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OSPF Metric Modification and Convergence Analysis during Redistribution with EIGRP

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ABSTRACT
In computer network world OSPF is widely used protocol to provide connectivity within the large organization. The role of any routing protocol is to calculate the best path towards the destination IP address. The OSPF being a multi-vender friendly protocol becomes the first choice to be used within the organization network to provide internal network connectivity. Apart from OSPF there are other routing protocols are present like Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), IS-IS, etc. which are also used for internal network connectivity. This study aims to discuss the OSPF metric change i.e. metric (cost) convergence and modification when used with other routing protocol like EIGRP. Optimized selection of OSPF metric (cost) parameters is the aim so as to achieve a better path selection within the network is the primary goal. With OSPF and EIGRP multiple combinations would be tested so as to find an optimum solution for metric calculation within a large user network.

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

Keywords
OSPF, EIGRP, Metric, Cost, Router, Redistribution, Bandwidth, Delay.

1. INTRODUCTION
Computer network consists of collection of multiple small networks and devices working together as a single unit to share resources. Resources can be anything depending upon user requirements like printer, internet, files, etc. To build a computer network the routing protocols and routed protocols are used together as a single unit. Routed protocols provide the framework how to carry data over the network. Internet Protocol (IP) version 4 or IPv6, IPX are examples of routed protocol as they provide the framework how to carry the user data in the network. This framework is predefined using these set of rules called routed protocol. On the other hand, routing protocols like OSPF, EIGRP, BGP, RIP have the task to determine where to carry the user data. These protocols have different algorithms through which each routing protocol calculate the best path selection towards the destination IP address throughout the network. The path selection criteria are different for each routing protocol as the parameters selected for calculation are different. The primary aim is to find the best path through which the user data can be carried within the large network using multiple parameters used by routing protocols.

Open Shortest Path First (OSPF) is the most commonly used Interior Gateway Protocol (IGP) to manage any organization whether the organization is small or large. OSPF is used widely inside large network to calculate the best path for sending user traffic. Because of its Industry Standard feature OSPF can also be used with multi-vendor environment where other protocols like EIGRP are not welcome.

This research aims to achieve a better selection of OSPF metric values which are required during redistribution i.e. when club with other routing protocol like EIGRP which has a totally different mechanism for Best Path Selection.

2. CURRENT WORKING DESIGN
The aim of any computer network is resource sharing for which the multiple networking devices works together. Networking devices like router, switch, firewall, access-points, etc. are used in both hardware and software deployment.

The various protocols are used with these devices like routing and routed protocols. The routing protocols works to find the best path over the computer network by using some pre-defined algorithms for metric calculation [1][2].

OSPF belongs to the category of Interior Gateway Protocol (IGP) in which other protocols like Routing Information Protocol (RIP), Enhanced Interior Gateway Routing Protocol (EIGRP), IS-IS etc., also falls.

Within a large network the primary choice is the OSPF to manage the network and find the best path for user traffic. EIGRP is also a good choice but not widely used like OSPF. OSPF also provides much more flexible and scalable design as compared to any other routing protocol. Because of its multi-vendor support OSPF becomes the best routing protocol to work within a large-scale computer network environment [3].

For any routing protocol the primary aim is the same i.e. to calculate the best path available in the user network. Different routing protocols have different algorithms that can find a different best path over the same computer network. Routing updates are exchanged between the routers which contains information such as Administrative Distance (AD), metric values and interface information like Bandwidth, Delay, Reliability, Load, Maximum Transmission Unit (MTU).

Administrative Distance (AD) defines the reliability of the source used for calculating the best path in the network. Smaller the value, more trusted is the source i.e. better selection as compared to other higher value source. 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 [4].

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. The path with lower metric value is chosen as the better path i.e. the path with lowest metric value is selected when there is tie of similar AD values for multiple paths [5].

Some common Administrative Distance values that are used in networking devices particularly in CISCO vendor are

Table 1. Admin Distance (default) values

Device Source	AD value
Directly Connected	000
Static Route	001
External-BGP	020
EIGRP (internal)	090
Open Shortest Path First (OSPF)	110
Routing Information Protocol (RIP)	120
Internal-BGP	200
Unreachable	255

OSPF uses bandwidth of the interface to calculate the metric (cost) parameter. Whereas EIGRP uses bandwidth, delay, MTU, load, etc. for calculation of metric on the network path. When more than one routing protocol is used then there is a need for redistribution i.e. mutual understanding of the rules of different routing protocol [6].

This is done using the sharing of information from one routing protocol to another. Information is exchanged with both ends hence refers to as mutual redistribution.

Topology tables are constructed by all routing protocols and are exchanged with their neighbors to learn information about the network. Networking devices (routers) exchange the information that are stored inside these tables for better understanding the design of the network [7].

From these topology tables the best routes are placed in routing table for final lookup during the forwarding phase.

During redistribution the Topology Table (TT) 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 EIGRP 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 EIGRP uses multiple parameters like bandwidth, delay, load, reliability, MTU, etc. for calculation of path metric [8].

3. TESTING AND ANALYSIS

3.1 Working Tools Description

For this research study the network design is chosen such that it is commonly used in production real-time environment. The topology consists of CISCO routers and switches along with end devices so as to have real-time result quite closely to real-time or live environment. The tools like simulators that replicate the functionality of real devices are used in this research work for checking real output.

In this research the official CISCO simulator tool i.e. CISCO packet tracer is used to simulate the network. This is available from CISCO and gives correct output during testing.

The emulator can show the real output as compared to an actual CISCO machine whether it’s a router or a switch. These emulators can provide a better testing environment as close to real devices. These are widely used for testing and fault finding even in real world. The advantages like easy availability and flexible design make it more favorable tool to work with.

3.2 Detailed Topology Description

The testing design topology consists of 5 CISCO routers with 4 CISCO switches simulating a large network. 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 simulating 4 user LANs. Each subnet can add total 254 users because of subnet mask used as 255.255.255.0 or /24.

The OSPF network is shown in green area on the left-hand side and the EIGRP network is shown with blue are on the right side. The router 5 is acting like a common router for both OSPF and EIGRP thus referred as a mutual redistribution point for exchanging. This router is responsible for exchanging the topology information between OSPF and EIGRP.

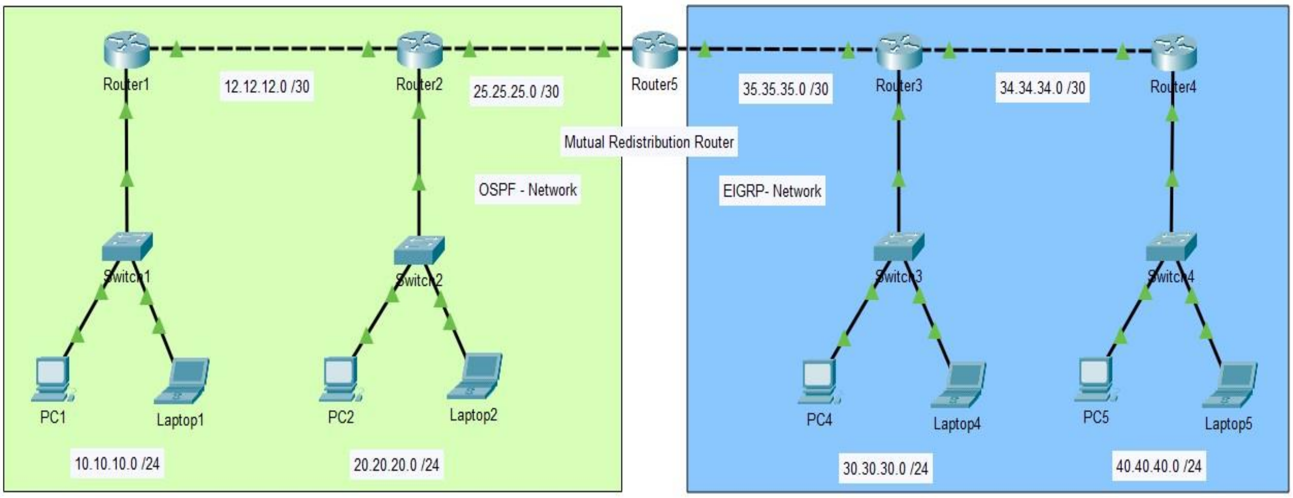

Figure 1: Topology with 4 LAN with 4 Routers and 1 Redistribution Router

3.3 Experimental Testing and Verification

Open Shortest Path First (OSPF) is configured on R1, R2 & R5.

The OSPF configuration done on these devices are

For Router R1 the configuration for OSPF protocol is

```
R1#sh run | sec router
router ospf 125
 log-adjacency-changes
 network 12.12.12.0 0.0.0.3 area 0
 network 10.10.10.0 0.0.0.255 area 0
```

Figure 2: Router R1 with OSPF configuration

For Router R2 the configuration for OSPF protocol is

```
R2#sh run | sec router
router ospf 125
 log-adjacency-changes
 network 25.25.25.0 0.0.0.3 area 0
 network 20.20.20.0 0.0.0.255 area 0
 network 12.12.12.0 0.0.0.3 area 0
```

Figure 3: Router R2 with OSPF configuration

For Router R5 the configuration for OSPF protocol is

```
R5#sh run | sec router ospf
router ospf 125
 log-adjacency-changes
 network 25.25.25.0 0.0.0.3 area 0
```

Figure 4: Router R5 with OSPF configuration

Router R5 is a common central point which provide mutual redistribution for exchanging of information between OSPF (code O) and EIGRP (code D). Router R3 and R4 are connected on the right side of R5 and are using EIGRP.

The configurations used on these routers are

For Router R5 the configuration for EIGRP protocol is

```
R5#sh run | sec router eigrp
router eigrp 345
 network 35.35.35.0 0.0.0.3
```

Figure 5: Router R5 with EIGRP configuration

For Router R3 the configuration for EIGRP protocol is

```
R3#sh run | sec router
router eigrp 345
 network 34.34.34.0 0.0.0.3
 network 30.30.30.0 0.0.0.255
 network 35.35.35.0 0.0.0.3
```

Figure 6: Router R3 with EIGRP configuration

For Router R4 the configuration for EIGRP protocol is

```
R4#sh run | sec router
router eigrp 345
 network 40.40.40.0 0.0.0.255
 network 34.34.34.0 0.0.0.3
```

Figure 7: Router R4 with EIGRP configuration

According to the current configuration of OSPF (O) and EIGRP (D) the Routing Table (RT) of all routers are populated as

The Router R1 Routing Table (RT) using OSPF protocol is

```
     10.0.0.0/8 is variably subnetted, 2 subn
C       10.10.10.0/24 is directly connected,
L       10.10.10.254/32 is directly connected
     12.0.0.0/8 is variably subnetted, 2 subn
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       20.20.20.0/24 [110/2] via 12.12.12.2,
     25.0.0.0/30 is subnetted, 1 subnets
O       25.25.25.0/30 [110/2] via 12.12.12.2,
```

Figure 8: Router R1 RT with OSPF before redistribution

The Router R1 using OSPF has learned the information about 20.20.20.0/24 and 25.25.25.0/24 network using OSPF which are connected on R2 and R5.

Whereas, the Router R2 using OSPF has learned the information about 10.10.10.0/24 network using OSPF which are connected on R1.

The Router R2 Routing Table (RT) using OSPF protocol is

```
     10.0.0.0/24 is subnetted, 1 subnets
O       10.10.10.0/24 [110/2] via 12.12.12.1,
     12.0.0.0/8 is variably subnetted, 2 subn
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 subn
C       20.20.20.0/24 is directly connected,
L       20.20.20.254/32 is directly connected
     25.0.0.0/8 is variably subnetted, 2 subn
C       25.25.25.0/30 is directly connected,
L       25.25.25.1/32 is directly connected,
```

Figure 9: Router R2 RT with OSPF before redistribution

The Router R3 Routing Table (RT) using EIGRP protocol is

```
     30.0.0.0/8 is variably subnetted, 2 subnet
C       30.30.30.0/24 is directly connected, Gi
L       30.30.30.254/32 is directly connected,
     34.0.0.0/8 is variably subnetted, 2 subnet
C       34.34.34.0/30 is directly connected, Gi
L       34.34.34.1/32 is directly connected, Gi
     35.0.0.0/8 is variably subnetted, 2 subnet
C       35.35.35.0/30 is directly connected, Gi
L       35.35.35.2/32 is directly connected, Gi
     40.0.0.0/24 is subnetted, 1 subnets
D       40.40.40.0/24 [90/3072] via 34.34.34.2,
```

Figure 10: R3 RT with EIGRP before redistribution

The Router R4 Routing Table (RT) using EIGRP protocol is

```
     30.0.0.0/24 is subnetted, 1 subnets
D       30.30.30.0/24 [90/3072] via 34.34.34.1,
     34.0.0.0/8 is variably subnetted, 2 subnet
C       34.34.34.0/30 is directly connected, Gi
L       34.34.34.2/32 is directly connected, Gi
     35.0.0.0/30 is subnetted, 1 subnets
D       35.35.35.0/30 [90/3072] via 34.34.34.1,
     40.0.0.0/8 is variably subnetted, 2 subnet
C       40.40.40.0/24 is directly connected, Gi
L       40.40.40.254/32 is directly connected,
```

Figure 11: R4 RT with EIGRP before redistribution

The Router R5 Routing Table (RT) using OSPF (O) and EIGRP (D) both before doing the redistribution is

```
     10.0.0.0/24 is subnetted, 1 subnets
O       10.10.10.0/24 [110/3] via 25.25.25.1, (
     12.0.0.0/30 is subnetted, 1 subnets
O       12.12.12.0/30 [110/2] via 25.25.25.1, (
     20.0.0.0/24 is subnetted, 1 subnets
O       20.20.20.0/24 [110/2] via 25.25.25.1, (
     25.0.0.0/8 is variably subnetted, 2 subnet
C       25.25.25.0/30 is directly connected, Gi
L       25.25.25.2/32 is directly connected, Gi
     30.0.0.0/24 is subnetted, 1 subnets
D       30.30.30.0/24 [90/3072] via 35.35.35.2,
     34.0.0.0/30 is subnetted, 1 subnets
D       34.34.34.0/30 [90/3072] via 35.35.35.2,
     35.0.0.0/8 is variably subnetted, 2 subnet
C       35.35.35.0/30 is directly connected, Gi
L       35.35.35.1/32 is directly connected, Gi
     40.0.0.0/24 is subnetted, 1 subnets
D       40.40.40.0/24 [90/3328] via 35.35.35.2,
```

Figure 12: Router R5 RT before Redistribution

4. RESULT AND DISCUSSION

The problem in given scenario is that the routers on the left side of R5 i.e. R1 and R2 which are inside OSPF domain are not getting complete information about the EIGRP network which is available on right side of R5.

Similarly, the routers on the right side of R5 i.e. R3 and R4 are not able to fetch the information about the OSPF network which is present on the left side of R5.

This results in partial or incomplete information and requires the need for mutual redistribution.

For the OSPF network all the routers in the domain i.e. R1, R2 & R5 shares the information and build up the topology table as per the rules of OSPF.

The OSPF uses link bandwidth for the calculation of metric referred as "Cost". The cost formula is reference bandwidth divided by the interface (link) bandwidth.

The reference bandwidth of 100 Mbps is used for OSPF cost calculation. For example, the OSPF path cost value is 1 (100 Mbps/100 Mbps) for a Link with bandwidth of 100 Mbps.

Whereas, for 1000 Mbps link bandwidth the cost calculated will be 0.1 (100 Mbps/ 1000 Mbps) but rounded off to 1.

Some key points to consider for OSPF Cost calculation are:

- Cost is always positive i.e. Cost value > 0
- Decimal Cost value should be rounded off to nearest positive number
- All Cost values <1, will be taken as 1

The path with the lowest total (cumulative) cost value is chosen as the best path for sending the data between source and destination. Total cost is sum of all outgoing interface (link) cost taken in the selected path.

Key point to note is that only the outgoing link cost is considered and not incoming link cost is used. If multiple path available, OSPF algorithm will compare the total cost for each path and will choose the least cost.

Default behavior of OSPF is to choose metric type 2 routes which are not good in real time production environment where there can be multiple redistribution points and cost is not updated on each hop.

The OSPF type 2 metric is default should be updated with type1 so as to have a better updated cost value to be used in the network.

The router R5 is a common router which will perform the translation of information between different routing protocols like EIGRP and OSPF in this case.

The R5 configuration before the redistribution shown as

```
R5#sh run | sec router
router eigrp 345
 network 35.35.35.0 0.0.0.3
router ospf 125
 log-adjacency-changes
 network 25.25.25.0 0.0.0.3 area 0
```

Figure 13: R5 OSPF & EIGRP before redistribution

The configuration on R5 should be updated with new OSPF metric type 1 along with redistribution.

The configuration on R5 with updated OSPF along with redistribution shown as

```
R5#sh run | sec router
router eigrp 345
 redistribute ospf 125 metric 100000 1 255 1 1500
 network 35.35.35.0 0.0.0.3
router ospf 125
 log-adjacency-changes
 redistribute eigrp 345 metric-type 1 subnets
 network 25.25.25.0 0.0.0.3 area 0
```

Figure 14: R5 after OSPF-EIGRP mutual redistribution

During the mutual redistribution process OSPF shares it Topology Table (TT) which was constructed using the bandwidth parameter with EIGRP process. On the other hand, EIGRP also shares its Topology table (TT) but used bandwidth (100000), delay (1), reliability (255), load (1) and MTU (1500) on the link for metric calculation.

This complex metric calculation is used by EIGRP thus translated into simple rules which the OSPF can understand. Thus, EIGRP network information is learnt by OSPF and OSPF network information is passed on to EIGRP based network.

The result would be OSPF routers like R1 & R2 which are present on the left side of R5 will get updated information about the network that is present in EIGRP domain.

Along with that, the EIGRP router like R3 & R4 will be updated with the network information available in OSPF network without any problem. Both protocols will calculate their desired metric for these newly updated routes learned via redistribution.

Routing Table (RT) for router R1 with EIGRP learned routes updated in OSPF Topology Table as O E1 codes

```
      10.0.0.0/8 is variably subnetted, 2 subne
C        10.10.10.0/24 is directly connected, G
L        10.10.10.254/32 is directly connected,
      12.0.0.0/8 is variably subnetted, 2 subne
C        12.12.12.0/30 is directly connected, G
L        12.12.12.1/32 is directly connected, G
      20.0.0.0/24 is subnetted, 1 subnets
O        20.20.20.0/24 [110/2] via 12.12.12.2,
      25.0.0.0/30 is subnetted, 1 subnets
O        25.25.25.0/30 [110/2] via 12.12.12.2,
      30.0.0.0/24 is subnetted, 1 subnets
O E1     30.30.30.0/24 [110/22] via 12.12.12.2,
      34.0.0.0/30 is subnetted, 1 subnets
O E1     34.34.34.0/30 [110/22] via 12.12.12.2,
      35.0.0.0/30 is subnetted, 1 subnets
O E1     35.35.35.0/30 [110/22] via 12.12.12.2,
      40.0.0.0/24 is subnetted, 1 subnets
O E1     40.40.40.0/24 [110/22] via 12.12.12.2,
```

Figure 15: Router R1 RT after redistribution into OSPF

New updated Routing Table (RT) for router R2 with EIGRP learned routes updated in OSPF Topology Table (TT) as O E1.

```
      10.0.0.0/24 is subnetted, 1 subnets
O        10.10.10.0/24 [110/2] via 12.12.12.1,
      12.0.0.0/8 is variably subnetted, 2 subne
C        12.12.12.0/30 is directly connected, G
L        12.12.12.2/32 is directly connected, G
      20.0.0.0/8 is variably subnetted, 2 subne
C        20.20.20.0/24 is directly connected, G
L        20.20.20.254/32 is directly connected,
      25.0.0.0/8 is variably subnetted, 2 subne
C        25.25.25.0/30 is directly connected, G
L        25.25.25.1/32 is directly connected, G
      30.0.0.0/24 is subnetted, 1 subnets
O E1     30.30.30.0/24 [110/21] via 25.25.25.2,
      34.0.0.0/30 is subnetted, 1 subnets
O E1     34.34.34.0/30 [110/21] via 25.25.25.2,
      35.0.0.0/30 is subnetted, 1 subnets
O E1     35.35.35.0/30 [110/21] via 25.25.25.2,
      40.0.0.0/24 is subnetted, 1 subnets
O E1     40.40.40.0/24 [110/21] via 25.25.25.2,
```

Figure 16: Router R2 RT after redistribution into OSPF

After the redistribution the R3 learned new information about the OSPF network. The new learned of OSPF like 10.10.10.0/24, 12.12.12.0/24, 20.20.20.0/24, 25.25.25.0/24.

On R3 new routes are marked as D EX showing OSPF learned routes which were not in EIGRP earlier.

```
      10.0.0.0/24 is subnetted, 1 subnets
D EX     10.10.10.0/24 [170/26112] via 35.35.35.1,
      12.0.0.0/30 is subnetted, 1 subnets
D EX     12.12.12.0/30 [170/26112] via 35.35.35.1,
      20.0.0.0/24 is subnetted, 1 subnets
D EX     20.20.20.0/24 [170/26112] via 35.35.35.1,
      25.0.0.0/30 is subnetted, 1 subnets
D EX     25.25.25.0/30 [170/26112] via 35.35.35.1,
      30.0.0.0/8 is variably subnetted, 2 subnets,
C        30.30.30.0/24 is directly connected, Giga
L        30.30.30.254/32 is directly connected, Gi
      34.0.0.0/8 is variably subnetted, 2 subnets,
C        34.34.34.0/30 is directly connected, Giga
L        34.34.34.1/32 is directly connected, Giga
      35.0.0.0/8 is variably subnetted, 2 subnets,
C        35.35.35.0/30 is directly connected, Giga
L        35.35.35.2/32 is directly connected, Giga
      40.0.0.0/24 is subnetted, 1 subnets
D        40.40.40.0/24 [90/3072] via 34.34.34.2, 0
```

Figure 17: Router R3 RT after redistribution into EIGRP

On R4 new routes are marked as D EX showing OSPF learned routes which were also not in EIGRP earlier.

```
      10.0.0.0/24 is subnetted, 1 subnets
D EX     10.10.10.0/24 [170/26368] via 34.34.34.1,
      12.0.0.0/30 is subnetted, 1 subnets
D EX     12.12.12.0/30 [170/26368] via 34.34.34.1,
      20.0.0.0/24 is subnetted, 1 subnets
D EX     20.20.20.0/24 [170/26368] via 34.34.34.1,
      25.0.0.0/30 is subnetted, 1 subnets
D EX     25.25.25.0/30 [170/26368] via 34.34.34.1,
      30.0.0.0/24 is subnetted, 1 subnets
D        30.30.30.0/24 [90/3072] via 34.34.34.1, 0
      34.0.0.0/8 is variably subnetted, 2 subnets,
C        34.34.34.0/30 is directly connected, Giga
L        34.34.34.2/32 is directly connected, Giga
      35.0.0.0/30 is subnetted, 1 subnets
D        35.35.35.0/30 [90/3072] via 34.34.34.1, 0
      40.0.0.0/8 is variably subnetted, 2 subnets,
C        40.40.40.0/24 is directly connected, Giga
L        40.40.40.254/32 is directly connected, Gi
```

Figure 18: Router R4 RT after redistribution into EIGRP

Therefore, the various types of variation are required to transform the different routing protocols information into each other. In case of OSPF the redistribution is done along with change in the metric type 1 including subnets as default type is just type 2 without including any classless network i.e. classful network only. Modification is necessary to have a clear information about the network routes which were available on the other end. Not only OSPF but EIGRP is also modified to use multiple metric calculation parameters like bandwidth, delay, reliability, load & MTU of the link used in the path.

5. CONCLUSION AND FUTURE SCOPE

The above experimental study concludes that the OSPF default metric calculation needs to be modified whenever there are multiple routing protocols are used with OSPF. The modification needed for having clear visibility of complete network where OSPF is not available.

During the mutual redistribution process OSPF shares it Topology Table (TT) which was constructed using the bandwidth parameter with EIGRP process.

On the other hand, EIGRP also shares its Topology table (TT). EIGRP uses lot s of interface (link) parameters like bandwidth (100000), delay (1), reliability (255), load (1) and MTU (1500) on the link for metric calculation.

This complex metric calculation is used by EIGRP thus translated into simple rules which the OSPF can understand. Thus, through mutual redistribution EIGRP network information is learnt by OSPF and OSPF network information is passed on to EIGRP based network.

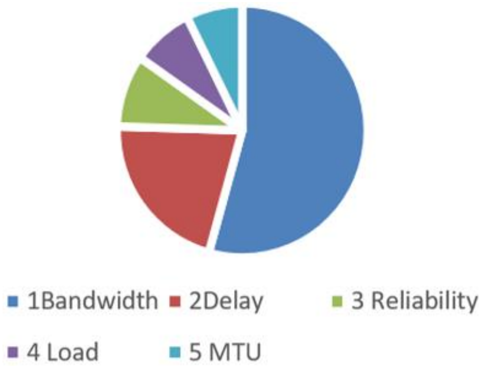

Figure 19: Metric parameters used by EIGRP

Future scope could be done for finding better results by further tuning of OSPF metric calculation parameters and testing them with other routing protocols like Routing Information Protocol (RIP), Border Gateway Protocol (BGP), etc.

Further study can be conducted for OSPF protocol how to change the metric (cost) computation by combining multiple link parameters like delay, MTU, etc. for further enhancement as other routing protocols. OSPF algorithm can be optimized to work better for better path selection.

6. ACKNOWLEDGMENTS

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