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Simulation Based Performance Analyses on RIPv2, EIGRP, and OSPF Using OPNET

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Abstract

Extensive experiments has been conducted to analyze and compare a set of characteristics of different routing protocols, such as RIPv2, EIGRP, and OSPF by using sophisticated simulation software called OPNET. The characteristics that will be studied include convergence time, scalability, end-to-end delay, and throughput. Different network topologies, such as the star, ring, and mesh, are being tested in the experiments. The experimental results show that RIPv2 has better performance than others in small and condensed networks. OSPF and EIGRP have better performance for medium-sized and scattered networks. Overall EIGRP is more stable and consistent in both small and relatively large networks. The future work may include the performance analyses on EGP protocols.

1. Brief Introduction to Routing Protocols

A routing protocol is a set of process, algorithm, and messages that are used to learn about remote networks and to quickly adapt whenever there is a change in the network topology. Routing protocols can be classified into different groups according to their characteristics: Interior Gateway Protocol (IGP) or Exterior Gateway Protocol (EGP); Distance Vector or Link State; Classful or Classless. Some of the most commonly used routing protocols are as the follows:

- RIP: A classful distance vector IGP

- RIPv2: RIP version 2. A classless distance vector IGP
- EIGRP: The advanced distance vector IGP developed by Cisco
- OSPF: A link state IGP

There are several ways to differentiate routing protocols. An important characteristic of a routing protocol is how quickly it converges when there is a change in the topology. The network has converged when all routers have complete and accurate information about the network. Other characteristics include scalability, resources usage, end-to-end delay, and management overhead. The primary goal of this project is to analyze these characteristics under a variety of network settings by using professional simulation software called OPNET.

2. Introduction to OPNET

Optimized Network Engineering Tools (OPNET) Modeler is the industry's leading simulator specialized for network research and development. It allows users to design and study communication networks, devices, protocols, and applications with great flexibility. OPNET is a simulator built on top of a discrete event system (DES). It simulates the system behavior by modeling each event happening in the system and processes it by user- defined processes. It uses a hierarchical strategy to organize all the models to build a whole network. OPNET also provides programming tools for us to define any type of packet format we want to use in our own protocols. Programming in OPNET includes the following major tasks: define protocol packet format, define the state transition machine for processes running the protocol, define process modules and transceiver modules we need in each device node, finally define the network model by connecting the device nodes together using user-defined link models.

OPNET model is divided into three domains including,

- **Network domain:**

The Network Domain's role is to define the topology of a communication network. Physical connection, interconnection and configuration can be included in the network model. It represents over all system such as network, sub-network on the geographical map to be simulated.

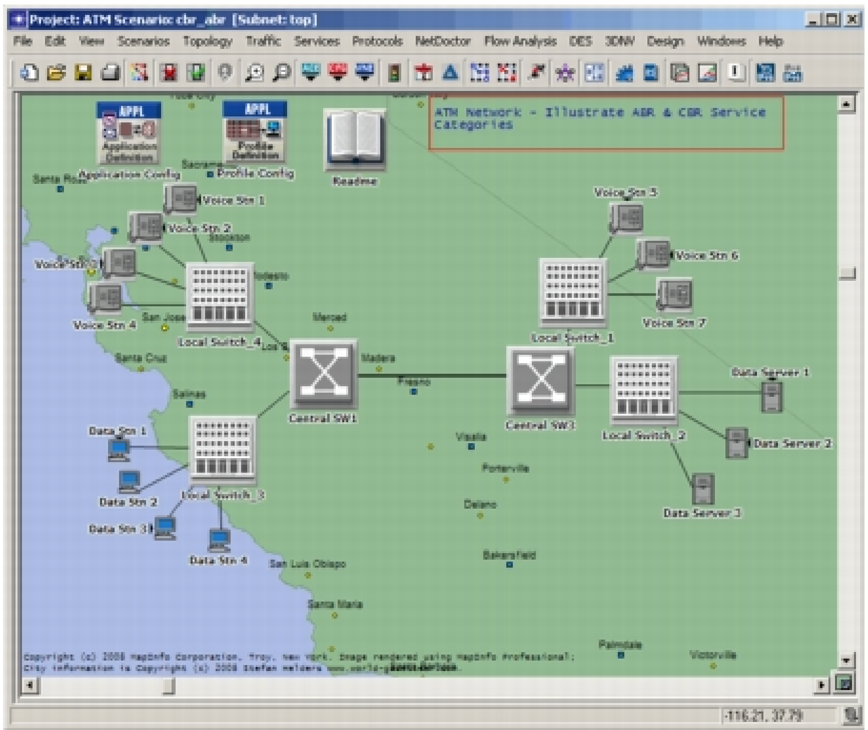


Figure 1   Network Domain

- **Node Domain:**

The Node Domain provides for the modeling of communication devices that can be deployed and interconnected at the network level. In OPNET Modeler terms, these devices are called *nodes*, and in the real world they may correspond to various types of computing and communicating equipment such as routers, bridges, workstations, terminals, mainframe computers, file servers, fast packet switches, satellites, and so on.

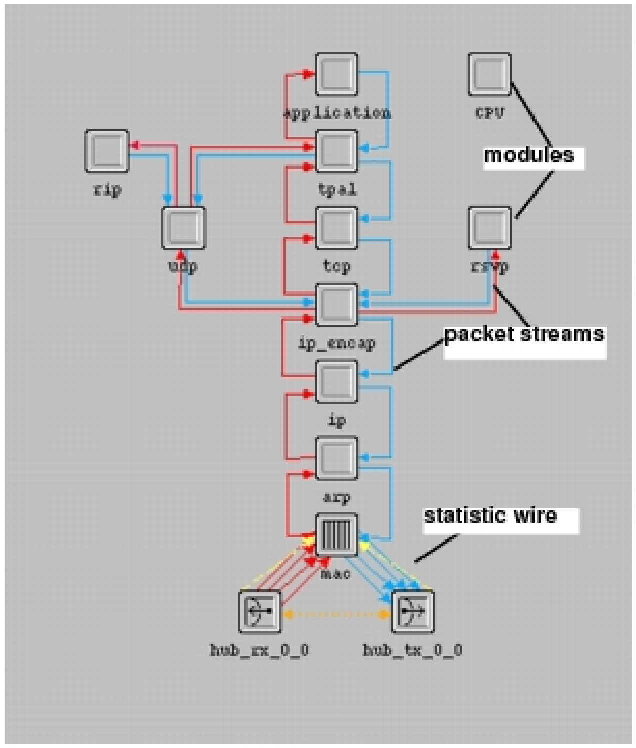


Figure 2 Node Domain

- **Process Domain:**

Process domain are used to specify the attribute of the processor and queue model by using source code C and C ++ which is inside the node models.

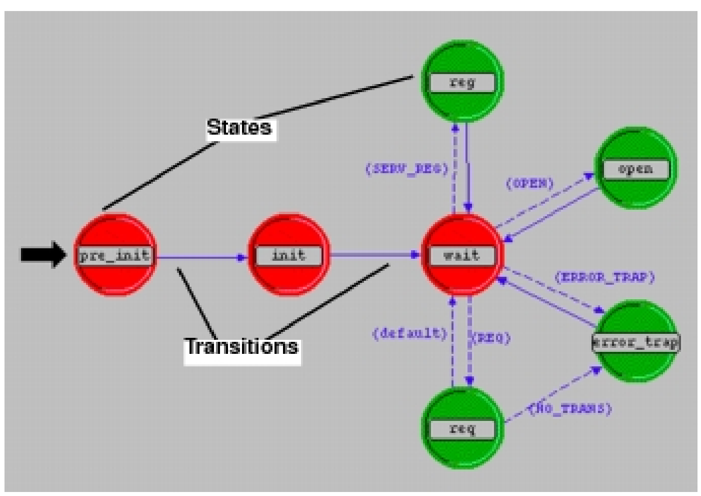


Figure 3 Process Domain

3. Design and Analysis in OPNET

When implementing a real model of the system in the OPNET, some steps are to be followed to design on simulator. Figure 4 shows the workflow for OPNET Modeler.

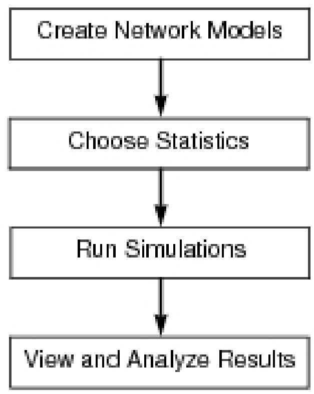


Figure 4   Design Steps.

4. Experiments

The protocols simulated in the research project are RIPv2, OSPF, and EIGRP routing protocol. The proposed routing protocols are compared and evaluated based on some quantitative metrics such as convergence duration, packet delay variation, end to end delay, and throughput.

4.1 Network Topologies

In this project, three network topologies are created including star, mesh, and ring. Under each network setting, routers are configured by using RIPv2, EIGRP and OSPF routing protocols.

- **Star:**

  In a star topology, each router has a dedicated point-to-point link only to a central controller. The term dedicated means that the link carries traffic only between the two routers it connects. A switch is used as the controller in our experiments. The routers are not directly linked to one another.   See Figure 5 below.

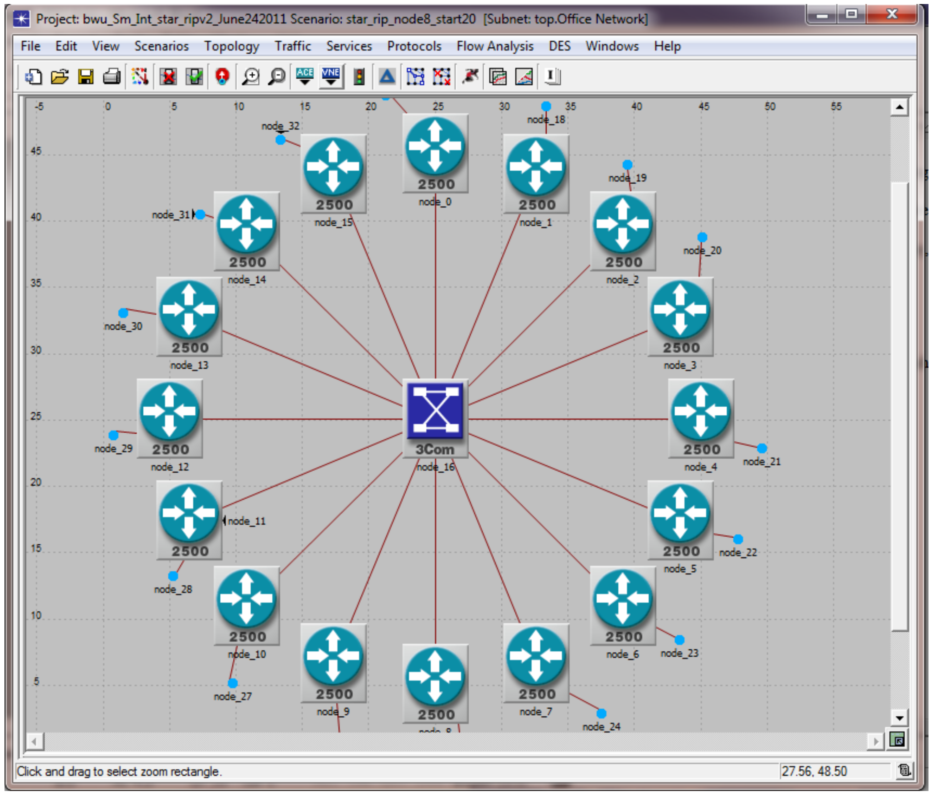


Figure 5 Star Topology

- **Mesh:**

In a full mesh topology, every router has a dedicated point-to-point link to every other router. We need *n (n-1)* links with *n* routers. This connection has build-in redundancy. If one link goes down, the router transmits via another link. A partial mesh topology has direct connectivity between some of the routers, but not all of them, as the full mesh topology does. The mesh topology in our experiment is a partial mesh. See figure 6 below,

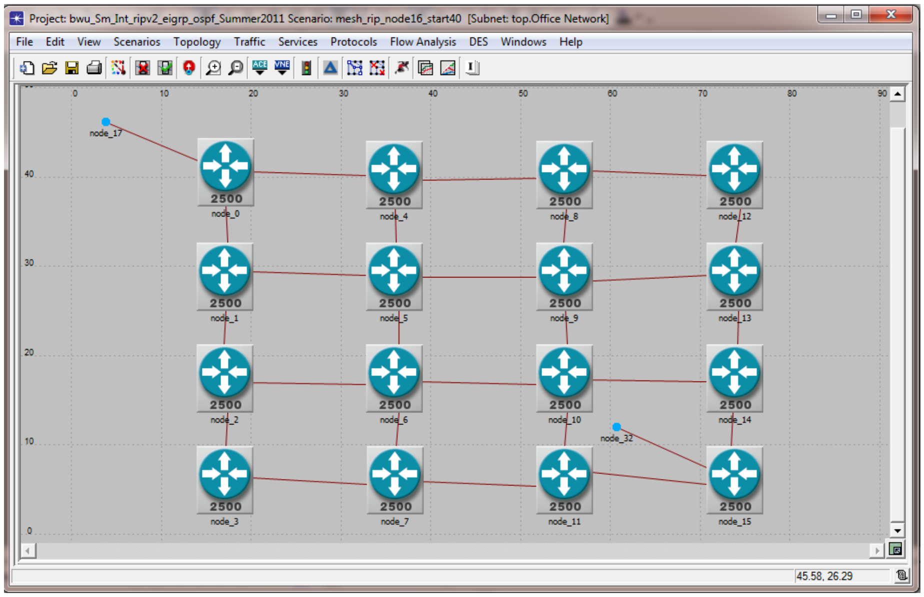


Figure 6 Partial Mesh Topology

- **Ring**

In a ring topology, each router has dedicated point-to-point connection with only the two routers on either side of it. See Figure 7 below.

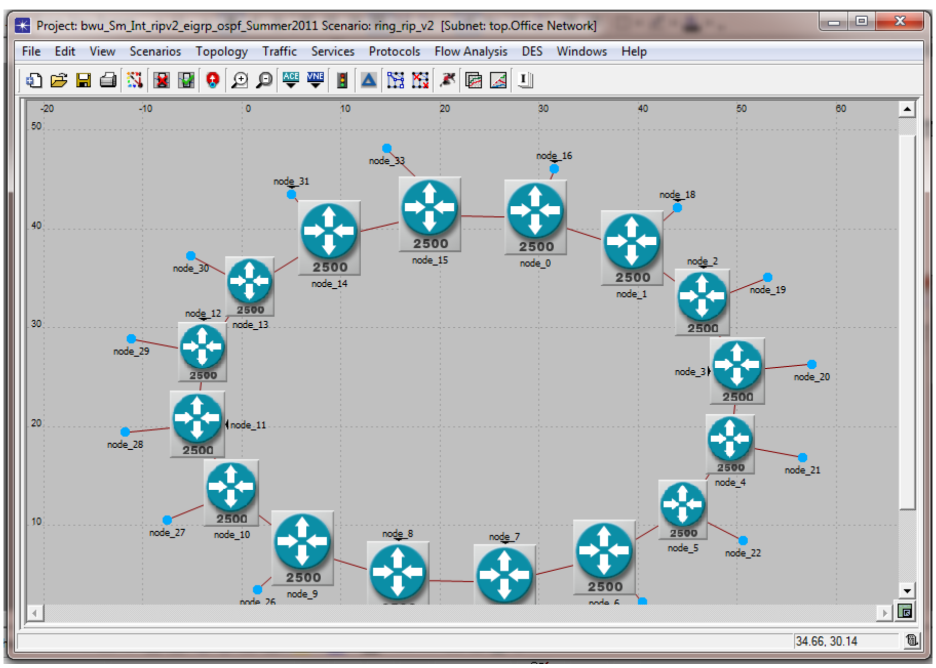


Figure 7 Ring Topology

4.2 Routing Protocols

Routers are configured with RIPv2, EIGRP and OSPF routing protocols under each network setting.

- **RIPv2**

To configure RIP v2, take these steps:

1) Click one of the routers. Use the Protocols > IP > Routing > Configure Routing Protocols menu operation, and choose RIP as the selected routing protocol.

2) Right click one of the routers again and choose Edit Attributes. Click the box **Apply changes to selected objects** in the lower right corner. See Figure 8.

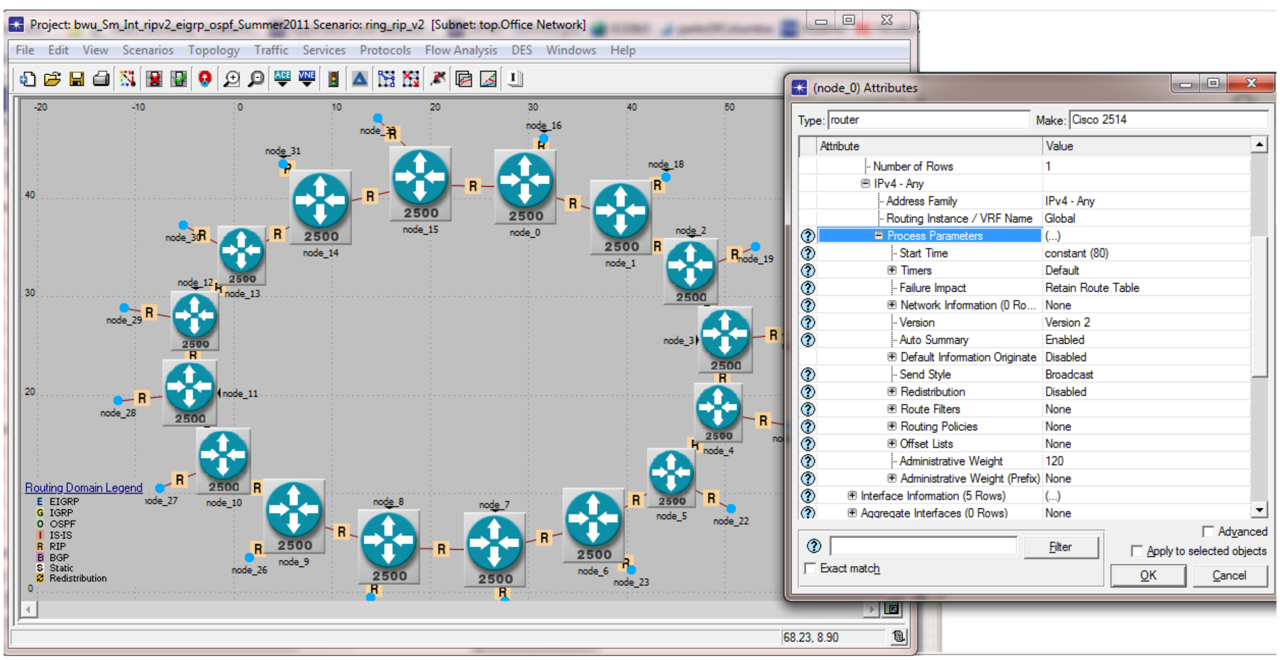


Figure 8 Configuring RIPv2

- **OSPF**

To configure OSPF, take these steps:

1) Click one of the routers. Use the Protocols > IP > Routing > Configure Routing Protocols menu operation, and choose OSPF as the selected routing protocol.

2) Right click one of the routers again and choose Edit Attributes. Click the box **Apply changes to selected objects** in the lower right corner. See Figure 9.

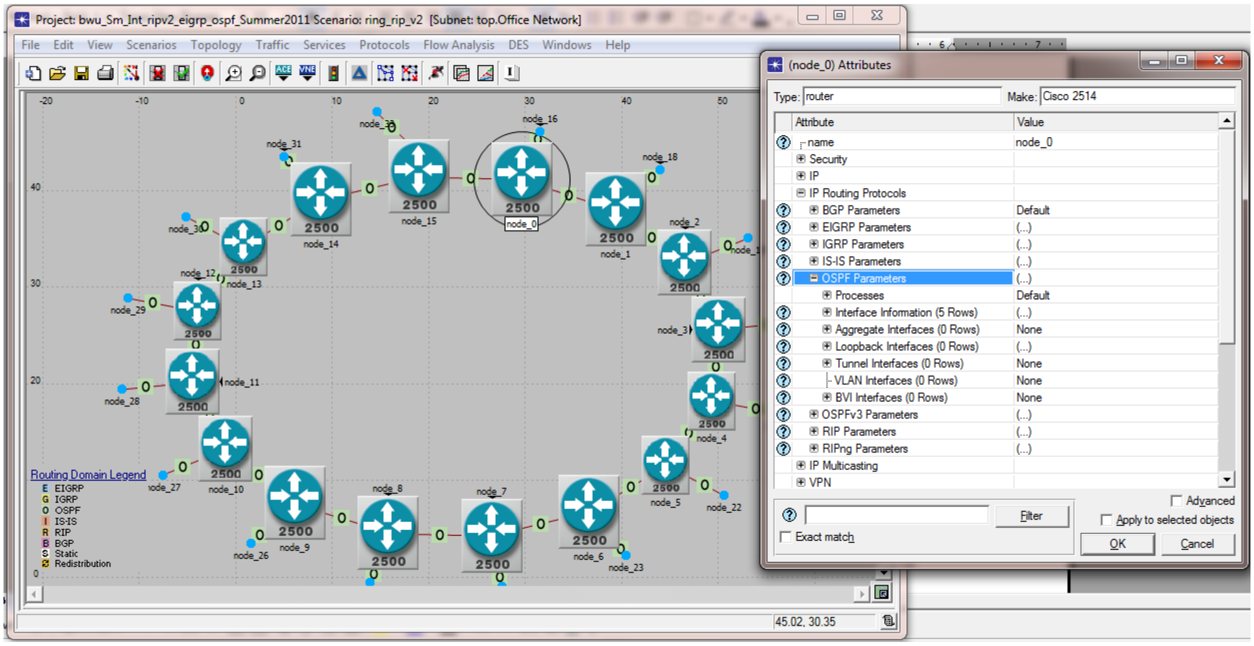


Figure 9 Configuring OSPF

- **EIGRP**

To configure EIGRP, take these steps:

1) Click one of the routers. Use the Protocols > IP > Routing > Configure Routing Protocols menu operation, and choose EIGRP as the selected routing protocol.

2) Right click one of the routers again and choose Edit Attributes. Click the box **Apply changes to selected objects** in the lower right corner. See Figure 10.

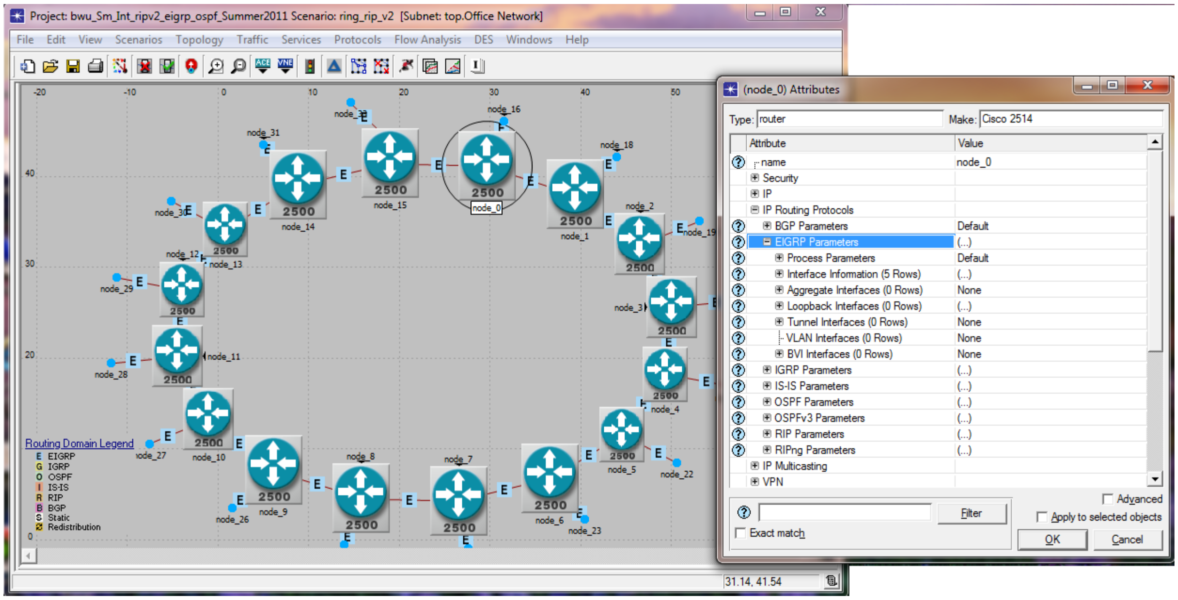


Figure 10 Configuring EIGRP

5 Simulation Results and Analysis

5.1 Star Topology

5.1.1 RIPv2

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	20.000000	20.001138	0.001138

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)
0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF2	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF3	0.000
2	192.0.2.0/24	RIP	120	1	192.0.0.2	Network.node_1	IF2	9.987
3	192.0.3.0/24	RIP	120	1	192.0.0.3	Network.node_2	IF2	7.532
4	192.0.4.0/24	RIP	120	1	192.0.0.4	Network.node_3	IF2	6.374
5	192.0.5.0/24	RIP	120	1	192.0.0.5	Network.node_4	IF2	8.300
6	192.0.6.0/24	RIP	120	1	192.0.0.6	Network.node_5	IF2	6.069
7	192.0.7.0/24	RIP	120	1	192.0.0.7	Network.node_6	IF2	6.356
8	192.0.8.0/24	RIP	120	1	192.0.0.8	Network.node_7	IF2	9.180
9	192.0.9.0/24	RIP	120	1	192.0.0.9	Network.node_8	IF2	20.001
10	192.0.10.0/24	RIP	120	1	192.0.0.10	Network.node_9	IF2	8.254
11	192.0.11.0/24	RIP	120	1	192.0.0.11	Network.node_10	IF2	8.615
12	192.0.12.0/24	RIP	120	1	192.0.0.12	Network.node_11	IF2	9.986
13	192.0.13.0/24	RIP	120	1	192.0.0.13	Network.node_12	IF2	5.100
14	192.0.14.0/24	RIP	120	1	192.0.0.14	Network.node_13	IF2	6.526
15	192.0.15.0/24	RIP	120	1	192.0.0.15	Network.node_14	IF2	5.444
16	192.0.16.0/24	RIP	120	1	192.0.0.16	Network.node_15	IF2	7.745

5.1.2 OSPF

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	80. 000000	105.000000	25.000000

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)

0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF2	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF3	0.000
2	192.0.2.0/24	OSPF 1	110	20	192.0.0.2	Network.node_1	IF2	64.067
3	192.0.3.0/24	OSPF 1	110	20	192.0.0.3	Network.node_2	IF2	64.067
4	192.0.4.0/24	OSPF 1	110	20	192.0.0.4	Network.node_3	IF2	64.067
5	192.0.5.0/24	OSPF 1	110	20	192.0.0.5	Network.node_4	IF2	64.067
6	192.0.6.0/24	OSPF 1	110	20	192.0.0.6	Network.node_5	IF2	64.067
7	192.0.7.0/24	OSPF 1	110	20	192.0.0.7	Network.node_6	IF2	64.067
8	192.0.8.0/24	OSPF 1	110	20	192.0.0.8	Network.node_7	IF2	64.067
9	192.0.9.0/24	OSPF 1	110	20	192.0.0.9	Network.node_8	IF2	95.033
10	192.0.10.0/24	OSPF 1	110	20	192.0.0.10	Network.node_9	IF2	64.067
11	192.0.11.0/24	OSPF 1	110	20	192.0.0.11	Network.node_10	IF2	64.067
12	192.0.12.0/24	OSPF 1	110	20	192.0.0.12	Network.node_11	IF2	64.067
13	192.0.13.0/24	OSPF 1	110	20	192.0.0.13	Network.node_12	IF2	64.067
14	192.0.14.0/24	OSPF 1	110	20	192.0.0.14	Network.node_13	IF2	64.067
15	192.0.15.0/24	OSPF 1	110	20	192.0.0.15	Network.node_14	IF2	64.067
16	192.0.16.0/24	OSPF 1	110	20	192.0.0.16	Network.node_15	IF2	64.067

5.1.3 EIGRP

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	20.000000	20.016003	0.016003

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)
0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF2	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF3	0.000
2	192.0.2.0/24	EIGRP 1	90	307200	192.0.0.2	Network.node_1	IF2	9.858
3	192.0.3.0/24	EIGRP 1	90	307200	192.0.0.3	Network.node_2	IF2	7.485
4	192.0.4.0/24	EIGRP 1	90	307200	192.0.0.4	Network.node_3	IF2	6.748
5	192.0.5.0/24	EIGRP 1	90	307200	192.0.0.5	Network.node_4	IF2	6.468
6	192.0.6.0/24	EIGRP 1	90	307200	192.0.0.6	Network.node_5	IF2	6.004
7	192.0.7.0/24	EIGRP 1	90	307200	192.0.0.7	Network.node_6	IF2	7.199
8	192.0.8.0/24	EIGRP 1	90	307200	192.0.0.8	Network.node_7	IF2	9.726
9	192.0.9.0/24	EIGRP 1	90	307200	192.0.0.9	Network.node_8	IF2	20.015
10	192.0.10.0/24	EIGRP 1	90	307200	192.0.0.10	Network.node_9	IF2	6.979
11	192.0.11.0/24	EIGRP 1	90	307200	192.0.0.11	Network.node_10	IF2	7.997
12	192.0.12.0/24	EIGRP 1	90	307200	192.0.0.12	Network.node_11	IF2	6.929
13	192.0.13.0/24	EIGRP 1	90	307200	192.0.0.13	Network.node_12	IF2	8.591

14	192.0.14.0/24	EIGRP 1	90	307200	192.0.0.14	Network.node_13	IF2	9.160
15	192.0.15.0/24	EIGRP 1	90	307200	192.0.0.15	Network.node_14	IF2	9.412
16	192.0.16.0/24	EIGRP 1	90	307200	192.0.0.16	Network.node_15	IF2	6.003

5.2 Mesh Topology

5.2.1 RIPv2

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	40.000000	50.271659	10.271659

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)
0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF3	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF2	0.000
2	192.0.2.0/24	Direct	0	0	192.0.2.1	Network.node_0	new_IF2	0.000
3	192.0.3.0/24	RIP	120	1	192.0.2.2	Network.node_1	new_IF2	9.589
4	192.0.4.0/24	RIP	120	1	192.0.2.2	Network.node_1	new_IF2	9.589
5	192.0.5.0/24	RIP	120	2	192.0.2.2	Network.node_1	new_IF2	9.589
6	192.0.6.0/24	RIP	120	2	192.0.2.2	Network.node_1	new_IF2	9.589
7	192.0.7.0/24	RIP	120	3	192.0.2.2	Network.node_1	new_IF2	19.851
8	192.0.8.0/24	RIP	120	1	192.0.1.2	Network.node_4	IF2	8.736
9	192.0.9.0/24	RIP	120	1	192.0.1.2	Network.node_4	IF2	8.736
10	192.0.10.0/24	RIP	120	2	192.0.1.2	Network.node_4	IF2	8.736
11	192.0.11.0/24	RIP	120	2	192.0.1.2	Network.node_4	IF2	8.736
12	192.0.12.0/24	RIP	120	3	192.0.2.2	Network.node_1	new_IF2	13.277
13	192.0.13.0/24	RIP	120	3	192.0.2.2	Network.node_1	new_IF2	13.277
14	192.0.14.0/24	RIP	120	4	192.0.2.2	Network.node_1	new_IF2	19.851
15	192.0.15.0/24	RIP	120	2	192.0.1.2	Network.node_4	IF2	13.724
16	192.0.16.0/24	RIP	120	2	192.0.1.2	Network.node_4	IF2	13.724
17	192.0.17.0/24	RIP	120	3	192.0.2.2	Network.node_1	new_IF2	13.277
18	192.0.18.0/24	RIP	120	3	192.0.2.2	Network.node_1	new_IF2	13.277
19	192.0.19.0/24	RIP	120	4	192.0.2.2	Network.node_1	new_IF2	13.277
20	192.0.20.0/24	RIP	120	4	192.0.2.2	Network.node_1	new_IF2	13.277
21	192.0.21.0/24	RIP	120	5	192.0.2.2	Network.node_1	new_IF2	19.851
22	192.0.22.0/24	RIP	120	3	192.0.1.2	Network.node_4	IF2	13.724
23	192.0.23.0/24	RIP	120	4	192.0.2.2	Network.node_1	new_IF2	13.277
24	192.0.24.0/24	RIP	120	5	192.0.2.2	Network.node_1	new_IF2	13.277
25	192.0.25.0/24	RIP	120	6	192.0.2.2	Network.node_1	new_IF2	50.042

5.2.2 OSPF

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	120.000000	135.000000	15.000000

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)
0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF3	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF2	0.000
2	192.0.2.0/24	Direct	0	0	192.0.2.1	Network.node_0	new_IF2	0.000
3	192.0.3.0/24	OSPF 1	110	20	192.0.2.2	Network.node_1	new_IF2	61.896
4	192.0.4.0/24	OSPF 1	110	20	192.0.2.2	Network.node_1	new_IF2	61.896
5	192.0.5.0/24	OSPF 1	110	30	192.0.2.2	Network.node_1	new_IF2	61.896
6	192.0.6.0/24	OSPF 1	110	30	192.0.2.2	Network.node_1	new_IF2	61.896
7	192.0.7.0/24	OSPF 1	110	40	192.0.2.2	Network.node_1	new_IF2	61.896
8	192.0.8.0/24	OSPF 1	110	20	192.0.1.2	Network.node_4	IF2	61.896
9	192.0.9.0/24	OSPF 1	110	20	192.0.1.2	Network.node_4	IF2	61.896
10	192.0.10.0/24	OSPF 1	110	30	192.0.2.2	Network.node_1	new_IF2	61.896
11		OSPF 1	110	30	192.0.1.2	Network.node_4	IF2	61.896
12	192.0.11.0/24	OSPF 1	110	30	192.0.2.2	Network.node_1	new_IF2	61.896
13		OSPF 1	110	30	192.0.1.2	Network.node_4	IF2	61.896
14	192.0.12.0/24	OSPF 1	110	40	192.0.2.2	Network.node_1	new_IF2	61.896
15		OSPF 1	110	40	192.0.1.2	Network.node_4	IF2	61.896
16	192.0.13.0/24	OSPF 1	110	40	192.0.2.2	Network.node_1	new_IF2	61.896
17		OSPF 1	110	40	192.0.1.2	Network.node_4	IF2	61.896
18	192.0.14.0/24	OSPF 1	110	50	192.0.2.2	Network.node_1	new_IF2	61.896
19		OSPF 1	110	50	192.0.1.2	Network.node_4	IF2	61.896
20	192.0.15.0/24	OSPF 1	110	30	192.0.1.2	Network.node_4	IF2	61.896
21	192.0.16.0/24	OSPF 1	110	30	192.0.1.2	Network.node_4	IF2	61.896
22	192.0.17.0/24	OSPF 1	110	40	192.0.2.2	Network.node_1	new_IF2	61.896
23		OSPF 1	110	40	192.0.1.2	Network.node_4	IF2	61.896
24	192.0.18.0/24	OSPF 1	110	40	192.0.2.2	Network.node_1	new_IF2	61.896
25		OSPF 1	110	40	192.0.1.2	Network.node_4	IF2	61.896
26	192.0.19.0/24	OSPF 1	110	50	192.0.2.2	Network.node_1	new_IF2	61.896
27		OSPF 1	110	50	192.0.1.2	Network.node_4	IF2	61.896
28	192.0.20.0/24	OSPF 1	110	50	192.0.2.2	Network.node_1	new_IF2	61.896
29		OSPF 1	110	50	192.0.1.2	Network.node_4	IF2	61.896
30	192.0.21.0/24	OSPF 1	110	60	192.0.2.2	Network.node_1	new_IF2	61.896
31		OSPF 1	110	60	192.0.1.2	Network.node_4	IF2	61.896
32	192.0.22.0/24	OSPF 1	110	40	192.0.1.2	Network.node_4	IF2	61.896
33	192.0.23.0/24	OSPF 1	110	50	192.0.2.2	Network.node_1	new_IF2	61.896

34		OSPF 1	110	50	192.0.1.2	Network.node_4	IF2	61.896
35	192.0.24.0/24	OSPF 1	110	60	192.0.2.2	Network.node_1	new_IF2	61.896
36		OSPF 1	110	60	192.0.1.2	Network.node_4	IF2	61.896
37	192.0.25.0/24	OSPF 1	110	70	192.0.2.2	Network.node_1	new_IF2	130.001
38		OSPF 1	110	70	192.0.1.2	Network.node_4	IF2	130.001

5.2.3 EIGRP

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	40.000000	40.001397	0.001397

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)
0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF3	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF2	0.000
2	192.0.2.0/24	Direct	0	0	192.0.2.1	Network.node_0	new_IF2	0.000
3	192.0.3.0/24	EIGRP 1	90	307200	192.0.2.2	Network.node_1	new_IF2	9.844
4	192.0.4.0/24	EIGRP 1	90	307200	192.0.2.2	Network.node_1	new_IF2	9.844
5	192.0.5.0/24	EIGRP 1	90	332800	192.0.2.2	Network.node_1	new_IF2	9.845
6	192.0.6.0/24	EIGRP 1	90	332800	192.0.2.2	Network.node_1	new_IF2	9.845
7	192.0.7.0/24	EIGRP 1	90	358400	192.0.2.2	Network.node_1	new_IF2	9.845
8	192.0.8.0/24	EIGRP 1	90	307200	192.0.1.2	Network.node_4	IF2	6.464
9	192.0.9.0/24	EIGRP 1	90	307200	192.0.1.2	Network.node_4	IF2	6.464
10	192.0.10.0/24	EIGRP 1	90	332800	192.0.1.2	Network.node_4	IF2	6.464
11		EIGRP 1	90	332800	192.0.2.2	Network.node_1	new_IF2	9.845
12	192.0.11.0/24	EIGRP 1	90	332800	192.0.1.2	Network.node_4	IF2	6.464
13		EIGRP 1	90	332800	192.0.2.2	Network.node_1	new_IF2	9.845
14	192.0.12.0/24	EIGRP 1	90	358400	192.0.1.2	Network.node_4	IF2	7.192
15		EIGRP 1	90	358400	192.0.2.2	Network.node_1	new_IF2	9.845
16	192.0.13.0/24	EIGRP 1	90	358400	192.0.1.2	Network.node_4	IF2	7.192
17		EIGRP 1	90	358400	192.0.2.2	Network.node_1	new_IF2	9.845
18	192.0.14.0/24	EIGRP 1	90	384000	192.0.1.2	Network.node_4	IF2	9.713
19		EIGRP 1	90	384000	192.0.2.2	Network.node_1	new_IF2	9.845
20	192.0.15.0/24	EIGRP 1	90	332800	192.0.1.2	Network.node_4	IF2	7.176
21	192.0.16.0/24	EIGRP 1	90	332800	192.0.1.2	Network.node_4	IF2	7.176
22	192.0.17.0/24	EIGRP 1	90	358400	192.0.1.2	Network.node_4	IF2	6.972
23		EIGRP 1	90	358400	192.0.2.2	Network.node_1	new_IF2	9.845
24	192.0.18.0/24	EIGRP 1	90	358400	192.0.1.2	Network.node_4	IF2	6.972
25		EIGRP 1	90	358400	192.0.2.2	Network.node_1	new_IF2	9.845
26	192.0.19.0/24	EIGRP 1	90	384000	192.0.1.2	Network.node_4	IF2	7.988

27		EIGRP 1	90	384000	192.0.2.2	Network.node_1	new_IF2	9.845
28	192.0.20.0/24	EIGRP 1	90	384000	192.0.1.2	Network.node_4	IF2	7.988
29		EIGRP 1	90	384000	192.0.2.2	Network.node_1	new_IF2	9.845
30	192.0.21.0/24	EIGRP 1	90	409600	192.0.1.2	Network.node_4	IF2	7.988
31		EIGRP 1	90	409600	192.0.2.2	Network.node_1	new_IF2	9.845
32	192.0.22.0/24	EIGRP 1	90	358400	192.0.1.2	Network.node_4	IF2	8.580
33	192.0.23.0/24	EIGRP 1	90	384000	192.0.1.2	Network.node_4	IF2	9.149
34		EIGRP 1	90	384000	192.0.2.2	Network.node_1	new_IF2	9.845
35	192.0.24.0/24	EIGRP 1	90	409600	192.0.1.2	Network.node_4	IF2	9.400
36		EIGRP 1	90	409600	192.0.2.2	Network.node_1	new_IF2	9.845
37	192.0.25.0/24	EIGRP 1	90	435200	192.0.2.2	Network.node_1	new_IF2	40.001
38		EIGRP 1	90	435200	192.0.1.2	Network.node_4	IF2	40.001

5.3 Ring Topology

5.3.1 RIPv2

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	80.000000	97.968936	17.968936

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)
0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF2	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF3	0.000
2	192.0.2.0/24	Direct	0	0	192.0.2.1	Network.node_0	new_IF2	0.000
3	192.0.3.0/24	RIP	120	1	192.0.0.2	Network.node_1	IF2	9.986
4	192.0.4.0/24	RIP	120	1	192.0.0.2	Network.node_1	IF2	9.986
5	192.0.5.0/24	RIP	120	2	192.0.0.2	Network.node_1	IF2	9.986
6	192.0.6.0/24	RIP	120	2	192.0.0.2	Network.node_1	IF2	9.986
7	192.0.7.0/24	RIP	120	3	192.0.0.2	Network.node_1	IF2	9.986
8	192.0.8.0/24	RIP	120	3	192.0.0.2	Network.node_1	IF2	9.986
9	192.0.9.0/24	RIP	120	4	192.0.0.2	Network.node_1	IF2	12.727
10	192.0.10.0/24	RIP	120	4	192.0.0.2	Network.node_1	IF2	12.727
11	192.0.11.0/24	RIP	120	5	192.0.0.2	Network.node_1	IF2	12.727
12	192.0.12.0/24	RIP	120	5	192.0.0.2	Network.node_1	IF2	12.727
13	192.0.13.0/24	RIP	120	6	192.0.0.2	Network.node_1	IF2	17.156
14	192.0.14.0/24	RIP	120	6	192.0.0.2	Network.node_1	IF2	17.156
15	192.0.15.0/24	RIP	120	7	192.0.0.2	Network.node_1	IF2	25.896
16	192.0.16.0/24	RIP	120	7	192.0.0.2	Network.node_1	IF2	25.896
17	192.0.17.0/24	RIP	120	7	192.0.1.2	Network.node_15	IF3	19.697

18	192.0.18.0/24	RIP	120	8	192.0.0.2	Network.node_1	IF2	25.896
19	192.0.19.0/24	RIP	120	6	192.0.1.2	Network.node_15	IF3	19.697
20	192.0.20.0/24	RIP	120	7	192.0.1.2	Network.node_15	IF3	19.697
21	192.0.21.0/24	RIP	120	5	192.0.1.2	Network.node_15	IF3	19.697
22	192.0.22.0/24	RIP	120	6	192.0.1.2	Network.node_15	IF3	19.697
23	192.0.23.0/24	RIP	120	4	192.0.1.2	Network.node_15	IF3	13.472
24	192.0.24.0/24	RIP	120	5	192.0.1.2	Network.node_15	IF3	19.697
25	192.0.25.0/24	RIP	120	3	192.0.1.2	Network.node_15	IF3	13.472
26	192.0.26.0/24	RIP	120	4	192.0.1.2	Network.node_15	IF3	13.472
27	192.0.27.0/24	RIP	120	2	192.0.1.2	Network.node_15	IF3	7.745
28	192.0.28.0/24	RIP	120	3	192.0.1.2	Network.node_15	IF3	13.472
29	192.0.29.0/24	RIP	120	1	192.0.1.2	Network.node_15	IF3	7.745
30	192.0.30.0/24	RIP	120	2	192.0.1.2	Network.node_15	IF3	7.745
31	192.0.31.0/24	RIP	120	1	192.0.1.2	Network.node_15	IF3	9.845

5.3.2 OSPF

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	80.000000	95.000000	15.000000

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)
0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF2	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF3	0.000
2	192.0.2.0/24	Direct	0	0	192.0.2.1	Network.node_0	new_IF2	0.000
3	192.0.3.0/24	OSPF 1	110	20	192.0.0.2	Network.node_1	IF2	95.000
4	192.0.4.0/24	OSPF 1	110	20	192.0.0.2	Network.node_1	IF2	95.000
5	192.0.5.0/24	OSPF 1	110	30	192.0.0.2	Network.node_1	IF2	95.000
6	192.0.6.0/24	OSPF 1	110	30	192.0.0.2	Network.node_1	IF2	95.000
7	192.0.7.0/24	OSPF 1	110	40	192.0.0.2	Network.node_1	IF2	95.000
8	192.0.8.0/24	OSPF 1	110	40	192.0.0.2	Network.node_1	IF2	95.000
9	192.0.9.0/24	OSPF 1	110	50	192.0.0.2	Network.node_1	IF2	95.000
10	192.0.10.0/24	OSPF 1	110	50	192.0.0.2	Network.node_1	IF2	95.000
11	192.0.11.0/24	OSPF 1	110	60	192.0.0.2	Network.node_1	IF2	95.000
12	192.0.12.0/24	OSPF 1	110	60	192.0.0.2	Network.node_1	IF2	95.000
13	192.0.13.0/24	OSPF 1	110	70	192.0.0.2	Network.node_1	IF2	95.000
14	192.0.14.0/24	OSPF 1	110	70	192.0.0.2	Network.node_1	IF2	95.000
15	192.0.15.0/24	OSPF 1	110	80	192.0.0.2	Network.node_1	IF2	95.000
16	192.0.16.0/24	OSPF 1	110	80	192.0.0.2	Network.node_1	IF2	95.000
17	192.0.17.0/24	OSPF 1	110	80	192.0.1.2	Network.node_15	IF3	95.000

18	192.0.18.0/24	OSPF 1	110	90	192.0.1.2	Network.node_15	IF3	95.000
19		OSPF 1	110	90	192.0.0.2	Network.node_1	IF2	95.000
20	192.0.19.0/24	OSPF 1	110	70	192.0.1.2	Network.node_15	IF3	95.000
21	192.0.20.0/24	OSPF 1	110	80	192.0.1.2	Network.node_15	IF3	95.000
22	192.0.21.0/24	OSPF 1	110	60	192.0.1.2	Network.node_15	IF3	95.000
23	192.0.22.0/24	OSPF 1	110	70	192.0.1.2	Network.node_15	IF3	95.000
24	192.0.23.0/24	OSPF 1	110	50	192.0.1.2	Network.node_15	IF3	95.000
25	192.0.24.0/24	OSPF 1	110	60	192.0.1.2	Network.node_15	IF3	95.000
26	192.0.25.0/24	OSPF 1	110	40	192.0.1.2	Network.node_15	IF3	95.000
27	192.0.26.0/24	OSPF 1	110	50	192.0.1.2	Network.node_15	IF3	95.000
28	192.0.27.0/24	OSPF 1	110	30	192.0.1.2	Network.node_15	IF3	95.000
29	192.0.28.0/24	OSPF 1	110	40	192.0.1.2	Network.node_15	IF3	95.000
30	192.0.29.0/24	OSPF 1	110	20	192.0.1.2	Network.node_15	IF3	95.000
31	192.0.30.0/24	OSPF 1	110	30	192.0.1.2	Network.node_15	IF3	95.000
32	192.0.31.0/24	OSPF 1	110	20	192.0.1.2	Network.node_15	IF3	95.000

5.3.3 EIGRP

Routing Convergence Table

Line#	Start Time	End Time	Duration
0	80.000000	80.003026	0.003026

Sample Node IP Forwarding Table

Line#	Destination	Source Protocol	Route Preference	Metric	Next Hop Address	Next Hop Node	Outgoing Interface	Insertion Time (secs)
0	192.0.0.0/24	Direct	0	0	192.0.0.1	Network.node_0	IF2	0.000
1	192.0.1.0/24	Direct	0	0	192.0.1.1	Network.node_0	IF3	0.000
2	192.0.2.0/24	Direct	0	0	192.0.2.1	Network.node_0	new_IF2	0.000
3	192.0.3.0/24	EIGRP 1	90	307200	192.0.0.2	Network.node_1	IF2	80.001
4	192.0.4.0/24	EIGRP 1	90	307200	192.0.0.2	Network.node_1	IF2	80.001
5	192.0.5.0/24	EIGRP 1	90	332800	192.0.0.2	Network.node_1	IF2	80.001
6	192.0.6.0/24	EIGRP 1	90	332800	192.0.0.2	Network.node_1	IF2	80.001
7	192.0.7.0/24	EIGRP 1	90	358400	192.0.0.2	Network.node_1	IF2	80.001
8	192.0.8.0/24	EIGRP 1	90	358400	192.0.0.2	Network.node_1	IF2	80.001
9	192.0.9.0/24	EIGRP 1	90	384000	192.0.0.2	Network.node_1	IF2	80.001
10	192.0.10.0/24	EIGRP 1	90	384000	192.0.0.2	Network.node_1	IF2	80.001
11	192.0.11.0/24	EIGRP 1	90	409600	192.0.0.2	Network.node_1	IF2	80.001
12	192.0.12.0/24	EIGRP 1	90	409600	192.0.0.2	Network.node_1	IF2	80.001
13	192.0.13.0/24	EIGRP 1	90	435200	192.0.0.2	Network.node_1	IF2	80.001
14	192.0.14.0/24	EIGRP 1	90	435200	192.0.0.2	Network.node_1	IF2	80.001
15	192.0.15.0/24	EIGRP 1	90	460800	192.0.0.2	Network.node_1	IF2	80.001

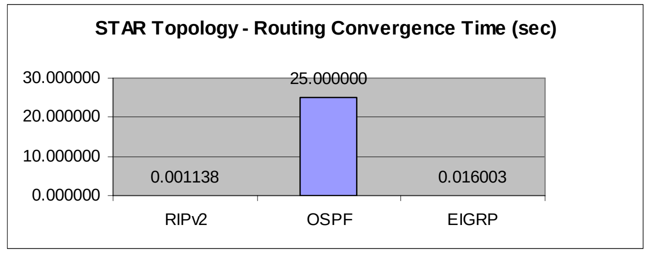
16	192.0.16.0/24	EIGRP 1	90	460800	192.0.0.2	Network.node_1	IF2	80.001
17	192.0.17.0/24	EIGRP 1	90	460800	192.0.1.2	Network.node_15	IF3	80.001
18	192.0.18.0/24	EIGRP 1	90	486400	192.0.0.2	Network.node_1	IF2	80.001
19		EIGRP 1	90	486400	192.0.1.2	Network.node_15	IF3	80.001
20	192.0.19.0/24	EIGRP 1	90	435200	192.0.1.2	Network.node_15	IF3	80.001
21	192.0.20.0/24	EIGRP 1	90	460800	192.0.1.2	Network.node_15	IF3	80.001
22	192.0.21.0/24	EIGRP 1	90	409600	192.0.1.2	Network.node_15	IF3	80.001
23	192.0.22.0/24	EIGRP 1	90	435200	192.0.1.2	Network.node_15	IF3	80.001
24	192.0.23.0/24	EIGRP 1	90	384000	192.0.1.2	Network.node_15	IF3	80.001
25	192.0.24.0/24	EIGRP 1	90	409600	192.0.1.2	Network.node_15	IF3	80.001
26	192.0.25.0/24	EIGRP 1	90	358400	192.0.1.2	Network.node_15	IF3	80.001
27	192.0.26.0/24	EIGRP 1	90	384000	192.0.1.2	Network.node_15	IF3	80.001
28	192.0.27.0/24	EIGRP 1	90	332800	192.0.1.2	Network.node_15	IF3	80.001
29	192.0.28.0/24	EIGRP 1	90	358400	192.0.1.2	Network.node_15	IF3	80.001
30	192.0.29.0/24	EIGRP 1	90	307200	192.0.1.2	Network.node_15	IF3	80.001
31	192.0.30.0/24	EIGRP 1	90	332800	192.0.1.2	Network.node_15	IF3	80.001
32	192.0.31.0/24	EIGRP 1	90	307200	192.0.1.2	Network.node_15	IF3	80.001

5. 4 Result Analyses

First we want to compare the convergence time of different routing protocols based on the same networking topology. The table and bar graph in 5.4.1 show the convergence time of three routing protocols for the star topology. The table and bar graph in 5.4.2 show the convergence time of three routing protocols for the mesh topology. The table and bar graph in 5.4.3 show the convergence time of three routing protocols for the ring topology. Then we want to look at convergence time difference for the same routing protocol under different networking topology. The table and bar graph in 5.4.4 show the convergence time under three topologies for RIPv2 routing protocol. The table and bar graph in 5.4.5 show the convergence time under three topologies for OSPF routing protocol. The table and bar graph in 5.4.6 show the convergence time under three topologies for EIGRP routing protocol.

5.4.1 Star Topology

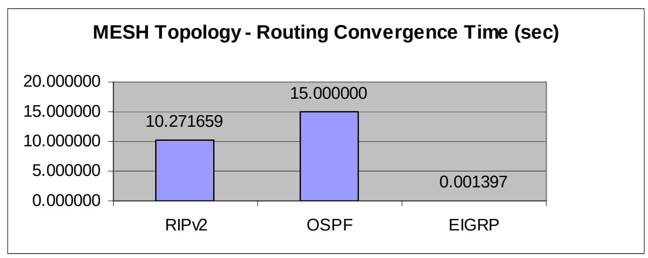
Routing Protocol	Convergence Time (sec)
RIPv2	0.001138
OSPF	25.000000
EIGRP	0.016003



From the above table and chart we can see that for the star topology, OSPF takes longer than the other two protocols. The reason is that for the start topology all nodes are attached to central switch. All nodes are adjacent to each other and the network diameter is 1. For the multi-access links, OSPF routing protocol requires to elect DR, BDR, and DRother among nodes. The election process takes time with a lot of neighbors. EIGRP is also more complicate than RIPv2 although both of them are distance vector routing protocol. For the simple network topology, RIPv2 wins over OSPF and EIGRP.

5.4.2 Mesh Topology

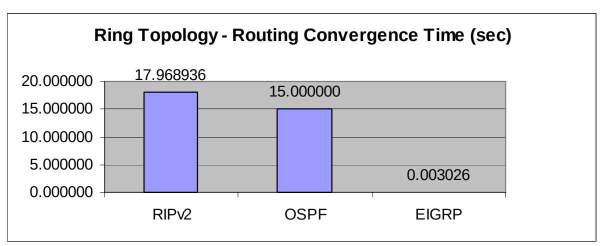
Routing Protocol	Convergence Time (sec)
RIPv2	10.271659
OSPF	15.000000
EIGRP	0.001397



From the above table and chart we can see that for the mesh topology, the convergence time of OSPF is improved. However, the performance of RIPv2 is downgraded. EIGRP remains almost the same. The reason is that for the mesh topology not all nodes are adjacent to each other and the network diameter is about 7. For a relative complex network topology with many links, EIGRP wins over OSPF and RIPv2.

5.4.3 Ring Topology

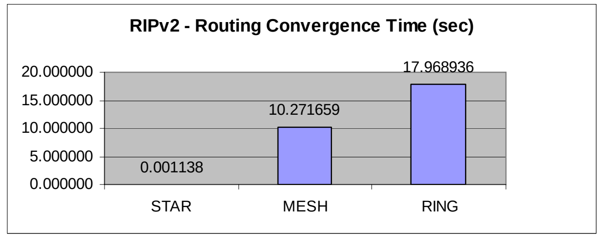
Routing Protocol	Convergence Time (sec)
RIPv2	17.968936
OSPF	15.000000
EIGRP	0.003026



From the above table and chart we can see that for the ring topology, the convergence time of OSPF is continuously improved. However, the performance of RIPv2 is downgraded significantly. The convergence time of EIGRP is increased though it remains the best among three. The reason is that for the ring topology all nodes have only two neighbors with limited number of links and the network diameter is about 15. For a relative complex network topology with large diameter and limited number of links, EIGRP again wins over OSPF and RIPv2. But OSPF's performance is improved and RIPv2's performance becomes the worst.

5.4.4 RIPv2

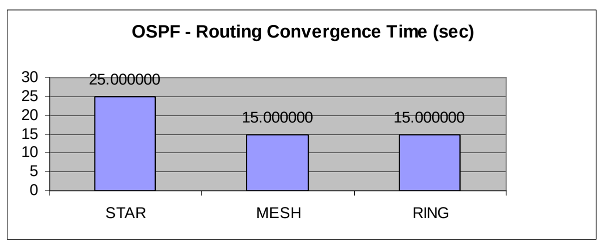
Topology	Convergence Time (sec)
STAR	0.001138
MESH	10.271659
RING	17.968936



The above table and chart show that for RIPv2 routing protocol with the increased complexity of network settings, such as larger node degrees and network diameters, the convergence time increases significantly. For a simple one-hop network, the network is converged almost immediately with convergence time 0.001138 second. For a 15-hop diameter network, the convergence time is 17.968936 seconds.

5.4.5 OSPF

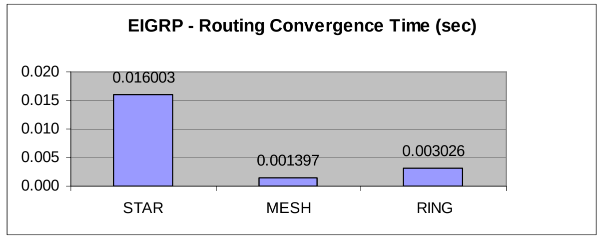
Topology	Convergence Time (sec)
STAR	25.000000
MESH	15.000000
RING	15.000000



The above table and chart shows that for OSPF routing protocol network degree is an import factor that affects the convergence time dramatically. For multi-access networks, OSPF requires the election of DR, BDR, and DRother nodes, which takes time for a dense network. The network diameter does not affect OSPF's performance as significantly as node degree for multi-access networks, and that is why the convergence time is the same for both mesh and ring topology.

5.4.6 EIGRP

Topology	Convergence Time (sec)
STAR	0.016003
MESH	0.001397
RING	0.003026



The table and chart above show that for EIGRP routing protocol it is pretty stable and consistent with the increased number of node degrees and network diameter. For all three different network topologies, the network converges shortly when EIGRP is used. The only downside is that EIGRP is Cisco's proprietary protocol and runs only on Cisco routers. RIPv2 and OSPF are open standard routing protocols.

6 Conclusions

In this project extensive experiments have been conducted to analyze the network convergence time of different routing protocols. Three routing protocols - RIPv2, EIGRP, and OSPF in three topologies – Star, Mesh, and Ring are tested by using sophisticated simulation software called OPNET. The experimental results show that RIPv2 has better performance than others in small and condensed networks. OSPF and EIGRP have better performance for medium-sized and scattered networks. Overall EIGRP is more stable and consistent in both small and relatively large networks. The future work may include the performance analyses on EGP protocols.

Acknowledgement

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7 References

[1] Cisco Networking Academy Program, Convergence, in: Chapter 1: WANs and Routers of CCNA1 & 2 Companion Guide (Third Edition), ISBN 1-58713-150-1.

[2] Cisco Networking Academy Program, Convergence, in: Chapter 3: Routing Overview of CCNP1: Advanced Routing Companion Guide (Second Edition), ISBN 1-58713-135-8.

[3] OPNET Document, http://www.opnet.com.

[4] Monir Hossain, How to start OPNET-Laboratory 2: Routing Information Protocol (RIP)-I, http://www.google.com

[5] Ljiljana Trajkovic, Final Project OSPF, EIGRP, and RIP performance analysis based on OPNET, http://www.sfu.ca/~donx.

[6] Mohammad Nazrul Islam, Simulation Based EIGRP over OSPF Performance Analysis, Master Thesis in Electrical Engineering Emphasis on Telecommunications, Thesis no: 4983, May 14, 2010.

[7] Usuari, Comparative analysis of the routing protocols RIPv2, OSPFv2 and Integrated IS-IS (Opnet & La Salle Reports), http://www.google.com.

[8] Cisco Networking Academy Program, Convergence, in: Chapter 3: Single-Area OSPF of CCNA3 & 4 Companion Guide (Third Edition), ISBN 1-58713-113-7.