Load Balancer System

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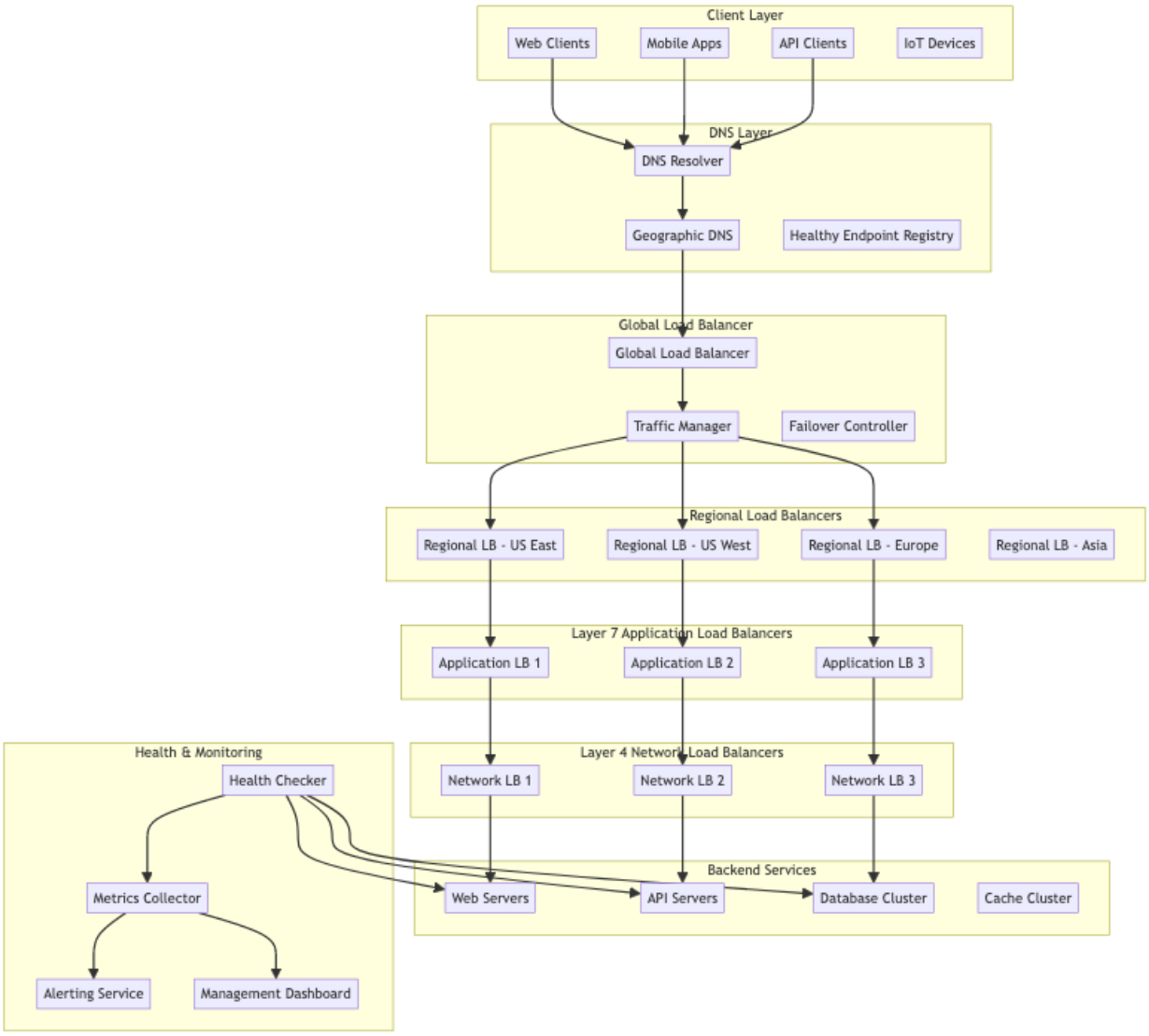

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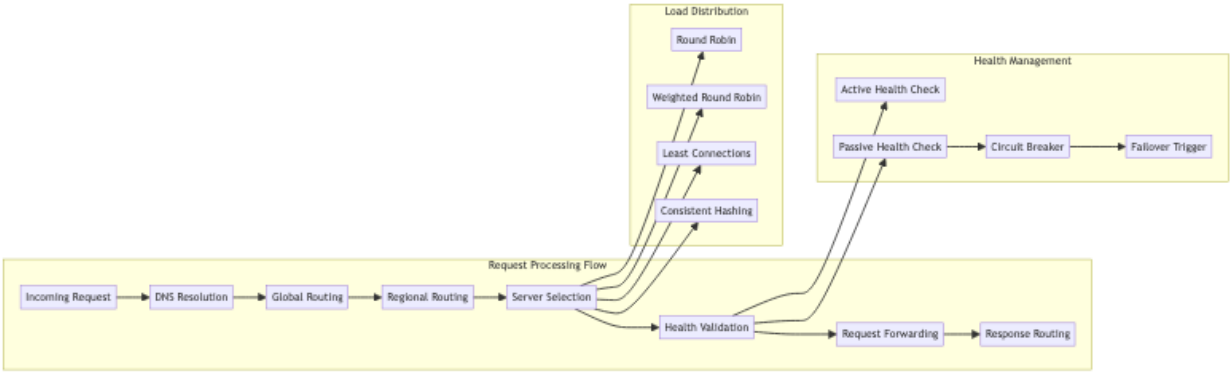

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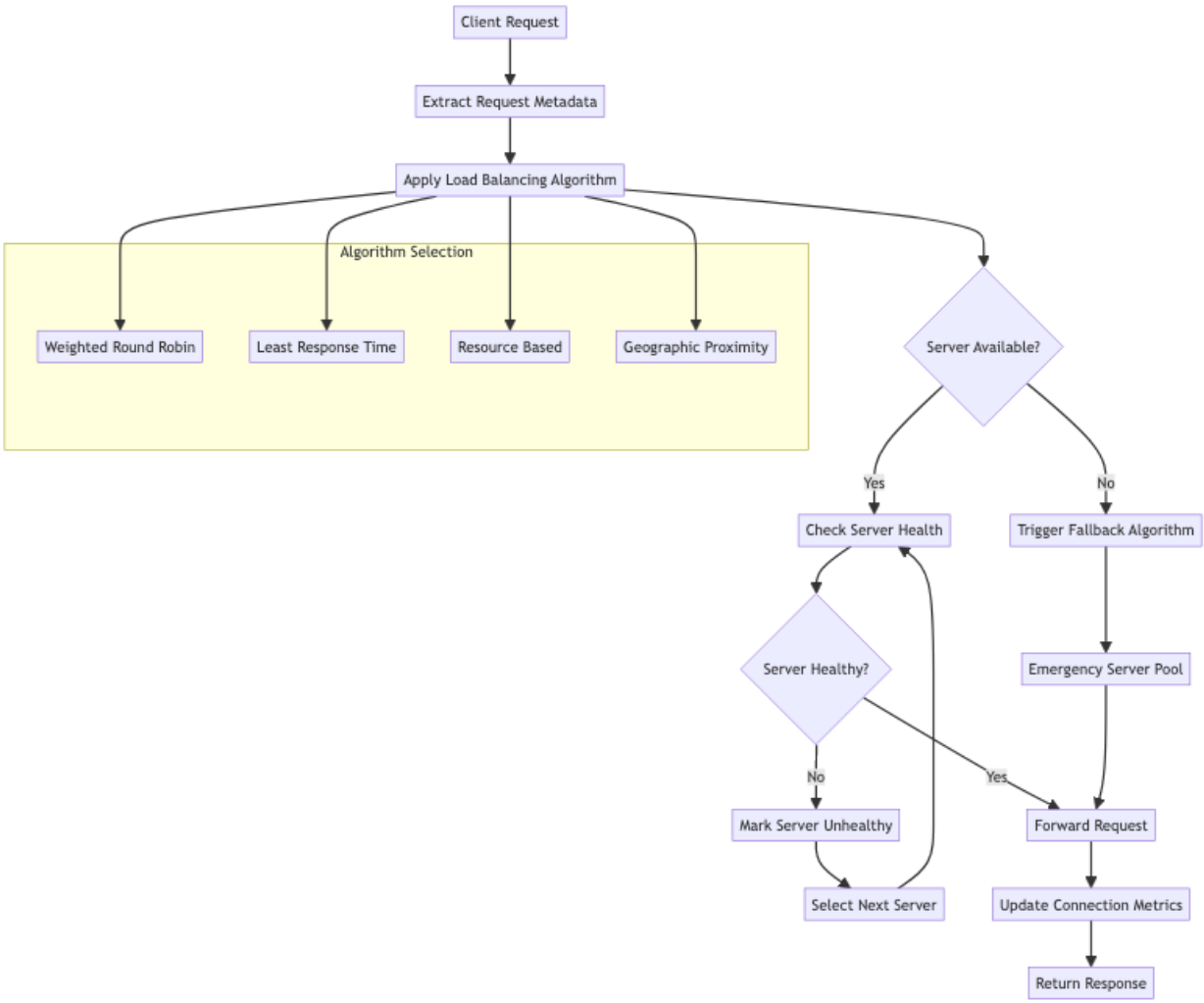

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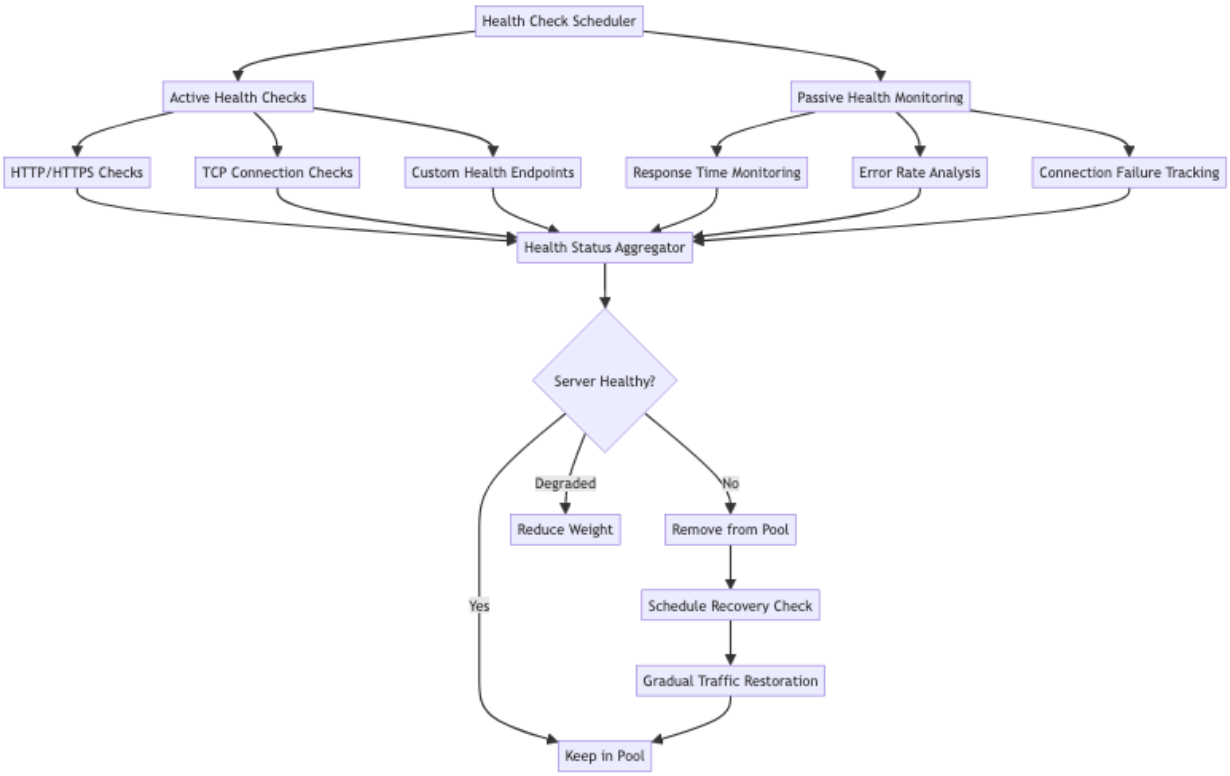

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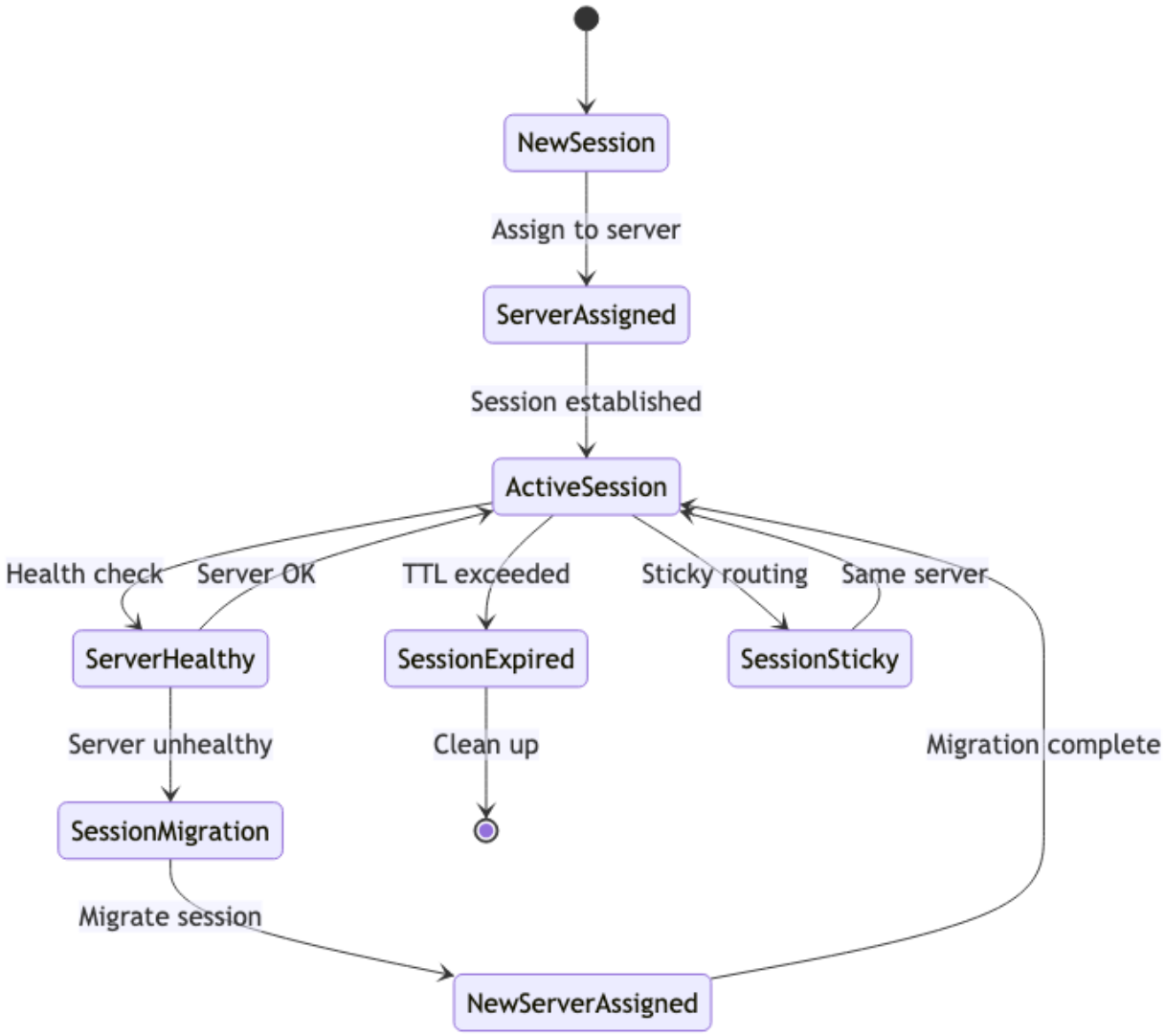

Core Algorithms

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1. Weighted Round Robin with Dynamic Adjustment

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Purpose: Distribute requests across servers based on their capacity and current performance while adapting to changing conditions.

Dynamic Weighted Round Robin Implementation:

```
WeightedRRConfig = {
  initialWeight: 100,               // Default server weight
  weightAdjustmentInterval: 30000, // 30 seconds
  maxWeight: 1000,                  // Maximum server weight
  minWeight: 1,                     // Minimum server weight

  performanceFactors: {
    responseTime: 0.4,              // 40% weight for response time
    cpuUsage: 0.3,                  // 30% weight for CPU usage
    activeConnections: 0.2,         // 20% weight for connection count
    errorRate: 0.1                  // 10% weight for error rate
  },

  adjustmentSensitivity: 0.1,       // 10% maximum adjustment per interval
  smoothingFactor: 0.8              // Exponential smoothing factor
}

class DynamicWeightedRoundRobin:
  constructor(config):
    this.config = config
    this.servers = new Map()        // serverId -> server info
    this.currentWeights = new Map() // serverId -> current weight
    this.totalWeight = 0
    this.currentIndex = 0
    this.lastAdjustment = Date.now()

  function addServer(serverId, serverInfo):
    server = {
      id: serverId,
      info: serverInfo,
      weight: this.config.initialWeight,
      effectiveWeight: this.config.initialWeight,
      currentWeight: 0,

      // Performance metrics
      responseTime: 0,
      cpuUsage: 0,
      activeConnections: 0,
      errorRate: 0,

      // Health status
      isHealthy: true,
      lastHealthCheck: Date.now()
    }
```

```
  this.servers.set(serverId, server)
  this.recalculateTotalWeight()

function selectServer():
  if this.servers.size === 0:
    return null

  // Adjust weights periodically
  if this.shouldAdjustWeights():
    this.adjustServerWeights()

  // Find server with highest current weight
  selectedServer = null
  maxWeight = -1

  for [serverId, server] of this.servers:
    if server.isHealthy and server.currentWeight > maxWeight:
      maxWeight = server.currentWeight
      selectedServer = server

  if selectedServer:
    // Update current weights
    selectedServer.currentWeight -= this.totalWeight

    for [serverId, server] of this.servers:
      if server.isHealthy:
        server.currentWeight += server.effectiveWeight

  return selectedServer

function adjustServerWeights():
  currentTime = Date.now()

  for [serverId, server] of this.servers:
    if not server.isHealthy:
      continue

    // Calculate performance score
    performanceScore = this.calculatePerformanceScore(server)

    // Calculate new weight based on performance
    targetWeight = this.config.initialWeight * performanceScore

    // Apply smoothing and constraints
    newWeight = this.applyWeightSmoothing(server.weight, targetWeight)
```

```
    newWeight = Math.max(this.config.minWeight, Math.min(this.config.maxWeight, newWei

    // Update server weight
    server.weight = newWeight
    server.effectiveWeight = newWeight

  this.recalculateTotalWeight()
  this.lastAdjustment = currentTime

function calculatePerformanceScore(server):
  score = 1.0

  // Response time factor (lower is better)
  if server.responseTime > 0:
    responseTimeScore = 1 / (1 + server.responseTime / 1000) // Normalize to seconds
    score *= (1 - this.config.performanceFactors.responseTime) +
             (this.config.performanceFactors.responseTime * responseTimeScore)

  // CPU usage factor (lower is better)
  cpuScore = 1 - server.cpuUsage
  score *= (1 - this.config.performanceFactors.cpuUsage) +
           (this.config.performanceFactors.cpuUsage * cpuScore)

  // Active connections factor (fewer is better, relatively)
  avgConnections = this.calculateAverageConnections()
  connectionScore = avgConnections > 0 ? Math.max(0, 2 - server.activeConnections / av
  score *= (1 - this.config.performanceFactors.activeConnections) +
           (this.config.performanceFactors.activeConnections * connectionScore)

  // Error rate factor (lower is better)
  errorScore = 1 - server.errorRate
  score *= (1 - this.config.performanceFactors.errorRate) +
           (this.config.performanceFactors.errorRate * errorScore)

  return Math.max(0.1, Math.min(5.0, score)) // Clamp between 0.1 and 5.0

function applyWeightSmoothing(currentWeight, targetWeight):
  // Exponential moving average for smooth weight transitions
  smoothedWeight = (this.config.smoothingFactor * currentWeight) +
                   ((1 - this.config.smoothingFactor) * targetWeight)

  // Apply adjustment sensitivity limit
  maxChange = currentWeight * this.config.adjustmentSensitivity
  change = smoothedWeight - currentWeight
```

```
    if Math.abs(change) > maxChange:
      change = Math.sign(change) * maxChange

    return currentWeight + change
```

2. Intelligent Health Checking Algorithm

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Purpose: Comprehensive health monitoring with adaptive check intervals and multiple health indicators for accurate server status determination.

Multi-Tier Health Checking System:

```
HealthCheckConfig = {
  checkTypes: ['tcp', 'http', 'custom'],
  checkIntervals: {
    healthy: 30000,              // 30 seconds for healthy servers
    unhealthy: 5000,             // 5 seconds for unhealthy servers
    degraded: 15000              // 15 seconds for degraded servers
  },

  thresholds: {
    responseTime: 5000,          // 5 seconds max response time
    consecutiveFailures: 3,       // Mark unhealthy after 3 failures
    consecutiveSuccesses: 2,      // Mark healthy after 2 successes
    errorRateThreshold: 0.05      // 5% error rate threshold
  },

  circuitBreaker: {
    enabled: true,
    failureThreshold: 5,         // Open circuit after 5 failures
    recoveryTimeout: 60000,      // 1 minute recovery timeout
    halfOpenMaxRequests: 3       // Max requests in half-open state
  }
}

class IntelligentHealthChecker:
  constructor(config):
    this.config = config
    this.serverHealth = new Map()
    this.circuitBreakers = new Map()
    this.healthHistory = new Map()
    this.checkScheduler = new HealthCheckScheduler()
```

```
function initializeServerHealth(serverId, serverConfig):
  healthStatus = {
    serverId: serverId,
    status: 'unknown',           // 'healthy', 'unhealthy', 'degraded', 'unknown'
    lastCheckTime: Date.now(),
    consecutiveFailures: 0,
    consecutiveSuccesses: 0,

    // Performance metrics
    responseTime: 0,
    errorRate: 0,
    availability: 1.0,

    // Check configuration
    checkInterval: this.config.checkIntervals.healthy,
    checkTypes: serverConfig.healthChecks || ['tcp', 'http'],

    // Circuit breaker state
    circuitState: 'closed'       // 'closed', 'open', 'half_open'
  }

  this.serverHealth.set(serverId, healthStatus)
  this.healthHistory.set(serverId, new CircularBuffer(100))

  // Initialize circuit breaker
  if this.config.circuitBreaker.enabled:
    this.circuitBreakers.set(serverId, new CircuitBreaker(serverId, this.config.circui

  // Schedule initial health check
  this.scheduleHealthCheck(serverId)

function performHealthCheck(serverId):
  serverHealth = this.serverHealth.get(serverId)

  if not serverHealth:
    return

  checkPromises = []

  // Execute all configured health check types
  for checkType in serverHealth.checkTypes:
    switch checkType:
      case 'tcp':
        checkPromises.push(this.performTCPCheck(serverId))
        break
```

```
      case 'http':
        checkPromises.push(this.performHTTPCheck(serverId))
        break
      case 'custom':
        checkPromises.push(this.performCustomCheck(serverId))
        break

  // Wait for all checks to complete
  Promise.allSettled(checkPromises).then(results => {
    this.processHealthCheckResults(serverId, results)
  })

function performHTTPCheck(serverId):
  return new Promise((resolve, reject) => {
    server = this.getServerConfig(serverId)
    startTime = Date.now()

    healthCheckUrl = `${server.protocol}://${server.host}:${server.port}${server.healt

    httpRequest = this.createHealthCheckRequest(healthCheckUrl)

    httpRequest.setTimeout(this.config.thresholds.responseTime)

    httpRequest.on('response', (response) => {
      responseTime = Date.now() - startTime

      if response.statusCode >= 200 and response.statusCode < 300:
        resolve({
          type: 'http',
          success: true,
          responseTime: responseTime,
          statusCode: response.statusCode
        })
      else:
        reject({
          type: 'http',
          success: false,
          responseTime: responseTime,
          statusCode: response.statusCode,
          error: `HTTP ${response.statusCode}`
        })
    })

    httpRequest.on('timeout', () => {
      reject({
```

```
        type: 'http',
        success: false,
        responseTime: this.config.thresholds.responseTime,
        error: 'timeout'
      })
    })

    httpRequest.on('error', (error) => {
      reject({
        type: 'http',
        success: false,
        responseTime: Date.now() - startTime,
        error: error.message
      })
    })
  })

function processHealthCheckResults(serverId, results):
  serverHealth = this.serverHealth.get(serverId)
  successfulChecks = results.filter(r => r.status === 'fulfilled' and r.value.success)
  failedChecks = results.filter(r => r.status === 'rejected' or not r.value.success)

  // Calculate aggregate health score
  healthScore = successfulChecks.length / results.length

  // Update performance metrics
  if successfulChecks.length > 0:
    avgResponseTime = successfulChecks.reduce((sum, check) => sum + check.value.respon
    serverHealth.responseTime = avgResponseTime

  // Determine health status based on checks
  isHealthy = this.determineHealthStatus(healthScore, serverHealth, results)

  if isHealthy:
    serverHealth.consecutiveSuccesses++
    serverHealth.consecutiveFailures = 0

    // Update status based on consecutive successes
    if serverHealth.status === 'unhealthy' and serverHealth.consecutiveSuccesses >= th
      this.markServerHealthy(serverId)
    else if serverHealth.status === 'degraded' and serverHealth.consecutiveSuccesses >
      this.markServerHealthy(serverId)
  else:
    serverHealth.consecutiveFailures++
    serverHealth.consecutiveSuccesses = 0
```

```
    // Update status based on consecutive failures
    if serverHealth.consecutiveFailures >= this.config.thresholds.consecutiveFailures:
      this.markServerUnhealthy(serverId, failedChecks)

  // Store health check result in history
  healthRecord = {
    timestamp: Date.now(),
    healthy: isHealthy,
    score: healthScore,
    responseTime: serverHealth.responseTime,
    checks: results.length,
    errors: failedChecks.map(check => check.reason || check.value?.error)
  }

  this.healthHistory.get(serverId).add(healthRecord)

  // Schedule next health check
  this.scheduleNextHealthCheck(serverId)

function markServerUnhealthy(serverId, failedChecks):
  serverHealth = this.serverHealth.get(serverId)

  previousStatus = serverHealth.status
  serverHealth.status = 'unhealthy'
  serverHealth.checkInterval = this.config.checkIntervals.unhealthy

  // Activate circuit breaker if configured
  if this.config.circuitBreaker.enabled:
    circuitBreaker = this.circuitBreakers.get(serverId)
    circuitBreaker.recordFailure()
    serverHealth.circuitState = circuitBreaker.getState()

  // Log status change
  if previousStatus !== 'unhealthy':
    this.logHealthStatusChange(serverId, previousStatus, 'unhealthy', failedChecks)
    this.notifyHealthStatusChange(serverId, 'unhealthy')

  // Remove from load balancer pool
  this.removeServerFromPool(serverId)
```

3. Session Affinity and Sticky Sessions

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Purpose: Maintain user session continuity by routing requests from the same user to the same backend server while handling server failures gracefully.

Consistent Hash-Based Session Affinity:

```
SessionAffinityConfig = {
  affinityMethod: 'consistent_hash',   // 'consistent_hash', 'cookie', 'ip_hash'
  sessionTimeout: 1800000,             // 30 minutes
  stickyness: 'soft',                  // 'soft', 'hard'

  cookieConfig: {
    name: 'lb_session',
    httpOnly: true,
    secure: true,
    sameSite: 'strict',
    path: '/'
  },

  failover: {
    enabled: true,
    migrateOnFailure: true,
    maxRetries: 2
  },

  hashRing: {
    virtualNodes: 160,
    hashFunction: 'sha256'
  }
}

class SessionAffinityManager:
  constructor(config):
    this.config = config
    this.sessionStore = new Map()      // sessionId -> server mapping
    this.serverSessions = new Map()    // serverId -> Set of sessions
    this.hashRing = new ConsistentHashRing(config.hashRing)
    this.sessionCleanupTimer = null

  function getServerForSession(sessionId, availableServers):
    existingMapping = this.sessionStore.get(sessionId)

    if existingMapping:
      // Check if assigned server is still available
      if availableServers.includes(existingMapping.serverId):
```

```
      // Update last access time
      existingMapping.lastAccess = Date.now()
      return existingMapping.serverId
    else:
      // Server is unavailable - handle failover
      return this.handleSessionFailover(sessionId, existingMapping, availableServers)

  // No existing session - assign new server
  return this.assignNewSession(sessionId, availableServers)

function assignNewSession(sessionId, availableServers):
  switch this.config.affinityMethod:
    case 'consistent_hash':
      serverId = this.hashRing.getNode(sessionId, availableServers)
      break
    case 'ip_hash':
      serverId = this.selectByIPHash(sessionId, availableServers)
      break
    case 'cookie':
      serverId = this.selectByCookie(sessionId, availableServers)
      break
    default:
      serverId = availableServers[0] // Fallback to first available

  if serverId:
    sessionMapping = {
      sessionId: sessionId,
      serverId: serverId,
      createdAt: Date.now(),
      lastAccess: Date.now(),
      failoverCount: 0
    }

    this.sessionStore.set(sessionId, sessionMapping)

    // Track sessions per server
    if not this.serverSessions.has(serverId):
      this.serverSessions.set(serverId, new Set())
    this.serverSessions.get(serverId).add(sessionId)

  return serverId

function handleSessionFailover(sessionId, sessionMapping, availableServers):
  if not this.config.failover.enabled:
    // Hard stickiness - remove session if server unavailable
```

```
    this.removeSession(sessionId)
    return null

  // Soft stickiness - migrate session to new server
  if sessionMapping.failoverCount >= this.config.failover.maxRetries:
    this.removeSession(sessionId)
    return null

  // Select new server for session
  newServerId = this.selectFailoverServer(sessionId, sessionMapping.serverId, availabl

  if newServerId:
    // Update session mapping
    sessionMapping.serverId = newServerId
    sessionMapping.lastAccess = Date.now()
    sessionMapping.failoverCount++

    // Update server session tracking
    this.updateServerSessionTracking(sessionId, sessionMapping.serverId, newServerId)

    // Migrate session data if configured
    if this.config.failover.migrateOnFailure:
      this.migrateSessionData(sessionId, sessionMapping.serverId, newServerId)

    // Log failover event
    this.logSessionFailover(sessionId, sessionMapping.serverId, newServerId)

  return newServerId

function selectFailoverServer(sessionId, failedServerId, availableServers):
  // Exclude the failed server from available options
  candidateServers = availableServers.filter(id => id !== failedServerId)

  if candidateServers.length === 0:
    return null

  // Use consistent hashing to select new server
  return this.hashRing.getNode(sessionId, candidateServers)

function migrateSessionData(sessionId, oldServerId, newServerId):
  try:
    // Retrieve session data from old server
    sessionData = this.getSessionDataFromServer(oldServerId, sessionId)

    if sessionData:
```

```
      // Transfer session data to new server
      success = this.setSessionDataOnServer(newServerId, sessionId, sessionData)

      if success:
        // Clean up session data from old server
        this.cleanupSessionDataFromServer(oldServerId, sessionId)

        return true
      else:
        logSessionMigrationError(sessionId, oldServerId, newServerId, 'transfer_failed
        return false
    else:
      // No session data found - this is acceptable for stateless sessions
      return true

  catch error:
    logSessionMigrationError(sessionId, oldServerId, newServerId, error.message)
    return false

function cleanupExpiredSessions():
  currentTime = Date.now()
  expiredSessions = []

  for [sessionId, sessionMapping] of this.sessionStore:
    timeSinceAccess = currentTime - sessionMapping.lastAccess

    if timeSinceAccess > this.config.sessionTimeout:
      expiredSessions.push(sessionId)

  // Remove expired sessions
  for sessionId in expiredSessions:
    this.removeSession(sessionId)

  // Schedule next cleanup
  if this.sessionCleanupTimer:
    clearTimeout(this.sessionCleanupTimer)

  this.sessionCleanupTimer = setTimeout(() => {
    this.cleanupExpiredSessions()
  }, 300000) // 5 minutes

function removeSession(sessionId):
  sessionMapping = this.sessionStore.get(sessionId)

  if sessionMapping:
```

```
    // Remove from session store
    this.sessionStore.delete(sessionId)

    // Remove from server session tracking
    serverSessions = this.serverSessions.get(sessionMapping.serverId)
    if serverSessions:
      serverSessions.delete(sessionId)

      if serverSessions.size === 0:
        this.serverSessions.delete(sessionMapping.serverId)

    // Clean up session data from server
    this.cleanupSessionDataFromServer(sessionMapping.serverId, sessionId)
```

4. Auto-Scaling and Capacity Management

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Purpose: Automatically adjust backend server capacity based on traffic patterns, performance metrics, and predictive analysis.

Predictive Auto-Scaling Algorithm:

```
AutoScalingConfig = {
  scalingTriggers: {
    cpuThreshold: 0.7,           // 70% CPU utilization
    memoryThreshold: 0.8,        // 80% memory utilization
    connectionThreshold: 1000,    // 1000 concurrent connections
    responseTimeThreshold: 1000   // 1 second response time
  },

  scalingPolicy: {
    scaleUpCooldown: 300000,     // 5 minutes
    scaleDownCooldown: 900000,   // 15 minutes
    minInstances: 2,
    maxInstances: 50,
    scaleUpFactor: 1.5,          // 50% increase
    scaleDownFactor: 0.8         // 20% decrease
  },

  prediction: {
    enabled: true,
    lookAheadMinutes: 30,        // Predict 30 minutes ahead
    historicalDataPoints: 168,   // 1 week of hourly data
    seasonalityDetection: true,
```

```
    trendAnalysis: true
  }
}

class AutoScalingManager:
  constructor(config):
    this.config = config
    this.metricsHistory = new TimeSeriesDB()
    this.scalingHistory = new Map()
    this.predictiveModel = new TrafficPredictor()
    this.lastScaleAction = Date.now()

  function evaluateScalingDecision():
    currentMetrics = this.collectCurrentMetrics()
    scalingDecision = {
      action: 'none',
      reason: 'within_thresholds',
      confidence: 0,
      targetCapacity: currentMetrics.currentCapacity
    }

    // Check current performance thresholds
    thresholdDecision = this.evaluateThresholdTriggers(currentMetrics)

    // Check predictive scaling if enabled
    predictiveDecision = null
    if this.config.prediction.enabled:
      predictiveDecision = this.evaluatePredictiveScaling(currentMetrics)

    // Combine decisions (predictive takes precedence if confidence is high)
    if predictiveDecision and predictiveDecision.confidence > 0.8:
      scalingDecision = predictiveDecision
    else if thresholdDecision.action !== 'none':
      scalingDecision = thresholdDecision

    // Validate scaling constraints
    scalingDecision = this.validateScalingConstraints(scalingDecision)

    return scalingDecision

  function evaluateThresholdTriggers(metrics):
    violations = []

    // Check CPU threshold
    if metrics.avgCpuUsage > this.config.scalingTriggers.cpuThreshold:
```

```
  violations.push({
    metric: 'cpu',
    value: metrics.avgCpuUsage,
    threshold: this.config.scalingTriggers.cpuThreshold,
    severity: (metrics.avgCpuUsage - this.config.scalingTriggers.cpuThreshold) / thi
  })

// Check memory threshold
if metrics.avgMemoryUsage > this.config.scalingTriggers.memoryThreshold:
  violations.push({
    metric: 'memory',
    value: metrics.avgMemoryUsage,
    threshold: this.config.scalingTriggers.memoryThreshold,
    severity: (metrics.avgMemoryUsage - this.config.scalingTriggers.memoryThreshold)
  })

// Check connection threshold
if metrics.totalConnections > this.config.scalingTriggers.connectionThreshold * metr
  violations.push({
    metric: 'connections',
    value: metrics.totalConnections,
    threshold: this.config.scalingTriggers.connectionThreshold * metrics.currentCapa
    severity: (metrics.totalConnections - this.config.scalingTriggers.connectionThre
  })

// Check response time threshold
if metrics.avgResponseTime > this.config.scalingTriggers.responseTimeThreshold:
  violations.push({
    metric: 'response_time',
    value: metrics.avgResponseTime,
    threshold: this.config.scalingTriggers.responseTimeThreshold,
    severity: (metrics.avgResponseTime - this.config.scalingTriggers.responseTimeThr
  })

if violations.length > 0:
  // Calculate target capacity based on worst violation
  worstViolation = violations.sort((a, b) => b.severity - a.severity)[0]
  targetCapacity = Math.ceil(metrics.currentCapacity * this.config.scalingPolicy.sca

  return {
    action: 'scale_up',
    reason: 'threshold_violation',
    confidence: Math.min(worstViolation.severity, 1.0),
    targetCapacity: targetCapacity,
    violations: violations
```

```
    }

  // Check for scale-down opportunity
  if this.canScaleDown(metrics):
    targetCapacity = Math.max(
      this.config.scalingPolicy.minInstances,
      Math.floor(metrics.currentCapacity * this.config.scalingPolicy.scaleDownFactor)
    )

    return {
      action: 'scale_down',
      reason: 'resource_underutilization',
      confidence: 0.6,
      targetCapacity: targetCapacity
    }

  return { action: 'none', reason: 'within_thresholds' }

function evaluatePredictiveScaling(currentMetrics):
  // Prepare prediction features
  features = this.preparePredictionFeatures(currentMetrics)

  // Get traffic prediction
  prediction = this.predictiveModel.predict(features, this.config.prediction.lookAhead

  if prediction.confidence < 0.5:
    return null // Low confidence prediction

  // Calculate required capacity for predicted traffic
  requiredCapacity = this.calculateRequiredCapacity(prediction.predictedLoad)

  if requiredCapacity > currentMetrics.currentCapacity:
    return {
      action: 'scale_up',
      reason: 'predicted_traffic_increase',
      confidence: prediction.confidence,
      targetCapacity: requiredCapacity,
      prediction: prediction
    }
  else if requiredCapacity < currentMetrics.currentCapacity * 0.7:
    return {
      action: 'scale_down',
      reason: 'predicted_traffic_decrease',
      confidence: prediction.confidence,
      targetCapacity: Math.max(this.config.scalingPolicy.minInstances, requiredCapacit
```

```
      prediction: prediction
    }

  return null

function executeScalingDecision(decision):
  if decision.action === 'none':
    return { success: true, message: 'No scaling needed' }

  // Check cooldown periods
  if not this.canExecuteScaling(decision.action):
    return { success: false, reason: 'cooldown_period_active' }

  try:
    switch decision.action:
      case 'scale_up':
        return this.executeScaleUp(decision)
      case 'scale_down':
        return this.executeScaleDown(decision)

  catch error:
    logScalingError(decision, error)
    return { success: false, error: error }

function executeScaleUp(decision):
  currentCapacity = this.getCurrentCapacity()
  targetCapacity = decision.targetCapacity
  instancesToAdd = targetCapacity - currentCapacity

  // Provision new instances
  newInstances = []

  for i in range(instancesToAdd):
    instance = this.provisionNewInstance()
    newInstances.push(instance)

  // Wait for instances to become ready
  readyInstances = await this.waitForInstancesReady(newInstances)

  // Add instances to load balancer pool
  for instance in readyInstances:
    this.addInstanceToPool(instance)

  // Record scaling action
  this.recordScalingAction(decision, readyInstances.length)
```

```
    return {
      success: true,
      action: 'scale_up',
      instancesAdded: readyInstances.length,
      newCapacity: currentCapacity + readyInstances.length
    }
```

5. Traffic Shaping and QoS Management

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Purpose: Implement quality of service controls and traffic shaping to prioritize critical traffic and prevent system overload.

Priority-Based Traffic Shaping:

```
QoSConfig = {
  trafficClasses: {
    critical: { priority: 1, bandwidth: 0.4, maxLatency: 50 },
    high: { priority: 2, bandwidth: 0.3, maxLatency: 100 },
    normal: { priority: 3, bandwidth: 0.2, maxLatency: 500 },
    low: { priority: 4, bandwidth: 0.1, maxLatency: 2000 }
  },

  rateLimiting: {
    enabled: true,
    globalLimit: 10000,          // 10K requests per second
    perClientLimit: 100,         // 100 requests per second per client
    burstAllowance: 1.5          // 50% burst capacity
  },

  circuitBreaker: {
    enabled: true,
    failureThreshold: 0.5,       // 50% failure rate
    requestVolumeThreshold: 20,   // Minimum 20 requests
    sleepWindow: 60000           // 1 minute recovery period
  }
}

class TrafficShaper:
  constructor(config):
    this.config = config
    this.trafficQueues = new Map()
    this.rateLimiters = new Map()
```

```
  this.circuitBreakers = new Map()
  this.bandwidthAllocator = new BandwidthAllocator(config.trafficClasses)

function classifyRequest(request):
  // Extract request characteristics
  clientId = this.extractClientId(request)
  requestType = this.analyzeRequestType(request)
  userTier = this.getUserTier(clientId)

  // Classify based on multiple factors
  trafficClass = this.determineTrafficClass(requestType, userTier, request)

  return {
    clientId: clientId,
    trafficClass: trafficClass,
    priority: this.config.trafficClasses[trafficClass].priority,
    requestMetadata: {
      type: requestType,
      userTier: userTier,
      estimatedProcessingTime: this.estimateProcessingTime(request)
    }
  }

function shouldAcceptRequest(classification):
  clientId = classification.clientId
  trafficClass = classification.trafficClass

  // Check circuit breaker first
  if this.isCircuitOpen(clientId):
    return { accepted: false, reason: 'circuit_breaker_open' }

  // Check rate limits
  rateLimitResult = this.checkRateLimit(clientId, trafficClass)
  if not rateLimitResult.allowed:
    return { accepted: false, reason: 'rate_limit_exceeded', retryAfter: rateLimitResu

  // Check bandwidth allocation
  bandwidthResult = this.checkBandwidthAllocation(trafficClass)
  if not bandwidthResult.allowed:
    return { accepted: false, reason: 'bandwidth_limit_exceeded' }

  // Check queue capacity
  queueResult = this.checkQueueCapacity(trafficClass)
  if not queueResult.allowed:
    return { accepted: false, reason: 'queue_full' }
```

```
  return { accepted: true }

function enqueueRequest(request, classification):
  trafficClass = classification.trafficClass

  // Get or create traffic queue for this class
  if not this.trafficQueues.has(trafficClass):
    this.trafficQueues.set(trafficClass, new PriorityQueue())

  queue = this.trafficQueues.get(trafficClass)

  // Create request wrapper with metadata
  requestWrapper = {
    request: request,
    classification: classification,
    enqueuedAt: Date.now(),
    processingDeadline: Date.now() + this.config.trafficClasses[trafficClass].maxLaten
  }

  // Enqueue with priority
  queue.enqueue(requestWrapper, classification.priority)

  // Update bandwidth allocation
  this.bandwidthAllocator.recordRequest(trafficClass)

  return requestWrapper

function dequeueNextRequest():
  // Process queues in priority order
  sortedClasses = Object.keys(this.config.trafficClasses)
    .sort((a, b) => this.config.trafficClasses[a].priority - this.config.trafficClasse

  for trafficClass in sortedClasses:
    queue = this.trafficQueues.get(trafficClass)

    if queue and not queue.isEmpty():
      // Check if this class has available bandwidth
      if this.bandwidthAllocator.hasAvailableBandwidth(trafficClass):
        requestWrapper = queue.dequeue()

        // Check if request hasn't exceeded deadline
        if Date.now() <= requestWrapper.processingDeadline:
          this.bandwidthAllocator.allocateBandwidth(trafficClass)
          return requestWrapper
```

```
        else:
          // Request expired - log and continue
          this.logExpiredRequest(requestWrapper)

  return null // No requests available for processing

function determineTrafficClass(requestType, userTier, request):
  // Health check requests
  if this.isHealthCheck(request):
    return 'high'

  // Admin or system requests
  if this.isAdminRequest(request):
    return 'critical'

  // Premium user requests
  if userTier === 'premium':
    return 'high'

  // API requests based on endpoint importance
  if this.isCriticalAPI(request):
    return 'critical'
  else if this.isImportantAPI(request):
    return 'high'

  // Time-sensitive requests (real-time features)
  if this.isRealTimeRequest(request):
    return 'high'

  // Background or batch requests
  if this.isBatchRequest(request):
    return 'low'

  // Default classification
  return 'normal'

function checkRateLimit(clientId, trafficClass):
  rateLimiter = this.getRateLimiter(clientId)

  // Check global rate limit
  globalResult = rateLimiter.checkGlobalLimit()
  if not globalResult.allowed:
    return globalResult

  // Check per-client rate limit
```

```
    clientResult = rateLimiter.checkClientLimit(clientId)
    if not clientResult.allowed:
      return clientResult

    // Check traffic class specific limits
    classResult = rateLimiter.checkClassLimit(trafficClass)

    return classResult

  function recordRequestOutcome(requestWrapper, outcome):
    clientId = requestWrapper.classification.clientId

    // Update circuit breaker
    circuitBreaker = this.getCircuitBreaker(clientId)

    if outcome.success:
      circuitBreaker.recordSuccess()
    else:
      circuitBreaker.recordFailure()

    // Update bandwidth allocator
    this.bandwidthAllocator.recordCompletion(
      requestWrapper.classification.trafficClass,
      outcome.processingTime
    )

    // Update rate limiter
    rateLimiter = this.getRateLimiter(clientId)
    rateLimiter.recordRequest(outcome.success)
```

Performance Optimizations

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Connection Management

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Connection Pooling and Keep-Alive:

```
ConnectionConfig = {
  maxConnectionsPerServer: 1000,
```

```
  connectionTimeout: 30000,
  keepAliveTimeout: 60000,
  maxIdleConnections: 100
}
```

Request Routing Optimization

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Fast Path Routing: - Pre-computed routing tables - Connection pre-warming - Response caching for static content - Request deduplication

Security Considerations

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Load Balancer Security Framework

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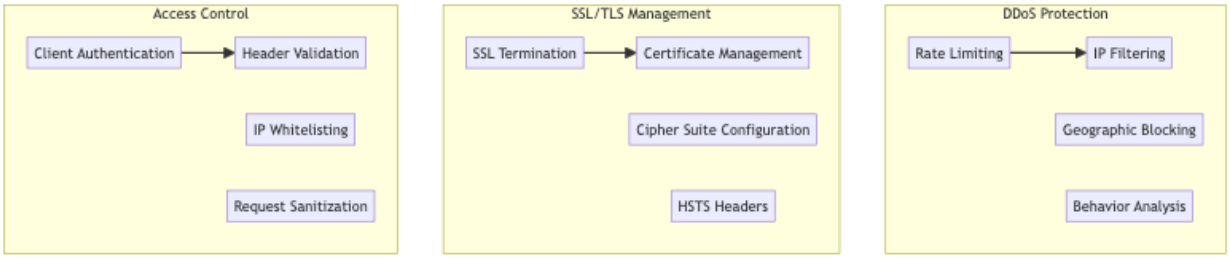

Testing Strategy

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Load Testing

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Performance Testing Scenarios: - Gradual load ramp-up testing - Spike load testing - Sustained load testing - Failover scenario testing

Reliability Testing

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High Availability Testing: - Server failure simulation - Network partition testing - Health check accuracy validation - Session failover testing

Trade-offs and Considerations

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Performance vs Reliability

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- **Health check frequency**: Accuracy vs overhead
- **Session stickiness**: Performance vs fault tolerance
- **Connection pooling**: Resource efficiency vs connection overhead
- **Load balancing algorithms**: Simplicity vs optimal distribution

Scalability vs Cost

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- **Auto-scaling sensitivity**: Responsiveness vs cost optimization
- **Instance sizes**: Resource efficiency vs scaling granularity
- **Geographic distribution**: Latency vs infrastructure cost
- **Redundancy levels**: Availability vs operational expenses

Security vs Performance

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- **SSL/TLS termination**: Security vs processing overhead
- **Request inspection**: Security vs latency
- **DDoS protection**: Protection level vs legitimate traffic impact
- **Access controls**: Security granularity vs complexity

This load balancer system provides a comprehensive foundation for traffic distribution and management with features like intelligent health checking, session affinity, auto-scaling, traffic shaping, and robust security while maintaining high performance, availability, and operational efficiency standards.