

OSPF Best Path Selection Manipulation using Reference Bandwidth

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ABSTRACT

As the network grows to fulfill the demand of communication, the need for data transfer speed is also increasing. Not only the size of network but the data transfer speed (rate) is ever demanding. For the communication, the need for networking is required which serves as the backbone. Various protocols are used in building the computer network including routing protocols such as RIP, OSPF, BGP, EIGRP, etc. Apart from these some routed protocols like IPV4, IPv6, IPX are also used. These routing protocols have different working styles but the primary aim of these protocols is the same which is to calculate the best path towards the destination address. This study aims to discuss the various parameters that can influence the best path selection process for achieving better data transfer speed through the existing network using Open Shortest Path First (OSPF) as a routing protocol.

General Terms

Routing Protocols, Best- Path Selection Criteria, Network convergence, Inter-networking, Source and Destination Address

Keywords

RIP, OSPF, Bandwidth, SPF, LSA, Metric, Cost, Administrative Distance (AD), IOS, Router Configuration

1. INTRODUCTION

In networking two major types of protocols are used namely routing protocol and routed protocol. Routing Protocol provides the “Best Path” by calculating some algorithms using given parameters over the network, so that the data (or voice) can be send over this selected path. The aim of routing protocol is to calculate the Best (Shortest) Path through the network from source to the destination. Different routing protocols have different mechanism (algorithm) how to calculate, but the primary aim remains the same. Broadly, there are three categories in which routing protocols falls as:

- Distance – Vector
- Link – State
- Path – Vector

Once the path is determined by the routing protocol, it’s time to carry the actual data from the source towards the destination address.

There routed protocols come into picture, like IPV4, IPv6, IPX, AppleTalk, etc. These routed protocols provide a framework "How to Carry" the actual data over the network. The working style of each routed protocol is different, depends upon size, load, framework, etc. But all do the same function which is to carry the data safely from source address towards destination address through the network. The path which routed protocols follow is determined by the routing

protocol. In simple words, routing protocol calculate (determine) the path and the routed protocol carry the data over this path [1].

This research was conducted with the aim of selecting the optimum network parameters that are required to calculate the cost (metric) so that a Better Path resulting Higher Data Transfer speed (rate) over the network can be achieved.

2. CURRENT WORKING DESIGN

In computer network, the two main components are the source and destination address. The information should be communicated (passed) from the source to destination from time to time. There are multiple paths through which the data can be transferred. The process of selection of best path over the network is known as routing i.e., the selecting a single path over the other available paths. This can be done using network administrators by manually calculating the path or by using software having some predefined algorithms like software programs. Hardware devices can use this software known as protocols. Protocols help to find the best route to ensure reliable and safe data transfer over the network. The data packets that need to be send are provided with extra information how to find and calculate the Best Path [2][3].

The primary purpose of routing protocol is to know about the existing network routes and make correct decisions over them. Some examples of commonly used routing protocols are RIP, OSPF, EIGRP, BGP, IS-IS, etc.

These dynamic routing protocols have predefined algorithms that can analyze and choose the optimal path towards the destination. This is mainly used because of its adaptability to any kind of changes in the network. Routing protocols can easily sense the network change or topology change and can calculate according to it. Convergence refers to the term that these routing protocols should reflect the exact accurate and updated information about the current network topology and time taken by the devices like router to do so should be least. Routing protocol with faster convergence time is preferred because disturbance or change can occur during the router to calculate networks for the optimal path i.e., Best Path. It can also be called an act of approach to a state where all routing tables have detailed information are in a steady state. Last but not the least is the accuracy of the information. The information which is updated by the router, should reflect the exact details about the values termed as accuracy.

Routing update mechanism is a process of information transfer between the neighboring routers. This can be achieved while routing at a particular time duration router to advertise its data through either via broadcast or multicast. Various routing protocols have different time intervals.

These routing updates contain information on routing

protocols such as Autonomous System (AS) number, Administrative Distance (AD), Metric values and interface details.

Administrative Distance (AD) can be defined as the reliability of routing updates received from the neighbor router. For example, if two sources are advertising updates for the same destination, the source with the Best (lower) AD value is chosen as the optimistic and the path suggested by this source will be the best selected path for the updates. The AD with the lowest value will be given more preference.

Some of the common Administrative Distance (AD) values that are used in CISCO devices are:

Table 1. Default Administrative Distance (AD) on CISCO

Source (through which route is learned)	Value
Connected	000
Static	001
EIGRP summary route	005
External BGP	020
EIGRP (internal)	090
IGRP	100
OSPF	110
IS-IS	115
RIP	120
EIGRP (external)	170
Internal BGP	200
Unreachable	255

Example, if there is network information update from EIGRP with AD=90 and the same network update is available through RIP with AD=120, the route or the path will be chosen with that of EIGRP AD=90 because of the lower value than the RIP AD=120.

Metric on the other hand is the second parameter which the router uses as a tie breaker when there is a conflict with AD values for two different paths. Similar to AD, routing protocols use different methods how to calculate the metric (cost) for a given path. The path with the lowest metric (cost) is selected when there is AD conflict. Example EIGRP uses parameters like Bandwidth, Load, MTU, etc. while RIP protocol uses Hop-Count as a metric value [4].

Considering the example for CISCO based network devices where there are 3 processes involved in building and maintaining the Routing Table (RT) on a router:

- Various routing processes, which actually run a network (or routing) protocol, such as EIGRP, BGP, IS-IS, and OSPF.
- The routing table itself, which accepts information from the routing processes and also replies to requests for information from the forwarding process.
- The forwarding process, which requests information from the routing table to make a packet forwarding decision.

There are four types of routing protocol, each having its own importance in data transfer over the network. The four types are:

- Distance Vector, which uses distance as the metric value and direction as a vector to select the best path towards the destination network address. Router receives the routing information from the neighbor router, which is received from its other neighbor and so on, until the destination network is reached. Each neighbor router in the path of a destination network is called a Hop. Each time a data packet goes through a router, the Hop-Count (value) is increased and the route with least Hop-Count (value) is chosen as the Best (shortest) path towards the destination. Example, Routing Information Protocol (RIP) directly shares an entire routing update to its connected neighbor with an increment of one hop.
- Link State Routing Protocol uses a complex metric table to choose the best path for the destination network. As the name itself indicates that it works in linked format. It uses tables like neighbor table, topology table to share the information within the network. Example, Open Shortest Path First (OSPF) that shares their own link information with the neighbor routers so as to have better view of the entire topology of the network. Its help the OSPF neighbor router to build and share the most updated information about the network.
- Hybrid Routing Protocol can be defined as the mixture of distance vector and the link state protocol. A hybrid routing protocol uses aspects from both to locate and build the network information. Enhanced Interior Gateway Routing Protocol (EIGRP) is the best example of hybrid routing protocol.
- Path Vector, which uses path attributes to determine the Best Path like Border Gateway Protocol (BGP). BGP has a completely different mechanism how to choose the best path towards the destination, unlike Distance Vector or Link State. It uses a complex path selection process which doesn't consist of metric (cost) using bandwidth or hop-count.

For all the routing protocol, the primary function remains the same i.e., to calculate the best path towards destination for which they choose different methods. There is no best nor worst routing protocol, it's totally depended upon the need and the network administrator understanding which one to deploy according to the current network design [5].

3. EXPERIMENTAL ANALYSIS

3.1 Working Design Tools

In this research work the most commonly used network topology consisting of networking devices like PC, Servers, Routers, Switch, etc. are used so as to simulate a real time environment.

There are tools like emulators and simulators which can design almost a real time network topology. For this study the GNS3 (Graphical Network Simulator v3) is used along with real devices images for CISCO, the most common and the widely used vendor. Using this combination results in a better and reliable output which is almost the same on any real device from the production environment. These tools are also used in real time debug and testing worldwide.

3.2 Topology Description

For the topology 5 CISCO router with Advance IP services image along with 2 Local Area Network (LAN) consisting of 1 Switch and 2 End devices like PCs and Servers are used.

The network topology along with IP address schema is shown in Figure 1. There is LAN 1 on the left with Source address 10.10.10.0/24 connected to the network core consisting of 5 Routers and LAN 2 with Destination address 20.20.20.0/24.

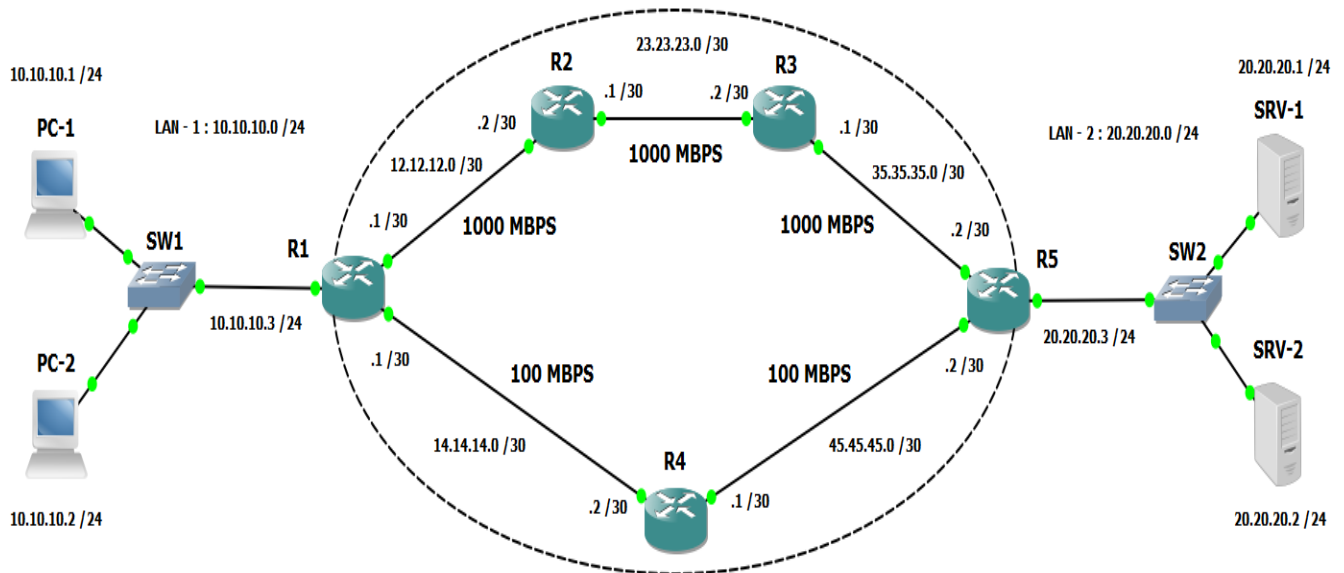


Fig 1: Working Topology with 5 Routers and 2 LAN

3.3 Testing and Verification using RIP

For the current topology first Routing Information Protocol (RIP) is used. After that OSPF will be used for comparing the result. Using RIP which is distance vector routing protocol with AD=120 and the Best Path calculation is determined using Hop-Count as a Metric (cost). Smallest Hop-Count will be desired path for RIP to reach the destination 20.20.20.0/24.

The configuration and the output are as shown.

For Router R1 the configurations are

```
R1#show interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Hardware is i82543 (Livengood), address 00:0c:0c:00:00:00
  Internet address is 12.12.12.1/30
  MTU 1500 bytes, BW 1000000 Kbit/sec, D
    reliability 255/255, txload 1/255,
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Full Duplex, 1000Mbps, link type is
```

Fig 2: Router R1 interface Gigabit Ethernet 0/0

The Bandwidth for the Gigabit Ethernet is 1000 Mbps which is taken on Router R1 as interface Gig0/0.

The Bandwidth for the Fast Ethernet is 100 Mbps which is 10x times smaller the Gigabit Ethernet.

```
R1#show interface f4/0
FastEthernet4/0 is up, line protocol is up
  Hardware is i82543 (Livengood), address 00:0c:0c:00:00:00
  Internet address is 14.14.14.1/30
  MTU 1500 bytes, BW 100000 Kbit/sec, D
    reliability 255/255, txload 1/255,
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Full-duplex, 100Mb/s, 100BaseTX/FX
```

Fig 3: Router R1 interface Fast Ethernet 4/0

Gigabit has 1000 MBPS & FastEth has 100 MBPS bandwidth.

```
R1#sh run | sec router rip
router rip
version 2
network 10.0.0.0
network 12.0.0.0
network 14.0.0.0
no auto-summary
R1#
```

Fig 4: Router R1 using RIP Routing Protocol

For Router R2 the RIP Routing Protocol configurations are

```
R2#sh run | sec router rip
router rip
version 2
network 12.0.0.0
network 23.0.0.0
no auto-summary
R2#
```

Fig 5: Router R2 using RIP Routing Protocol

For Router R3 the RIP Routing Protocol configurations are

```
R3#sh run | sec router rip
router rip
version 2
network 23.0.0.0
network 35.0.0.0
no auto-summary
R3#
```

Fig 6: Router R3 using RIP Routing Protocol

Router R1, Router R2 and Router R3 are connected above in the topology are using Gigabit Ethernet Interface which has 1000 MPBS bandwidth. Router R1 is connected to R4 via Fast Ethernet Interface which has 100 MBPS bandwidth.

For Router R4 the RIP Routing Protocol configurations are

```
R4#sh run | sec router rip
router rip
version 2
network 14.0.0.0
network 45.0.0.0
no auto-summary
R4#
```

Fig 7: Router R4 using RIP Routing Protocol

For Router R5 the RIP Routing Protocol configuration are

```
R5#sh run | sec router rip
router rip
version 2
network 20.0.0.0
network 35.0.0.0
network 45.0.0.0
no auto-summary
R5#
```

Fig 8: Router R5 using RIP Routing Protocol

Based upon the current configuration and the working design of RIP, the Router R1 has chosen R4 as the Next-Hop to forward the traffic towards the destination of 20.20.20.0/24.

Router R1 has chosen R4 (14.14.14.2) as the Next-Hop to reach the destination 20.20.20.0/24. According to R1, the destination 20.20.20.0/24 is reachable via AD=120 and Metric=2 (Hops) using RIP routing protocol.

```
20.0.0.0/24 is subnetted, 1 subnets
  20.20.20.0 [120/2] via 14.14.14.2,
23.0.0.0/30 is subnetted, 1 subnets
  23.23.23.0 [120/1] via 12.12.12.2,
35.0.0.0/30 is subnetted, 1 subnets
  35.35.35.0 [120/2] via 14.14.14.2,
  [120/2] via 12.12.12.2,
45.0.0.0/30 is subnetted, 1 subnets
  45.45.45.0 [120/1] via 14.14.14.2,
```

Fig 9: Router R1 Routing Table using RIP

Therefore PC-1 with Source address 10.10.10.1/24 will reach the Destination address 20.20.20.1/24 and use the path as

```
PC-1#ping 20.20.20.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 20.20.20.1
!!!!
Success rate is 100 percent (5/5), round-trip
```

Fig 10: PC-1 PING Destination IP 20.20.20.1

So, from above result it's clear that R1 is using Best Path via R4 for reaching the Destination 20.20.20.0/24 under the RIP as the routing protocol which uses least Hop-Count as Metric (cost) for route calculation.

```
PC-1#traceroute 20.20.20.1
Type escape sequence to abort.
Tracing the route to 20.20.20.1
VRF info: (vrf in name/id, vrf out name/id)
 1 10.10.10.3 36 msec 28 msec 28 msec
 2 14.14.14.2 60 msec 76 msec 56 msec
 3 45.45.45.2 112 msec 108 msec 108 msec
 4 20.20.20.1 156 msec 136 msec 164 msec
PC-1#
```

Fig 11: PC-1 Traceroute via R1->R4->R5

From above verification it's clear that the Router R1 has taken the Best Path via Router R4 through 100 MBPS interface as shown below in Figure 12.

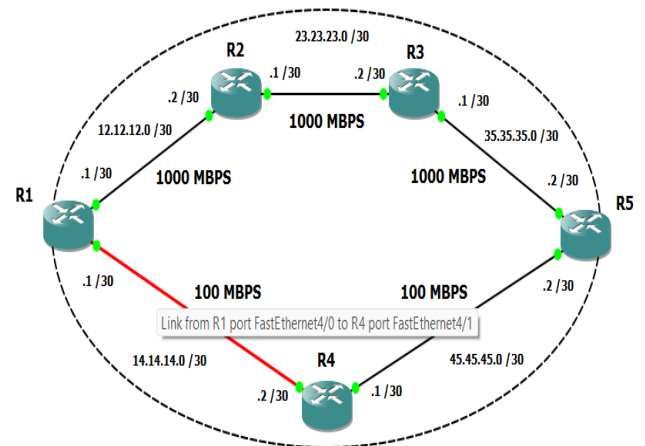


Fig 12: Best Path via R1->R4->R5 using RIP

3.4 Testing and Verification using OSPF

The Open Shortest Path First (OSPF) protocol is a Link-State routing protocol which shares the complete network information with other OSPF neighbor routers. The routers then use the Shortest Path First (SPF) process based on Dijkstra algorithm to calculate the Best Path. The default Administrative Distance (AD) value for OSPF on CISCO platform is 110. For calculating the Cost or Metric the OSPF uses “Bandwidth” of the interface as a parameter. The higher the bandwidth, the better is the path. The Metric (cost) is inversely proportional to the Bandwidth i.e., Higher the Bandwidth, Lower is the Metric or Cost. As like always, lower cost is preferred for the Best Path selection.

OSPF Shortest Path First (SPF) Algorithm works when there is any change in routing information or upon initialization (booting) the router generates Link State Advertisements (LSA). These LSA contain the collection of all link-states on that router. Router propagate these LSA in network using multicast, normally on address of 224.0.0.5/6. Each router that receives this LSA would store a copy of it in its local database known as Link State Database (LSDB) then flood this LSA to other neighbor routers in the network using the same mechanism. After database is updated, router selects a single best path route for each destination from all available routes in the network. Routers uses SPF algorithm to select the best route. Like other routing protocol OSPF uses a metric component called cost to select the best route for populating the router routing table [6].

A packet will face more overhead in crossing a 56Kbps serial link than crossing a 100Mbps link, because of lower bandwidth availability on serial (just 56Kbps). Respectively it will take less time in crossing a higher bandwidth link than a lower bandwidth link. OSPF uses this logic to calculate the cost (metric). Cost is the inverse proportional of bandwidth.

OSPF relies on costs that are inversely proportional to the interface or the link bandwidth. Therefore, higher (1000 Mbps) bandwidth links are preferred to lower (10Mbps) ones. The cost formula is reference bandwidth divided by interface bandwidth. The default reference bandwidth of 100 Mbps is used for OSPF cost calculation [7].

For example, if an Ethernet interface (10Mbps) is taken, the OSPF path cost value is $100 \text{ Mbps} / 10 \text{ Mbps} = 10$.

Key points to note related to Cost are:

- Cost is a positive integer value.
- Any decimal value would be rounded back in nearest positive integer.
- Any value below 1 would be considered as 1.

Table 2. Default OSPF Cost of essential interfaces

Interface Type	Bandwidth	Metric Calculation	Cost
Ethernet Link	10 Mbps	$100/10 = 10$	10
Fast Ethernet Link	100 Mbps	$100/100 = 1$	1
Serial Link	1544 Kbps	$100/1.544 = 64.76$	64

Shortest Path Tree (SPT) is the data structure used by OSPF routers. SPT is just like a family tree where router is the root

and destination networks are its leaves. SPF algorithm calculates the branch cost between leaves and root. Branch with lowest cost will be used to reach the leaf. In simple terms the route that has lowest cumulative cost value between the source and the destination will be selected for routing table.

Cumulative Cost => Sum of all outgoing interfaces cost in route

Best route for routing table => Route which has the lowest Cumulative Cost

Summary:

- OSPF uses SPT tree to calculate the best route for routing table.
- SPT tree cannot grow beyond a logical boundary called area. If a router has interfaces in multiple areas, it needs to build a separate tree for each area.
- SPF algorithm calculates all possible routes from source router to destination network.
- Cumulative cost is the sum of all the costs of the outgoing OSPF interfaces it the path towards destination.
- Only outgoing interface cost is considered and OSPF doesn't add the cost of incoming interface during cumulative cost calculation.
- If multiple routes exist, SPF compares the cumulative costs. Route which has the lowest cumulative cost will be chosen for routing table.

Considering the same topology that was used previously, OSPF configuration on different routers using the same IP address configuration and bandwidth as compared to the Routing Information Protocol (RIP) [8].

For Router R1 the OSPF Routing Protocol configurations are

```
R1#sh run | sec router ospf
router ospf 1
 network 10.10.10.0 0.0.0.255 area 0
 network 12.12.12.0 0.0.0.3 area 0
 network 14.14.14.0 0.0.0.3 area 0
R1#
```

Fig 13: Router R1 using OSPF

For Router R2 the OSPF Routing Protocol configurations are

```
R2#sh run | sec router ospf
router ospf 2
 network 12.12.12.0 0.0.0.3 area 0
 network 23.23.23.0 0.0.0.3 area 0
R2#
```

Fig 14: Router R2 using OSPF

For Router R3 the OSPF Routing Protocol configurations are

```
R3#show run | sec router ospf
router ospf 3
 network 23.23.23.0 0.0.0.3 area 0
 network 35.35.35.0 0.0.0.3 area 0
R3#
```

Fig 15: Router R3 using OSPF

For Router R4 the OSPF Routing Protocol configurations are

```
R4#show run | sec router ospf
router ospf 4
 network 14.14.14.0 0.0.0.3 area 0
 network 45.45.45.0 0.0.0.3 area 0
R4#
```

Fig 16: Router R4 using OSPF

For Router R5 the OSPF Routing Protocol configurations are

```
R5#show run | sec router ospf
router ospf 5
 network 20.20.20.0 0.0.0.255 area 0
 network 35.35.35.0 0.0.0.3 area 0
 network 45.45.45.0 0.0.0.3 area 0
R5#
```

Fig 17: Router R5 using OSPF

From the above OSPF Router configuration, the Output for the Best path towards the destination 20.20.20.0/24 on R1 comes via Router R4 i.e., R1->R4->R5 through Lower (100 Mbps) link and via Higher 1000 Mbps link as shown below.

```
20.0.0.0/24 is subnetted, 1 subnets
 20.20.20.0 [110/3] via 14.14.14.2,
23.0.0.0/30 is subnetted, 1 subnets
 23.23.23.0 [110/2] via 12.12.12.2,
35.0.0.0/30 is subnetted, 1 subnets
 35.35.35.0 [110/3] via 14.14.14.2,
 [110/3] via 12.12.12.2,
45.0.0.0/30 is subnetted, 1 subnets
 45.45.45.0 [110/2] via 14.14.14.2,
```

Fig 18: Router R1 Routing Table using default OSPF

Router R1 is showing the same path like RIP via Router R4, which was not expected! R1 should have chosen R2 with 1000 Mbps Link because of higher bandwidth.

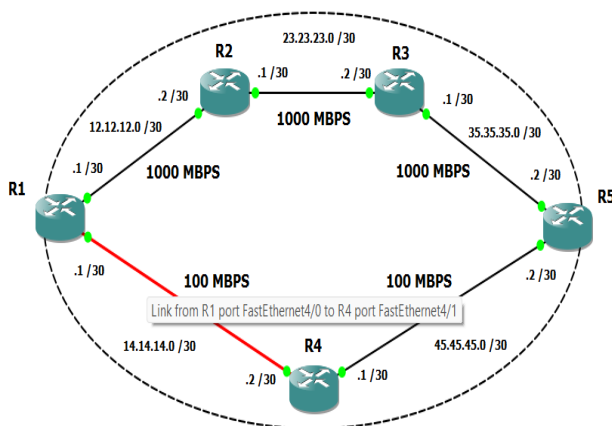


Fig 19: Best Path via R1->R4->R5 using default OSPF

4. RESULT AND DISCUSSION

The problem here is that Router R1 has chosen a lower bandwidth interface as the best path towards the destination connected on Router R5. This is due to the Cost calculation formula used using reference bandwidth of 100 Mbps in OSPF metric [9].

According to the default (current) mechanism in which the reference bandwidth is taken as 100 Mbps the key point lies in the fact that for both 1000 Mbps (Gigabit Ethernet) and 100 Mbps (Fast Ethernet) links the cost calculated and used as 1.

The Cost (metric) using 100 Mbps (Fast Ethernet) as

$$\Rightarrow 100 \text{ Mbps (ref. b/w)} / 100 \text{ Mbps (FE)} = 1$$

The Cost (metric) using 1000 Mbps (Gigabit Ethernet) as

$$\Rightarrow 100 \text{ Mbps (ref. b/w)} / 1000 \text{ Mbps (GE)} = 0.1 \{ \sim 1 \}$$

The Cumulate Cost through R1->R4->R5 comes out to be 3 i.e., for 100 Mbps (1) + 100 Mbps (1) + 1000 Mbps (1)

While the Cumulate Cost through R1->R2->R3->R5 comes out to be 4 i.e., 1000 Mbps (1) + 1000 Mbps (1) + 1000 Mbps + 1000 Mbps (1)

The cost values as computed per interface on R1 are

```
R1#show ip ospf interface f4/0
FastEthernet4/0 is up, line protocol is up
 Internet Address 14.14.14.1/30, Area 0, Attached
 Process ID 1, Router ID 14.14.14.1, Network Type
 Topology-MTID Cost Disabled Shutdown
 0 1 no no
```

Fig 20: Cost value “1” for 100 Mbps link

```
R1#show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
 Internet Address 12.12.12.1/30, Area 0, Attached
 Process ID 1, Router ID 14.14.14.1, Network Type
 Topology-MTID Cost Disabled Shutdown
 0 1 no no
```

Fig 21: Cost value “1” for 1000 Mbps link

Therefore, as per the Lowest Cost (metric) OSPF has chosen the Link with less Cost (metric) value of 3 i.e., via Router R4 with 100 Mbps link towards the destination address 20.20.20.0/24 [10].

Because of this default mechanism and default reference bandwidth value of 100 Mbps the path with less bandwidth is chosen as best by OSPF, which is slower as compared to the faster available 1000 Mbps path. Hence, manipulation is required for OSPF cost (metric) calculation based upon bandwidth of the network available.

Solution for this problem could be the modification done for considering the reference bandwidth value from 100 Mbps to 1000 Mbps. Using the reference bandwidth value of 1000 Mbps new Cost (metric) would be 1 for 1000 Mbps (Gigabit Ethernet) and 10 for 100 Mbps (Fast Ethernet) links.

The new Cost (metric) using 100 Mbps (Fast Ethernet) as
=> 1000 Mbps (ref. b/w) /100 Mbps (FE) = 10

The new Cost (metric) using 1000 Mbps (Gigabit Ethernet) as
=> 1000 Mbps (ref. b/w) / 1000 Mbps (GE) = 1

The new Cumulate Cost through R1->R4->R5 would be 21
i.e., for 100 Mbps (10) + 100 Mbps (10) + 1000 Mbps (1)

Whereas, the new Cumulate Cost through R1->R2->R3->R5
comes out to be 4 i.e., 1000 Mbps (1) + 1000 Mbps (1) + 1000
Mbps + 1000 Mbps (1)

Therefore, as per the Lowest Cost (metric) OSPF should
choose the Link with less Cost (metric) value of 4 i.e., via
Router R2 with 1000 Mbps link towards the destination
address 20.20.20.0/24.

The new cost (metric) reference bandwidth value of 1000
Mbps should be consistent throughout the network i.e., all
OSPF routers must follow the same approach for the
computation.

For Router R1 the new OSPF Protocol configurations are

```
R1#sh run | sec router ospf
router ospf 1
  auto-cost reference-bandwidth 1000
  network 10.10.10.0 0.0.0.255 area 0
  network 12.12.12.0 0.0.0.3 area 0
  network 14.14.14.0 0.0.0.3 area 0
R1#
```

Fig 22: Router R1 using updated OSPF Cost Value

For Router R2 the new OSPF Protocol configurations are

```
R2#sh run | sec router ospf
router ospf 2
  auto-cost reference-bandwidth 1000
  network 12.12.12.0 0.0.0.3 area 0
  network 23.23.23.0 0.0.0.3 area 0
R2#
```

Fig 23: Router R2 using updated OSPF Cost Value

For Router R3 the new OSPF Protocol configurations are

```
R3#sh run | sec router ospf
router ospf 3
  auto-cost reference-bandwidth 1000
  network 23.23.23.0 0.0.0.3 area 0
  network 35.35.35.0 0.0.0.3 area 0
R3#
```

Fig 24: Router R3 using updated OSPF Cost Value

All the router which are above int the topology like Router
R1, Router R2 and Router R3 are updated.

As these routers already using the Gigabit Ethernet having
1000 Mbps bandwidth. Therefore, no major change in metric
calculation over R1->R2->R3->R5.

For Router R4 the new OSPF Protocol configurations are

```
R4#sh run | sec router ospf
router ospf 4
  auto-cost reference-bandwidth 1000
  network 14.14.14.0 0.0.0.3 area 0
  network 45.45.45.0 0.0.0.3 area 0
R4#
```

Fig 25: Router R4 using updated OSPF Cost Value

For Router R5 the new OSPF Protocol configurations are

```
R5#sh run | sec router ospf
router ospf 5
  auto-cost reference-bandwidth 1000
  network 20.20.20.0 0.0.0.255 area 0
  network 35.35.35.0 0.0.0.3 area 0
  network 45.45.45.0 0.0.0.3 area 0
R5#
```

Fig 26: Router R5 using updated OSPF Cost Value

Once the new reference bandwidth of 1000 Mbps is applied
on all the OSPF routers the Cost value changes per interface.

The new cost values as computed per interface on R1 are

```
R1#show ip ospf interface f4/0
FastEthernet4/0 is up, line protocol is up
  Internet Address 14.14.14.1/30, Area 0, Attach
  Process ID 1, Router ID 14.14.14.1, Network Ty
  Topology-MTID  Cost  Disabled  Shutdown
                0      10      no      no
```

Fig 27:New Cost value “10” for 100 Mbps link

```
R1#show ip ospf interface g0/0
GigabitEthernet0/0 is up, line protocol is up
  Internet Address 12.12.12.1/30, Area 0, Attach
  Process ID 1, Router ID 14.14.14.1, Network Ty
  Topology-MTID  Cost  Disabled  Shutdown
                0      1      no      no
```

Fig 28:New Cost value “1” for 1000 Mbps link

According to the new reference bandwidth the Router R1 has
selected the new Best Path towards 20.20.20.0/24 via R2.

```
20.0.0.0/24 is subnetted, 1 subnets
  20.20.20.0 [110/4] via 12.12.12.2,
23.0.0.0/30 is subnetted, 1 subnets
  23.23.23.0 [110/2] via 12.12.12.2,
35.0.0.0/30 is subnetted, 1 subnets
  35.35.35.0 [110/3] via 12.12.12.2,
45.0.0.0/30 is subnetted, 1 subnets
  45.45.45.0 [110/13] via 12.12.12.2
```

Fig 29: Router R1Table using updated OSPF Cost Value

The path is via R1->R2->R3->R5 i.e., using Cost (metric)=4
as shown with [110/4] via 12.12.12.2 (R2) where 110=AD
value of OSPF and 4=Cost (metric) towards the destination

address of 20.20.20/24.

Now again, PC-1 with Source address 10.10.10.1/24 will reach the Destination address 20.20.20.1/24 as shown

```
PC-1#ping 20.20.20.1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 20.20.20.1,
!!!!
Success rate is 100 percent (5/5), round-trip
```

Fig 30: PC-1 PING again Destination IP 20.20.20.1

But this time, the new path verified on PC-1 via traceroute as

```
PC-1#traceroute 20.20.20.1
Type escape sequence to abort.
Tracing the route to 20.20.20.1
VRF info: (vrf in name/id, vrf out name/id)
 0 10.10.10.3 24 msec 28 msec 28 msec
 1 12.12.12.2 60 msec 76 msec 60 msec
 2 23.23.23.2 92 msec 108 msec 100 msec
 3 35.35.35.2 140 msec 140 msec 136 msec
 4 20.20.20.1 152 msec 172 msec 172 msec
```

Fig 31: PC-1 Traceroute via R1->R2->R3->R5

With the new result on Router R1 shows the updated path as expected i.e., via Router R2. R1 has chosen R2 with 1000 Mbps Link because of higher bandwidth as compared to R4 with lower bandwidth of 100 Mbps.

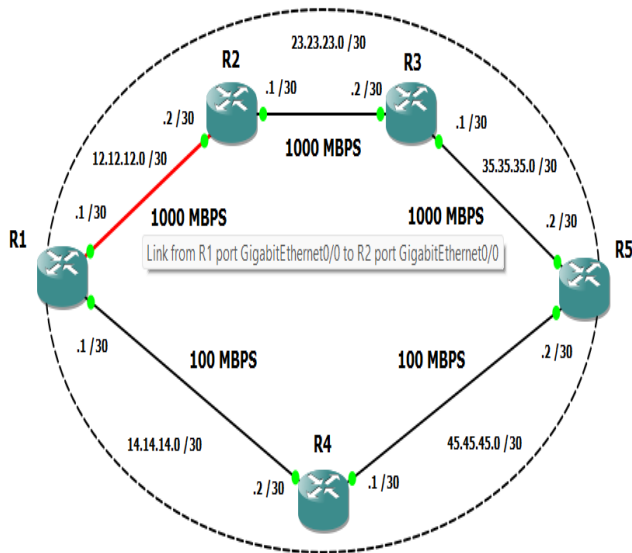


Fig 32: Best Path via R1->R2->R3 using updated OSPF

5. CONCLUSION AND FUTURE SCOPE

From the above experimental study, it's concluded that the OSPF Best Path selection mechanism can be manipulated

using some parameters like reference bandwidth.

Therefore, whenever OSPF is deployed in real production environment the default cost (metric) can result into sub-optimal path selection. The parameters like reference bandwidth should be modified as per the network topology so as to achieve a better path selection process resulting higher data transfer speed (rate).

Future scope could be done for the same using multiple parameters like bandwidth and delay on the interface.

Further study can be conducted towards finding new parameters and modification related to the OSPF Shortest Path First (SPF) algorithm resulting higher throughput and lower transmission time over the network.

6. ACKNOWLEDGMENTS

Thanks to Er. Deepak Malik (C.C.I.E. No. 51724) CISCO network expert, who has contributed towards development of this research work by providing the correct set of tools and simplified approach.

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