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DESIGN AND IMPLEMENTATION OF ROUTE REDISTRIBUTION AND PERFORMANCE STUDY THEREOF

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Obazee Nosakhare Jeffrey

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ABSTRACT

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The advancement in communication systems and networks has led to a growing need to share routes information between routing instances, especially in networks configured in dissimilar routing protocols. Thus, route redistribution is without doubt, an important part in IP network design.

The first part of this thesis began with the study of routing protocols and network topologies. Route redistribution was demonstrated; the configuration of route redistribution between classful and classless protocols was later clarified using Cisco Packet Tracer program.

In the outcome of this project, designs were made for numerous hybrid mesh-ring network topologies configured in different routing protocols. Route redistribution was successfully performed using boundary routers. All forms of route redistribution scenarios were studied, and their behavior was critically modelled in real-time video conferencing application using industrial simulation software, Optimized Network Engineering tool, OPNET Modeler.

Protocol performance metrics such as convergence time, end-to-end-delay, jitter and queuing delay were used to analyze that the hybrid topology of Enhanced Interior Gateway Routing Protocol (EIGRP) and the Interior Gateway Routing Protocol (IGRP) has the best performance in simple networks. The hybrid network of EIGRP and the Route Information Protocol (RIP) has the poorest performance both in simple and complex networks. The integrated mesh-ring topology of the EIGRP and the Open Shortest Path First (OSPF) performs best in complex networks.

Keywords Route Redistribution, OPNET, Convergence Time

CONTENTS

LIST OF ABBREVIATIONS

AD	Administrative Distance
AS	Autonomous System
ASBR	Autonomous System Boundary Router
CT	Convergence Time
EIGRP	Enhanced Interior Gateway Routing Protocol
ETE D	End to End Delay
ETE V	End to End Delay Variation
GUI	Graphical User Interface
IGRP	Interior Gateway Routing Protocol
IP	Internet protocol
RIP	Route Information Protocol
RP	Routing Protocol
RR	Route Redistribution
MP	Multiple Point
OPNET	Optimized Network Engineering Tool
OSPF	Open Shortest Path First
QD	Queuing Delay
SP	Single Point
SPF	Dijkstra's Shortest Path First
Wav	Weighted Average

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1 INTRODUCTION

In order to route data packets across networks, intelligent and dedicated devices are needed. These devices (known as routers) make the decision to forward packets to its destination address by consulting a table called routing or forwarding table. The router uses the routing table to look at a packet destination address and determine the best route to take in transmitting the packets to its destination. Thus, the routing table is populated by the router' choice of the best path. /6/

Dynamic Routing protocols play an essential part in today's communications network; it is the internet heartbeat. /4/

All routing protocol performance differs from each other in terms of their convergence quality, the end-to-end delay, jitter and throughput. Various routing protocols exist in IP networks. /14/

In order for routes to be propagated between different routing domains; router vendor has introduced a concept called route redistribution (RR). It is relatively easy to manage a network configured with a single protocol. Multiple routing protocols within a network are quite complex and difficult to manage. There is therefore an increasing need to propagate route information across protocol boundaries especially among networks configured with different routing protocols /13/

Consider a world class research industry working on a project in nanotechnology. They intend to communicate with their research laboratory elsewhere in order to exchange information. The two different sites are configured in Enhanced Interior Gateway Routing Protocol (EIGRP) and Open Shortest Path First (OSPF).The protocols can only communicate mutually if EIGRP routes are redistributing into OSPF and vice versa. In this project work, one routing protocol will be injected into another and route redistribution will be made.

2 BACKGROUND AND AIM OF THE PROJECT

An internetwork configured in different routing domains may intend to at least temporarily share routing information among these instances. Thus, merger companies whose networks are configured in say route information protocol OSPF and EIGRP may in the course of merging decide exclusively to use EIGRP. The process of migration from one routing protocol to another is time consuming and may cause system failures. Thus, redistribution becomes a necessity for providing temporal connectivity between two or more routing domains./3/

Mirzahossein Kiavash, Nguyen Michael and Elmasry Sarah (2013) in their design work implemented Route Information Protocol (RIP), OSPF and EIGRP in the simple ring and mesh topology. They also did work on a large mesh topology./12/

The configuration of route redistribution has also been done by many engineers using software similar to a Cisco Packer Tracer program. The performance study of these merged networks after configuring redistribution has been little studied.

The main idea in this thesis was to create a hybrid simple ring-mesh topology using border routers called Autonomous System Boundary Routers (ASBRs). These routers are acting as intersects between these different routing domains. RR was enabled on them, providing the possibility of bidirectional communication between the different routing processes. In so doing, it was possible to model an unrealistically simple scenario of merging networks in order to study their performance. Thus, by gradually progressing from simple topology to a more complex hybrid ring–mesh, closely related models to real life communication networks could be made. One or more (ASBRs) with RR was used to bridge these network topologies.

In figure 1 below, EIGRP and OSPF were separately configured using the ASBR. It is on this router that mutual RR can be performed. Thus, the routing table of the ASBR will display EIGRP and OSPF routes.

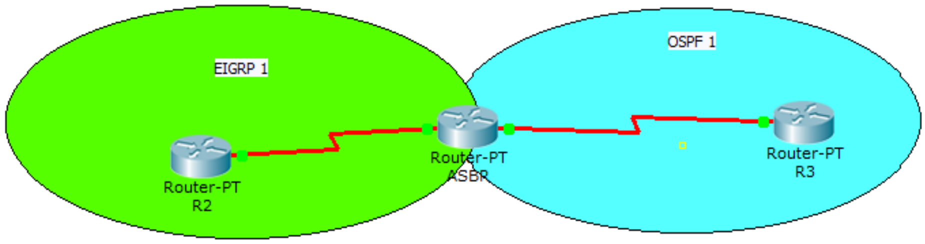


Figure 1. Routing Domains of Routing Domains of EIGRP1 and OSPF1

This thesis will examine:

- Which integrated network has the most reliable performance from an exhaustive analysis of all routing protocol performance characteristics such as end-to-end delay, jitter, queuing delay and convergence time?

- Which redistribution scenario has the fastest convergence time and smallest end-to-end data delay, end-to-end delay variation and the least queuing delay?

- What hybrid is considered the most suitable in IP networks?

3 ROUTING PROTOCOLS AND ROUTE REDISTRIBUTION

Routing protocols (RP) are a set of processes and algorithms that give information about remote networks and immediate adaptability whenever there exist a change in network topology. They are broadly classified into link state or distance routing protocol, classful or classless routing. A significant characteristic of routing protocols is how fast it converges when there is a change in topology. /1/

3.1 Link State Routing

Link state routing protocols perform a similar function to a road map. They are newer and more complex routing protocols. They tracked the status and connection of each network and produced a calculated metric based on these factors. The efficiency of the link state routing protocol is better when compared to that of the distance vector routing protocol. It uses the Dijkstra algorithm to calculate the path to the destination. OSPF is an example of link state routing. /16/

3.2 Distance Vector Routing Protocols

The distance vector routing protocol means that in this protocols routes are advertised as vectors of distance and direction .In this protocol, the distance is expressed in terms of a matrix, such as hop count and direction is, therefore, the next hop. RIPv1, IGRP and EIGRP are examples of distance vector routing protocols./16/

3.3 Classful Routing and Classless Routing Protocols

Routing protocols, such as RIPv1, IGRP send routing update without subnet masks and are thus are called classless protocol. The classful routing protocol uses a variable subnet mask and sends a subnet mask along with their updates. EIGRP, OSPF and RIPv2 are classless routing protocols. / 25/

3.4 Route Information Protocol (RIP)

RIP, which a classful routing protocol, has a maximum hop count of 15.It updates it routing table periodically and it therefore suitable for small networks. Beyond 16 hops, RIP is considered unreachable. Other characteristics of RIP are: /19/

- It uses the metric in determining the distance to a destination.
- Routing loops is controlled in RIP since the maximum hop counts is 15.
- Its AD is 120.

3.5 Open Shortest Path First (OSPF)

The open shortest path first is a link state routing protocol developed for Internet Protocol (IP) networks. It collects routing information by maintaining three routing table.

The determination of the best path is by sharing routing information with its adjacent neighbors. All interfaces and routers are given a cost, and it finds the best path to a network by selecting the path of the least cost. It is an interior gateway routing protocol. A key significance feature of OSPF is its ability to adapt promptly whenever there is a change in topology i.e. it converges faster and its a classless routing protocol. It uses cost (bandwidth) as it's metric. It administrative distance is 110.

In OSPF, the network topology information is kept in a topology database.

It maintains a link condition by sending small hello message.

OSPF has low Bandwidth Utilization. The OSPF uses the Dijkstra algorithm to find the shortest path to a destination./15/

3.6 Interior Gateway Routing Protocol (IGRP)

IGRP is a distance vector routing protocol which was designed by Cisco. The main characteristics of IGRP are: /11/

- It determines its path to the destination using the Bellman-Ford Distance Vector algorithm.

- Its AD is 100.
- The maximum number of hops count supported by default is 100.
- IP routing is supported by IGRP.
- It sends subnet masks along with its updates and thus it is classless.

It has a fast convergence and uses it composite metric of bandwidth, delay, MTU, reliability, load as its metric.

3.7 Enhanced Interior Gateway Routing Protocol (EIGRP)

The Enhanced interior gateway routing protocol (EIGRP) is a hybrid routing protocol developed by Cisco. Its features and capabilities are far more than that of the family from which it came. It is an advanced distance vector routing protocol and uses bandwidth and delay as a metric. It was developed to replace IGRP. It was solely designed to have a class such that is will be possible for the protocol to include variable length subnet masks and classless. It has high convergence quality as it utilizes the Diffused Update Algorithm in calculating the shortest path to the destination. EIGRP characteristics are given below.

- EIGRP convergence quality is very high and can store its neighbor route in a neighbor table and topology table respectively.
- Compared to RIP and OSPF, which send periodic and full updates, EIGRP send partial trigger updates when a change occurs. These updates contain only information of the route that has changed. The characteristics of EIGRP listed below.
- It is a classless routing protocol.
- It uses the Diffusing Update Algorithm (DUAL) to determine its best path when forwarding a data packet to its final destination.
- Its administrative distance of 90 is applied for internal routes
- EIGRP uses an administrative distance of 170 for route marks as external./8/

3.8 Network Performance Metrics

The performance metrics of routing protocols includes the average queuing delay, the end-to-end delay, the end-to-end delay variation (jitter) and convergence time.

3.8.1 Average Queuing Delay

The queuing delay implies the time taken from the packets arrival at the queue to the time it leave and gets transmitted. In real–time video applications, the smaller the queuing delay, the better. /5/

3.8.2 End-to-End Delay of Data Packets

The end-to-end delay is the average of all delays encountered by the data packet as it travels from the source to the destination. The smaller the end-to-end delay, the better the networks./5/

3.8.3 End-to-End Delay Variation.

As packets transit from the source to the destination, they encounter different kind of delays. The variance in this delay is the end-to-end delay variation. The position of data in the different queue and its size affects the jitter. A small amount of jitter implies good transmission quality./5/

3.8.4 Convergence Time

An important aspect of dynamic routing is convergence. Routers are able to reach a state in which they have accurate knowledge of their surrounding topology. A given topology is considered convergent when all participating routers has updated their routing table and has reached a state of agreement about the nature of the network topology and the best route to forward a packet .Routers share routing information among themselves via the implemented routing protocol which reflects the state of the network topology. When a link fails; routers recalculate metric and their routing table is updated based on this information. We can say a fully operable network has converged when their entire routing table is fully updated./25/

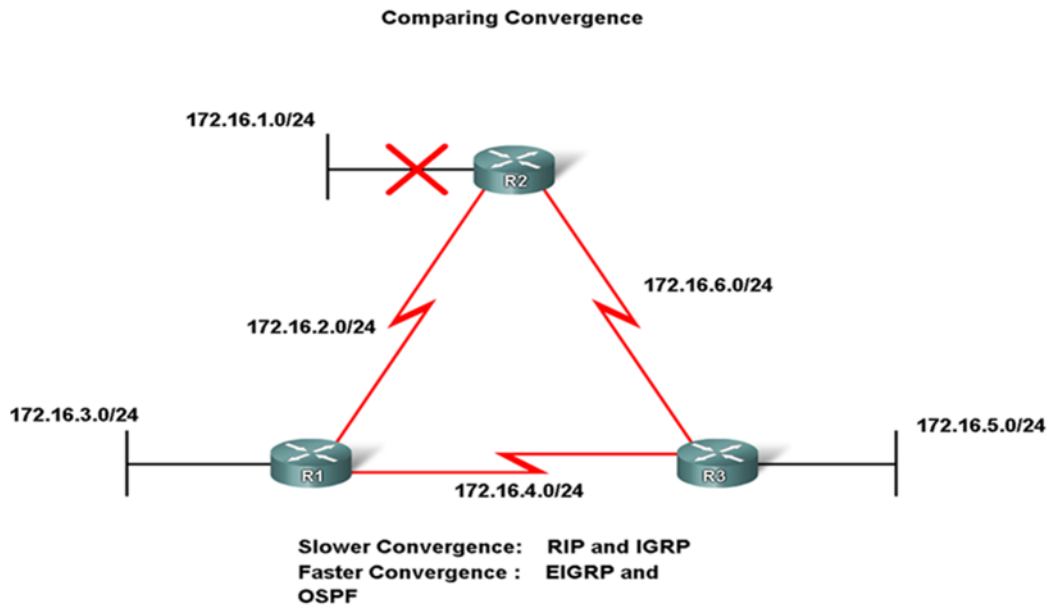


Figure 2. Convergence of Routing Protocols./2/

3.9 Network Topology

The structural arrangement pattern of all interconnected devices in a network refers to a network topology. Types of topology are trees, ring, mesh and star. The ring and mesh topology and discussed below.

3.9.1 Ring Topology

Devices are connected to one another to form a large cyclic shape. The movement of packets from the source router to another occurs in a ring.

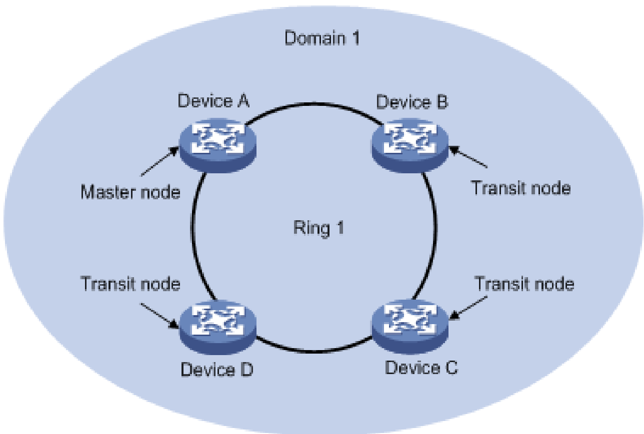


Figure 3. A ring topology./21/

3.9.2 Mesh Topology

All routers are connected to any other router in a mesh topology producing a point–to-point connection. Heavy data loading does not affect a mesh topology. Mesh topologies are of two types

- full mesh
- partial mesh

A significant aspect of mesh topology is that if any device or router fails, communication can still take place between other routers.

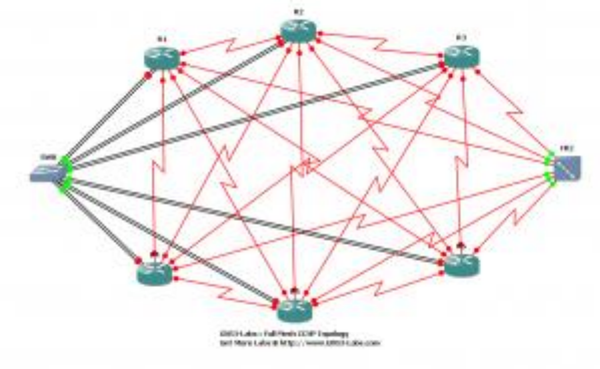


Figure 4. A full mesh topology./9/

3.9.3 Integrated Topology

A hybrid network is formed when two or more topologies combine. The advantages of the integrated topology are independent of the individual topologies from which it was formed.

3.10 Effects of Topology Type on RP Performance

The performance of routing performance is dependent on the type of topology in which it is configure and the routing protocol mechanisms. /7/

3.11 The need for Route Redistribution

The word redistribution is a Cisco term. The need for RR exists when route from one instance need to be shared with another completely different domain. Most networks are configured in more than one routing protocol. It is desirable and cheap to implement a single routing protocol in an IP internetwork. Multiple running protocols in a network nowadays are now common place due to migration from one routing protocol to another, inaccurate network design, multiple departments needing autonomy and merging companies. The route received by the given protocols are marked as external and are usually given less preferred as compared to the protocols internal routes./3/

Some key parameters affect redistribution. The idea of RR simply means transferring route from one source onto another routing domain. For a given router running a different routing protocol, the different processes cannot communicate as the router will not run the redistribution by default. RR must be explicitly configured./13/

It becomes imperative to redistributes the route in an expanding network or merging companies or in the network that is transiting from one phase to another. Consider a given network in which RIP is configured. As the network continues to grow in size due to expansion; e.g. expansion to hop count of 15, it would be impracticable to use RIP. It becomes a necessity to migrate to another routing protocol /20/

RR consist of the followings forms: /22/

- Bidirectional redistribution at a single point in a network.
- Bidirectional redistribution at multipoint between two given networks.
- Bidirectional redistribution between multiple networks occurring at multiple points.

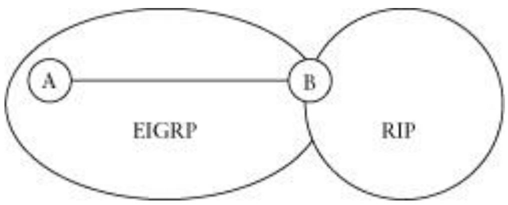


Figure 5. Single Point Mutual RR /22/

One-way redistribution involves the injected of routes from one routing protocol to another and occurs in one direction only and bidirectional (mutual) redistribution occurs in both direction which may involves one or multiple points in a networks./22/

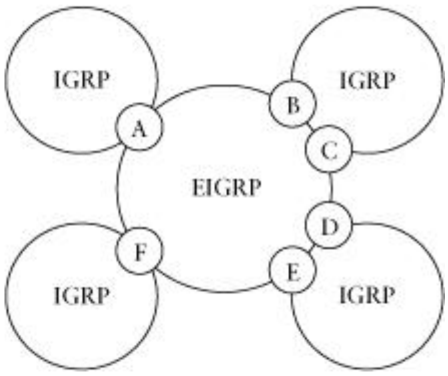


Figure 6. Multiple Points RR between Multiple Networks /22/

The above figure shows multiple points RR between EIGRP and multiple networks of IGRP.

3.12 Principles of Route Redistribution

In RR the route is injected into a target protocol, and the route is taken from a source routing protocol. An intermediary router called autonomous system boundary router (ASBR) must exist between two redistribution points.

To configure RR redistribution, we apply a metric and ‘redistribute’ command.

Three essential characteristics are most important in the redistribution. Variation in the routing protocol metric, administrative distance and classful or classless capability affect the RR. /18/

In a large establishment, some division of the company networks could be configured in a different routing protocol. The reason is that, they may want to be autonomous while using RR to exchange routes at key subnets, thus RR may be a necessary permanent solution. /3/

3.13 Metric

The metric is a very significant factor is redistribution. In redistributing the routes across the routers, the metric of one routing protocol differing from the other. The RIP Information protocol uses hop count as its metric. EIGRP uses a combination of MTU, delay reliability. OSPF uses cost as its metric, while EIGRP uses a combination of bandwidth and delay. An understandable must be configured when redistributing routes between different processes.

When a given protocol say RIP is redistributed into EIGRP. RIP uses cost and EGRP uses a composite of bandwidth and delay. The metric of RIP is disregarded. It is only EIGRP metric that will be used. /18/

3.14 Administrative Distance

The administrative distance measures the reliability of a given routing protocol. The lesser the administrative distance, the more reliable the network. It is an integer value with a range of 0 to 255.

When two routing protocols are implemented in networks, the administrative distance becomes a key factor in determining the best route to a destination.

A redistributed route, nevertheless will inherit the administrative distance of the redistributed protocol. /18/

The figure 7 below show the EIGRP uses an AD 90 for routes within its domain while RIP uses an AD of 120.Thus, the two protocols cannot communicate .When redistributing RIP routes into EIGRP; an AD acceptable to the two routing protocols is used.

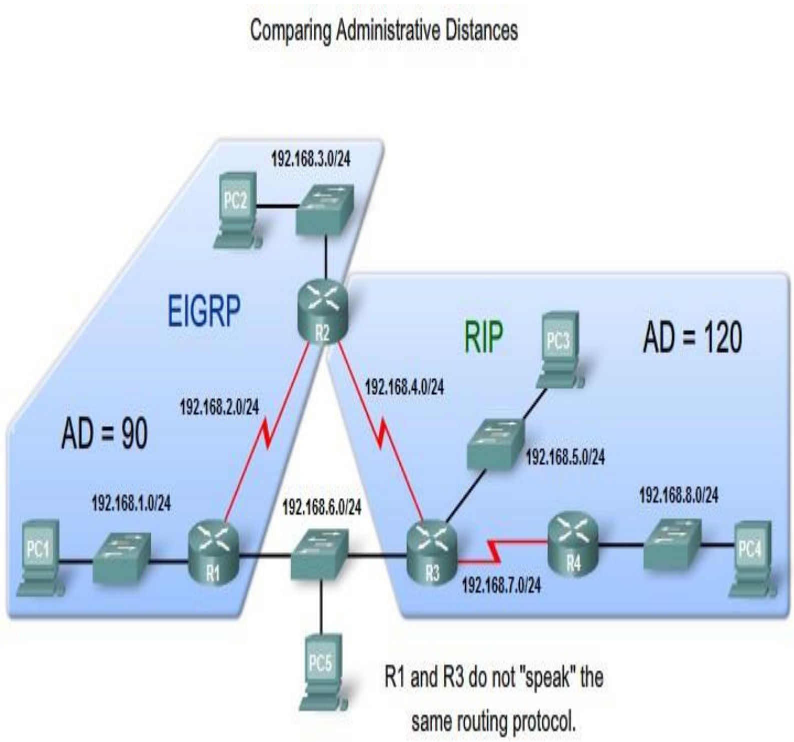


Figure 7. AD of different Routing Protocols. /2/

The AD is a key deciding factor when a route to a destination is learned from two routing protocol, say IGRP and EIGRP when both the subnet and subnet mask of the route are the same.

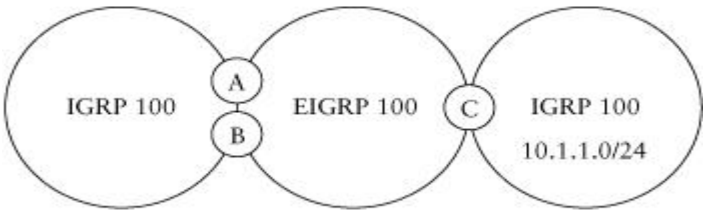


Figure 8. IGRP and EIGRP Domains. /22/

Consider the RR of the subnet 10.1.1.0/24 into EIGRP process from the IGRP domain in the right. All domains in the figure above have the same domain number (autonomous system number) of 100.This indicates that all three routing protocol are within the same administration. The AD of the route as it enters EIGRP 100 immediately changes from 100 to 170. It inherits the EIGRP AD of 170 for external routes after entering its domain. This AD is later discarded after it enters the IGRP instance. The route becomes a normal IGRP route again after transiting into IGRP100 domain in the left from the EIGRP 100 inheriting its old administrative distance of 100.Therefore, the path to the destination 10.1.1.0/24 now has two routes, the one through A and another external EIGRP route through C. From the normal principle for administrative distance between two routes, the route with the lower AD should be preferred. Instead, this rule is ignored and the route from the EIGRP external with an AD of 170 will be added to the routing table. /22/

Table 1. Default AD of Routing Protocols. /17/

Routing Protocol	**Administrative Distance**
EIGRP	170
RIP	120
OSPF	110
Internal EIGRP	90
External EIGRP	170
IGRP	100

3.15 RR between Classful and Classless Protocol

Classful and classless capability of routing protocols affects redistribution and the manner in which routes are added to routing table.

3.15.1 Redistributing into RIP

The RIP uses hop count as its metric. The maximum metric is 15.A metric of 10 was defined in OPNET Modeler for routes redistributing into RIP. /18/

3.15.2 Redistributing into OSPF

. For routes injected into OSPF, the following applies: /18/

- The metric or cost of the source route is used if redistributing from another OSPF instances
- Route learned from the Border gateway protocol uses a cost of 1
- A cost of 20 is used for all other routes.

3.15.3 Redistributing Routes into EIGRP/IGRP

EIGRP uses the bandwidth and delay in calculating its distance metric. In redistributing routes into EIGRP/IGRP, it is still important to specify all five composite metric. The standard metric values are tabulated below. /18/

Table 2. EIGRP/IGRP Composite metric. /18/

Distance Metric	**Value**
Bandwidth	10000
Reliability	255
Load	1
MTU	1500
Delay	1000

If no metric if specified, EIGRP/IGRP will use a default metric of 0 and no route will be redistributed.

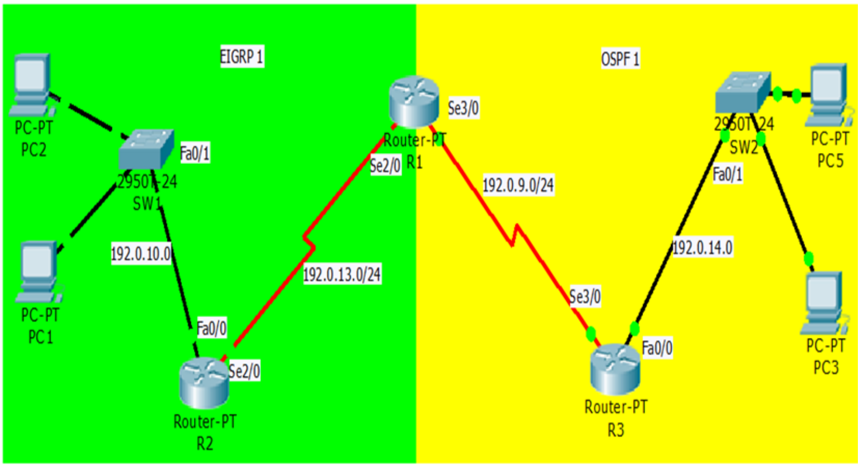
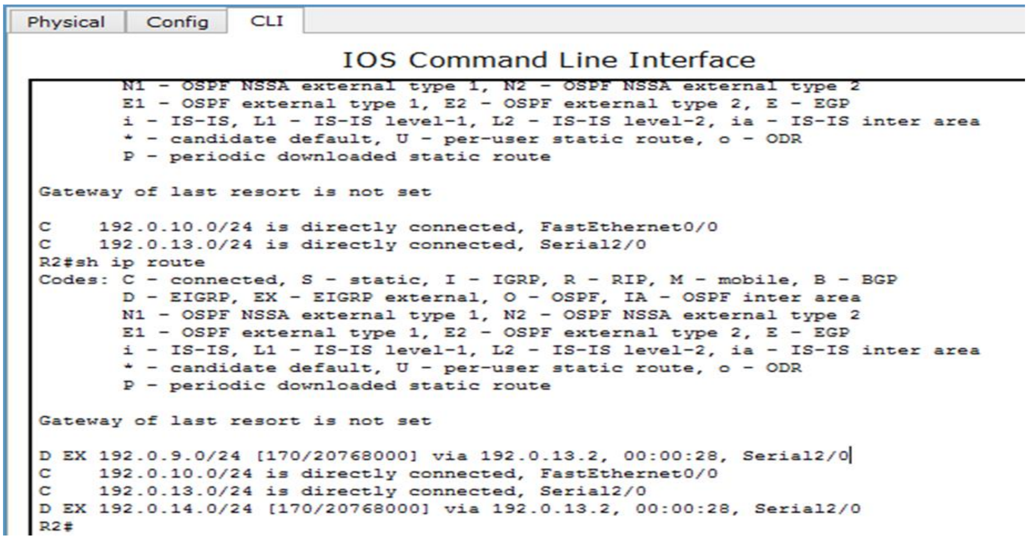


Figure 9. RR between OSPF 1 and EIGRP 1

In redistributing routes between classful and classless, it is necessary to use the command "subnets", otherwise, the routes will never be redistributed. Below in table 3 are the commands used in RR between EIGRP 1 and OSPF 1.

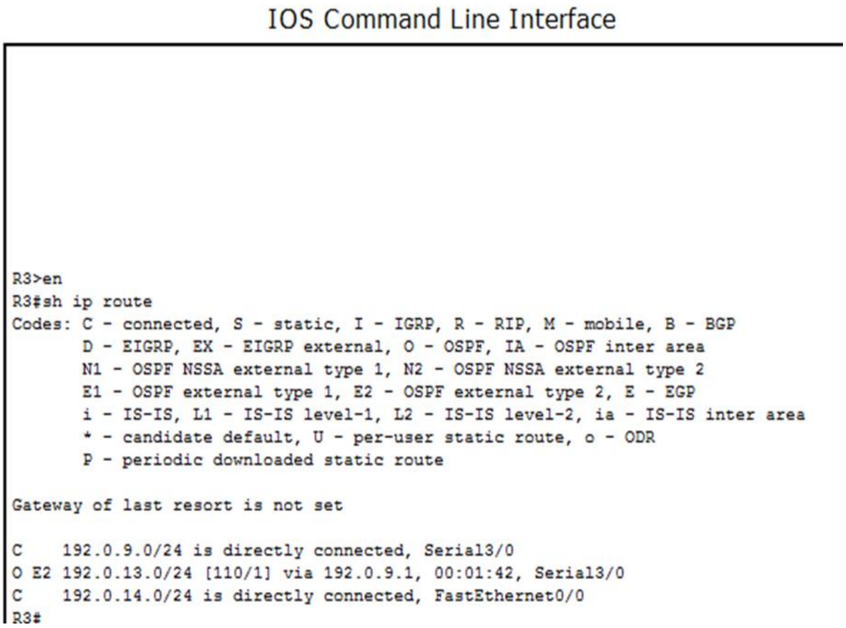
Table 3. OSPF1 and EIGRP Configuration.

```
R1#conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)#router eigrp 1       //The router eigrp1 instance is enabled
Router(config-router)#network 192.0.13.0 255.255.255.0
R1(config-router)#redistribute ospf 1 metric 10000 1000 255 1 500
//        A metric of 10000 for bandwidth, 1000 for delay, 255 for reliability, 1 for
//        load and 1500 for MTU is defined for redistributed routes into eigrp
R1(config-router)#do wr
Building configuration.
[OK]
R1(config-router)#router ospf 1
Router(config-router)#network 192.0.9.0 255.255.255.0 area 0
R1(config-router)#redistribute eigrp 1 subnets
R1(config-router)#do wr
Building configuration
[OK]
```



```
Physical   Config   CLI
IOS Command Line Interface
       N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
       E1 - OSPF external type 1, E2 - OSPF external type 2, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

C    192.0.10.0/24 is directly connected, FastEthernet0/0
C    192.0.13.0/24 is directly connected, Serial2/0
R2#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       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, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

D EX 192.0.9.0/24 [170/20768000] via 192.0.13.2, 00:00:28, Serial2/0
C    192.0.10.0/24 is directly connected, FastEthernet0/0
C    192.0.13.0/24 is directly connected, Serial2/0
D EX 192.0.14.0/24 [170/20768000] via 192.0.13.2, 00:00:28, Serial2/0
R2#
```

Figure 10. IP route for EIGRP showing redistributed routes



```
IOS Command Line Interface

R3>en
R3#sh ip route
Codes: C - connected, S - static, I - IGRP, R - RIP, M - mobile, B - BGP
       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, E - EGP
       i - IS-IS, L1 - IS-IS level-1, L2 - IS-IS level-2, ia - IS-IS inter area
       * - candidate default, U - per-user static route, o - ODR
       P - periodic downloaded static route

Gateway of last resort is not set

C    192.0.9.0/24 is directly connected, Serial3/0
O E2 192.0.13.0/24 [110/1] via 192.0.9.1, 00:01:42, Serial3/0
C    192.0.14.0/24 is directly connected, FastEthernet0/0
R3#
```

Figure 11. External Route (E2) in OSPF Domain.

3.15.4 Network Simulation

It is expensive and laborious to set up a real-time networking laboratory involving many routers and the networking devices.

In the simulation, the behavior of the system is carefully observed by using another system e.g., a computer program.

The computer-assisted simulation is an important aspect of modern design. Real-time behavior a system can be hypothetically modelled and its performance is then critically observed to know how it will behave under different conditions.

Simulation is an imperative modern technology. It has application in science, engineering, or other applications fields for different purposes.

Industries and universities research center are widely using software simulation nowadays. It is relatively cheap and saves time to pretest proposed protocols and wireless networks./23/

3.15.5 Introduction to OPNET Simulation

The Optimized Network Engineering Tools, OPNET is the industry's leading network development software introduced in 1986 by a student of MIT. /10/

It has immense application among engineers, university students, researchers and the US military./26/

OPNET performs the following functions:

- •simulation of telecommunication and network environment
- •It performs simulation of a given system behavior by modelling each event in the system through user defined processes. /14/
- •In network simulation, real-time traffic such as voice calling, video conferencing, and emails are used.

3.15.6 OPNET Modeler Component Description

The application configuration, profile configuration and failure recovery are the components used in this project

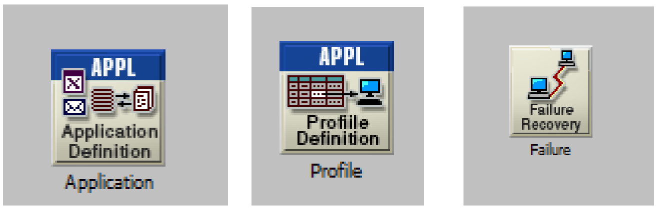


Figure 12. Application Definition, Profile Definition and Failure Recovery

The application definition object performs the function of generating different types of traffic. It can generate video streaming (light) and video conferencing traffic in real time. The injection of real-time traffic is done by the profile and application object /24/

The Failure Recovery is used in configuring a given router to failure and recover at different times./24/

In creating a new project in OPNET Modeler, the following steps can be taken:

- Open the OPNET software

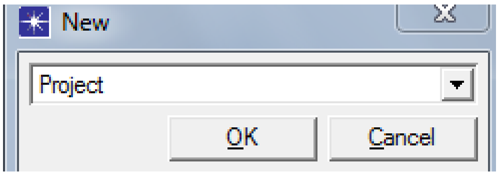


Figure 13. Project Menu

- From the file menu, select new. A drop box immediately pops up. It prompts you to give a project name and scenario name.
- Select from the drop box menu, there are options to either import your topology or create new. Select 'create empty scenario' and click OK.
- A new window pops up. Select 'Cisco' and click next

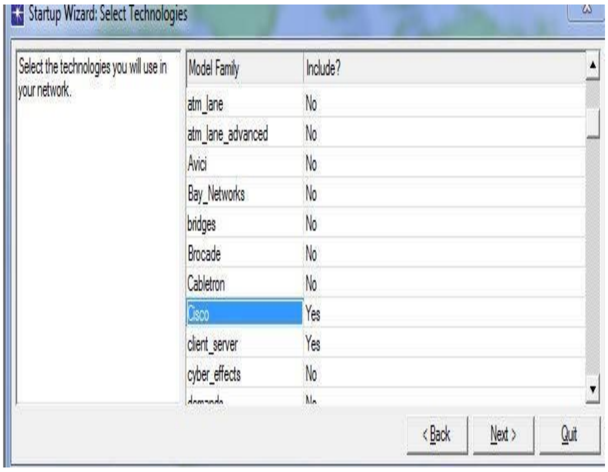


Figure 14. Scenerio Menu

- The next step is how to choose the network scale. The physical size of the network is selected here. Select the 'logical' and click next

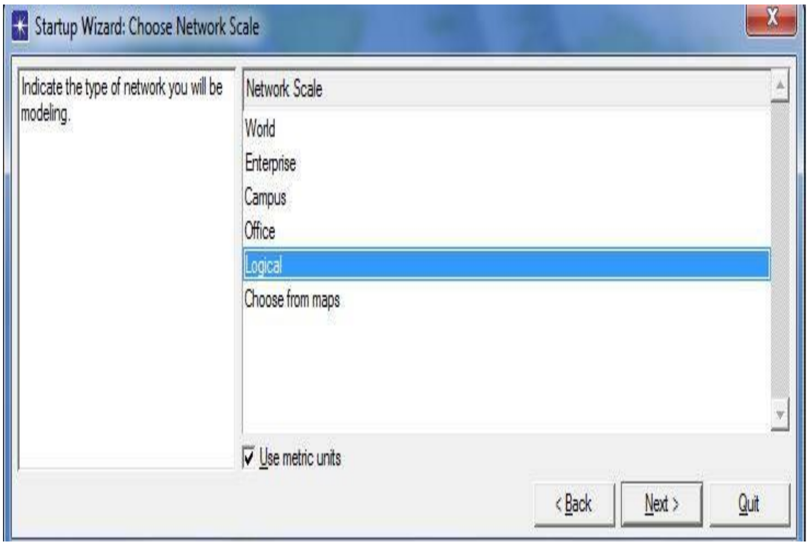


Figure 15. Scenerio Menu 2

The figure 16 below is the Object Palette containing the different collections of Cisco routers.

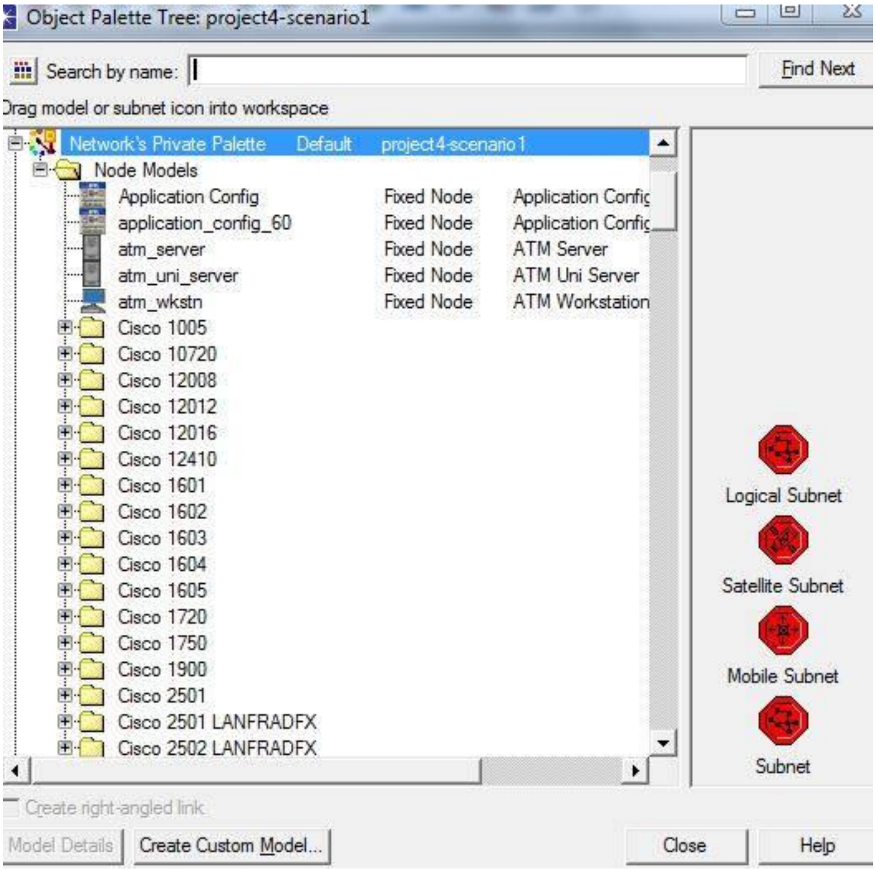


Figure 16. Object Palette Tree.

4 DESIGN AND IMPLEMENTATION OF RR

The design was made for a mutual redistribution of either of RIP, OSPF or IGRP into EIGRP considering first a simple network topology. The complexity of the topology was thereafter increased. In this design it was assumed that all other (OSPF, RIP AND IGRP) domains intend to exchange their routes with EIGRP. It is used as a mesh since mesh is expensive; hence less of it is used. All other routing protocols were configured in a ring topology as ring is economically more effective. Hybrid mesh-ring is form.

The first of this task was to create two autonomous systems with EIGRP configured in mesh and OSPF, RIP or IGRP implemented in a ring topology. RR redistribution was done at the border router to enable bidirectional communication between the two instances. Simple and complex redistribution scenarios were created.

The first scenario involves 6 Cisco routers, a configuration application, profile and link failure, Cisco 7000 routers, PPP_DS DUPLIX LINK.

The OPNET Modeler rapid configuration tool was used to create a mesh and ring topology of 6 routers each for both routing protocols. A single router, called an autonomous system boundary router was used to redistributes the routes mutually between the two routing protocols.

4.1 Configuration of Router

All routers were configured to run a single protocol with the exception of ASBRs which runs at least two protocols. Configuration was done on the selected interfaces using figure 17 below.

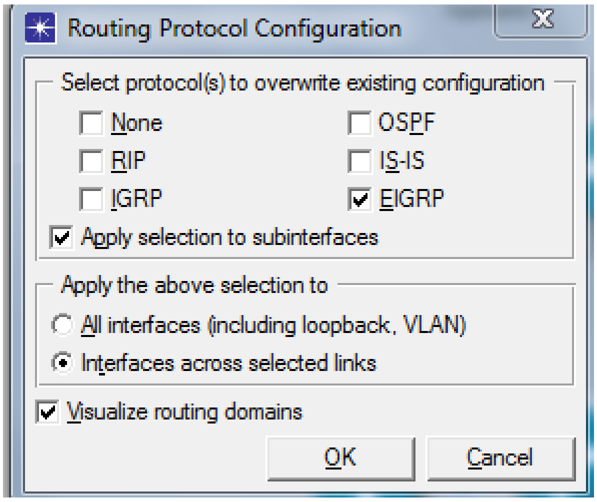


Figure 17. Routing Protocol Configuration

4.2 Application Configuration

The number of rows in the application definition object was set to 1.The application was named 'video' and high resolution real time video conferencing application was specified as shown in figure 18 below.

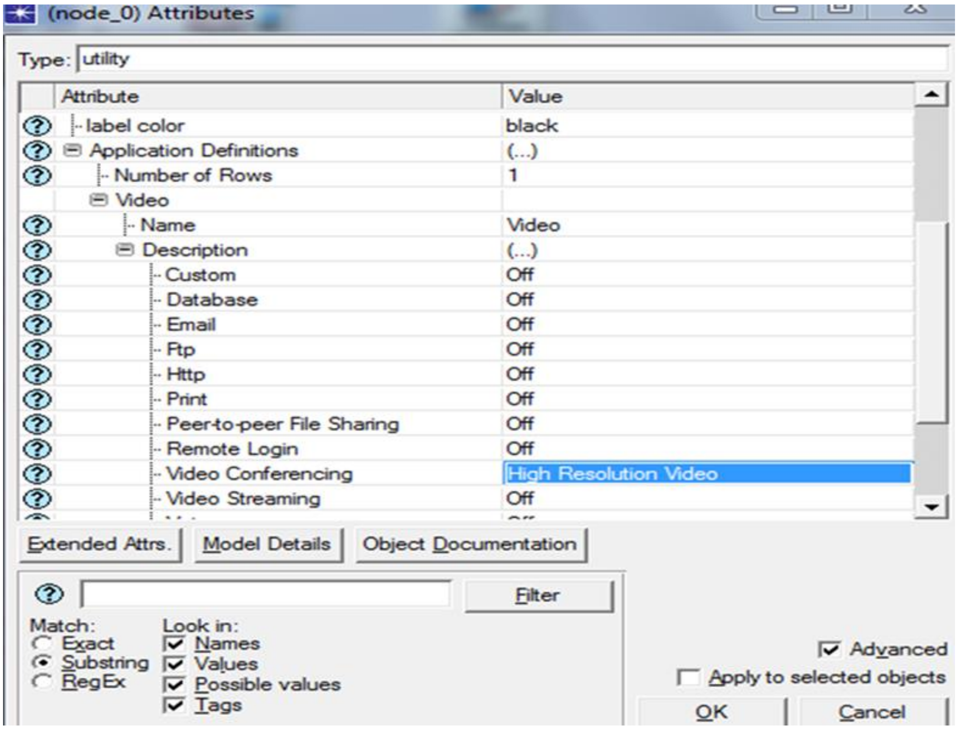


Figure 18. Application Definition Object

4.3 Profile Configuration

The number of rows in the profile configuration was set as 1.The profile name was chosen as ‘video’. A video application was specified as the application name.

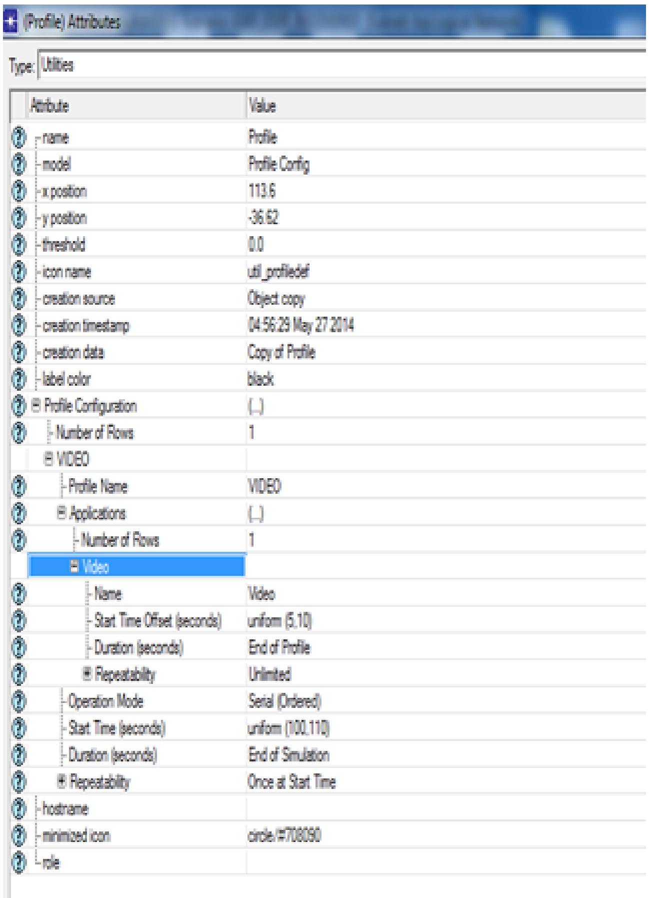


Figure 19.. Profile Configuration

4.4 Failure Configuration

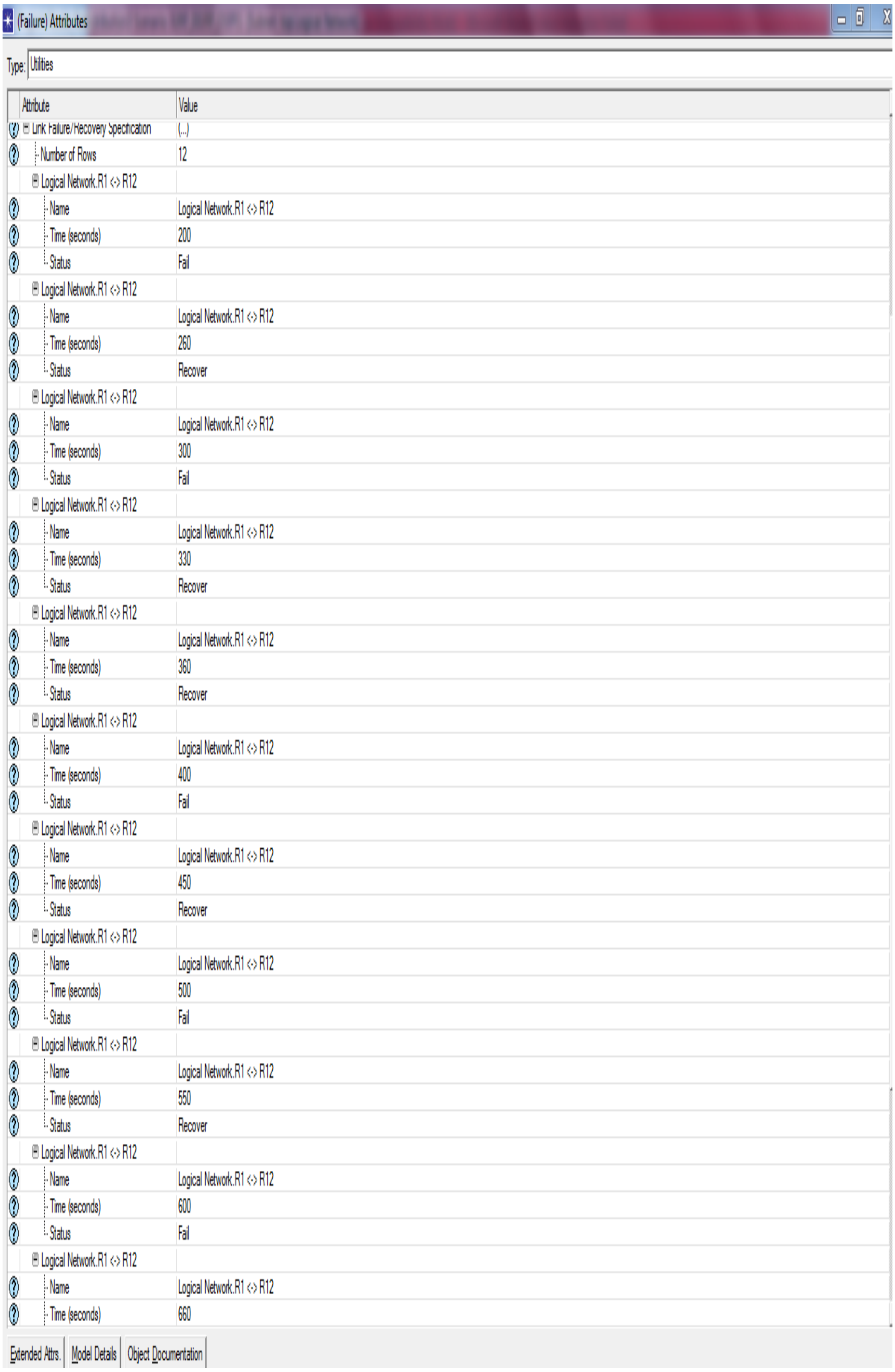


Figure 20. Failure Configuration

The R1 and R12 was configured to failure and recover at different times. Any disturbance in the topology creates an additional time for the network to converge.

4.5 Statistics and Data Collection

The statistics for convergence duration, ETE delay, variation in the ETE delay, and the queuing delay were enabled as shown in the figure below in global statistics menu.

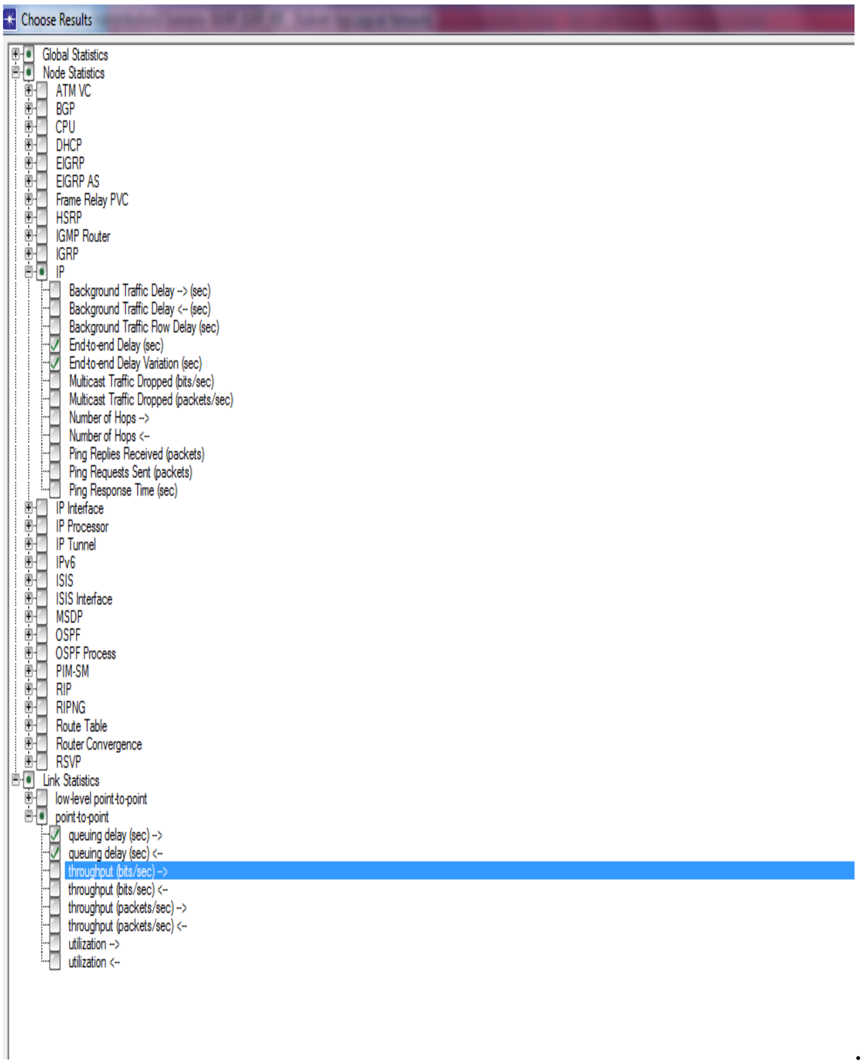


Figure 21. Global Statistics menu

The simulation was configured from the DES menu and lastly, the IP routing table was specified as ‘export’ in order to output the routing table as shown in figures 22 and 23.

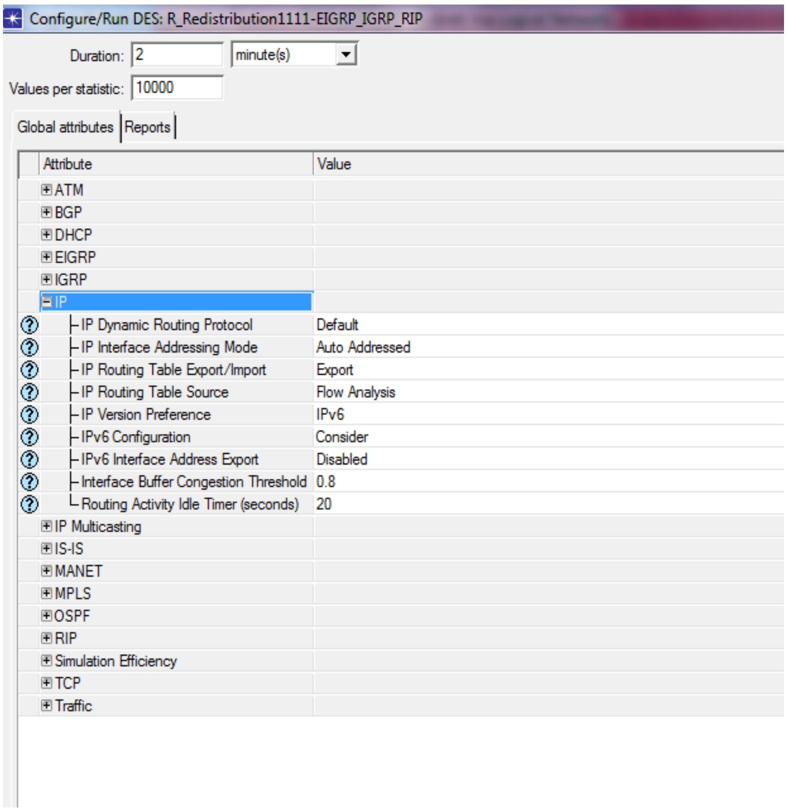


Figure 22. IP routing table set to export.

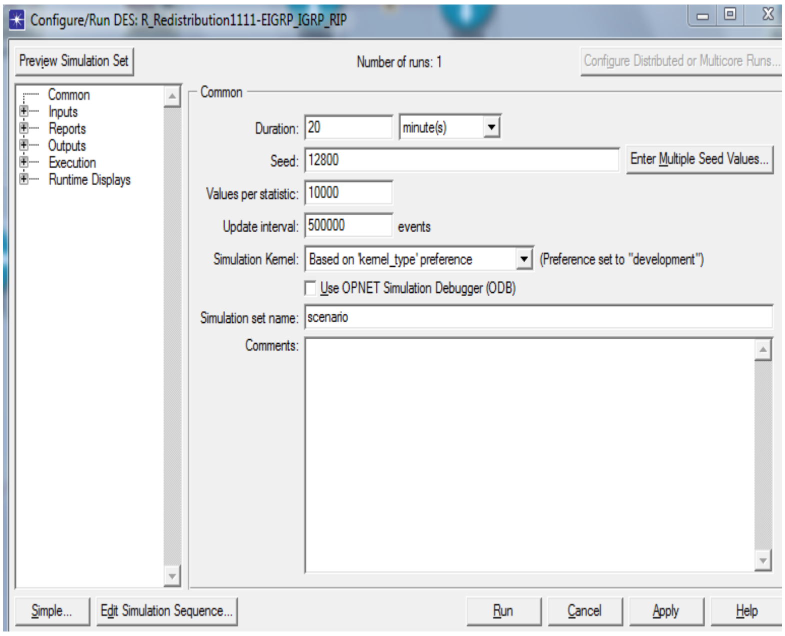


Figure 23. Simulation set for 20mins.

The description of implementation here was subdivided into the following parts.

4.6 Single Point (SP) RR

- RR between EIGRP and OSPF
- RR between EIGRP and IGRIP
- RR between EIGRP and RIP

4.7 Multiple Point (MP) RR

The second part of the project consist of three scenarios

- Injecting OSPF into EIGRP(and vice versa)
- RR between EIGRP and IGRP
- RR between EIGRP and RIP

4.8 Multiple Point RR between Three Routing Protocols

The third part consist of three routing protocols made up of three scenarios: The design is similar to the second, instead of using six domains of OSPF or IGRP in a topology, three domains of each were used, while keeping EIGRP in mesh unchanged. Thus, 3 ASBRs were used to perform RR between EIGRP and OSPF, and 3 ASBRs to also redistribute routes between EIGRP and IGRP. The scenarios to be considered includes:

- IGRP/EIGRP/OSPF
- IGRP/EIGRP/RIP
- EIGRP/IGRP/RIP.

The design for SP RR was made in a such way that EIGRP was implemented in a mesh topology consisting of six routers and one other routing domain (in a ring topology) was merged with it using a single ASBR.EIGRP was configured in a mesh since the topology can withstand huge traffic, providing room for future complexity of the networks as more instances of another routing protocol may be added to it. Since it is the most important domains in which all other lesser departments has to exchange data, the mesh topology is necessary. The failure of one of the links will not affect the entire EIGRP instance. The merging was necessary considering simple networks configured in either of RIP, OSPF and IGRP. These domains may want to be autonomous and intend to manage their networks, while exchanging routes at key subnets.

4.8.1 RR between OSPF and EIGRP

In the below figure, a simple hybrid mesh ring topology is shown

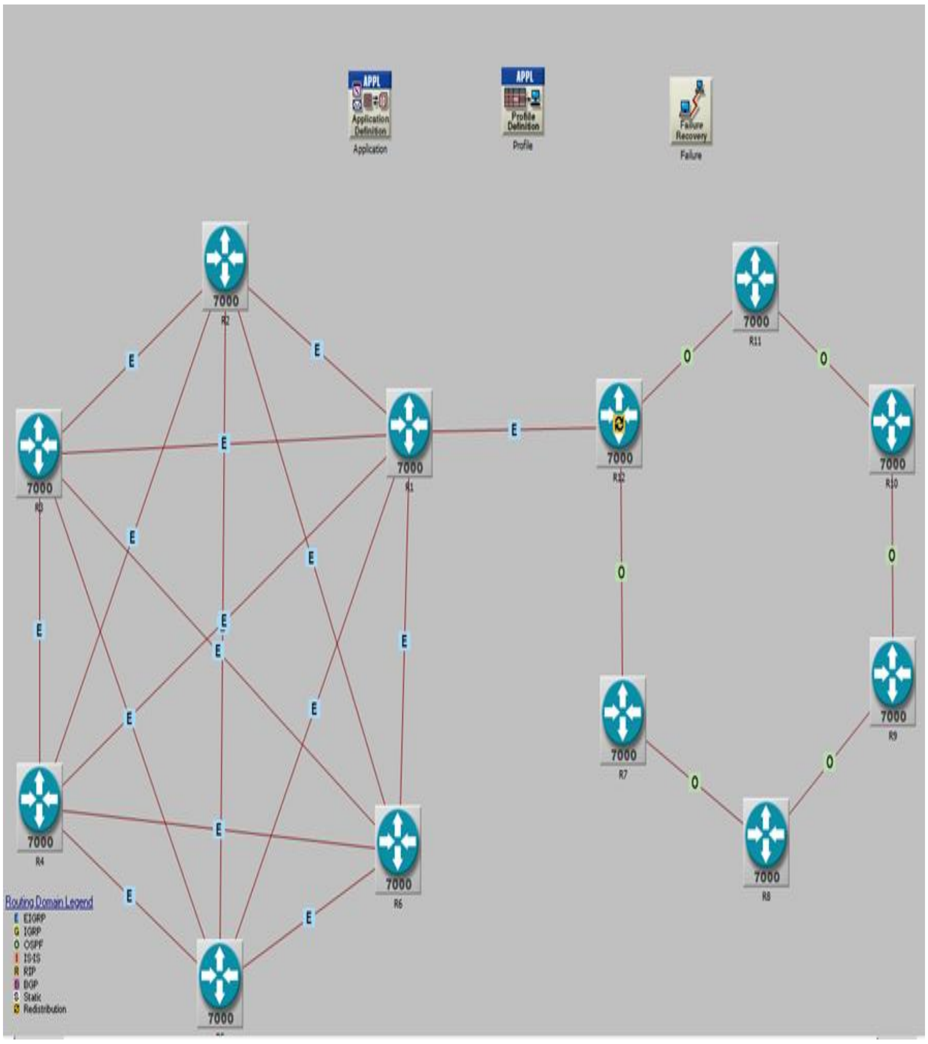


Figure 24. Mutual RR between EIGRP and OSPF

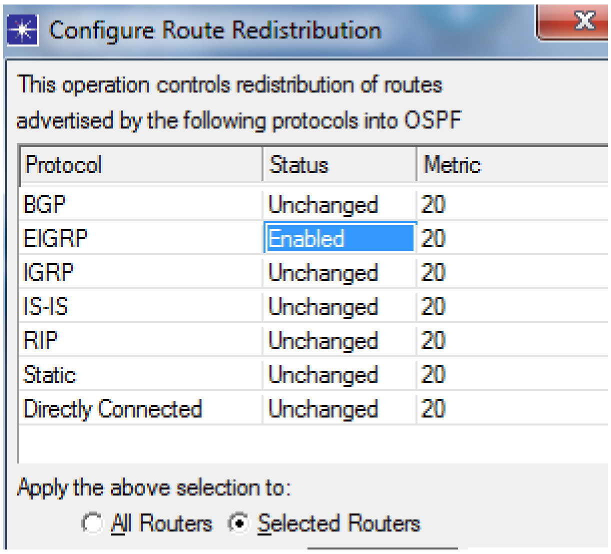
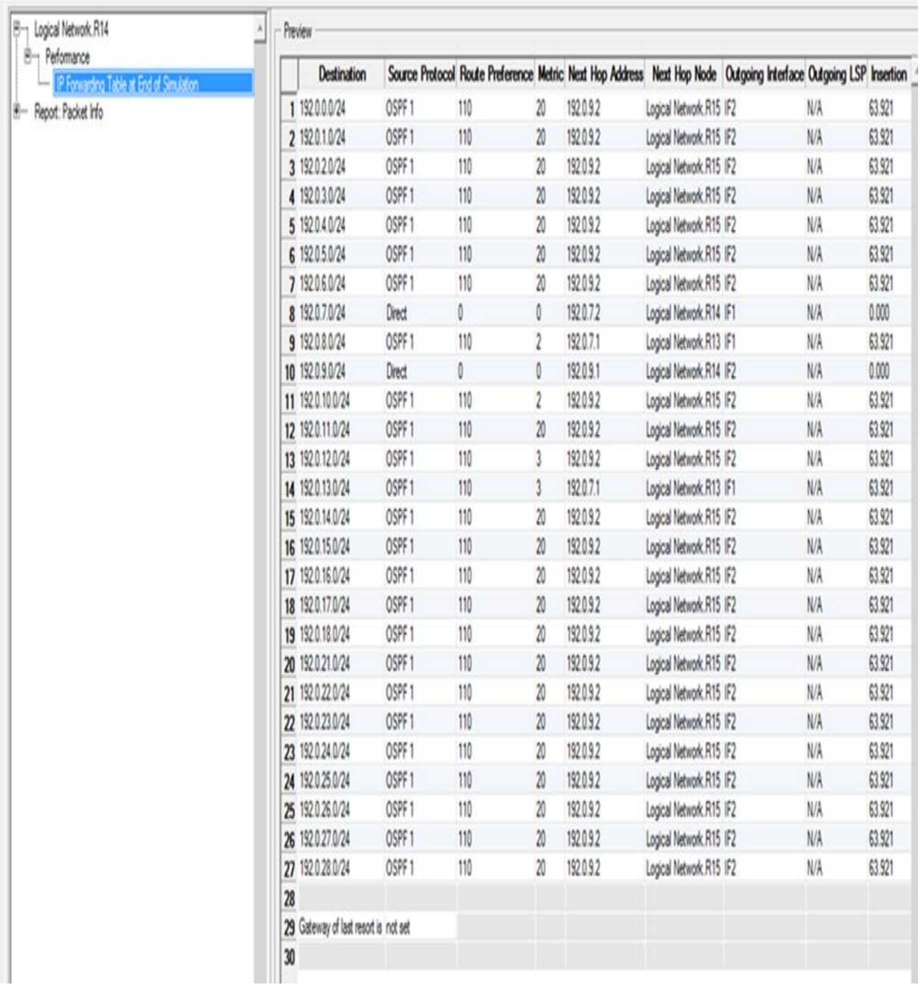


Figure 25. OSPF metric for RR

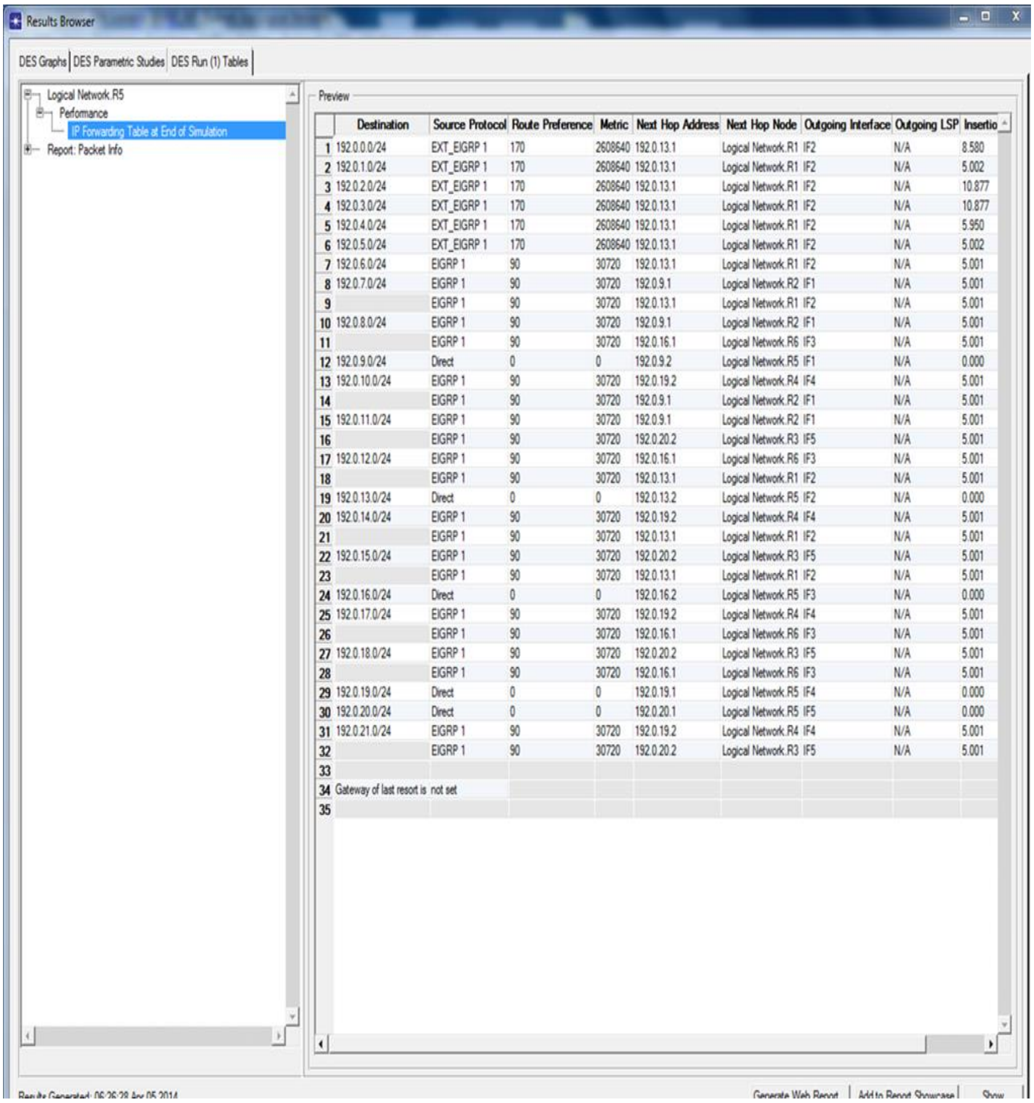
The routing table in figure 26 below was taken from R14 (figure 24 above). The Source protocol is the OSPF instance, which is given a number 1(autonomous system number). The OSPF AD is 110 which remained unchanged in the table. Its metric for routes injected from the EIGRP 1 domain is 20.Its has a lower metrics of 2 and 3 for routes within its administration.



	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Outgoing LSP	Insertion
1	192.0.0.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
2	192.0.1.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
3	192.0.2.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
4	192.0.3.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
5	192.0.4.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
6	192.0.5.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
7	192.0.6.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
8	192.0.7.0/24	Direct	0	0	192.0.7.2	Logical Network.R14	IF1	N/A	0.000
9	192.0.8.0/24	OSPF 1	110	2	192.0.7.1	Logical Network.R13	IF1	N/A	63.921
10	192.0.9.0/24	Direct	0	0	192.0.9.1	Logical Network.R14	IF2	N/A	0.000
11	192.0.10.0/24	OSPF 1	110	2	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
12	192.0.11.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
13	192.0.12.0/24	OSPF 1	110	3	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
14	192.0.13.0/24	OSPF 1	110	3	192.0.7.1	Logical Network.R13	IF1	N/A	63.921
15	192.0.14.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
16	192.0.15.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
17	192.0.16.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
18	192.0.17.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
19	192.0.18.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
20	192.0.21.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
21	192.0.22.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
22	192.0.23.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
23	192.0.24.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
24	192.0.25.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
25	192.0.26.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
26	192.0.27.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
27	192.0.28.0/24	OSPF 1	110	20	192.0.9.2	Logical Network.R15	IF2	N/A	63.921
28									
29	Gateway of last resort is	not set							
30									

Figure 26. Routing table for OSPF from R14

26



	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Outgoing LSP	Insertio
1	192.0.0.0/24	EXT_EIGRP 1	170	2608640	192.0.13.1	Logical Network.R1	IF2	N/A	8.580
2	192.0.1.0/24	EXT_EIGRP 1	170	2608640	192.0.13.1	Logical Network.R1	IF2	N/A	5.002
3	192.0.2.0/24	EXT_EIGRP 1	170	2608640	192.0.13.1	Logical Network.R1	IF2	N/A	10.877
4	192.0.3.0/24	EXT_EIGRP 1	170	2608640	192.0.13.1	Logical Network.R1	IF2	N/A	10.877
5	192.0.4.0/24	EXT_EIGRP 1	170	2608640	192.0.13.1	Logical Network.R1	IF2	N/A	5.950
6	192.0.5.0/24	EXT_EIGRP 1	170	2608640	192.0.13.1	Logical Network.R1	IF2	N/A	5.002
7	192.0.6.0/24	EIGRP 1	90	30720	192.0.13.1	Logical Network.R1	IF2	N/A	5.001
8	192.0.7.0/24	EIGRP 1	90	30720	192.0.9.1	Logical Network.R2	IF1	N/A	5.001
9		EIGRP 1	90	30720	192.0.13.1	Logical Network.R1	IF2	N/A	5.001
10	192.0.8.0/24	EIGRP 1	90	30720	192.0.9.1	Logical Network.R2	IF1	N/A	5.001
11		EIGRP 1	90	30720	192.0.16.1	Logical Network.R6	IF3	N/A	5.001
12	192.0.9.0/24	Direct	0	0	192.0.9.2	Logical Network.R5	IF1	N/A	0.000
13	192.0.10.0/24	EIGRP 1	90	30720	192.0.19.2	Logical Network.R4	IF4	N/A	5.001
14		EIGRP 1	90	30720	192.0.9.1	Logical Network.R2	IF1	N/A	5.001
15	192.0.11.0/24	EIGRP 1	90	30720	192.0.9.1	Logical Network.R2	IF1	N/A	5.001
16		EIGRP 1	90	30720	192.0.20.2	Logical Network.R3	IF5	N/A	5.001
17	192.0.12.0/24	EIGRP 1	90	30720	192.0.16.1	Logical Network.R6	IF3	N/A	5.001
18		EIGRP 1	90	30720	192.0.13.1	Logical Network.R1	IF2	N/A	5.001
19	192.0.13.0/24	Direct	0	0	192.0.13.2	Logical Network.R5	IF2	N/A	0.000
20	192.0.14.0/24	EIGRP 1	90	30720	192.0.19.2	Logical Network.R4	IF4	N/A	5.001
21		EIGRP 1	90	30720	192.0.13.1	Logical Network.R1	IF2	N/A	5.001
22	192.0.15.0/24	EIGRP 1	90	30720	192.0.20.2	Logical Network.R3	IF5	N/A	5.001
23		EIGRP 1	90	30720	192.0.13.1	Logical Network.R1	IF2	N/A	5.001
24	192.0.16.0/24	Direct	0	0	192.0.16.2	Logical Network.R5	IF3	N/A	0.000
25	192.0.17.0/24	EIGRP 1	90	30720	192.0.19.2	Logical Network.R4	IF4	N/A	5.001
26		EIGRP 1	90	30720	192.0.16.1	Logical Network.R6	IF3	N/A	5.001
27	192.0.18.0/24	EIGRP 1	90	30720	192.0.20.2	Logical Network.R3	IF5	N/A	5.001
28		EIGRP 1	90	30720	192.0.16.1	Logical Network.R6	IF3	N/A	5.001
29	192.0.19.0/24	Direct	0	0	192.0.19.1	Logical Network.R5	IF4	N/A	0.000
30	192.0.20.0/24	Direct	0	0	192.0.20.1	Logical Network.R5	IF5	N/A	0.000
31	192.0.21.0/24	EIGRP 1	90	30720	192.0.19.2	Logical Network.R4	IF4	N/A	5.001
32		EIGRP 1	90	30720	192.0.20.2	Logical Network.R3	IF5	N/A	5.001
33									
34	Gateway of last resort is	not set							
35									

Figure 27. EIGRP Routing Table

As shown in figure 27, routes from OSPF1 injected into EIGRP 1(the domain of EIGRP), the AD of 170 was used .Those routes within EIGRP instance, the AD of 90 and lower metric of 30720 was used. All external routes are marked EXT_EIGRP1 with the metric of 2608640.

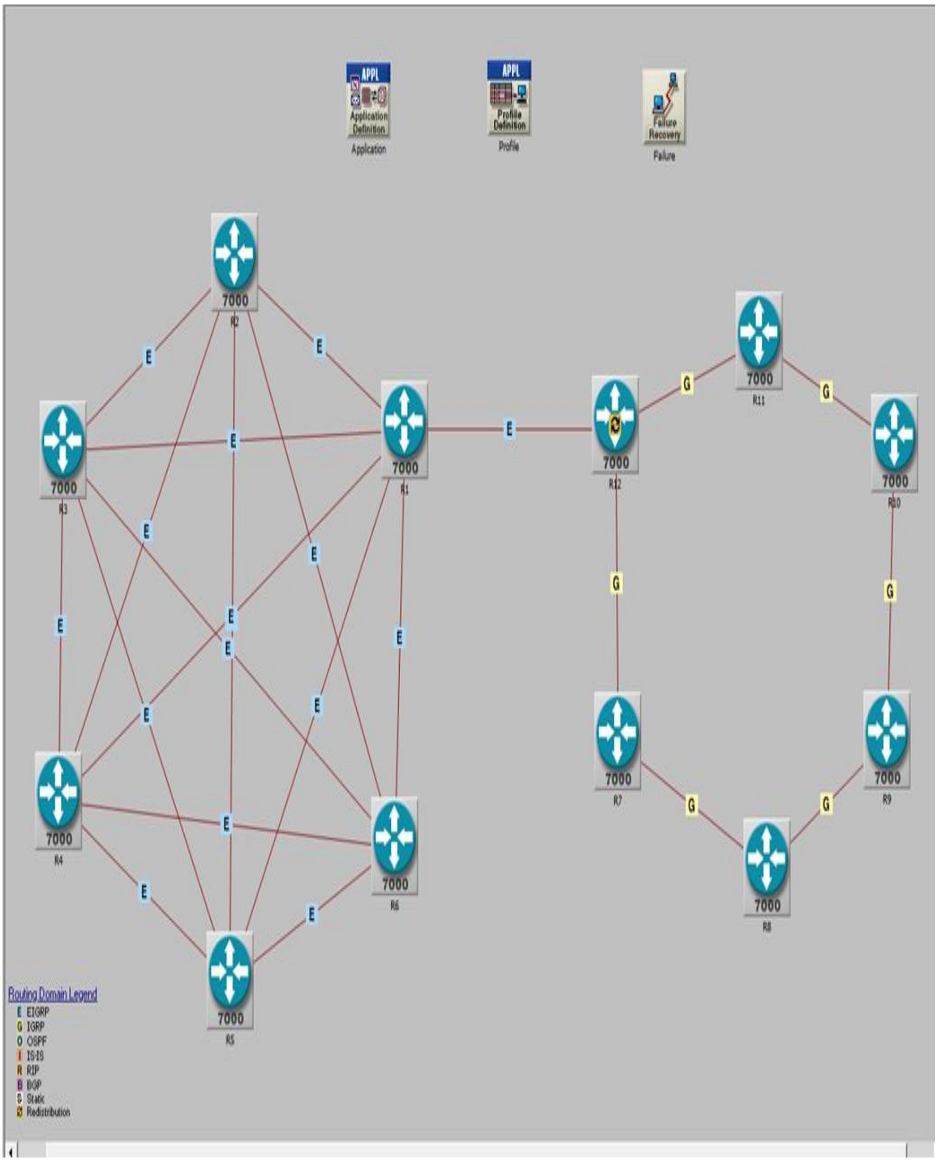


Figure 28. EIGRP/OSPF Hybrid Topology for Single Point RR

OSPF in figure 24 above was replaced with IGRP. Below is a screenshot from OPNET modeler of composite metrics used by EIGRP/IGRP in the redistribution of routes.

Configure Route Redistribution

This operation controls redistribution of routes advertised by the following protocols into IGRP

Protocol	Status	Bandwidth	Delay	Reliability	Load	MTU
BGP	Unchanged	1000	100	255	0	1500
EIGRP	Enabled	1000	100	255	0	1500
OSPF	Unchanged	1000	100	255	0	1500
IS-IS	Unchanged	1000	100	255	0	1500
RIP	Unchanged	1000	100	255	0	1500
Static	Unchanged	1000	100	255	0	1500
Directly Connected	Unchanged	1000	100	255	0	1500

Apply the above selection to: ( ) All Routers (•) Selected Routers

OK Cancel

Figure 29. IGRP RR Metrics

Performance.IP Forwarding Table at End of Simulation for Logical Network.R10

File Edit View Help

	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Outgoing LSP	
1	192.0.0.0/24	Direct	0	0	192.0.0.1	Logical Network.R10	IF1	N/A	0.000
2	192.0.1.0/24	Direct	0	0	192.0.1.1	Logical Network.R10	IF2	N/A	0.000
3	192.0.2.0/24	IGRP	100	120	192.0.0.2	Logical Network.R9	IF1	N/A	5.000
4	192.0.3.0/24	IGRP	100	130	192.0.1.2	Logical Network.R11	IF2	N/A	5.000
5		IGRP	100	130	192.0.0.2	Logical Network.R9	IF1	N/A	6.919
6	192.0.4.0/24	IGRP	100	120	192.0.1.2	Logical Network.R11	IF2	N/A	2.434
7	192.0.5.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	2.434
8	192.0.6.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
9	192.0.7.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
10	192.0.8.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
11	192.0.9.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
12	192.0.10.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
13	192.0.13.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
14	192.0.14.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
15	192.0.15.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
16	192.0.16.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
17	192.0.17.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
18	192.0.18.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
19	192.0.19.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
20	192.0.20.0/24	IGRP	100	10110	192.0.1.2	Logical Network.R11	IF2	N/A	5.992
21									
22	Gateway of last resort is not set								

Figure 30. IGRP Routing Table from Router R10.

In figure 30, the IGRP metric for internal routes was 120 and 130 respectively while a higher metric of 10110 was for external routes. The IGRP AD remains unchanged for both internal and external routes.

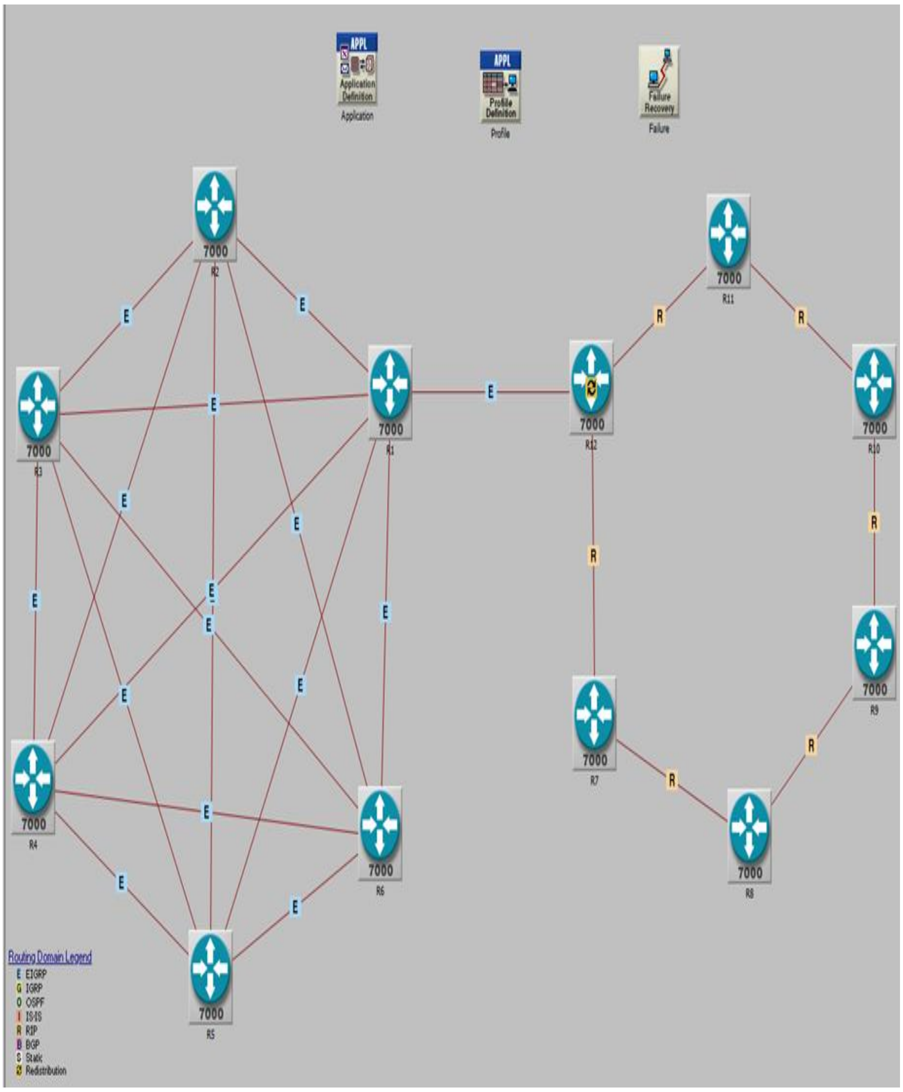
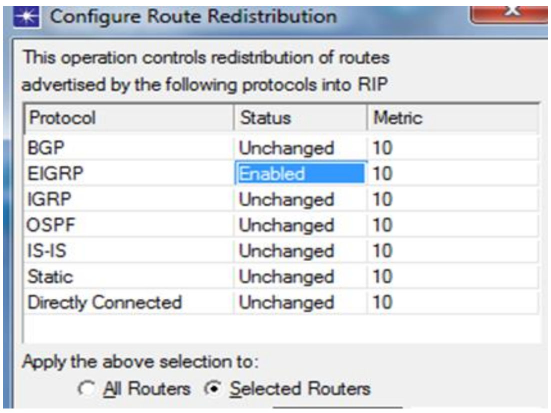


Figure 31. RR between EIGRP and RIP

A metric of 10 was configured for routes into the RIP process as shown in figure 32 below.



Configure Route Redistribution

This operation controls redistribution of routes advertised by the following protocols into RIP

Protocol	Status	Metric
BGP	Unchanged	10
EIGRP	Enabled	10
IGRP	Unchanged	10
OSPF	Unchanged	10
IS-IS	Unchanged	10
Static	Unchanged	10
Directly Connected	Unchanged	10

Apply the above selection to:
All Routers   Selected Routers

Figure 32. RIP metric of RR

As shown in figure 33 below, the lower metrics of 1 and 2 was used for routes internal to RIP and the higher metrics of 11 was used for external routes

Performance.IP Forwarding Table at End of Simulation for Logical Network.R11

File Edit View Help

	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Outgoing LSP	Insertion Time (secs)
1	192.0.0.0/24	Direct	0	0	192.0.0.1	Logical Network.R11	IF1	N/A	0.000
2	192.0.1.0/24	Direct	0	0	192.0.1.1	Logical Network.R11	IF2	N/A	0.000
3	192.0.2.0/24	RIP	120	1	192.0.0.2	Logical Network.R10	IF1	N/A	8.769
4	192.0.3.0/24	RIP	120	2	192.0.0.2	Logical Network.R10	IF1	N/A	8.769
5	192.0.4.0/24	RIP	120	2	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
6	192.0.5.0/24	RIP	120	1	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
7	192.0.6.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
8	192.0.7.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
9	192.0.8.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
10	192.0.9.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
11	192.0.10.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
12	192.0.11.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
13	192.0.12.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
14	192.0.13.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
15	192.0.14.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
16	192.0.15.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
17	192.0.16.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
18	192.0.17.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
19	192.0.18.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
20	192.0.19.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
21	192.0.20.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930
22	192.0.21.0/24	RIP	120	11	192.0.1.2	Logical Network.R12	IF2	N/A	9.930

Figure 33. Routing Table of RIP from R11.

4.9 Multiple Point Redistribution

In this part, six ASBR were used in performing the route redistribution. EIGRP was implemented in a mesh topology consisting of six routers. It is assumed here that all others domains intend to exchange routes with EIGRP. In real situation, a given research center, with the decision to configure its entire network to be using only EIGRP, built and configured a new main center in mesh topology. It intended temporarily to exchange information with other lesser departments previously using RIP, IGRP and OSPF before migration to exclusive EIGRP use is fully completed.

- RR between EIGRP and multiple networks of OSPF
- RR between EIGRP and multiple networks of IGRP
- RR between EIGRP and multiple networks of RIP

4.9.1 RR between EIGRP and OSPF

In the diagram below, 6 domains of OSPF is exchanging data with EIGRP. This is a complex topology of mesh-ring

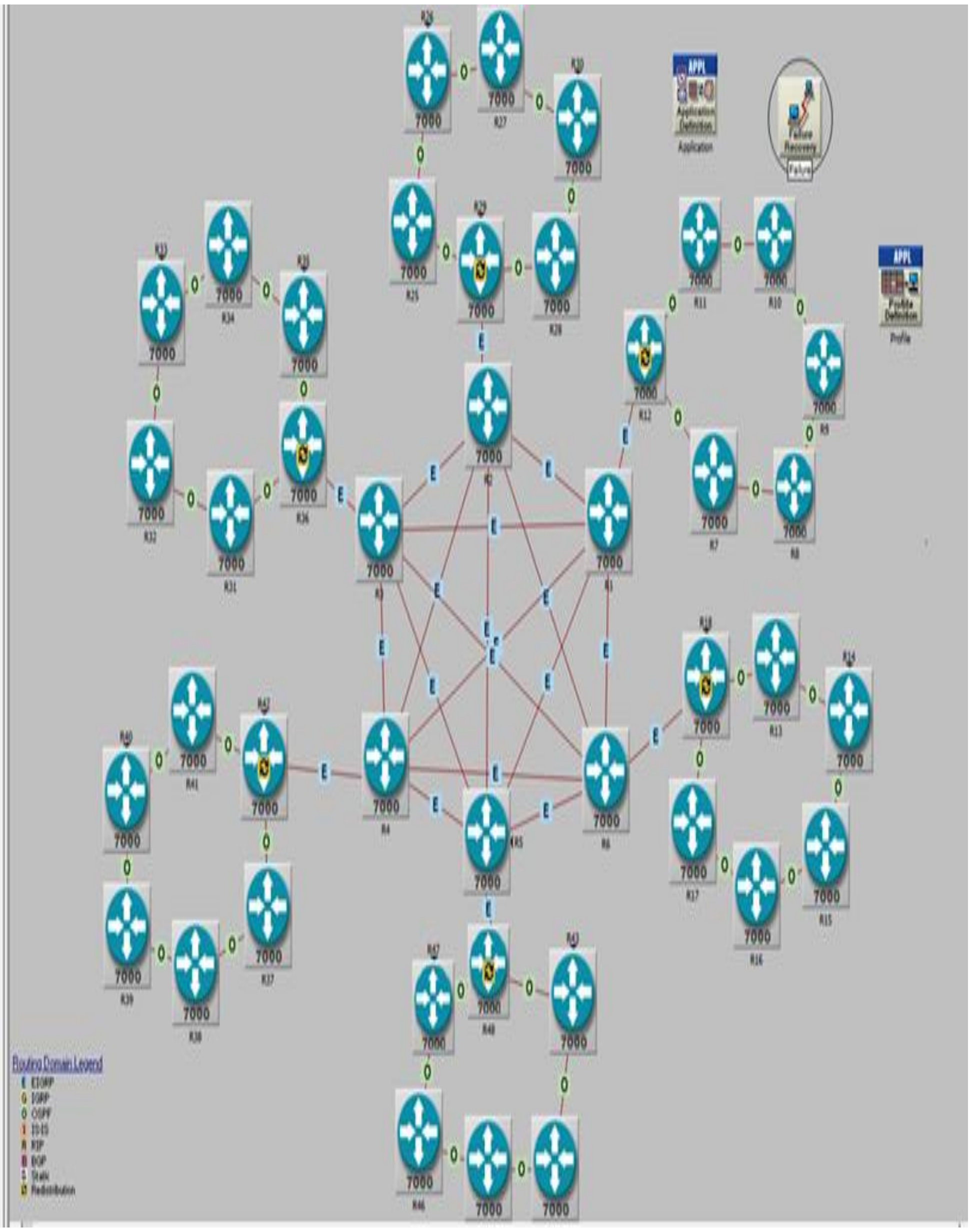


Figure 34.. RR between EIGRP and OSPF using 6 ASBR

4.9.2 RR between EIGRP and Multiple networks of IGRP

All domains of OSPF in figure 34 above were replaced with IGRP as seen below.

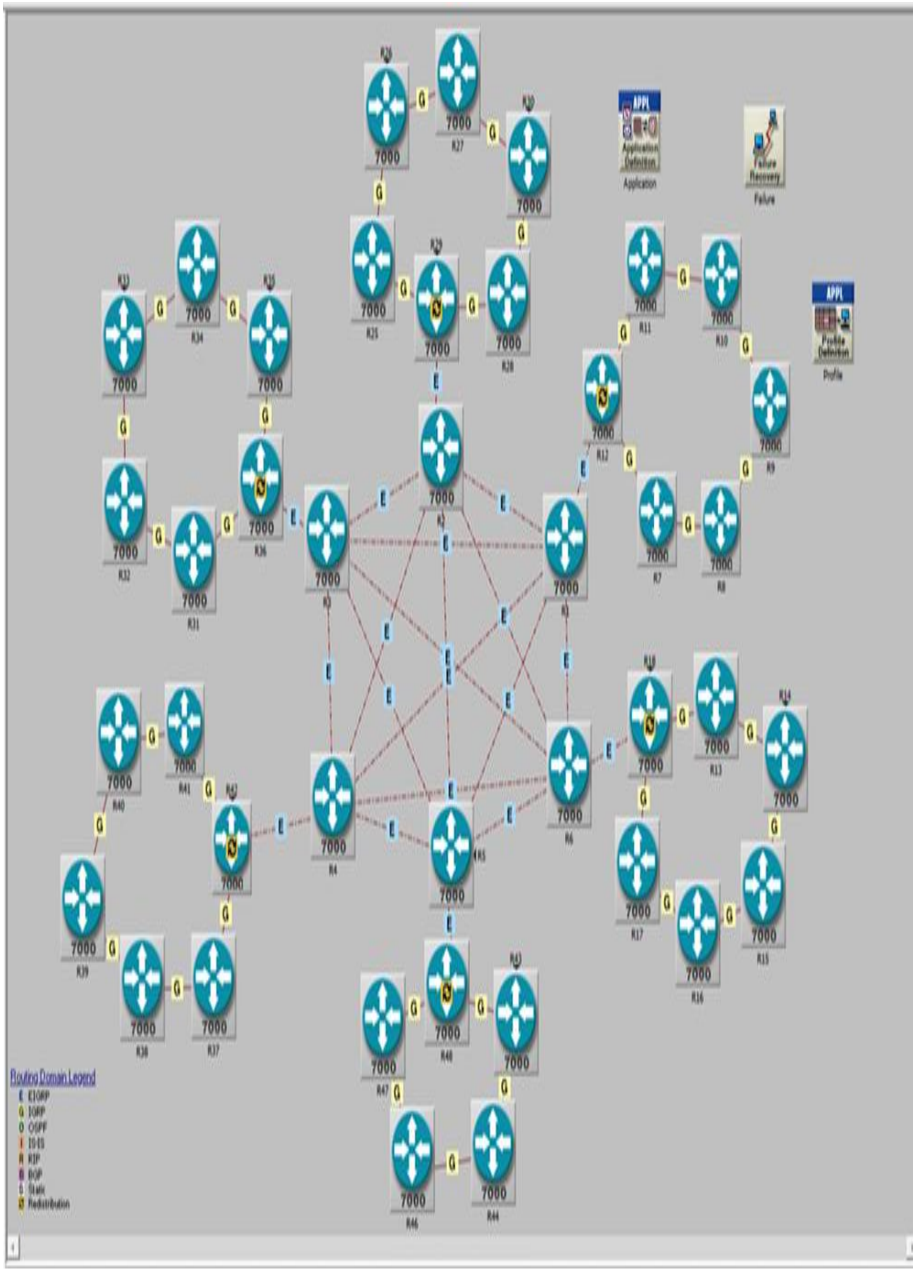


Figure 35. RR between EIGRP and IGRP

4.10 Mutual Redistribution between Three Routing Domains

- RR between OSPF, EIGRP and RIP using 3 ASBR for redistributing routes between OSPF and EIGRP and 3 ASBR for redistributing routes between EIGRP and RIP.

- RR between OSPF, EIGRP and RIP, using 3 ASBR each.

The designs in figure 36, 37 and 38 were done in such a way that one ASBR is redistributing routes between IGRP and EIGRP and another ASBR is also redistributing routes between EIGRP and OSPF. It is analogous to the system made up of seven divisions of a company having three of its divisions using IGRP and another three configured in OSPF. All six divisions may decide exclusively to manage their own networks, but must exchange route at key subnets with a main center using mesh topology. In the design, more of a ring, which is cheap is used and less of mesh-an expensive topology is used, making the hybrid network economically effective.

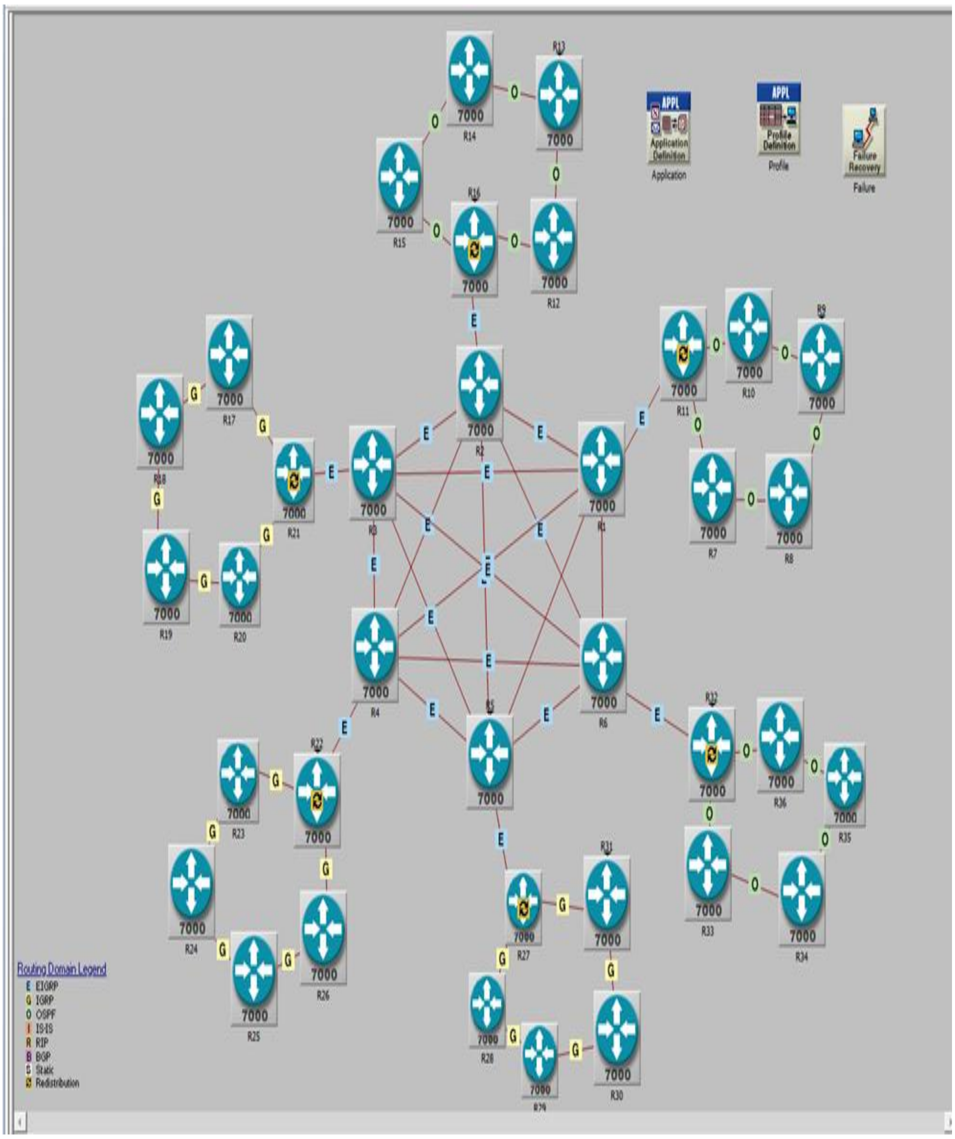


Figure 36. IGRP/EIGRP/OSPF for Multiple Point RR.

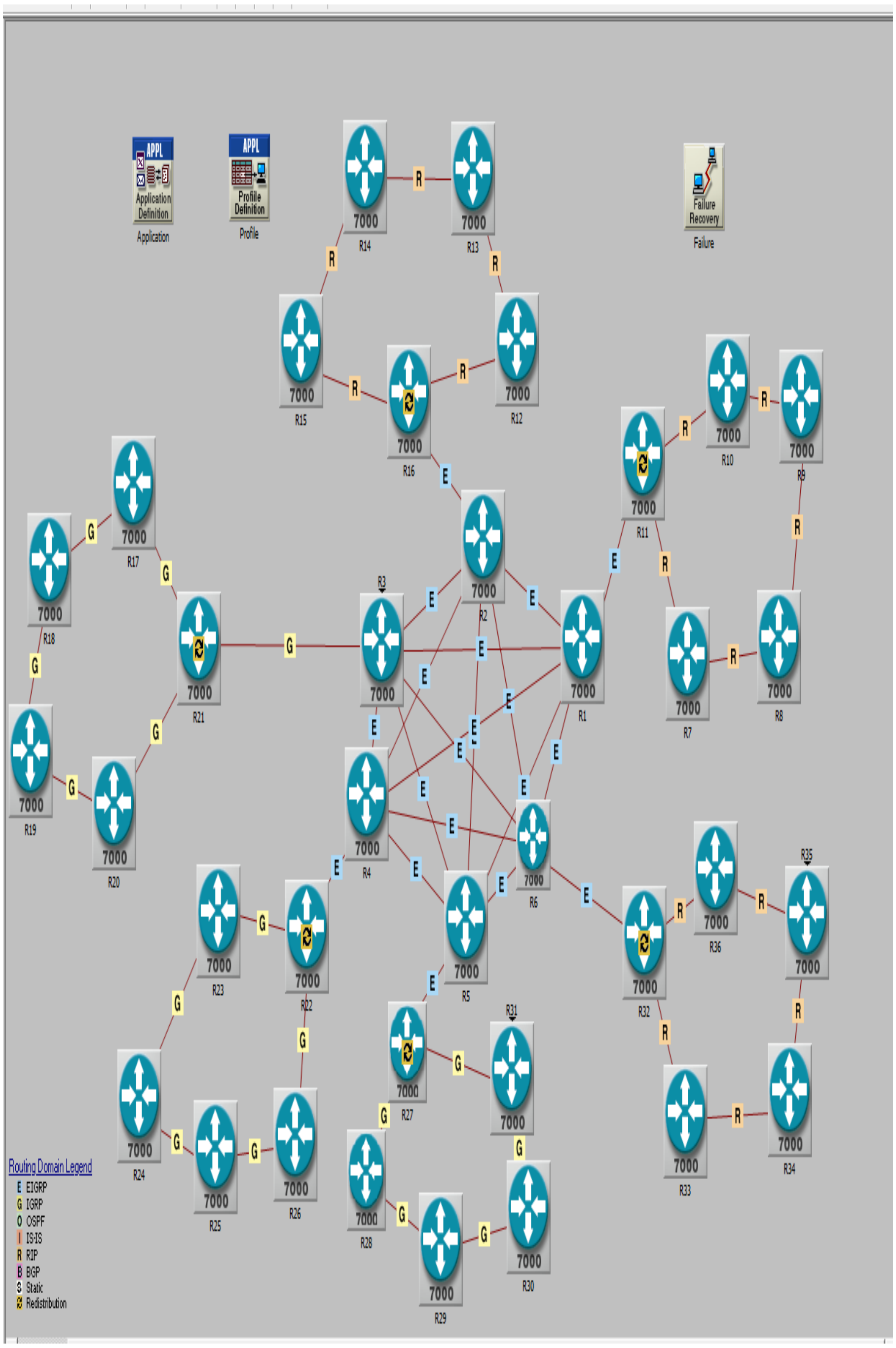


Figure 37. IGRP/EIGRP/RIP Multiple Point RR.

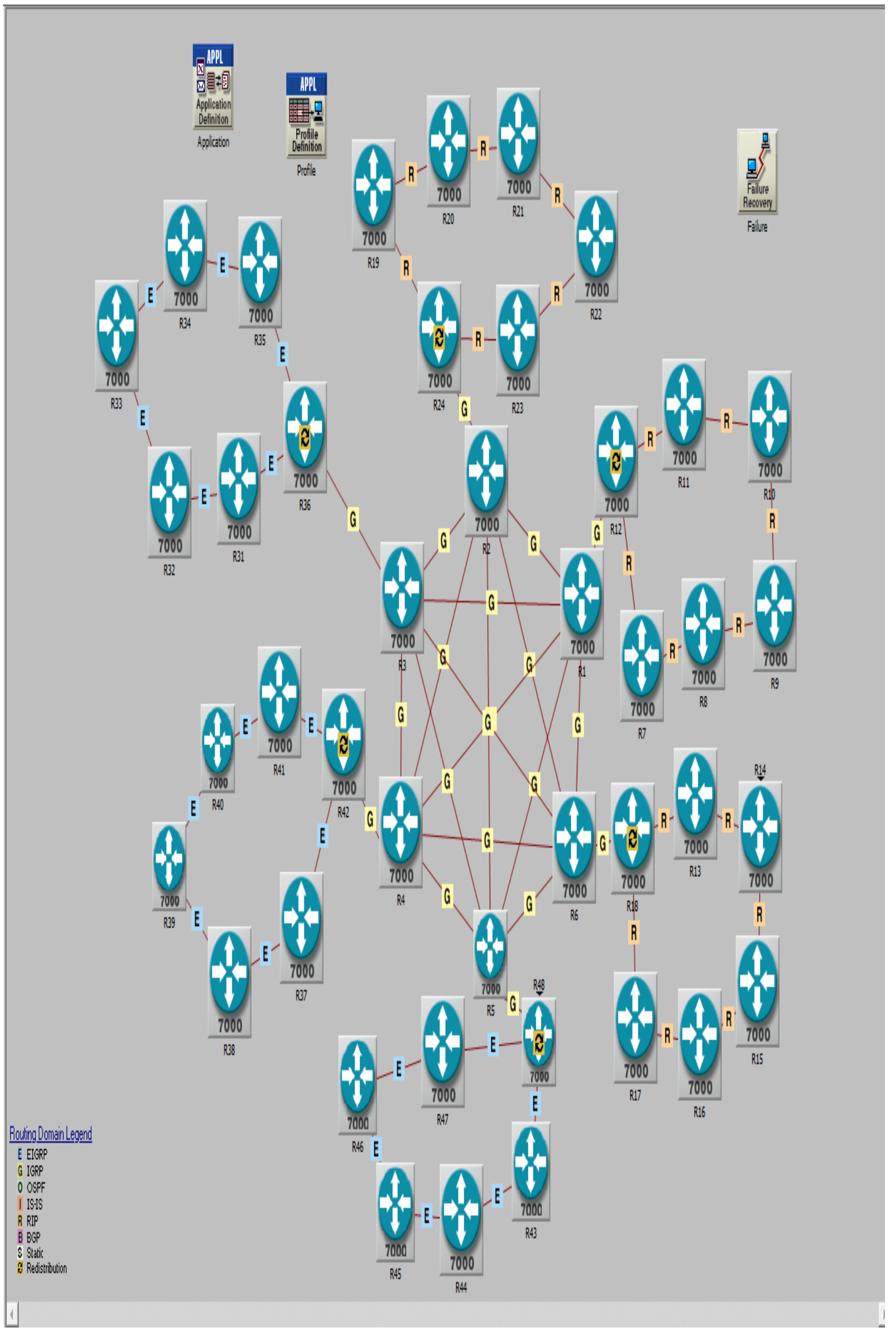


Figure 38. EIGRP/IGRP/RIP Multiple Point RR.

5 RESULTS AND ANALYSIS

5.1 Analysis of Convergence Time

The graph of convergence time in figure 39 (single point redistribution), figure 40 (multiple point redistributions) and figure 41 (for multiple point redistributions between three routing protocols) were analyzed below.

5.1.1 Convergence Time for Single Point RR

The blue line in figure 39 below is the EIGRP/IGRP. The red line indicates EIGRP/OSPF and lastly the green line is the graph of EIGRP/RIP .The horizontal portion of the graph is the simulation time and the vertical is the CT. The CT is smallest for EIGRP/IGRP and highest for EIGRP/RIP.

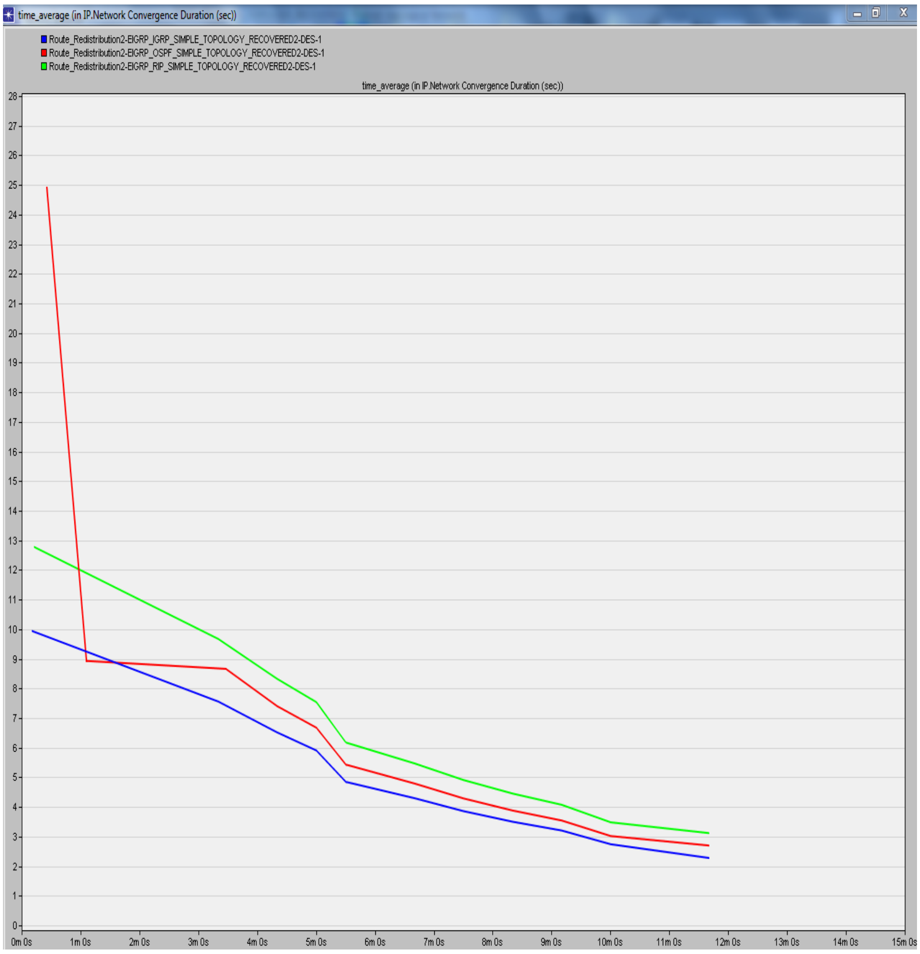


Figure 39. Convergence Time for Single Point RR.

Table 4. Performance Metrics for Single Point RR

SP	CT/s	QD/s	ETE D/s	ETE Delay V/s
EIGRP/IGRP	2.3	0.0000115	0.000500	0.00052
EIGRP/OSPF	2.7	0.0000115	0.000525	0.00050
EIGRP/RIP	3.1	0.0000280	0.000575	0.00057

5.1.2 Convergence Time for Multiple Point RR

When comparing the CT from table 4 above and the CT from table 5 below, the observable change in the CT of EIGRP/IGRP for both SP RR and MP RR, is negligibly small, but that of EIGRP/RIP has increased by about 1.1s

Table 5 Performance Metrics for Multiple Point RR

MP	CT/s	QD/s	ETE D/s	ETE Delay V/s
EIGRP/IGRP	2.1	0.0000117	0.00046	0.00080
EIGRP/OSPF	2.5	0.0000200	0.00029	0.00035
EIGRP/RIP	4.0	0.0000296	0.00031	0.00102

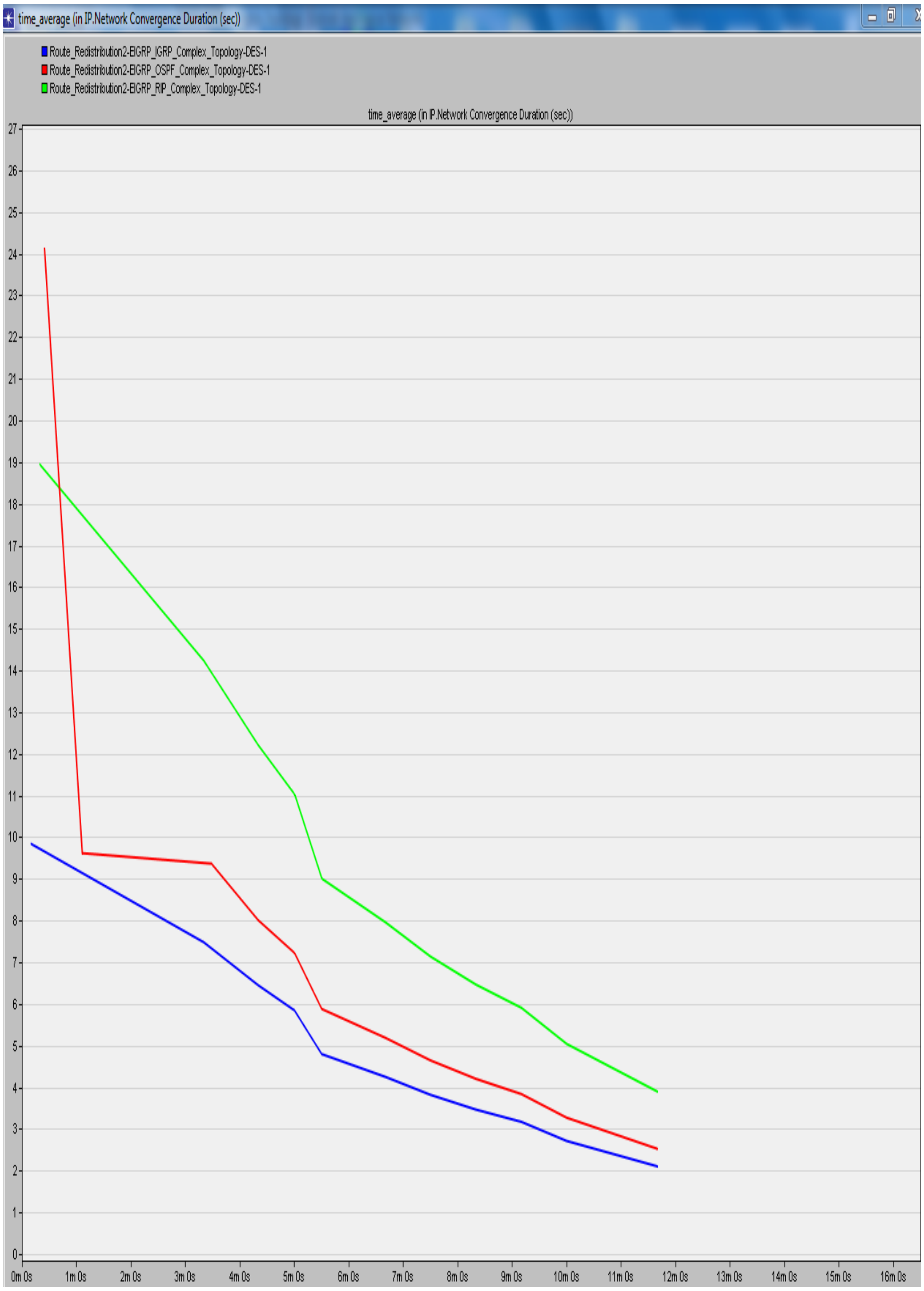


Figure 40. Convergence Time for Multiple Point RR

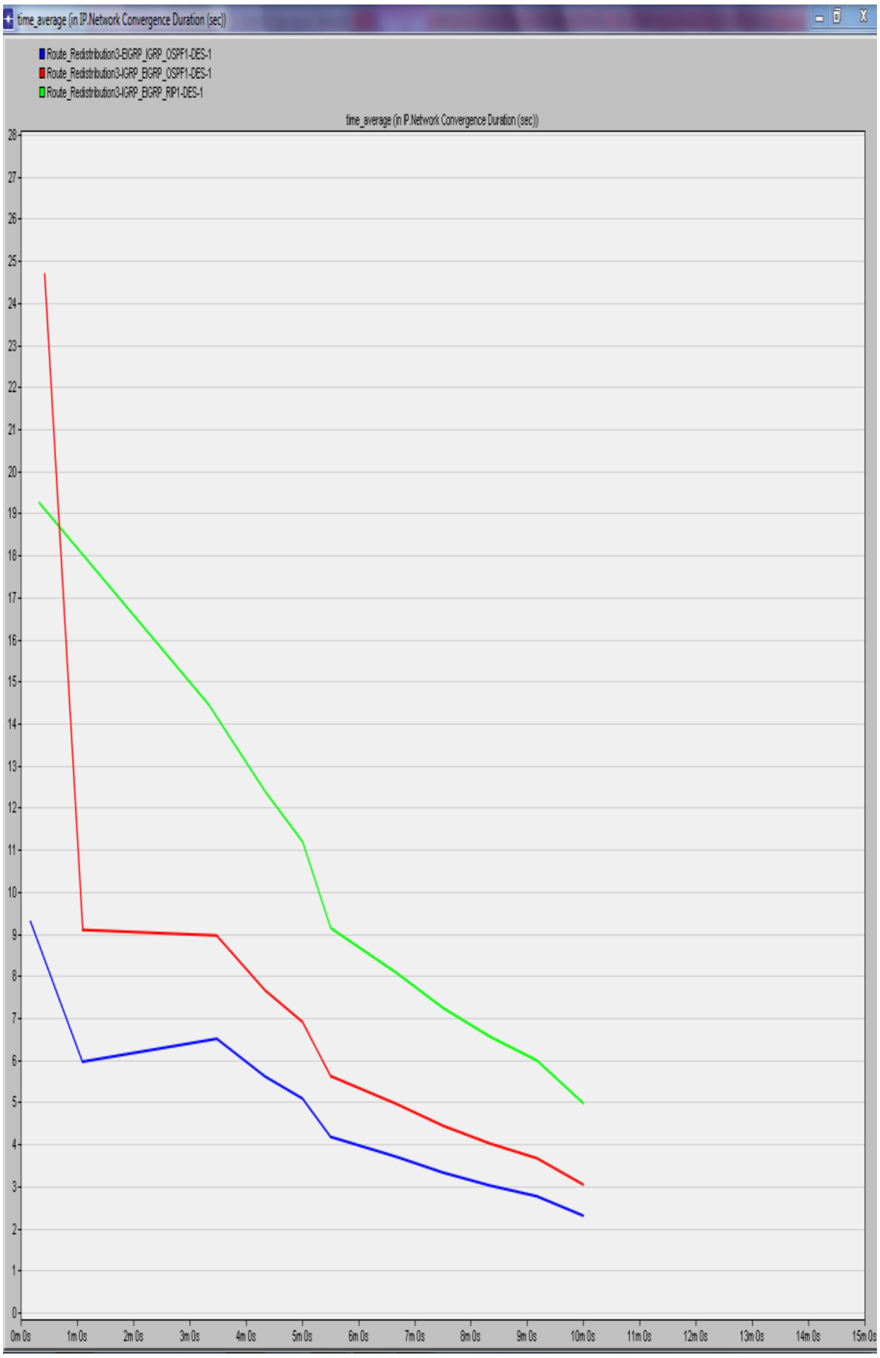


Figure 41. The graph of CT when EIGRP was replaced with IGRP

The CT for EIGRP/IGRP/OSPF, the blue portion of the graph is about 2.3s and that of IGRP/EIGRP/OSPF is exactly 3.0s.From figure 37 and 38, EIGRP in the mesh was replaced with IGRP, the change in CT was 30% decrease.

5.2 Analysis of ETE delay

The ETE delay for single point redistribution (figure 42), multiple point redistribution (figure 43) were analyzed as seen below.

5.2.1 ETE Delay for Single Point RR

The blue line in figure 42 below indicates EIGRP/IGRP and the red line signifies EIGRP/OSPF. The green line shows the graph of EIGRP/RIP. The vertical part of the graph is the ETE delay in seconds, and the horizontal is the simulation time in minutes. The three networks attain stability after about 5mins of simulation time. The EIGRP/RIP remains most unstable networks within the 5mins of simulation. EIGRP/IGRP is the least stable. EIGRP/IGRP has the least ETE delay and EIGRP/RIP has the worst delay.

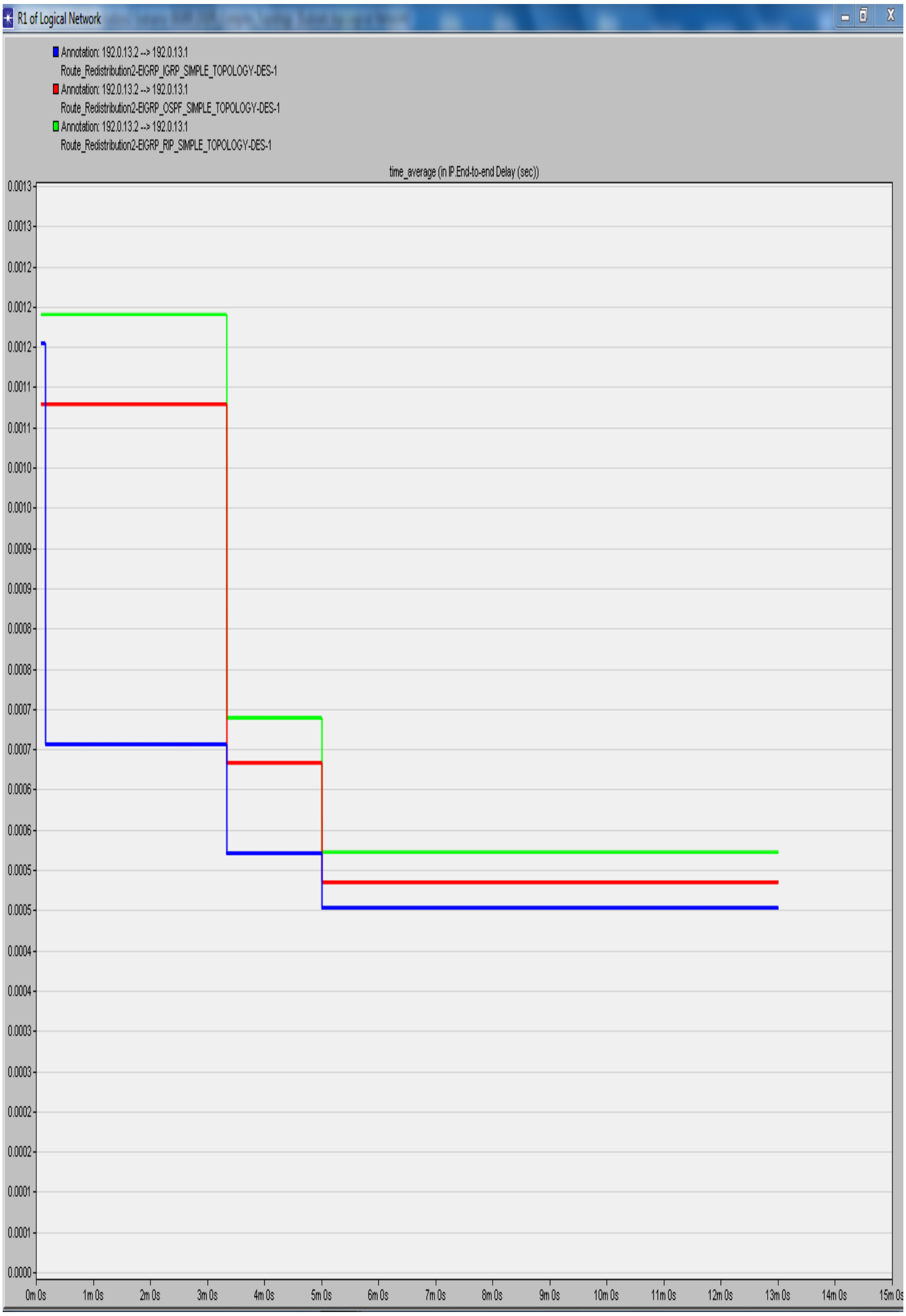


Figure 42. ETE Delay for Single Point RR

5.2.2 ETE Delay for Multiple Point RR

As seen in the graph below, the ETE as measured between the subnet 192.0.7.1 to 192.0.7.2 (MP RR), is smallest for EIGRP/OSPF and highest for EIGRP/IGRP.

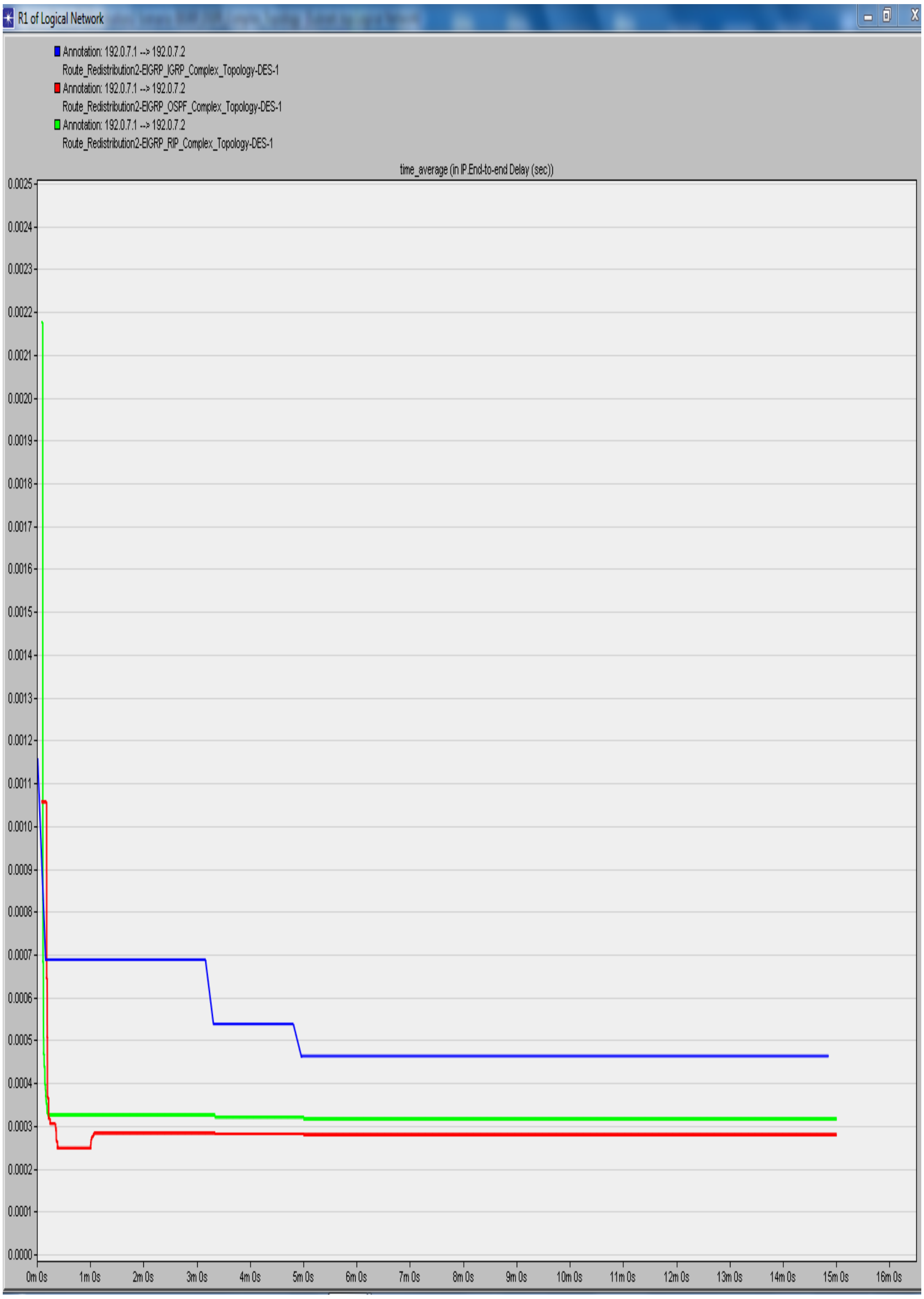


Figure 43. ETE delay for Multiple Point RR

5.2.3 ETE Delay Variation

The analyses of ETE delay variation (jitter) for both SP and MP redistribution and their graphs are shown in figure 44 and figure 45.

5.2.4 ETE Delay Variation for Single Point RR

The ETE delay variation is lowest for EIGRP/OSPF and highest for EIGRP/RIP. Thus, EIGRP/OSPF has the best variation in ETE delay.

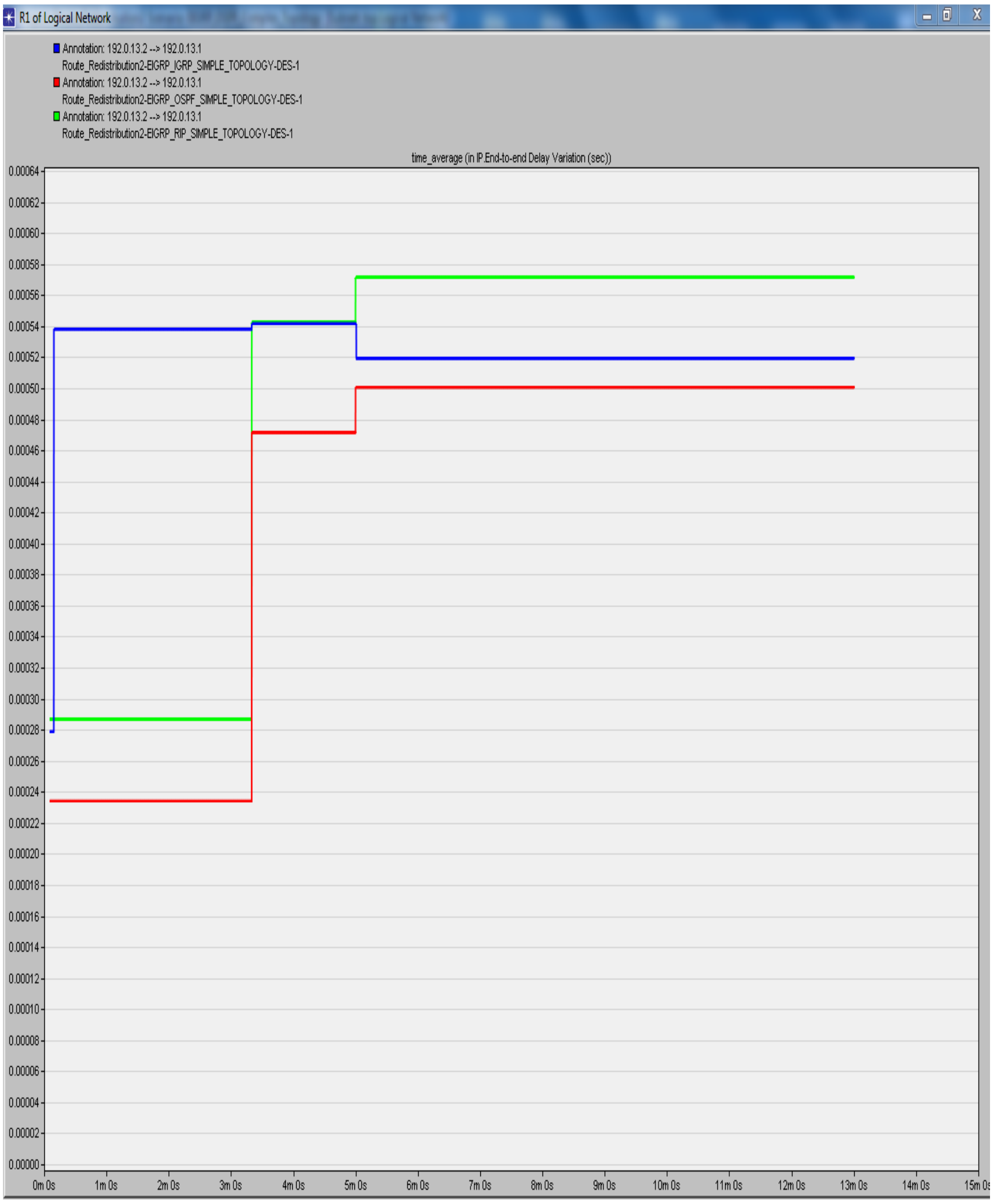


Figure 44. ETE Delay Variation for Single Point RR.

5.2.5 ETE Delay Variation for Multiple Point RR

As seen in the graph below, there is a markedly wide variation in ETE delay of EIGRP/IGRP, EIGRP/OSPF and EIGRP/RIP with EIGRP/RIP being the least.

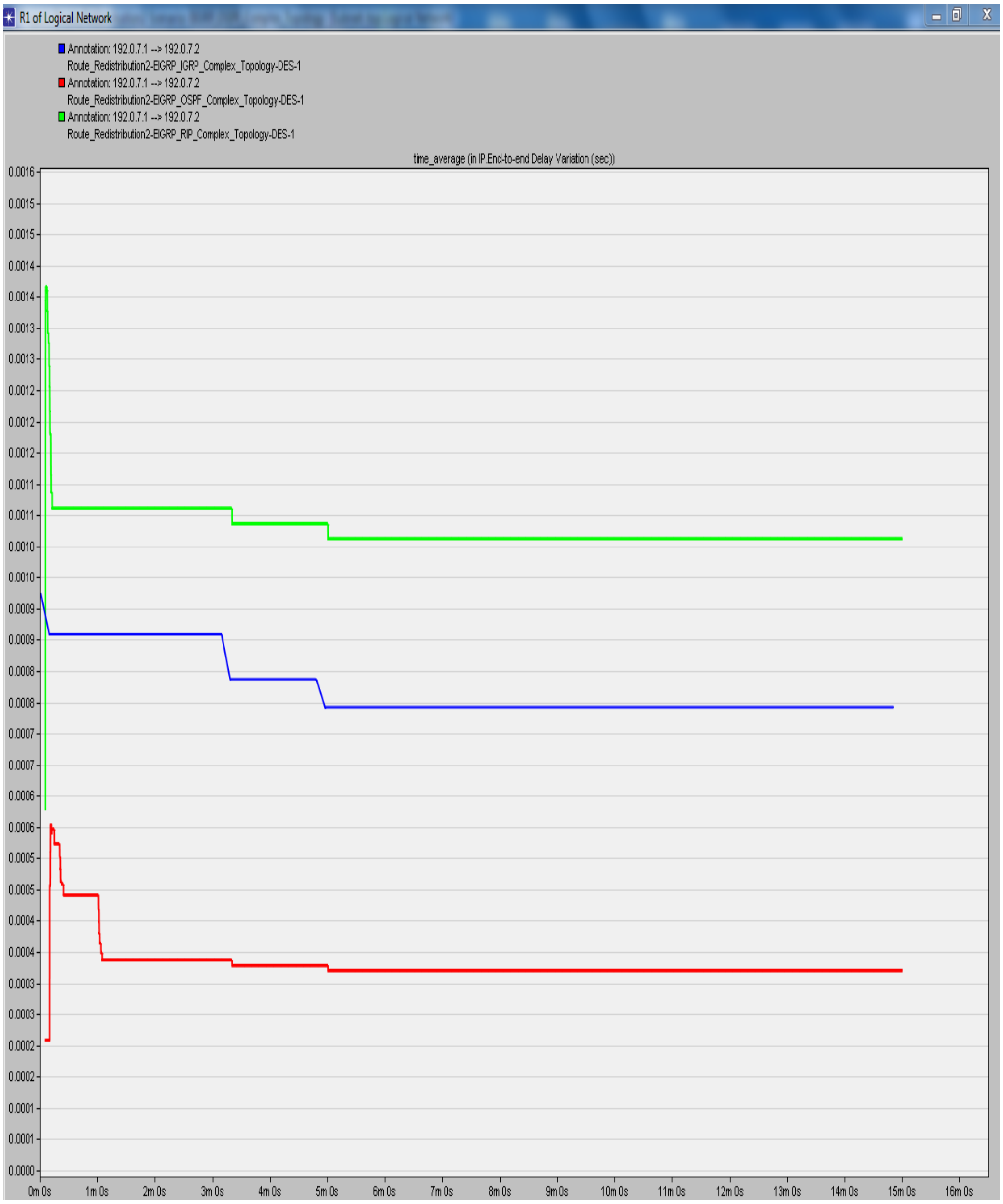


Figure 45. ETE Delay Variation for Multiple Point RR.

5.3 Analysis of Queuing Delay

The queuing delay analysis for both single and multiple redistribution and their respective graphs are shown below.

5.3.1 Queuing Delay for Single Point RR

In the figure below the EIGRP/OSPF and EIGRP/IGRP have the same queuing delay. The hybrid network of EIGRP/RIP reaches stability quicker (at about 1.0min of simulation time) and has the highest obtainable value of about 0.0000280s as compared to the delay of about 0.0000115s for both EIGRP/OSPF and EIGRP/IGRP. It took some time for the hybrid network of EIGRP/IGRP and EGRP/OSPF to stabilize while EIGRP/IGRP reaches stability in about 1.0min of simulation time.

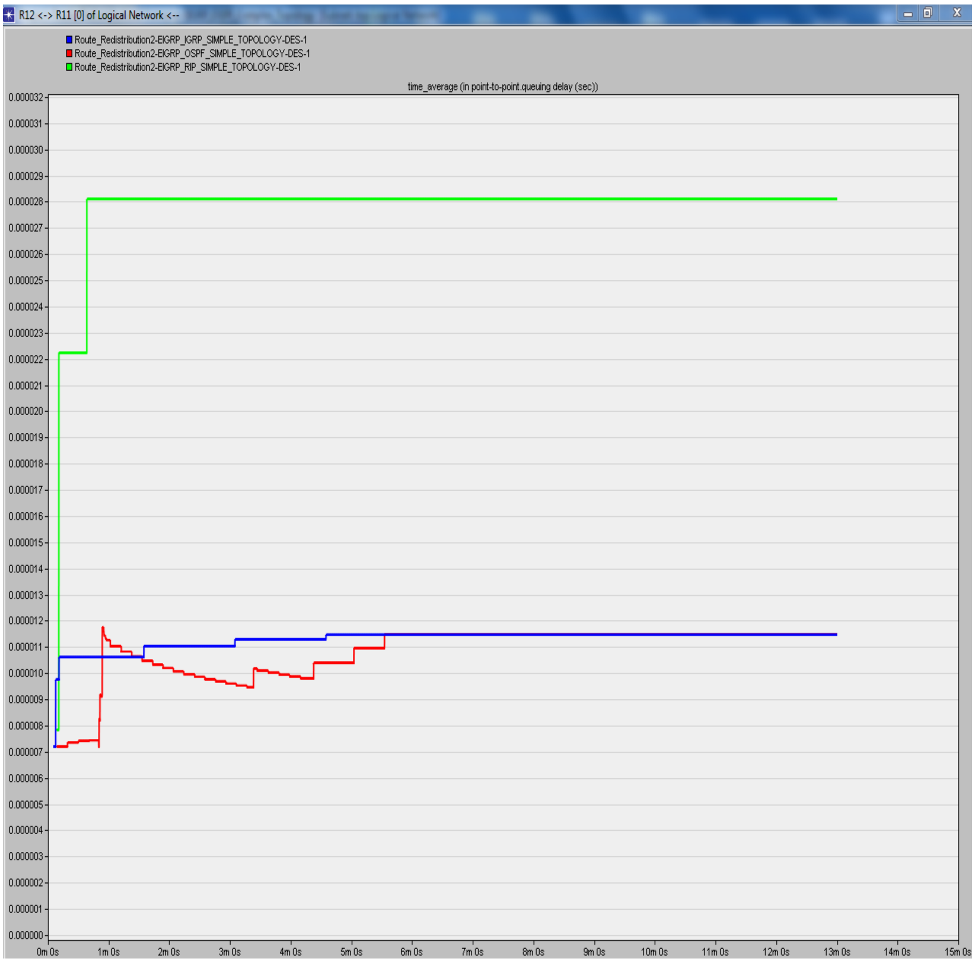


Figure 46. Queuing Delay for Single Point RR

5.3.2 Queuing Delay for Multiple Point RR

The QD for EIGRP/RIP is highest. EIGRP/IGRP is lowest.

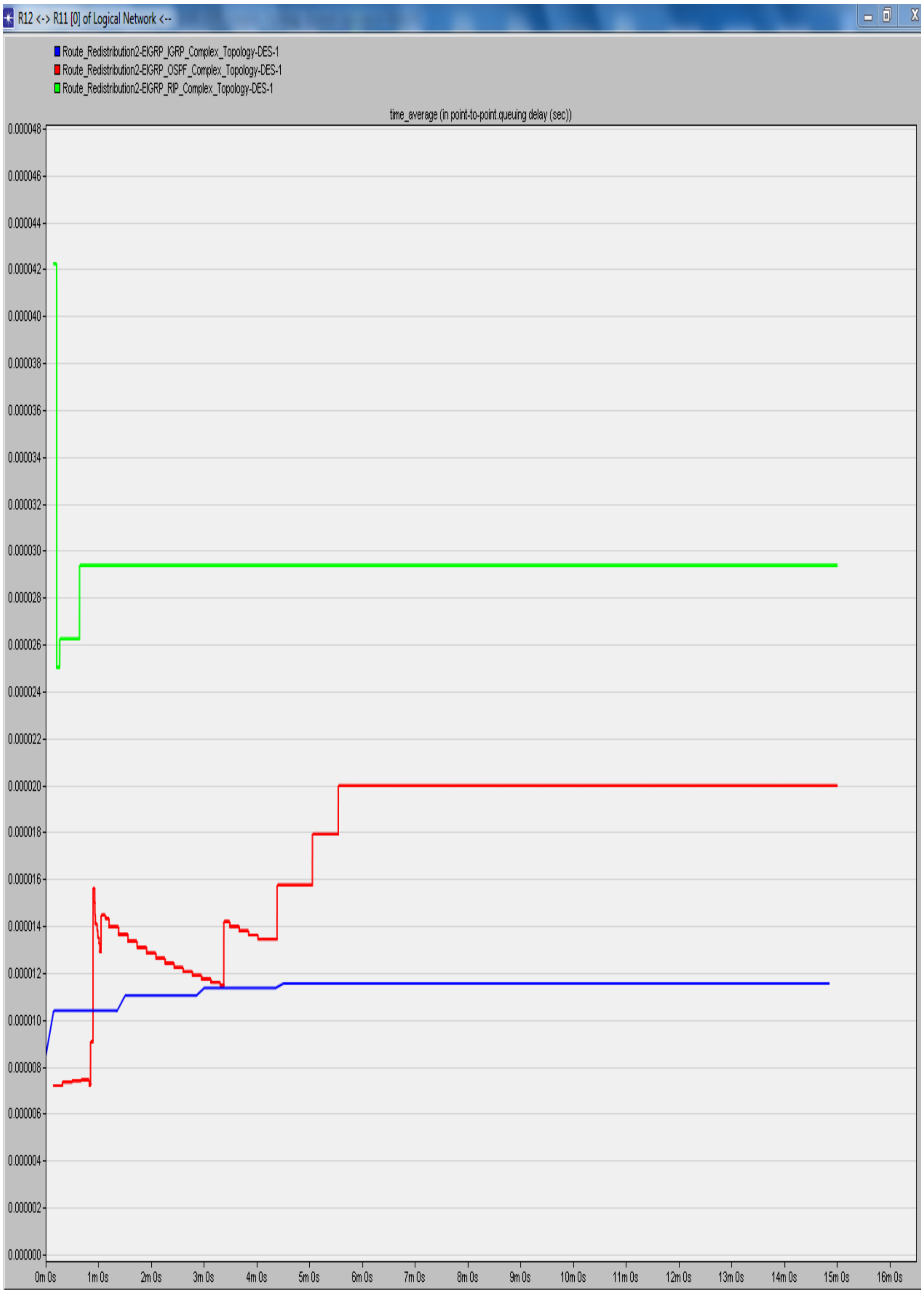


Figure 47. Queuing Delay for Multiple Point RR.

The ranking used in selecting the best performing hybrid topology in SP RR and MP RR is shown below. The best network is rank 3 and the worst is 1.

Table 6. Rank Table

RANKING	VALUE
BEST	3
WORSE	2
WORST	1

Table 7. Performance Analysis of Hybrid Networks for Single Point RR

SP	CT	QD	ETE D	ETE D V	Wave	RANK
EIGRP/IGRP	3	3	3	3	3.00	IST
EIGRP/OSPF	2	3	2	2	2,25	2ND
EIGRP/RIP	1	1	1	1	1.00	3RD

Table 8. Analysis of Hybrid Networks for Multiple Point RR

MP	CT	QD	ETE D	ETE D V	Wave	RANK
EIGRP/IGRP	3	3	1	2	2.25	2nd
EIGRP/OSPF	2	2	3	3	2,50	Ist
EIGRP/RIP	1	1	2	3	1.00	3RD

6 CONCLUSIONS

The route redistribution is still the most popular means of propagating routes between routing domains because its configuration is easy and flexible allowing the support of numerous policy based scenarios. Nevertheless erroneous configuration can create inconsistence convergence times and routing loops. /13/.

Since OPNET Modeler was the GUI, no configuration was done. It was used to study how merged networks performed after performing route redistribution between them; these problems were not observed.

Another significance aspect of this thesis is the knowledge gained from OPNET Modeler in designing network topologies , performing both single point and multiple point redistribution and the software use as an indispensable analytic tool for computer networks.

New and important hybrid mesh-ring designs were proposed for merging networks. It was also observed that the network topology in which a given routing protocol is configured can significantly affect the CT. Thus, the following deductions were arrived at:

- RP performance is affected by the type of hybrid network topology as seen in the 30% decrease in CT as EIGRP in mesh is replaced by IGRP for RR between three routing domains

- EIGRP/IGRP has the best performance in simple networks from a composite analysis of convergence time, ETE delay, ETE delay variation (jitter), and queuing delay.

- EIGRP/OSPF performs best in complex networks.

- The EIGRP/RIP performs poorest in both simple and complex networks.

- In a hybrid topology of mesh –ring with EIGRP configured in a mesh and one of each of OSPF, RIP and IGRP in a ring with RR at the border router (ABSR), the hybrid network of EIGRP/IGRP has the fastest CT.

6.1 Future Work

The performance of these integrated networks will be thoroughly studied as their topology changes. i.e. how will the network be affected (in terms of networks performance metrics) as their different topologies are interchanged.

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