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Optimising OSPF Path Metric with Reference Bandwidth Modification and Convergence Analysis

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ABSTRACT
OSPF is a widely used interior gateway protocol to provide connectivity within the large-scale organization. The role of routing protocols is to calculate the best path selection towards the destination address. OSPF being an open standard protocol which provides multi-vender support becomes the best choice to be used within the network for providing internal connectivity. Like OSPF there are many other routing protocols like Border Gateway Protocol, Enhanced Interior Gateway Routing Protocol, Routing Information Protocol, IS-IS, etc. which are also used to provide internal network connectivity. This study aims to discuss OSPF path parameters that is cost or metric convergence and their modification when used with multiple bandwidths available in the network path. Optimised selection of OSPF path metric parameters is the aim so as to achieve a better path selection criterion within the network. With OSPF path selection metric multiple combinations would be tested so as to find an optimum solution for metric calculation within a large OSPF network.

General Terms
Routed Protocol, Routing Protocol, IGP, Internet, Best Path, Network, Source IP Address, Destination IP Address.

Keywords
OSPF, Delay, Reference Bandwidth, Path Metric, Cost, Router, Bandwidth, IOS.

1. INTRODUCTION
Networking protocols are two types classified as routed protocol and routing protocol. Routed protocol has the task to carry the user traffic over the path that is calculated by routing protocols. Different types of routed protocols have different frame format to carry user data. Some of the common examples of routed protocols are IPv4, IPv6, IPX, Apple Talk, etc. These protocols have different structure to carry data but a common aim i.e. user traffic transportation from source to destination address.

On the other hand, routing protocols have the responsibility to calculate best path between source IP address and destination IP address. The path calculated by routing protocols are used by routed protocol to transport user traffic. Routing protocols works continuously just to check the availability for best path within the network. [1]

Routing protocols never carry user traffic but help routed protocols by providing correct path information between source and destination. Some examples of routing protocols are OSPF, EIGRP, BGP, RIP, IS-IS, etc. These all have a same aim of calculation of best path towards destination IP address. [2]

This research was conducted with an aim of finding an optimum solution in OSPF for best path selection using correct reference bandwidth values and test them on real network using network simulator (emulator) like GNS3 for real world output.

2. CURRENT WORKING DESIGN
OSPF is a Link State Routing Protocol that 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. OSPF uses tables like neighbor table, topology table to share the information within the network. Example, Open Shortest Path First that shares their own link information with the neighbor routers so as to have better view of the entire topology of the network. It helps the OSPF neighbor router to build and share the most updated information about the network. [3]

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 network updates contain information about routing protocols such as Autonomous System number, Administrative Distance (AD), Metric values and interface details. Administrative Distance 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 lowest 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 values that are used in CISCO devices are:

Table 1. Some Default AD values on CISCO

Route Source	Value
Connected	000
Static Routes	001
BGP – External	020
EIGRP	090
OSPF	110
RIP	120
BGP – Internal	200
Unreachable	255

Example, if there is network information update from OSPF with AD = 110 and the same network update is available through RIP with AD = 120, the route or the path will the chosen with OSPF (AD = 110) because of the lower value than the RIP AD = 120.

Metric is the next (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 methos how to calculate the metric or cost for a given path. The path with the lowest metric (cost) is selected when there is AD conflict. [4]

Example protocol OSPF uses link Bandwidth, EIGRP uses parameters like Bandwidth, Load, MTU, etc. while RIP protocol uses Hop-Count as a metric value.

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:

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

The Open Shortest Path First 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 functional AD value for OSPF on CISCO platform is 110, as default. For calculating the Cost or Metric the OSPF uses "Bandwidth" of the link (interface) as a parameter. The higher the bandwidth, the better is the path. The Metric or cost value is inversely proportional to the Bandwidth i.e., Higher the Bandwidth, Lower is the Metric. As always, lower cost value is preferred for the Best Path selection in OSPF.

OSPF relies on costs that are inversely proportional to the interface or the link bandwidth. Therefore, higher 1 Gigabit (1000 Mbps) bandwidth links are preferred to lower (10 Mbps) ones. The cost formula is Reference Bandwidth (RB) divided by interface Bandwidth. The default reference bandwidth of 100 Mbps is used for OSPF cost calculation. [5]

A packet will face more overhead in crossing a 1544 Kbps serial link than crossing a 100 Mbps link, because of lower bandwidth availability on serial interfaces (1544 Kbps). 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 or metric. Cost is the inverse proportional of bandwidth. [6]

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

Key points for OSPF Cost are:

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

Table 2. Default OSPF Cost Values

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 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 routers. Branch with lowest cost value 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 (RT). [7]

Cumulative Cost => Sum of all Outgoing Interfaces Cost in route

Best Route for Routing Table (RT) => Route which has the lowest Cumulative Cost

Overall OSPF working summary:

1. 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.
2. SPF algorithm calculates all possible routes from source router to destination network.
3. Cumulative cost is the sum of all the costs of the outgoing OSPF interfaces it the path towards destination.
4. Only outgoing interface cost is considered and OSPF doesn't add the cost of incoming interface during cumulative cost calculation.
5. If multiple routes exist, SPF compares the cumulative costs. Route which has the lowest cumulative cost will be chosen for routing table.

3. EXPERIMENTAL ANALYSIS

3.1 Working Design Tools

In this research work the network simulator GNS3 (Graphical Network Simulator v3) is used with real networking operating system of CISCO routers so as get a perfect replica of network functioning like real-world.

Using this GNS3 simulation tool results are better and more reliable. The output obtained is similar to real devices used in production environment. The tools like GNS3 are used by network engineers to mimic and troubleshoot a real-life live environment.

3.2 Topology Description

For the OSPF network topology 7 CISCO Routers with Advance IP Services as Operating System (OS) Version 15.x is used. The Operating System (OS) are of latest series for 7200 series platform provided by CISCO for IOS 15.x and above.

The network topology with IP Address is shown in Figure 1. There are two paths shown from Router R1 as source towards Router R5 as destination. The client machine (PC) is connected on R1 has two options to reach the destination Server on R5.

The path via R1-> R2-> R3-> R4-> R5 has Bandwidth of 1000 Mbps, whereas the path via R1-> R7-> R6-> R5 has bandwidth of 100 Mbps. The total number of routers jumps (hops) via R2 are 4, whereas via R7 the jumps (hops) are only 3.

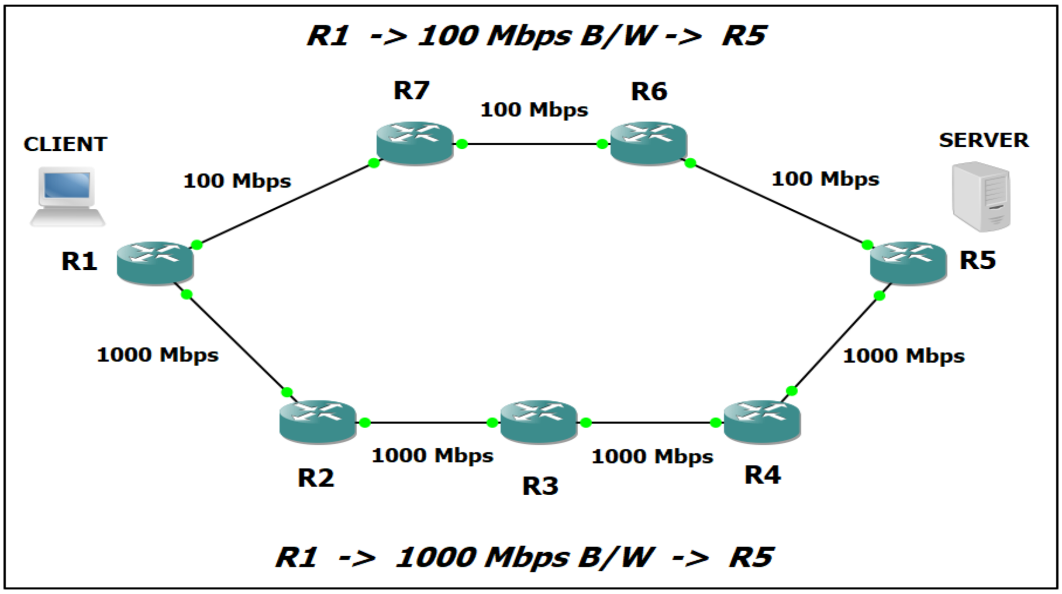

Fig 1: OSPF working topology of 7 Routers with 2 Paths from Source R1 towards Destination R5

3.3 Testing and Verification using OSPF

OSPF configuration is done on all routers using IPv4 as the network routed protocol for carrying the user traffic between source network from Router R1 to destination network on Router R5.

The Router R1 has two types of Link (interface) one connected towards R7 with 100 Mbps and other connected towards Router R2 with 1000 Mbps.

Router R1 link description towards R7 with 100 Mbps

```
R1#show interface fa 4/0
FastEthernet4/0 is up, line protocol is up
  Hardware is i82543 (Livengood), address is
  Internet address is 17.17.17.1/24
  MTU 1500 bytes, BW 100000 Kbit/sec, DLY 100
     reliability 255/255, txload 1/255, rxloa
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Full-duplex, 100Mb/s, 100BaseTX/FX
```

Fig 2: R1 link towards R7 using 100 Mbps bandwidth

Router R1 link description towards R2 with 1000 Mbps

```
R1#show interface gig 0/0
GigabitEthernet0/0 is up, line protocol is up
  Hardware is i82543 (Livengood), address is
  Internet address is 12.12.12.1/24
  MTU 1500 bytes, BW 1000000 Kbit/sec, DLY 10
     reliability 255/255, txload 1/255, rxloa
  Encapsulation ARPA, loopback not set
  Keepalive set (10 sec)
  Full Duplex, 1000Mbps, link type is auto, m
```

Fig 3: R1 link towards R2 using 1000 Mbps bandwidth

The Routers R1, R2, R3, R4, R5, R6 & R7 all are configured with OSPF configuration. The OSPF router link for R1, R2, R3, R4 & R5 is having more Bandwidth (1000 Mbps) while the OSPF router link for R1, R7, R6 & R5 is having less bandwidth (100 Mbps) i.e. 10 times less as compared to other path.

For Router R1 the OSPF Routing Protocol configurations are

```
R1#show run | sec router ospf
router ospf 1
 network 1.1.1.0 0.0.0.255 area 0
 network 12.12.12.0 0.0.0.255 area 0
 network 17.17.17.0 0.0.0.255 area 0
R1#
```

Fig 4: Router R1 using default OSPF

For Router R2 the OSPF Routing Protocol configurations are

```
R2#show run | sec router ospf
router ospf 2
 network 2.2.2.0 0.0.0.255 area 0
 network 12.12.12.0 0.0.0.255 area 0
 network 23.23.23.0 0.0.0.255 area 0
R2#
```

Fig 5: Router R2 using default OSPF

For Router R3 the OSPF Routing Protocol configurations are

```
R3#show run | sec router ospf
router ospf 3
 network 3.3.3.0 0.0.0.255 area 0
 network 23.23.23.0 0.0.0.255 area 0
 network 34.34.34.0 0.0.0.255 area 0
R3#
```

Fig 6: Router R3 using default OSPF

For Router R4 the OSPF Routing Protocol configurations are

```
R4#show run | sec router ospf
router ospf 4
 network 4.4.4.0 0.0.0.255 area 0
 network 34.34.34.0 0.0.0.255 area 0
 network 45.45.45.0 0.0.0.255 area 0
R4#
```

Fig 7: Router R4 using default OSPF

For Router R5 the OSPF Routing Protocol configurations are

```
R5#show run | sec router ospf
router ospf 5
 network 5.5.5.0 0.0.0.255 area 0
 network 45.45.45.0 0.0.0.255 area 0
 network 56.56.56.0 0.0.0.255 area 0
R5#
```

Fig 8: Router R5 using default OSPF

For Router R6 the OSPF Routing Protocol configurations are

```
R6#show run | sec router ospf
router ospf 6
 network 6.6.6.0 0.0.0.255 area 0
 network 56.56.56.0 0.0.0.255 area 0
 network 67.67.67.0 0.0.0.255 area 0
R6#
```

Fig 9: Router R6 using default OSPF

For Router R7 the OSPF Routing Protocol configurations are

```
R7#show run | sec router ospf
router ospf 7
 network 7.7.7.0 0.0.0.255 area 0
 network 17.17.17.0 0.0.0.255 area 0
 network 67.67.67.0 0.0.0.255 area 0
R7#
```

Fig 10: Router R7 using default OSPF

Based upon the current OSPF configuration the OSPF Cost calculation for Fast Ethernet (100 Mbps) link towards R7 is 1.

```
R1#show ip ospf interface fa 4/0
FastEthernet4/0 is up, line protocol is
  Internet Address 17.17.17.1/24, Area
  Process ID 1, Router ID 1.1.1.1, Netw
  Topology-MTID    Cost    Disabled
        0           1         no
  Transmit Delay is 1 sec, State DR, Pr
  Designated Router (ID) 1.1.1.1, Inter
  Backup Designated router (ID) 7.7.7.7
  Timer intervals configured, Hello 10,
```

Fig 11: R1 Link Cost (1) towards R7 using default OSPF

Whereas, the OSPF Cost calculation for Gigabit Ethernet (1000 Mbps) link towards R2 is also the same as 1. That's due to the default Cost calculation of Reference Bandwidth (RB) value of 100 Mbps and any value below 1 is considered as 1.

For 100 Mbps (100/100 = 1) & for 1000 Mbps (100/1000 = 0.1) therefore, Cost is also 1.

OSPF Cost calculation for Gigabit Ethernet (1000 Mbps) link towards R2 is also 1.

```
R1#show ip ospf interface gig 0/0
GigabitEthernet0/0 is up, line protocol
  Internet Address 12.12.12.1/24, Area
  Process ID 1, Router ID 1.1.1.1, Netw
  Topology-MTID    Cost    Disabled
        0           1         no
  Transmit Delay is 1 sec, State DR, Pr
  Designated Router (ID) 1.1.1.1, Inter
  Backup Designated router (ID) 2.2.2.2
  Timer intervals configured, Hello 10,
```

Fig 12: R1 Link Cost (1) towards R2 using default OSPF

Based upon the above method the total cost computed via Router R7 towards destination Router R5 is 4 (1+1+1+1) whereas, total cost computed via Router R2 towards destination Router R5 is 5 (1+1+1+1+1+1) due to more routers in the path.

Therefore, because of lower path cost (metric) of 4, the source Router R1 chooses the link with 100 Mbps Bandwidth via R7 instead of better bandwidth (1000 Mbps) available via R2.

```
R1#show ip route 5.5.5.5
Routing entry for 5.5.5.5/32
  Known via "ospf 1", distance 110, m
  Last update from 17.17.17.7 on Fast
  Routing Descriptor Blocks:
  * 17.17.17.7, from 5.5.5.5, 00:31:5
      Route metric is 4, traffic shar
R1#
```

Fig 13: Path from R1 towards destination R5 via R7

To check the connectivity for destination 5.5.5.5 from R1 source 1.1.1.1, ping test is conducted successfully.

```
R1#ping 5.5.5.5 so lo 1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 5.5.5.5, t
Packet sent with a source address of 1.1.1.1
!!!!!
```

Fig 14: Ping from source R1 towards destination R5

To check the correct path for destination 5.5.5.5 from R1 source 1.1.1.1, Traceroute test is conducted successfully.

```
R1#traceroute 5.5.5.5 so lo 1
Type escape sequence to abort.
Tracing the route to 5.5.5.5
VRF info: (vrf in name/id, vrf out name/id)
  1 17.17.17.7 144 msec 116 msec 80 msec
  2 67.67.67.67 164 msec 156 msec 112 msec
  3 56.56.56.5 252 msec 252 msec *
R1#
```

Fig 15: Trace from R1 towards destination R5 via R7

The above test conducted clearly shows that despite of availability of better path with higher Bandwidth (1000 Mbps), the default OSPF path calculation prefer path with lesser Bandwidth (100 Mbps) only.

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 (RB) of 100 Mbps in OSPF metric.

According to the OSPF default mechanism in which the reference bandwidth is taken as 100 Mbps, the key element 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

- 100 Mbps (Ref. B/W) /100 Mbps (FE) = 1

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

- 100 Mbps (Ref. B/W) / 1000 Mbps (GE) = 0.1 {~1}

The Cumulate Cost through R1-> R7-> R6-> R5 comes out to be 4 i.e., for 100 Mbps (1) + 100 Mbps (1) + 100 Mbps (1) + 1000 Mbps (1).

Whereas, the Cumulate Cost through R1-> R2-> R3-> R4-> R5 comes out to be 5 i.e., 1000 Mbps (1) + 1000 Mbps (1) + 1000 Mbps + 1000 Mbps (1) + 1000 Mbps (1).

The computed best path with default OSPF cost (metric) is via R7 with 100 Mbps Bandwidth as shown in Figure 16.

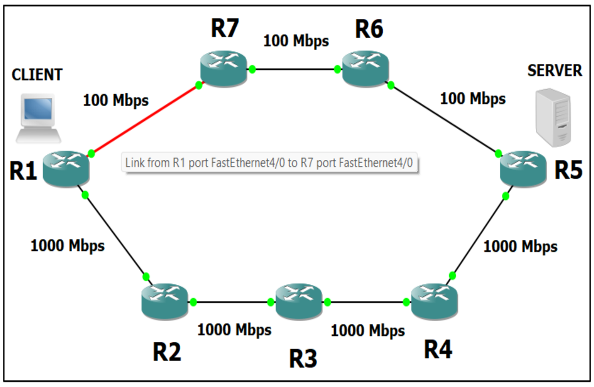

Fig 16: R1 default Path via R7 towards destination R5

Solution for this path selection problem could be the modification done for considering the Reference Bandwidth (RB) value from default 100 Mbps to 1000 Mbps.

Using the Reference Bandwidth (RB) value of 1000 Mbps the new Cost value would be 1 for 1000 Mbps (Gigabit Ethernet) and 10 for 100 Mbps (Fast Ethernet) links.

The new Cost value using 100 Mbps (Fast Ethernet) as

- 1000 Mbps (Ref. B/W) / 100 Mbps (FE) = 10

The new Cost value using 1000 Mbps (Gigabit Ethernet) as

- 1000 Mbps (Ref. B/W) / 1000 Mbps (GE) = 1

The new Cumulate Cost through R1-> R7-> R6-> R5 would be 31 i.e., for 100 Mbps (10) + 100 Mbps (10) + 100 Mbps (10) + 1000 Mbps (1).

Whereas, the new Cost through R1-> R2-> R3-> R4-> R5 comes out to be 5 i.e., 1000 Mbps (1) + 1000 Mbps (1) + 1000 Mbps + 1000 Mbps (1) + 1000 Mbps (1).

Therefore, as per the Lowest Cost (metric) OSPF should choose the Link with less Cost (metric) value of 5 i.e., via Router R2 with 1000 Mbps link towards the destination address 5.5.5.5.0/24.

The new Cost or Metric Reference Bandwidth (RB) value of 1000 Mbps should be consistent throughout all the routers in the network i.e., all OSPF routers must follow the same RB approach for the computation as

"auto-cost reference-bandwidth 1000" i.e. Ref. B/W = 1000

For Router R1 the new OSPF Protocol configurations are

```
R1#show run | sec router ospf
router ospf 1
 auto-cost reference-bandwidth 1000
 network 1.1.1.0 0.0.0.255 area 0
 network 12.12.12.0 0.0.0.255 area 0
 network 17.17.17.0 0.0.0.255 area 0
R1#
```

Fig 17: Router R1 using updated OSPF

For Router R2 the new OSPF Protocol configurations are

```
R2#show run | sec router ospf
router ospf 2
 auto-cost reference-bandwidth 1000
 network 2.2.2.0 0.0.0.255 area 0
 network 12.12.12.0 0.0.0.255 area 0
 network 23.23.23.0 0.0.0.255 area 0
R2#
```

Fig 18: Router R2 using updated OSPF

For Router R3 the new OSPF Protocol configurations are

```
R3#show run | sec router ospf
router ospf 3
 auto-cost reference-bandwidth 1000
 network 3.3.3.0 0.0.0.255 area 0
 network 23.23.23.0 0.0.0.255 area 0
 network 34.34.34.0 0.0.0.255 area 0
R3#
```

Fig 19: Router R3 using updated OSPF

For Router R4 the new OSPF Protocol configurations are

```
R4#show run | sec router ospf
router ospf 4
 auto-cost reference-bandwidth 1000
 network 4.4.4.0 0.0.0.255 area 0
 network 34.34.34.0 0.0.0.255 area 0
 network 45.45.45.0 0.0.0.255 area 0
R4#
```

Fig 20: Router R4 using updated OSPF

For Router R5 the new OSPF Protocol configurations are

```
R5#show run | sec router ospf
router ospf 5
 auto-cost reference-bandwidth 1000
 network 5.5.5.0 0.0.0.255 area 0
 network 45.45.45.0 0.0.0.255 area 0
 network 56.56.56.0 0.0.0.255 area 0
R5#
```

Fig 21: Router R5 using updated OSPF

For Router R6 the new OSPF Protocol configurations are

```
R6#show run | sec router ospf
router ospf 6
 auto-cost reference-bandwidth 1000
 network 6.6.6.0 0.0.0.255 area 0
 network 56.56.56.0 0.0.0.255 area 0
 network 67.67.67.0 0.0.0.255 area 0
R6#
```

Fig 22: Router R6 using updated OSPF

For Router R7 the new OSPF Protocol configurations are

```
R7#show run | sec router ospf
router ospf 7
 auto-cost reference-bandwidth 1000
 network 7.7.7.0 0.0.0.255 area 0
 network 17.17.17.0 0.0.0.255 area 0
 network 67.67.67.0 0.0.0.255 area 0
R7#
```

Fig 23: Router R7 using updated OSPF

Based upon the updated OSPF configuration the OSPF Cost calculation for Fast Ethernet (100 Mbps) link towards R7 is 10.

```
R1#show ip ospf interface fa 4/0
FastEthernet4/0 is up, line protocol is
  Internet Address 17.17.17.1/24, Area 0
  Process ID 1, Router ID 1.1.1.1, Netw
  Topology-MTID    Cost    Disabled    S
        0           10        no
  Transmit Delay is 1 sec, State DR, Pr
  Designated Router (ID) 1.1.1.1, Inter
  Backup Designated router (ID) 7.7.7.7
  Timer intervals configured, Hello 10,
```

Fig 24: R1 Link Cost (10) towards R7 after updating

New OSPF Cost calculation for Gigabit Ethernet (1000 Mbps) link towards R2 is now 1.

```
R1#show ip ospf interface gig 0/0
GigabitEthernet0/0 is up, line protocol
  Internet Address 12.12.12.1/24, Area 0
  Process ID 1, Router ID 1.1.1.1, Netw
  Topology-MTID    Cost    Disabled    S
        0           1         no
  Transmit Delay is 1 sec, State DR, Pr
  Designated Router (ID) 1.1.1.1, Inter
  Backup Designated router (ID) 2.2.2.2
  Timer intervals configured, Hello 10,
```

Fig 25: R1 Link Cost (1) towards R2 after updating

Based upon the above method the updated total cost computed via Router R7 towards destination Router R5 is 31 (10+10+10+1) whereas, total cost computed via Router R2 towards destination Router R5 is 5 (1+1+1+1+1) even for more routers in the path.

Therefore, because of lower path Cost (metric) of 5, the source Router R1 chooses the link with 1000 Mbps Bandwidth via R2 instead of lower bandwidth (100 Mbps) available via R7.

```
R1#show ip route 5.5.5.5
Routing entry for 5.5.5.5/32
  Known via "ospf 1", distance 110,
  Last update from 12.12.12.2 on Gi
  Routing Descriptor Blocks:
  * 12.12.12.2, from 5.5.5.5, 00:02
      Route metric is 5, traffic sh
R1#
```

Fig 26: Path from R1 towards destination R5 via R2

To check the connectivity, ping test is conducted successfully.

```
R1#ping 5.5.5.5 so lo 1
Type escape sequence to abort.
Sending 5, 100-byte ICMP Echos to 5.5.5.5, t
Packet sent with a source address of 1.1.1.1
!!!!!
```

Fig 27: Ping from source R1 towards destination R5

To check the correct path for destination 5.5.5.5 from R1 source 1.1.1.1, Traceroute test is conducted successfully.

```
R1#traceroute 5.5.5.5 so lo 1
Type escape sequence to abort.
Tracing the route to 5.5.5.5
VRF info: (vrf in name/id, vrf out name/id
  1 12.12.12.2 112 msec 132 msec 100 msec
  2 23.23.23.3 156 msec 148 msec 204 msec
  3 34.34.34.4 252 msec 156 msec 252 msec
  4 45.45.45.5 248 msec 296 msec *
R1#
```

Fig 28: Trace from R1 towards destination R5 via R2

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 R7 with lower Bandwidth of 100 Mbps.

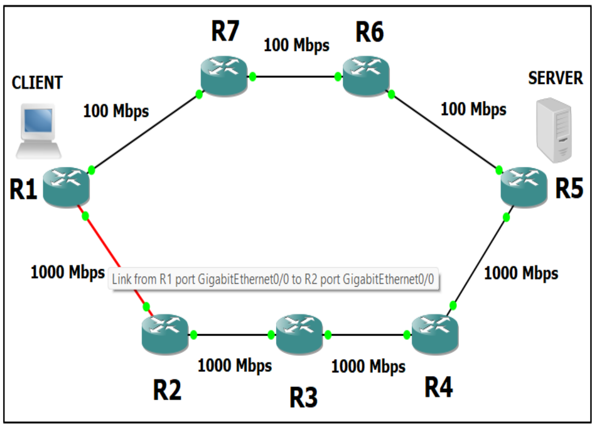

Fig 29: R1 updated Best Path via R2 towards R5

5. CONCLUSION AND FUTURE SCOPE

From the above experimental research study, it's concluded that the OSPF default Best path selection mechanism is not the best. Optimisation is required for OSPF using correct Reference Bandwidth (RB) calculated according to the network actual available bandwidth.

Therefore, whenever OSPF is deployed in real production environment the default cost or metric can result into sub-optimal path selection.

The link (interface) 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 algorithm resulting higher throughput with lower transmission time over the user network.

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