Quorus Comprehensive System Design

Overview

Quorus is an enterprise-grade file transfer system designed for high reliability, scalability, and multi-tenant operation within corporate network environments. The system is optimized for internal corporate network transfers, providing both programmatic APIs and declarative YAML-based workflow definitions for complex file transfer orchestration with comprehensive multi-tenancy support.

Primary Use Cases

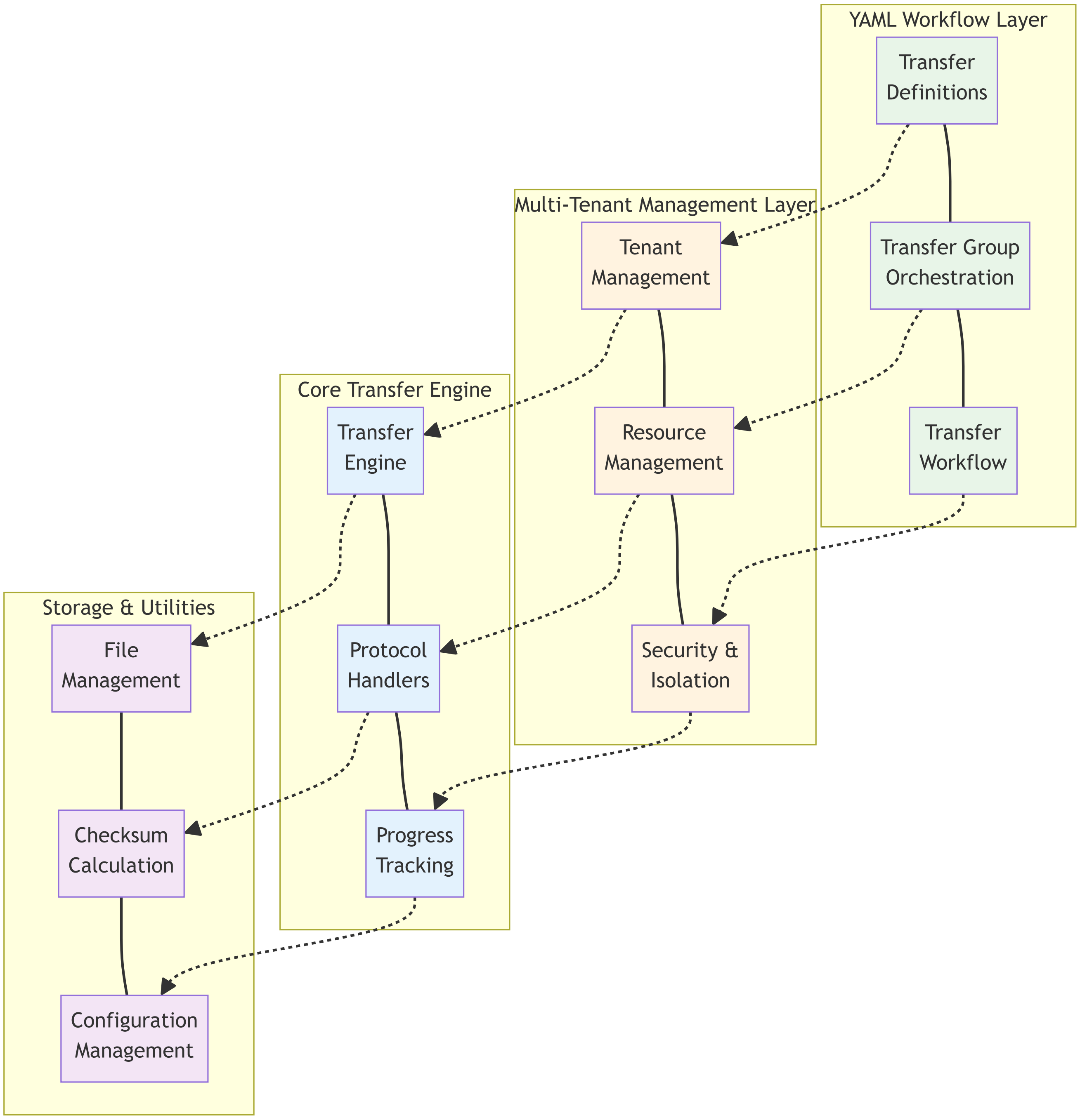
Quorus is designed primarily for **internal corporate network file transfers**, including:

- **Data center to data center** transfers within the same organization
- **Department to department** file sharing and data distribution
- **Application to application** data synchronization across internal systems
- **Backup and archival** operations within corporate infrastructure
- **ETL pipeline** data movement between internal databases and storage systems
- **Multi-tenant SaaS** file operations within controlled network environments
- **Hybrid cloud** transfers between on-premises and private cloud infrastructure

The system is architected to leverage the **high bandwidth, low latency, and trusted security** characteristics of internal corporate networks while providing enterprise-grade reliability, monitoring, and governance.

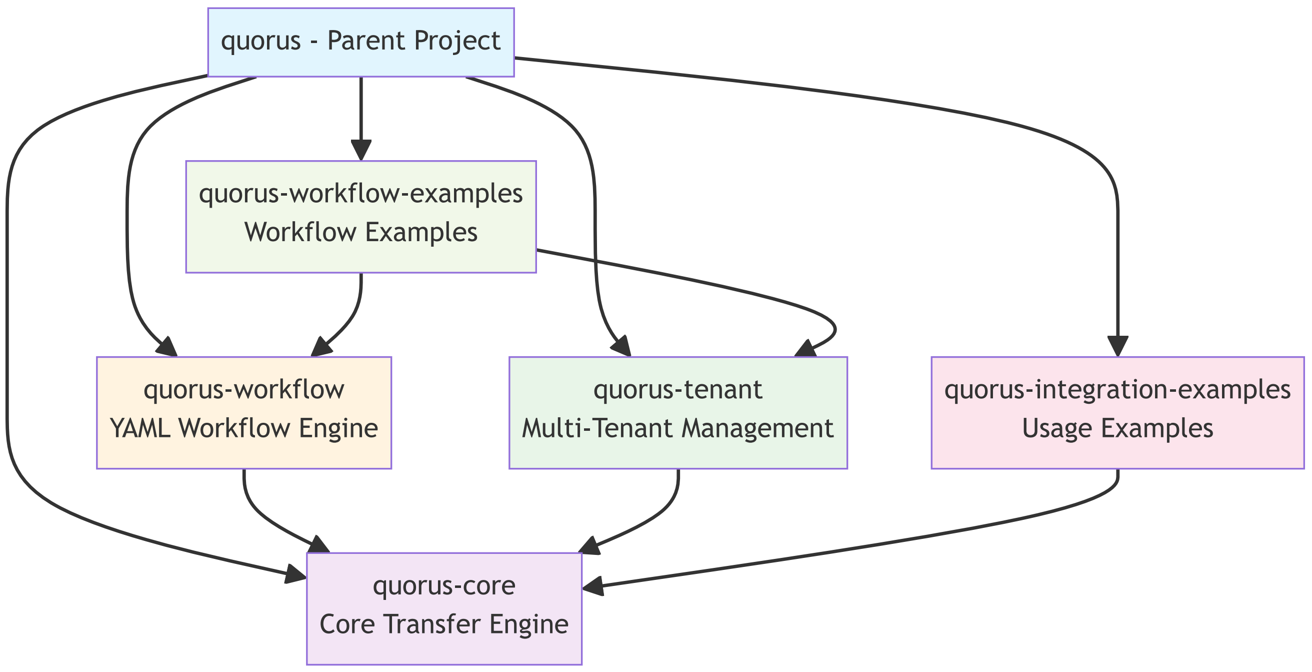
System Architecture

High-Level Architecture



Module Structure

The system is organized into multiple Maven modules for clear separation of concerns:


quorus - Parent Project
quorus-workflow-examples Workflow Examples
quorus-workflow YAML Workflow Engine
quorus-tenant Multi-Tenant Management
quorus-integration-examples Usage Examples
quorus-core Core Transfer Engine

Core Components

1. Transfer Engine (quorus-core)

The foundation of the system providing basic file transfer capabilities.

Key Components:

- `TransferEngine` : Main interface for transfer operations
- `TransferProtocol` : Pluggable protocol implementations
- `ProgressTracker` : Real-time progress monitoring
- `ChecksumCalculator` : File integrity verification

Features:

- **Internal network protocols** (HTTP/HTTPS, SMB/CIFS, NFS, FTP/SFTP)
- **High-throughput transfers** optimized for corporate network bandwidth
- **Concurrent transfer management** with intelligent scheduling
- **Retry mechanisms** with exponential backoff for network resilience
- **Progress tracking** with rate calculation and bandwidth utilization
- **SHA-256 integrity verification** for data consistency
- **Thread-safe operations** for multi-tenant environments
- **Network-aware routing** for optimal internal path selection

2. Multi-Tenant Management (quorus-tenant)

Enterprise-grade multi-tenancy with isolation and resource management.

Key Components:

- `TenantService` : Tenant lifecycle management
- `ResourceManagementService` : Quota and usage tracking
- `TenantSecurityService` : Authentication and authorization
- `TenantAwareStorageService` : Storage isolation

Features:

- Hierarchical tenant structure
- Resource quotas and limits
- Data isolation strategies
- Cross-tenant security controls
- Compliance and governance

3. YAML Workflow Engine (quorus-workflow)

Declarative workflow definition and execution system.

Key Components:

- `WorkflowDefinitionParser` : YAML parsing and validation
- `WorkflowEngine` : Workflow execution orchestration
- `DependencyResolver` : Dependency analysis and planning
- `VariableResolver` : Variable substitution and templating

Features:

- Declarative YAML definitions
- Complex dependency management
- Conditional execution
- Dry run and virtual run modes
- Variable substitution and templating

Multi-Tenancy Architecture

Core Multi-Tenancy Concepts

1. Tenant

A logical isolation boundary representing an organization, department, or business unit with its own:

- Configuration and policies
- Resource quotas and limits
- Security boundaries
- Workflow definitions
- Execution history and metrics

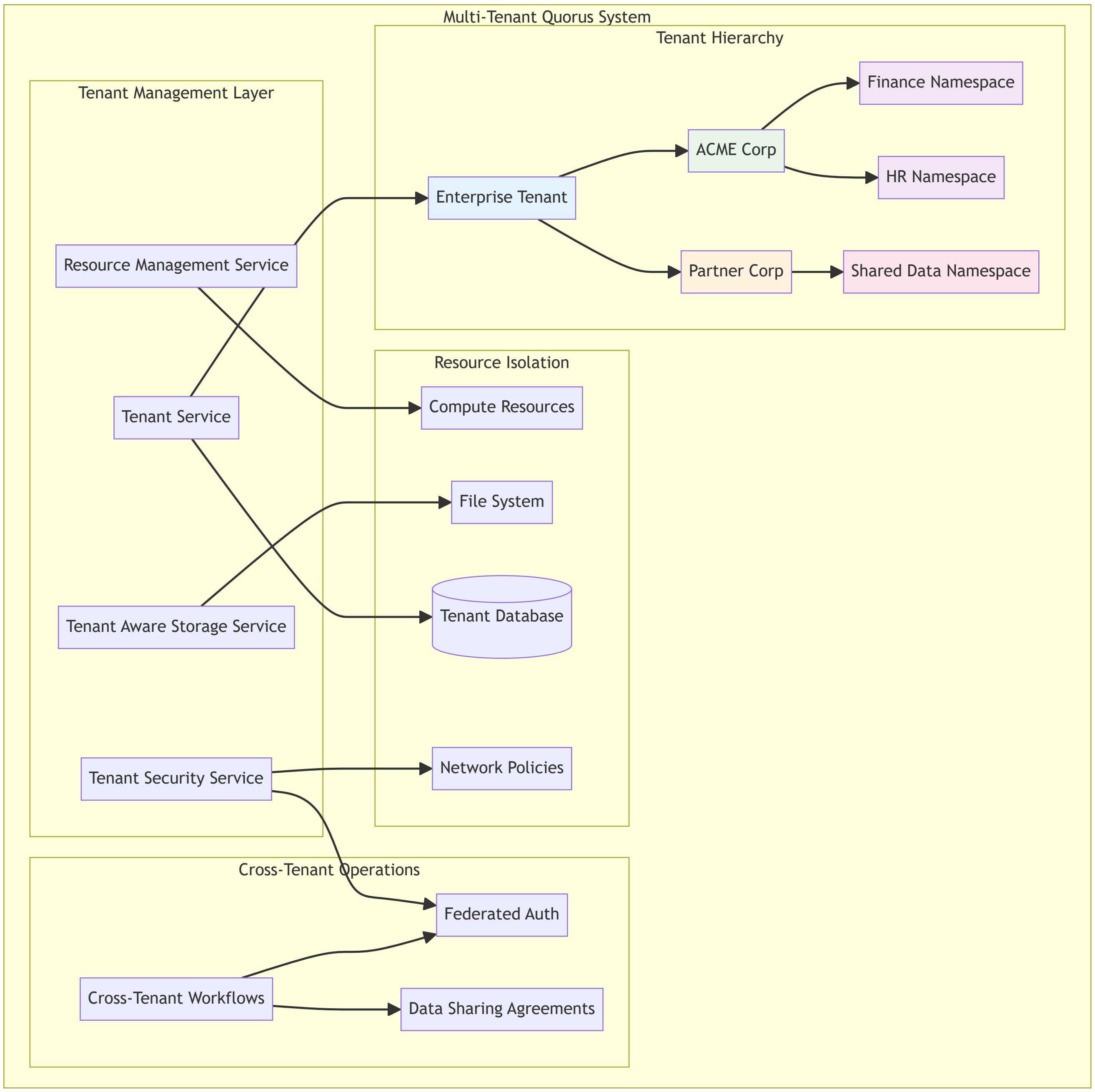
2. Tenant Hierarchy

Support for nested tenants (e.g., Company → Department → Team) with inheritance of policies and quotas.

3. Tenant Isolation Levels

- **Logical Isolation**: Shared infrastructure with data separation
- **Physical Isolation**: Dedicated resources per tenant
- **Hybrid Isolation**: Mix of shared and dedicated resources

Multi-Tenant System Architecture



1. Tenant Management Service

```java
// New package: dev.mars.quorus.tenant
public interface TenantService {
    // Tenant lifecycle
    Tenant createTenant(TenantConfiguration config);
    Tenant updateTenant(String tenantId, TenantConfiguration config);
    void deleteTenant(String tenantId);
    // Tenant discovery
    Tenant getTenant(String tenantId);
    List<Tenant> getChildTenants(String parentTenantId);
    TenantHierarchy getTenantHierarchy(String tenantId);

    // Resource management
    ResourceQuota getResourceQuota(String tenantId);
    ResourceUsage getResourceUsage(String tenantId);
    boolean checkResourceLimit(String tenantId, ResourceType type, long amount);
}
```

2. Multi-Tenant Workflow Engine

```java
public interface MultiTenantWorkflowEngine extends WorkflowEngine {
    // Tenant-aware execution
    WorkflowExecution execute(WorkflowDefinition definition, TenantContext context);

    // Cross-tenant operations
    WorkflowExecution executeCrossTenant(WorkflowDefinition definition,
                                       List<TenantContext> tenants);

    // Tenant isolation
    List<WorkflowExecution> getExecutions(String tenantId);
    WorkflowMetrics getMetrics(String tenantId, TimeRange range);
}
```

3. Tenant-Aware Security Service

```java
public interface TenantSecurityService {
    // Authentication
    TenantPrincipal authenticate(String tenantId, AuthenticationToken token);

    // Authorization
    boolean authorize(TenantPrincipal principal, String resource, String action);

    // Data protection
    EncryptionKey getTenantEncryptionKey(String tenantId);
    String encryptForTenant(String tenantId, String data);
    String decryptForTenant(String tenantId, String encryptedData);

    // Cross-tenant security
    boolean isCrossTenantAllowed(String sourceTenant, String targetTenant);
    DataSharingAgreement getDataSharingAgreement(String tenant1, String tenant2);
}
```

4. Resource Management Service

```java
public interface ResourceManagementService {
    // Quota management
    boolean reserveResources(String tenantId, ResourceRequest request);
    void releaseResources(String tenantId, ResourceRequest request);

    // Usage tracking
    void recordUsage(String tenantId, ResourceUsage usage);
    ResourceMetrics getUsageMetrics(String tenantId, TimeRange range);

    // Billing and cost allocation
    CostReport generateCostReport(String tenantId, TimeRange range);
    void allocateCosts(String tenantId, TransferExecution execution);
}
```

YAML Workflow System

Core Concepts

1. Transfer Definition

A single file transfer operation with source, destination, and metadata.

2. Transfer Group

A collection of related transfers that can be executed with dependencies, sequencing, and shared configuration.

3. Transfer Workflow

A higher-level orchestration of transfer groups with complex dependency trees, triggers, and conditional execution.

4. Transfer Plan

The resolved execution plan after dependency analysis and validation.

YAML Schema Design

Single Transfer Definition

```yaml
# transfer-internal-data.yaml
apiVersion: quorus.dev/v1
kind: Transfer
metadata:
  name: internal-data-sync
  description: "Sync customer data from CRM to data warehouse"
  tenant: acme-corp              # Tenant identifier
  namespace: finance             # Sub-tenant/namespace
  labels:
    environment: production
    priority: high
    team: data-ops
    dataClassification: confidential
    costCenter: "CC-12345"
    networkZone: "internal-dmz"
  annotations:
    created-by: "john.doe@company.com"
    ticket: "JIRA-12345"

spec:
  source:
    # Internal corporate API endpoint
    uri: "https://crm-internal.acme-corp.local/api/customers/export"
    protocol: https
    authentication:
      type: service-account      # Internal service account
      serviceAccount: "quorus-data-sync"
    headers:
      X-Internal-Service: "quorus"
      X-Data-Classification: "${metadata.labels.dataClassification}"
      X-Network-Zone: "${metadata.labels.networkZone}"
    timeout: 300s
    # Internal network optimization
    networkOptimization:
      useInternalRouting: true
      preferredDataCenter: "dc-east-1"

  destination:
    # Internal corporate storage path
    path: "/corporate-storage/data-warehouse/customers/customers-${date:yyyy-MM-dd}.json"
    protocol: nfs                # Internal NFS mount
    createDirectories: true
    permissions: "640"           # Corporate security standard
    # Corporate encryption standards
    encryption:
      enabled: true
      algorithm: "AES-256-GCM"
      keySource: "corporate-kms"
      keyId: "${tenant.security.keyManagement.keyId}"

  validation:
    expectedSize:
      min: 10MB                  # Larger internal datasets
      max: 5GB
    checksum:
      algorithm: "SHA-256"
      required: true
    # Internal data quality checks
    dataQuality:
      validateSchema: true
      schemaVersion: "v2.1"
      rejectOnValidationFailure: true

  retry:
    maxAttempts: 5               # More retries for internal reliability
    backoff: exponential
    initialDelay: 500ms          # Faster retry for internal network
    maxDelay: 10s

  # Corporate monitoring integration
  monitoring:
    enabled: true
    progressReporting: true
    metricsEnabled: true
    alertOnFailure: true
    # Corporate monitoring systems
    integrations:
      splunk: true
      datadog: true
      corporateSOC: true
    tags:
      tenant: "${tenant.id}"
      namespace: "${metadata.namespace}"
      costCenter: "${metadata.labels.costCenter}"
      networkZone: "${metadata.labels.networkZone}"
      dataClassification: "${metadata.labels.dataClassification}"
```

Transfer Group Definition

```
# backup-workflow.yaml
apiVersion: quorus.dev/v1
kind: TransferGroup
metadata:
  name: daily-backup-workflow
```

```yaml
  description: "Daily backup workflow for critical data"
  tenant: acme-corp
  namespace: finance
  labels:
    schedule: daily
    criticality: high

spec:
  # Execution strategy
  execution:
    strategy: sequential  # sequential, parallel, mixed
    maxConcurrency: 3
    timeout: 3600s
    continueOnError: false

  # Shared configuration
  defaults:
    retry:
      maxAttempts: 3
      backoff: exponential
    monitoring:
      progressReporting: true

  # Variable definitions
  variables:
    BACKUP_DATE: "${date:yyyy-MM-dd}"
    BACKUP_ROOT: "${tenant.storage.root}/backup/${BACKUP_DATE}"
    AUTH_TOKEN: "${env:API_TOKEN}"

  # Transfer definitions
  transfers:
    - name: user-data
      source:
        uri: "https://api.company.com/users/export"
        headers:
          Authorization: "${AUTH_TOKEN}"
      destination:
        path: "${BACKUP_ROOT}/users.json"
      dependsOn: []

    - name: order-data
      source:
        uri: "https://api.company.com/orders/export"
        headers:
          Authorization: "${AUTH_TOKEN}"
      destination:
        path: "${BACKUP_ROOT}/orders.json"
      dependsOn: ["user-data"]  # Wait for user-data to complete

    - name: analytics-data
      source:
        uri: "https://analytics.company.com/export"
      destination:
        path: "${BACKUP_ROOT}/analytics.json"
      dependsOn: ["user-data", "order-data"]
      condition: "${user-data.success} && ${order-data.success}"

  # Post-execution actions
  onSuccess:
    - action: notify
      target: "slack://data-ops-channel"
      message: "Daily backup completed successfully"
    - action: cleanup
      target: "/backup"
      retentionDays: 30
  onFailure:
    - action: notify
      target: "email://ops-team@company.com"
      message: "Daily backup failed: ${error.message}"
    - action: rollback
      strategy: deletePartial
```

Multi-Tenant Workflow Definition

```
# multi-tenant-workflow.yaml
apiVersion: quorus.dev/v1
kind: TransferWorkflow
metadata:
  name: cross-tenant-data-sync
  tenant: enterprise            # Parent tenant

spec:
  # Multi-tenant execution
  tenants:
    - name: acme-corp
      namespace: finance
      role: source              # source, destination, both

    - name: partner-corp
      namespace: shared-data
      role: destination

  # Tenant-specific execution policies
  execution:
    isolation: logical          # logical, physical, hybrid
    crossTenantAllowed: true
    approvalRequired: true
    dryRun: false
    virtualRun: false
    parallelism: 5
    timeout: 7200s

  # Cross-tenant security
  security:
    # Data sharing agreements
    dataSharing:
      agreements: ["DSA-2024-001"]
      dataClassification: "internal"
      retentionPolicy: "30d"

    # Cross-tenant authentication
    authentication:
      federatedAuth: true
      trustedTenants: ["partner-corp"]

  # Environment-specific variables
  environments:
    production:
      SOURCE_DB: "prod-db.company.com"
      TARGET_STORAGE: "s3://prod-backup"
    staging:
      SOURCE_DB: "staging-db.company.com"
      TARGET_STORAGE: "s3://staging-backup"

  groups:
    - name: extract-acme-data
      tenant: acme-corp
      namespace: finance
```

```yaml
      transferGroup:
        spec:
          transfers:
            - name: customer-export
              source:
                uri: "${acme-corp.api.endpoint}/customers"
                authentication:
                  type: tenant-oauth2
              destination:
                path: "${shared.storage}/acme-customers.json"

    - name: sync-to-partner
      tenant: partner-corp
      namespace: shared-data
      dependsOn: ["extract-acme-data"]
      condition: "${acme-corp.dataSharing.approved}"
      transferGroup:
        spec:
          transfers:
            - name: partner-import
              source:
                path: "${shared.storage}/acme-customers.json"
              destination:
                uri: "${partner-corp.api.endpoint}/import"
                authentication:
                  type: tenant-oauth2

  # Workflow triggers
  triggers:
    - name: schedule
      type: cron
      schedule: "0 2 * * *"  # Daily at 2 AM
      timezone: "UTC"

    - name: file-watcher
      type: fileSystem
      path: "/incoming/trigger.flag"
      action: create

  # Validation rules
  validation:
    - name: source-connectivity
      type: connectivity
      targets: ["${SOURCE_DB}"]

    - name: storage-capacity
      type: diskSpace
      path: "/staging"
      required: 10GB

    - name: dependency-check
      type: yamlDependencies
      recursive: true
```

Tenant Configuration

```yaml
# tenant-config.yaml
apiVersion: quorus.dev/v1
kind: TenantConfiguration
metadata:
  name: acme-corp
  namespace: enterprise
  labels:
    tier: premium
    region: us-east-1
    industry: finance

spec:
  # Tenant hierarchy
  hierarchy:
    parent: null  # Root tenant
    children: ["acme-corp-finance", "acme-corp-hr", "acme-corp-it"]

  # Resource quotas and limits
  resources:
    quotas:
      # Transfer limits
      maxConcurrentTransfers: 50
      maxDailyTransfers: 1000
      maxMonthlyDataTransfer: 10TB
      maxFileSize: 5GB

      # Storage limits
      maxStorageUsage: 1TB
      maxRetentionDays: 365

      # Compute limits
      maxCpuCores: 16
      maxMemoryGB: 64
      maxBandwidthMbps: 1000

    # Resource allocation strategy
    allocation:
      strategy: shared  # shared, dedicated, hybrid
      priority: high    # low, medium, high, critical

  # Security policies
  security:
    # Network access controls
    networking:
      allowedSourceCIDRs: ["10.0.0.0/8", "192.168.0.0/16"]
      allowedDestinations: ["s3://acme-corp-*", "/data/acme-corp/*"]
      requireVPN: true
      allowCrossRegion: false

    # Authentication and authorization
    authentication:
      provider: "oauth2"  # oauth2, saml, ldap, api-key
      endpoint: "https://auth.acme-corp.com"

    authorization:
      rbac:
        enabled: true
        defaultRole: "transfer-user"
        adminRole: "transfer-admin"

    # Data protection
    dataProtection:
      encryptionAtRest: true
      encryptionInTransit: true
      encryptionAlgorithm: "AES-256"
      keyManagement: "aws-kms"  # aws-kms, azure-kv, vault

  # Compliance and governance
  governance:
    # Data classification
    dataClassification:
      defaultLevel: "internal"
      allowedLevels: ["public", "internal", "confidential"]
    # Audit and compliance
    audit:
      enabled: true
      retentionDays: 2555  # 7 years
      exportFormat: "json"

    compliance:
      frameworks: ["SOX", "GDPR", "HIPAA"]
      dataResidency: "us-east-1"
      crossBorderTransfer: false

  # Monitoring and alerting
  monitoring:
    # Metrics collection
    metrics:
      enabled: true
      granularity: "1m"
      retention: "90d"

    # Alerting configuration
    alerting:
      channels:
        - type: "slack"
          webhook: "https://hooks.slack.com/acme-corp"
        - type: "email"
          recipients: ["ops@acme-corp.com"]
        - type: "webhook"
          endpoint: "https://monitoring.acme-corp.com/alerts"

      thresholds:
        errorRate: 5%
        quotaUsage: 80%
        transferLatency: 30s

  # Workflow defaults
  defaults:
    # Default retry policy
    retry:
      maxAttempts: 3
      backoff: exponential
      initialDelay: 1s

    # Default validation
    validation:
      checksumRequired: true
      sizeValidation: true

    # Default monitoring
    monitoring:
      progressReporting: true
      metricsEnabled: true
```

Workflow Engine Architecture

Core Components

1. YAML Parser & Validator

```
// New package: dev.mars.quorus.workflow
public interface WorkflowDefinitionParser {
    WorkflowDefinition parse(Path yamlFile) throws WorkflowParseException;
    ValidationResult validate(WorkflowDefinition definition);
    DependencyGraph buildDependencyGraph(List<WorkflowDefinition> definitions);
}
```

2. Workflow Engine

```
public interface WorkflowEngine {
    WorkflowExecution execute(WorkflowDefinition definition, ExecutionContext context);
    WorkflowExecution dryRun(WorkflowDefinition definition, ExecutionContext context);
    WorkflowExecution virtualRun(WorkflowDefinition definition, ExecutionContext context);

    // Monitoring and control
    WorkflowStatus getStatus(String executionId);
    boolean pause(String executionId);
    boolean resume(String executionId);
    boolean cancel(String executionId);
}
```

3. Dependency Resolver

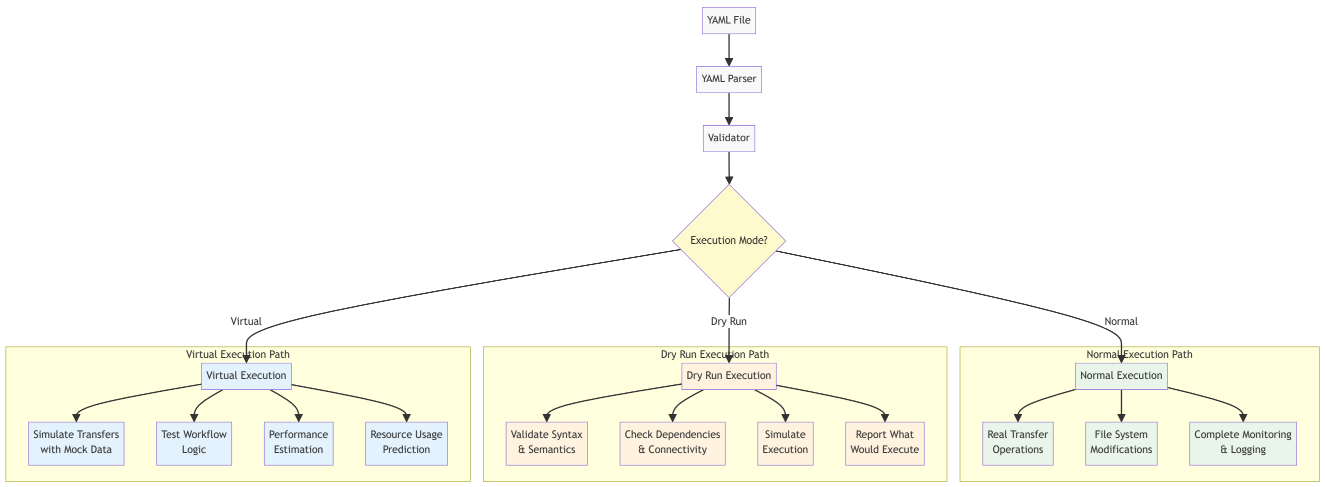
```
public interface DependencyResolver {
    ExecutionPlan resolve(List<WorkflowDefinition> definitions);
    ValidationResult validateDependencies(DependencyGraph graph);
    List<WorkflowDefinition> getExecutionOrder(DependencyGraph graph);
}
```

4. Variable Resolver

```
public interface VariableResolver {
    String resolve(String expression, ExecutionContext context);
    Map<String, String> resolveAll(Map<String, String> variables, ExecutionContext context);

    // Built-in functions
    // ${date:yyyy-MM-dd} -> current date
    // ${env:VAR_NAME} -> environment variable
    // ${file:path/to/file} -> file content
    // ${transfer.result.checksum} -> result from previous transfer
}
```

Execution Modes



1. Normal Execution

- Full transfer execution with real network operations
- File system modifications
- Complete monitoring and logging

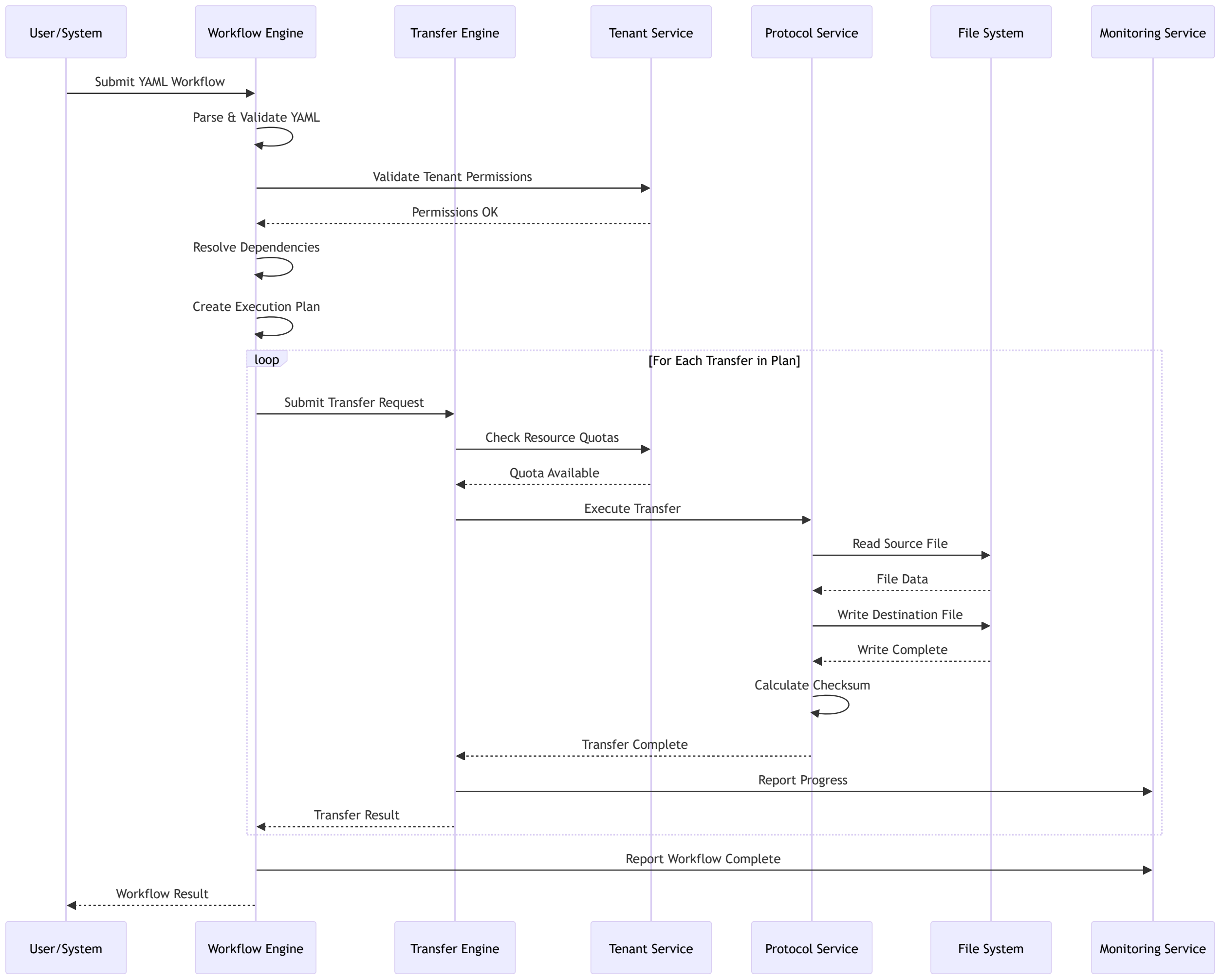
2. Dry Run

- Validate YAML syntax and semantics
- Check dependencies and connectivity
- Simulate execution without actual transfers
- Report what would be executed

3. Virtual Run

- Simulate transfers with mock data
- Test workflow logic and dependencies
- Performance estimation
- Resource usage prediction

Transfer Process Flow



Data Models

Core Domain Models

Transfer Request

```
public class TransferRequest {
    private String requestId;
    private URI sourceUri;
    private Path destinationPath;
    private String protocol;
    private String tenantId;
    private String namespace;
    private Map<String, String> metadata;
    private long expectedSize;
    private String expectedChecksum;
    // ... other fields
}
```

Transfer Job

```java
public class TransferJob {
    private String jobId;
    private TransferRequest request;
    private TransferStatus status;
    private long bytesTransferred;
    private long totalBytes;
    private Instant startTime;
    private String actualChecksum;
    private String tenantId;
    // ... other fields
}
```

Multi-Tenant Models

Tenant Configuration

```java
public class TenantConfiguration {
    private String tenantId;
    private String parentTenantId;
    private ResourceQuota resourceQuota;
    private SecurityPolicy securityPolicy;
    private ComplianceSettings compliance;
    private Map<String, String> variables;
    // ... other fields
}
```

Workflow Models

Workflow Definition

```java
public class WorkflowDefinition {
    private String name;
    private String tenantId;
    private String namespace;
    private ExecutionStrategy execution;
    private List<TransferGroupDefinition> groups;
    private Map<String, String> variables;
    private List<TenantContext> tenants;
    // ... other fields
}
```

Data Isolation Strategies

1. Database-Level Isolation

```sql
-- Tenant-aware schema design
CREATE TABLE transfers (
    id UUID PRIMARY KEY,
    tenant_id VARCHAR(255) NOT NULL,
    namespace VARCHAR(255),
    request_data JSONB,
    status VARCHAR(50),
    created_at TIMESTAMP DEFAULT NOW(),
    -- Tenant isolation constraints
    CONSTRAINT fk_tenant FOREIGN KEY (tenant_id) REFERENCES tenants(id),
    INDEX idx_tenant_namespace (tenant_id, namespace)
);

-- Row-level security
CREATE POLICY tenant_isolation ON transfers
    FOR ALL TO application_role
    USING (tenant_id = current_setting('app.current_tenant'));
```

2. Storage Isolation

```
public class TenantAwareStorageService {
    private final String getTenantStorageRoot(String tenantId) {
        return String.format("/data/tenants/%s", tenantId);
    }

    private final void validateTenantAccess(String tenantId, Path path) {
        String tenantRoot = getTenantStorageRoot(tenantId);
        if (!path.startsWith(tenantRoot)) {
            throw new SecurityException("Cross-tenant storage access denied");
        }
    }
}
```

3. Network Isolation

```
# Kubernetes NetworkPolicy example
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: tenant-isolation
spec:
  podSelector:
    matchLabels:
      tenant: acme-corp
  policyTypes:
  - Ingress
  - Egress
  ingress:
  - from:
    - podSelector:
        matchLabels:
          tenant: acme-corp
  egress:
  - to:
    - podSelector:
        matchLabels:
          tenant: acme-corp
```

Enterprise Features

1. Governance & Compliance

```yaml
governance:
  approvals:
    required: true
    approvers: ["data-ops-lead", "security-team"]

  compliance:
    dataClassification: confidential
    retentionPolicy: 7years
    encryptionRequired: true
    auditLogging: true

  security:
    allowedSources: ["*.company.com", "trusted-partner.com"]
    allowedDestinations: ["s3://company-*", "/backup/*"]
    requiresVPN: true
```

2. Resource Management

```yaml
resources:
  limits:
    maxConcurrentTransfers: 10
    maxBandwidth: 100MB/s
    maxDiskUsage: 1TB

  quotas:
    dailyTransferLimit: 1TB
    monthlyTransferLimit: 30TB

  scheduling:
    priority: high
    preferredHours: "02:00-06:00"
    blackoutWindows: ["12:00-13:00"]
```

3. Monitoring & Alerting

```yaml
monitoring:
  metrics:
    - transferRate
    - errorRate
    - queueDepth
    - resourceUtilization

  alerts:
    - name: transfer-failure
      condition: "errorRate > 5%"
      severity: critical
      channels: ["slack", "email", "pagerduty"]

    - name: slow-transfer
      condition: "transferRate < 1MB/s"
      severity: warning
      channels: ["slack"]
```

Security Architecture

Authentication

- **Enterprise directory integration** (Active Directory, LDAP)
- **Single Sign-On (SSO)** with corporate identity providers (SAML, OAuth2)
- **Service account authentication** for automated internal systems
- **Certificate-based authentication** for high-security internal transfers
- **Tenant-specific authentication** configuration for multi-tenant deployments

Authorization

- **Role-based access control (RBAC)** integrated with corporate directory
- **Department and team-based** access controls
- **Data classification-aware** permissions (confidential, internal, public)
- **Network segment-based** access controls for internal zones
- **Fine-grained resource access** controls for sensitive data

Data Protection

- **Encryption at rest** using corporate key management systems
- **TLS encryption** optimized for internal network performance
- **Data classification** and handling policies for corporate data
- **Network-level encryption** for high-security internal transfers
- **Tenant-specific encryption** keys for multi-tenant isolation

Internal Network Security

- **Network segmentation** awareness and routing
- **Corporate firewall** integration and rule management
- **VPN and private network** support for remote sites
- **Internal certificate authority** integration
- **Network monitoring** and intrusion detection integration

Audit & Compliance

- **Corporate audit system** integration
- **Compliance framework** support (SOX, GDPR, HIPAA, PCI-DSS)
- **Data lineage tracking** for internal data movement
- **Regulatory reporting** for internal data governance
- **Tenant-isolated audit trails** for multi-tenant compliance

Configuration Management

Hierarchical Configuration

```
# Global defaults (system-level)
global:
  defaults:
    retry:
      maxAttempts: 3
    security:
      encryptionRequired: true

# Tenant-level overrides
tenant:
  acme-corp:
    defaults:
      retry:
        maxAttempts: 5  # Override global
      security:
        encryptionAlgorithm: "AES-256-GCM"  # Add tenant-specific

    # Namespace-level overrides
    namespaces:
      finance:
        defaults:
          retry:
            maxAttempts: 7  # Override tenant
          validation:
            checksumRequired: true  # Add namespace-specific
```

Variable Resolution with Tenancy

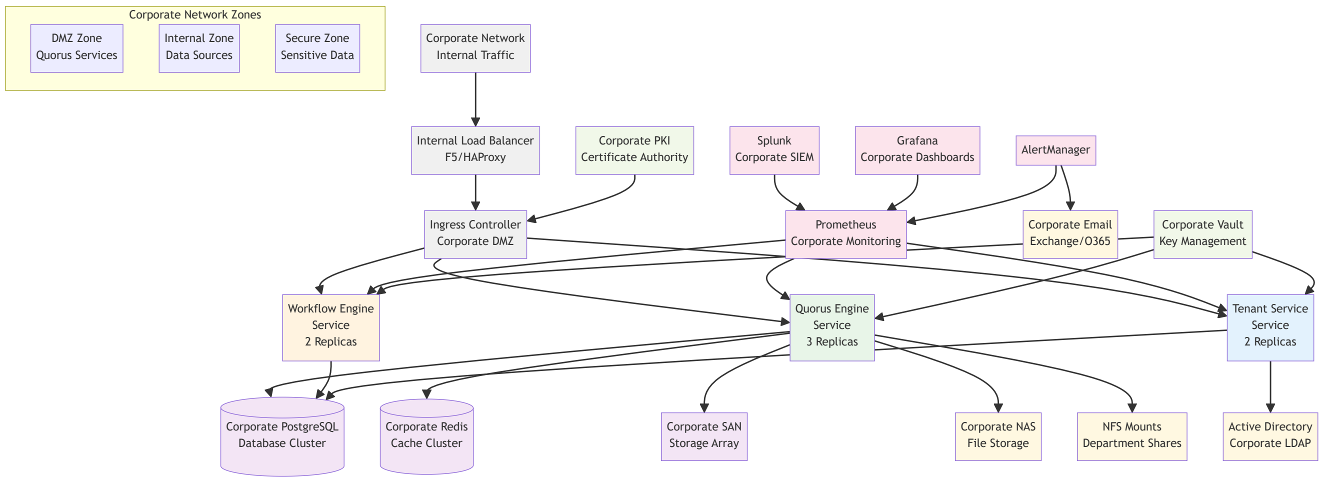
```
variables:
  # System variables
  system:
    version: "1.0.0"
    region: "us-east-1"

  # Tenant variables
  tenant:
    id: "acme-corp"
    name: "ACME Corporation"
    storage:
      root: "/data/tenants/acme-corp"
      backup: "s3://acme-corp-backup"
    api:
      endpoint: "https://api.acme-corp.com"

  # Namespace variables
  namespace:
    name: "finance"
    costCenter: "CC-12345"
    approver: "finance-lead@acme-corp.com"
```

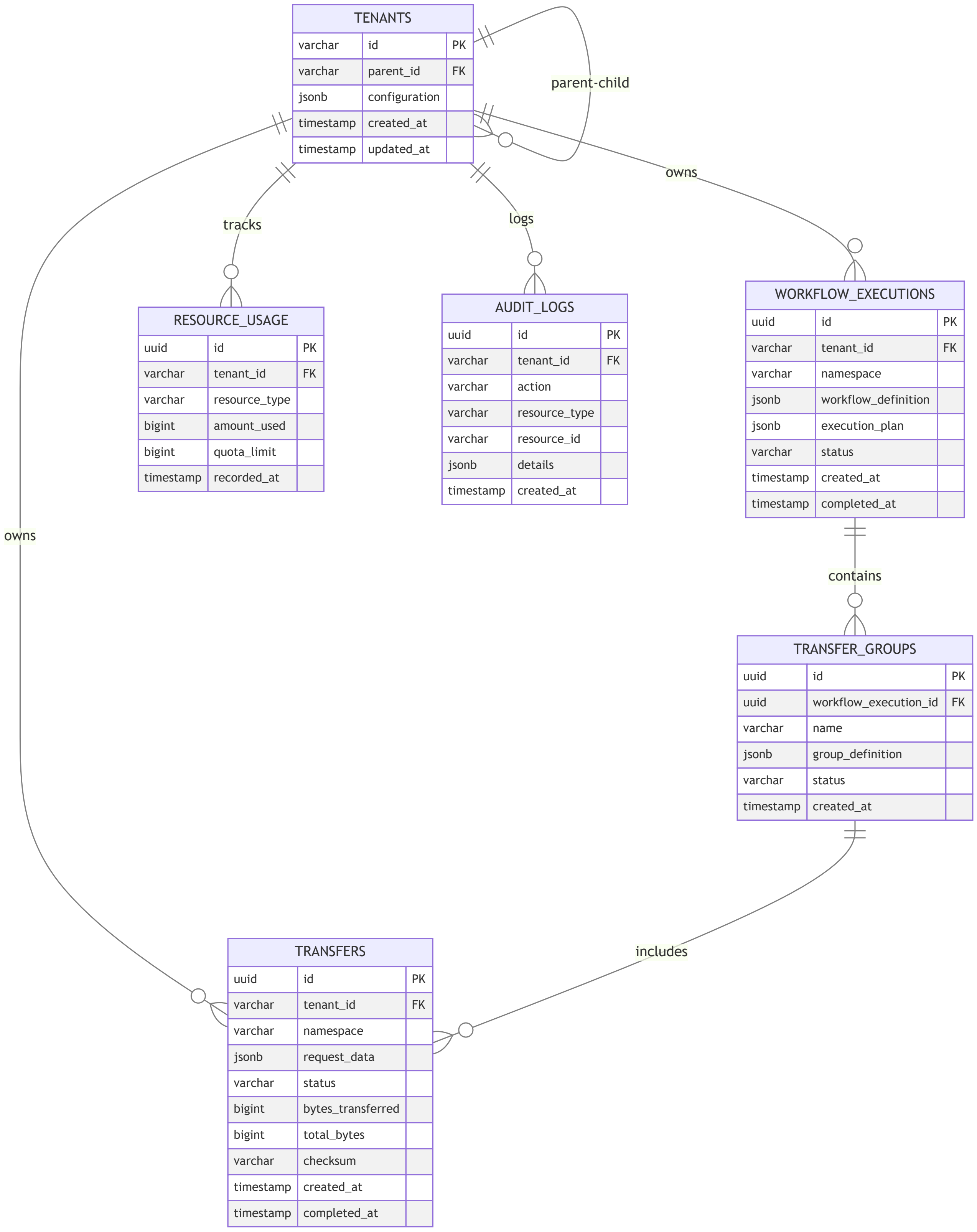
Deployment Architecture

Corporate Network Deployment


Corporate Network Zones
DMZ Zone Quorus Services
Internal Zone Data Sources
Secure Zone Sensitive Data
Corporate Network Internal Traffic
Internal Load Balancer F5/HAProxy
Corporate PKI Certificate Authority
Splunk Corporate SIEM
Grafana Corporate Dashboards
AlertManager
Ingress Controller Corporate DMZ
Prometheus Corporate Monitoring
Corporate Email Exchange/O365
Corporate Vault Key Management
Workflow Engine Service 2 Replicas
Quorus Engine Service 3 Replicas
Tenant Service Service 2 Replicas
Corporate PostgreSQL Database Cluster
Corporate Redis Cache Cluster
Corporate SAN Storage Array
Corporate NAS File Storage
NFS Mounts Department Shares
Active Directory Corporate LDAP

```yaml
# Kubernetes deployment example
apiVersion: apps/v1
kind: Deployment
metadata:
  name: quorus-engine
spec:
  replicas: 3
  selector:
    matchLabels:
      app: quorus-engine
  template:
    metadata:
      labels:
        app: quorus-engine
    spec:
      containers:
      - name: quorus-engine
        image: quorus/engine:latest
        resources:
          requests:
            memory: "512Mi"
            cpu: "500m"
          limits:
            memory: "1Gi"
            cpu: "1000m"
        env:
        - name: QUORUS_TENANT_ID
          valueFrom:
            fieldRef:
              fieldPath: metadata.labels['tenant']
```

Database Schema



```sql
-- Core tables
CREATE TABLE tenants (
    id VARCHAR(255) PRIMARY KEY,
    parent_id VARCHAR(255),
    configuration JSONB,
    created_at TIMESTAMP DEFAULT NOW(),
    updated_at TIMESTAMP DEFAULT NOW(),
    FOREIGN KEY (parent_id) REFERENCES tenants(id)
);

CREATE TABLE transfers (
    id UUID PRIMARY KEY,
    tenant_id VARCHAR(255) NOT NULL,
    namespace VARCHAR(255),
    request_data JSONB,
    status VARCHAR(50),
    bytes_transferred BIGINT DEFAULT 0,
    total_bytes BIGINT,
    checksum VARCHAR(255),
    created_at TIMESTAMP DEFAULT NOW(),
    completed_at TIMESTAMP,
    FOREIGN KEY (tenant_id) REFERENCES tenants(id)
);

CREATE TABLE workflow_executions (
    id UUID PRIMARY KEY,
    tenant_id VARCHAR(255) NOT NULL,
    namespace VARCHAR(255),
    workflow_definition JSONB,
    execution_plan JSONB,
    status VARCHAR(50),
    created_at TIMESTAMP DEFAULT NOW(),
    completed_at TIMESTAMP,
    FOREIGN KEY (tenant_id) REFERENCES tenants(id)
);

CREATE TABLE transfer_groups (
    id UUID PRIMARY KEY,
    workflow_execution_id UUID NOT NULL,
    name VARCHAR(255),
    group_definition JSONB,
    status VARCHAR(50),
    created_at TIMESTAMP DEFAULT NOW(),
    FOREIGN KEY (workflow_execution_id) REFERENCES workflow_executions(id)
);

CREATE TABLE resource_usage (
    id UUID PRIMARY KEY,
    tenant_id VARCHAR(255) NOT NULL,
    resource_type VARCHAR(100),
    amount_used BIGINT,
    quota_limit BIGINT,
    recorded_at TIMESTAMP DEFAULT NOW(),
    FOREIGN KEY (tenant_id) REFERENCES tenants(id)
);

CREATE TABLE audit_logs (
    id UUID PRIMARY KEY,
    tenant_id VARCHAR(255) NOT NULL,
    action VARCHAR(100),
    resource_type VARCHAR(100),
    resource_id VARCHAR(255),
    details JSONB,
    created_at TIMESTAMP DEFAULT NOW(),
    FOREIGN KEY (tenant_id) REFERENCES tenants(id)
);
```

Design Principles

1. Internal Network Optimization

- **High-throughput transfers** leveraging corporate network bandwidth
- **Protocol selection** optimized for internal network characteristics
- **Network-aware routing** for optimal internal path selection
- **Corporate infrastructure integration** (AD, PKI, monitoring)

2. Modularity

- Clear separation between core engine and enterprise features
- Pluggable architecture for protocols and storage
- Independent module development and testing
- **Corporate system integration** modules

3. Multi-Tenancy for Corporate Structure

- **Department and team-based** tenant isolation
- **Corporate hierarchy** alignment with organizational structure
- **Resource quotas** based on business unit allocations
- **Cost center integration** for chargeback and reporting

4. Declarative Configuration

- **YAML-based workflow definitions** for corporate data operations
- **Infrastructure-as-code** approach for corporate governance
- **Version-controlled** transfer configurations in corporate repositories
- **Corporate approval workflows** for configuration changes

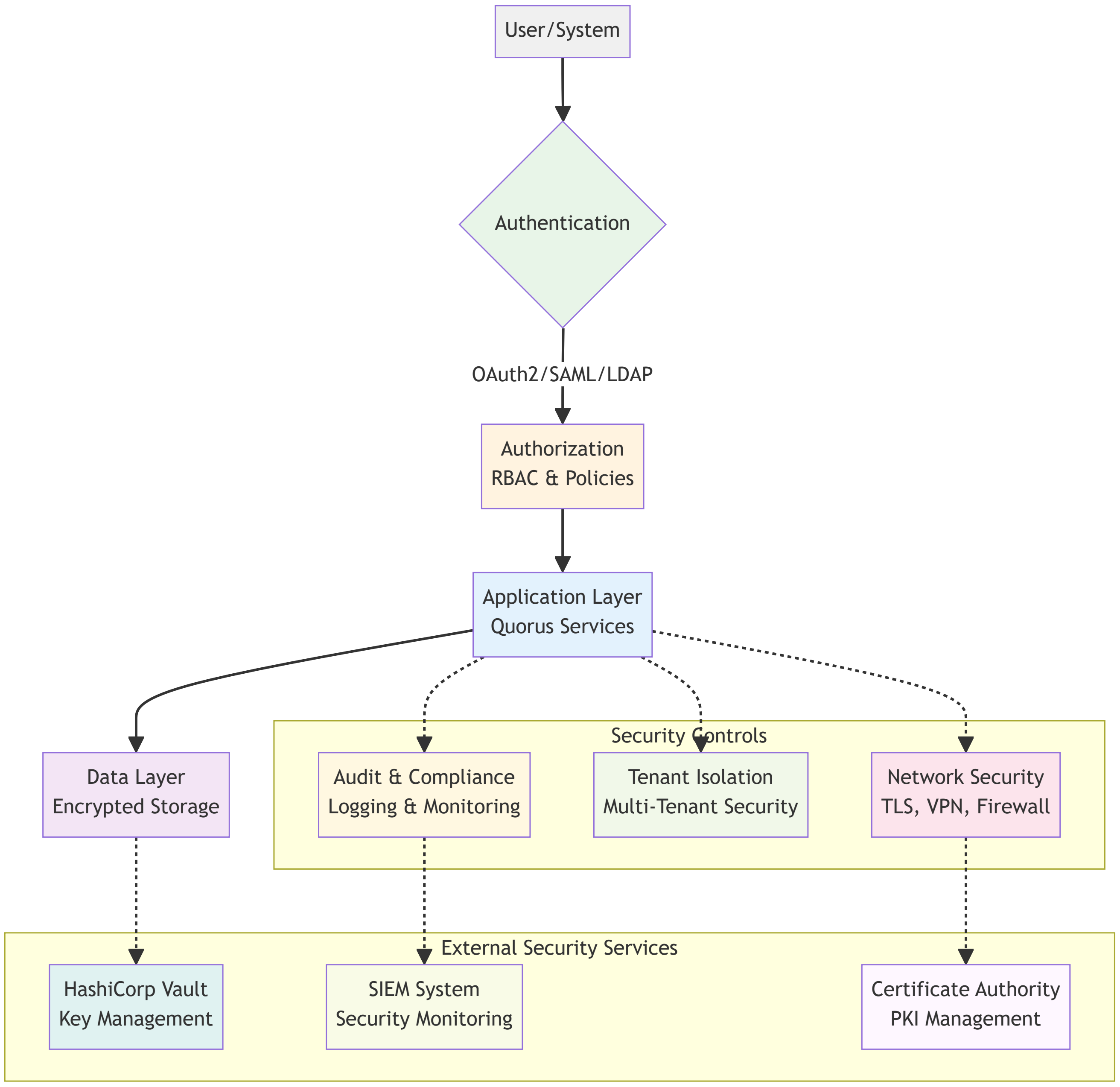
5. Enterprise-Grade Security

- **Corporate directory integration** (Active Directory, LDAP)
- **Certificate-based authentication** using corporate PKI
- **Network-level security** through corporate firewalls and VLANs
- **Data classification** and handling for corporate data governance
- **Audit logging** integrated with corporate SIEM systems

6. Corporate Observability

- **Corporate monitoring system** integration (Splunk, DataDog, etc.)
- **Real-time progress tracking** with corporate dashboard integration
- **Alerting** through corporate notification systems (Exchange, Teams)
- **Compliance reporting** for corporate audit requirements

Security Architecture



Security Layer Details

Authentication Layer

- **OAuth2 Provider** - Modern token-based authentication
- **SAML Provider** - Enterprise SSO integration
- **LDAP Provider** - Directory service authentication
- **API Key Authentication** - Service-to-service authentication

Authorization Layer

- **Role-Based Access Control (RBAC)** - User role management
- **Attribute-Based Access Control (ABAC)** - Fine-grained permissions
- **Policy Engine** - Centralized policy management
- **Permission Manager** - Access control enforcement

Data Protection Layer

- **Encryption at Rest** - Database and file encryption
- **Encryption in Transit** - TLS/mTLS for all communications
- **Key Management Service** - Centralized key management
- **Hardware Security Module** - Secure key storage

Network Security Layer

- **TLS/mTLS** - Secure communication protocols
- **VPN Gateway** - Secure network access
- **Firewall Rules** - Network traffic filtering
- **Network Policies** - Kubernetes network isolation

Audit & Compliance Layer

- **Audit Logging** - Comprehensive activity logging
- **Compliance Monitor** - Regulatory compliance tracking
- **Data Residency** - Geographic data controls
- **Retention Policies** - Data lifecycle management

Tenant Isolation Layer

- **Tenant Isolation** - Multi-tenant data separation
- **Row Level Security** - Database-level isolation
- **Namespace Isolation** - Kubernetes namespace separation
- **Quota Management** - Resource usage controls

Internal Network Optimizations

Corporate Network Characteristics

Quorus is designed to leverage the unique characteristics of internal corporate networks:

High Bandwidth Availability

- **Gigabit/10Gb Ethernet** standard in corporate environments
- **Dedicated network segments** for data transfer operations
- **Quality of Service (QoS)** policies for prioritizing transfer traffic
- **Network bandwidth reservation** for critical transfer operations

Low Latency Communications

- **Sub-millisecond latency** within data centers
- **Predictable network paths** through corporate routing
- **Optimized TCP window sizing** for internal network characteristics
- **Connection pooling** for frequently accessed internal services

Trusted Network Environment

- **Reduced encryption overhead** where appropriate within secure zones
- **Certificate-based authentication** for internal service-to-service communication
- **Network-level security** through corporate firewalls and VLANs

- **Simplified authentication** using corporate directory services

Internal Protocol Optimizations

SMB/CIFS Protocol Support

```yaml
source:
  uri: "smb://fileserver.corp.local/shares/data/export.csv"
  protocol: smb
  authentication:
    type: kerberos
    domain: "CORP"
  options:
    smbVersion: "3.1.1"
    directIO: true
    largeBuffers: true
```

NFS Protocol Support

```yaml
source:
  uri: "nfs://storage.corp.local/exports/data"
  protocol: nfs
  options:
    nfsVersion: "4.1"
    rsize: 1048576      # 1MB read buffer
    wsize: 1048576      # 1MB write buffer
    tcp: true
```

Internal HTTP Optimizations

```yaml
source:
  uri: "http://internal-api.corp.local/data/export"
  protocol: http
  options:
    keepAlive: true
    connectionPoolSize: 50
    tcpNoDelay: true
    bufferSize: 65536
    compressionEnabled: false  # Skip compression on fast internal networks
```

Corporate Integration Features

Active Directory Integration

- **Seamless authentication** using corporate credentials
- **Group-based authorization** aligned with corporate structure
- **Service account management** for automated transfers
- **Audit trail integration** with corporate security systems

Corporate Storage Integration

- **SAN/NAS connectivity** for high-performance storage access
- **Storage tiering** awareness for optimal placement
- **Backup integration** with corporate backup systems

- **Disaster recovery** coordination with corporate DR plans

Network Monitoring Integration

- **SNMP integration** with corporate network monitoring
- **Bandwidth utilization** reporting to network operations
- **Network path optimization** based on corporate topology
- **Traffic shaping** coordination with network QoS policies

Scalability & Performance

Horizontal Scaling

- Stateless service design
- Load balancing across instances
- Distributed execution coordination

Resource Management

- Configurable concurrency limits
- Resource quotas per tenant
- Dynamic resource allocation

Performance Optimization

- Efficient buffer management
- Connection pooling
- Asynchronous I/O operations

Monitoring & Observability

Metrics

- Transfer performance metrics
- Resource utilization tracking
- Error rates and latency measurements

Logging

- Structured logging with correlation IDs
- Tenant-scoped log aggregation
- Configurable log levels

Alerting

- Threshold-based alerting
- Tenant-specific notification channels
- Integration with external monitoring systems

Error Handling & Recovery

Retry Mechanisms

- Exponential backoff strategies
- Configurable retry limits
- Circuit breaker patterns

Failure Recovery

- Graceful degradation
- Automatic failover
- Manual recovery procedures

Error Reporting

- Structured error messages
- Error categorization and classification
- Integration with monitoring systems

Future Enhancements

Planned Features

- Additional protocol support (FTP, SFTP, S3)
- Advanced workflow features (loops, conditions)
- Real-time streaming transfers
- Machine learning for optimization

Scalability Improvements

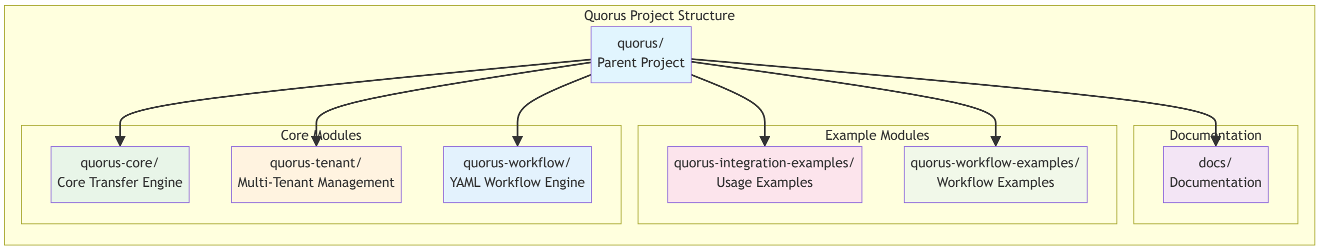
- Distributed coordination with Raft consensus
- Advanced clustering capabilities
- Global load balancing

Enterprise Features

- Advanced governance and compliance
- Integration with enterprise systems
- Custom protocol development SDK

File Organization

Project Structure Overview



Module Details

Core Modules

```
quorus-core/                    # Core transfer engine
├── src/main/java/dev/mars/quorus/
│   ├── core/                   # Domain models
│   ├── transfer/               # Transfer engine
│   ├── protocol/               # Protocol handlers
│   ├── storage/                # File management
│   └── config/                 # Configuration
└── src/test/java/              # Unit tests

quorus-tenant/                  # Multi-tenant management
├── src/main/java/dev/mars/quorus/tenant/
│   ├── model/                  # Tenant models
│   ├── service/                # Tenant services
│   ├── security/               # Multi-tenant security
│   └── resource/               # Resource management
└── src/test/java/              # Unit tests

quorus-workflow/                # YAML workflow engine
├── src/main/java/dev/mars/quorus/workflow/
│   ├── definition/             # YAML models
│   ├── parser/                 # YAML parsing
│   ├── engine/                 # Workflow engine
│   └── resolver/               # Dependency resolution
└── src/test/java/              # Unit tests
```

Example Modules

```
quorus-integration-examples/    # Usage examples
├── src/main/java/dev/mars/quorus/examples/
│   └── BasicTransferExample.java
└── README.md

quorus-workflow-examples/       # Workflow examples
├── basic/                      # Simple examples
├── enterprise/                 # Complex workflows
└── templates/                  # Reusable templates
```

Documentation

```
docs/                           # Documentation
├── quorus-comprehensive-system-design.md
├── quorus-implementation-plan.md
```

```
    └── README.md
```

Related Documents

- **Implementation Plan** - Detailed 52-week development roadmap with Gantt chart timeline, milestones, and deliverables
- **API Documentation** - REST API specifications (future)

Conclusion

The Quorus comprehensive system design provides a solid foundation for enterprise-grade file transfer operations with:

- **Multi-tenant architecture** supporting complex organizational structures
- **Declarative YAML workflows** for infrastructure-as-code approach
- **Robust security framework** with authentication, authorization, and compliance
- **Scalable architecture** supporting horizontal scaling and high availability
- **Enterprise features** including governance, monitoring, and resource management

The modular design ensures maintainability and extensibility while meeting the demanding requirements of enterprise environments. The system is designed to grow from simple single-tenant deployments to complex multi-tenant enterprise scenarios with thousands of users and petabytes of data transfer.