

**ENSC 427: COMMUNICATION NETWORKS**  
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**FINAL PROJECT**

**Comparison of RIP, OSPF and EIGRP Routing**  
**Protocols based on Riverbed**

**Project Group # 11**

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## **Abstract**

Computer networks are a system of interconnected computers for sharing digital information by selecting the best routes between any two nodes which based on the routing protocol. There are many types of routing protocols which can be dynamic or static, as well as distance – vector or link – state. In this project, there are three typical types of routing protocol chose to simulate which are Routing Information Protocol (RIP), Open Shortest Path First (OSPF), and Enhanced Interior Gateway Routing Protocol (EIGRP). RIP is one of the oldest distance – vector routing protocols and uses `next - hop` as its metric. OSPF is a routing protocol for internet protocol networks. OSPF builds a database of routes to its neighbors and using an algorithm to calculate the best possible path. EIGRP is a hybrid between link – state and advanced distance – vector routing protocol that is used on a computer network to help automate routing decisions and configuration. EIGRP is the fastest router convergence among the three protocols.

Detailed descriptions of these routing protocols are provided later in this project. We are using Riverbed to simulate RIP, OSPF and EIGRP in order to compare their simulation results and compare performance. We aim to analyze the performance of these three protocols such as their router convergence or convergence duration in order to determine the best routing protocol for a given network topology.

# 1. Introduction

## 1.1 Routing Protocol Basics

A routing protocol specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network. A routing protocol includes an algorithm to determine the best route among immediate neighbors. Routing protocols are according to the OSI routing framework. Routing protocols are layer management protocols for the network layer.

## 1.2 Routing Metric Basics

Different routing protocols have different metrics. If there are two more routes between two nodes, each router must determine a method of metrics by choose the routing protocol to calculate the best path. A metric is a variable assigned to routers as a means of ranking them from the most preferred to the last preferred.

## 1.3 Static Routing and Dynamic Routing

Static routing is a form of routing that occurs when a router uses a manually – configured routing entry, rather than information from a dynamic routing protocol to forward traffic. Static routes are usually configured by a network administrator by adding in entries into a routing table. In static routing, all the changes in the logical network layout need to be manually done by the system administrator. However, Dynamic routing is adaptive routing which describes the capability of a system are characterized by their destination, to alter the path that the route takes through the system in response to a changed conditions. Dynamic routing allows routers to select the best path while there is a real time logical network layout change. In our project, RIP, OSPF and EIGRP are belonging to the dynamic routing protocols.

## 1.4 Distance Vector and Link State

Distance vector protocols is a vector which contains both distance and direction such as RIP, determine the path to remote networks using hop count as the metric. Distance vector protocol is based on Bellman – Ford algorithm and Ford –Fulkerson algorithm to calculate paths. It also transmits routing information that includes a distance vector,

typically expressed as the number of hops to the destination. Distance vector requires a router informs its neighbours of topology changes periodically.

Link state protocols are routing protocols which calculate the best paths to networks differently than distance vector routing protocols. Link state protocols also calculating their network routes by building a complete topology of the entire network area. It is calculating the best path from the topology of all the interconnected networks.

## 2. Three Routing Protocols

### 2.1 Routing Information Protocol (RIP)

RIP stands for Routing Information Protocol in which distance vector routing protocol. RIP is the first routing protocol implemented on TCP or IP. RIP can't guarantee that the route it's using is loop free like OSPF or EIGRP can. RIP is basically just making a guess based on the limited information that it knows. RIP uses `next - hop` as its metric and calculates the best route based on the number of hop it takes to reach the specified subnet. The advantage of RIP is that it's very simple to implement, and that it's an open standards based protocol.

The maximum number of hops allowed for RIP is 15. If the number of hops goes beyond 15, the route will be considered as unreachable. At the first developed, RIP only transmitted full updates every 30 seconds. As the networks become larger, `the reactive time of RIP is longer.

RIP has four basic timers which are Update Timer (default 30 seconds), Invalid Timer (default 180 seconds), Hold – Down Timer (default 180 seconds), and flush Timer (default 240 seconds).

- Update Timer defines how often the router will send out a routing table update.
- Invalid Timer indicates how long a route will remain in a routing table before being marked as invalid. Moreover, the route is marked with a metric of 16, means the route is unreachable.

- Hold – Down Timer specifies how long RIP will keep a route from receiving updates when it is in a hold – down state. A route will go into a hold down state if the invalid timer has expired or the route goes into a higher metric that what it is currently using.
- Flush Timer indicates how long a route can remain in a routing table before getting flushed out. The flush timers operates simultaneously with every 60 seconds, the route will get flushed out after it is marked invalid.

The popularity of routing information protocol is largely due to its simplicity and its easy configurability. RIP's disadvantages include slow convergence times and its scalability limitations. In conclusion, routing information protocol works best for small networks.

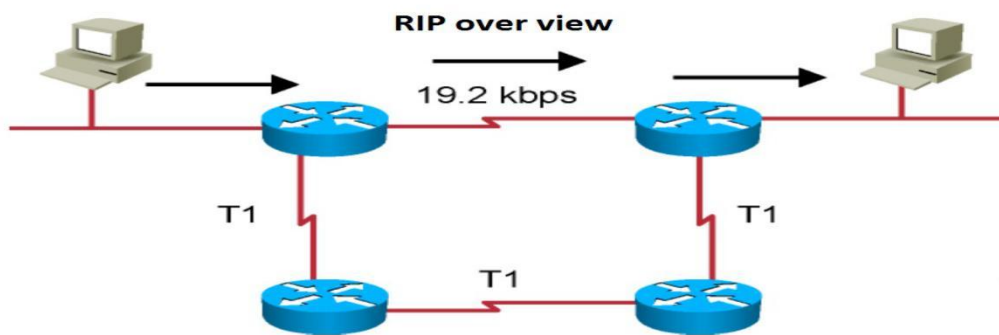


Figure 1: RIP over view

## 2.2 Open Shortest Path First (OSPF)

OSPF stands for open shortest path first which uses link-state routing algorithm. OSPF is a routing protocol for internet protocol networks. It uses a link state routing algorithm and falls into the group of interior routing protocols. OSPF is the most widely used interior gateway protocol in larger enterprise networks. OSPF routing protocol is a typical link-state routing protocol, commonly used for the same routing domain. Here, the routing domain is an Autonomous System(AS).

With the expansion of the network, when a large network routers run OSPF routing protocol will result in an increase in the number of routers, then the LSDB very large and take up a lot of storage space. It also makes the complexity of running the SPF algorithm increases the CPU load heavy.

After the network size increases, the probability of topology changes also increased, the network will always be in "hunting", it will cause a lot of network OSPF protocol packets in



the transmission, reducing the bandwidth utilization of the network. Even more serious is that each change will cause all the routers in the network to re-route calculation.

OSPF protocol is dividing the autonomous system into different areas to solve the above problems. Area is logically divided router from different groups, each with a zone number to identify. Boundary region is a router rather than a link. A network segment belongs to only one region, or each OSPF interface must be specified to belong to an area. As shown in Figure 2.

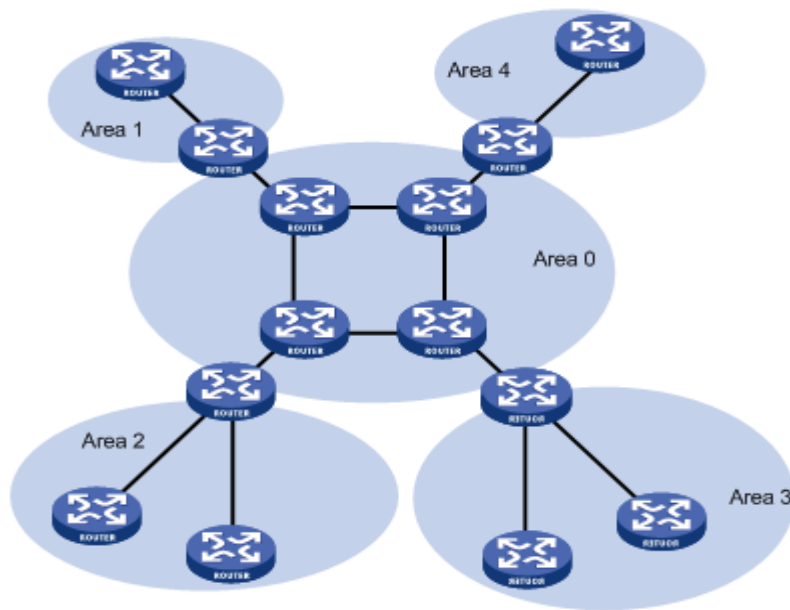


Figure 2 : OSPF Area Diagram

OSPF routing computation can be simply described as follows:

- Each OSPF router generated based on the network topology around itself, LSA (Link State Advertisement, LSA) and LSA update packets will be sent to other OSPF routers in the network.
- Each OSPF router collects other router advertisements LSA, put all LSA together compose a LSDB (Link State Database). LSA is a network topology around a router description, LSDB is a description of the entire autonomous system network topology.

- OSPF router change LSDB into a weighted directed graph, which is on the whole a true reflection of the network topology. All the routers have the same map.
- The follows graph is a simple network formed by five routers; all the paths are figured out, the path information are stored in the link database. The link database for the above model is : [A, B, 3], [A, D, 6], [B, A, 3], [B, C, 5], [C, D, 3], [C, B, 5], [C, E, 6], [E, C, 6], [E, D, 3], [D, E, 3] , [D, C, 3] and [D, A, 6]. Each term is referred to the originating router, the router connected to and the cost of the link between the two routers. Once the database of each router is finished, the router determines the Shortest Path Tree to all the destinations.

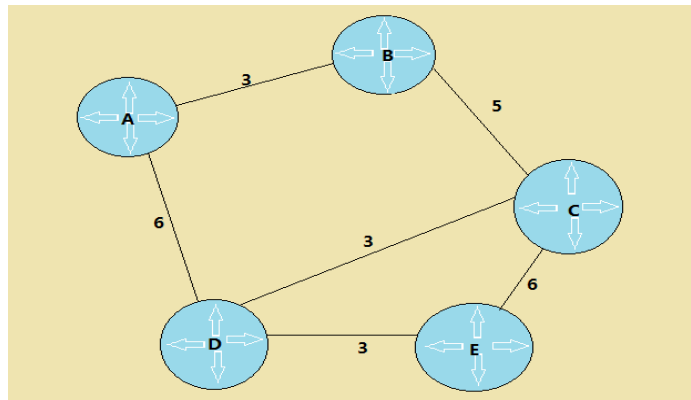


Figure 3: OSPF simple network

- The metric of OSPF is the cost of sending packets across a certain interface. The formula to calculate the cost is:  $\text{cost} = 100000000 / \text{bandwidth in bps}$ . The cost of OSPF computing and interface bandwidth is also inversely proportional to, the higher the bandwidth, the smaller the Cost value.

For example, calculating cost of a 10 Mbit / s interface, convert the 10 Mbit into bit, it is 10 000 000 bit, then with 100 million divided by the bandwidth, the result is  $100000000 / 10000000 \text{ bit} = 10$ , so that is a 10 Mbit / s interface.

Each router has a directed graph, using the SPF algorithm to calculate the tree itself is the root of the shortest path tree, tree shows the routes to the nodes in the autonomous system. When the Shortest Path Tree is completed, the router will work on the routing table.

## 2.3 Enhanced Interior Gateway Routing Protocol (EIGRP)

EIGRP is an advanced distance-vector routing protocol that is used on a computer network to help automate routing decisions and configuration. EIGRP is in many different structures and media for interior gateway protocol. In the designed network, EIGRP is the good extension of time to provide fast convergence to minimize network traffic.

Some advantages of EIGRP are :

- Very low network resource usage during normal operation.
- When the changes occur, only propagate routing table changes, not the entire routing table; this reduces the load placed of routing protocol in the network.
- Fast convergence time as a change in the network topology (confluent in some cases can be almost instantaneous).
- EIGRP is an enhanced distance vector protocol, which relies on the diffusion Update Algorithm (DUAL) to calculate the shortest path to a network destination.

EIGRP uses the minimum bandwidth on the path of the destination network, and calculate a route from the total delay metrics. Although you can configure additional weights, we do not recommend it, because it can cause your network routing loops. Bandwidth and latency metrics depends on the value leading to the destination network router interface.

In the following Figure 4, the router calculates the best path to the network a:

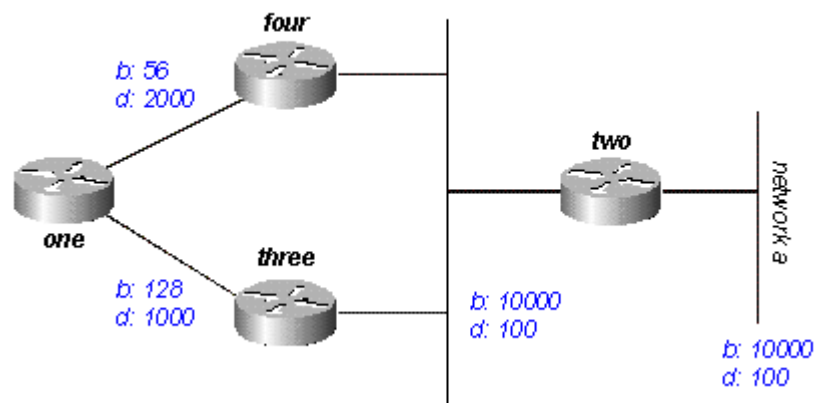


Figure 4: EIGRP simple network

This network is constructed by four routers and two paths. The router four, with a minimum bandwidth of 56 and total delay is 2200; the other path through router three, the minimum bandwidth of 128 and total delay is 1200. Select the path router with a lower metric.

$$\text{Metric} = (\text{bandwidth} + \text{Delay}) * 256$$

Let's calculate the weights. EIGRP calculates the total weight by extending the bandwidth and latency metrics. EIGRP bandwidth expansion using the following formula:

$$\text{Bandwidth} = (10000000 / \text{bandwidth (i)}) * 256$$

Where the bandwidth (i) is a minimum bandwidth of all outgoing interface in the routing network to the destination indicated in kilobits.

The default EIGRP algorithm DUAL requires guaranteed and ordered delivery of packets for transmission. DUAL, the Diffusing Update Algorithm is the default convergence algorithm which is used in EIGRP to prevent routing loops from recalculating routes. DUAL tracks all routes and detect the optimal path in terms of efficiency and cost which will be added in the routing table.

### 3. Routing Protocol Parameters

#### 3.1 RIP Parameters

The following figure shows the default Riverbed values for update interval parameters and other parameters for RIP routers.

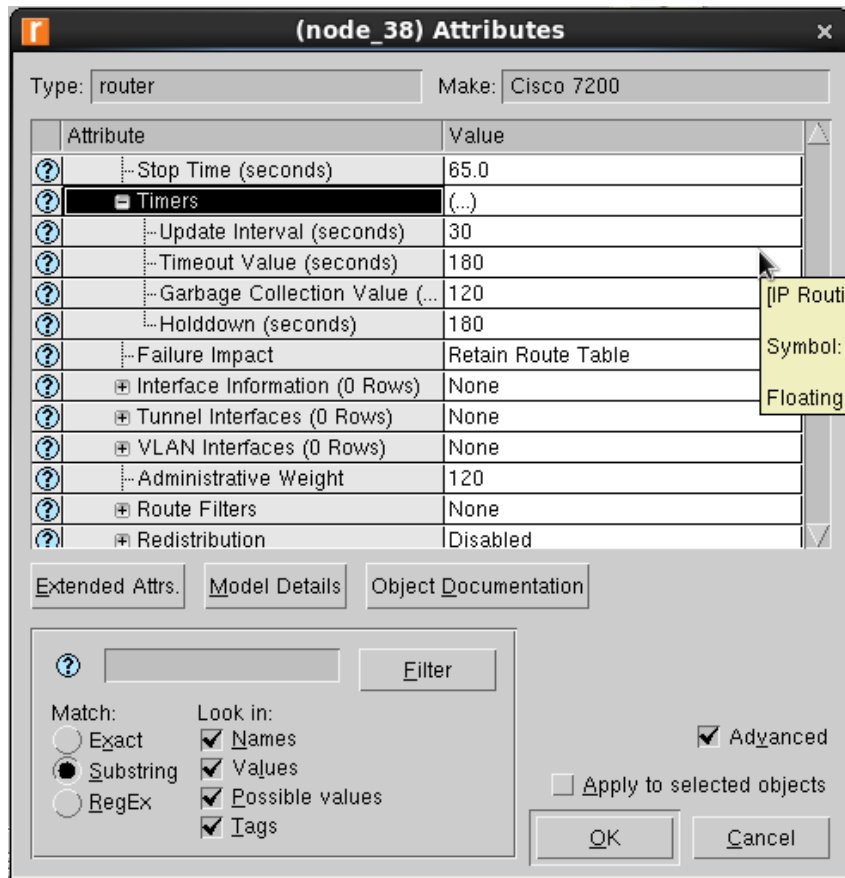


Figure 5: RIP Parameters

As a result, we can generate those parameters as a table shown below:

	Description	Default
Update Interval (seconds)	How often an RIP router sends updates to its neighbours	30
Timeout Values (seconds)	Used to indicate an invalid route. When the router expired, the router is removed	180
Flush (seconds)	Garbage collection value which indicates a route should be removed from the routing table	120
Holddown (seconds)	Used to avoid route flapping. During holddown time, updates in invalid routes are ignored	180
Maximum hops	Maximum number of packet supported by RIP	16

Table 1: RIP Parameters

### 3.2 OSPF Parameters

The following figure shows the default Riverbed values for hello interval parameters and other parameters for OSPF routers.

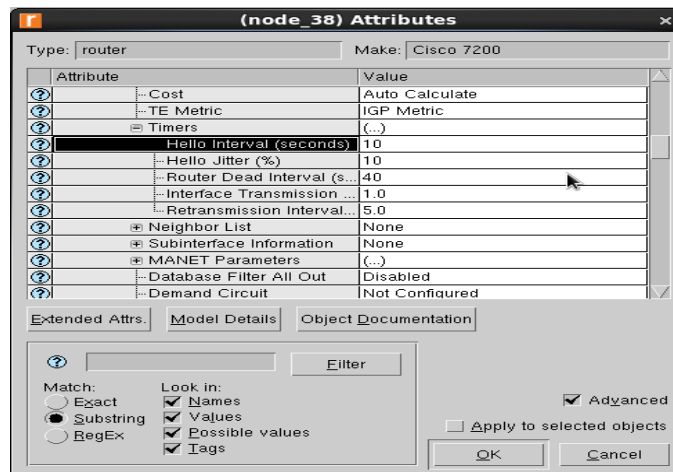


Figure 6: OSPF Parameters

As a result, we can generate those parameters as a table shown below:

	Description	Default
Hello Interval (seconds)	How often an OSPF router sends hello messages to its neighbours.	10
Router dead interval (seconds)	Used to declare neighbour routers dead when no hello messages have been received. This is usually a multiple of the Hello interval	40
Interface transmission (seconds)	Estimated time to transmit a Link State Advertisement packet	1
Retransmission Interval (seconds)	The time between LSA retransmissions. Have to be greater than the expected round-trip time between any two routers in the network	5
Interface cost	The values used to calculate the shortest path in the network	1

Table 2: OSPF Parameters

Moreover, for the SPF calculation, there are two options for the router to calculate shortest path:

1. Periodic: Recalculate at each specified interval, unless no change has occurred.
2. LSA driven: Recalculate after every LSA has been received.

### 3.3 EIGRP Parameters

The following figure shows the default Riverbed values for update interval parameters and other parameters for EIGRP routers.

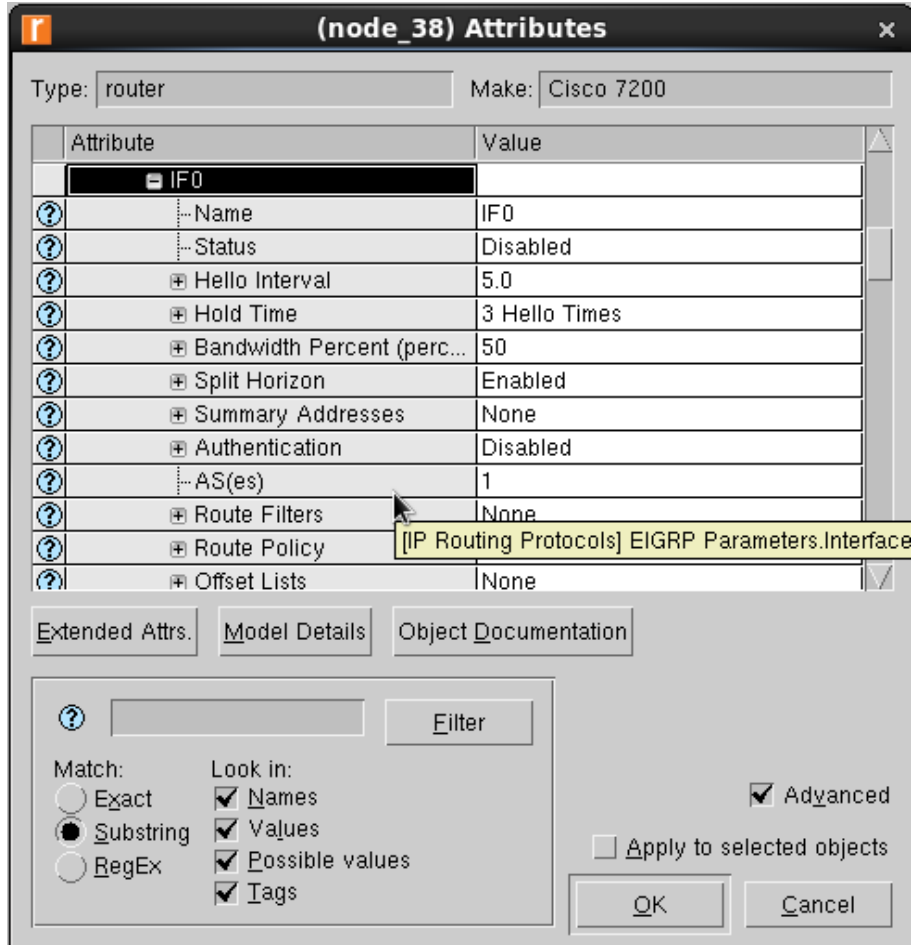


Figure 7: EIGRP Parameters



As a result, we can generate those parameters as a table shown below:

	Description	Default
Hello Interval (seconds)	How often an EIGRP router sends hello messages to its neighbours.	5
Hold time	Used to declare the amount of time a neighbour should wait for another hello message from this process model before marking its node as down	3 Hello Times
Route filters	Specifies the distribute lists used to filter routes received on or sent from this interface	None
Split Horizon	Does not advertise route to the neighbour from which route was learned	Enabled
Maximum Hops	Maximum number of packet supported by EIGRP	100

Table 3: EIGRP Parameters

## 4. Topologies of Riverbed

To simulate different conditions of network, we built three topologies which are tree, large mesh, and star topologies. We built the network topologies with several of elements from palette to set up the environment. In order to form different topologies, we used different placement of nodes for the three protocols to compare the performance.

### 4.1 Star Topology

In star topology, each single network is linked to the central node which is the hub. Also, the hub is the server and the others are the clients. The disadvantage of star topology is that the central point can lead to the failure of entire network. For our star topology, we use five nodes to connect to the central point to form the topology which is shown in the below figure.

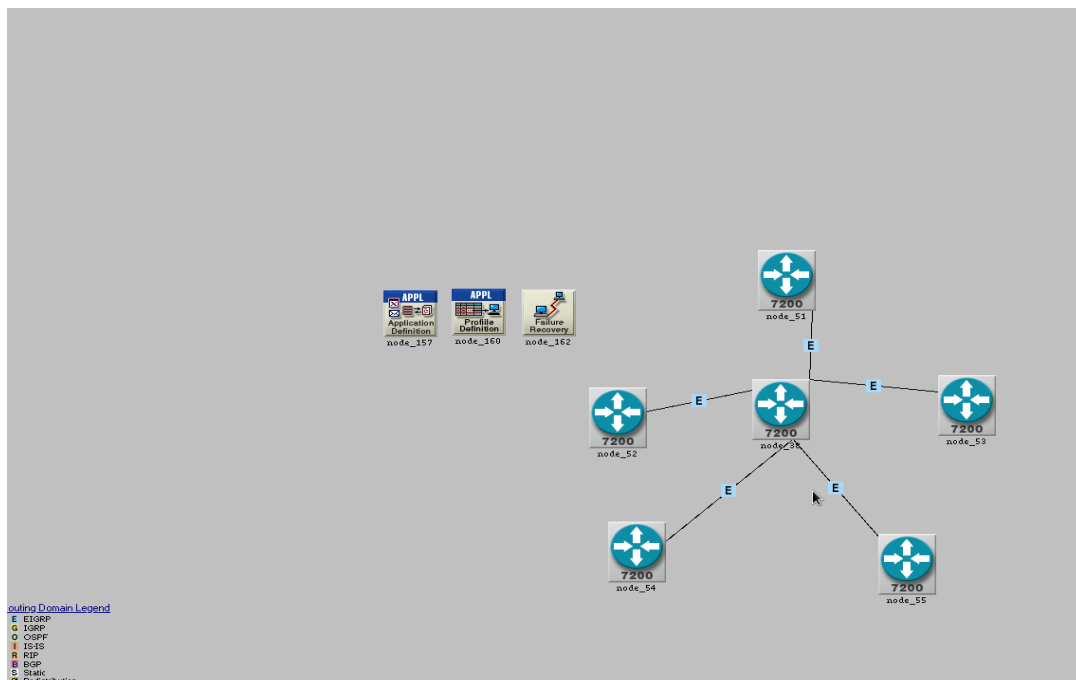


Figure8. Star topology

## 4.2 Large mesh topology

For large mesh topology, every node is connected to each other in the network. There are two types of mesh topologies. One is the fully connected network that is a communication network that has each node is linked to each other. However, large mesh topology requires a lot of links as the formula  $C = \frac{n(n-1)}{2}$  (where n is the number of nodes). The other type of mesh network is the partially connected mesh topology that has some of the nodes is connected in the network. For our second topology, we build a fully connected mesh network with 19 Cisco 7200 nodes which are shown in the figure below.

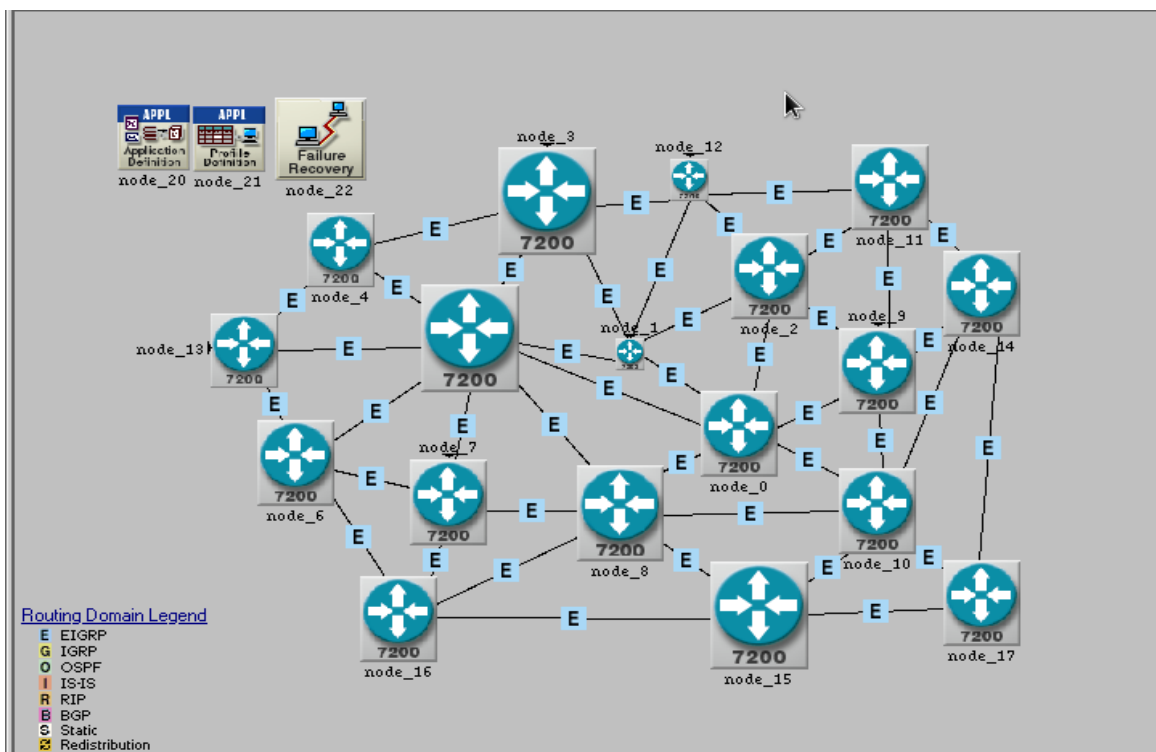


Figure9. Large Mesh topology

## 4.3 Tree Topology

In tree topology, the structure is consisted with bus topologies and star topologies. Also, it has the form of hierarchy that has a root node that duplicate similar forms. The root node repeats the same structure for each level. And, each level has the same number of nodes to be

connected. In this project, we built the tree topology with 155 nodes in 4 levels which are shown in the following figure.

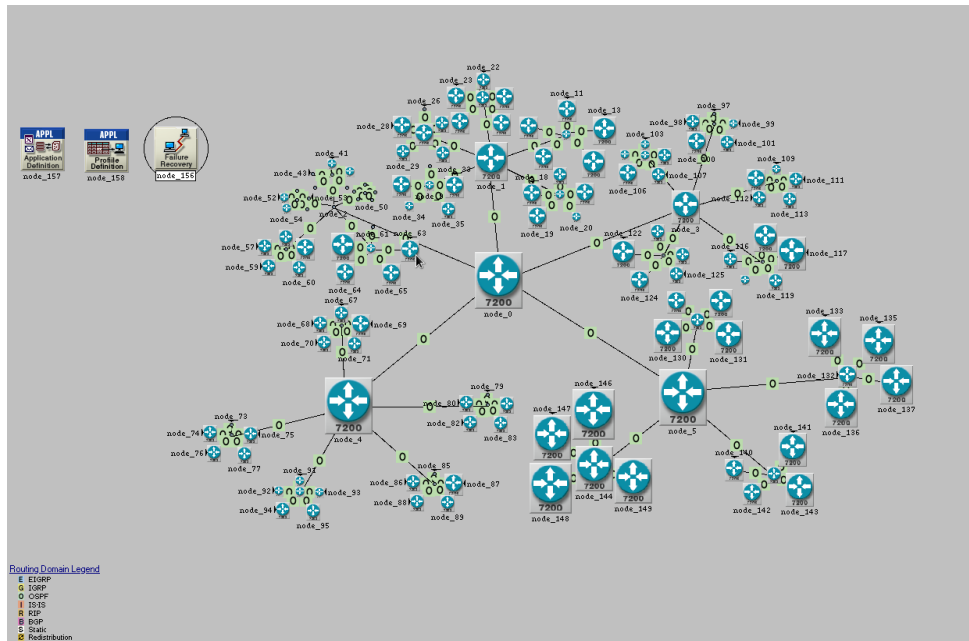


Figure10. Tree topology

## 5. Simulation Setup

To setup the simulation, we place the profile and application definitions for setting up the attributes. Also, we use the failure/recovery configuration to setup the time and duration for the failure and recovery. In the following figure, it shows the file (High resolution video) we try to send with the network we have.

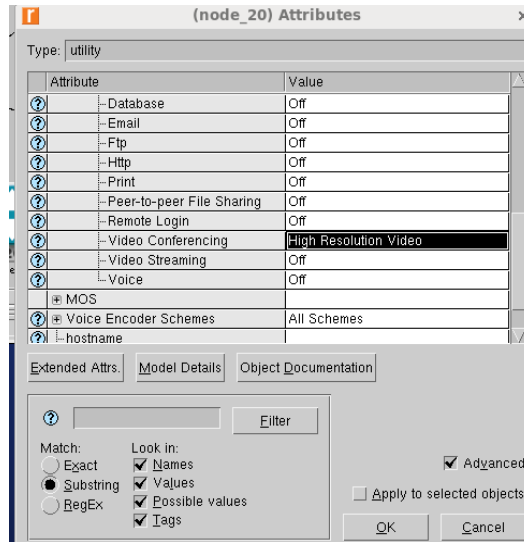


Figure11. Profile Configuration

### 5.1 Simulation Setup for Failure/Recovery Configuration

In order to show the failure and recovery, we enabled the failure and recovery modeling. Also, we set the failure time to be at 200 seconds and the recovery time to be at 500 seconds as the figure shown below. The failure and recovery configurations were set to be the same for the three scenarios and topologies.

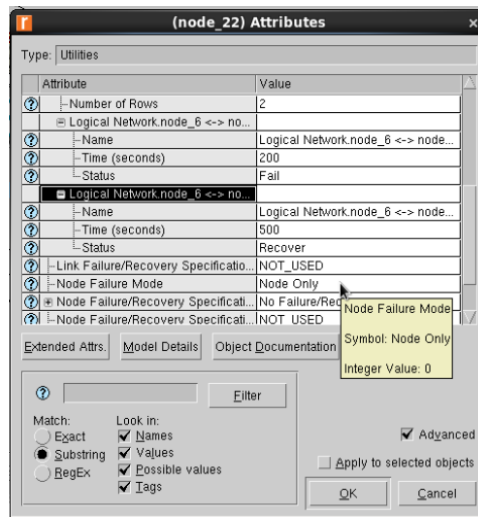


Figure12. Failure/Recovery Configuration

## 5.2 Setup for the simulation Global attributes

The three protocols RIP, OSPF, EIGRP are set with its IP dynamic routing protocol respectively. Also, we set the IP routing to export mode and the IP version to IPv4 which is shown in the figure below.

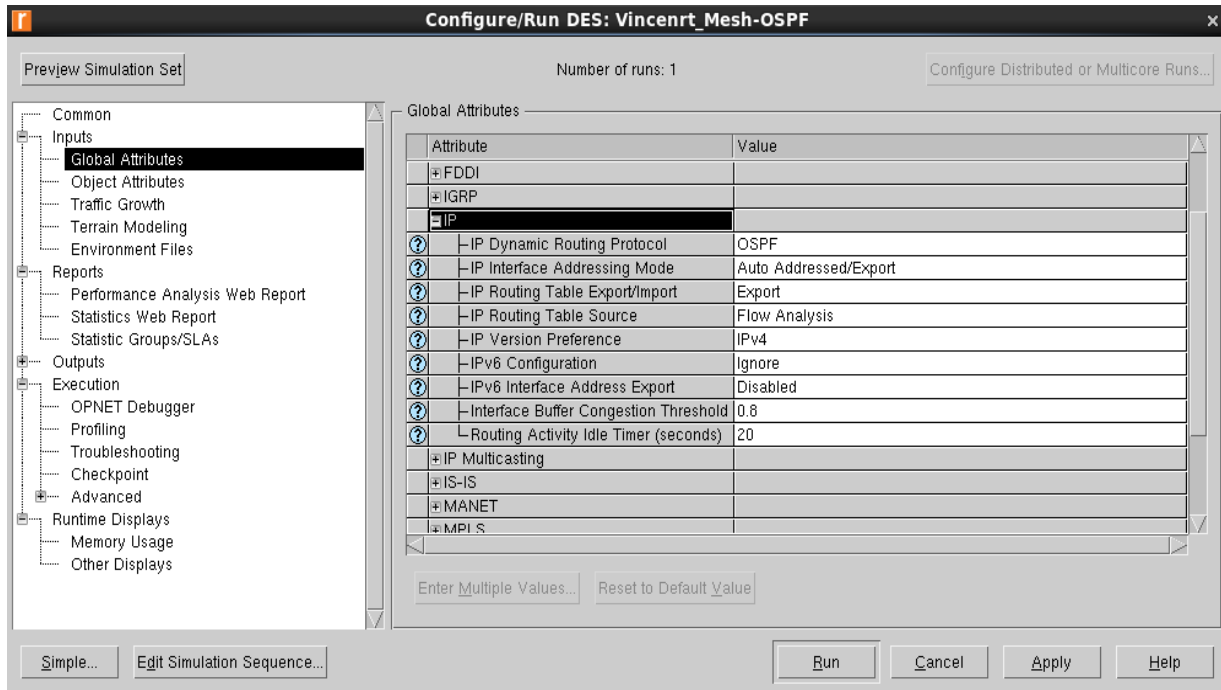


Figure13. IP Routing for Global Attributes

To guarantee the results can continue running until the end of simulation which is 15mins (900 sec), the efficiency for the each protocols are enabled. Also, the stop time of the three protocols RIP, OSPF, and EIGRP are set to 1200, 260, and 1500 respectively.

Global Attributes

Attribute	Value
- Simulation Efficiency	
- ARP Sim Efficiency	Enabled
- ATM SSCOP Sim Efficiency Mode	Enabled
- ATM Sim Efficiency (None)	Disabled
- BGP Sim Efficiency Mode	Enabled
- EIGRP Sim Efficiency	Enabled
- EIGRP Stop Time (seconds)	1500
- FDDI Transmission Efficiency	Enabled
- IGMP Sim Efficiency	Enabled
- IGRP Sim Efficiency	Enabled
- IGRP Stop Time (seconds)	365
- IPv6 ND Simulation Efficiency	Disabled
- ISIS Sim Efficiency	Enabled
- ISIS Stop Time (seconds)	260
- LACP Simulation Efficiency	Enabled
- OSPF Sim Efficiency	Enabled
- OSPF Stop Time (seconds)	260
- PIM-SM Sim Efficiency	Enabled
- RIP Sim Efficiency	Enabled
- RIP Stop Time (seconds)	1200
- RIPng Sim Efficiency	Enabled
- RIPng Stop Time (seconds)	65
- TR Transmission Efficiency	Enabled
- compound_cell_enabled	Disabled
+ TCP	
+ Traffic	

Enter Multiple Values...    Reset to Default Value

Figure14. Simulation Stop time for each protocols

Configure/Run DES: Vincenrt\_Mesh-EIGRP

Preview Simulation Set      Number of runs: 1      Configure Distributed or Multicore Runs...

Common

Duration: 15 minute(s)

Seed: 128      Enter Multiple Seed Values...

Values per statistic: 100

Update interval: 500000 events

Simulation Kernel: Based on 'kernel\_type' preference (Preference set to "development")

Use OPNET Simulation Debugger (ODB)

Simulation set name: scenario

Comments:

Simple...    Edit Simulation Sequence...    Run    Cancel    Apply    Help

Figure15. Configure/Run the simulation with 15 minutes

### 5.3 Setup for the Individual DES statics for viewing results

In order to compare the three protocols, we set the individual statics differently. We planned to view the results of RIP, OSPF, and EIGRP for each topology. It shows the comparison of Convergence Activity and traffic sent (bits/sec). The following three figures shows the statics for showing the results.



Figure16. RIP DES statics



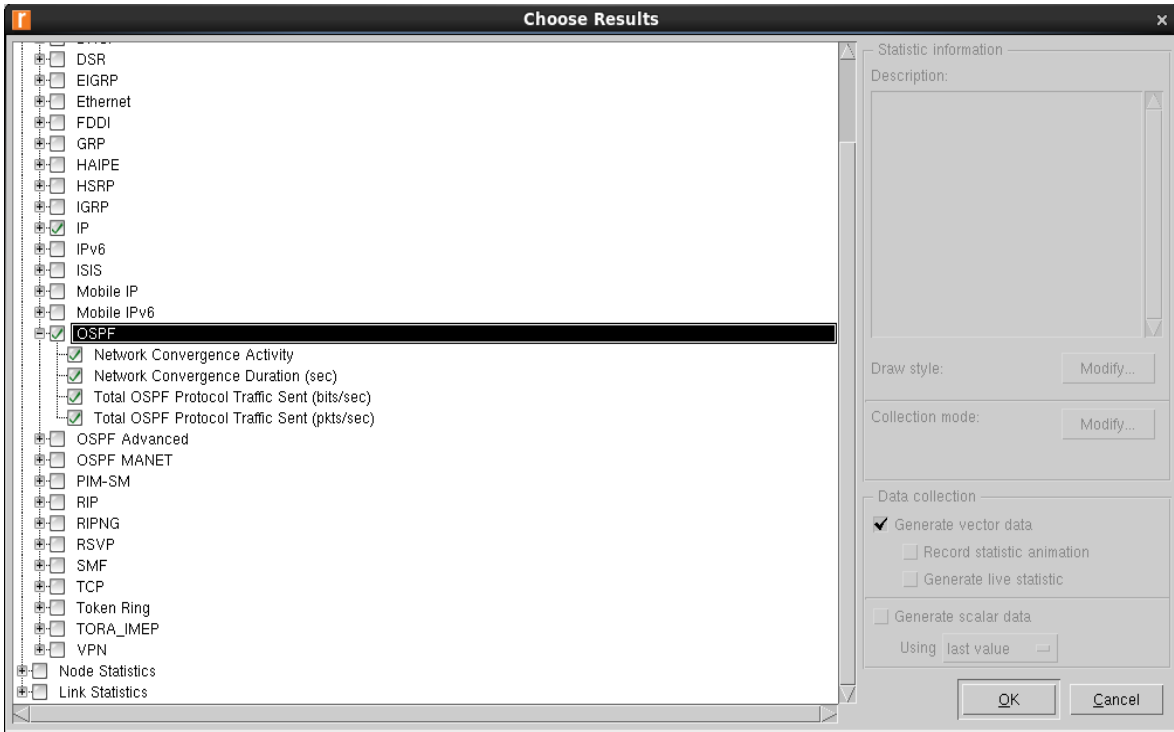


Figure17. OSPF DES statics

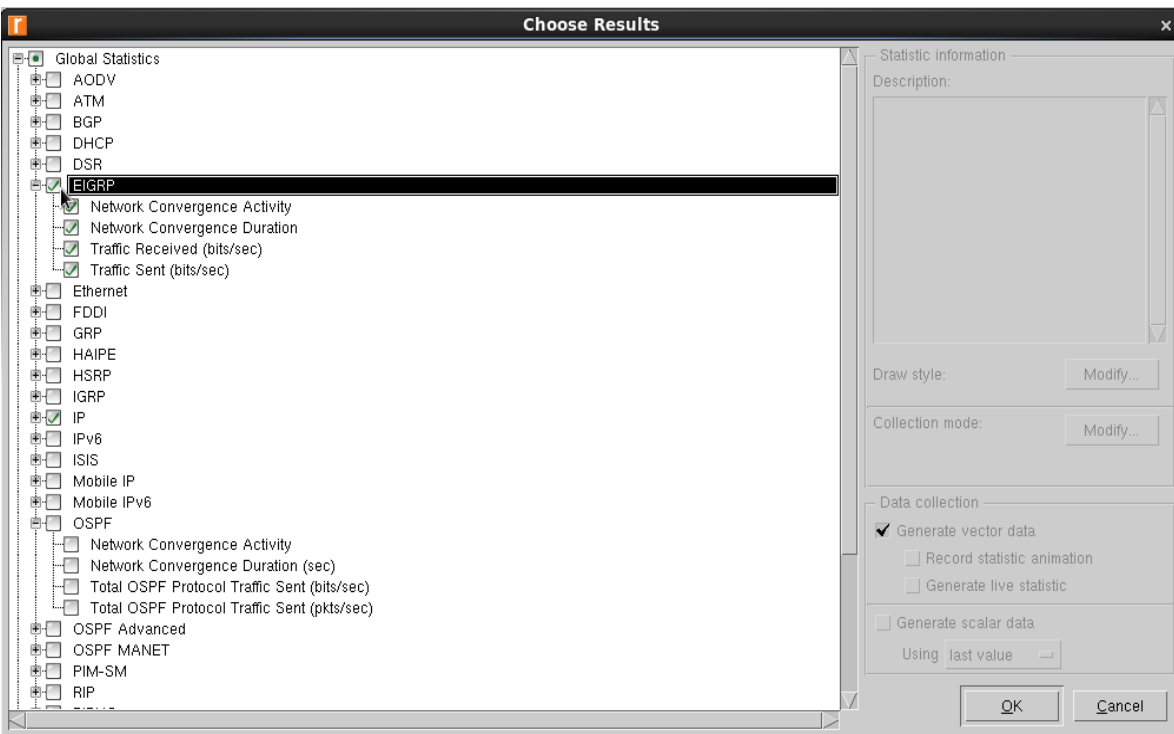


Figure18. EIGRP DES statics

## 6. Result and Analysis

Based on the three topologies we set up above, we simulated the performance of each routing protocol on each topology and compared the results.

### 6.1 We ran the simulation of convergence activities for the three protocols:

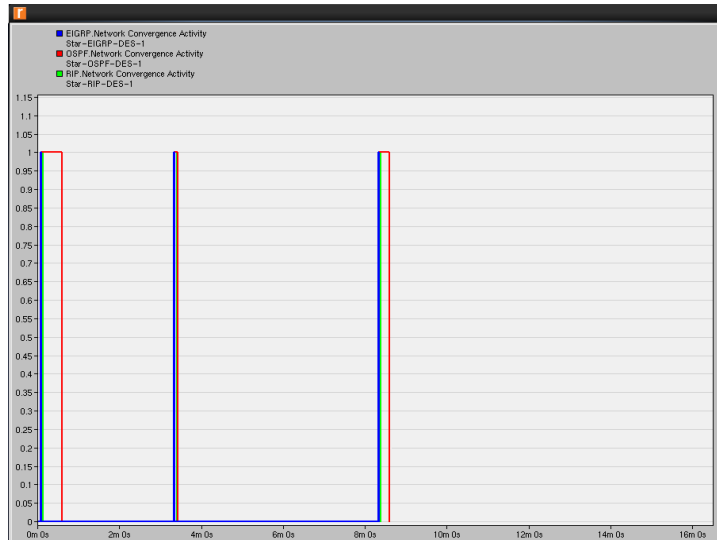


Figure 19: Overlaid Convergence Activity on Star Topology

The figure above shows the convergence activity of each protocol (blue for EIGRP, red for OSPF and green for RIP) in star topology. From left to right, the first, second and third peaks represent the initial time, link failure at 200 seconds as we set and link recovery at 500 seconds. As we can see, in small network, EIGRP is the fastest protocol because it reacts right away when failure detected and recovery detected. RIP is a bit slower than EIGRP and OSPF is slowest because the distance between red and two specific times (200s and 500s) are longest.

Next we ran the simulation in the larger network which is large-mesh topology.

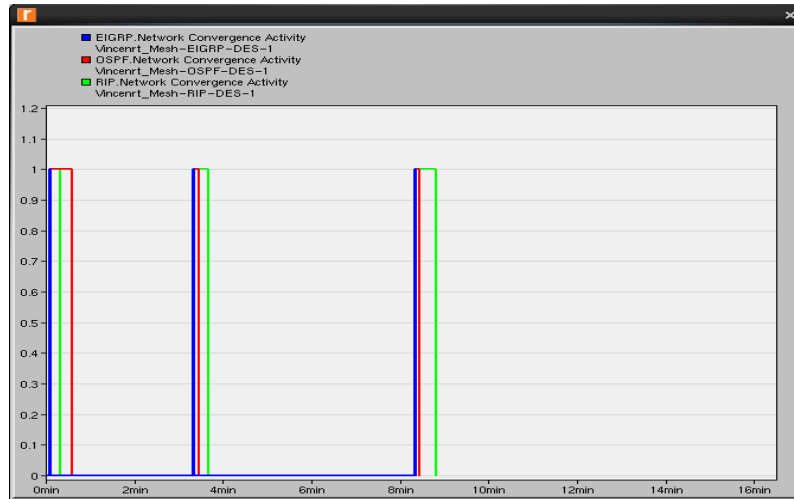


Figure 20: Overlaid Convergence Activity on Mesh Topology

Obviously, EIGRP is still the fastest protocol. And OSPF still has the longest initial setup time. But when failure and recovery happened, OSPF is way faster than RIP. When the size of network is being bigger, RIP will also have slower convergence. The reason why RIP is the slowest one was RIP is limited by its hop count which is only 15. This is also due to the prompt LSA's and the LAS driven SPF calculations. We should also notice that even though the network size was increasing, EIGRP's convergence times are almost the same as those of small topologies such as star topology.

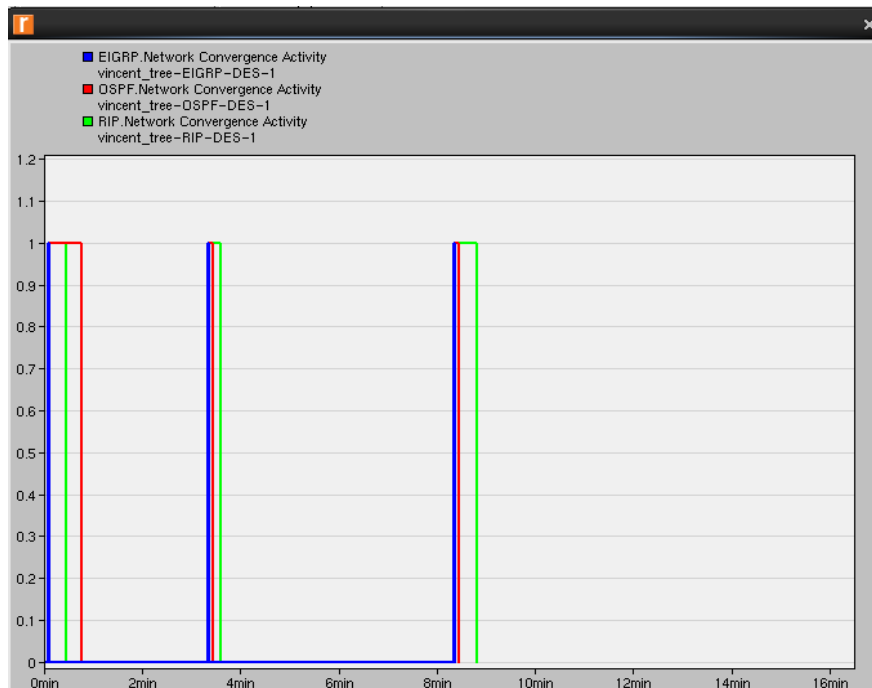


Figure 21: Overlaid Convergence Activity on Tree Topology

This is the biggest network of the three. However, EIGRP is still the fastest protocol among all three. OSPF still has the longest initialization time and RIP is slightly shorter than OSPF. The fail convergence time is same as the mesh topology where EIGRO > OSPF > RIP, but the difference between RIP and OSPF were not significant. At the end, RIP also has longest recover time.

As a result, EIGRP is the fastest protocol for any network. RIP has a better performance than OSPF when the network was small because RIP doesn't need to map out the network and distribute a large amount of information then choose a path. In addition, OSPF has the better and better performance relative to RIP when the size the network is getting bigger and bigger.

### 6.2 We ran the simulation of traffic sent (bits/second) for the three protocols:

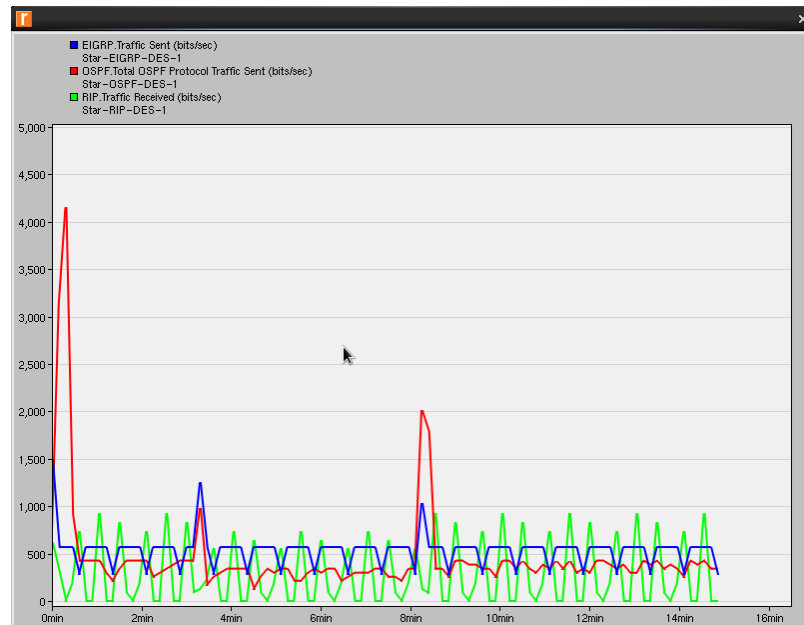


Figure 22: Overlaid Traffic Sent on Star Topology

The figure above shows the router traffic sent in bits/second of three protocols using Star topology. Again, from left to right, the first peak is the initial traffic, the second one is the link failure and the last one is the recovery. As we can easily see, at the first peak, OSPF has a significantly high initial traffic. The reason of that is OSPF has to collect large amount of data of the network and do the algorithm at the beginning then choose the best path. We also observed that EIGRP has the highest bandwidth efficiency and RIP has the lowest. We can also see that if there are no new routers added, OSPF has better bandwidth efficiency than EIGRP. However, RIP has not a big difference from OSPF and EIGRP because RIP will update the routing table every 30 seconds.

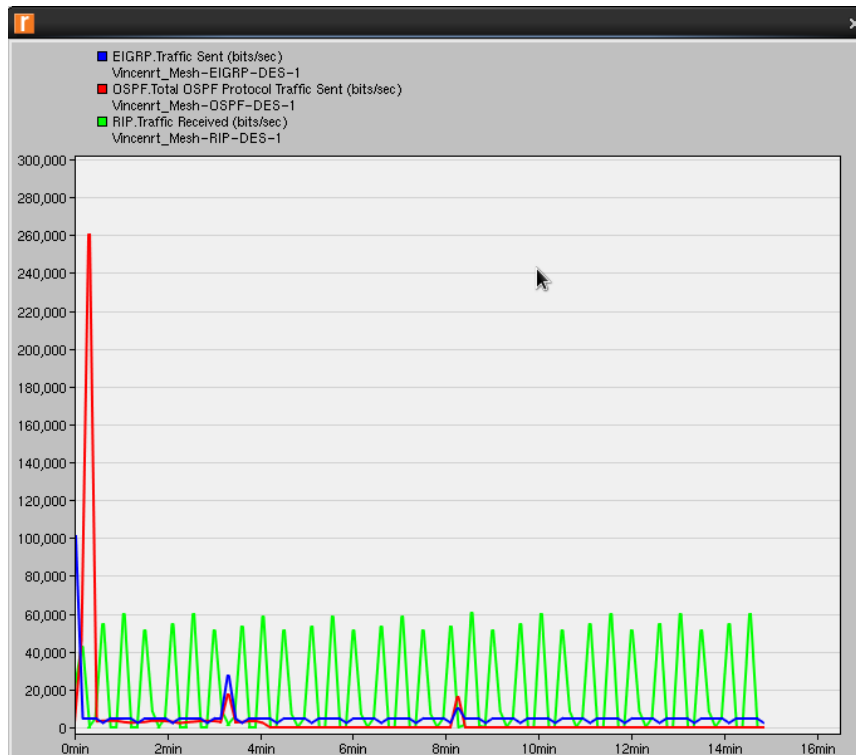


Figure 23: Overlaid Traffic Sent on Mesh Topology

The figure above shows the router traffic sent in bits/second of three protocols using Mesh topology. Obviously, in this topology the output for each protocol has increased because the size of the network has increased a lot. At the beginning, the initialization is similar to the small traffic graph, which OSPF has an output of 0.26Mbps, EIGRP has 0.1 Mbps and RIP only has 60 Kbps. It is because OSPF uses link state and has to collect large amount of data of the network and do the algorithm at the beginning and RIP does not need that big amount of work at the beginning. And also because EIGRP uses hybrid, it has to map out the whole network at the beginning too. When failure occurred, EIGRP has higher throughput than OSPF. But when recovery occurred OSPF has higher throughput than EIGRP which has the same situation as at the beginning but both of their throughputs decreased. For bandwidth efficiency, OSPF and EIGRP have much higher efficiencies than RIP in this graph. As RIP is updating every 30 seconds, RIP wastes about 60Kbps in every 30 seconds. As a result, RIP has less difference from EIGRP and RIP in small network such as star topology. Therefore, RIP is only suitable for small network.

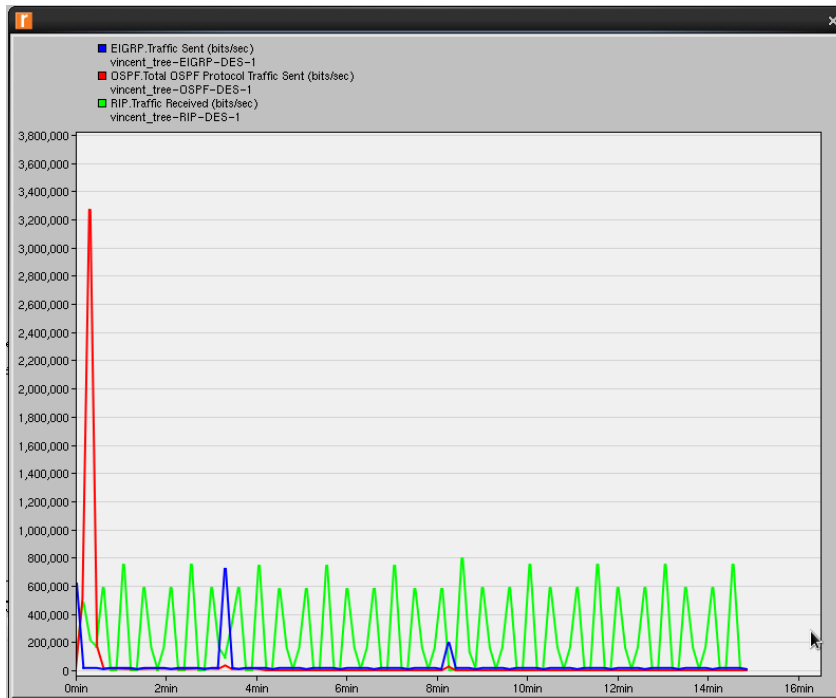


Figure 24: Overlaid Traffic Sent on Tree Topology

The figure above shows the router traffic sent in bits/second of three protocols using Tree topology. In this graph we can again see at the initial peak OSPF still has the highest throughput which was 3.2 Mbps. EIGRP was also similar as the mesh topology, it has 0.6 Mbps throughput. As we mentioned that OSPF uses link state and EIGRP uses hybrid of RIP and EIGRP. Moreover, when failure and recovery occurred EIGRP has higher throughput than OSPF. For bandwidth efficiency, the situation is similar as the mesh topology. OSPF and EIGRP have much higher efficiencies than RIP in this graph. As RIP is updating every 30 seconds, RIP wastes about 60Kbps again in every 30 seconds. As a result, RIP has less difference from EIGRP and RIP in small network such as star topology. Therefore, RIP is only suitable for small network.

## 7. Conclusion

To compare the performance of RIP, OSPF, and EIGRP, our group analyzed the results with OPNET. To simulate different conditions for each protocols, we built three different topologies for the three protocols to test the performance. Firstly, we designed a star topology and observe the results of convergence activity, convergence duration, and traffic sent (bits/sec). Also, we designed a large mesh and tree topologies to provide different topologies for comparing the three protocols. In order to compare the update time for calculating the path, we compare the convergence activity of the three protocols with fail and recovery time. EIGRP is the fastest routing protocol for each topology by analyzing the results from every result plots. EIGRP has the least delay time from the failing and recovering time which are set at 200 seconds and 500 seconds respectively. In star topology, RIP is faster than OSPF. However, OSPF is faster than RIP when the protocols are used in large mesh topology. To conclude, EIGRP is the best protocol in both convergence speed and traffic sent no matter which topology. However, the research shows that EIGRP cost more money than OSPF and RIP. Therefore, OSPF has been commonly used for companies. And, RIP is the slowest protocol and has worst performance in large topology. RIP is still a better choice in small network environment.

## 8. Difficulties

Our first choice of project is TCP/IP technology which we encountered a lots errors and cannot finish the simulations with RiverBed. Therefore, we check the lists from the ENSC427 website and decided another topic for our project. According to our research, we chose the topic "Comparison of RIP, OSPF and EIGRP Routing Protocols based on OPNET" since the three protocols are commonly used during recent years. Therefore, we planned to compare the performance between RIP, OSPF, and EIGRP. The major problem we have for the new topic is that the protocols stop running in half way of the simulation process. Also, we are not able to simulate the results after the recovery time. The features for us to compare performance are also the problems we had.

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