Payment Processing System

□ Table of Contents

- Payment Processing System
  - Requirements Gathering
    - Functional Requirements
    - Non-Functional Requirements
  - Traffic Estimation & Capacity Planning
    - User Base Analysis
    - Traffic Calculations
  - Database Schema Design
    - Transaction Database Schema
    - Fraud Detection Schema
  - Sample API Endpoints
    - Payment Processing APIs
    - Refund APIs
    - Payment Methods APIs
    - Fraud Detection APIs
    - Webhook APIs
    - Analytics & Reporting APIs
  - High-Level Design (HLD)
    - System Architecture Overview
    - Payment Flow Architecture
  - Low-Level Design (LLD)
    - Transaction Processing Pipeline
    - Fraud Detection Engine
    - Multi-Currency Settlement
  - Core Algorithms
    - 1. Real-time Fraud Detection Algorithm
    - 2. Payment Routing and Optimization Algorithm
    - 3. Multi-Currency Exchange Rate Management
    - 4. Settlement and Reconciliation Algorithm
    - 5. PCI DSS Compliance and Security
  - Performance Optimizations
    - High Throughput Processing
    - Caching Strategy
  - Security Considerations
    - Comprehensive Security Framework
    - Regulatory Compliance
  - Testing Strategy
    - Load Testing Scenarios
  - Trade-offs and Considerations
    - Security vs Performance
    - Availability vs Consistency

    * Cost vs Features

Requirements Gathering

□ Back to Top

Functional Requirements

□ Back to Top

Core Payment Features: - Process credit/debit card payments - Support multiple payment methods (PayPal, Apple Pay, Google Pay, bank transfers) - Handle domestic and international transactions - Multi-currency support with real-time exchange rates - Recurring payments and subscriptions - Refunds and partial refunds - Payment splitting between multiple recipients - Digital wallet integration - Cryptocurrency payment support - Payment scheduling and delayed payments

Transaction Management: - Real-time payment authorization - Transaction status tracking - Payment history and receipts - Dispute management and chargebacks - Fraud detection and prevention - Transaction reconciliation - Batch payment processing - Payment retry logic for failed transactions

Compliance & Security: - PCI DSS compliance - KYC (Know Your Customer) verification - AML (Anti-Money Laundering) checks - GDPR data protection compliance - SOX compliance for financial reporting - Regional compliance (SEPA, ACH, etc.)

Non-Functional Requirements

□ Back to Top

Performance: - Payment processing latency < 200ms - Support 100,000 transactions per second - 99.99% uptime SLA - Handle traffic spikes during sales events - Sub-second fraud detection

Scalability: - Horizontal scaling across multiple regions - Handle Black Friday/Cyber Monday traffic - Auto-scaling based on transaction volume - Support for millions of merchants

Security: - End-to-end encryption for sensitive data - Tokenization of payment credentials - Real-time fraud monitoring - Multi-factor authentication - Zero trust security model - Regular security audits and penetration testing

Reliability: - Zero transaction data loss - Automatic failover and disaster recovery - Data replication across multiple data centers - Circuit breaker patterns for external services

Traffic Estimation & Capacity Planning

□ Back to Top

User Base Analysis

□ Back to Top

- **Merchants:** 2 million active merchants
- **End Customers:** 100 million registered users
- **Daily Transactions:** 50 million transactions
- **Peak TPS:** 100,000 transactions per second
- **Average Transaction Value:** $75
- **Peak Traffic Multiplier:** 5x during sales events

Traffic Calculations

□ Back to Top

Transaction Volume:

```
Daily Transactions = 50M transactions/day
Peak TPS = 50M × 5 / (24 × 3600) = 289 TPS average
Black Friday Peak = 289 × 5 = 1,445 TPS sustained
Flash Sale Peak = 100,000 TPS (short bursts)

Transaction Types Distribution:
- Credit/Debit Cards: 70% (35M/day)
- Digital Wallets: 20% (10M/day)
- Bank Transfers: 8% (4M/day)
- Cryptocurrency: 2% (1M/day)
```

Storage Requirements:

```
Transaction Data:
- Transaction record = 2KB (payment details + metadata)
- Daily storage = 50M × 2KB = 100GB/day
- Annual storage = 100GB × 365 = 36.5TB/year
- 7-year retention = 36.5TB × 7 = 255TB
```

```
Fraud Detection Data:
- Behavioral patterns = 500 bytes per transaction
- Daily fraud data = 50M × 500B = 25GB/day
- ML model features storage = 10TB
```

Infrastructure Sizing:

```
Application Servers:
- Payment processing: 50 servers
- Fraud detection: 30 servers
- Settlement processing: 20 servers
- Reporting & analytics: 15 servers

Database Requirements:
- Transaction DB: 100 shards, 64GB RAM each
- User/Merchant DB: 20 shards, 32GB RAM each
- Fraud detection DB: 10 shards, 128GB RAM each
- Audit logs DB: 50 shards, 16GB RAM each

Cache Infrastructure:
- Redis clusters: 500GB total memory
- Session cache: 100GB
- Fraud detection cache: 200GB
- Exchange rates cache: 50GB
```

Database Schema Design

□ Back to Top

Transaction Database Schema

□ Back to Top

```sql
-- Transactions table (sharded by merchant_id)
CREATE TABLE transactions (
    transaction_id VARCHAR(128) PRIMARY KEY, -- UUID
    merchant_id BIGINT NOT NULL,
    customer_id BIGINT,
    payment_method_id BIGINT NOT NULL,
    amount DECIMAL(15,2) NOT NULL,
    currency_code CHAR(3) NOT NULL,
    original_amount DECIMAL(15,2), -- For currency conversion
    original_currency CHAR(3),
    exchange_rate DECIMAL(10,6),
    transaction_type ENUM('payment', 'refund', 'chargeback', 'fee') NOT NULL,
    status ENUM('pending', 'authorized', 'captured', 'failed', 'cancelled', 'refunded')
    payment_processor ENUM('stripe', 'paypal', 'square', 'braintree') NOT NULL,
    processor_transaction_id VARCHAR(255),
    description TEXT,
    metadata JSON,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    updated_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
    authorized_at TIMESTAMP,
    captured_at TIMESTAMP,
    failed_at TIMESTAMP,

    INDEX idx_merchant_created (merchant_id, created_at),
    INDEX idx_customer_created (customer_id, created_at),
    INDEX idx_status_created (status, created_at),
    INDEX idx_processor_id (processor_transaction_id)
);

-- Payment methods table
CREATE TABLE payment_methods (
    payment_method_id BIGINT PRIMARY KEY AUTO_INCREMENT,
    customer_id BIGINT NOT NULL,
    method_type ENUM('card', 'bank_account', 'digital_wallet', 'crypto') NOT NULL,
    provider ENUM('visa', 'mastercard', 'amex', 'paypal', 'apple_pay', 'google_pay') NOT
    token VARCHAR(255) NOT NULL, -- Tokenized sensitive data
    last_four_digits VARCHAR(4),
    expiry_month TINYINT,
    expiry_year SMALLINT,
    cardholder_name VARCHAR(255),
    billing_address_id BIGINT,
    is_default BOOLEAN DEFAULT FALSE,
    is_verified BOOLEAN DEFAULT FALSE,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    updated_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,

    INDEX idx_customer_type (customer_id, method_type),
    INDEX idx_token (token),
    FOREIGN KEY (customer_id) REFERENCES customers(customer_id)
);

-- Merchants table
CREATE TABLE merchants (
    merchant_id BIGINT PRIMARY KEY AUTO_INCREMENT,
    business_name VARCHAR(255) NOT NULL,
    business_type ENUM('individual', 'corporation', 'partnership', 'non_profit') NOT NUL
    tax_id VARCHAR(50),
    business_address_id BIGINT,
    contact_email VARCHAR(255) NOT NULL,
    contact_phone VARCHAR(20),
    website_url VARCHAR(512),
    industry_code VARCHAR(10), -- NAICS code
    risk_level ENUM('low', 'medium', 'high') DEFAULT 'medium',
    kyc_status ENUM('pending', 'approved', 'rejected', 'under_review') DEFAULT 'pending'
    kyc_verified_at TIMESTAMP NULL,
    settlement_currency CHAR(3) DEFAULT 'USD',
    fee_structure JSON, -- Custom fee arrangement
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    updated_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,
    is_active BOOLEAN DEFAULT TRUE,

    INDEX idx_business_name (business_name),
    INDEX idx_kyc_status (kyc_status),
    INDEX idx_risk_level (risk_level)
);
```

Fraud Detection Schema

□ Back to Top

```
-- Fraud detection rules
CREATE TABLE fraud_rules (
    rule_id BIGINT PRIMARY KEY AUTO_INCREMENT,
    rule_name VARCHAR(255) NOT NULL,
    rule_type ENUM('velocity', 'geolocation', 'device', 'behavioral', 'amount') NOT NULL
    rule_condition JSON NOT NULL, -- Rule parameters and thresholds
    action ENUM('flag', 'block', 'require_verification') NOT NULL,
    risk_score INT NOT NULL, -- 0-100
    is_active BOOLEAN DEFAULT TRUE,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    updated_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP ON UPDATE CURRENT_TIMESTAMP,

    INDEX idx_rule_type (rule_type),
    INDEX idx_is_active (is_active)
);

-- Fraud detection events
CREATE TABLE fraud_events (
    event_id BIGINT PRIMARY KEY AUTO_INCREMENT,
    transaction_id VARCHAR(128) NOT NULL,
    rule_id BIGINT NOT NULL,
    risk_score INT NOT NULL,
    event_type ENUM('rule_triggered', 'manual_review', 'false_positive') NOT NULL,
    event_data JSON,
    reviewed_by BIGINT NULL, -- Staff member who reviewed
    review_decision ENUM('approve', 'decline', 'pending') NULL,
    review_notes TEXT,
    created_at TIMESTAMP DEFAULT CURRENT_TIMESTAMP,
    reviewed_at TIMESTAMP NULL,

    INDEX idx_transaction_id (transaction_id),
    INDEX idx_rule_id (rule_id),
    INDEX idx_created_at (created_at),
    FOREIGN KEY (transaction_id) REFERENCES transactions(transaction_id),
    FOREIGN KEY (rule_id) REFERENCES fraud_rules(rule_id)
);
```

Sample API Endpoints

□ Back to Top

Payment Processing APIs

□ Back to Top

```
POST /api/v1/transactions
Authorization: Bearer <merchant_api_key>
Content-Type: application/json

{
    "amount": 99.99,
    "currency": "USD",
    "payment_method_id": 12345,
    "customer_id": 67890,
    "description": "Premium subscription purchase",
    "metadata": {
        "order_id": "ORDER-2024-001",
        "product_id": "premium_plan"
    }
}
```

```
Response (201 Created):
{
    "success": true,
    "data": {
        "transaction_id": "txn_1a2b3c4d5e6f",
        "status": "authorized",
        "amount": 99.99,
        "currency": "USD",
        "fee_amount": 3.19,
        "net_amount": 96.80,
        "created_at": "2024-01-15T10:30:00Z",
        "estimated_settlement": "2024-01-17T10:30:00Z"
    }
}
```

```
POST /api/v1/transactions/{transaction_id}/capture
Authorization: Bearer <merchant_api_key>
Content-Type: application/json

{
    "amount": 99.99 // Optional: partial capture
}

Response (200 OK):
{
    "success": true,
    "data": {
        "transaction_id": "txn_1a2b3c4d5e6f",
        "status": "captured",
        "captured_amount": 99.99,
        "captured_at": "2024-01-15T10:35:00Z"
    }
}
```

Refund APIs

□ Back to Top

```
POST /api/v1/transactions/{transaction_id}/refund
Authorization: Bearer <merchant_api_key>
Content-Type: application/json

{
    "amount": 50.00, // Partial refund
    "reason": "customer_request",
    "description": "Partial refund for damaged item"
}

Response (201 Created):
{
    "success": true,
    "data": {
        "refund_id": "ref_9z8y7x6w5v4u",
        "transaction_id": "txn_1a2b3c4d5e6f",
        "amount": 50.00,
        "status": "pending",
        "estimated_arrival": "2024-01-20T10:30:00Z",
        "created_at": "2024-01-15T11:00:00Z"
    }
}
```

Payment Methods APIs

□ Back to Top

```
POST /api/v1/customers/{customer_id}/payment_methods
Authorization: Bearer <api_key>
Content-Type: application/json

{
    "type": "card",
    "card": {
        "number": "4242424242424242",
        "exp_month": 12,
        "exp_year": 2028,
        "cvc": "123",
        "cardholder_name": "John Doe"
    },
    "billing_address": {
        "line1": "123 Main St",
        "city": "San Francisco",
        "state": "CA",
        "postal_code": "94105",
        "country": "US"
    }
}
```

```
Response (201 Created):
{
    "success": true,
    "data": {
        "payment_method_id": 12345,
        "type": "card",
        "card": {
            "brand": "visa",
            "last_four": "4242",
            "exp_month": 12,
            "exp_year": 2028
        },
        "is_verified": true,
        "created_at": "2024-01-15T10:25:00Z"
    }
}
```

Fraud Detection APIs

□ Back to Top

```
GET /api/v1/transactions/{transaction_id}/fraud_analysis
Authorization: Bearer <merchant_api_key>

Response (200 OK):
{
    "success": true,
    "data": {
        "transaction_id": "txn_1a2b3c4d5e6f",
        "risk_score": 25,
        "risk_level": "low",
        "triggered_rules": [],
        "recommendations": [
            {
                "action": "proceed",
                "confidence": 0.95,
                "reason": "Low risk transaction from verified customer"
            }
        ],
        "device_fingerprint": {
            "device_id": "dev_abc123",
            "is_known_device": true,
            "location": "San Francisco, CA"
        }
    }
}
```

Webhook APIs

□ Back to Top

```
POST /merchant/webhooks/payments
Content-Type: application/json
X-Signature: sha256=abc123...

{
    "event_type": "transaction.captured",
    "event_id": "evt_1a2b3c4d",
    "created_at": "2024-01-15T10:35:00Z",
    "data": {
        "transaction_id": "txn_1a2b3c4d5e6f",
        "status": "captured",
        "amount": 99.99,
        "currency": "USD",
        "merchant_id": 12345
    }
}

// Merchant should respond with 200 OK
Response (200 OK):
{
    "received": true
}
```

Analytics & Reporting APIs

□ Back to Top

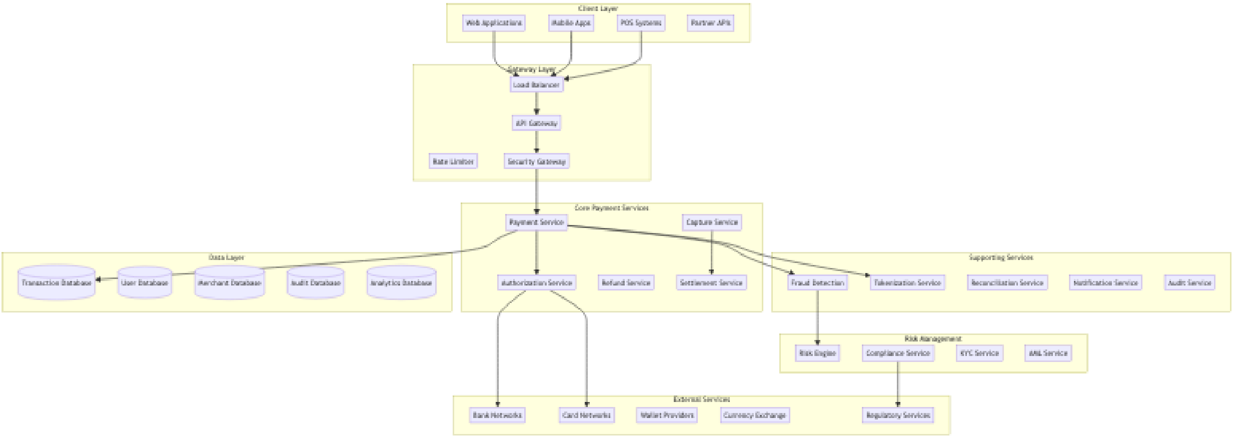
```
GET /api/v1/merchants/{merchant_id}/analytics?start_date=2024-01-01&end_date=2024-01-31
Authorization: Bearer <merchant_api_key>

Response (200 OK):
{
    "success": true,
    "data": {
        "period": {
            "start_date": "2024-01-01",
            "end_date": "2024-01-31"
        },
        "summary": {
            "total_transactions": 15420,
            "total_volume": 1547823.45,
            "successful_transactions": 14891,
            "failed_transactions": 529,
            "success_rate": 96.57,
            "average_transaction_value": 100.38
        },
        "daily_breakdown": [
            {
                "date": "2024-01-01",
                "transaction_count": 234,
                "volume": 23456.78,
                "success_rate": 95.3
            }
        ],
        "payment_methods": {
            "credit_card": {"count": 10794, "percentage": 70.0},
            "debit_card": {"count": 3084, "percentage": 20.0},
            "digital_wallet": {"count": 1542, "percentage": 10.0}
        }
    }
}
```

High-Level Design (HLD)

□ Back to Top

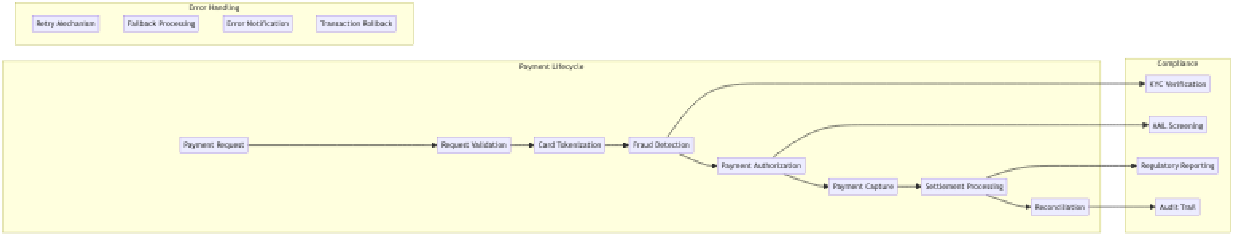
System Architecture Overview

□ Back to Top



Payment Flow Architecture

□ Back to Top

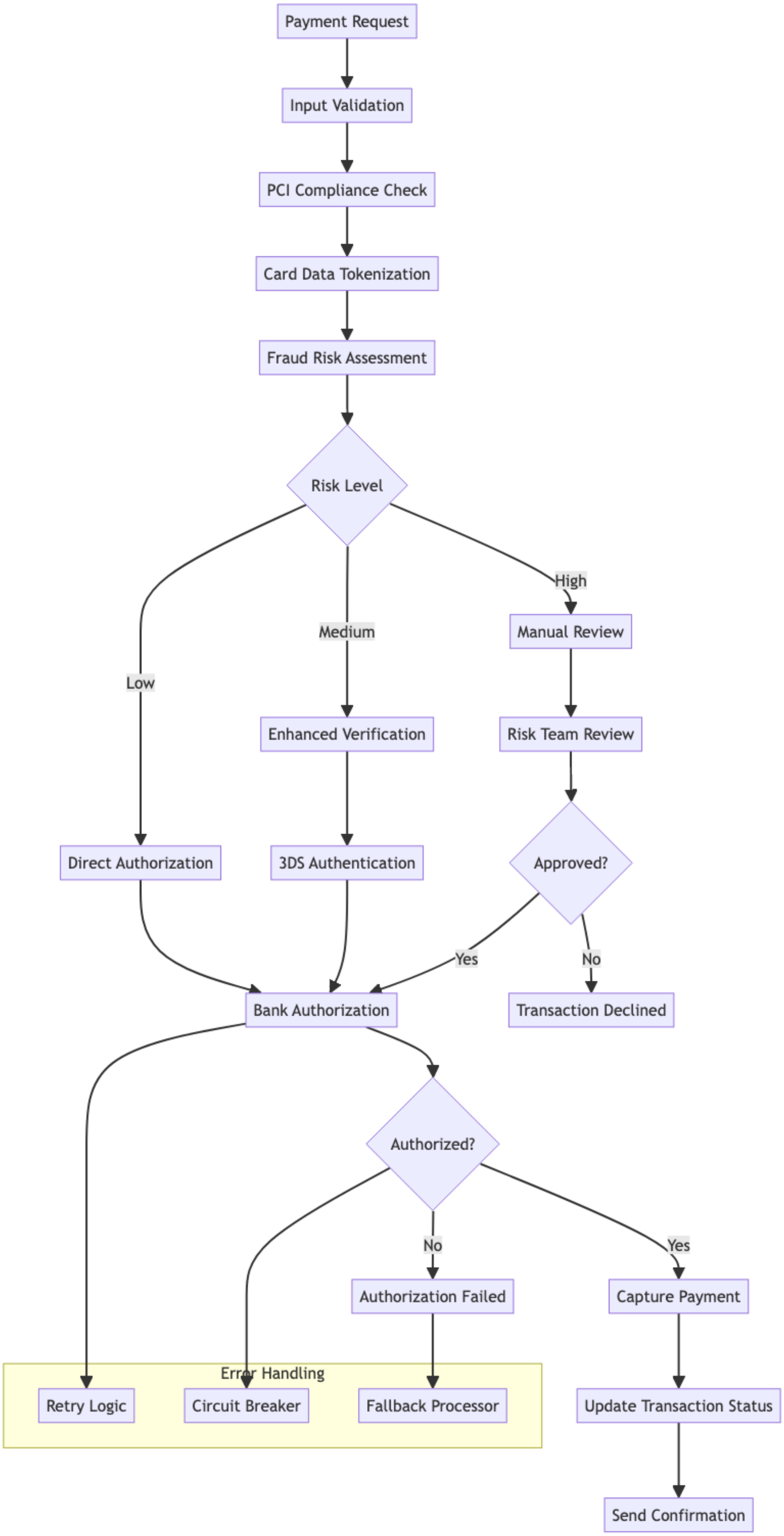


Low-Level Design (LLD)

□ Back to Top

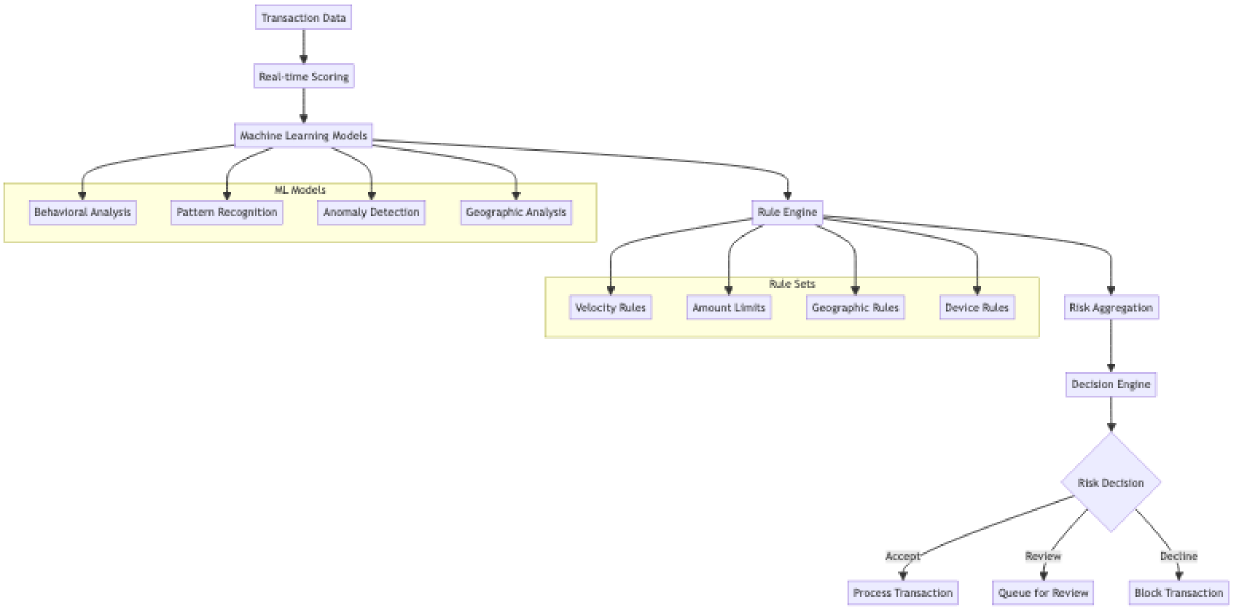
Transaction Processing Pipeline

□ Back to Top


Payment Request
Input Validation
PCI Compliance Check
Card Data Tokenization
Fraud Risk Assessment
Risk Level
Low
Medium
High
Manual Review
Enhanced Verification
Risk Team Review
Direct Authorization
3DS Authentication
Approved?
Yes
No
Bank Authorization
Transaction Declined
Authorized?
No
Yes
Authorization Failed
Capture Payment
Error Handling
Retry Logic
Circuit Breaker
Fallback Processor
Update Transaction Status
Send Confirmation

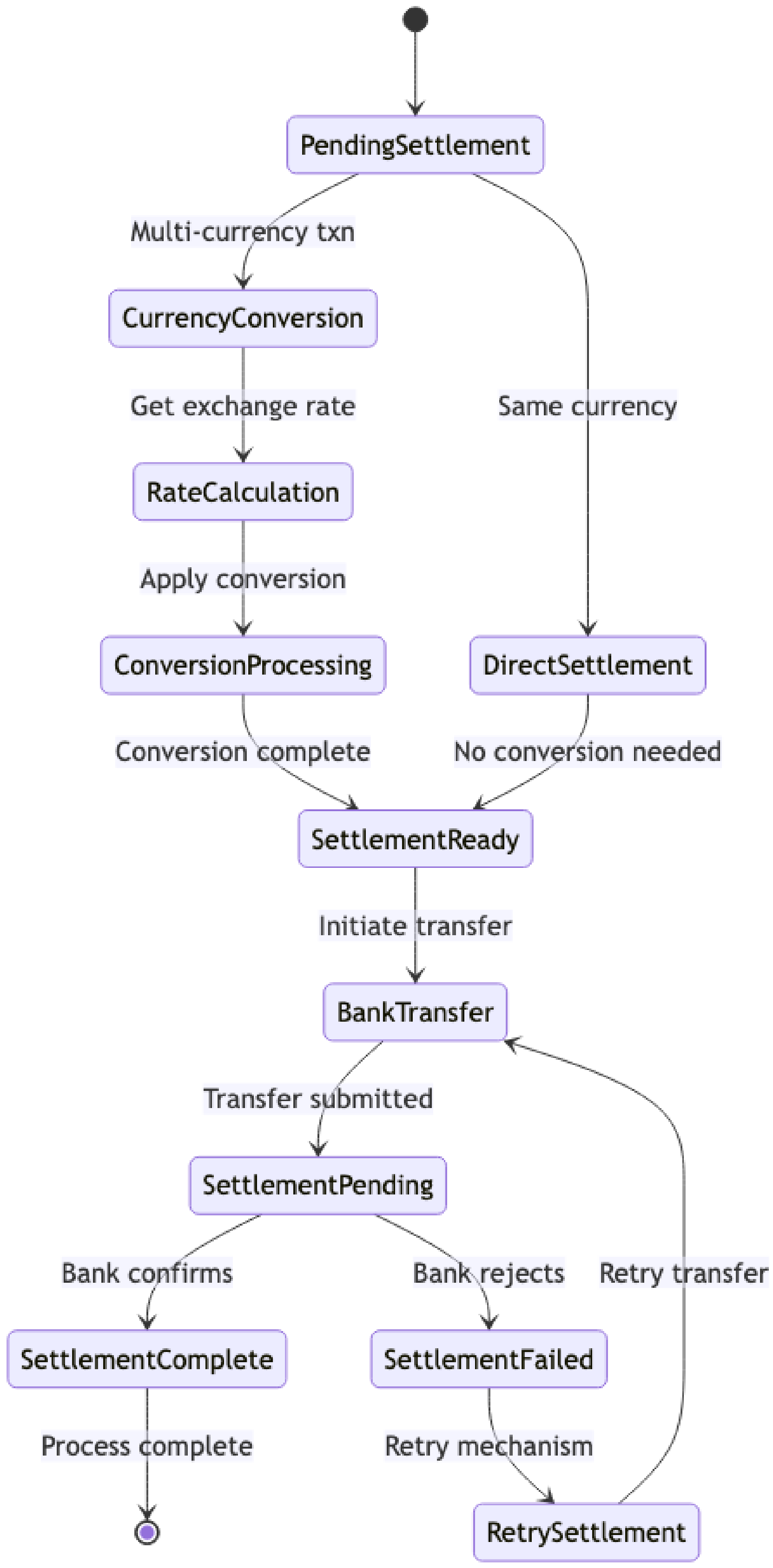
Fraud Detection Engine

□ Back to Top



Multi-Currency Settlement

□ Back to Top


PendingSettlement
Multi-currency txn
CurrencyConversion
Get exchange rate
RateCalculation
Apply conversion
ConversionProcessing
Same currency
DirectSettlement
Conversion complete
No conversion needed
SettlementReady
Initiate transfer
BankTransfer
Transfer submitted
SettlementPending
Bank confirms
Bank rejects
Retry transfer
SettlementComplete
SettlementFailed
Process complete
Retry mechanism
RetrySettlement

Core Algorithms

□ Back to Top

---

1. Real-time Fraud Detection Algorithm

□ Back to Top

Purpose: Detect fraudulent transactions in real-time with minimal false positives.

Multi-Layer Fraud Detection:

```
FraudDetectionConfig = {
  riskThresholds: {
    low: 0.3,      // Accept automatically
    medium: 0.7,   // Require additional verification
    high: 0.9      // Decline or manual review
  },
  velocityLimits: {
    maxTransactionsPerHour: 10,
    maxAmountPerDay: 10000,
    maxFailedAttemptsPerHour: 3
  },
  geographicRules: {
    enableLocationChecking: true,
    maxDistanceKm: 1000,    // Max travel distance between transactions
    timeWindowMinutes: 60   // Time window for location checks
  }
}

function detectFraud(transaction, userProfile, context):
  riskScore = 0
  riskFactors = []

  // Velocity-based risk assessment
  velocityRisk = assessVelocityRisk(transaction, userProfile)
  riskScore += velocityRisk.score * 0.25
  if velocityRisk.triggered:
    riskFactors.push(...velocityRisk.factors)

  // Amount-based risk assessment
  amountRisk = assessAmountRisk(transaction, userProfile)
  riskScore += amountRisk.score * 0.20
  if amountRisk.triggered:
    riskFactors.push(...amountRisk.factors)

  // Geographic risk assessment
  geoRisk = assessGeographicRisk(transaction, userProfile, context)
  riskScore += geoRisk.score * 0.20
  if geoRisk.triggered:
    riskFactors.push(...geoRisk.factors)

  // Behavioral pattern analysis
  behaviorRisk = assessBehavioralRisk(transaction, userProfile)
  riskScore += behaviorRisk.score * 0.15
  if behaviorRisk.triggered:
    riskFactors.push(...behaviorRisk.factors)

  // Device and network analysis
  deviceRisk = assessDeviceRisk(transaction, context)
  riskScore += deviceRisk.score * 0.10
  if deviceRisk.triggered:
    riskFactors.push(...deviceRisk.factors)

  // Machine learning model prediction
  mlRisk = mlFraudModel.predict(transaction, userProfile, context)
  riskScore += mlRisk.score * 0.10
  if mlRisk.triggered:
    riskFactors.push(...mlRisk.factors)

  // Determine risk level and action
  riskLevel = categorizeRisk(riskScore)
  recommendedAction = determineAction(riskLevel, riskFactors)

  return {
    riskScore: riskScore,
    riskLevel: riskLevel,
    riskFactors: riskFactors,
    recommendedAction: recommendedAction,
    requiresReview: riskScore >= FraudDetectionConfig.riskThresholds.medium
  }
```

Velocity Risk Assessment:

```
function assessVelocityRisk(transaction, userProfile):
  currentTime = Date.now()
  hourStart = currentTime - 3600000   // 1 hour
  dayStart = currentTime - 86400000   // 24 hours
```

```
// Check transaction count velocity
recentTransactions = getTransactionCount(userProfile.userId, hourStart, currentTime)
if recentTransactions > FraudDetectionConfig.velocityLimits.maxTransactionsPerHour:
  return {
    triggered: true,
    score: 0.8,
    factors: ['excessive_transaction_frequency']
  }

// Check amount velocity
dailyAmount = getTransactionAmount(userProfile.userId, dayStart, currentTime)
if dailyAmount + transaction.amount > FraudDetectionConfig.velocityLimits.maxAmountPer
  return {
    triggered: true,
    score: 0.7,
    factors: ['excessive_daily_amount']
  }

// Check failed attempts
failedAttempts = getFailedTransactionCount(userProfile.userId, hourStart, currentTime)
if failedAttempts > FraudDetectionConfig.velocityLimits.maxFailedAttemptsPerHour:
  return {
    triggered: true,
    score: 0.9,
    factors: ['excessive_failed_attempts']
  }

// Calculate velocity score based on normal patterns
normalVelocity = calculateNormalVelocity(userProfile)
currentVelocity = recentTransactions / (3600000 / 1000) // transactions per second
velocityRatio = currentVelocity / Math.max(normalVelocity, 0.001)

velocityScore = Math.min(velocityRatio * 0.3, 0.6)

return {
  triggered: false,
  score: velocityScore,
  factors: []
}
```

2. Payment Routing and Optimization Algorithm

□ Back to Top

Purpose: Route payments through optimal processors to maximize success rates and minimize costs.

Payment Processor Selection:

```
ProcessorConfig = {
  processors: [
    {
      id: 'processor_a',
      successRate: 0.95,
      cost: 0.029,        // 2.9% + $0.30
      fixedFee: 0.30,
      regions: ['US', 'CA', 'EU'],
      cardTypes: ['visa', 'mastercard', 'amex'],
      currencies: ['USD', 'EUR', 'CAD']
    },
    {
      id: 'processor_b',
      successRate: 0.92,
      cost: 0.025,        // 2.5% + $0.25
      fixedFee: 0.25,
      regions: ['US', 'CA'],
      cardTypes: ['visa', 'mastercard'],
      currencies: ['USD', 'CAD']
    }
  ],
  routingStrategy: 'success_rate_optimized', // or 'cost_optimized'
  fallbackEnabled: true,
  maxRetries: 3
}

function selectOptimalProcessor(transaction, context):
  eligibleProcessors = ProcessorConfig.processors.filter(processor =>
    isProcessorEligible(processor, transaction, context)
  )

  if eligibleProcessors.length === 0:
    return { success: false, reason: 'no_eligible_processors' }

  // Score processors based on multiple factors
  scoredProcessors = eligibleProcessors.map(processor => ({
    ...processor,
    score: calculateProcessorScore(processor, transaction, context)
  }))

  // Sort by score (descending)
  rankedProcessors = scoredProcessors.sort((a, b) => b.score - a.score)

  // Select primary processor and fallbacks
  primaryProcessor = rankedProcessors[0]
  fallbackProcessors = rankedProcessors.slice(1, 3) // Up to 2 fallbacks

  return {
    success: true,
    primary: primaryProcessor,
    fallbacks: fallbackProcessors
  }

function calculateProcessorScore(processor, transaction, context):
  score = 0

  // Success rate factor (40% weight)
  successRateScore = processor.successRate
  score += successRateScore * 0.4

  // Cost factor (30% weight) - lower cost = higher score
  totalCost = (transaction.amount * processor.cost) + processor.fixedFee
  costScore = 1 - (totalCost / transaction.amount) // Normalize cost as percentage
  score += costScore * 0.3

  // Historical performance for this merchant (20% weight)
  merchantPerformance = getMerchantProcessorPerformance(context.merchantId, processor.id
  score += merchantPerformance.successRate * 0.2

  // Current processor load (10% weight)
  processorLoad = getCurrentProcessorLoad(processor.id)
  loadScore = Math.max(0, 1 - processorLoad) // Higher load = lower score
  score += loadScore * 0.1

  return score
```

Retry and Fallback Logic:

```
function processPaymentWithFallback(transaction, processorSelection):
  attempts = []

  // Try primary processor
  primaryResult = attemptPayment(transaction, processorSelection.primary)
  attempts.push(primaryResult)

  if primaryResult.success:
    return {
      success: true,
      result: primaryResult,
      attempts: attempts,
      finalProcessor: processorSelection.primary.id
    }

  // Try fallback processors if primary fails
  for fallbackProcessor in processorSelection.fallbacks:
    // Check if retry is warranted
    if not shouldRetryWithFallback(primaryResult, fallbackProcessor):
      continue

    fallbackResult = attemptPayment(transaction, fallbackProcessor)
    attempts.push(fallbackResult)

    if fallbackResult.success:
      return {
        success: true,
        result: fallbackResult,
        attempts: attempts,
        finalProcessor: fallbackProcessor.id
      }

  // All processors failed
  return {
    success: false,
    attempts: attempts,
    reason: 'all_processors_failed'
  }

function shouldRetryWithFallback(previousResult, fallbackProcessor):
  // Don't retry for certain error types
  nonRetryableErrors = [
    'insufficient_funds',
    'invalid_card',
    'expired_card',
    'blocked_card'
  ]

  if nonRetryableErrors.includes(previousResult.errorCode):
    return false

  // Check if fallback processor supports the card type
  if not fallbackProcessor.cardTypes.includes(previousResult.cardType):
    return false
  // Retry for technical failures
  retryableErrors = [
    'processor_timeout',
    'network_error',
    'temporary_decline',
    'processor_unavailable'
  ]

  return retryableErrors.includes(previousResult.errorCode)
```

3. Multi-Currency Exchange Rate Management

□ Back to Top

Purpose: Handle currency conversions with real-time rates and risk management.

Exchange Rate Calculation:

```
CurrencyConfig = {
  baseCurrency: 'USD',
  rateUpdateFrequency: 60000,  // 1 minute
  rateProviders: ['provider_a', 'provider_b', 'provider_c'],
  maxSpreadPercent: 2.0,       // Maximum spread allowed
  riskBuffer: 0.005            // 0.5% risk buffer
}

function calculateExchangeRate(fromCurrency, toCurrency, amount):
  if fromCurrency === toCurrency:
    return { rate: 1.0, amount: amount, fees: 0 }

  // Get current market rates from multiple providers
  marketRates = await getMarketRates(fromCurrency, toCurrency)

  // Calculate average rate with outlier removal
  cleanedRates = removeOutliers(marketRates)
  averageRate = calculateWeightedAverage(cleanedRates)

  // Apply risk buffer and spread
  riskAdjustedRate = averageRate * (1 - CurrencyConfig.riskBuffer)

  // Calculate conversion fees
  conversionFee = calculateConversionFee(amount, fromCurrency, toCurrency)

  // Calculate final converted amount
  convertedAmount = (amount * riskAdjustedRate) - conversionFee

  return {
    rate: riskAdjustedRate,
    marketRate: averageRate,
    amount: convertedAmount,
    fees: conversionFee,
    spread: Math.abs(riskAdjustedRate - averageRate) / averageRate * 100
  }

function hedgeCurrencyRisk(transactions, timeWindow = 3600000): // 1 hour
  // Group transactions by currency pair
  currencyPairs = groupByCurrencyPair(transactions)

  hedgingActions = []

  for pair in currencyPairs:
    netExposure = calculateNetExposure(pair.transactions)

    // Hedge if exposure exceeds threshold
    if Math.abs(netExposure.amount) > getHedgeThreshold(pair.fromCurrency, pair.toCurren
      hedgeAction = {
        fromCurrency: pair.fromCurrency,
        toCurrency: pair.toCurrency,
        amount: netExposure.amount,
        direction: netExposure.amount > 0 ? 'sell' : 'buy',
        hedgeInstrument: 'forward_contract',
        maturity: timeWindow + 86400000 // 1 day settlement
      }

      hedgingActions.push(hedgeAction)

  return hedgingActions
```

4. Settlement and Reconciliation Algorithm

□ Back to Top

Purpose: Ensure accurate settlement of funds and reconciliation with bank statements.

Settlement Processing:

```
SettlementConfig = {
  batchSize: 1000,
  settlementSchedule: {
    frequency: 'daily',
    time: '23:00',
    timezone: 'UTC'
  },
  holdPeriod: {
    newMerchant: 7 * 24 * 3600 * 1000,  // 7 days for new merchants
    regular: 2 * 24 * 3600 * 1000,       // 2 days for regular merchants
    premium: 24 * 3600 * 1000             // 1 day for premium merchants
  }
}

function processSettlement(merchantId, settlementDate):
  merchant = getMerchant(merchantId)

  // Get eligible transactions for settlement
  eligibleTransactions = getEligibleTransactions(merchantId, settlementDate)

  if eligibleTransactions.length === 0:
    return { success: true, message: 'no_transactions_to_settle' }

  // Calculate net settlement amount
  settlementSummary = calculateSettlementSummary(eligibleTransactions)

  // Apply fees and reserves
  fees = calculateMerchantFees(settlementSummary, merchant)
  reserves = calculateReserves(settlementSummary, merchant)

  netSettlementAmount = settlementSummary.grossAmount - fees.total - reserves.total

  if netSettlementAmount <= 0:
    return { success: false, reason: 'negative_settlement_amount' }

  // Create settlement batch
  settlementBatch = {
    id: generateSettlementId(),
    merchantId: merchantId,
    settlementDate: settlementDate,
    transactions: eligibleTransactions,
    grossAmount: settlementSummary.grossAmount,
    fees: fees,
    reserves: reserves,
    netAmount: netSettlementAmount,
    status: 'pending'
  }
  // Initiate bank transfer
  transferResult = initiateBankTransfer(
    merchant.bankAccount,
    netSettlementAmount,
    settlementBatch.id
  )

  if transferResult.success:
    settlementBatch.status = 'initiated'
    settlementBatch.bankTransactionId = transferResult.transactionId

    // Store settlement record
    storeSettlementBatch(settlementBatch)

    // Send settlement notification
    sendSettlementNotification(merchantId, settlementBatch)

    return { success: true, settlementBatch: settlementBatch }
  else:
    return { success: false, reason: 'bank_transfer_failed', error: transferResult.error
```

Reconciliation Engine:

```
function performReconciliation(date, bankStatements):
  reconciliationReport = {
    date: date,
    totalTransactions: 0,
    matchedTransactions: 0,
    unmatchedInternal: [],
    unmatchedBank: [],
    discrepancies: [],
    status: 'pending'
  }

  // Get internal transaction records for the date
  internalTransactions = getInternalTransactions(date)
  reconciliationReport.totalTransactions = internalTransactions.length

  // Match transactions with bank statements
  for internalTxn in internalTransactions:
    bankMatch = findBankMatch(internalTxn, bankStatements)

    if bankMatch:
      if amountsMatch(internalTxn.amount, bankMatch.amount):
        reconciliationReport.matchedTransactions++
        markAsReconciled(internalTxn.id, bankMatch.id)
      else:
        // Amount discrepancy
        discrepancy = {
          type: 'amount_mismatch',
          internalTransaction: internalTxn,
          bankTransaction: bankMatch,
          difference: Math.abs(internalTxn.amount - bankMatch.amount)
        }
        reconciliationReport.discrepancies.push(discrepancy)
    else:
      // No matching bank transaction found
      reconciliationReport.unmatchedInternal.push(internalTxn)

  // Find bank transactions without internal matches
  for bankTxn in bankStatements:
    if not isMatched(bankTxn.id):
      reconciliationReport.unmatchedBank.push(bankTxn)

  // Determine reconciliation status
  if reconciliationReport.discrepancies.length === 0 and
     reconciliationReport.unmatchedInternal.length === 0 and
     reconciliationReport.unmatchedBank.length === 0:
    reconciliationReport.status = 'reconciled'
  else:
    reconciliationReport.status = 'discrepancies_found'

  // Store reconciliation report
  storeReconciliationReport(reconciliationReport)

  // Alert on significant discrepancies
  if hasSignificantDiscrepancies(reconciliationReport):
    alertFinanceTeam(reconciliationReport)

  return reconciliationReport
```

5. PCI DSS Compliance and Security

□ Back to Top

Purpose: Ensure payment data security and regulatory compliance.

Data Tokenization System:

```
TokenizationConfig = {
  tokenFormat: 'format_preserving',    // Preserves original format
  keyRotationPeriod: 90 * 24 * 3600 * 1000,  // 90 days
  encryptionAlgorithm: 'AES-256-GCM',
  tokenLength: 16,
  checksumValidation: true
}

function tokenizeCardData(cardNumber, expiryDate, cvv):
  // Validate card data
  if not validateCardNumber(cardNumber):
    return { success: false, error: 'invalid_card_number' }

  // Generate format-preserving token
  token = generateFormatPreservingToken(cardNumber)

  // Encrypt sensitive data
  encryptedData = {
    cardNumber: encrypt(cardNumber, getCurrentEncryptionKey()),
    expiryDate: encrypt(expiryDate, getCurrentEncryptionKey()),
    cvv: encrypt(cvv, getCurrentEncryptionKey())
  }

  // Store in secure vault
  vaultRecord = {
    token: token,
    encryptedData: encryptedData,
    keyVersion: getCurrentKeyVersion(),
    createdAt: Date.now(),
    lastUsed: Date.now()
  }

  storeInVault(token, vaultRecord)

  // Return token (safe to store/transmit)
  return {
    success: true,
    token: token,
    last4Digits: cardNumber.slice(-4),
    cardType: detectCardType(cardNumber)
  }

function detokenizeCardData(token):
  // Retrieve from secure vault
  vaultRecord = getFromVault(token)

  if not vaultRecord:
    return { success: false, error: 'token_not_found' }

  // Check token expiry
  if isTokenExpired(vaultRecord):
    return { success: false, error: 'token_expired' }

  // Decrypt sensitive data
  decryptionKey = getEncryptionKey(vaultRecord.keyVersion)

  decryptedData = {
    cardNumber: decrypt(vaultRecord.encryptedData.cardNumber, decryptionKey),
    expiryDate: decrypt(vaultRecord.encryptedData.expiryDate, decryptionKey),
    cvv: decrypt(vaultRecord.encryptedData.cvv, decryptionKey)
  }

  // Update last used timestamp
  updateLastUsed(token)

  return {
    success: true,
    cardData: decryptedData
  }
```

Performance Optimizations

□ Back to Top

High Throughput Processing

□ Back to Top

Batch Processing Optimization:

```
BatchConfig = {
  maxBatchSize: 1000,
  batchTimeout: 5000,     // 5 seconds
  parallelWorkers: 10,
  retryAttempts: 3
}
```

Database Optimization: - Use read replicas for reporting queries - Implement database sharding by merchant ID - Optimize indices for transaction lookups - Use time-series databases for analytics

Caching Strategy

□ Back to Top

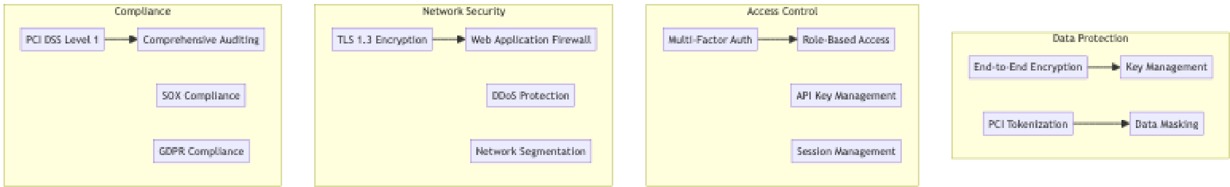
Multi-Layer Caching: - Redis for session data and temporary tokens - Application-level caching for merchant configurations - CDN caching for static assets - Database query result caching

Security Considerations

□ Back to Top

Comprehensive Security Framework

□ Back to Top



Regulatory Compliance

□ Back to Top

Compliance Framework: - PCI DSS Level 1 compliance - SOX financial reporting compliance - GDPR data protection compliance - Anti-money laundering (AML) compliance - Know Your Customer (KYC) requirements

Testing Strategy

□ Back to Top

Load Testing Scenarios

□ Back to Top

High Volume Testing: - Black Friday transaction volumes - Flash sale payment spikes - DDoS attack simulation - Database failover testing

Security Testing: - Penetration testing - Vulnerability assessments - PCI DSS compliance validation - Fraud detection accuracy testing

Trade-offs and Considerations

□ Back to Top

Security vs Performance

□ Back to Top

- **Encryption overhead**: Security vs processing speed
- **Fraud detection**: Accuracy vs transaction approval rates
- **Tokenization**: Security vs system complexity
- **Compliance**: Regulatory requirements vs operational efficiency

Availability vs Consistency

□ Back to Top

- **Transaction processing**: Strong consistency vs high availability
- **Settlement**: Accuracy vs processing speed
- **Reconciliation**: Real-time vs batch processing
- **Fraud detection**: Real-time vs comprehensive analysis

Cost vs Features

□ Back to Top

- **Multiple processors**: Redundancy vs processing fees
- **Global coverage**: Worldwide acceptance vs infrastructure cost
- **Real-time analytics**: Business insights vs computational resources
- **Compliance**: Regulatory compliance vs operational complexity

This payment processing system provides a comprehensive foundation for handling financial transactions with features like intelligent fraud detection, optimal payment routing, multi-currency support, and robust security measures while maintaining PCI DSS compliance and high availability standards.