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***Abstract*—** One of the decisions that need to be made when designing and configuring a computer network in which routing protocol should be used. This paper presents a simulation of a high load File Transfer Protocol (FTP) Application and a high load Peer to Peer (P2P) Application using Riverbed Academic Modeler 17.5. The simulation is configured and run in a World environment to replicate a global network. Each simulation employs either RIP, OSPF, or EIGRP routing protocol. The queuing delay, throughput, link utilization, and IP packets dropped are used as performance parameters to determine which routing protocol is the most efficient for this network setup.

Keywords—File Transfer Protocol (FTP), Peer to Peer(P2P), Enhanced Interior Gateway Protocol (EIGRP), Open Shortest Path First (OSPF), Routing Information Protocol (RIP), Data Evaluation System (DES).

I. Introduction

Routing protocols are essential for ensuring that the best path is used to route packets to its destination. Different dynamic interior routing protocols are available such as RIP, OSPF, and EIGRP. RIP is a distance-vector routing protocol. It uses "hop count" to determine the least number of routers needed to route packets from client to server. EIGRP is a hybrid routing protocol because it combines the best features of both distance vector protocols and link state protocols. It uses bandwidth, delay, load, and reliability to determine the best route. OSPF is a link state routing protocol that uses link cost as a metric. The least cost link path is used to determine the best route. This paper presents a simulated World environment using Riverbed Modeler to examine and analyze the designed network [1]. The simulation allows for a deeper understanding of real-world network design, testing, and implementation. Performance evaluation of the designed network is equally as important as configuring and designing the network itself. Hardware configurations are selected to allow for Cisco's EIGRP routing protocol to be evaluated. That process itself aids in the understanding of what hardware options can be implemented in a network configuration. The design of the network in this paper is entirely organic, as we could build any type of network as needed. Experimentation with the Riverbed Modeler software was crucial in completing this type of analysis.

This paper is organized as follows: section II introduces the related work. In section III, the designed network is presented. Section IV discusses performance evaluation of the designed network. Finally, section V offers the conclusion and future work.

II. Related Work

Kumar *et al.* created a network model which utilizes two subnets connected with a 10BaseT link [2]. One subnet contains Wireless LAN workstations running a high load FTP Application. The other subnet contains a Wireless LAN server supporting the High Load FTP Application. Routing protocols were evaluated, with EIGRP was the recommended protocol after analysis.

Rufai *et al.* provided an in-depth analysis of IS-IS, OSPF, RIP, EIGRP, and IGRP Routing Protocols [3]. A network containing seven routers, 1x100BaseT LAN, 1x10BaseT LAN, and HTTP server were used to analyze the performance of a multitude of different applications with each of these five routing protocols. There is also a failure link programmed in the Riverbed simulation to analyze consistent data flow, and proper recovery when this link failed. No recommendations were given, but the paper highlights the pros and cons of each routing protocol.

Jalali *et al.* analyze RIP, IGRP, OSPF and EGRP routing protocols using OPNET Simulator [4]. A network of five Cisco 7000 routers connected with PPP_DS3 links allows two workstations to communicate via a video streaming application. This analysis also contains a programmed link failure at designated times throughout the simulation. The authors concluded that EIGRP is the recommended routing protocol in their designed network. These results are used as a relative benchmark for evaluating the routing protocols within our work, as there were a significant number of similar components used in the network design.

Wei *et al.* analyzed the performance of HTTP and FTP using an OPNET simulation [5]. To analyze performance, TCP queuing delays are measured for both FTP and HTTP. For the analysis of HTTP, the number of clients is also another parameter to determine performance. It was found that HTTP queuing delays were double that of FTP queuing delays.

Xu *et al.* analyzed the performance of routing protocols using OPNET [6]. The analyzed routing protocols are RIP, OSPF, and EIGRP. It was found that EIGRP performed better in terms of network convergence, routing traffic, and Ethernet delay when analyzing HTTP traffic. RIP performed better with voice packet delays. OSPF was found to show better performance using HTTP in terms of page response time and packet end-to-end delay for video conferencing.

Rakheja *et. al.* found the highest performing routing protocol by analyzing the cost of delivery, amount of overhead on each router, failure recovery, queuing delays, and throughput [7]. The analyzed protocols are RIP, OSPF, IGRP, and EIGRP. It was found that OSPF had the lowest cost of transmission as well as the highest throughput. EIGRP, however, provided the lowest queuing delays.

Thornier analyzed different routing protocols; EIGRP, RIP, and OSPF using the OPNET modeler [8]. There were five subnets all connected in a ring using a PPP_DS3 link. Two subnets contained an extra PPP_DS3 link anticipating a failure. Up to 10 routers per subnet were in place that supported three 100BaseT LANs. The author concluded that RIP was very effective with voice packet transmission, while EIGRP displayed better management of traffic and lower Ethernet delays. OSPF provided better convergence as well as better handling of HTTP traffic.

III. DESIGNED NETWORK

The designed network consists of three individual subnets as shown in figure 1. Each scenario uses a World Network configuration. The P2P application runs on two 10BaseT LAN setups in subnet_northeast as shown in figure 2. The FTP Application runs on two Ethernet Workstations in subnet_africa as shown in figure 3. The clients communicate with a PPP Server running the P2P Application and a PPP Server running the FTP Application, which resides in subnet_midatlantic, as shown in figure 4. Each subnet must communicate through the IPv32 cloud utilizing PPP_DS3 links. Each application scenario runs one of the routing protocols, either RIP, OSPF, or EIGRP. This analysis is conducted to determine which routing protocol is best suited for this network/application setup. The duration of the simulation is 10 minutes for each scenario. DES, or Data Evaluation System, Node Statistics include Queuing Delay, Throughput, and Link Utilization are analyzed. Also, IP Packet Drop Rate is analyzed under DES Global Statistic.

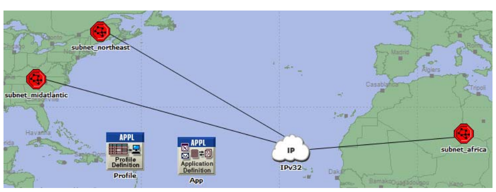

Figure 1. The Designed Network

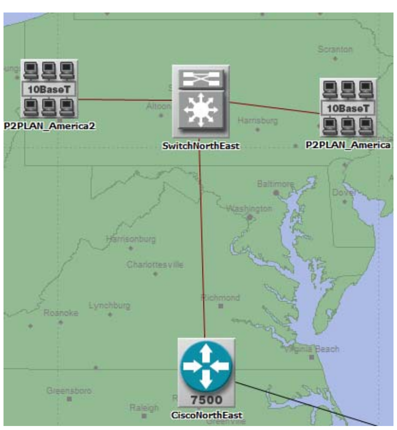

Figure 2. Subnet_Northeast

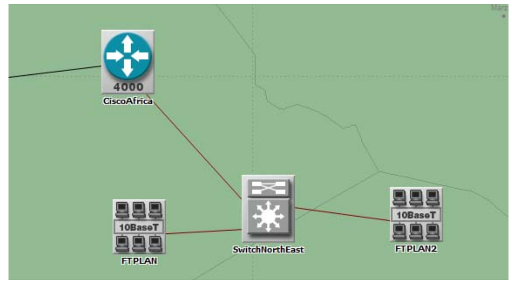

Figure 3. Subnet_Africa

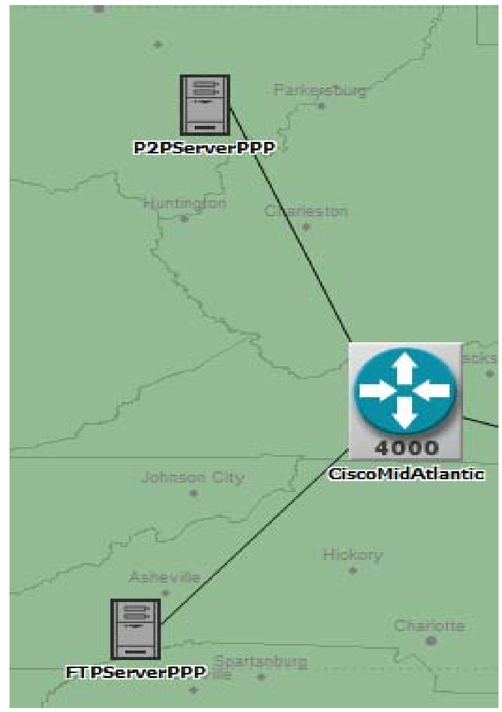

Figure 4. Subnet_Midatlantic

IV. PERFORMANCE EVALUATION

The first statistic analyzed was the average IP packet traffic drop rate for each of the routing protocols. As seen in figure 5, EIGRP displayed an initial average packet drop of between eight and nine packets, before eventually tapering off to an average of roughly five packets dropped at the end of the simulation. The average number of packets dropped by the OSPF routing protocol was roughly 4 at the beginning of the simulation, and then tapering off to an average of about 2 packets. RIP did not have any packets dropped through the simulation.

When observing the traffic between the IP Cloud and each of the respective subnets, EIGRP provides the lowest queuing delay. Subnet_africa, in figure 6, which contains the FTP Clients, shows more consistent queuing delays using EIGRP rather than RIP or OSPF. RIP displayed steady increases as time went on, similar to OSPF; but, EIGRP ended with ~.00002 second less queuing delay than OSPF and .00006 second less queuing delay than RIP.

Subnet_midatlantic, in figure 7, which contains the P2P and FTP Servers, shows marginal differences of no more than .000010 seconds when comparing each of the routing protocols. It should be noted that EIGRP, again, demonstrated the least amount of queuing delay in subnet_midatlantic.

The subnet_northeast, in figure 8, which contains the P2P Clients, shows more distinct differences between the routing protocols. EIGRP again had the lowest queuing delay, with .00005 seconds less than OSPF and ~.00010 seconds less than RIP.

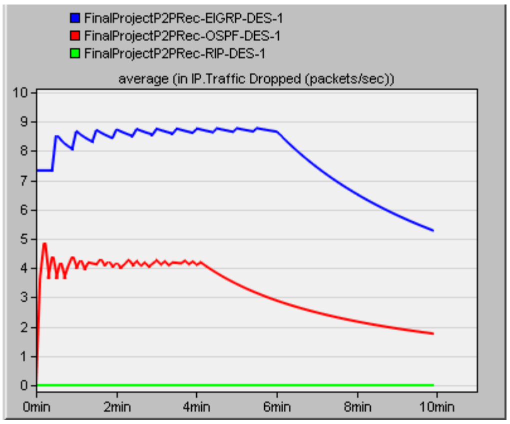

Figure 5. Average IP Traffic Dropped

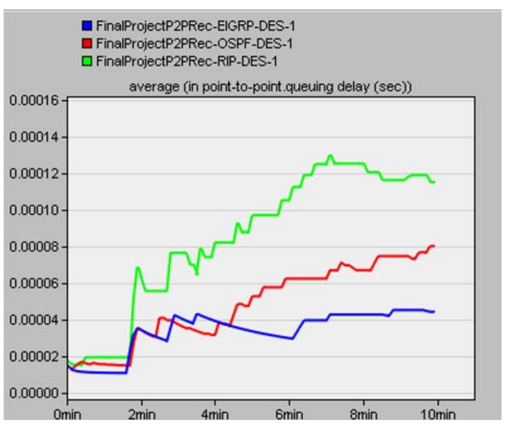

Figure 6. Average Queuing Delay from IP Cloud to subnet_africa

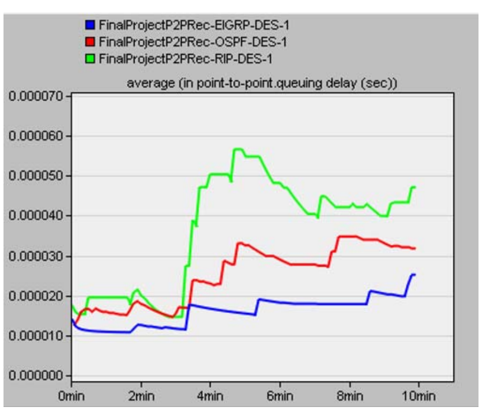

Figure 7. Average Queuing Delay from IP Cloud to subnet_midatlantic

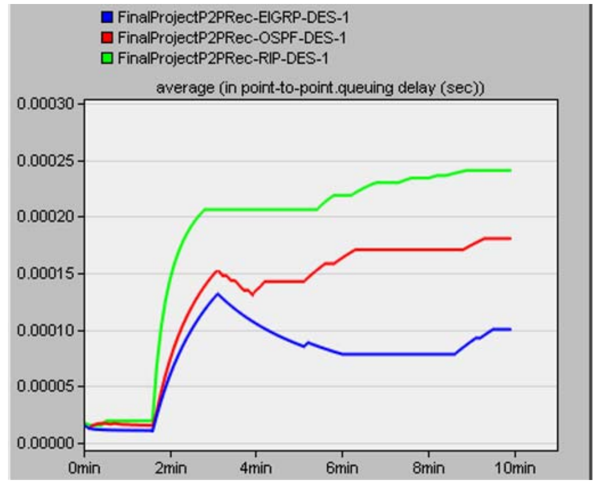

Figure 8. Average Queuing Delay from IP Cloud to subnet_northeast

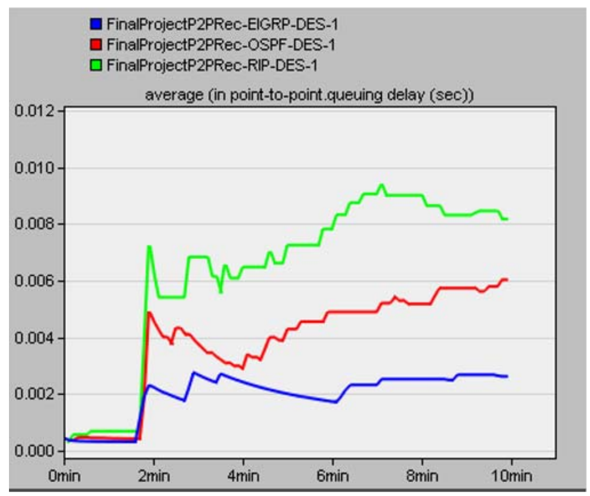

Figure 9. Average Queuing Delay of FTP Application within subnet_midatlantic

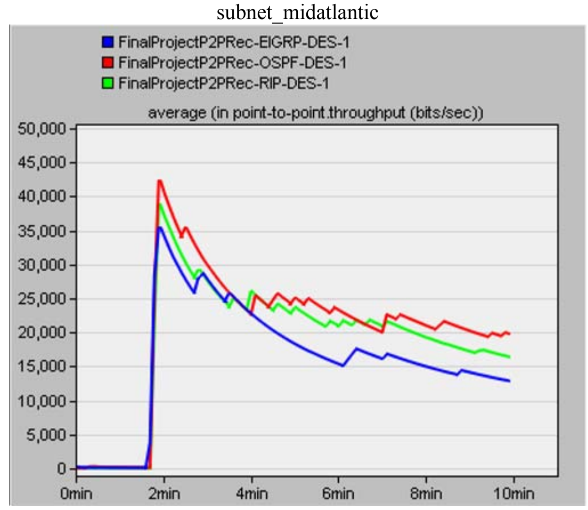

Figure 10. Average Throughput of FTP Application within subnet_midatlantic

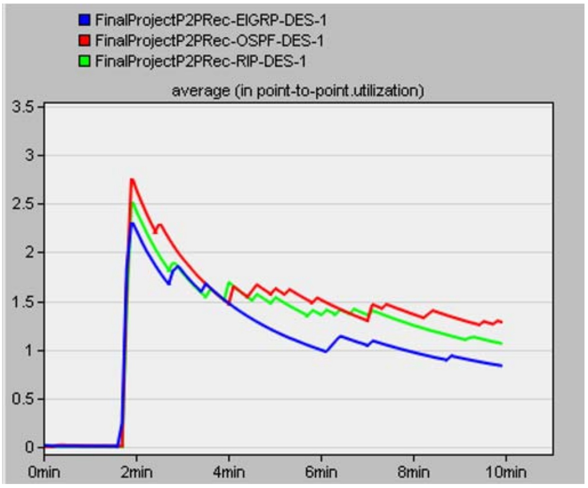

Figure 11. Average Link Utilization of FTP Application within subnet_midatlantic

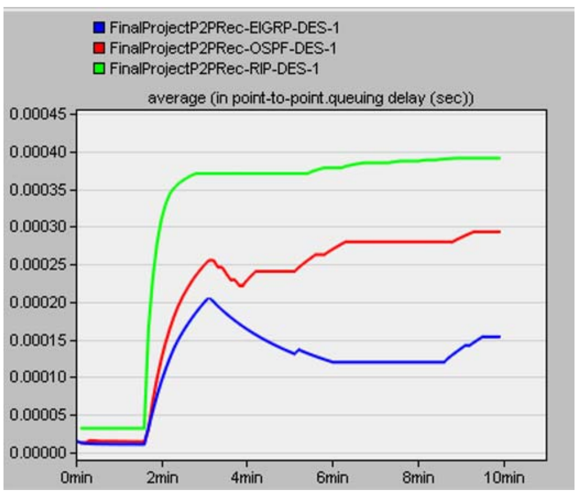

Figure 12. Average Queuing Delay of P2P Application within subnet_midatlantic

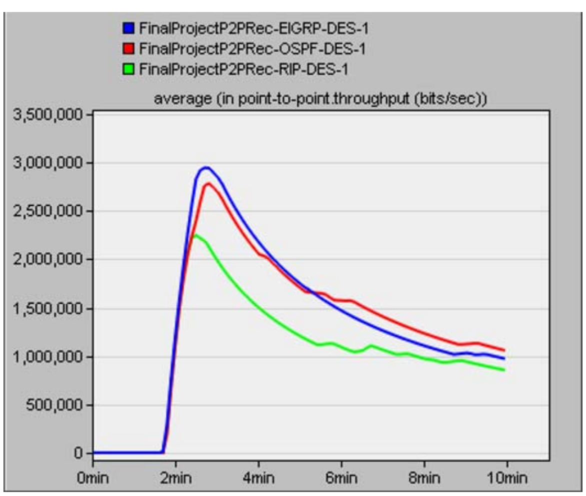

Figure 13. Average Throughput of P2P Application within subnet_midatlantic

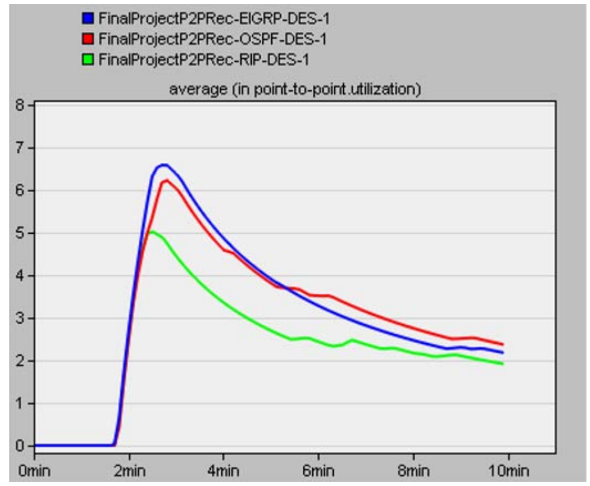

Figure 14. Average Link Utilization of P2P Application within subnet_midatlantic

As an aside, to analyze differences in Cisco hardware, the FTP application clients in subnet_northeast utilize a Cisco 7500 router, while the P2P clients and the subnet containing the application servers utilize a Cisco 4000 router. For the purposes of this work, this analysis will not be in depth.

The average queuing delay, average throughput, and average link utilization were analyzed from the FTP Application supporting server to the first hop Cisco 4000 router. As shown in figure 9, EIGRP provides the lowest queuing delay at ~.004 seconds less than OSPF and .006 seconds less than RIP. EIGRP also provided for a more consistent queuing delay than the exponential increase of RIP and OSPF. This correlates with the throughput and link utilization.

Figure 10 illustrates that EIGRP provided for the lowest throughput over the simulation compared with RIP and OSPF. At 6 minutes into the simulation, OSPF was providing ~10,000 bits/sec more throughput than EIGRP, and RIP providing ~7000 bits/sec more than EIGRP. Greater throughput results in greater queuing delays by OSPF and RIP. By 10 minutes into the simulation, EIGRP was ~7000 bits/sec lower than OSPF and ~5000 bits/sec lower than RIP.

Average link utilization for the FTP application in figure 11 correlates 1:1 with FTP throughput.

Lastly, the average queuing delay, average throughput, and average link utilization were analyzed for the P2P Application supporting server to the first hop Cisco 7500 Router. As shown in figure 12, EIGRP provided for the lowest queuing delay with ~.00025 seconds lower than RIP and ~.00015 seconds lower than OSPF.

Again, we observe in figure 13 that both OSPF and EIGRP provide comparable average throughput for the P2P Server. They provide ~100,000 bits/sec more than RIP.

Figure 14 illustrates that average link utilization correlates 1:1 with P2P average throughput.

V. Conclusion

In each scenario of the analyzed network, EIGRP provided the lowest average queuing delays. When analyzing application server average throughputs, OSPF provided the greatest amount of data transfer. Overall analysis showed RIP had a perfect packet routing, with no dropped packets. It is the recommendation after observing all results that the EIGRP protocol to be implemented for this setup. Queuing delay gains using EIGRP are more prominent than the throughput gained with the other routing protocols. RIP and OSPF may still be considered if packet drops are an important parameter with this application setup.

In the future work, a separate analysis of this work will be investigated to determine differences in throughput and delay using Cisco 7500 router upgrade. The Cisco 7500, as expected, can improve throughput by 1.5x and decrease queuing delays marginally.

VI. References

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