UNIVERSITÀ DI PISA

Department of Information Engineering

# Network Automation and Deployment

## Advanced Networking

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ACADEMIC YEAR 2024/2025

# Contents

# 1 Introduction

- This project automates network deployment and configuration.
- YAML defines network data, and Jinja2 generates configuration files.
- Containerlab is used to create and deploy the network topology.
- The network consists of multiple routers across different autonomous systems (AS).
- BGP (Border Gateway Protocol) is the primary routing protocol for communication.
- The goal is to automate router setups and collect BGP routing data efficiently.

## 1.1 Border Gateway Protocol (BGP)

- BGP is a protocol used to exchange routing information between networks.
- It connects multiple autonomous systems (AS) to form the internet.
- It determines the best path for data transfer based on policies, not distance.
- BGP ensures stable and scalable routing for large networks.
- Both service providers and enterprises use BGP for reliable connectivity.
- It operates in two modes: **iBGP (internal)** and **eBGP (external)**.
  - **iBGP** enables internal routing within an AS for consistency.
  - **eBGP** allows routers in different ASes to communicate.

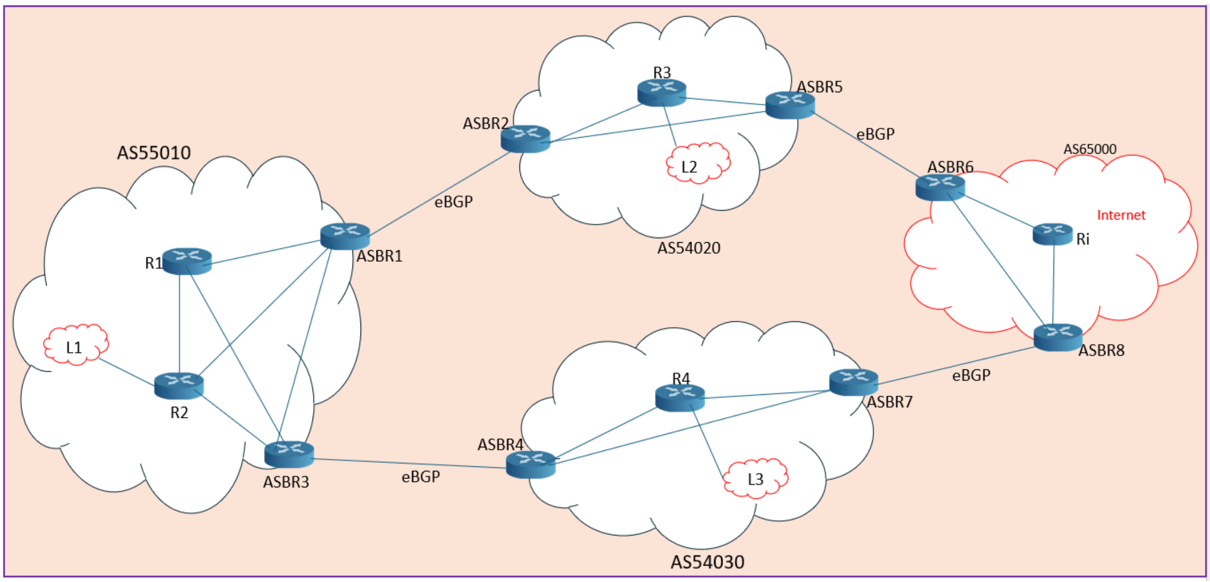


Figure 1: Network topology designed for the project, featuring internal routers (R1, R2, R3, R4), ASBRs (ASBR1–ASBR8), and hosts (h1, h2, h3) for local network. The topology connects multiple autonomous systems (AS55010, AS54020, AS54030, and AS65000) using BGP for routing.

## 1.2 Network Topology and Routing Tables

- The network consists of multiple autonomous systems (AS55010, AS54020, AS54030, and AS65000).
- Each AS has internal routers connected using iBGP for internal routing.
- eBGP(ASBR) is used between ASBR routers to exchange routing information across ASes.

- The topology connects local networks (h1, h2, h3) to their respective AS routers.
- AS65000 represents the external Internet, providing global connectivity.
- The routing table details interfaces, next-hop addresses, and BGP types.
- Loopback interfaces serve as router identifiers and ensure stable routing.
- The table helps visualize BGP peerings and interconnections between ASes.

| Device | Interface | Connected To | IP | Network St | NH | AS Number | BGP Type |
|---|---|---|---|---|---|---|---|
| R1 | Loopback0 | - | 192.168.1.1/32 | 192.168.1.1/32 | - | 55010 | iBGP |
| | eth1 | R2 | 10.1.1.1/30 | 10.1.1.0/30 | 10.1.1.2 | 55010 | iBGP |
| | eth2 | ASBR1 | 10.1.2.1/30 | 10.1.2.0/30 | 10.1.2.2 | 55010 | iBGP |
| | eth3 | ASBR3 | 10.1.3.1/30 | 10.1.3.0/30 | 10.1.3.2 | 55010 | iBGP |
| R2 | Loopback0 | - | 192.168.2.1/32 | 192.168.2.1/32 | - | 55010 | iBGP |
| | eth4 | R1 | 10.1.1.2/30 | 10.1.1.0/30 | 10.1.1.1 | 55010 | iBGP |
| | eth5 | ASBR1 | 10.1.4.1/30 | 10.1.4.0/30 | 10.1.4.2 | 55010 | iBGP |
| | eth6 | ASBR3 | 10.1.5.1/30 | 10.1.5.0/30 | 10.1.5.2 | 55010 | iBGP |
| | eth7 | h1 | 192.168.10.1/24 | 192.168.10.0/24 | - | 55010 | - |
| ASBR1 | Loopback0 | - | 192.168.5.1/32 | 192.168.5.1/32 | - | 55010 | iBGP |
| | eth8 | R1 | 10.1.2.2/30 | 10.1.2.0/30 | 10.1.2.1 | 55010 | iBGP |
| | eth9 | R2 | 10.1.4.2/30 | 10.1.4.0/30 | 10.1.4.1 | 55010 | iBGP |
| | eth10 | ASBR3 | 10.1.6.1/30 | 10.1.6.0/30 | 10.1.6.2 | 55010 | iBGP |
| | eth11 | AS54020 | 10.1.7.1/30 | 10.1.7.0/30 | 10.1.7.2 | 54020 | eBGP |
| ASBR3 | Loopback0 | - | 192.168.7.1/32 | 192.168.7.1/32 | - | 55010 | iBGP |
| | eth12 | R1 | 10.1.3.2/30 | 10.1.3.0/30 | 10.1.3.1 | 55010 | iBGP |
| | eth13 | R2 | 10.1.5.2/30 | 10.1.5.0/30 | 10.1.5.1 | 55010 | iBGP |
| | eth14 | ASBR1 | 10.1.6.2/30 | 10.1.6.0/30 | 10.1.6.1 | 55010 | iBGP |
| | eth15 | AS54030 | 10.1.8.1/30 | 10.1.8.0/30 | 10.1.8.2 | 54030 | eBGP |

Table 1: IP Routing Table for AS55010

| Device | Interface | Connected To | IP | Network St | NH | AS Number | BGP Type |
|---|---|---|---|---|---|---|---|
| R3 | Loopback0 | - | 192.168.3.1/32 | 192.168.3.1/32 | - | 54020 | iBGP |
| | eth23 | ASBR2 | 10.2.1.2/30 | 10.2.1.0/30 | 10.2.1.1 | 54020 | iBGP |
| | eth24 | ASBR5 | 10.2.3.1/30 | 10.2.3.0/30 | 10.2.3.2 | 54020 | iBGP |
| | eth25 | h2 | 192.168.20.1/24 | 192.168.20.0/24 | - | 54020 | - |
| ASBR2 | Loopback0 | - | 192.168.6.1/32 | 192.168.6.1/32 | - | 54020 | iBGP |
| | eth20 | R3 | 10.2.1.1/30 | 10.2.1.0/30 | 10.2.1.2 | 54020 | iBGP |
| | eth21 | ASBR5 | 10.2.2.1/30 | 10.2.2.0/30 | 10.2.2.2 | 54020 | iBGP |
| | eth22 | AS55010 | 10.1.7.2/30 | 10.1.7.0/30 | 10.1.7.1 | 55010 | eBGP |
| ASBR5 | Loopback0 | - | 192.168.9.1/32 | 192.168.9.1/32 | - | 54020 | iBGP |
| | eth26 | ASBR2 | 10.2.2.2/30 | 10.2.2.0/30 | 10.2.2.1 | 54020 | iBGP |
| | eth27 | R3 | 10.2.3.2/30 | 10.2.3.0/30 | 10.2.3.1 | 54020 | iBGP |

| Device | Interface | Connected To | IP | Network St | NH | AS Number | BGP Type |
|---|---|---|---|---|---|---|---|
| | eth28 | AS65000 | 10.3.1.1/30 | 10.3.1.0/30 | 10.3.1.2 | 65000 | eBGP |

Table 2: IP Routing Table for AS54020

| Device | Interface | Connected To | IP | Network St | NH | AS Number | BGP Type |
|---|---|---|---|---|---|---|---|
| R4 | Loopback0 | - | 192.168.4.1/32 | 192.168.4.1/32 | - | 54030 | iBGP |
| | eth43 | ASBR4 | 10.5.2.2/30 | 10.5.2.0/30 | 10.5.2.1 | 54030 | iBGP |
| | eth44 | ASBR7 | 10.5.3.1/30 | 10.5.3.0/30 | 10.5.3.2 | 54030 | iBGP |
| | eth45 | h3 | 192.168.30.1/24 | 192.168.30.0/24 | - | 54030 | - |
| ASBR4 | Loopback0 | - | 192.168.8.1/32 | 192.168.8.1/32 | - | 54030 | iBGP |
| | eth40 | AS55010 | 10.1.8.2/30 | 10.1.8.0/30 | 10.1.8.1 | 55010 | eBGP |
| | eth41 | R4 | 10.5.2.1/30 | 10.5.2.0/30 | 10.5.2.2 | 54030 | iBGP |
| | eth42 | ASBR7 | 10.5.4.1/30 | 10.5.4.0/30 | 10.5.4.2 | 54030 | iBGP |
| ASBR7 | Loopback0 | - | 192.168.11.1/32 | 192.168.11.1/32 | - | 54030 | iBGP |
| | eth50 | R4 | 10.5.3.2/30 | 10.5.3.0/30 | 10.5.3.1 | 54030 | iBGP |
| | eth51 | ASBR4 | 10.5.4.2/30 | 10.5.4.0/30 | 10.5.4.1 | 54030 | iBGP |
| | eth48 | AS65000 | 10.6.1.1/30 | 10.6.1.0/30 | 10.6.1.2 | 65000 | eBGP |

Table 3: IP Routing Table for AS54030

| Device | Interface | Connected To | IP | Network St | NH | AS Number | BGP Type |
|---|---|---|---|---|---|---|---|
| Ri | Loopback0 | - | 192.168.13.1/32 | 192.168.13.1/32 | - | 65000 | iBGP |
| | eth64 | ASBR6 | 10.4.1.2/30 | 10.4.1.0/30 | 10.4.1.1 | 65000 | iBGP |
| | eth65 | ASBR8 | 10.5.1.1/30 | 10.5.1.0/30 | 10.5.1.2 | 65000 | iBGP |
| ASBR6 | Loopback0 | - | 192.168.10.1/32 | 192.168.10.1/32 | - | 65000 | iBGP |
| | eth61 | AS54020 | 10.3.1.2/30 | 10.3.1.0/30 | 10.3.1.1 | 54020 | eBGP |
| | eth62 | Ri | 10.4.1.1/30 | 10.4.1.0/30 | 10.4.1.2 | 65000 | iBGP |
| | eth63 | ASBR8 | 10.6.2.1/30 | 10.6.2.0/30 | 10.6.2.2 | 65000 | iBGP |
| ASBR8 | Loopback0 | - | 192.168.12.1/32 | 192.168.12.1/32 | - | 65000 | iBGP |
| | eth66 | AS54030 | 10.6.1.2/30 | 10.6.1.0/30 | 10.6.1.1 | 54030 | eBGP |
| | eth67 | Ri | 10.5.1.2/30 | 10.5.1.0/30 | 10.5.1.1 | 65000 | iBGP |
| | eth68 | ASBR6 | 10.6.2.2/30 | 10.6.2.0/30 | 10.6.2.1 | 65000 | iBGP |

Table 4: IP Routing Table for AS65000

# 2 Task1 : Network Automation System

- **Device Provisioning**:
  - Automated creation of startup-config files for all routers using a **YAML data store** and **Jinja2 templates**.
  - Parameters such as **IP addresses**, **AS numbers**, and **BGP neighbors** are dynamically configured.
- **Configuration Generation**:
  - Example: Generated `R1` configuration includes:
    - Loopback and interface IPs.
    - BGP configuration with router ID, neighbors, and network statements.
- **Efficiency and Scalability**:
  - The system allows network administrators to **easily specify parameters** and generate configurations for multiple routers, reducing manual effort and ensuring consistency.

```yaml
routers:
  R1:
    interfaces:
      Loopback0:
        ip: 192.168.1.1/32
      eth1:
        ip: 10.1.1.1/30
      eth2:
        ip: 10.1.2.1/30
      eth3:
        ip: 10.1.3.1/30
    bgp:
      as: 55010
      neighbors:
        - ip: 10.1.1.2
          as: 55010
        - ip: 10.1.2.2
          as: 55010
        - ip: 10.1.3.2
          as: 55010
```

(a) YAML Data

```
hostname R1
service routing protocols model multi-agent
ip routing

interface Loopback0
 ip address 192.168.1.1/32
 no shutdown

interface eth1
 no switchport
 ip address 10.1.1.1/30
 no shutdown

interface eth2
 no switchport
 ip address 10.1.2.1/30
 no shutdown

interface eth3
 no switchport
 ip address 10.1.3.1/30
 no shutdown

router bgp 55010
 bgp router-id 192.168.1.1
 neighbor 10.1.1.2 remote-as 55010
 neighbor 10.1.2.2 remote-as 55010
 neighbor 10.1.3.2 remote-as 55010
 neighbor 10.1.1.2 next-hop-self
 neighbor 10.1.2.2 next-hop-self
 neighbor 10.1.3.2 next-hop-self
 network 192.168.1.1/32
 network 10.1.1.0/30
 network 10.1.2.0/30
```

(b) Rendered CFG

Figure 2: Router 1 YAML data and corresponding configuration file generated using Jinja2 templates. The YAML file defines parameters such as IP addresses, AS numbers, and BGP neighbors, while the rendered CFG file applies these configurations.

# 3 Task 2: Network Deployment

## 3.1 Network Deployment

- Internal Routers:
  - R1, R2, R3, R4 are internal routers within AS55010, handling intra-AS routing.
  - All internal routers are running with IPv4 and IPv6 addresses assigned.
- Autonomous System Border Routers (ASBRs):
  - ASBR1 to ASBR8 are border routers that peer with external ASes (e.g., AS54020, AS54030).
  - All ASBRs are running and have both IPv4 and IPv6 addresses
- Hosts:
  - h1, h2, h3 are Linux hosts connected to the network for testing and validation.
  - All hosts are running with IPv4 and IPv6 addresses.

.

| Name | Kind/Image | State | IPv4/6 Address |
|---|---|---|---|
| clab-bgp-ASBR1 | ceos<br>ceos:4.33.1F | running | 172.20.20.3<br>3fff:172:20:20::3 |
| clab-bgp-ASBR2 | ceos<br>ceos:4.33.1F | running | 172.20.20.12<br>3fff:172:20:20::c |
| clab-bgp-ASBR3 | ceos<br>ceos:4.33.1F | running | 172.20.20.11<br>3fff:172:20:20::b |
| clab-bgp-ASBR4 | ceos<br>ceos:4.33.1F | running | 172.20.20.15<br>3fff:172:20:20::f |
| clab-bgp-ASBR5 | ceos<br>ceos:4.33.1F | running | 172.20.20.2<br>3fff:172:20:20::2 |
| clab-bgp-ASBR6 | ceos<br>ceos:4.33.1F | running | 172.20.20.14<br>3fff:172:20:20::e |
| clab-bgp-ASBR7 | ceos<br>ceos:4.33.1F | running | 172.20.20.9<br>3fff:172:20:20::9 |
| clab-bgp-ASBR8 | ceos<br>ceos:4.33.1F | running | 172.20.20.7<br>3fff:172:20:20::7 |

| | | | |
|---|---|---|---|
| clab-bgp-R1 | ceos<br>ceos:4.33.1F | running | 172.20.20.10<br>3fff:172:20:20::a |
| clab-bgp-R2 | ceos<br>ceos:4.33.1F | running | 172.20.20.8<br>3fff:172:20:20::8 |
| clab-bgp-R3 | ceos<br>ceos:4.33.1F | running | 172.20.20.4<br>3fff:172:20:20::4 |
| clab-bgp-R4 | ceos<br>ceos:4.33.1F | running | 172.20.20.6<br>3fff:172:20:20::6 |
| clab-bgp-Ri | ceos<br>ceos:4.33.1F | running | 172.20.20.5<br>3fff:172:20:20::5 |
| clab-bgp-h1 | linux<br>alpine:latest | running | 172.20.20.16<br>3fff:172:20:20::10 |
| clab-bgp-h2 | linux<br>alpine:latest | running | 172.20.20.13<br>3fff:172:20:20::d |
| clab-bgp-h3 | linux<br>alpine:latest | running | 172.20.20.17<br>3fff:172:20:20::11 |

```
(venv) root@Containerlab4:~/networking_project/task2#
```

Figure 3: Network deployment using Containerlab, showing the successful initialization of routers (R1, R2, R3, R4), ASBRs (ASBR1–ASBR8), and hosts (h1, h2, h3). The deployment ensures proper connectivity and routing across all devices.

### 3.1.1 DHCP Configuration

- IPv4 DHCP Server:
  - Active on interface Ethernet7 with subnet 192.168.10.0/24.
  - Address range: 192.168.10.10 to 192.168.10.99 (1 out of 90 addresses leased).
- DNS and Gateway:
  - DNS server: 8.8.8.8.
- Lease Duration:
  - Lease duration: 1 day.

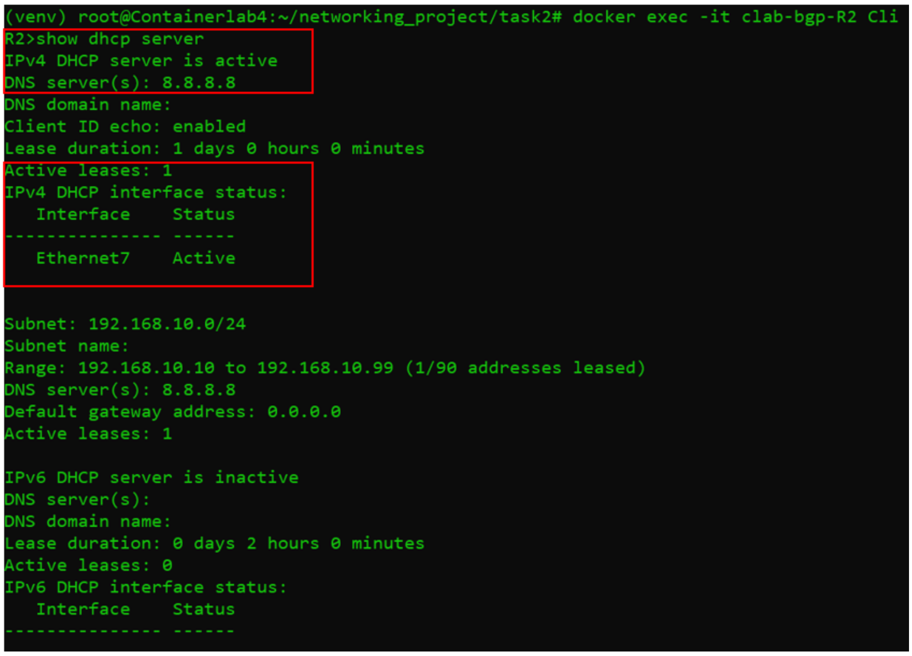


Figure 4: DHCP server configuration on R2, with the subnet `192.168.10.0/24` and address range `192.168.10.10 to 192.168.10.99`. The server provides dynamic IP assignment to hosts connected to `eth7`.

### 3.1.2 BGP Announcement for Local Host

- All local networks (including Loopback and connected interfaces) are correctly announced through BGP.
- The DHCP server network (192.168.10.0/24) is advertised and marked as valid and active in the BGP table.
- Traffic flow is verified, ensuring that the local host can communicate through the preferred BGP exit point.

```
(venv) root@Containerlab4:~/networking_project/task2# docker exec -it clab-bgp-R2 Cli
R2>show ip bgp neighbors 10.1.1.1 advertised-routes
BGP routing table information for VRF default
Router identifier 192.168.2.1, local AS number 55010
Route status codes: s - suppressed contributor, * - valid, > - active, E - ECMP head, e - ECMP
                    S - Stale, c - Contributing to ECMP, b - backup, L - labeled-unicast, q - Queued for advertisement
                    % - Pending best path selection
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI Origin Validation codes: V - valid, I - invalid, U - unknown
AS Path Attributes: Or-ID - Originator ID, C-LST - Cluster List, LL Nexthop - Link Local Nexthop

          Network                Next Hop              Metric  AIGP       LocPref Weight  Path
 * >      10.1.1.0/30            10.1.1.2              -       -          100     -       i
 * >      10.1.4.0/30            10.1.1.2              -       -          100     -       i
 * >      10.1.5.0/30            10.1.1.2              -       -          100     -       i
 * >      192.168.2.1/32         10.1.1.2              -       -          100     -       i
 * >      192.168.10.0/24        10.1.1.2              -       -          100     -       i
R2>show ip bgp 192.168.10.0/24
BGP routing table information for VRF default
Router identifier 192.168.2.1, local AS number 55010
BGP routing table entry for 192.168.10.0/24
 Paths: 1 available
  Local
    - from - (192.168.2.1)
      Origin IGP, metric -, localpref -, IGP metric -, weight 0, tag 0
      Received 11:18:00 ago, valid, local, best, redistributed (Connected)
      Rx SAFI: Unicast
R2>
```

Figure 5: BGP announcement of the local host network (`192.168.10.0/24`) from R2. The route is marked as valid and active, ensuring the host can communicate through the preferred BGP exit point.

#### 3.1.3 Transit Configuration

- AS54020 and AS54030 are configured as transit ASes for AS55010.
  - AS Path Verification:
    - Routes from AS55010 show the correct AS path (54020 55010 i and 54030 55010 i).
    - Routes to AS54020 and AS54030 include 55010 i in the AS path.
  - Traffic Flow:
    - Traffic is routed through AS54020 and AS54030, ensuring transit functionality for AS55010.

```
(venv) root@Containerlab4:~/networking_project/task2# docker exec -it clab-bgp-Ri Cli
Ri>show ip bgp
BGP routing table information for VRF default
Router identifier 192.168.13.1, local AS number 65000
Route status codes: s - suppressed contributor, * - valid, > - active, E - ECMP head, e - ECMP
                    S - Stale, c - Contributing to ECMP, b - backup, L - labeled-unicast
                    % - Pending best path selection
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI Origin Validation codes: V - valid, I - invalid, U - unknown
AS Path Attributes: Or-ID - Originator ID, C-LST - Cluster List, LL Nexthop - Link Local Nexthop

          Network                Next Hop              Metric  AIGP       LocPref Weight  Path
 * >      10.1.1.0/30            10.4.1.1              0       -          100     0       54020 55010 i
 *        10.1.1.0/30            10.5.1.2              0       -          100     0       54030 55010 i
 * >      10.1.2.0/30            10.4.1.1              0       -          100     0       54020 55010 i
 *        10.1.2.0/30            10.5.1.2              0       -          100     0       54030 55010 i
 * >      10.1.3.0/30            10.4.1.1              0       -          100     0       54020 55010 i
 *        10.1.3.0/30            10.5.1.2              0       -          100     0       54030 55010 i
 * >      10.1.4.0/30            10.4.1.1              0       -          100     0       54020 55010 i
```

Figure 6: Transit configuration for AS55010, showing routes advertised to AS54020 and AS54030. The AS path (`54020 55010 i` and `54030 55010 i`) confirms proper transit functionality.

#### 3.1.4 Preference Configuration (ASBR1)

- Higher Local Preference:
  - Routes received from 10.1.7.2 (AS54020) have a local preference of 300, making them the preferred paths.
- Internal Routes:
  - Internal routes (e.g., 10.5.4.1/30) have the default local-preference 100 and are marked as active.

- Traffic Flow:
  - Traffic is preferentially routed through AS54020 (10.1.7.2) due to the higher local preference, ensuring optimal exit point selection.

```
ASBR1>show ip bgp
BGP routing table information for VRF default
Router identifier 192.168.5.1, local AS number 55010
Route status codes: s - suppressed contributor, * - valid, > - active, E - ECMP head, e - ECMP
                    S - Stale, c - Contributing to ECMP, b - backup, L - labeled-unicast
                    % - Pending best path selection
Origin codes: i - IGP, e - EGP, ? - incomplete
RPKI Origin Validation codes: V - valid, I - invalid, U - unknown
AS Path Attributes: Or-ID - Originator ID, C-LST - Cluster List, LL Nexthop - Link Local Nexthop

          Network                Next Hop              Metric  AIGP       LocPref Weight  Path
 * >      10.4.1.0/30            10.1.7.2              0       -          300     0       54020 65000 i
 * >      10.5.1.0/30            10.1.7.2              0       -          300     0       54020 65000 i
 * >      10.5.2.0/30            10.1.6.2              0       -          100     0       54030 i
 * >      10.5.3.0/30            10.1.6.2              0       -          100     0       54030 i
 * >      10.5.4.0/30            10.1.6.2              0       -          100     0       54030 i
 * >      10.6.1.0/30            10.1.7.2              0       -          300     0       54020 65000 i
 * >      10.6.2.0/30            10.1.7.2              0       -          300     0       54020 65000 i
```

Figure 7: Preference configuration on ASBR1, with a local preference of 300 for routes received from `10.1.7.2` (AS54020). These routes are marked as active, ensuring optimal exit point selection.

#### 3.1.5 ASBR Peering Negotiation

- Internal Peering:
  - Neighbors 10.1.2.1, 10.1.4.1, and 10.1.6.2 (AS55010) are in the Established state for IPv4 Unicast.
  - All internal peers have successfully negotiated and exchanged routes.
- External Peering:
  - Neighbor 10.1.7.2 (AS54020) is in the Established state for IPv4 Unicast.
  - External peering is successfully negotiated, and routes are exchanged.
- Stable Sessions::
  - All BGP sessions (internal and external) show stable uptime and no queued messages, indicating healthy peering.

```
(venv) root@Containerlab4:~/networking_project/task2# docker exec -it clab-bgp-ASBR1 Cli
ASBR1>show bgp summary
BGP summary information for VRF default
Router identifier 192.168.5.1, local AS number 55010
Neighbor          AS Session State AFI/SAFI              AFI/SAFI State   NLRI Rcd   NLRI Acc
-------- ----------- ------------- --------------------- -------------- ---------- ----------
10.1.2.1       55010 Established   IPv4 Unicast          Negotiated              4          4
10.1.4.1       55010 Established   IPv4 Unicast          Negotiated              5          5
10.1.6.2       55010 Established   IPv4 Unicast          Negotiated             19         19
10.1.7.2       54020 Established   IPv4 Unicast          Negotiated             16         16
ASBR1>show ip bgp summary
BGP summary information for VRF default
Router identifier 192.168.5.1, local AS number 55010
Neighbor Status Codes: m - Under maintenance
  Neighbor V AS           MsgRcvd   MsgSent  InQ OutQ  Up/Down State   PfxRcd PfxAcc
  10.1.2.1 4 55010            793       800    0    0 11:08:34 Estab   4      4
  10.1.4.1 4 55010            800       804    0    0 11:12:20 Estab   5      5
  10.1.6.2 4 55010            787       794    0    0 11:06:42 Estab   19     19
  10.1.7.2 4 54020            795       788    0    0 11:04:46 Estab   16     16
ASBR1>
```

Figure 8: ASBR1 peering status, showing established BGP sessions with internal neighbors (`10.1.2.1`, `10.1.4.1`, `10.1.6.2`) and external neighbor `10.1.7.2` (AS54020). All sessions are stable and exchanging routes.

# 4 Task 3: BGP Monitoring System

## 4.1 Monitoring

- BGP Monitoring Data:
  - JSON files (e.g., ASBR1_bgp_monitor.json) are generated for each router, capturing BGP routing information.
  - Each file includes details such as hostname, routerId, asn, and bgpRouteEntries.
- Route Details:
  - BGP route entries (e.g., 10.1.1.0/30) include nextHop, localPreference, and routeType (e.g., active, valid).
  - Routes are marked as active and valid, indicating proper BGP operation.
- Comprehensive Coverage:
  - Monitoring covers all routers (ASBR1 to ASBR8, R1 to R4, and Ri), ensuring full visibility into the network's BGP state.

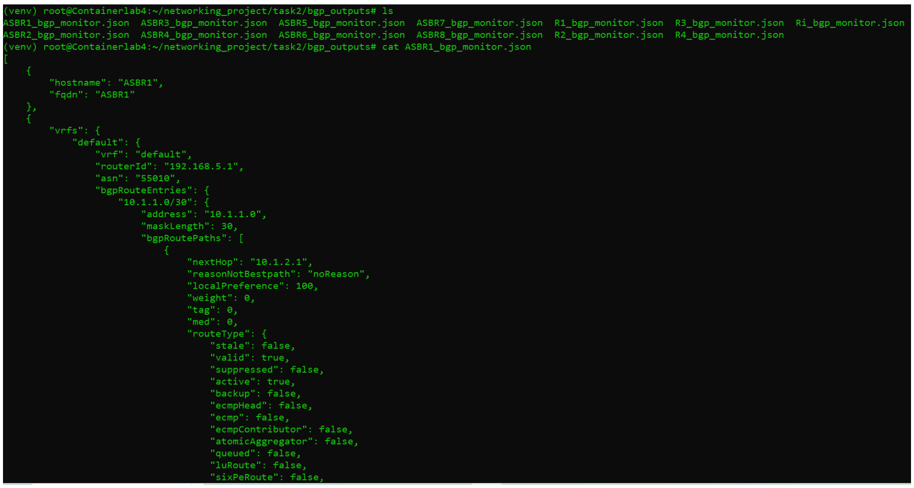


Figure 9: BGP monitoring system output, showing JSON files generated for each router (e.g., `ASBR1_bgp_monitor.json`). The files capture BGP routing information, including active routes, next-hop addresses, and local preferences.

# 5 Conclusion

- **Automated Device Provisioning:** Used Jinja2 and Python to generate startup configurations dynamically.
- **Deployed a Fully Functional Network:** Established a multi-AS topology with BGP configurations using Containerlab and Arista cEOS.
- **Implemented BGP Monitoring:** Developed an automated system to track BGP peering and routing information via Arista eAPI.