

# Configuration: Full Three-Tier Cascaded Setup (TP-Link → Opal → ASUS)

The three-tier cascaded configuration represents the most comprehensive networking solution for complex VR deployments, combining long-range connectivity, intermediate processing, and optimized final delivery. This setup addresses scenarios where VR equipment must be deployed in locations with challenging connectivity requirements, such as separate buildings, outdoor areas, or locations with significant physical obstacles.

## Understanding the Three-Tier Architecture

### The Specialized Role of Each Tier

Think of the three-tier setup as a specialized transportation system, where each stage is optimized for specific challenges:

**Tier 1 (TP-Link CPE):** The long-haul transport layer, designed to capture network connectivity from distant sources or overcome physical obstacles. The CPE excels at long-range, high-gain connections but provides basic routing services.

**Tier 2 (GLiNet Opal):** The processing and adaptation layer, handling complex network requirements like VPN connections, traffic management, and protocol adaptation. The Opal serves as the "diplomatic interface" between institutional requirements and VR needs.

**Tier 3 (ASUS RT-AX1800S):** The final optimization layer, providing WiFi 6 performance, advanced QoS, and VR-specific network features. This tier focuses entirely on creating the optimal wireless environment for VR applications.

### When Three-Tier Configuration is Necessary

**Physical Distance Challenges:** When VR equipment must be deployed more than 100 meters from the network source, the CPE provides the long-range connectivity that standard routers cannot achieve.

**Obstacle Navigation:** Buildings, terrain, or other physical obstacles may require high-gain directional antennas to establish reliable connectivity.

**Signal Boosting Requirements:** Weak institutional WiFi signals may need amplification and optimization before being suitable for VR applications.

**Complex Network Requirements:** Some deployments require VPN connections, multiple authentication methods, or complex traffic management that benefits from distributed processing across multiple devices.

## Comprehensive IP Addressing Architecture

The three-tier setup requires careful IP address planning to prevent conflicts while maintaining clear network hierarchy:

### Tier 1 (TP-Link CPE) - 192.168.1.x:

- **Device IP:** 192.168.1.1
- **DHCP Range:** 192.168.1.100 - 192.168.1.199

- **Purpose:** Provides connectivity from institutional network to Tier 2

#### **Tier 2 (GLiNet Opal) - 192.168.2.x:**

- **WAN IP:** 192.168.1.100 (assigned by CPE)
- **LAN IP:** 192.168.2.1
- **DHCP Range:** 192.168.2.100 - 192.168.2.150
- **Purpose:** Intermediate processing and traffic management

#### **Tier 3 (ASUS Router) - 192.168.10.x:**

- **WAN IP:** 192.168.2.100 (assigned by Opal)
- **LAN IP:** 192.168.10.1
- **VR DHCP Range:** 192.168.10.100 - 192.168.10.200
- **Purpose:** VR-optimized wireless delivery

This addressing scheme ensures clear separation between tiers while preventing IP conflicts that could disrupt network connectivity.

### Detailed Configuration Process

#### **Phase 1: TP-Link CPE Configuration (Long-Range Connectivity)**

1. **Site Survey and Planning** Before configuration, conduct a thorough site survey:
  - **Signal Strength Assessment:** Use the CPE's built-in tools to measure signal strength from the source
  - **Line of Sight Analysis:** Identify any obstacles that might affect signal propagation
  - **Interference Mapping:** Use spectrum analysis to identify potential interference sources
  - **Physical Mounting Planning:** Select optimal mounting locations for both coverage and access
2. **CPE Network Configuration** Configure the CPE for optimal performance in the three-tier architecture:
  - **Operating Mode:** Client mode to receive institutional WiFi, then provide ethernet output
  - **IP Configuration:** Static IP 192.168.1.1 with DHCP enabled for downstream devices
  - **Wireless Settings:** Optimize channel selection and transmission power for source connectivity
  - **Security Configuration:** Match institutional network security requirements
3. **Performance Optimization** Fine-tune the CPE for maximum throughput:
  - **Antenna Alignment:** Use signal strength meters to optimize directional antenna positioning
  - **Channel Selection:** Choose the least congested channel based on spectrum analysis
  - **Transmission Power:** Balance between maximum range and interference minimization
  - **Quality Monitoring:** Establish baseline performance metrics for ongoing monitoring

#### **Phase 2: GLiNet Opal Configuration (Intermediate Processing)**

1. **Connection Establishment** Connect the Opal to the CPE via ethernet:
  - **Physical Connection:** Ethernet cable from CPE LAN port to Opal WAN port
  - **Network Configuration:** Configure Opal WAN as DHCP client to receive 192.168.1.100
  - **Connectivity Verification:** Ensure Opal can access internet through CPE before proceeding

2. **Intermediate Processing Setup** Configure the Opal for its role as the processing tier:

- **LAN Network:** Configure 192.168.2.1 with appropriate DHCP range
- **Traffic Management:** Configure QoS to prioritize downstream ASUS router traffic
- **Security Processing:** Configure VPN client if institutional requirements mandate VPN usage
- **Monitoring Setup:** Enable logging and monitoring for performance tracking

3. **Advanced Services Configuration** Implement advanced networking features:

- **DNS Configuration:** Configure appropriate DNS servers (institutional or public)
- **Firewall Rules:** Configure firewall rules to allow necessary VR traffic while maintaining security
- **Traffic Shaping:** Configure traffic shaping to smooth data flow to the ASUS router

### Phase 3: ASUS Router Configuration (VR Optimization)

1. **Final Tier Connection** Establish the connection between Opal and ASUS router:

- **Physical Connection:** Ethernet from Opal LAN port to ASUS WAN port
- **Network Configuration:** ASUS WAN configured as DHCP client to receive 192.168.2.100
- **LAN Configuration:** Configure ASUS LAN as 192.168.10.1 with VR-appropriate DHCP range

2. **VR-Specific Optimization** Configure the ASUS router specifically for VR performance:

- **WiFi 6 Features:** Enable all available WiFi 6 features (OFDMA, MU-MIMO, 1024-QAM)
- **Channel Configuration:** Select optimal 5GHz channels for VR devices (149-165 range)
- **QoS Configuration:** Configure gaming mode and device-specific QoS rules for VR equipment
- **Security Settings:** Configure appropriate wireless security for VR devices

### Performance Optimization Across All Tiers

#### Bandwidth Management Strategy

##### Tier 1 (CPE) Bandwidth Management:

- **Institutional Connection:** Monitor and document available bandwidth from institutional network
- **Downstream Allocation:** Reserve 80-90% of available bandwidth for Opal router
- **Background Traffic:** Limit CPE management traffic to minimize impact on data flow

##### Tier 2 (Opal) Bandwidth Management:

- **Upstream Optimization:** Configure QoS to efficiently utilize CPE-provided bandwidth
- **VPN Overhead:** Account for VPN encryption overhead if institutional requirements mandate VPN usage
- **ASUS Allocation:** Prioritize ASUS router traffic to ensure consistent VR performance

##### Tier 3 (ASUS) Bandwidth Management:

- **VR Prioritization:** Configure QoS to prioritize VR devices over administrative traffic
- **Device Allocation:** Allocate minimum guaranteed bandwidth per VR device
- **Background Limitation:** Strictly limit bandwidth for non-VR applications

## Latency Optimization

### Expected Latency Characteristics:

- **CPE Processing:** 2-5ms additional latency for wireless-to-ethernet conversion
- **Opal Processing:** 3-7ms additional latency for routing and potential VPN processing
- **ASUS Processing:** 2-5ms additional latency for final wireless delivery
- **Total Added Latency:** 7-17ms through complete three-tier chain

### Latency Reduction Techniques:

- **Hardware Acceleration:** Enable hardware acceleration on all routers where available
- **QoS Prioritization:** Configure strict priority queuing for VR traffic at each tier
- **Processing Optimization:** Disable unnecessary services that could introduce latency
- **Network Monitoring:** Continuously monitor latency to identify performance degradation

## Advanced Integration and Monitoring

### Inter-Tier Communication Optimization

#### Ethernet Connection Quality:

- **Cable Standards:** Use CAT6 or better cables for all inter-router connections
- **Connection Testing:** Test ethernet connections with cable certification equipment
- **Redundancy Planning:** Consider backup connection methods for critical deployments

#### Wireless Interference Management:

 When multiple routers operate in proximity:

- **Channel Separation:** Ensure each wireless-capable router uses different channels
- **Power Management:** Adjust transmission power to minimize interference between tiers
- **Antenna Positioning:** Position antennas to minimize cross-interference

## Comprehensive Performance Monitoring

### Key Performance Indicators (KPIs):

- **End-to-End Throughput:** Measure actual throughput from VR devices to internet
- **Latency Measurements:** Monitor latency at each tier and total system latency
- **Connection Stability:** Track connection drops and reconnection times
- **Bandwidth Utilization:** Monitor bandwidth usage patterns to optimize allocation

### Monitoring Tools and Techniques:

- **Built-in Monitoring:** Use each router's built-in performance monitoring tools
- **Network Testing:** Conduct regular speed tests from VR devices to internet
- **Professional Tools:** Consider professional network monitoring tools for complex deployments
- **Documentation:** Maintain performance logs for trend analysis and troubleshooting

## Troubleshooting the Three-Tier Configuration

### Systematic Troubleshooting Approach

When issues arise in a three-tier configuration, use a systematic approach to isolate problems:

### Step 1: Verify Each Tier Independently

- **CPE Connectivity:** Verify CPE can connect to institutional network independently
- **Opal Functionality:** Test Opal's ability to route traffic when connected directly to CPE
- **ASUS Performance:** Verify ASUS router provides optimal VR performance when connected to Opal

### Step 2: Test Inter-Tier Connections

- **CPE to Opal:** Verify ethernet connectivity and IP assignment
- **Opal to ASUS:** Verify ethernet connectivity and proper routing
- **End-to-End:** Test complete path from VR device to internet

### Step 3: Performance Analysis

- **Bandwidth Testing:** Measure throughput at each tier to identify bottlenecks
- **Latency Analysis:** Measure latency through each tier to identify delays
- **Error Rate Monitoring:** Check for packet loss or errors at each tier

### Common Issues and Solutions

#### Problem: High Latency Through Complete Chain

- **Root Cause Analysis:** Test latency at each tier to identify bottleneck
- **QoS Optimization:** Verify QoS configuration prioritizes VR traffic at each tier
- **Hardware Acceleration:** Ensure hardware acceleration is enabled where available

#### Problem: Inconsistent VR Performance

- **Bandwidth Monitoring:** Check for bandwidth competition from non-VR applications
- **Wireless Interference:** Analyze wireless spectrum for interference sources
- **Connection Stability:** Monitor for intermittent connection issues at any tier

#### Problem: Configuration Complexity

- **Documentation:** Maintain clear documentation of all configuration settings
- **Change Management:** Implement change control procedures for configuration modifications
- **Training:** Ensure multiple team members understand the configuration

### Why Three-Tier Configuration Excels for Complex VR Deployments

The three-tier cascaded setup addresses the most challenging aspects of institutional VR deployments by distributing different network functions across specialized equipment. This approach provides several critical advantages:

**Distance and Obstacle Management:** The CPE tier handles the physical challenges of connecting to distant or obstructed network sources, providing capabilities that standard routers simply cannot match.

**Institutional Network Complexity:** The Opal tier manages the complex authentication, security, and policy requirements that institutions often impose, while providing the processing power needed for VPN connections and traffic management.

**VR Performance Optimization:** The ASUS tier focuses entirely on creating the optimal wireless environment for VR applications, providing WiFi 6 features and advanced QoS without compromising upstream network requirements.

**Fault Isolation and Maintenance:** The three-tier design makes it much easier to identify and resolve network issues. Problems can be isolated to specific tiers, and individual components can be maintained or upgraded without affecting the entire system.

**Scalability and Future-Proofing:** Each tier can be upgraded independently as requirements change or technology advances. This modular approach protects the investment in network infrastructure while allowing for technology evolution.

The complexity of the three-tier setup is justified by the demanding requirements of professional VR deployments in institutional environments. When properly configured and maintained, this architecture provides enterprise-grade performance and reliability for the most challenging VR networking scenarios.