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Optimizing OSPF Cost Value for Best Path Selection Using Metric-Type Variation

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Abstract

Open Shortest Path First (OSPF) is a multi-vendor routing standard. Any routing protocol's goal is to discover the optimum path between source and destination addresses inside a computer network. Other routing protocols include Routing Information Protocol (RIP), Border Gateway Protocol (BGP), Enhanced Interior Gateway Routing Protocol (EIGRP), and IS-IS. which are also used in computer networking. Each routing protocol has different set of rules through which they calculate the best path selection. OSPF is often used with the combination of these routing protocol because of its flexible design. This research focuses on the implementation of OSPF network cost (metric) value for best path calculation using network simulation tool like GNS3 for getting correct outcome just like a real networking device working in a live production environment. This research would use the different combinations of OSPF cost calculation using metric-types for external routes learned from different routing protocols like RIP. Being able to accurately identify cost (metric) values obtain by testing for OSPF when used with other routing protocols, just like a real-world environment.

Keywords: *Cost; Metric-type; Network; OSPF; Redistribution.*

1. Introduction

To build a computer network the routing protocols and routed protocols are used together as a single unit. The two most used internet routing protocols are Border Gateway Protocol (BGP) and Open Shortest Path First (OSPF). These routing protocols are responsible for determining the optimum way among the network's many links (paths). These routing protocols work continually to determine the optimum way across the network, whereas routed protocols such as IPv4, IPv6, IPX, AppleTalk, and others carry actual data, i.e., user traffic. [1] These routed protocols use various frame formats, but the aim is the same. The purpose is to transport user traffic from one source to another and so on. Border Gateway Protocol (BGP) is the dominant choice for public networks such as the internet since it allows for greater flexibility in terms of path selection, traffic shaping, policy manipulation, and so on. BGP is primarily used by Internet Service Providers (ISP) and Service Providers (SP) operating as Autonomous Systems (AS) to send public traffic across the internet. OSPF, on the other hand, is employed within the organisation because of its scalable and flexible architecture, which allows for internal maintenance. Another advantage of OSPF is that it is an Industry Standard protocol, which implies that various companies such as CISCO, Juniper, Huawei, Dell, and others utilise OSPF as a common routing protocol for interoperability. [2] The goal of this research is to improve the path selection cost mechanism in OSPF by using the default cost measure for various types of connections in a real-time production environment.

2. Current Working Method

In every network, the fundamental goal is to convey data from the source device serving as a sender to the destination device. A network is made up of numerous components, such as a router, switch, firewall, server, access point, Wireless Lan Controller, and so on. These devices might be hardware- or software-based. To work, these gadgets rely on several protocols. Protocols such as IPv4, IPv6, IPX, and others offer a framework for carrying user traffic and are referred to as routing protocols. Protocols such as EIGRP, RIP, OSPF, and BGP, which try to discover the optimum path across the network, are known as routing protocols. These routing protocols are broadly classed.

- Interior Gateway Protocol (IGP)
- Exterior Gateway Protocol (EGP)

The categorization is based on their functioning capabilities, which includes whether they are employed inside a single administrative domain known as an Autonomous System (AS) or can communicate with two or more Autonomous Systems. Autonomous System (AS) is described as a single large organisation capable of managing its own network and possessing a unique AS number worldwide. These organisations are allocated a unique number on the internet for identifying purposes. These AS work together to forward communications across a shared network known as the internet. The Interior Gateway Protocol (IGP) is a set of protocols that only function within a single AS. These cannot be used to transmit information between distinct AS. The well-known IGPs include Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), Open Shortest Path First (OSPF), Intermediate System to Intermediate System (IS-IS), and so on. These routing protocols function solely inside a single AS. [3] Exterior Gateway Protocols (EGP) are those that facilitate the exchange of information between different Autonomous Systems. These are often used on the internet to communicate public network information from one AS to another. Border Gateway Protocol (BGP) is the sole protocol that currently falls under this category of EGP. BGP is the mechanism that operates the internet by exchanging routes between various AS throughout the world. [4] However, within the AS, OSPF is the dominant choice for managing the internal network. OSPF and RIP are both open standards that may be implemented by any manufacturer. Because of its hierarchical design, OSPF offers far greater flexibility and scalability than RIP. OSPF may also be employed in a multi-vendor scenario and is the best option among all IGPs. The purpose of all routing protocol is the same: compute the optimal path available in the network. Different routing protocols use different methods to analyse and determine the optimum path. Routers share routing updates, which include information such as the Autonomous System (AS) number, Administrative Distance (AD), Metric values, and network interface information. [5] Administrative Distance (AD) indicates the dependability of the source utilised to choose the optimum path in the network. The lower the value, the more trustworthy the source, resulting in a better pick when compared to other higher-value sources. For example, the AD value of OSPF is less (110) as compared to RIP (120) i.e. OSPF is better and more trusted than RIP protocol in CISCO based network. Metric is next parameter used by networking devices (routers) to decide which path is better if there are multiple paths with the same AD value. When many pathways have comparable AD values, the one with the lowest metric value is chosen as the best path. [6] OSPF calculates the metric (cost) parameter based on the interface bandwidth. RIP, on the other hand, calculates metrics based on network paths using hops. When many routing protocols are utilised, there is a requirement for redistribution, which is the mutual knowledge of the rules of each routing protocol. This is accomplished by exchanging information between routing protocols. Information is transferred at both ends, thus the term "mutual redistribution." [9-12] Some popular Administrative Distance values that are used in networking equipment, mainly by CISCO vendors, include All routing protocols generate topology tables, which are then exchanged with neighbours to learn about the network. Networking equipment, such as routers, share information contained in these tables to better comprehend the network's design.

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Table 1 Different AD Values for CISCO

Device Source	Value
Directly Connected	0
Static Route	1
External BGP	20
EIGRP (Internal)	90
OSPF	110
RIP	120
Internal BGP	200
Unreachable	255

From these topology tables the best routes are placed in routing table for final lookup during the forwarding phase [7]. During redistribution the Topology Table build by each routing protocol is exchanged with other routing protocol. This sharing of topology table helps the devices to learn about the network design at another end. OSPF and RIP both uses different algorithm (mechanism) during the redistribution phase. OSPF uses parameters like bandwidth to calculate the metric or cost for the path used while RIP uses parameters like hop-count i.e. how many hops away is the redistributed router for calculation of path metric. [8]

3. Tools and Topology Used

In this research investigation, the generally used network topology was adopted. This topology consists of networking equipment such as routers, switches, computers, and servers. These are used to imitate a real-time live environment, producing the same results as actual devices in a production or live deployment. Simulators and emulators are used to imitate the functioning of real-world equipment. GNS3 (Graphic Network Simulator v3) is employed in this research. GNS3 network tool integrates with real device operating systems to create a more realistic testing environment. Engineers frequently use GNS3 to test and mimic their real network architecture in order to discover faults. Major organisations throughout the world utilise these tools extensively for debugging and testing purposes. The advantage of utilising emulator-based tools over simulators is that they operate better and are almost identical to the real device. The topology employs seven Cisco routers with six LAN ports. Each router is linked to a switch that has a local LAN attached to it. One end device on each LAN is a PC, while the other is a server. Each Local Area Network uses a subnet mask of 255.255.255.0 or /24, therefore a total of 254 distinct devices can be connected inside the LAN.

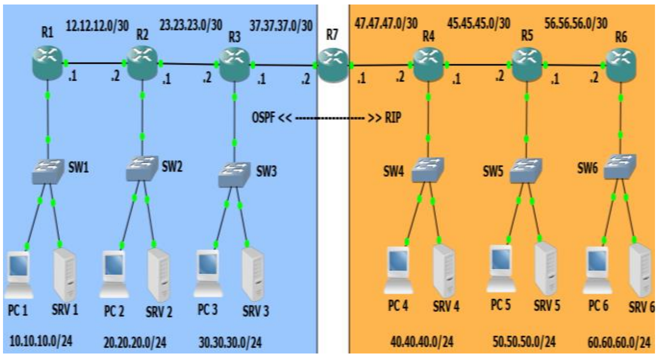

Figure 1 OSPF - RIP Network Topology with R7 as Redistribution Point

Each router is connected to a different network. There are networks like 10.10.10.0/24, 20.20.20.0/24, 30.30.30.0/24, 40.40.40.0/24, 50.50.50.0/24 & 60.60.60.0/24 simulating 6 user LAN networks. Each subnet can add total 254 users because of subnet mask used as 255.255.255.0 or /24. The OSPF network is shown on the left-hand side and the RIP network is shown are on the right side. The router R7 is acting like a common router thus referred as a mutual redistribution point for exchanging the topology information between OSPF and RIP updates shown in Figure 1.

4. Testing and Verification

For testing LAB setup, Open Shortest Path First (OSPF) is configured on R1, R2, R3 & R7 whereas, Routing Information Protocol (RIP) is configured on R4, R5, R6 & R7. Therefore, on R7 partial information of OSPF and RIP is done according to

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the topology. For Router R1, R2, R3 & R7 the configuration for OSPF protocol is shown in Figures 2 to 9.

```
R1#show run | sec router ospf
router ospf 1
 log-adjacency-changes
 network 10.10.10.0 0.0.0.255 area 0
 network 12.12.12.0 0.0.0.3 area 0
```

Figure 2 Router R1 OSPF Configuration

```
R2#show run | sec router ospf
router ospf 2
 log-adjacency-changes
 network 12.12.12.0 0.0.0.3 area 0
 network 20.20.20.0 0.0.0.255 area 0
 network 23.23.23.0 0.0.0.3 area 0
```

Figure 3 Router R2 OSPF Configuration

```
R3#show run | sec router ospf
router ospf 3
 log-adjacency-changes
 network 23.23.23.0 0.0.0.3 area 0
 network 30.30.30.0 0.0.0.255 area 0
 network 37.37.37.0 0.0.0.3 area 0
```

Figure 4 Router R3 OSPF Configuration

```
R7#show run | sec router ospf
router ospf 7
 log-adjacency-changes
 network 37.37.37.0 0.0.0.3 area 0
```

Figure 5 Router R7 OSPF Configuration

For Router R4, R5, R6 & R7 the configuration for RIP protocol is

```
R4#show run | sec router rip
router rip
 version 2
 network 40.0.0.0
 network 45.0.0.0
 network 47.0.0.0
 no auto-summary
```

Figure 6 Router R4 RIP Configuration

```
R5#show run | sec router rip
router rip
 version 2
 network 45.0.0.0
 network 50.0.0.0
 network 56.0.0.0
 no auto-summary
```

Figure 7 Router R5 RIP Configuration

```
R6#show run | sec router rip
router rip
 version 2
 network 56.0.0.0
 network 60.0.0.0
 no auto-summary
```

Figure 8 Router R6 RIP Configuration

```
R7#show run | sec router rip
router rip
 version 2
 network 47.0.0.0
 no auto-summary
```

Figure 9 Router R7 RIP Configuration

According to the current configuration the Routing Table (RT) of R1, R2, R3, R4, R5, R6 & R7 are shown in Figures 10 to 17.

```
L - local, C - connected, S - static, R - RIP, M - mobile, B -
D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
E1 - OSPF external type 1, E2 - OSPF external type 2
i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS
ia - IS-IS inter area, * - candidate default, U - per-user sta
o - ODR, P - periodic downloaded static route, + - replicated
```

Figure 10 CISCO Codes for Routing Table

```
      10.0.0.0/8 is variably subnetted, 2 s
C        10.10.10.0/24 is directly connecte
L        10.10.10.254/32 is directly connec
      12.0.0.0/8 is variably subnetted, 2 s
C        12.12.12.0/30 is directly connecte
L        12.12.12.1/32 is directly connecte
      20.0.0.0/24 is subnetted, 1 subnets
O        20.20.20.0 [110/2] via 12.12.12.2,
      23.0.0.0/30 is subnetted, 1 subnets
O        23.23.23.0 [110/2] via 12.12.12.2,
      30.0.0.0/24 is subnetted, 1 subnets
O        30.30.30.0 [110/3] via 12.12.12.2,
      37.0.0.0/30 is subnetted, 1 subnets
O        37.37.37.0 [110/3] via 12.12.12.2,
```

Figure 11 R1 RT before Redistribution

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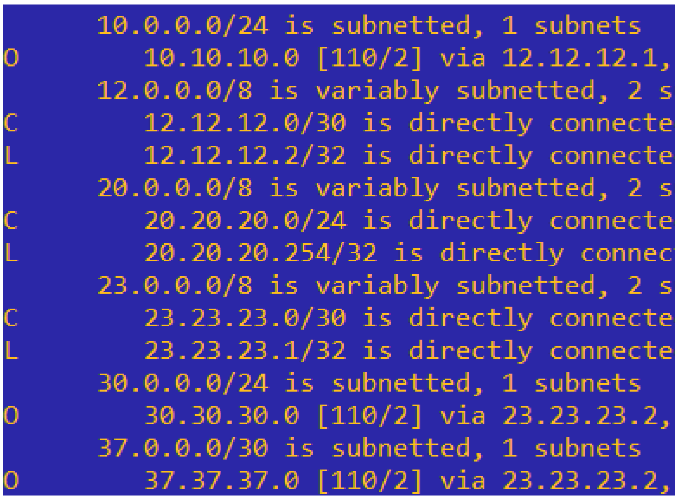

Figure 12 R2 RT before Redistribution

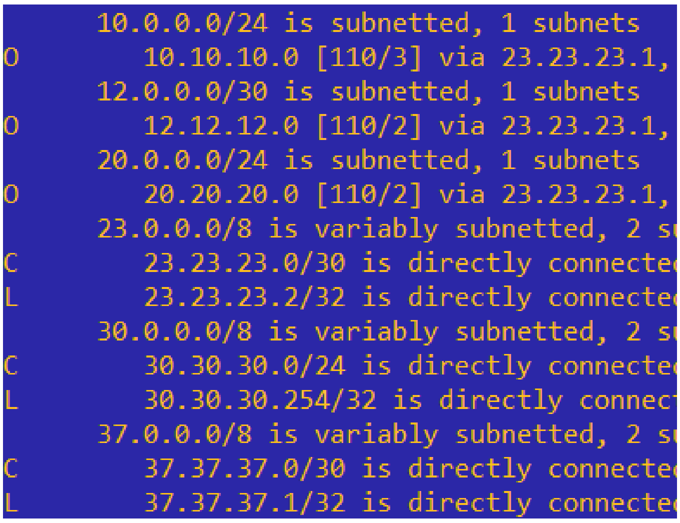

Figure 13 R3 RT before Redistribution

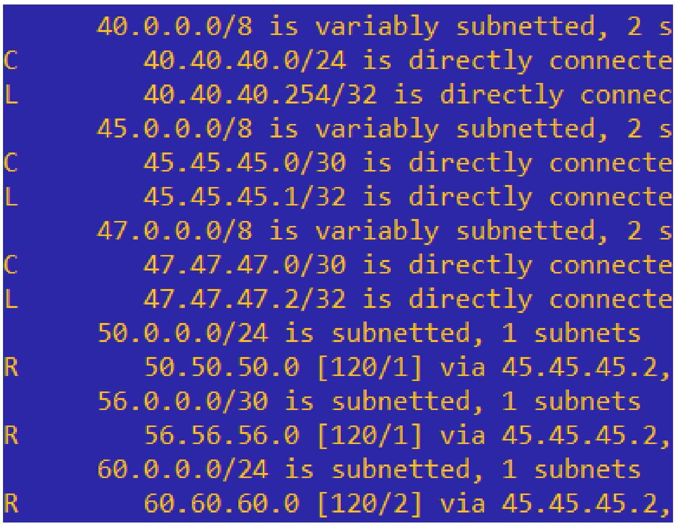

Figure 14 R4 RT before Redistribution

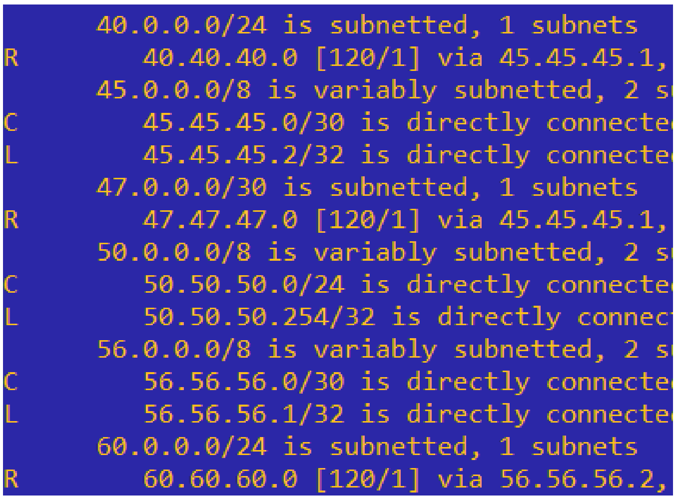

Figure 15 R5 RT before Redistribution

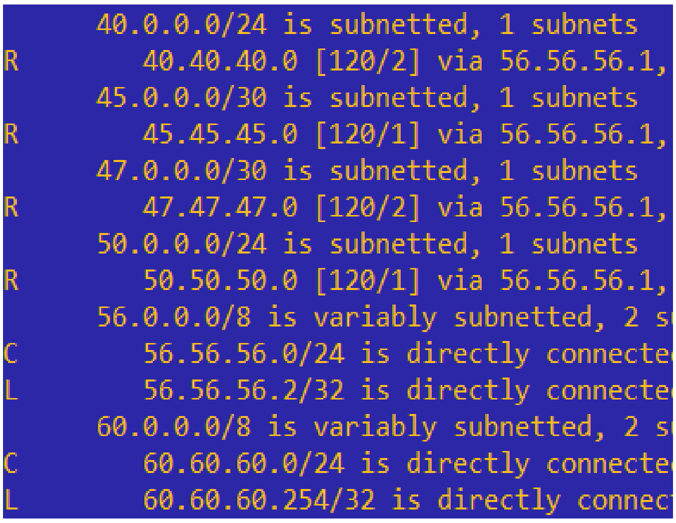

Figure 16 R6 RT before Redistribution

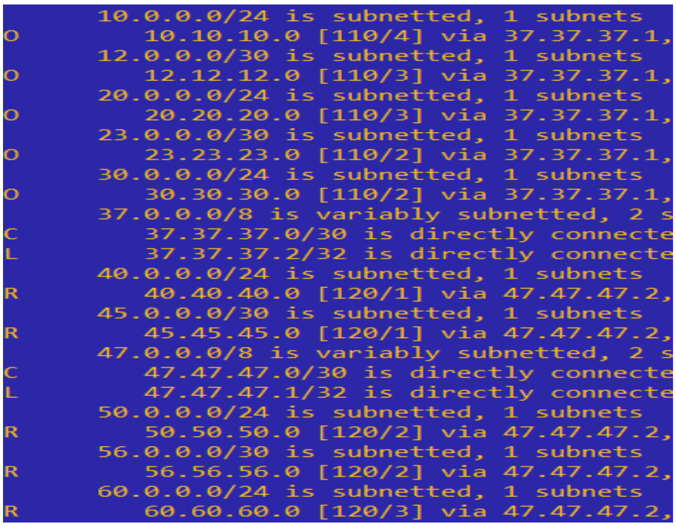

Figure 17 R7 RT before Redistribution

As R7 has information about both Routing Protocols but it will maintain separate Topology Tables for each protocol i.e. Topology Tables (TT) are separated and not shared with each other. Therefore, mutual redistribution is required. After Mutual Redistribution the output on R7 is

```
R7#show run | sec router ospf
router ospf 7
 log-adjacency-changes
 redistribute rip subnets
 network 37.37.37.0 0.0.0.3 area 0
```

Figure 18 R7 OSPF Configuration after Redistribution

```
R7#show run | sec router rip
router rip
 version 2
 redistribute ospf 7 metric 1
 network 47.0.0.0
 no auto-summary
```

Figure 19 R7 RIP Configuration after Redistribution

After mutual redistribution partial or incomplete information is shared.

```
      10.0.0.0/8 is variably subnetted, 2 su
C        10.10.10.0/24 is directly connected
L        10.10.10.254/32 is directly connect
      12.0.0.0/8 is variably subnetted, 2 su
C        12.12.12.0/30 is directly connected
L        12.12.12.1/32 is directly connected
      20.0.0.0/24 is subnetted, 1 subnets
O        20.20.20.0 [110/2] via 12.12.12.2,
      23.0.0.0/30 is subnetted, 1 subnets
O        23.23.23.0 [110/2] via 12.12.12.2,
      30.0.0.0/24 is subnetted, 1 subnets
O        30.30.30.0 [110/3] via 12.12.12.2,
      37.0.0.0/30 is subnetted, 1 subnets
O        37.37.37.0 [110/3] via 12.12.12.2,
      40.0.0.0/24 is subnetted, 1 subnets
O E2     40.40.40.0 [110/20] via 12.12.12.2,
      45.0.0.0/30 is subnetted, 1 subnets
O E2     45.45.45.0 [110/20] via 12.12.12.2,
      47.0.0.0/30 is subnetted, 1 subnets
O E2     47.47.47.0 [110/20] via 12.12.12.2,
      50.0.0.0/24 is subnetted, 1 subnets
O E2     50.50.50.0 [110/20] via 12.12.12.2,
      56.0.0.0/30 is subnetted, 1 subnets
O E2     56.56.56.0 [110/20] via 12.12.12.2,
      60.0.0.0/24 is subnetted, 1 subnets
O E2     60.60.60.0 [110/20] via 12.12.12.2,
```

Figure 20 R1 RT after Default Redistribution

```
      10.0.0.0/24 is subnetted, 1 subnets
O        10.10.10.0 [110/2] via 12.12.12.1,
      12.0.0.0/8 is variably subnetted, 2 su
C        12.12.12.0/30 is directly connected
L        12.12.12.2/32 is directly connected
      20.0.0.0/8 is variably subnetted, 2 su
C        20.20.20.0/24 is directly connected
L        20.20.20.254/32 is directly connect
      23.0.0.0/8 is variably subnetted, 2 su
C        23.23.23.0/30 is directly connected
L        23.23.23.1/32 is directly connected
      30.0.0.0/24 is subnetted, 1 subnets
O        30.30.30.0 [110/2] via 23.23.23.2,
      37.0.0.0/30 is subnetted, 1 subnets
O        37.37.37.0 [110/2] via 23.23.23.2,
      40.0.0.0/24 is subnetted, 1 subnets
O E2     40.40.40.0 [110/20] via 23.23.23.2,
      45.0.0.0/30 is subnetted, 1 subnets
O E2     45.45.45.0 [110/20] via 23.23.23.2,
      47.0.0.0/30 is subnetted, 1 subnets
O E2     47.47.47.0 [110/20] via 23.23.23.2,
      50.0.0.0/24 is subnetted, 1 subnets
O E2     50.50.50.0 [110/20] via 23.23.23.2,
      56.0.0.0/30 is subnetted, 1 subnets
O E2     56.56.56.0 [110/20] via 23.23.23.2,
      60.0.0.0/24 is subnetted, 1 subnets
O E2     60.60.60.0 [110/20] via 23.23.23.2,
```

Figure 21 R2 RT after Default Redistribution

```
      10.0.0.0/24 is subnetted, 1 subnets
O        10.10.10.0 [110/3] via 23.23.23.1,
      12.0.0.0/30 is subnetted, 1 subnets
O        12.12.12.0 [110/2] via 23.23.23.1,
      20.0.0.0/24 is subnetted, 1 subnets
O        20.20.20.0 [110/2] via 23.23.23.1,
      23.0.0.0/8 is variably subnetted, 2 su
C        23.23.23.0/30 is directly connected
L        23.23.23.2/32 is directly connected
      30.0.0.0/8 is variably subnetted, 2 su
C        30.30.30.0/24 is directly connected
L        30.30.30.254/32 is directly connect
      37.0.0.0/8 is variably subnetted, 2 su
C        37.37.37.0/30 is directly connected
L        37.37.37.1/32 is directly connected
      40.0.0.0/24 is subnetted, 1 subnets
O E2     40.40.40.0 [110/20] via 37.37.37.2,
      45.0.0.0/30 is subnetted, 1 subnets
O E2     45.45.45.0 [110/20] via 37.37.37.2,
      47.0.0.0/30 is subnetted, 1 subnets
O E2     47.47.47.0 [110/20] via 37.37.37.2,
      50.0.0.0/24 is subnetted, 1 subnets
O E2     50.50.50.0 [110/20] via 37.37.37.2,
      56.0.0.0/30 is subnetted, 1 subnets
O E2     56.56.56.0 [110/20] via 37.37.37.2,
      60.0.0.0/24 is subnetted, 1 subnets
O E2     60.60.60.0 [110/20] via 37.37.37.2,
```

Figure 22 R3 RT after Default Redistribution

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```
     10.0.0.0/24 is subnetted, 1 subnets
R       10.10.10.0 [120/1] via 47.47.47.1,
     12.0.0.0/30 is subnetted, 1 subnets
R       12.12.12.0 [120/1] via 47.47.47.1,
     20.0.0.0/24 is subnetted, 1 subnets
R       20.20.20.0 [120/1] via 47.47.47.1,
     23.0.0.0/30 is subnetted, 1 subnets
R       23.23.23.0 [120/1] via 47.47.47.1,
     30.0.0.0/24 is subnetted, 1 subnets
R       30.30.30.0 [120/1] via 47.47.47.1,
     37.0.0.0/30 is subnetted, 1 subnets
R       37.37.37.0 [120/1] via 47.47.47.1,
     40.0.0.0/8 is variably subnetted, 2 s
C       40.40.40.0/24 is directly connecte
L       40.40.40.254/32 is directly connec
     45.0.0.0/8 is variably subnetted, 2 s
C       45.45.45.0/30 is directly connecte
L       45.45.45.1/32 is directly connecte
     47.0.0.0/8 is variably subnetted, 2 s
C       47.47.47.0/30 is directly connecte
L       47.47.47.2/32 is directly connecte
     50.0.0.0/24 is subnetted, 1 subnets
R       50.50.50.0 [120/1] via 45.45.45.2,
     56.0.0.0/30 is subnetted, 1 subnets
R       56.56.56.0 [120/1] via 45.45.45.2,
     60.0.0.0/24 is subnetted, 1 subnets
R       60.60.60.0 [120/2] via 45.45.45.2,
```

Figure 23 R4 RT after Default Redistribution

```
     10.0.0.0/24 is subnetted, 1 subnets
R       10.10.10.0 [120/2] via 45.45.45.1,
     12.0.0.0/30 is subnetted, 1 subnets
R       12.12.12.0 [120/2] via 45.45.45.1,
     20.0.0.0/24 is subnetted, 1 subnets
R       20.20.20.0 [120/2] via 45.45.45.1,
     23.0.0.0/30 is subnetted, 1 subnets
R       23.23.23.0 [120/2] via 45.45.45.1,
     30.0.0.0/24 is subnetted, 1 subnets
R       30.30.30.0 [120/2] via 45.45.45.1,
     37.0.0.0/30 is subnetted, 1 subnets
R       37.37.37.0 [120/2] via 45.45.45.1,
     40.0.0.0/24 is subnetted, 1 subnets
R       40.40.40.0 [120/1] via 45.45.45.1,
     45.0.0.0/8 is variably subnetted, 2 s
C       45.45.45.0/30 is directly connecte
L       45.45.45.2/32 is directly connecte
     47.0.0.0/30 is subnetted, 1 subnets
R       47.47.47.0 [120/1] via 45.45.45.1,
     50.0.0.0/8 is variably subnetted, 2 s
C       50.50.50.0/24 is directly connecte
L       50.50.50.254/32 is directly connec
     56.0.0.0/8 is variably subnetted, 2 s
C       56.56.56.0/30 is directly connecte
L       56.56.56.1/32 is directly connecte
     60.0.0.0/24 is subnetted, 1 subnets
R       60.60.60.0 [120/1] via 56.56.56.2,
```

Figure 24 R5 RT after Default Redistribution

```
     10.0.0.0/24 is subnetted, 1 subnets
R       10.10.10.0 [120/3] via 56.56.56.1,
     12.0.0.0/30 is subnetted, 1 subnets
R       12.12.12.0 [120/3] via 56.56.56.1,
     20.0.0.0/24 is subnetted, 1 subnets
R       20.20.20.0 [120/3] via 56.56.56.1,
     23.0.0.0/30 is subnetted, 1 subnets
R       23.23.23.0 [120/3] via 56.56.56.1,
     30.0.0.0/24 is subnetted, 1 subnets
R       30.30.30.0 [120/3] via 56.56.56.1,
     37.0.0.0/30 is subnetted, 1 subnets
R       37.37.37.0 [120/3] via 56.56.56.1,
     40.0.0.0/24 is subnetted, 1 subnets
R       40.40.40.0 [120/2] via 56.56.56.1,
     45.0.0.0/30 is subnetted, 1 subnets
R       45.45.45.0 [120/1] via 56.56.56.1,
     47.0.0.0/30 is subnetted, 1 subnets
R       47.47.47.0 [120/2] via 56.56.56.1,
     50.0.0.0/24 is subnetted, 1 subnets
R       50.50.50.0 [120/1] via 56.56.56.1,
     56.0.0.0/8 is variably subnetted, 2 s
C       56.56.56.0/24 is directly connecte
L       56.56.56.2/32 is directly connecte
     60.0.0.0/8 is variably subnetted, 2 s
C       60.60.60.0/24 is directly connecte
L       60.60.60.254/32 is directly connec
```

Figure 25 R6 RT after Default Redistribution

```
     10.0.0.0/24 is subnetted, 1 subnets
O       10.10.10.0 [110/4] via 37.37.37.1,
     12.0.0.0/30 is subnetted, 1 subnets
O       12.12.12.0 [110/3] via 37.37.37.1,
     20.0.0.0/24 is subnetted, 1 subnets
O       20.20.20.0 [110/3] via 37.37.37.1,
     23.0.0.0/30 is subnetted, 1 subnets
O       23.23.23.0 [110/2] via 37.37.37.1,
     30.0.0.0/24 is subnetted, 1 subnets
O       30.30.30.0 [110/2] via 37.37.37.1,
     37.0.0.0/8 is variably subnetted, 2 s
C       37.37.37.0/30 is directly connecte
L       37.37.37.2/32 is directly connecte
     40.0.0.0/24 is subnetted, 1 subnets
R       40.40.40.0 [120/1] via 47.47.47.2,
     45.0.0.0/30 is subnetted, 1 subnets
R       45.45.45.0 [120/1] via 47.47.47.2,
     47.0.0.0/8 is variably subnetted, 2 s
C       47.47.47.0/30 is directly connecte
L       47.47.47.1/32 is directly connecte
     50.0.0.0/24 is subnetted, 1 subnets
R       50.50.50.0 [120/2] via 47.47.47.2,
     56.0.0.0/30 is subnetted, 1 subnets
R       56.56.56.0 [120/2] via 47.47.47.2,
     60.0.0.0/24 is subnetted, 1 subnets
R       60.60.60.0 [120/3] via 47.47.47.2,
```

Figure 26 R7 RT after Default Redistribution

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5. Results and Discussion

5.1. Results

Router R4 used the Routing Information Protocol (RIP) to create a routing table with the learnt routes valued at [120/x]. The first argument is the AD value of 120, and the second parameter in the output is the metric, which is one of two or three allocated to each RIP learnt route denoted with [AD/Metric]. The RIP metric indicates how many hops away the network is from the present router that displays the routing table. The OSPF Router R3 has assigned a default metric value of 20 to routes learnt through redistribution, i.e., RIP routes from R4, R5, and R6 are assigned a fixed metric value of 20 and are identified as OSPF E2 type routes in the routing table. Whereas the OSPF learned routes from R2, R1 like 10.10.10.0/24, 20.20.20.0/24, etc. are marked as O with the metric 3 and 2 respectively. The Routers R1, R2 and R3 all are using OSPF default cost metric of 20 for external routes from RIP which are marked as O E2. The problem in given scenario is that the routers on the left side of R7 i.e. R1, R2 and R3 which are inside OSPF domain are not getting complete information about the metric used for RIP network which is available on right side of R7. This results in partial or incomplete information and requires the need for better mutual redistribution method shown in Figures 18 to 26.

5.2. Discussion

The issue here is that the metric value on each router should fluctuate when the redistribution point, R7, moves further away. The measure should not be the same since the same value indicates that the redistribution point, i.e. Router R7, is equidistant from R1, R2, and R3. However, in the real router, R7 routes such as 37.37.37.0/30 are generated with various metric values on R1, R2, and R3. On router R3, it is directly linked, hence the metric value is zero; on router R2, it is designated with a metric value of one. On router R1, these routes are computed using a metric of 3. As a result, the external routes learnt from router R7 that are RIP should be indicated with some distinct values on R1, R2, and R3, and shouldn't use a single value of metric 20. The OSPF employs link bandwidth to calculate the statistic known as "Cost". The cost formula equals reference bandwidth divided by interface or connection bandwidth. The default reference bandwidth of 100 Mbps is used to calculate OSPF costs. For example, if a Fast Ethernet interface (100Mbps) is used, the OSPF path cost value is 100 Mbps / 100 Mbps = 1. The cost of a Giga Ethernet interface (1000Mbps) is 0.1 ~ 1 (rounded to 1). Important aspects to notice about cost are:

- Cost is a positive integer value; that is, Cost > 0.
- Any decimal value will be rounded back to the next positive (+) integer.
- Any value less than 1 would be treated as one.

The route with the lowest Cumulative Cost value between the source and destination will be chosen for the routing table. Cumulative Cost = The sum of all outgoing interface costs in the path. However, the OSPF has additional mechanisms in place to address cost variations during redistribution. If not defined, these external routes, also known as OSPF Type-2 (O E2), employ a cost value of 20. If certain External routes are identified as Type-1 (O E1) during redistribution, the default Cost computation value changes. To use OSPF Type-1 routes, the configuration must be updated on the redistribution point, i.e., Router R7 only as

```
R7#show run | sec router ospf
router ospf 7
 log-adjacency-changes
 redistribute rip metric-type 1 subnets
 network 37.37.37.0 0.0.0.3 area 0
```

Figure 27 R7 OSPF after Complete Redistribution Using Type-1

The impact would be seen on the Routers like R1, R2 and R3 which are now using new metric values.

```
     40.0.0.0/24 is subnetted, 1 subnets
O E1     40.40.40.0 [110/23] via 12.12.12.2,
     45.0.0.0/30 is subnetted, 1 subnets
O E1     45.45.45.0 [110/23] via 12.12.12.2,
     47.0.0.0/30 is subnetted, 1 subnets
O E1     47.47.47.0 [110/23] via 12.12.12.2,
     50.0.0.0/24 is subnetted, 1 subnets
O E1     50.50.50.0 [110/23] via 12.12.12.2,
     56.0.0.0/30 is subnetted, 1 subnets
O E1     56.56.56.0 [110/23] via 12.12.12.2,
     60.0.0.0/24 is subnetted, 1 subnets
O E1     60.60.60.0 [110/23] via 12.12.12.2,
```

Figure 28 R1 RT for RIP Routes after Complete Redistribution

```
     40.0.0.0/24 is subnetted, 1 subnets
O E1    40.40.40.0 [110/22] via 23.23.23.2,
     45.0.0.0/30 is subnetted, 1 subnets
O E1    45.45.45.0 [110/22] via 23.23.23.2,
     47.0.0.0/30 is subnetted, 1 subnets
O E1    47.47.47.0 [110/22] via 23.23.23.2,
     50.0.0.0/24 is subnetted, 1 subnets
O E1    50.50.50.0 [110/22] via 23.23.23.2,
     56.0.0.0/30 is subnetted, 1 subnets
O E1    56.56.56.0 [110/22] via 23.23.23.2,
     60.0.0.0/24 is subnetted, 1 subnets
O E1    60.60.60.0 [110/22] via 23.23.23.2,
```

Figure 29 R2 RT for RIP Routes after Complete Redistribution

```
     40.0.0.0/24 is subnetted, 1 subnets
O E1    40.40.40.0 [110/21] via 37.37.37.2,
     45.0.0.0/30 is subnetted, 1 subnets
O E1    45.45.45.0 [110/21] via 37.37.37.2,
     47.0.0.0/30 is subnetted, 1 subnets
O E1    47.47.47.0 [110/21] via 37.37.37.2,
     50.0.0.0/24 is subnetted, 1 subnets
O E1    50.50.50.0 [110/21] via 37.37.37.2,
     56.0.0.0/30 is subnetted, 1 subnets
O E1    56.56.56.0 [110/21] via 37.37.37.2,
     60.0.0.0/24 is subnetted, 1 subnets
O E1    60.60.60.0 [110/21] via 37.37.37.2,
```

Figure 30 R3 RT for RIP Routes after Complete Redistribution

The redistributed external routes are now marked with O E1 and using updated metric values on each router. The metric value calculate on Router R3 is External Default (20) + the link Cost as 100 Mbps / 1000 Mbps = 0.1 ~ 1 i.e. {20+1} = 21. Therefore, the metric value is updated for the external routes marked with OSPF Type-1 using the new mechanism. The external routes are marked with O E2 throughout the OSPF domain and the metric increments as the calculating OSPF router moves away from the redistribution point Router R7 shown in Figures 27 to 30.

Conclusion

The above experimental study concludes that the OSPF default metric calculation for external routes needs to be change and a better metric calculation is required whenever two or more routing protocols are used with OSPF via redistribution method. Therefore, whenever OSPF is deployed in real production environment the cost (metric) used for default OSPF external type routes like OSPF Type-2 is fixed and not correct. The routes must be modified to be of External Type-1 (O E1) so that a better metric value is calculated then the default fixed metric cost of 20. The change in metric for each router results in an updated metric calculation process and provides a better view about the topology used in the network. Future scope could be done for providing an enhanced and better metric calculation using multiple parameters during the redistribution where there is a need for using more than one routing protocol. Further study can be conducted towards finding new parameters required for cost calculation or changing the existing OSPF Shortest Path First algorithm with some modifications resulting in better selection and enhanced cost computation for OSPF links in the network.

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