OSPF and BGP Implementation Report

Network Configuration with Four Cisco 4321 Routers

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Executive Summary

This report documents the implementation of OSPF (Open Shortest Path First) and BGP (Border Gateway Protocol) routing protocols on a four-router network using Cisco 4321 routers in Cisco Packet Tracer. The network consists of two Autonomous Systems (AS 100 and AS 200) with OSPF providing intra-AS routing and BGP handling inter-AS routing.

Key Achievements:

- Successfully configured four Cisco 4321 routers with appropriate IP addressing
- Implemented OSPF within each autonomous system for internal routing
- Configured BGP for inter-autonomous system communication
- Established full connectivity between all network segments
- Implemented proper route redistribution between OSPF and BGP

Network Protocols Overview

What is OSPF?

Open Shortest Path First (OSPF) is a link-state interior gateway protocol (IGP) used for routing within an autonomous system.

Key Characteristics:

- **Protocol Type:** Link-state routing protocol
- **Algorithm:** Dijkstra's Shortest Path First algorithm
- **Administrative Distance:** 110

- **Convergence:** Fast convergence due to link-state database
- **Scalability:** Hierarchical design with areas for large networks
- **Metric:** Cost based on bandwidth

Why OSPF is Used:

- Provides loop-free routing within an autonomous system
- Supports equal-cost multi-path (ECMP) routing
- Efficient bandwidth utilization
- Fast convergence after network changes
- Supports VLSM (Variable Length Subnet Masking)

What is BGP?

Border Gateway Protocol (BGP) is an exterior gateway protocol (EGP) used for routing between autonomous systems on the Internet.

Key Characteristics:

- **Protocol Type:** Path-vector routing protocol
- **Administrative Distance:** 20 (eBGP), 200 (iBGP)
- **Convergence:** Slower convergence, policy-based routing
- **Scalability:** Designed for Internet-scale routing
- **Metric:** Path attributes (AS_PATH, LOCAL_PREF, MED, etc.)

Types of BGP:

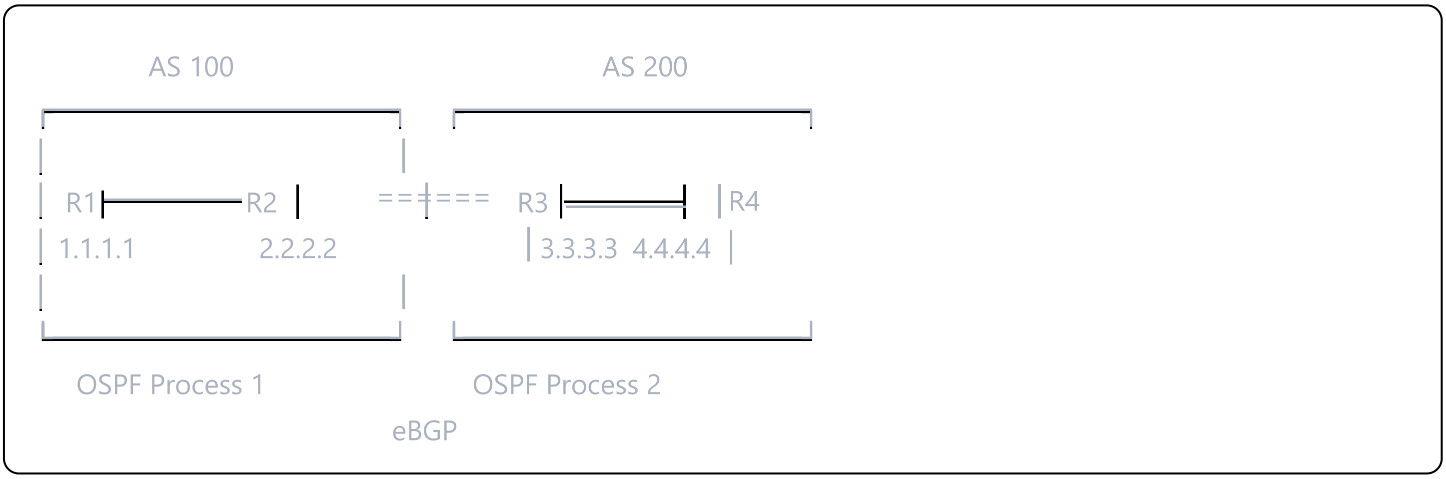
- **eBGP (External BGP):** Between different autonomous systems
- **iBGP (Internal BGP):** Within the same autonomous system

Why BGP is Used:

- Policy-based routing decisions
- Loop prevention through AS_PATH attribute
- Supports complex routing policies
- Essential for Internet connectivity
- Provides redundancy and load balancing

Network Architecture

Physical Topology



IP Addressing Scheme

Router	Interface	IP Address	Subnet Mask	Connected To	Description
R1	G0/0/0	10.0.0.1/30	255.255.255.252	R2	R1-R2 Link
R1	Lo0	1.1.1.1/32	255.255.255.255	Loopback	Router ID
R2	G0/0/0	10.0.0.2/30	255.255.255.252	R1	R2-R1 Link
R2	G0/0/1	10.0.0.5/30	255.255.255.252	R3	R2-R3 Link
R2	Lo0	2.2.2.2/32	255.255.255.255	Loopback	Router ID
R3	G0/0/0	10.0.0.6/30	255.255.255.252	R2	R3-R2 Link
R3	G0/0/1	10.0.0.9/30	255.255.255.252	R4	R3-R4 Link
R3	Lo0	3.3.3.3/32	255.255.255.255	Loopback	Router ID
R4	G0/0/0	10.0.0.10/30	255.255.255.252	R3	R4-R3 Link
R4	Lo0	4.4.4.4/32	255.255.255.255	Loopback	Router ID

Autonomous System Design

- **AS 100:** Contains R1 and R2
  - OSPF Process ID: 1
  - Internal routing via OSPF
  - R2 acts as BGP border router
- **AS 200:** Contains R3 and R4
  - OSPF Process ID: 2
  - Internal routing via OSPF
  - R3 acts as BGP border router

Configuration Implementation

Step 1: Basic Interface Configuration

Router R1 Configuration

```cisco
configure terminal
hostname R1
interface GigabitEthernet0/0/0
 ip address 10.0.0.1 255.255.255.252
 no shutdown

interface loopback0
 ip address 1.1.1.1 255.255.255.255
 no shutdown
```

Router R2 Configuration

```cisco
configure terminal
hostname R2
interface GigabitEthernet0/0/0
 ip address 10.0.0.2 255.255.255.252
 no shutdown

interface GigabitEthernet0/0/1
 ip address 10.0.0.5 255.255.255.252
 no shutdown

interface loopback0
 ip address 2.2.2.2 255.255.255.255
 no shutdown
```

Router R3 Configuration

```
configure terminal
hostname R3
interface GigabitEthernet0/0/0
 ip address 10.0.0.6 255.255.255.252
 no shutdown

interface GigabitEthernet0/0/1
 ip address 10.0.0.9 255.255.255.252
 no shutdown

interface loopback0
 ip address 3.3.3.3 255.255.255.255
 no shutdown
```

Router R4 Configuration

cisco

```
configure terminal
hostname R4
interface GigabitEthernet0/0/0
 ip address 10.0.0.10 255.255.255.252
 no shutdown

interface loopback0
 ip address 4.4.4.4 255.255.255.255
 no shutdown
```

Step 2: OSPF Configuration AS 100

OSPF Configuration (R1 and R2)

Router R1:

cisco

```
router ospf 1
router-id 1.1.1.1
network 10.0.0.0 0.0.0.3 area 0
network 1.1.1.1 0.0.0.0 area 0
```

Router R2:

```cisco
router ospf 1
router-id 2.2.2.2
network 10.0.0.0 0.0.0.3 area 0
network 10.0.0.4 0.0.0.3 area 0
network 2.2.2.2 0.0.0.0 area 0
```

AS 200 OSPF Configuration (R3 and R4) Router R3:

```cisco
router ospf 2
router-id 3.3.3.3
network 10.0.0.4 0.0.0.3 area 0
network 10.0.0.8 0.0.0.3 area 0
network 3.3.3.3 0.0.0.0 area 0
```

Router R4:

```cisco
router ospf 2
router-id 4.4.4.4
network 10.0.0.8 0.0.0.3 area 0
network 4.4.4.4 0.0.0.0 area 0
```

Step 3: BGP Configuration

External BGP (eBGP) Configuration Router R2 (AS 100):

```cisco
router bgp 100
bgp log-neighbor-changes
neighbor 10.0.0.6 remote-as 200
network 1.1.1.1 mask 255.255.255.255
network 2.2.2.2 mask 255.255.255.255
```

Router R3 (AS 200):

```cisco
router bgp 200
bgp log-neighbor-changes
neighbor 10.0.0.5 remote-as 100
network 3.3.3.3 mask 255.255.255.255
network 4.4.4.4 mask 255.255.255.255
```

Step 4: Route Redistribution Configuration

To enable full connectivity between all routers, route redistribution was implemented:

Router R2:

```cisco
router ospf 1
redistribute bgp 100 subnets

router bgp 100
redistribute ospf 1
```

Router R3:

```cisco
router ospf 2
redistribute bgp 200 subnets

router bgp 200
redistribute ospf 2
```

Command Explanations

OSPF Commands Detailed

`router ospf [process-id]`

- **Purpose:** Enables OSPF routing process
- **Parameters:** Process ID (1-65535) - locally significant
- **Usage:** `router ospf 1`

`router-id [ip-address]`

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Purpose: Sets OSPF router identifier

Parameters: IP address format (typically loopback IP)

- **Usage:** `router-id 1.1.1.1`

`network [network] [wildcard-mask] area [area-id]`

- **Purpose:** Advertises networks into OSPF
- **Parameters:**
  - Network: Network address
  - Wildcard mask: Inverse of subnet mask
  - Area: OSPF area number
- **Usage:** `network 10.0.0.0 0.0.0.3 area 0`

BGP Commands Detailed

`router bgp [as-number]`

- **Purpose:** Enables BGP routing process
- **Parameters:** AS number (1-65535)
- **Usage:** `router bgp 100`

`neighbor [ip-address] remote-as [as-number]`

- **Purpose:** Defines BGP neighbor relationship
- **Parameters:**
  - IP address: Neighbor's IP
  - AS number: Neighbor's AS number
- **Usage:** `neighbor 10.0.0.6 remote-as 200`

`network [network] mask [subnet-mask]`

- **Purpose:** Advertises network via BGP
- **Parameters:**
  - Network: Network address
  - Mask: Subnet mask
- **Usage:** `network 1.1.1.1 mask 255.255.255.255`

`redistribute [protocol] [process-id] subnets`

- **Purpose:** Redistributes routes from one protocol to another
- **Parameters:**
  - Protocol: Source routing protocol
  - Process-id: Process identifier
  - Subnets: Include subnet routes
- **Usage:** `redistribute ospf 1 subnets`

Loopback Addresses

What are Loopback Addresses?

Loopback interfaces are virtual interfaces that are always up and reachable as long as the router is functioning. They are not associated with any physical interface.

Why Loopback Addresses are Used

1. **Stable Router ID:** Provides consistent OSPF router identification

2. **BGP Route Advertisement:** Used to advertise specific networks
3. **Management Access:** Provides reliable management access point
4. **Testing Connectivity:** Useful for end-to-end reachability testing
5. **Load Balancing:** Can represent networks for traffic distribution

Loopback Implementation in This Network

Router	Loopback IP	Purpose
R1	1.1.1.1/32	OSPF Router ID, BGP advertisement
R2	2.2.2.2/32	OSPF Router ID, BGP advertisement
R3	3.3.3.3/32	OSPF Router ID, BGP advertisement
R4	4.4.4.4/32	OSPF Router ID, BGP advertisement

Troubleshooting and Testing

Initial Connectivity Issues

Problem Identification

Initial testing revealed that routers could not ping across AS boundaries:

- R4 could not ping R1's loopback (1.1.1.1)
- R1 could not ping R4's loopback (4.4.4.4)

Root Cause Analysis

The issue was identified as asymmetric routing:

1. **Forward Path:** Routes existed via OSPF/BGP
2. **Return Path:** Missing routes for return traffic

Solution Implementation

Route redistribution was implemented to solve the connectivity issue:

```cisco
# On R2 (AS 100 border router)
router ospf 1
redistribute bgp 100 subnets

router bgp 100
redistribute ospf 1

# On R3 (AS 200 border router)
router ospf 2
redistribute bgp 200 subnets

router bgp 200
redistribute ospf 2
```

Verification Commands

OSPF Verification

```cisco
show ip ospf neighbor         # View OSPF neighbor relationships
show ip ospf database         # Display OSPF link-state database
show ip route ospf           # Show OSPF-learned routes
```

BGP Verification

```cisco
show ip bgp summary          # BGP neighbor status and statistics
show ip bgp                  # BGP routing table
show ip route bgp            # Show BGP-learned routes
```

Connectivity Testing

```cisco
ping [destination-ip]                    # Basic connectivity test
ping [destination-ip] source loopback0   # Test with specific source
traceroute [destination-ip]              # Path verification
```

Test Results

OSPF Neighbor Verification

R1 OSPF Neighbors:

```
Neighbor ID     Pri   State           Dead Time   Address         Interface
2.2.2.2           1     FULL/BDR        00:00:39    10.0.0.2        GigabitEthernet0/0/0
```

R3 OSPF Neighbors:

```
Neighbor ID     Pri   State           Dead Time   Address         Interface
4.4.4.4           1     FULL/BDR        00:00:38    10.0.0.10       GigabitEthernet0/1/0
2.2.2.2           1     FULL/BDR        00:00:35    10.0.0.5        GigabitEthernet0/0/0
```

BGP Summary Verification

R3 BGP Summary:

```
BGP router identifier 3.3.3.3, local AS number 200
Neighbor        V    AS MsgRcvd MsgSent   TblVer  InQ OutQ Up/Down  State/PfxRcd
10.0.0.5        4   100       5       3        5    0    0 00:01:02    4
```

Final Connectivity Tests

All connectivity tests were successful after implementing route redistribution:

From R4:

```
R4#ping 1.1.1.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 1.1.1.1, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms

R4#ping 2.2.2.2
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 2.2.2.2, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
```

From R1:

```
R1#ping 3.3.3.3
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 3.3.3.3, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/1/4 ms

R1#ping 4.4.4.4
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 4.4.4.4, timeout is 2 seconds:
!!!!!
Success rate is 100 percent (5/5), round-trip min/avg/max = 1/2/4 ms
```

Network Routing Tables

Final Routing Table Analysis

After successful configuration, the routing tables showed proper route learning:

R4 Routing Table for 1.1.1.1

```
Routing entry for 1.1.1.1/32
Known via "ospf 2", distance 110, metric 20, type intra area
Last update from 10.0.0.9 on GigabitEthernet0/0/0, 00:00:09 ago
Routing Descriptor Blocks:
* 10.0.0.9, from 3.3.3.3, 00:00:09 ago, via GigabitEthernet0/0/0
  Route metric is 20, traffic share count is 1
```

This shows that R4 learned about R1's loopback through OSPF redistribution via R3.

Configuration Best Practices Implemented

1. **Router ID Configuration:** Used loopback addresses for stable router IDs
2. **Area Design:** Used Area 0 (backbone area) for simplified topology
3. **Route Redistribution:** Implemented bidirectional redistribution for full connectivity
4. **BGP Logging:** Enabled neighbor change logging for troubleshooting
5. **Interface Descriptions:** Used meaningful IP addressing scheme

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Conclusion

This project successfully demonstrated the implementation of OSPF and BGP routing protocols in a multiautonomous system environment. The key achievements include:

Technical Accomplishments

1. **Successful Protocol Implementation:** Both OSPF and BGP were properly configured and operational
2. **Inter-AS Connectivity:** Established communication between different autonomous systems
3. **Route Redistribution:** Implemented proper route sharing between protocols
4. **Troubleshooting Resolution:** Identified and resolved connectivity issues through systematic analysis
5. **Network Scalability:** Created a foundation that can be expanded for larger networks

Learning Outcomes

1. **Protocol Understanding:** Gained deep knowledge of OSPF and BGP operation
2. **Troubleshooting Skills:** Developed systematic approach to network problem resolution
3. **Configuration Mastery:** Learned proper implementation of enterprise routing protocols
4. **Network Design:** Understanding of autonomous system design principles

Practical Applications

This configuration demonstrates real-world scenarios where:

- Organizations need to connect multiple sites (autonomous systems)
- Internal routing (OSPF) and external routing (BGP) must coexist
- Route redistribution is required for full connectivity
- Redundancy and scalability are important considerations

The implemented network serves as a solid foundation for understanding enterprise routing architectures and can be extended to include additional features such as route filtering, path manipulation, and redundancy configurations.
