NGINX WORKSHOP: From Scaling Problems to High Availability

DevOps Bootcamp

Workshop Overview

"From Scaling Problems → Reverse Proxies → Advanced NGINX → HA Architecture"

In this workshop, we'll explore:

- The challenges of scaling applications with NGINX
- How reverse proxies solve scaling problems
- Using NGINX as a powerful reverse proxy and load balancer
- Advanced NGINX features and configurations
- Building robust architecture patterns with and without orchestration
- Route-based proxying and service composition

The Scaling Problem

Why Scaling Exists

- Traffic spikes and concurrency challenges
- CPU/RAM exhaustion under load
- Server crashes and downtime
- Poor user experience with timeouts and errors

Real-World Analogy

Think of a single cashier at a busy store:

- Customers form long queues
- Some give up and leave
- One point of failure

What Users Experience

- Request timeouts
- 500 Internal Server Errors
- Slow page loads
- Complete service unavailability

Types of Scaling

Vertical Scaling (Scale Up)

- Add more CPU/RAM to the same machine
- **Pros**: Fast implementation, simple
- **Cons**: Limited resources, expensive, SPOF (Single Point of Failure)

Horizontal Scaling (Scale Out)

- Add more instances/containers
- Foundation for modern DevOps and microservices
- **Pros**: Almost unlimited scaling, redundancy

Approaches to Scaling

Using Managed Cloud Infrastructure

- Cloud load balancers and auto-scaling services
- Platform handles scaling automatically
- Health checks and instance management
- **Pros**: Easy to implement, managed service
- **Cons**: Expensive, less control over infrastructure

Scaling Manually on Your VPS

- You control everything (infrastructure + scaling logic)
- Budget-friendly approach for learning
- Requires manual design of:
  - Load balancing mechanisms
  - High availability (HA) patterns
  - Failover procedures
  - Monitoring solutions

The Need for Load Distribution

The Missing Piece

- Adding multiple instances isn't enough
- You need something to distribute traffic among them
- This is where reverse proxies come in

What Problems Need Solving

- How do requests reach the right instance?
- What happens when an instance fails?
- How do users access multiple instances through one URL?
- How do we balance the load evenly?

Reverse Proxies

- Single entry point for your application
- Distributes requests to backend instances
- Handles health checks and failover

Understanding the OSI Model & Load Balancing Layers

The OSI 7-Layer Model

The Open Systems Interconnection model defines how network protocols interact:

1. **Physical** - Cables, signals
2. **Data Link** - MAC addresses, switches
3. **Network** - IP addresses, routing
4. **Transport** - TCP/UDP, ports
5. **Session** - Connection management
6. **Presentation** - Encryption, compression
7. **Application** - HTTP, HTTPS, FTP

L4 vs L7 Load Balancing

Layer 4 (Transport Layer) Load Balancing

- **Works with**: IP addresses and ports only
- **Routing decisions**: Based on source/destination IP and port
- **Protocol awareness**: TCP/UDP level only
- **Performance**: Very fast, low latency
- **Use cases**: When you need maximum performance
- **Example**: Route all traffic to port 80 regardless of URL path

Layer 7 (Application Layer) Load Balancing

- **Works with**: Full HTTP request content
- **Routing decisions**: Based on URLs, headers, cookies, request content
- **Protocol awareness**: Understands HTTP/HTTPS
- **Performance**: Slightly higher latency due to content inspection
- **Use cases**: Advanced routing, microservices, API gateways
- **Example**: Route `/api/*` to API servers, `/static/*` to CDN

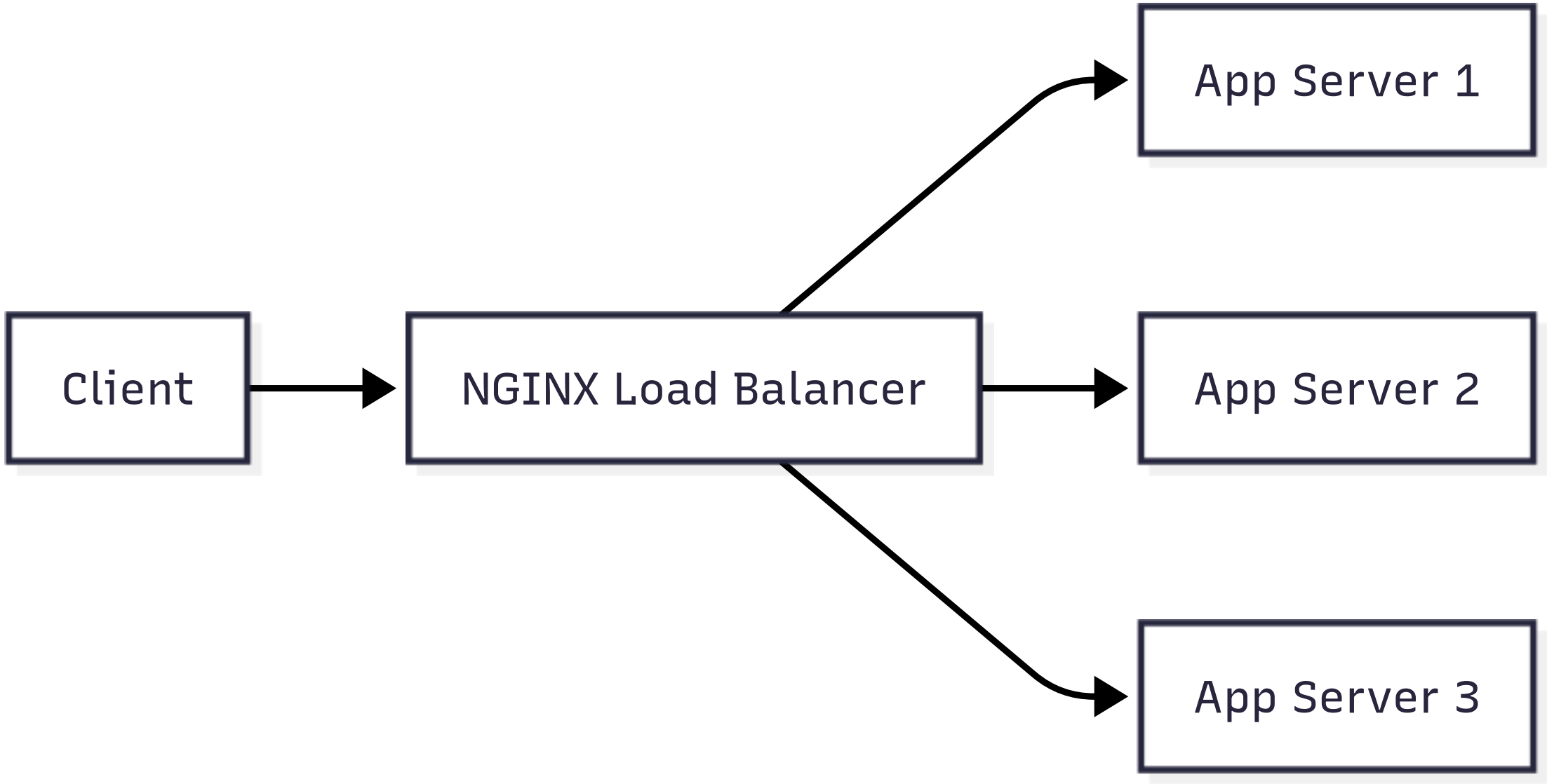
Intro to Reverse Proxies & Load Balancers

Reverse Proxy

- Sits between clients and servers
- Single entry point for applications
- Hides internal architecture complexity
- Can provide security, caching, SSL termination

Load Balancer

- Distributes traffic between multiple instances
- Can be **L4 (Transport Layer)** or **L7 (Application Layer)**
- Ensures high availability
- Provides health checks and failover


Client
NGINX Load Balancer
App Server 1
App Server 2
App Server 3

What is NGINX?

Core Capabilities

- **L7 Reverse Proxy**: Application layer routing
- **Load Balancer**: Traffic distribution
- **Cache**: Content caching for performance
- **Static Server**: Serve static files efficiently
- **API Gateway Lite**: Route API requests
- **SSL Terminator**: Handle HTTPS connections

NGINX as L7 Load Balancer

NGINX operates at Layer 7, which enables:

- Path-based routing (`/api` , `/admin` , `/static`)
- Header-based routing
- Cookie-based session affinity
- Content-based load balancing decisions

Why NGINX is Popular

- High performance and low resource usage
- Extensive documentation and community
- Battle-tested in production environments
- Flexible configuration options

NGINX: Load Distribution, Not Scaling

Important Distinction

- **NGINX does NOT provide scaling by itself**
- NGINX distributes high load across existing instances
- For NGINX to be effective, you need multiple application instances

What NGINX Actually Does

- Distributes incoming requests across multiple backend servers
- Balances load to prevent any single server from being overwhelmed
- Provides health checks to route traffic only to healthy instances

The Real Scaling Challenge

- NGINX can efficiently distribute traffic to 3 instances
- But what if you need 10, 50, or 100+ instances?
- Manual creation and management of instances doesn't scale

This Leads To...

The need for solutions that can automatically add/remove nodes based on demand!

How NGINX Solves Distribution Problems

Request Distribution

- NGINX distributes requests to multiple backend instances
- Various load balancing algorithms available

Health Checks

- Can detect failed backends and avoid routing to them
- Automatic failover to healthy instances

Single Access Point

- Users access a single endpoint
- NGINX handles routing to appropriate backend

Session Management

- Sticky sessions to maintain user state
- Consistent user experience

But Remember

- NGINX handles traffic distribution, not instance creation
- You still need to provision additional instances manually

Load Balancing Techniques with NGINX

Round Robin

- Cycles through servers sequentially
- Simple and fair distribution

Least Connections

- Sends requests to server with fewest active connections
- Better for long-running connections

IP Hash

- Uses client IP to determine target server
- Ensures session persistence

Weighted Strategies

- Assigns different weights to servers
- Accommodates different server capabilities

NGINX Native Support

- All major algorithms supported natively
- Custom configurations possible

How to Use NGINX

Basic Reverse Proxy Config

```
upstream backend {
        server app1:8001;
        server app2:8002;
        server app3:8003;
}

server {
        listen 80;
        location / {
                proxy_pass http://backend;
        }
}
```

Key Features

- Load balancing across containers/instances
- Health checks for backend servers
- SSL termination
- Rate limiting
- Request/response logging
- Custom upstream behavior

NGINX with and without Orchestration

Standalone NGINX Benefits

- Simple setup and management
- No additional complexity from orchestration tools
- Perfect for small to medium applications
- Lower resource overhead

When to Add Orchestration

- Managing many application instances
- Need for auto-scaling based on metrics
- Self-healing capabilities required
- Complex deployment patterns

Key Point

NGINX works perfectly well without Swarm, Kubernetes, or other orchestration tools!

Horizontal Scaling with Multiple Instances

Adding Application Instances Manually

Running multiple app instances:

- Port 8001
- Port 8002
- Port 8003
- ...

NGINX Configuration

```
upstream backend {
        server app1:8001;
        server app2:8002;
        server app3:8003;
}

server {
        listen 80;
        location / {
                proxy_pass http://backend;
        }
}
```

The Limitation

- You must manually add/remove servers from the configuration
- No automatic scaling based on load
- Requires manual intervention to handle traffic spikes

Route-Based Reverse Proxying

Advanced NGINX Feature

NGINX can route requests to different backends based on URL paths:

Example Configuration

```
server {
        listen 80;

        # Route static assets to CDN
        location /static/ {
                proxy_pass http://cdn.example.com;
        }

        # Route API requests to backend services
        location /api/ {
                proxy_pass http://api-backend;
        }

        # Route admin requests to admin service
        location /admin/ {
                proxy_pass http://admin-service;
        }

        # Default route to main application
        location / {
                proxy_pass http://main-app;
        }
}
```

Service Composition with NGINX

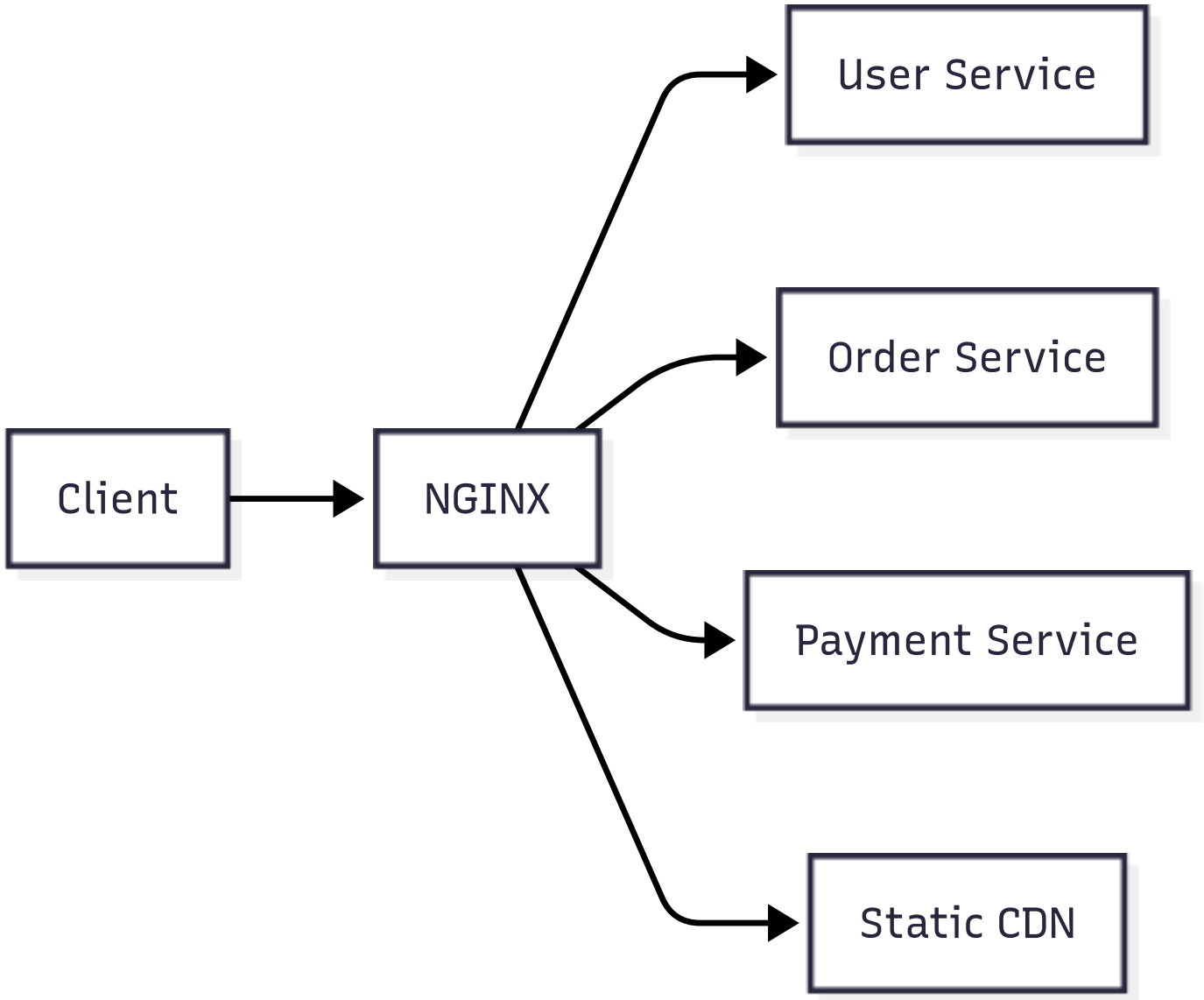
API Gateway Pattern

- Route different paths to different microservices
- Aggregate multiple services behind single domain
- Handle cross-cutting concerns (authentication, rate limiting)
- **Limited API Gateway capabilities**: Requires Lua scripting for advanced auth/authorization
- **Better alternatives**: Dedicated API Gateways like Kong, Zuul, AWS API Gateway, or Istio Gateway
- **NGINX Plus**: Commercial version with enhanced API Gateway features

Static Content Optimization

- Route static content (/static, /images, /css) to CDN
- Serve static files directly from NGINX for performance
- Reduce backend server load

Microservices Architecture



Solutions for Dynamic Scaling (Adding Nodes)

The Next Step: Automatic Instance Management

While NGINX handles load distribution, we need solutions to:

- Automatically add more instances when traffic increases
- Remove instances when traffic decreases
- Handle instance failures automatically
- Manage the lifecycle of application nodes

Orchestration Solutions

- **Docker Swarm**: Native Docker clustering
- **Kubernetes**: Container orchestration platform
- **Cloud Services**: AWS Auto Scaling Groups, GCP Managed Instance Groups

The Complete Picture

```
Internet
        ↓
NGINX (Traffic Distribution)
        ↓
Orchestration Platform (Dynamic Node Management)
        ↓
Auto-scaling Application Instances
```

Load Testing with NGINX

Testing Scenarios

- Single container through NGINX
- Multiple containers with NGINX load balancing
- Route-based proxying performance

Tools for Testing

- `hey` (HTTP load generator)
- `ab` (Apache Bench)
- `k6` (Modern load testing)

Metrics to Compare

- Throughput (requests per second)
- Latency (response times)
- Error rates under load
- Resource utilization

Advanced NGINX Features

Performance Tuning

- **Buffers**: Control memory usage for request/response processing
- **Timeouts**: Configure connection and read/write timeouts
- **Caching**: Store frequently accessed content

Security & Control

- **Rate Limiting**: DDoS protection and traffic control
- **Sticky Sessions**: Ensures session affinity
- **Logging Pipeline**: Integration with ELK stack

Route-Based Features

- **Path Rewriting**: Modify URLs in transit
- **Header Manipulation**: Add, remove, or modify HTTP headers
- **Authentication**: Handle authentication at the proxy layer

Architecture Considerations

When to Use NGINX Standalone

- Small to medium traffic applications
- Simple deployment requirements
- Need for route-based routing
- Cost-sensitive environments

When to Add Dynamic Scaling Later

- High-traffic applications requiring auto-scaling
- Complex deployment requirements
- Need for service mesh features
- Advanced observability needs

Key Takeaway

NGINX handles traffic distribution effectively, but when you need to dynamically add/remove nodes based on demand, orchestration tools become valuable additions.

Advanced Routing Examples

Content Delivery Optimization

```
server {
        listen 80;

        # Static assets to CDN with caching headers
        location ~* \.(jpg|jpeg|png|gif|ico|css|js)$ {
                proxy_pass http://cdn-backends;
                expires 1y;
                add_header Cache-Control "public, immutable";
        }

        # API requests with rate limiting
        location /api/ {
                limit_req zone=api burst=10 nodelay;
                proxy_pass http://api-servers;
        }

        # WebSocket connections
        location /ws/ {
                proxy_pass http://websocket-servers;
                proxy_http_version 1.1;
                proxy_set_header Upgrade $http_upgrade;
                proxy_set_header Connection "upgrade";
        }
}
```

Workshop Conclusion

Key Takeaways

- Scaling is essential for modern applications
- NGINX is a powerful load distribution solution
- Route-based proxying enables service composition
- NGINX works perfectly without orchestration tools
- For dynamic scaling, combine NGINX with orchestration platforms

What You've Learned

- NGINX handles traffic distribution, not instance scaling
- Load balancing across multiple instances
- Route-based proxying for different services
- High availability patterns with NGINX
- When to consider orchestration tools for dynamic node management

Thank you for attending!