 Technical Risks

* **Complexity Management**: Break down into smaller, manageable phases
* **Integration Challenges**: Early validation of integration points
* **Performance Issues**: Establish baseline metrics and continuous monitoring

#### 46.1.8.2 Operational Risks

* **Skill Gaps**: Training and knowledge transfer programs
* **Resource Constraints**: Phased approach with clear prioritization
* **Change Management**: Stakeholder alignment and communication plan

#### 46.1.8.3 Business Risks

* **Timeline Delays**: Buffer time and parallel execution where possible
* **Budget Overruns**: Regular cost monitoring and optimization
* **Business Continuity**: Comprehensive testing and rollback procedures

### 46.1.9 Conclusion

This three-pronged approach ensures comprehensive implementation of the RH OVE ecosystem while maintaining focus on specific domains of expertise. Each sub-project can be executed with dedicated teams while maintaining coordination points for integration and shared components.

The phased approach within each sub-project allows for iterative improvement and validation, reducing overall project risk while ensuring alignment with business objectives and operational requirements.

# 47 Detailed Timeline

## 47.1 RH OVE Ecosystem - Detailed Project Timeline

### 47.1.1 Project Overview

This document provides detailed timelines, milestones, and dependencies for the three sub-projects within the RH OVE Ecosystem implementation.

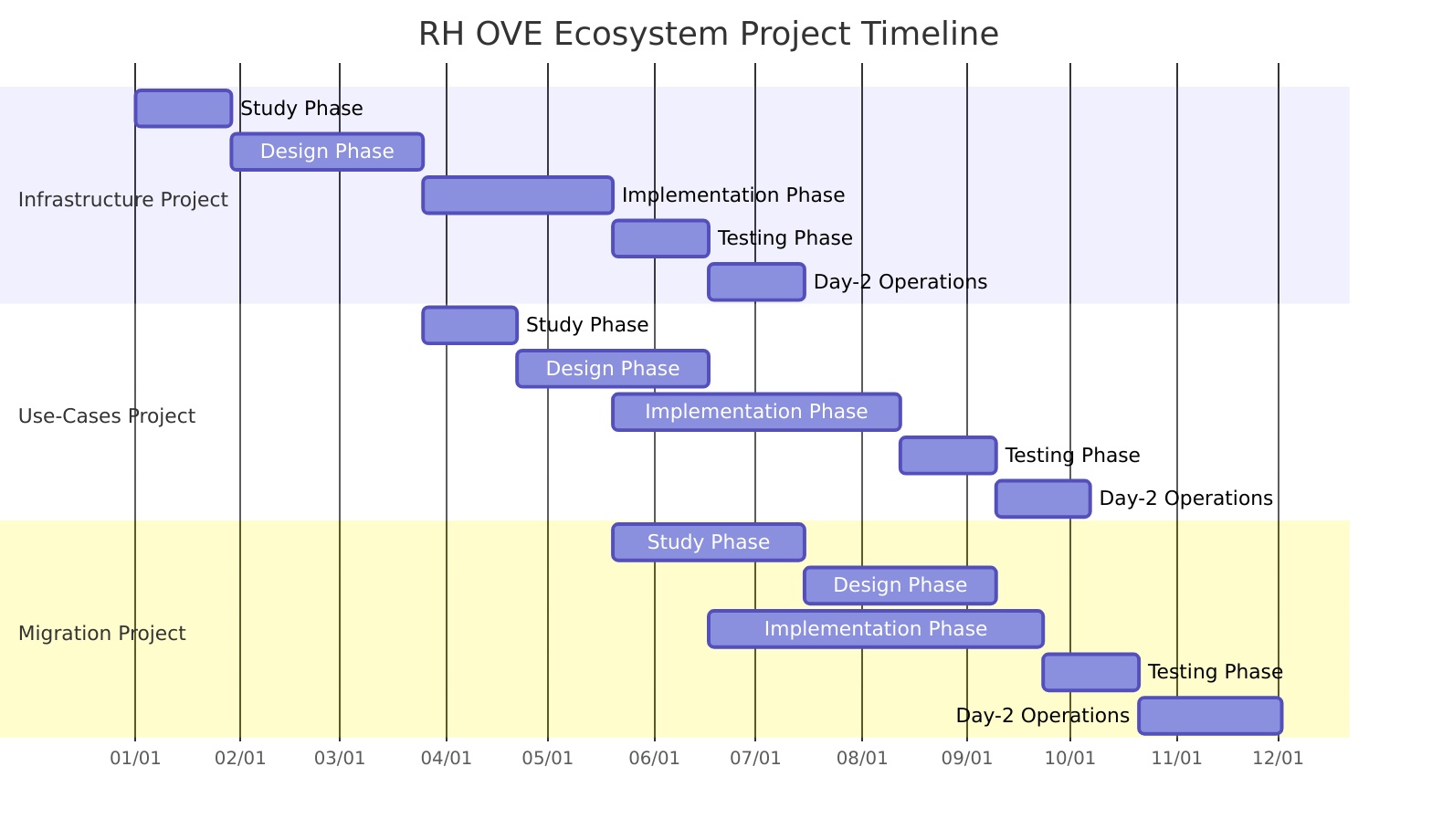
**Project Duration**: 12-18 months  
**Start Date**: TBD  
**Target Completion**: TBD

### 47.1.2 Timeline Summary

| Sub-Project | Duration | Dependencies | Key Deliverables |
| --- | --- | --- | --- |
| **RH OVE Infrastructure** | 6-8 months | None (Foundation) | Multi-cluster platform, ADRs, Operations runbooks |
| **Use-Cases Implementation** | 8-10 months | Infrastructure 70% complete | Working use-cases, Integration patterns |
| **Migration from VMware** | 10-12 months | Infrastructure 80% complete | Migrated workloads, Decommissioned legacy |

### 47.1.3 Project Timeline Visualization

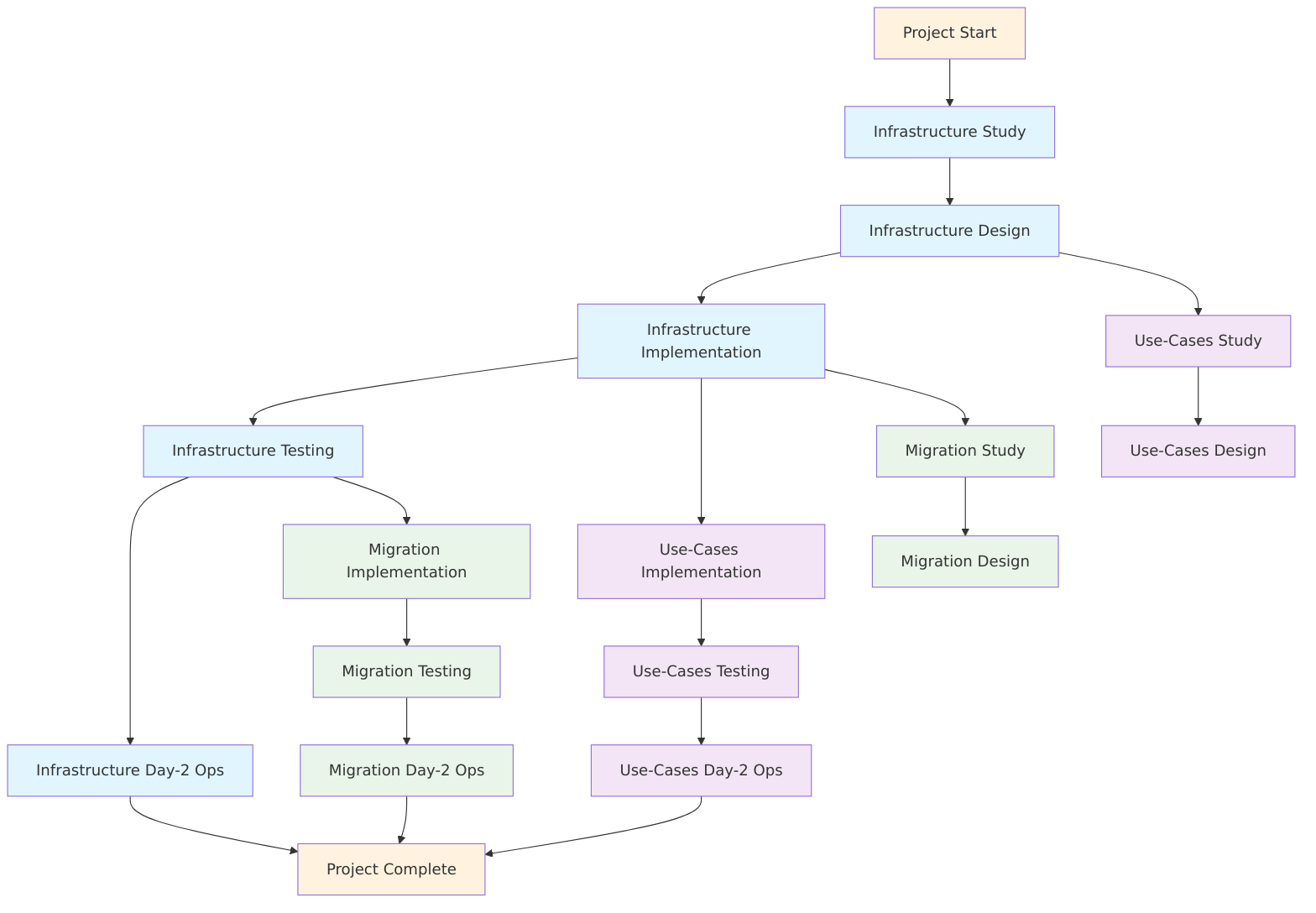
**Gantt Chart**



Gantt Chart

#### 47.1.3.1 Timeline Dependencies Diagram

**Flowchart/Graph Diagram**



Flowchart/Graph Diagram

#### 47.1.3.2 Resource Allocation Timeline

**[Mermaid Gantt Chart - Rendering Failed]**

gantt  
 title Detailed Resource Allocation by Phase  
 dateFormat YYYY-MM-DD  
 axisFormat %m/%d  
   
 section Infrastructure Team  
 Infrastructure Architect :inf-arch, 2024-01-01, 84d  
 Infrastructure Architect PT :inf-arch-pt, 2024-03-25, 28d  
 DevOps Engineers (2) :inf-devops, 2024-01-29, 140d  
 System Administrators (2) :inf-sysadmin, 2024-03-25, 112d  
 Security Engineer :inf-security, 2024-01-29, 84d  
 Network Engineer :inf-network, 2024-01-01, 140d  
   
 section Use-Cases Team  
 Solution Architect :uc-arch, 2024-03-25, 84d  
 Application Developers (3) :uc-dev, 2024-04-22, 140d  
 Testing Specialist :uc-test, 2024-08-12, 56d  
 DevOps Engineer :uc-devops, 2024-05-20, 168d  
 Security Specialist :uc-security, 2024-04-22, 112d  
 Business Analyst :uc-ba, 2024-03-25, 56d  
   
 section Migration Team  
 Migration Specialist :mig-specialist, 2024-04-22, 308d  
 VMware Administrators (2) :mig-vmware, 2024-04-22, 196d  
 RH OVE Engineers (2) :mig-rhove, 2024-08-12, 196d  
 Application Owners (2) :mig-appowner, 2024-07-15, 182d  
 Performance Engineer :mig-perf, 2024-06-17, 210d  
 Backup Administrator :mig-backup, 2024-05-20, 280d  
   
 section Critical Milestones  
 Infrastructure 70% Complete :milestone, 2024-06-17, 1d  
 Infrastructure 80% Complete :milestone, 2024-07-08, 1d  
 All Projects Complete :milestone, 2025-02-24, 1d

*Note: Diagram rendering failed, showing code instead.*

#### 47.1.3.3 Resource Allocation Notes

**Infrastructure Team Variable Allocation:** - **Infrastructure Architect**: Full-time during Study/Design phases, part-time for consulting during implementation - **DevOps Engineers**: Start during Design phase, continue through implementation and operations - **System Administrators**: Join during Implementation phase, continue for Day-2 operations - **Security Engineer**: Active during Design through Testing phases - **Network Engineer**: Active from Study through Implementation phases

**Use-Cases Team Variable Allocation:** - **Solution Architect**: Active during Study and Design phases primarily - **Application Developers**: Core implementation team, active longest duration - **Testing Specialist**: Primarily active during Testing phase with some overlap - **DevOps Engineer**: Active during Implementation and operations phases - **Security Specialist**: Active during Design, Implementation, and Testing phases - **Business Analyst**: Active during Study and early Design phases

**Migration Team Variable Allocation:** - **Migration Specialist**: Project-long involvement for strategy and coordination - **VMware Administrators**: Active during Study through early Implementation - **RH OVE Engineers**: Active during Implementation through Day-2 operations - **Application Owners**: Active during Design, Implementation, and Testing phases - **Performance Engineer**: Active during Testing and early Implementation phases - **Backup Administrator**: Active during Implementation through Day-2 operations

### 47.1.4 Sub-Project 1: RH OVE Infrastructure Project

#### 47.1.4.1 Phase 1: Study Phase (Weeks 1-4)

**Duration**: 4 weeks  
**Effort**: 3-4 FTEs

##### 47.1.4.1.1 Milestones

* **Week 2**: Current state assessment completed
* **Week 3**: Gap analysis finalized
* **Week 4**: Requirements gathering complete

##### 47.1.4.1.2 Deliverables

* Current infrastructure assessment report
* Gap analysis document
* Technical requirements specification
* Resource capacity planning

##### 47.1.4.1.3 Key Activities

* Analyze existing infrastructure components
* Document current network, storage, and compute resources
* Identify skill gaps and training needs
* Define non-functional requirements (performance, security, scalability)

#### 47.1.4.2 Phase 2: Design Phase (Weeks 5-12)

**Duration**: 8 weeks  
**Effort**: 4-5 FTEs

##### 47.1.4.2.1 Milestones

* **Week 7**: High-Level Design (HLD) approved
* **Week 10**: Low-Level Design (LLD) completed
* **Week 12**: ADRs finalized and approved

##### 47.1.4.2.2 Deliverables

* High-Level Design document
* Low-Level Design document
* 8 Architecture Decision Records (ADRs)
* Security architecture design
* Network topology design

##### 47.1.4.2.3 Key Activities

* Design multi-cluster architecture
* Define GitOps workflows with ArgoCD
* Plan Cilium CNI implementation
* Design backup and monitoring strategies
* Create security and IAM frameworks

#### 47.1.4.3 Phase 3: Implementation Phase (Weeks 13-20)

**Duration**: 8 weeks  
**Effort**: 5-6 FTEs

##### 47.1.4.3.1 Milestones

* **Week 15**: Management cluster deployed
* **Week 17**: First workload cluster operational
* **Week 19**: GitOps pipeline functional
* **Week 20**: Monitoring and backup systems active

##### 47.1.4.3.2 Deliverables

* Deployed multi-cluster RH OVE environment
* GitOps configuration and workflows
* Monitoring stack (Prometheus, Grafana, Dynatrace)
* Backup solution (Rubrik integration)
* Admission controllers configuration

##### 47.1.4.3.3 Key Activities

* Deploy management and workload clusters
* Configure Cilium CNI and network policies
* Implement GitOps with ArgoCD
* Set up monitoring and alerting
* Configure backup and disaster recovery

#### 47.1.4.4 Phase 4: Testing Phase (Weeks 21-24)

**Duration**: 4 weeks  
**Effort**: 4-5 FTEs

##### 47.1.4.4.1 Milestones

* **Week 22**: Security testing completed
* **Week 23**: Performance benchmarks established
* **Week 24**: Infrastructure acceptance testing passed

##### 47.1.4.4.2 Deliverables

* Security assessment report
* Performance benchmark results
* Test execution reports
* Infrastructure acceptance criteria validation

##### 47.1.4.4.3 Key Activities

* Conduct security penetration testing
* Perform load and stress testing
* Validate disaster recovery procedures
* Execute acceptance test scenarios

#### 47.1.4.5 Phase 5: Day-2 Operations (Weeks 25-28)

**Duration**: 4 weeks  
**Effort**: 3-4 FTEs

##### 47.1.4.5.1 Milestones

* **Week 26**: Operations runbooks completed
* **Week 27**: Team training finished
* **Week 28**: Operations handover complete

##### 47.1.4.5.2 Deliverables

* Day-2 operations runbooks
* Troubleshooting guides
* Performance tuning procedures
* Team training materials

### 47.1.5 Sub-Project 2: Use-Cases Implementation Project

#### 47.1.5.1 Phase 1: Study Phase (Weeks 15-18)

**Duration**: 4 weeks  
**Effort**: 2-3 FTEs  
**Dependency**: Infrastructure Design Phase 75% complete

##### 47.1.5.1.1 Milestones

* **Week 16**: Use-case requirements gathered
* **Week 17**: Business value assessment completed
* **Week 18**: Use-case prioritization finalized

##### 47.1.5.1.2 Deliverables

* Use-case requirements specification
* Business value assessment
* Implementation priority matrix
* Resource allocation plan

#### 47.1.5.2 Phase 2: Design Phase (Weeks 19-26)

**Duration**: 8 weeks  
**Effort**: 3-4 FTEs

##### 47.1.5.2.1 Milestones

* **Week 21**: VM lifecycle use-cases designed
* **Week 23**: Application deployment patterns defined
* **Week 25**: Enterprise integration patterns completed
* **Week 26**: All use-case designs approved

##### 47.1.5.2.2 Deliverables

* Use-case HLD and LLD documents
* Integration architecture designs
* Security and compliance frameworks
* Performance and scalability specifications

#### 47.1.5.3 Phase 3: Implementation Phase (Weeks 27-38)

**Duration**: 12 weeks  
**Effort**: 4-6 FTEs  
**Dependency**: Infrastructure Implementation 80% complete

##### 47.1.5.3.1 Milestones

* **Week 29**: VM lifecycle use-cases implemented
* **Week 32**: Hybrid applications deployed
* **Week 35**: Database services operational
* **Week 37**: Security and observability complete
* **Week 38**: All use-cases integrated

##### 47.1.5.3.2 Deliverables

* Implemented use-cases with working demonstrations
* Configuration manifests and scripts
* Integration patterns and templates
* Security controls and policies

#### 47.1.5.4 Phase 4: Testing Phase (Weeks 39-42)

**Duration**: 4 weeks  
**Effort**: 3-4 FTEs

##### 47.1.5.4.1 Milestones

* **Week 40**: Functional testing completed
* **Week 41**: Integration testing finished
* **Week 42**: Business validation approved

##### 47.1.5.4.2 Deliverables

* Test execution reports
* Performance validation results
* Business outcome measurements
* User acceptance documentation

#### 47.1.5.5 Phase 5: Day-2 Operations (Weeks 43-46)

**Duration**: 4 weeks  
**Effort**: 2-3 FTEs

##### 47.1.5.5.1 Milestones

* **Week 44**: Use-case runbooks completed
* **Week 45**: Monitoring dashboards operational
* **Week 46**: Knowledge transfer complete

##### 47.1.5.5.2 Deliverables

* Use-case operational runbooks
* Monitoring and alerting configurations
* Best practices documentation
* Training materials

### 47.1.6 Sub-Project 3: Migration Workload from VMware Project

#### 47.1.6.1 Phase 1: Study Phase (Weeks 21-28)

**Duration**: 8 weeks  
**Effort**: 3-4 FTEs  
**Dependency**: Infrastructure Implementation 60% complete

##### 47.1.6.1.1 Milestones

* **Week 23**: VMware inventory completed
* **Week 25**: Workload assessment finished
* **Week 27**: Migration strategy approved
* **Week 28**: Migration waves defined

##### 47.1.6.1.2 Deliverables

* Complete VMware workload inventory
* Workload assessment and compatibility analysis
* Migration strategy document
* Migration wave planning
* Risk assessment and mitigation plan

#### 47.1.6.2 Phase 2: Design Phase (Weeks 29-36)

**Duration**: 8 weeks  
**Effort**: 4-5 FTEs

##### 47.1.6.2.1 Milestones

* **Week 31**: Migration architecture designed
* **Week 33**: VM templates standardized
* **Week 35**: Migration procedures documented
* **Week 36**: Pilot migration plan approved

##### 47.1.6.2.2 Deliverables

* Migration architecture design
* VM template standards and configurations
* Migration procedure documentation
* Rollback and recovery procedures
* Pilot migration plan

#### 47.1.6.3 Phase 3: Implementation Phase (Weeks 37-50)

**Duration**: 14 weeks  
**Effort**: 5-7 FTEs  
**Dependency**: Infrastructure Testing 100% complete

##### 47.1.6.3.1 Milestones

* **Week 39**: Pilot migration completed
* **Week 42**: Wave 1 migrations finished
* **Week 46**: Wave 2 migrations completed
* **Week 49**: Wave 3 migrations finished
* **Week 50**: All critical workloads migrated

##### 47.1.6.3.2 Deliverables

* Migrated virtual machines and applications
* Updated VM templates and configurations
* Migration execution reports
* Performance optimization results
* Updated network and security configurations

#### 47.1.6.4 Phase 4: Testing Phase (Weeks 51-54)

**Duration**: 4 weeks  
**Effort**: 4-5 FTEs

##### 47.1.6.4.1 Milestones

* **Week 52**: Application functionality validated
* **Week 53**: Performance benchmarks achieved
* **Week 54**: Business continuity confirmed

##### 47.1.6.4.2 Deliverables

* Application validation reports
* Performance comparison analysis
* Business continuity test results
* User acceptance confirmation

#### 47.1.6.5 Phase 5: Day-2 Operations (Weeks 55-60)

**Duration**: 6 weeks  
**Effort**: 3-4 FTEs

##### 47.1.6.5.1 Milestones

* **Week 57**: Migration runbooks completed
* **Week 58**: Legacy decommissioning planned
* **Week 60**: Operations transition complete

##### 47.1.6.5.2 Deliverables

* Migration operations runbooks
* Legacy infrastructure decommissioning plan
* Post-migration monitoring procedures
* Lessons learned documentation

#### 47.1.6.6 Resource Planning

#### 47.1.6.7 Team Composition by Sub-Project

##### 47.1.6.7.1 Infrastructure Project

* Infrastructure Architect: 1 FTE
* DevOps Engineers: 2 FTEs
* System Administrators: 2 FTEs
* Security Engineer: 1 FTE
* Network Engineer: 1 FTE

##### 47.1.6.7.2 Use-Cases Implementation

* Solution Architect: 1 FTE
* Application Developers: 3 FTEs
* Testing Specialist: 1 FTE
* DevOps Engineer: 1 FTE
* Security Specialist: 1 FTE
* Business Analyst: 1 FTE

##### 47.1.6.7.3 Migration Project

* Migration Specialist: 1 FTE
* VMware Administrators: 2 FTEs
* RH OVE Engineers: 2 FTEs
* Application Owners: 2 FTEs
* Performance Engineer: 1 FTE
* Backup Administrator: 1 FTE

#### 47.1.6.8 Cross-Project Coordination

##### 47.1.6.8.1 Weekly Sync Meetings

* Architecture review board
* Technical coordination committee
* Risk and issue management
* Resource allocation review

##### 47.1.6.8.2 Monthly Steering Committee

* Progress against milestones
* Budget and resource adjustments
* Risk escalation and mitigation
* Stakeholder communication

### 47.1.7 Risk Management

#### 47.1.7.1 High-Risk Areas

1. **Resource Availability**: Specialized skills in RH OVE and VMware
2. **Technical Complexity**: Multi-cluster networking and storage
3. **Business Continuity**: Migration impact on critical workloads
4. **Timeline Dependencies**: Sequential phases with limited parallel execution

#### 47.1.7.2 Mitigation Strategies

1. **Cross-training**: Develop skills across multiple team members
2. **Proof of Concepts**: Validate technical approaches early
3. **Phased Migration**: Minimize business impact through careful wave planning
4. **Buffer Time**: Include 15-20% contingency in timeline estimates

### 47.1.8 Success Metrics

#### 47.1.8.1 Infrastructure Project

* 99.9% infrastructure uptime SLA
* Security compliance audit pass rate: 100%
* Performance benchmarks met or exceeded
* Team satisfaction with operational procedures

#### 47.1.8.2 Use-Cases Project

* All documented use-cases successfully demonstrated
* Business value metrics achieved
* User adoption rates meet targets
* Documentation completeness and accuracy

#### 47.1.8.3 Migration Project

* 100% critical workload migration success
* Performance parity or improvement: 95% of workloads
* Business continuity maintained throughout migration
* Legacy infrastructure decommissioning completed on schedule

# 48 Infrastructure Plan

## 48.1 RH OVE Infrastructure Project Plan

### 48.1.1 Executive Summary

This sub-project focuses on the comprehensive setup and operation of the RH OVE infrastructure, targeting the study, design, implementation, testing, and Day-2 operations of the multi-cluster environment.

### 48.1.2 Scope

Ensure the complete lifecycle of infrastructure operation, from study to implementation and ongoing support. This includes designing and deploying core components, establishing monitoring and security protocols, and documenting operational procedures.

### 48.1.3 Documentation Areas

* **Architecture**: Review and define the network, storage, and IAM strategies.
* **ADRs (Architecture Decision Records)**: Finalize key decisions including multi-cluster patterns and GitOps.
* **Deployment**: Identify prerequisites, and cover installation and configuration tasks.
* **Management**: Focus on admission control, GitOps, monitoring, and backup strategies.
* **Operations**: Develop detailed guidance for day-to-day operations, troubleshooting, and performance tuning.

### 48.1.4 Work Phases

1. **Study Phase**
   * Gather comprehensive understanding of current and future needs.
   * Perform gap analysis on existing infrastructure.
2. **Design Phase**
   * Create High-Level Design (HLD) and Low-Level Design (LLD) documents.
   * Validate designs against organizational goals.
3. **Implementation Phase**
   * Deploy infrastructure components utilizing best practices.
   * Integrate security, monitoring, and backup systems.
4. **Testing Phase**
   * Conduct thorough infrastructure robustness, security, and performance tests.
   * Validate alignment with ADRs.
5. **Day-2 Operations Phase**
   * Establish ongoing monitoring.
   * Document troubleshooting and tuning procedures.

### 48.1.5 Required Personas

* **Infrastructure Architect**: Define overarching infrastructure architecture.
* **DevOps Engineer**: Implement and automate delivery using CI/CD and GitOps.
* **System Administrator**: Oversee operations, ensuring stability and performance.
* **Security Engineer**: Ensure alignment with security protocols and compliance.
* **Network Engineer**: Design and implement network components and policies.

### 48.1.6 Success Criteria

* Successful deployment of a robust, secure, and scalable infrastructure that supports RH OVE multi-cluster functionality.
* Full documentation of operational guidelines and procedures.
* Stakeholder satisfaction with alignment to strategic goals.

# 49 Use-Cases Plan

## 49.1 Use-Cases Implementation Project Plan

### 49.1.1 Executive Summary

This sub-project focuses on implementing and showcasing various use-cases within the RH OVE ecosystem. The use-cases demonstrate the system’s capabilities in multi-cluster environments, covering diverse application scenarios.

### 49.1.2 Scope

Study, design, implement, test, and operate comprehensive use-cases showcasing RH OVE capabilities, including hybrid applications, database services, legacy modernization, and more.

### 49.1.3 Documentation Areas

* **Use Cases**: Overview, multi-env setup, hybrid applications, database services, legacy modernization, disaster recovery, observability, security, integration.
* **References**: Best practices and glossary.

### 49.1.4 Work Phases

1. **Study Phase**
   * Analyze use case requirements and their alignment with organizational goals.
2. **Design Phase**
   * Develop High-Level and Low-Level Designs for each use case.
   * Ensure designs support strategic objectives.
3. **Implementation Phase**
   * Build and deploy configurations, manifests, and scripts for each use case.
4. **Testing Phase**
   * Conduct functional and integration testing
   * Validate business outcomes and performance benchmarks.
5. **Day-2 Operations Phase**
   * Develop runbooks and SOPs for operational support.
   * Ensure ongoing integration and optimization.

### 49.1.5 Required Personas

* **Solution Architect**: Guide the architectural design of use-cases.
* **Application Developer**: Implement required code and configurations.
* **Testing Specialist**: Validate use-case functionality and integration.
* **DevOps Engineer**: Automate deployment processes.
* **Security Specialist**: Ensure security compliance and measures.
* **Business Analyst**: Define requirements and assess business value.

### 49.1.6 Success Criteria

* Implementation of documented use-cases that align to strategic goals and demonstrate RH OVE’s capabilities to stakeholders.
* Comprehensive documentation of each use-case, including lessons learned and best practices for replication.

# 50 Migration Plan

## 50.1 Migration Workload from VMware Project Plan

### 50.1.1 Executive Summary

This sub-project focuses on the migration of existing workloads from VMware environments to the RH OVE platform. The migration will ensure minimal downtime and optimal performance while maintaining functionality and business continuity.

### 50.1.2 Scope

Plan and execute the migration of workloads from VMware environments to RH OVE, including assessment of current workloads, migration strategy development, testing, and operation of migrated components.

### 50.1.3 Documentation Areas

* **VM Lifecycle**: VM importation, template management, scaling performance, and backup recovery strategies.
* **Migration-Specific ADRs**: Strategy decisions, compatibility considerations, and performance optimization.
* **Migration Planning**: Assessment procedures, migration waves, risk mitigation, and rollback procedures.

### 50.1.4 Work Phases

1. **Study Phase**
   * Inventory and analyze existing VMware workloads and their requirements.
   * Identify dependencies and performance baselines.
2. **Design Phase**
   * Create migration strategies with comprehensive HLD and LLD documentation.
   * Define migration waves and prioritization.
3. **Implementation Phase**
   * Execute migration workflows.
   * Import VMs and configure templates in the new environment.
4. **Testing Phase**
   * Validate workload functionality and performance post-migration.
   * Ensure compliance with business requirements.
5. **Day-2 Operations Phase**
   * Develop monitoring, backup, and disaster recovery procedures for migrated workloads.
   * Document lessons learned and operational guidelines.

### 50.1.5 Required Personas

* **Migration Specialist**: Lead migration strategy and execution.
* **VMware Administrator**: Provide expertise on source environment and legacy systems.
* **RH OVE Engineer**: Implement target environment configurations and optimization.
* **Application Owner**: Validate business functionality post-migration.
* **Performance Engineer**: Ensure performance requirements are met in the new environment.
* **Backup Administrator**: Implement backup and recovery procedures for migrated workloads.

### 50.1.6 Success Criteria

* Successful migration of all critical workloads with minimal disruption to business operations.
* Achievement of performance parity or improvement post-migration.
* Complete decommissioning of legacy VMware infrastructure where applicable.
* Comprehensive documentation of migration procedures and operational guidelines.

# 51 Personas

## 51.1 Skills Matrix

This table outlines the key skills and expertise required for each persona involved in the RH OVE project.

| Persona | Key Skills and Expertise |
| --- | --- |
| Infrastructure Architect | Cloud architecture, multi-cluster systems, strategic planning |
| DevOps Engineer | CI/CD pipelines, automation tools, GitOps, ArgoCD |
| System Administrator | Unix/Linux systems, network configurations, troubleshooting |
| Security Engineer | Security protocols, penetration testing, compliance standards |
| Network Engineer | Network topology, load balancing, disaster recovery |
| Solution Architect | Use-case design, systems integration, architectural patterns |
| Application Developer | Programming languages (Python, Java), application frameworks, microservices |
| Testing Specialist | Test automation, QA processes, performance testing |
| Security Specialist | Application security, vulnerability assessments, security audits |
| Business Analyst | Requirements gathering, stakeholder communication, problem-solving |
| Migration Specialist | Migration strategies, VMware expertise, project coordination |
| VMware Administrator | VMware infrastructure, virtualization techniques, backup/recovery |
| RH OVE Engineer | RH OVE management, infrastructure optimization, performance tuning |
| Application Owner | Business requirements alignment, post-migration validation |
| Performance Engineer | Performance analysis, system benchmarking, tuning |
| Backup Administrator | Backup management, data integrity, recovery processes |

## 51.2 Persona Perspectives

### 51.2.1 Infrastructure Project

**Infrastructure Architect** - Defines the overarching architecture and integration patterns. - Leads the High-Level and Low-Level design phases. - Ensures strategic alignment with business objectives.

**DevOps Engineer** - Implements automation and CI/CD pipelines. - Oversees the setup of GitOps with ArgoCD. - Manages ongoing system optimization and updates.

**System Administrator** - Manages the day-to-day operations. - Ensures system stability and performance. - Handles system troubleshooting and maintenance.

**Security Engineer** - Implements security protocols and compliance measures. - Conducts regular security audits and vulnerability assessments. - Designs and implements IAM policies.

**Network Engineer** - Designs network architecture and policies. - Oversees network configuration and optimization. - Ensures robust connectivity and disaster recovery protocols.

### 51.2.2 Use-Cases Implementation

**Solution Architect** - Guides architectural design for use-cases. - Aligns use-case requirements with system capabilities. - Ensures solution scalability and performance efficiency.

**Application Developer** - Develops application components as per designed specifications. - Implements integration logic and application workflows. - Collaborates on code reviews and deployment processes.

**Testing Specialist** - Develops testing strategies for functional and integration testing. - Executes test cases and validates use-case functionality. - Provides recommendations for performance enhancements.

**Security Specialist** - Designs use-case-specific security measures. - Ensures compliance with relevant legislation and policies. - Conducts security drills and audits.

**Business Analyst** - Facilitates requirements gathering and prioritization. - Defines business value of implemented use-cases. - Liaises between technical teams and business stakeholders.

### 51.2.3 Migration Workload from VMware

**Migration Specialist** - Leads the strategy and execution of migration activities. - Coordinates migration phases including assessment and validation.

**VMware Administrator** - Provides expertise on source VMware environments. - Ensures correct configuration and performance tuning.

**RH OVE Engineer** - Manages RH OVE platform setup and optimization post-migration. - Supports both the development and operation phases.

**Application Owner** - Represents application requirements during migration. - Validates business functionality and performance post-migration.

**Performance Engineer** - Assesses and optimizes performance during and after migration. - Establishes performance benchmarks and monitoring thresholds.

**Backup Administrator** - Manages backup and recovery strategies during migration. - Ensures data integrity and availability throughout the process.

# 52 RACI Matrix

## 52.1 RH OVE Ecosystem RACI Matrix

### 52.1.1 Executive Summary

The RACI matrix defines the roles and responsibilities of team members across different phases and activities within each sub-project of the RH OVE Ecosystem.

### 52.1.2 RACI Guide

* **R (Responsible)**: Person(s) who perform the work
* **A (Accountable)**: Person who ensures task completion and has decision authority
* **C (Consulted)**: Person(s) who provide input and feedback
* **I (Informed)**: Person(s) who need to be informed of progress and outcomes

### 52.1.3 RH OVE Infrastructure Project

| Task | Infrastructure Architect | DevOps Engineer | System Administrator | Security Engineer | Network Engineer |
| --- | --- | --- | --- | --- | --- |
| Requirements Gathering | R | I | I | C | C |
| HLD & LLD Design | A | C | C | C | C |
| Cluster Deployment | C | A, R | R | I | C |
| Network Configuration | I | C | I | C | A, R |
| Security Implementation | C | C | C | A, R | I |
| GitOps Pipeline Setup | C | A, R | C | I | I |
| System Monitoring Setup | I | C | A, R | C | C |

### 52.1.4 Use-Cases Implementation Project

| Task | Solution Architect | Application Developer | Testing Specialist | DevOps Engineer | Security Specialist | Business Analyst |
| --- | --- | --- | --- | --- | --- | --- |
| Use-Case Requirements Analysis | R, A | I | I | C | I | C |
| HLD & LLD for Use-Cases | A | C | C | C | C | I |
| Application Deployment | C | A, R | I | C | C | I |
| Integration Development | C | A, R | C | R | C | I |
| Functional Testing | I | C | A, R | C | C | I |
| Security Compliance | C | C | C | C | A, R | I |
| Stakeholder Review | A | I | C | I | I | R |

### 52.1.5 Migration Workload from VMware Project

| Task | Migration Specialist | VMware Administrator | RH OVE Engineer | Application Owner | Performance Engineer | Backup Administrator |
| --- | --- | --- | --- | --- | --- | --- |
| Inventory & Analysis | R, A | R | C | C | I | I |
| Migration Strategy Development | A | C | C | C | C | C |
| Migration Execution | C | C | A, R | I | C | C |
| Performance Testing | C | C | C | C | A, R | I |
| Rollback & Recovery Planning | C | C | A | C | C | R |
| Business Continuity Verification | C | C | C | R, A | C | I |
| Post-Migration Monitoring | C | I | A, R | I | C | C |

### 52.1.6 Conclusion

The RACI matrix provides a structured overview of responsibilities and accountabilities across the RH OVE Ecosystem implementation. It ensures clear communication and role clarity, contributing to project success.

# 53 Risk Register

## 53.1 RH OVE Ecosystem Risk Register

### 53.1.1 Document Information

* **Document Version**: 1.0
* **Last Updated**: TBD
* **Risk Assessment Period**: Project Duration (12-18 months)

### 53.1.2 Risk Assessment Scale

#### 53.1.2.1 Probability Scale

* **1 - Very Low** (0-10%): Risk unlikely to occur
* **2 - Low** (11-30%): Risk may occur in exceptional circumstances
* **3 - Medium** (31-50%): Risk may occur under certain conditions
* **4 - High** (51-80%): Risk likely to occur in most circumstances
* **5 - Very High** (81-100%): Risk almost certain to occur

#### 53.1.2.2 Impact Scale

* **1 - Very Low**: Minimal impact on project objectives
* **2 - Low**: Minor impact with easy workarounds
* **3 - Medium**: Moderate impact requiring management attention
* **4 - High**: Major impact requiring significant resources
* **5 - Very High**: Critical impact threatening project success

#### 53.1.2.3 Risk Score = Probability × Impact

### 53.1.3 Infrastructure Project Risks

| Risk ID | Risk Description | Category | Probability | Impact | Risk Score | Owner | Mitigation Strategy | Status |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| INF-001 | Resource contention with 2,000 VMs and 200 applications exceeding cluster capacity | Technical | 3 | 4 | 12 | Infrastructure Architect | Implement auto-scaling, capacity monitoring, and multi-cluster load balancing | Open |
| INF-002 | Network bottlenecks during peak usage with 40 Gbps requirement | Technical | 3 | 4 | 12 | Network Engineer | Design redundant network paths, implement QoS policies, traffic shaping | Open |
| INF-003 | Storage IOPS degradation with 200,000 IOPS requirement | Technical | 3 | 3 | 9 | System Administrator | Implement tiered storage, SSD caching, performance monitoring | Open |
| INF-004 | Cilium CNI configuration complexity in multi-cluster setup | Technical | 4 | 3 | 12 | DevOps Engineer | PoC validation, expert consultation, phased rollout | Open |
| INF-005 | Security vulnerabilities in multi-tenant environment | Security | 2 | 5 | 10 | Security Engineer | Regular security audits, penetration testing, network segmentation | Open |
| INF-006 | GitOps pipeline failures affecting deployment automation | Operational | 3 | 3 | 9 | DevOps Engineer | Implement pipeline monitoring, rollback procedures, backup deployment methods | Open |
| INF-007 | Backup system (Rubrik) integration issues with large dataset (1 PB) | Technical | 3 | 4 | 12 | System Administrator | Extensive testing, vendor support engagement, backup strategy validation | Open |
| INF-008 | Skills gap in RH OVE administration and troubleshooting | Resource | 4 | 3 | 12 | Project Manager | Training programs, knowledge transfer sessions, external consultant support | Open |
| INF-009 | Hardware procurement delays affecting project timeline | External | 3 | 4 | 12 | Infrastructure Architect | Early procurement planning, multiple vendor options, buffer time | Open |
| INF-010 | Monitoring system (Prometheus/Grafana) overload with 2,200 workloads | Technical | 3 | 3 | 9 | System Administrator | Distributed monitoring architecture, metric sampling, alert optimization | Open |

### 53.1.4 Use-Cases Implementation Risks

| Risk ID | Risk Description | Category | Probability | Impact | Risk Score | Owner | Mitigation Strategy | Status |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UC-001 | Application compatibility issues with RH OVE platform (200 hybrid apps) | Technical | 3 | 4 | 12 | Solution Architect | Compatibility assessment, application inventory, testing framework | Open |
| UC-002 | Performance degradation in hybrid workload scenarios | Technical | 3 | 3 | 9 | Performance Engineer | Performance benchmarking, optimization guidelines, monitoring dashboards | Open |
| UC-003 | Integration complexity between containers, PaaS, and VMs | Technical | 4 | 3 | 12 | Solution Architect | Integration patterns, service mesh implementation, API gateway setup | Open |
| UC-004 | Business stakeholder availability for use-case validation | Business | 3 | 3 | 9 | Business Analyst | Early stakeholder engagement, flexible scheduling, clear communication plan | Open |
| UC-005 | Use-case dependencies causing implementation delays | Operational | 3 | 3 | 9 | Project Manager | Dependency mapping, parallel development tracks, modular implementation | Open |
| UC-006 | Security compliance requirements for PaaS services | Security | 2 | 4 | 8 | Security Specialist | Compliance framework development, security controls validation, audit preparation | Open |
| UC-007 | Data consistency issues in hybrid application scenarios | Technical | 2 | 4 | 8 | Application Developer | Data architecture design, consistency protocols, transaction management | Open |
| UC-008 | Observability gaps in complex multi-tier applications | Operational | 3 | 3 | 9 | DevOps Engineer | Distributed tracing implementation, log aggregation, custom metrics | Open |

### 53.1.5 Migration Project Risks

| Risk ID | Risk Description | Category | Probability | Impact | Risk Score | Owner | Mitigation Strategy | Status |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| MIG-001 | Data loss during migration of 500 TB across 1,000 VMs | Technical | 2 | 5 | 10 | Migration Specialist | Multiple backup strategies, checksum validation, pilot testing | Open |
| MIG-002 | Extended downtime exceeding 2-hour window per application | Business | 3 | 4 | 12 | Migration Specialist | Rehearsal migrations, optimized procedures, rollback planning | Open |
| MIG-003 | VMware licensing and dependency issues during transition | Legal/Technical | 3 | 3 | 9 | VMware Administrator | License audit, dependency mapping, phased decommissioning | Open |
| MIG-004 | Application performance degradation post-migration | Technical | 3 | 4 | 12 | Performance Engineer | Performance baselines, optimization procedures, monitoring setup | Open |
| MIG-005 | Network connectivity issues during migration waves | Technical | 3 | 3 | 9 | Network Engineer | Network planning, connectivity testing, backup communication paths | Open |
| MIG-006 | Resource contention during concurrent migrations (200 VMs per wave) | Technical | 4 | 3 | 12 | RH OVE Engineer | Resource planning, migration scheduling, capacity monitoring | Open |
| MIG-007 | Legacy application compatibility with new infrastructure | Technical | 4 | 4 | 16 | Application Owner | Compatibility testing, application modernization planning, fallback options | Open |
| MIG-008 | Staff resistance to new platform and procedures | Change Management | 3 | 3 | 9 | Project Manager | Change management program, training, communication strategy | Open |
| MIG-009 | Rollback complexity if migration fails | Operational | 2 | 4 | 8 | Migration Specialist | Detailed rollback procedures, automated rollback tools, testing protocols | Open |
| MIG-010 | Compliance and audit trail maintenance during migration | Regulatory | 2 | 4 | 8 | Backup Administrator | Audit procedures, compliance documentation, regulatory liaison | Open |

### 53.1.6 Cross-Project Risks

| Risk ID | Risk Description | Category | Probability | Impact | Risk Score | Owner | Mitigation Strategy | Status |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CP-001 | Resource conflicts between concurrent sub-projects | Resource | 4 | 3 | 12 | Project Manager | Resource allocation matrix, coordination meetings, escalation procedures | Open |
| CP-002 | Timeline dependencies causing cascading delays | Schedule | 3 | 4 | 12 | Project Manager | Buffer time allocation, parallel execution planning, milestone monitoring | Open |
| CP-003 | Technical debt accumulation due to rapid deployment | Technical | 3 | 3 | 9 | Technical Architect | Code reviews, refactoring cycles, technical debt tracking | Open |
| CP-004 | Budget overruns due to scope creep and complexity | Financial | 3 | 4 | 12 | Project Manager | Budget monitoring, change control process, stakeholder communication | Open |
| CP-005 | Knowledge silos limiting cross-team collaboration | Organizational | 3 | 3 | 9 | Project Manager | Knowledge sharing sessions, documentation standards, cross-training | Open |
| CP-006 | Vendor support availability for critical issues | External | 2 | 4 | 8 | Project Manager | SLA agreements, escalation procedures, alternative support channels | Open |

### 53.1.7 Risk Monitoring and Review

#### 53.1.7.1 Weekly Risk Review

* **Frequency**: Every Tuesday during project execution
* **Attendees**: Risk owners, project managers, technical leads
* **Agenda**: New risks, status updates, mitigation progress

#### 53.1.7.2 Monthly Risk Assessment

* **Frequency**: First Friday of each month
* **Attendees**: Steering committee, project sponsors
* **Agenda**: Risk trend analysis, escalation decisions, resource adjustments

#### 53.1.7.3 Risk Escalation Criteria

* **Immediate Escalation**: Risk score ≥ 15 (High probability + High impact)
* **Weekly Escalation**: Risk score ≥ 12
* **Monthly Review**: Risk score ≥ 9

### 53.1.8 Risk Response Strategies

#### 53.1.8.1 High-Priority Risks (Score ≥ 12)

1. **MIG-007**: Legacy application compatibility - Requires immediate compatibility assessment
2. **CP-002**: Timeline dependencies - Needs buffer time implementation
3. **INF-001**: Resource contention - Auto-scaling implementation priority
4. **MIG-002**: Extended downtime - Rehearsal migration mandatory

#### 53.1.8.2 Medium-Priority Risks (Score 9-11)

* Regular monitoring and mitigation progress tracking
* Monthly review of mitigation effectiveness
* Proactive communication with stakeholders

#### 53.1.8.3 Low-Priority Risks (Score ≤ 8)

* Quarterly review and assessment
* Documentation of lessons learned
* Contingency planning development

### 53.1.9 Success Metrics for Risk Management

#### 53.1.9.1 Target KPIs

* **Risk Closure Rate**: >80% of identified risks mitigated by project completion
* **Schedule Impact**: <5% schedule variance due to risk materialization
* **Budget Impact**: <10% budget variance due to risk management costs
* **Quality Impact**: Zero critical system failures due to unmanaged risks

#### 53.1.9.2 Risk Management Effectiveness

* Early identification of 90% of project risks
* Successful mitigation of all high-priority risks
* No project-threatening risks materialized
* Stakeholder satisfaction with risk communication and management

# 54 Budget Estimate

## 54.1 RH OVE Ecosystem Budget Estimate

### 54.1.1 Executive Summary

This budget estimate outlines the financial requirements for the RH OVE Ecosystem implementation, considering infrastructure, use-cases, and migration workload projects.

### 54.1.2 Budget Categories

1. **Infrastructure Costs**
2. **Migration Costs**
3. **Use-Cases Implementation Costs**
4. **Operational Costs**
5. **Contingency Fund**

### 54.1.3 Detailed Budget Estimate

#### 54.1.3.1 1. Infrastructure Costs

| Item | Estimated Cost (USD) |
| --- | --- |
| Compute Resources | $1,000,000 |
| Storage Solutions | $500,000 |
| Networking Equipment | $300,000 |
| Security Implementations | $150,000 |
| Software Licenses | $200,000 |
| Total Infrastructure Cost | **$2,150,000** |

#### 54.1.3.2 2. Migration Costs

| Item | Estimated Cost (USD) |
| --- | --- |
| Migration Tools | $200,000 |
| VMware Licenses | $100,000 |
| Personnel Training | $150,000 |
| Consulting Services | $250,000 |
| Total Migration Cost | **$700,000** |

#### 54.1.3.3 3. Use-Cases Implementation Costs

| Item | Estimated Cost (USD) |
| --- | --- |
| Application Development Tools | $300,000 |
| Testing Frameworks | $100,000 |
| Security Compliance | $150,000 |
| Monitoring Solutions | $100,000 |
| Total Use-Cases Cost | **$650,000** |

#### 54.1.3.4 4. Operational Costs

| Item | Estimated Cost (USD) |
| --- | --- |
| Personnel Salaries | $1,200,000 |
| Maintenance Contracts | $200,000 |
| Utilities and Overhead | $150,000 |
| Total Operational Cost | **$1,550,000** |

#### 54.1.3.5 5. Contingency Fund

* **10% of Total Estimated Cost**: Approx. $505,000

### 54.1.4 Total Estimated Project Cost

* **Overall Total**: **$5,555,000**

### 54.1.5 Notes:

* The costs provided are approximations based on industry standards and may vary based on final project requirements and vendor agreements.
* Contingency fund is reserved for unexpected expenses and scope changes.
* Regular financial reviews will be conducted to ensure budget compliance and adjust estimates as needed.

# 55 Sizing Plan

## 55.1 RH OVE Ecosystem Sizing Plan

### 55.1.1 Executive Summary

This document outlines the sizing estimates for the RH OVE Ecosystem implementation. It addresses the expected capacity and complexity for each sub-project. The plan ensures that proper resource allocation and infrastructure setups are achieved to meet performance and scalability demands.

## 55.2 \*\* TO BE REVIEW FOR NODE SIZING \*\*

### 55.2.1 Infrastructure Sizing

**Scope**: Support up to 200 hybrid applications (containerized, PaaS, and VMs) and 2,000 virtual machines.

#### 55.2.1.1 Key Metrics

* **Application Types**: Hybrid, combining containers, PaaS services, and virtual machines.
* **Maximum Applications**: 200
* **Maximum Virtual Machines**: 2,000
* **Expected Compute Resources**:
  + CPUs: Approximately 10,000 vCPUs
  + Memory: Approximately 20 TB RAM
  + Storage: Approximately 1 PB (Petabyte)
* **Network Capacity**: High-throughput connectivity with redundant failover capabilities.
* **Security and Compliance**: Adherence to regulatory standards with IAM components and network policies.

#### 55.2.1.2 Resource Allocation

##### 55.2.1.2.1 Node Size Options

To optimize resource allocation and cost efficiency, three node size configurations are proposed:

###### 55.2.1.2.1.1 Option 1: Small Nodes (Recommended for Development/Testing)

* **Node Configuration**: 16 vCPUs, 64 GB RAM, 1 TB NVMe SSD
* **Number of Nodes**: 625 nodes
* **Use Case**: Development environments, testing workloads, small applications
* **Cost Efficiency**: Lower initial investment, flexible scaling
* **Pros**:
  + Lower hardware costs per node
  + Better granular scaling
  + Reduced blast radius for failures
* **Cons**:
  + Higher management overhead
  + More network complexity

###### 55.2.1.2.1.2 Option 2: Medium Nodes (Recommended for Production)

* **Node Configuration**: 32 vCPUs, 128 GB RAM, 2 TB NVMe SSD
* **Number of Nodes**: 313 nodes
* **Use Case**: Production workloads, hybrid applications, medium-scale VMs
* **Cost Efficiency**: Balanced performance and cost
* **Pros**:
  + Optimal resource density
  + Balanced management overhead
  + Good performance isolation
* **Cons**:
  + Higher individual node cost
  + Less flexible for small workloads

###### 55.2.1.2.1.3 Option 3: Large Nodes (Recommended for High-Performance Workloads)

* **Node Configuration**: 64 vCPUs, 256 GB RAM, 4 TB NVMe SSD
* **Number of Nodes**: 157 nodes
* **Use Case**: High-performance applications, large VMs, compute-intensive workloads
* **Cost Efficiency**: Best performance per dollar for large workloads
* **Pros**:
  + Maximum resource density
  + Lower management overhead
  + Best for large workloads
* **Cons**:
  + Higher blast radius
  + Less flexibility for smaller workloads
  + Higher individual node investment

##### 55.2.1.2.2 Recommended Hybrid Approach

**Distribution across clusters**: - **Management Cluster**: 6 Medium nodes (dedicated for cluster management) - **Production Clusters**: - 60% Medium nodes (188 nodes) - Primary production workloads - 30% Large nodes (47 nodes) - High-performance applications - 10% Small nodes (62 nodes) - Development and testing

**Total Node Count**: 303 nodes **Total Resources**: ~10,000 vCPUs, ~20 TB RAM, ~600 TB Storage

##### 55.2.1.2.3 Network and Storage Specifications

* **Network Bandwidth**: Up to 40 Gbps per cluster
* **Storage IOPS**: Minimum 200,000 IOPS aggregate
* **Network Architecture**:
  + 25 Gbps per node connectivity
  + Redundant spine-leaf topology
  + Dedicated storage network (10 Gbps)

#### 55.2.1.3 Application Gabari Descriptions

To ensure compatibility and optimal performance, applications are categorized based on typical resource demands and architectural patterns:

##### 55.2.1.3.1 1. Microservices Applications

* **Configuration**: Typically small, scalable units with minimal resource needs per instance (1-2 vCPUs, 2-4 GB RAM)
* **Key Considerations**: Designed for high scalability, containerized deployments, and stateless architecture
* **Use Cases**: Web services, REST APIs, lightweight backend services

##### 55.2.1.3.2 2. Monolithic Applications

* **Configuration**: Larger resource footprint with robust processing needs (4-8 vCPUs, 16-32 GB RAM)
* **Key Considerations**: May not scale horizontally; benefits from vertical scaling
* **Use Cases**: Legacy applications, computational intensive tasks, single-platform systems

##### 55.2.1.3.3 3. Distributed Applications

* **Configuration**: Moderate resources per service, optimized for distributed workload (2-4 vCPUs, 8-16 GB RAM per node)
* **Key Considerations**: Requires synchronization across nodes, often benefits from microservices/design separation
* **Use Cases**: Databases, clustered applications, interconnected services

##### 55.2.1.3.4 4. Resource-Intensive Applications

* **Configuration**: High-performance requirements, large scale of resources (8-16 vCPUs, 32-64 GB RAM)
* **Key Considerations**: Compute-intensive, may need specific hardware accelerators (e.g., GPUs)
* **Use Cases**: Data analytics, machine learning workloads, scientific computing

### 55.2.2 Migration Sizing

**Scope**: Plan for the migration of 1,000 virtual machines and 100 applications.

#### 55.2.2.1 Key Metrics

* **Virtual Machines**: 1,000
  + VM Types: Includes various OS types and legacy configurations
  + Average VM size: 4 vCPUs, 16 GB RAM per VM
  + Storage per VM: 500 GB
* **Applications**: 100
  + Application Types: Legacy, modern monoliths, and distributed services
* **Data Migration Volume**: 500 TB

#### 55.2.2.2 Migration Planning

* **Migration Waves**: 5 waves, 200 VMs + 20 Applications per wave
* **Expected Downtime**: Max 2 hours per application
* **Risk Mitigation**:
  + Pilot migrations for high-risk workloads
  + Rollback strategies for failed migrations

### 55.2.3 Strategic Considerations

#### 55.2.3.1 Infrastructure

1. **Scalability**: Design to accommodate future growth up to 300 applications and 3,000 VMs.
2. **Redundancy**: Implement failover and disaster recovery protocols.
3. **Monitoring and Logging**: Comprehensive observability with real-time analytics.

#### 55.2.3.2 Migration

1. **Compatibility**: Analyze application dependencies and compatibility early.
2. **Data Integrity**: Ensure lossless data transfer methods.
3. **Operational Support**: Equip teams with runbooks for migration phases.

### 55.2.4 Appendices

#### 55.2.4.1 Sizing Assumptions

* Based on existing organizational usage patterns and vendor best practices.

#### 55.2.4.2 Dependencies

* Align sizing with strategic initiatives.
* Regular reviews to anticipate scaling needs and compliance demands.

#### 55.2.4.3 Risk Factors

* Sizing models subject to change with evolving requirements and emerging technologies.

# 56 Weekly Charge Breakdown

## 56.1 Weekly Workload Breakdown by Persona and Project

### 56.1.1 Overview

This document provides a detailed weekly workload breakdown in person-days for all personas across the three sub-projects of the RH OVE Ecosystem implementation.

**Project Duration**: 60 weeks (15 months)  
**Total Estimated Workload**: 2,694 person-days

### 56.1.2 Persona Skill Levels and Availability

| Persona Type | Skill Level | Standard Days/Week | Notes |
| --- | --- | --- | --- |
| Infrastructure Architect | Senior | 5 | Part-time (2.5 days) during Implementation |
| Solution Architect | Senior | 5 | Full-time during active phases |
| Migration Specialist | Senior | 5 | Full-time throughout migration project |
| DevOps Engineer | Mid-Senior | 5 | Multiple resources (2x) |
| Security Engineer | Senior | 5 | Full-time during active phases |
| Network Engineer | Senior | 5 | Full-time during active phases |
| Security Specialist | Senior | 5 | Full-time during active phases |
| Application Owner | Mid-Senior | 5 | Multiple resources (2x) |
| Performance Engineer | Mid-Senior | 5 | Full-time during active phases |
| Business Analyst | Mid-Senior | 5 | Full-time during active phases |
| RH OVE Engineer | Mid-Senior | 5 | Multiple resources (2x) |
| Application Developer | Mid-Level | 5 | Multiple resources (3x) |
| System Administrator | Mid-Level | 5 | Multiple resources (2x) |
| Testing Specialist | Mid-Level | 5 | Full-time during active phases |
| VMware Administrator | Mid-Level | 5 | Multiple resources (2x) |
| Backup Administrator | Mid-Level | 5 | Full-time during active phases |

### 56.1.3 Project 1: RH OVE Infrastructure

#### 56.1.3.1 Weekly Allocation by Phase (Person-Days)

| Week | Phase | Infrastructure Architect | DevOps Engineer (2x) | System Administrator (2x) | Security Engineer | Network Engineer | Weekly Total (Days) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1-4 | Study | 5 | 0 | 0 | 0 | 5 | 10 |
| 5-12 | Design | 5 | 10 | 0 | 5 | 5 | 25 |
| 13-20 | Implementation | 2.5 (PT) | 10 | 10 | 5 | 5 | 32.5 |
| 21-24 | Testing | 0 | 10 | 10 | 5 | 0 | 25 |
| 25-28 | Day-2 Ops | 0 | 10 | 10 | 0 | 0 | 20 |

**Infrastructure Project Total: 582.5 person-days**

#### 56.1.3.2 Phase-wise Workload Summary

* **Study Phase (Weeks 1-4)**: 40 person-days
* **Design Phase (Weeks 5-12)**: 200 person-days
* **Implementation Phase (Weeks 13-20)**: 260 person-days
* **Testing Phase (Weeks 21-24)**: 100 person-days
* **Day-2 Operations (Weeks 25-28)**: 80 person-days

### 56.1.4 Project 2: Use-Cases Implementation

#### 56.1.4.1 Weekly Allocation by Phase (Person-Days)

| Week | Phase | Solution Architect | Application Developer (3x) | Testing Specialist | DevOps Engineer | Security Specialist | Business Analyst | Weekly Total (Days) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 15-18 | Study | 5 | 0 | 0 | 0 | 0 | 5 | 10 |
| 19-26 | Design | 5 | 0 | 0 | 0 | 5 | 5 | 15 |
| 27-38 | Implementation | 0 | 15 | 0 | 5 | 5 | 0 | 25 |
| 39-42 | Testing | 0 | 15 | 5 | 5 | 5 | 0 | 30 |
| 43-46 | Day-2 Ops | 0 | 0 | 0 | 5 | 0 | 0 | 5 |

**Use-Cases Project Total: 560 person-days**

#### 56.1.4.2 Phase-wise Workload Summary

* **Study Phase (Weeks 15-18)**: 40 person-days
* **Design Phase (Weeks 19-26)**: 120 person-days
* **Implementation Phase (Weeks 27-38)**: 300 person-days
* **Testing Phase (Weeks 39-42)**: 120 person-days
* **Day-2 Operations (Weeks 43-46)**: 20 person-days

### 56.1.5 Project 3: Migration from VMware

#### 56.1.5.1 Weekly Allocation by Phase (Person-Days)

| Week | Phase | Migration Specialist | VMware Admin (2x) | RH OVE Engineer (2x) | Application Owner (2x) | Performance Engineer | Backup Administrator | Weekly Total (Days) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 21-28 | Study | 5 | 10 | 0 | 0 | 0 | 0 | 15 |
| 29-36 | Design | 5 | 10 | 0 | 10 | 0 | 0 | 25 |
| 37-50 | Implementation | 5 | 10 | 10 | 10 | 5 | 5 | 45 |
| 51-54 | Testing | 5 | 0 | 10 | 10 | 5 | 5 | 35 |
| 55-60 | Day-2 Ops | 5 | 0 | 10 | 0 | 5 | 5 | 25 |

**Migration Project Total: 869 person-days**

#### 56.1.5.2 Phase-wise Workload Summary

* **Study Phase (Weeks 21-28)**: 120 person-days
* **Design Phase (Weeks 29-36)**: 200 person-days
* **Implementation Phase (Weeks 37-50)**: 630 person-days
* **Testing Phase (Weeks 51-54)**: 140 person-days
* **Day-2 Operations (Weeks 55-60)**: 150 person-days

### 56.1.6 Summary by Sub-Project

| Sub-Project | Duration (Weeks) | Total Workload (Person-Days) | Average Weekly Workload (Days) |
| --- | --- | --- | --- |
| RH OVE Infrastructure | 28 | 582.5 | 20.8 |
| Use-Cases Implementation | 32 | 560 | 17.5 |
| Migration from VMware | 40 | 869 | 21.7 |
| **Total** | **60** | **2,011.5** | **33.5** |

### 56.1.7 Peak Resource Utilization

#### 56.1.7.1 Highest Workload Weeks

| Week Range | Projects Active | Weekly Workload (Days) | Key Activities |
| --- | --- | --- | --- |
| 37-42 | Infrastructure + Use-Cases + Migration | 102.5 | Implementation overlap |
| 43-46 | Use-Cases + Migration | 30 | Testing phases |
| 47-50 | Migration Implementation | 45 | Critical migration waves |

#### 56.1.7.2 Resource Overlap Analysis

**Weeks 15-28**: Infrastructure and Use-Cases overlap  
**Weeks 21-46**: All three projects active simultaneously  
**Weeks 47-60**: Migration project completion phase

### 56.1.8 Workload Distribution by Persona Type

| Persona Type | Total Weeks Active | Total Workload (Days) | Percentage |
| --- | --- | --- | --- |
| Migration Specialist | 40 | 200 | 9.9% |
| Application Developer (3x) | 16 | 240 | 11.9% |
| RH OVE Engineer (2x) | 24 | 240 | 11.9% |
| VMware Administrator (2x) | 28 | 280 | 13.9% |
| DevOps Engineer (2x) | 36 | 360 | 17.9% |
| Infrastructure Architect | 18.5 | 92.5 | 4.6% |
| System Administrator (2x) | 16 | 160 | 8.0% |
| Security Engineer | 16 | 80 | 4.0% |
| Network Engineer | 20 | 100 | 5.0% |
| Solution Architect | 12 | 60 | 3.0% |
| Testing Specialist | 4 | 20 | 1.0% |
| Security Specialist | 12 | 60 | 3.0% |
| Business Analyst | 4 | 20 | 1.0% |
| Application Owner (2x) | 26 | 260 | 12.9% |
| Performance Engineer | 18 | 90 | 4.5% |
| Backup Administrator | 30 | 150 | 7.5% |

### 56.1.9 Notes

1. **Part-time allocation**: Infrastructure Architect works part-time (2.5 days/week) during Implementation phase
2. **Resource multiplication**: Numbers in parentheses (e.g., 2x, 3x) indicate multiple resources of the same type
3. **Phase overlap**: Some personas work across multiple phases with varying intensity
4. **Workload estimates**: Based on standard 5-day work weeks for full-time resources
5. **Flexibility**: Resource allocation can be adjusted based on project needs and availability

### 56.1.10 Risk Factors Affecting Workload

1. **Skill scarcity**: Specialized RH OVE and migration expertise may require extended timelines
2. **Timeline compression**: Accelerated delivery may require additional parallel resources
3. **Scope changes**: Additional use-cases or migration complexity could increase workload
4. **Resource availability**: Team member availability and scheduling conflicts may impact timelines
5. **Learning curve**: New team members may require additional time for technology familiarization

# 57 Product URLs

## 57.1 Product URLs and References

### 57.1.1 Overview

This document provides an exhaustive list of product URLs, documentation, and resources for all components used in the RH OVE ecosystem design and implementation.

### 57.1.2 Core Platform Components

#### 57.1.2.1 Red Hat OpenShift

* **Product Homepage**: <https://www.redhat.com/en/technologies/cloud-computing/openshift>
* **Documentation**: <https://docs.openshift.com/>
* **Container Platform Docs**: <https://docs.openshift.com/container-platform/latest/>
* **Installation Guide**: <https://docs.openshift.com/container-platform/latest/installing/>
* **API Reference**: <https://docs.openshift.com/container-platform/latest/rest_api/>
* **Red Hat Customer Portal**: <https://access.redhat.com/>
* **OpenShift Blog**: <https://www.redhat.com/en/blog/channel/red-hat-openshift>

#### 57.1.2.2 Red Hat OpenShift Virtualization Engine (RH OVE)

* **Product Page**: <https://www.redhat.com/en/technologies/cloud-computing/openshift/virtualization-engine>
* **Datasheet**: <https://www.redhat.com/en/resources/red-hat-openshift-virtualization-engine-datasheet>
* **Documentation**: <https://docs.redhat.com/en/documentation/openshift_container_platform/4.14/html-single/virtualization/>
* **Getting Started**: <https://docs.redhat.com/en/documentation/openshift_container_platform/4.15/html/virtualization/about>
* **Reference Implementation**: <https://access.redhat.com/sites/default/files/attachments/openshift_virtualization_reference_implementation_guide.pdf>

#### 57.1.2.3 KubeVirt (Upstream)

* **Project Homepage**: <https://kubevirt.io/>
* **GitHub Repository**: <https://github.com/kubevirt/kubevirt>
* **Documentation**: <https://kubevirt.io/user-guide/>
* **Architecture**: <https://kubevirt.io/user-guide/architecture/>
* **Installation**: <https://kubevirt.io/user-guide/cluster_admin/installation/>
* **API Validation**: <https://kubevirt.io/user-guide/cluster_admin/api_validation/>
* **GitOps Guide**: <https://kubevirt.io/user-guide/cluster_admin/gitops/>

### 57.1.3 Networking Components

#### 57.1.3.1 Cilium

* **Project Homepage**: <https://cilium.io/>
* **Documentation**: <https://docs.cilium.io/>
* **GitHub Repository**: <https://github.com/cilium/cilium>
* **OpenShift Installation**: <https://docs.cilium.io/en/stable/installation/k8s-install-openshift-okd.html>
* **Blog**: <https://cilium.io/blog/>
* **OpenShift Certification**: <https://cilium.io/blog/2021/04/19/openshift-certification/>
* **Learning Hub**: <https://www.tigera.io/learn/guides/cilium-vs-calico/cilium/>

#### 57.1.3.2 Hubble (Network Observability)

* **Documentation**: <https://docs.cilium.io/en/stable/gettingstarted/hubble/>
* **GitHub Repository**: <https://github.com/cilium/hubble>
* **UI Repository**: <https://github.com/cilium/hubble-ui>

#### 57.1.3.3 Multus CNI (Multi-Network)

* **Project Homepage**: <https://github.com/k8snetworkplumbingwg/multus-cni>
* **Documentation**: <https://github.com/k8snetworkplumbingwg/multus-cni/blob/master/docs/how-to-use.md>
* **OpenShift Documentation**: <https://docs.openshift.com/container-platform/latest/networking/multiple_networks/understanding-multiple-networks.html>
* **Network Attachment Definitions**: <https://docs.openshift.com/container-platform/latest/networking/multiple_networks/configuring-additional-network-types.html>
* **SR-IOV Network Operator**: <https://docs.openshift.com/container-platform/latest/networking/hardware_networks/about-sriov.html>
* **CNCF Landscape**: <https://landscape.cncf.io/card-mode?category=cni&grouping=category>
* **Kubernetes Network SIG**: <https://github.com/kubernetes/community/tree/master/sig-network>

#### 57.1.3.4 SR-IOV Network Operator

* **GitHub Repository**: <https://github.com/k8snetworkplumbingwg/sriov-network-operator>
* **OpenShift SR-IOV Documentation**: <https://docs.openshift.com/container-platform/latest/networking/hardware_networks/installing-sriov-operator.html>
* **Configuration Guide**: <https://docs.openshift.com/container-platform/latest/networking/hardware_networks/configuring-sriov-device.html>
* **Performance Tuning**: <https://docs.openshift.com/container-platform/latest/networking/hardware_networks/using-dpdk-and-rdma.html>

#### 57.1.3.5 Network Plumbing Working Group

* **GitHub Organization**: <https://github.com/k8snetworkplumbingwg>
* **Community Meetings**: <https://github.com/k8snetworkplumbingwg/community>
* **CNI Plugins**: <https://github.com/containernetworking/plugins>

### 57.1.4 Policy and Security

#### 57.1.4.1 Kyverno

* **Project Homepage**: <https://kyverno.io/>
* **Documentation**: <https://kyverno.io/docs/>
* **GitHub Repository**: <https://github.com/kyverno/kyverno>
* **Installation**: <https://kyverno.io/docs/installation/>
* **Policy Examples**: <https://kyverno.io/policies/>
* **Admission Controllers Guide**: <https://kyverno.io/docs/introduction/admission-controllers/>
* **Helm Chart**: <https://github.com/kyverno/kyverno/tree/main/charts/kyverno>

### 57.1.5 GitOps and CI/CD

#### 57.1.5.1 Argo CD

* **Project Homepage**: <https://argoproj.github.io/argo-cd/>
* **Documentation**: <https://argo-cd.readthedocs.io/>
* **GitHub Repository**: <https://github.com/argoproj/argo-cd>
* **Getting Started**: <https://argo-cd.readthedocs.io/en/stable/getting_started/>
* **OpenShift GitOps**: <https://docs.openshift.com/container-platform/latest/cicd/gitops/understanding-openshift-gitops.html>

#### 57.1.5.2 Red Hat OpenShift GitOps

* **Product Page**: <https://www.redhat.com/en/technologies/cloud-computing/openshift/gitops>
* **Documentation**: <https://docs.openshift.com/container-platform/latest/cicd/gitops/>
* **Operator Hub**: <https://operatorhub.io/operator/openshift-gitops-operator>

### 57.1.6 Monitoring and Observability

#### 57.1.6.1 Dynatrace

* **Product Homepage**: <https://www.dynatrace.com/>
* **Platform Documentation**: <https://docs.dynatrace.com/>
* **OpenShift Integration**: <https://docs.dynatrace.com/docs/ingest-from/setup-on-k8s/deployment/other/ocp-operator-hub>
* **Kubernetes Monitoring**: <https://docs.dynatrace.com/docs/observe/infrastructure-monitoring/container-platform-monitoring/kubernetes-monitoring/>
* **Operator GitHub**: <https://github.com/Dynatrace/dynatrace-operator>
* **Red Hat Partner Page**: <https://www.dynatrace.com/hub/detail/red-hat-openshift/>
* **Blog**: <https://www.dynatrace.com/news/blog/>

#### 57.1.6.2 Prometheus

* **Project Homepage**: <https://prometheus.io/>
* **Documentation**: <https://prometheus.io/docs/>
* **GitHub Repository**: <https://github.com/prometheus/prometheus>
* **OpenShift Monitoring**: <https://docs.openshift.com/container-platform/latest/monitoring/>

#### 57.1.6.3 Grafana

* **Project Homepage**: <https://grafana.com/>
* **Documentation**: <https://grafana.com/docs/>
* **GitHub Repository**: <https://github.com/grafana/grafana>

### 57.1.7 Backup and Recovery

#### 57.1.7.1 Rubrik

* **Product Homepage**: <https://www.rubrik.com/>
* **OpenShift Solutions**: <https://www.rubrik.com/solutions/openshift>
* **Kubernetes Solutions**: <https://www.rubrik.com/solutions/kubernetes>
* **Documentation**: <https://docs.rubrik.com/>
* **Compatibility Matrix**: <https://docs.rubrik.com/en-us/compat_matrix/index.html>
* **Blog**: <https://www.rubrik.com/blog/>
* **Red Hat Partnership**: <https://www.redhat.com/en/blog/red-hat-openshift-virtualization-and-rubrik>

### 57.1.8 ITSM and CMDB Integration

#### 57.1.8.1 ServiceNow

* **Product Homepage**: <https://www.servicenow.com/>
* **CMDB Documentation**: <https://docs.servicenow.com/bundle/xanadu-servicenow-platform/page/product/configuration-management/>
* **Developer Documentation**: <https://developer.servicenow.com/>
* **REST API Guide**: <https://docs.servicenow.com/bundle/xanadu-application-development/page/integrate/inbound-rest/concept/c_RESTAPI.html>
* **IntegrationHub**: <https://docs.servicenow.com/bundle/xanadu-servicenow-platform/page/administer/integrationhub/>

### 57.1.9 Storage Solutions

#### 57.1.9.1 Container Storage Interface (CSI)

* **CSI Specification**: <https://github.com/container-storage-interface/spec>
* **Kubernetes CSI Documentation**: <https://kubernetes-csi.github.io/docs/>
* **OpenShift Storage**: <https://docs.openshift.com/container-platform/latest/storage/>

#### 57.1.9.2 Containerized Data Importer (CDI)

* **GitHub Repository**: <https://github.com/kubevirt/containerized-data-importer>
* **Documentation**: <https://kubevirt.io/user-guide/storage/disks_and_volumes/>

### 57.1.10 Additional Tools and Utilities

#### 57.1.10.1 virtctl

* **Documentation**: <https://kubevirt.io/user-guide/virtual_machines/accessing_virtual_machines/>
* **GitHub Repository**: <https://github.com/kubevirt/kubevirt/tree/main/cmd/virtctl>

#### 57.1.10.2 OpenShift CLI (oc)

* **Documentation**: <https://docs.openshift.com/container-platform/latest/cli_reference/openshift_cli/getting-started-cli.html>
* **Download**: <https://mirror.openshift.com/pub/openshift-v4/clients/ocp/>

### 57.1.11 Community and Learning Resources

#### 57.1.11.1 Red Hat Learning

* **Red Hat Training**: <https://www.redhat.com/en/services/training>
* **OpenShift Learning Portal**: <https://learn.openshift.com/>
* **Red Hat Developer**: <https://developers.redhat.com/>

#### 57.1.11.2 Community Forums

* **Red Hat Customer Portal**: <https://access.redhat.com/discussions>
* **OpenShift Commons**: <https://commons.openshift.org/>
* **KubeVirt Community**: <https://kubevirt.io/community/>
* **CNCF Slack**: <https://slack.cncf.io/>

#### 57.1.11.3 GitHub Organizations

* **Red Hat**: <https://github.com/redhat>
* **OpenShift**: <https://github.com/openshift>
* **KubeVirt**: <https://github.com/kubevirt>
* **Cilium**: <https://github.com/cilium>
* **Kyverno**: <https://github.com/kyverno>
* **Argo Project**: <https://github.com/argoproj>

### 57.1.12 Professional Services and Support

#### 57.1.12.1 Red Hat Consulting

* **Services Overview**: <https://www.redhat.com/en/services/consulting>
* **OpenShift Consulting**: <https://www.redhat.com/en/services/consulting/openshift>

#### 57.1.12.2 Partner Ecosystem

* **Red Hat Partner Directory**: <https://connect.redhat.com/en/partner-directory>
* **Certified Container Images**: <https://catalog.redhat.com/software/containers/explore>
* **Operator Hub**: <https://operatorhub.io/>

This comprehensive list provides direct access to all the resources, documentation, and tools needed for implementing and managing the RH OVE ecosystem.

# 58 Best Practices

## 58.1 Best Practices

### 58.1.1 Overview

This document outlines best practices for designing, deploying, and managing the multi-cluster RH OVE ecosystem, ensuring performance, security, and operational efficiency. This includes guidance on managing centralized services within the management cluster and distributing workloads across application clusters.

### 58.1.2 Multi-Cluster Architecture Best Practices

#### 58.1.2.1 Cluster Design

* **Separation of Concerns**: Maintain clear separation between management and application clusters
* **Environment Isolation**: Use dedicated clusters for production, staging, and development
* **Resource Planning**: Size clusters appropriately for their intended workloads
* **Network Segmentation**: Implement proper network isolation between cluster environments

#### 58.1.2.2 Management Cluster

* **High Availability**: Deploy management services with HA configuration
* **Resource Allocation**: Dedicate sufficient resources for centralized services
* **Backup Strategy**: Implement comprehensive backup for management cluster state
* **Security Hardening**: Apply strict security controls as this cluster manages the entire fleet

#### 58.1.2.3 Application Clusters

* **Standardization**: Use consistent cluster configurations across environments
* **Agent Deployment**: Ensure proper deployment of management agents (ArgoCD, RHACS, monitoring)
* **Local Resources**: Optimize local resource allocation for workload requirements
* **Compliance**: Maintain consistent security and compliance postures

### 58.1.3 Architecture Best Practices

#### 58.1.3.1 Namespace Design

* **Use Application Namespaces**: Segregate workloads by application or team-based namespaces for enhanced security and resource management
* **Environment Prefixes**: Use consistent naming conventions (e.g., prod-, staging-, dev-)
* **Label and Annotate**: Use consistent labeling and annotations for automation and policy application
* **Cross-Cluster Consistency**: Maintain similar namespace structures across clusters

#### 58.1.3.2 Multi-Tenancy

* **RBAC Implementation**: Apply Role-Based Access Control to enforce access restrictions
* **Network Policies**: Utilize Cilium to enforce strict network policies between tenants
* **Resource Quotas**: Implement appropriate resource quotas per tenant/namespace
* **Policy Distribution**: Use centralized policy management with cluster-specific enforcement

### 58.1.4 Multi-Cluster GitOps Best Practices

#### 58.1.4.1 Repository Structure

* **Centralized Repositories**: Use centralized Git repositories for all cluster configurations
* **Environment Branching**: Implement proper branching strategies for different environments
* **Application Separation**: Separate application definitions from infrastructure configurations
* **Policy as Code**: Store all policies and governance rules in version control

#### 58.1.4.2 Deployment Strategies

* **Progressive Deployment**: Deploy to development, then staging, then production clusters
* **Automated Validation**: Implement automated testing and validation in CI/CD pipelines
* **Rollback Procedures**: Maintain clear rollback procedures for failed deployments
* **Change Management**: Implement proper change management processes for critical updates

### 58.1.5 Deployment Best Practices

#### 58.1.5.1 Infrastructure Planning

* **Capacity Planning**: Assess resource needs well in advance and plan infrastructure accordingly
* **High Availability (HA)**: Configure HA for critical components and services
* **Cluster Sizing**: Right-size clusters based on workload requirements and growth projections
* **Geographic Distribution**: Consider geographic distribution for disaster recovery

#### 58.1.5.2 Configuration Management

* **Infrastructure as Code (IaC)**: Use GitOps and Argo CD for configuration management and deployment consistency
* **Version Control**: Ensure all configurations and manifests are version controlled
* **Template Management**: Use Helm charts or Kustomize for template management
* **Secret Management**: Implement proper secret management across clusters

### 58.1.6 Security Best Practices

#### 58.1.6.1 Network Security

* **Zero Trust Network**: Implement zero trust principles using Cilium’s microsegmentation and network policies.
* **Encryption**: Enforce encryption of data in transit and at rest.

#### 58.1.6.2 Container and VM Security

* **Security Contexts**: Apply security contexts to restrict container capabilities and privileges.
* **Image Scanning**: Regularly scan container and VM images for vulnerabilities.

### 58.1.7 Operational Best Practices

#### 58.1.7.1 Monitoring and Alerts

* **Comprehensive Monitoring**: Utilize tools like Dynatrace and Prometheus for end-to-end monitoring.
* **Alerting Systems**: Set up robust alerting and notification systems for proactive issue resolution.

#### 58.1.7.2 Backup and Recovery

* **Regular Backups**: Schedule regular backups and test recovery procedures periodically.
* **Data Retention Policies**: Define and implement data retention and cleanup policies.

### 58.1.8 Continuous Improvement

#### 58.1.8.1 Reviews and Audits

* **Performance Reviews**: Conduct regular performance reviews and optimizations.
* **Security Audits**: Perform periodic security audits and policy compliance checks.

#### 58.1.8.2 Community Engagement

* **Stay Updated**: Engage with the community via forums and contribute to open-source projects.
* **Professional Development**: Encourage ongoing learning and certification for team members.

#### 58.1.8.3 Documentation and Knowledge Sharing

* **Maintain Documentation**: Keep operational runbooks and architecture diagrams updated.
* **Knowledge Transfer**: Conduct regular training sessions and share lessons learned.

### 58.1.9 Conclusion

Adhering to these best practices ensures a well-architected, secure, and efficient RH OVE ecosystem that can adapt and scale with changing business needs.

# 59 SBOM

## 59.1 Software Bill of Materials (SBOM)

### 59.1.1 Overview

This document provides a comprehensive Software Bill of Materials (SBOM) for the RH OVE Multi-Cluster Ecosystem, consolidating all required software components, versions, and dependencies needed for successful deployment and operation.

### 59.1.2 Core Platform Components

#### 59.1.2.1 Red Hat OpenShift Container Platform

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| OpenShift Container Platform | 4.12+ (recommended 4.14+) | Commercial | Kubernetes platform foundation | Red Hat |
| OpenShift CLI (oc) | Matches cluster version | Apache 2.0 | Command-line interface | Red Hat |
| OpenShift Web Console | Integrated with OCP | Commercial | Web-based management interface | Red Hat |

#### 59.1.2.2 Virtualization Stack

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| OpenShift Virtualization Operator | 4.14+ | Commercial | VM management on OpenShift | Red Hat |
| KubeVirt | Latest (upstream) | Apache 2.0 | Kubernetes VM orchestration | KubeVirt Community |
| virtctl | Matches KubeVirt version | Apache 2.0 | VM command-line tool | KubeVirt Community |
| Containerized Data Importer (CDI) | Latest | Apache 2.0 | VM disk import/management | KubeVirt Community |
| libvirt | 7.0+ | LGPL 2.1+ | Virtualization API | Red Hat Enterprise Linux |
| QEMU/KVM | 6.0+ | GPL v2 | Hypervisor | Red Hat Enterprise Linux |

### 59.1.3 Networking Components

#### 59.1.3.1 Container Network Interface (CNI)

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Cilium CNI | 1.12+ | Apache 2.0 | Primary network plugin with eBPF | Cilium |
| Cilium Operator | Matches Cilium version | Apache 2.0 | Cilium management operator | Cilium |
| Hubble | Integrated with Cilium | Apache 2.0 | Network observability | Cilium |
| Multus CNI | 3.8+ | Apache 2.0 | Multi-network support | Network Plumbing WG |
| SR-IOV Network Operator | 4.12+ | Apache 2.0 | High-performance networking | Red Hat |
| SR-IOV CNI | Latest | Apache 2.0 | SR-IOV network plugin | Network Plumbing WG |

#### 59.1.3.2 Network Tools

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| iptables | 1.8+ | GPL v2 | Network filtering | Linux |
| eBPF | Kernel 4.14+ | GPL v2 | Network programming | Linux Kernel |
| OVS (Open vSwitch) | 2.15+ | Apache 2.0 | Virtual switching | Open vSwitch |

### 59.1.4 Security and Policy Management

#### 59.1.4.1 Security Platforms

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Red Hat Advanced Cluster Security | Latest | Commercial | Security and compliance platform | Red Hat |
| Kyverno | 1.8+ | Apache 2.0 | Policy engine | Kyverno Community |
| Falco | 0.32+ | Apache 2.0 | Runtime security monitoring | CNCF |

#### 59.1.4.2 Certificate and Identity Management

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| cert-manager | 1.10+ | Apache 2.0 | Certificate lifecycle management | CNCF |
| External Secrets Operator | 0.7+ | Apache 2.0 | Secret management | External Secrets |
| OpenShift OAuth | Integrated | Commercial | Authentication provider | Red Hat |

### 59.1.5 GitOps and Continuous Deployment

#### 59.1.5.1 GitOps Platform

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Red Hat OpenShift GitOps | Latest | Commercial | GitOps platform based on Argo CD | Red Hat |
| Argo CD | 2.6+ | Apache 2.0 | GitOps continuous deployment | Argo Project |
| Argo Workflows | 3.4+ | Apache 2.0 | Workflow orchestration | Argo Project |
| Argo Rollouts | 1.4+ | Apache 2.0 | Progressive delivery | Argo Project |

#### 59.1.5.2 Source Control Integration

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Git | 2.30+ | GPL v2 | Version control system | Git Community |
| GitHub/GitLab Webhooks | API v4+ | Various | Repository integration | GitHub/GitLab |

### 59.1.6 Monitoring and Observability

#### 59.1.6.1 Metrics and Monitoring

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Dynatrace Operator | Latest | Commercial | Full-stack observability platform | Dynatrace |
| Prometheus | 2.40+ | Apache 2.0 | Metrics collection and storage | CNCF |
| Grafana | 9.0+ | AGPL v3 | Metrics visualization | Grafana Labs |
| AlertManager | 0.25+ | Apache 2.0 | Alert management | Prometheus |
| Node Exporter | 1.5+ | Apache 2.0 | Node metrics collection | Prometheus |
| kube-state-metrics | 2.7+ | Apache 2.0 | Kubernetes metrics | Kubernetes |

#### 59.1.6.2 Logging

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| OpenShift Logging | 5.6+ | Commercial | Log aggregation platform | Red Hat |
| Elasticsearch | 7.17+ | Elastic License | Log storage and search | Elastic |
| Fluentd | 1.15+ | Apache 2.0 | Log collection and forwarding | CNCF |
| Kibana | 7.17+ | Elastic License | Log visualization | Elastic |

#### 59.1.6.3 Distributed Tracing

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Jaeger | 1.40+ | Apache 2.0 | Distributed tracing | CNCF |
| OpenTelemetry Operator | 0.70+ | Apache 2.0 | Telemetry collection | CNCF |

### 59.1.7 Storage Solutions

#### 59.1.7.1 Container Storage Interface (CSI)

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| AWS EBS CSI Driver | 1.15+ | Apache 2.0 | Block storage for AWS | Kubernetes |
| Azure Disk CSI Driver | 1.25+ | Apache 2.0 | Block storage for Azure | Kubernetes |
| GCE Persistent Disk CSI | 1.10+ | Apache 2.0 | Block storage for GCP | Kubernetes |
| Ceph CSI | 3.8+ | Apache 2.0 | Distributed storage | Ceph |
| NetApp Trident | 22.10+ | Apache 2.0 | Enterprise storage | NetApp |
| Dell CSI Driver | 2.8+ | Apache 2.0 | Dell enterprise storage | Dell Technologies |

#### 59.1.7.2 Storage Management

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| OpenShift Data Foundation | 4.12+ | Commercial | Software-defined storage | Red Hat |
| Local Storage Operator | 4.12+ | Apache 2.0 | Local storage management | Red Hat |

### 59.1.8 Backup and Disaster Recovery

#### 59.1.8.1 Backup Solutions

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Rubrik | Latest | Commercial | Enterprise backup platform | Rubrik |
| Velero | 1.10+ | Apache 2.0 | Kubernetes backup | VMware |
| OADP (OpenShift API for Data Protection) | 1.1+ | Apache 2.0 | Backup operator | Red Hat |

### 59.1.9 Multi-Cluster Management

#### 59.1.9.1 Cluster Management

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Red Hat Advanced Cluster Management | Latest | Commercial | Multi-cluster management | Red Hat |
| Karmada | 1.6+ | Apache 2.0 | Multi-cluster orchestration | Karmada Community |
| Skupper | 1.2+ | Apache 2.0 | Application connectivity | Red Hat |

### 59.1.10 Development and Tooling

#### 59.1.10.1 Command Line Tools

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| kubectl | Matches cluster version | Apache 2.0 | Kubernetes CLI | Kubernetes |
| helm | 3.10+ | Apache 2.0 | Package manager | CNCF |
| kustomize | 4.5+ | Apache 2.0 | Configuration management | Kubernetes |
| jq | 1.6+ | MIT | JSON processing | jq |
| yq | 4.30+ | MIT | YAML processing | yq |

#### 59.1.10.2 Container Tools

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Podman | 4.3+ | Apache 2.0 | Container management | Red Hat |
| Buildah | 1.28+ | Apache 2.0 | Container image building | Red Hat |
| Skopeo | 1.10+ | Apache 2.0 | Container image operations | Red Hat |

### 59.1.11 Operating System Requirements

#### 59.1.11.1 Base Operating System

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Red Hat Enterprise Linux CoreOS | 4.12+ | Commercial | Container-optimized OS | Red Hat |
| Red Hat Enterprise Linux | 8.6+ or 9.0+ | Commercial | General-purpose OS | Red Hat |

#### 59.1.11.2 System Dependencies

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| systemd | 239+ | LGPL 2.1+ | System and service manager | systemd |
| Docker/Podman | 4.0+ | Apache 2.0 | Container runtime | Various |
| CRI-O | 1.25+ | Apache 2.0 | Container runtime | CRI-O |
| runc | 1.1+ | Apache 2.0 | Container runtime | OCI |

### 59.1.12 Integration and ITSM

#### 59.1.12.1 ITSM Integration

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| ServiceNow | Latest | Commercial | ITSM platform | ServiceNow |
| ServiceNow MID Server | Latest | Commercial | Integration middleware | ServiceNow |

#### 59.1.12.2 Event Management

| Component | Version | License | Purpose | Source |
| --- | --- | --- | --- | --- |
| Splunk | 8.2+ | Commercial | SIEM platform | Splunk |
| Elastic Security | 7.17+ | Elastic License | Security analytics | Elastic |

### 59.1.13 Hardware Requirements

#### 59.1.13.1 Minimum Hardware Specifications

| Component | Requirement | Purpose |
| --- | --- | --- |
| CPU (Master Nodes) | 4+ cores per node | Control plane operations |
| Memory (Master Nodes) | 16GB+ per node | Control plane operations |
| Storage (Master Nodes) | 120GB+ per node | etcd and system data |
| CPU (Worker Nodes) | 8+ cores per node | Workload execution |
| Memory (Worker Nodes) | 32GB+ per node | VM and container workloads |
| Storage (Worker Nodes) | 500GB+ per node | Application data |
| Network | 10Gbps+ | High-performance networking |
| Virtualization | Intel VT-x/AMD-V | Hardware virtualization support |

### 59.1.14 Network Requirements

#### 59.1.14.1 Port Requirements

| Port Range | Protocol | Purpose |
| --- | --- | --- |
| 6443 | TCP | Kubernetes API server |
| 22623 | TCP | Machine config server |
| 80/443 | TCP | HTTP/HTTPS ingress |
| 9000-9999 | TCP | Host level services |
| 10250-10259 | TCP | Kubernetes node ports |
| 30000-32767 | TCP | NodePort services |

### 59.1.15 License Summary

#### 59.1.15.1 Commercial Licenses Required

* Red Hat OpenShift Container Platform
* OpenShift Virtualization
* Red Hat Advanced Cluster Security
* Red Hat Advanced Cluster Management
* Red Hat Enterprise Linux / CoreOS
* Dynatrace (monitoring platform)
* Rubrik (backup platform)
* ServiceNow (ITSM platform)

#### 59.1.15.2 Open Source Components

* KubeVirt and related components (Apache 2.0)
* Cilium networking (Apache 2.0)
* Argo CD and GitOps tools (Apache 2.0)
* Kyverno policy engine (Apache 2.0)
* Prometheus monitoring stack (Apache 2.0)
* Various Kubernetes ecosystem tools (Apache 2.0)

### 59.1.16 Version Compatibility Matrix

#### 59.1.16.1 Supported OpenShift Versions

| OpenShift Version | KubeVirt | Cilium | RHACM | RHACS |
| --- | --- | --- | --- | --- |
| 4.12.x | 4.12+ | 1.12+ | 2.7+ | 4.2+ |
| 4.13.x | 4.13+ | 1.13+ | 2.8+ | 4.3+ |
| 4.14.x | 4.14+ | 1.14+ | 2.9+ | 4.4+ |
| 4.15.x | 4.15+ | 1.15+ | 2.10+ | 4.5+ |

### 59.1.17 Security Considerations

#### 59.1.17.1 CVE Monitoring

All components should be regularly updated to address security vulnerabilities. Subscribe to security advisories from:

* Red Hat Security Advisories
* CNCF Security SIG
* Individual project security lists
* National Vulnerability Database (NVD)

#### 59.1.17.2 Supply Chain Security

* Verify image signatures for all container images
* Use Red Hat certified operators when available
* Implement image scanning in CI/CD pipelines
* Maintain software inventory and track dependencies

### 59.1.18 Maintenance and Updates

#### 59.1.18.1 Update Frequency

* **Security patches**: As soon as available
* **Minor versions**: Monthly evaluation
* **Major versions**: Quarterly evaluation
* **OpenShift**: Follow Red Hat support lifecycle

#### 59.1.18.2 End-of-Life Planning

Track EOL dates for all components and plan migrations:

* OpenShift: 18-month support lifecycle per version
* Kubernetes: 12-month support window
* Third-party components: Vendor-specific lifecycles

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**Last Updated**: 2025-08-04  
**Next Review**: 2025-11-04

This SBOM should be reviewed and updated quarterly or whenever significant changes are made to the RH OVE ecosystem architecture.

# 60 Task Management

## 60.1 RH OVE Ecosystem - Task Management

This document describes the task management system for the RH OVE Ecosystem project.

### 60.1.1 Task Runner

This project uses Go’s **Task** (gotask) as a task runner to simplify common development and maintenance tasks.

#### 60.1.1.1 Installing Task

If you don’t have task installed:

## macOS  
brew install go-task/tap/go-task  
  
## Linux  
sh -c "$(curl -ssL https://taskfile.dev/install.sh)"  
  
## Or via Go  
go install github.com/go-task/task/v3/cmd/task@latest  
  
## Or download from releases  
## https://github.com/go-task/task/releases

### 60.1.2 Global Tasks (Project Root)

From the project root directory, run:

task --list

#### 60.1.2.1 Available Global Tasks

* task setup - Setup the entire project environment
* task clean - Clean all temporary files and caches
* task export-workload - Export workload data to XLSX
* task docs:build - Generate project documentation
* task docs:serve - Serve documentation locally
* task health-check - Run project health check
* task update - Update all dependencies
* task status - Show project status
* task init - Initialize a new development environment
* task ci - Run continuous integration checks

### 60.1.3 Scripts-Specific Tasks

From the scripts/ directory, run:

cd scripts  
task --list

#### 60.1.3.1 Available Scripts Tasks

* task setup - Setup the scripts environment
* task install - Install dependencies
* task add <dep> - Add a new dependency (with prompt)
* task export-workload - Run the workload export script
* task export-workload-py - Run export script directly with Python
* task check - Check Python syntax
* task format - Format code
* task lint - Lint code
* task test - Run tests
* task clean - Clean Python cache files
* task update - Update dependencies
* task info - Show project information
* task dev-setup - Install development tools
* task dev - Run development workflow
* task build - Build/validate the project
* task watch - Watch for changes and run export
* task validate - Validate all aspects of the project

### 60.1.4 Quick Start

1. **Initial Setup:**

* task init

1. **Export Workload Data:**

* task export-workload

1. **Check Project Health:**

* task health-check

1. **Development Workflow (from root):**

* task scripts:dev-setup  
  task scripts:dev

1. **Watch for Changes (from root):**

* task scripts:watch

1. **Or work directly in scripts directory:**

* cd scripts  
  task dev-setup  
  task watch

### 60.1.5 File Structure

.  
├── Taskfile.yml # Global task definitions  
├── scripts/  
│ ├── Taskfile.yml # Scripts-specific task definitions  
│ ├── pyproject.toml # Python project configuration  
│ └── \*.py # Python scripts  
└── docs/  
 └── export/ # Generated export files

### 60.1.6 Advanced Features

#### 60.1.6.1 Task Dependencies

Tasks can depend on other tasks:

tasks:  
 build:  
 deps:  
 - check  
 - lint  
 cmds:  
 - echo "Building..."

#### 60.1.6.2 File Watching

Task supports file watching with sources and generates:

tasks:  
 export-workload:  
 sources:  
 - "{{.SOURCE\_FILE}}"  
 - export\_workload\_to\_xlsx.py  
 generates:  
 - "{{.EXPORT\_FILE}}"  
 cmds:  
 - uv run export-workload

#### 60.1.6.3 Variables and Templating

Use variables for configuration:

vars:  
 PROJECT\_NAME: RH OVE Ecosystem  
 SCRIPTS\_DIR: scripts  
  
tasks:  
 info:  
 cmds:  
 - echo "Project: {{.PROJECT\_NAME}}"

### 60.1.7 Adding New Tasks

To add new tasks, edit the appropriate Taskfile.yml:

* Global tasks: Edit ./Taskfile.yml
* Scripts tasks: Edit ./scripts/Taskfile.yml

#### 60.1.7.1 Example Task

tasks:  
 my-task:  
 desc: Description of what the task does  
 deps:  
 - other-task  
 sources:  
 - src/\*\*/\*.py  
 generates:  
 - dist/output.txt  
 cmds:  
 - echo "Running task..."  
 - command-to-run  
 - echo "Task complete!"

### 60.1.8 Dependencies

* task - Go-based task runner
* uv - Python package manager (for scripts)
* mkdocs - Documentation generator (optional)
* watchexec - File watcher (optional, for task watch)

# 61 Glossary

## 61.1 Glossary

### 61.1.1 Overview

This glossary provides definitions for key terms and concepts used throughout the RH OVE ecosystem documentation.

### 61.1.2 A

**Admission Control**

A Kubernetes mechanism that validates and mutates API requests before they are persisted to etcd. In RH OVE, this includes OpenShift built-in controllers, KubeVirt webhooks, and Kyverno policies.

**Argo CD**

A declarative GitOps continuous delivery tool for Kubernetes that automatically synchronizes applications with their desired state defined in Git repositories.

### 61.1.3 B

**Backup Policy**

A set of rules and schedules that define how, when, and what data should be backed up in the RH OVE environment, typically managed by Rubrik.

### 61.1.4 C

**CDI (Containerized Data Importer)**

A Kubernetes extension that provides facilities for enabling Persistent Volume Claims (PVCs) to be used as disks for KubeVirt VMs by importing, uploading, and cloning disk images.

**Cilium**

An open-source software for providing and transparently securing network connectivity and load balancing between application workloads using eBPF technology.

**CMDB (Configuration Management Database)**

A repository that acts as a data warehouse for IT installations, containing information about configuration items and their relationships, often integrated with ServiceNow.

**CNI (Container Network Interface)**

A specification and libraries for writing plugins to configure network interfaces in Linux containers, with Cilium being the recommended CNI for RH OVE.

**CRD (Custom Resource Definition)**

A Kubernetes extension mechanism that allows users to define custom resources that extend the Kubernetes API, extensively used in KubeVirt for VM management.

### 61.1.5 D

**DataVolume**

A KubeVirt CRD that provides a declarative way to import, upload, and clone data into PVCs, serving as the primary storage mechanism for VM disks.

**Day-2 Operations**

Post-deployment operational activities including maintenance, monitoring, updates, scaling, and optimization of the RH OVE environment.

**Dynatrace**

An application performance monitoring and observability platform that provides full-stack monitoring for RH OVE environments.

### 61.1.6 E

**eBPF (extended Berkeley Packet Filter)**

A kernel technology that allows programs to run in kernel space without changing kernel source code or loading kernel modules, used by Cilium for high-performance networking.

### 61.1.7 G

**GitOps**

An operational framework that takes DevOps best practices used for application development and applies them to infrastructure automation, using Git as the single source of truth.

### 61.1.8 H

**Hugepages**

Large memory pages that can improve performance for memory-intensive applications by reducing memory management overhead in virtual machines.

**Hubble**

The network observability layer for Cilium that provides deep visibility into network flows, security policies, and performance metrics.

**HyperConverged**

A top-level CRD in OpenShift Virtualization that manages the deployment and configuration of all virtualization components.

### 61.1.9 K

**KubeVirt**

An open-source Kubernetes add-on that enables running virtual machines alongside containers in a Kubernetes cluster, forming the foundation of OpenShift Virtualization.

**Kyverno**

A policy engine designed for Kubernetes that validates, mutates, and generates configurations using admission controller webhooks and background scans.

### 61.1.10 M

**MacVLAN**

A Linux networking driver that allows creating multiple virtual network interfaces with different MAC addresses on a single physical network interface, commonly used with Multus for VM networking.

**Multus CNI**

A Container Network Interface (CNI) plugin that enables attachment of multiple network interfaces to pods and VMs in Kubernetes, allowing complex networking scenarios beyond single-network configurations.

### 61.1.11 N

**NAD (Network Attachment Definition)**

See NetworkAttachmentDefinition.

**NetworkAttachmentDefinition**

A CRD used by Multus that defines additional network interfaces for pods and VMs, enabling multi-network configurations beyond the default cluster network.

**Network Plumbing Working Group**

A Kubernetes community working group focused on developing networking enhancements, including Multus CNI and related multi-networking technologies.

**NUMA (Non-Uniform Memory Access)**

A computer memory design used in multiprocessing where memory access time depends on the memory location relative to the processor, important for VM performance tuning.

### 61.1.12 O

**OpenShift Virtualization**

Red Hat’s enterprise virtualization solution that allows running virtual machines alongside containers on the same OpenShift platform.

### 61.1.13 P

**PVC (Persistent Volume Claim)**

A request for storage by a user or application in Kubernetes, used extensively in RH OVE for VM disk storage.

### 61.1.14 Q

**QEMU Guest Agent**

A daemon that runs inside virtual machines to provide enhanced integration between the VM and the hypervisor, enabling better monitoring and management.

### 61.1.15 R

**RBAC (Role-Based Access Control)**

A method of restricting system access to authorized users based on their roles within an organization, fundamental to multi-tenant security in RH OVE.

**RH OVE (Red Hat OpenShift Virtualization Engine)**

Red Hat’s solution for running virtual machines on OpenShift, based on the upstream KubeVirt project.

**Rubrik**

An enterprise data management platform that provides backup, recovery, and data protection services, certified for integration with RH OVE.

### 61.1.16 S

**ServiceNow**

An IT service management platform that provides CMDB functionality and can be integrated with RH OVE for automated configuration tracking.

**SR-IOV (Single Root I/O Virtualization)**

A specification that allows efficient sharing of PCIe devices between virtual machines, enabling high-performance networking for VMs.

### 61.1.17 V

**VirtualMachine (VM)**

A KubeVirt CRD that represents a virtual machine definition, including CPU, memory, storage, and network configurations.

**VirtualMachineInstance (VMI)**

A KubeVirt CRD that represents a running virtual machine instance, showing the actual runtime state of a VM.

**VirtualMachineInstanceReplicaSet**

A KubeVirt CRD that ensures a specified number of VMI replicas are running, similar to Kubernetes ReplicaSets for pods.

**virtctl**

A command-line tool for managing KubeVirt virtual machines, providing functionality to start, stop, console access, and manage VMs.

### 61.1.18 Common Acronyms

* **API**: Application Programming Interface
* **CDI**: Containerized Data Importer
* **CMDB**: Configuration Management Database
* **CNI**: Container Network Interface
* **CPU**: Central Processing Unit
* **CRD**: Custom Resource Definition
* **DNS**: Domain Name System
* **HA**: High Availability
* **I/O**: Input/Output
* **IOPS**: Input/Output Operations Per Second
* **ITSM**: IT Service Management
* **JSON**: JavaScript Object Notation
* **LDAP**: Lightweight Directory Access Protocol
* **NFS**: Network File System
* **OIDC**: OpenID Connect
* **RBAC**: Role-Based Access Control
* **REST**: Representational State Transfer
* **SLA**: Service Level Agreement
* **SSD**: Solid State Drive
* **TLS**: Transport Layer Security
* **VM**: Virtual Machine
* **VMI**: Virtual Machine Instance
* **YAML**: YAML Ain’t Markup Language

This glossary provides essential terminology for understanding and working with the RH OVE ecosystem. Terms are regularly updated as the technology and documentation evolve.