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SIMULATION-BASED EVALUATION OF LOAD BALANCING IMPLEMENTATION IN ENTERPRISE NETWORKS USING EIGRP AND OSPF ROUTING PROTOCOLS

Abstract. *The study investigates the load-balancing capabilities of the Enhanced Interior Gateway Routing Protocol (EIGRP) and Open Shortest Path First (OSPF) routing protocols in enterprise networks. It adopts a simulation-based approach to examine the implementation of load balancing within these networks. The study explores the protocols' features, metrics, and performance through simulations, focusing on Quality of Service (QoS) factors, including latency throughput, jitter, and packet loss. The results indicate that EIGRP and OSPF demonstrate comparable performance in effectively managing load-balanced networks. However, EIGRP exhibits slight advantages in terms of latency and throughput.*

With the rapid development of technology, the expansion of communication networks (CNs), such as the Internet, has become increasingly important. In modern communication networks, dynamic routing protocols are preferred over static routing methods. As networks evolve and grow, it is essential to implement a dynamic routing design that can seamlessly adapt to these changes, eliminating the need for manual intervention by network administrators [1]. Routing protocols such as Interior Gateway Protocols (IGPs) and Exterior Gateway Protocols (EGPs) play a critical role in these networks by facilitating the efficient exchange of routing information. Enhanced Interior Gateway Routing Protocol (EIGRP) and Open Shortest Path First (OSPF) are popular IGPs widely used in enterprise networks due to their efficiency and effectiveness.

EIGRP, a hybrid routing protocol, combines features of distance vector and link state routing protocols. It optimizes bandwidth usage and provides fast recovery from topology changes through the Diffusing Update Algorithm (DUAL). EIGRP supports load balancing and route summarization and is scalable to large networks through hierarchical routing and support for Variable Length Subnet Masking (VLSM) and Classless Inter-Domain Routing (CIDR). It provides additional security and versatility through authentication, protocol independence, route tagging, and redistribution [2,3]. On the other hand, OSPF is an open standard link-state routing protocol that efficiently disseminates routing information throughout an interconnected network. Routers within an OSPF network construct a topological map using Link State Advertisements (LSAs). The subsequent application of the Dijkstra algorithm helps to determine the shortest path to each network router. Known for its stability and scalability, OSPF can handle large networks and quickly adapt to changes in network topology. It includes features such as route summarization, authentication, and multiple hierarchical levels that help optimize overall network performance. The routing protocol uses a cost metric correlated to the link's bandwidth to select the optimal route for traffic [2,3]. Load balancing is vital for optimizing network performance and resource use. It enables traffic distribution across multiple paths, improving workload distribution, preventing congestion, and improving network efficiency. EIGRP supports equal-cost load balancing, which allows traffic to be distributed across multiple equal-cost paths. On the other hand, OSPF also supports equal-cost load balancing. Both protocols can achieve load balancing, but EIGRP supports unequal-cost load balancing, which allows traffic to be distributed across paths with different costs.

Investigating, evaluating, and improving routing methods are essential tasks in communication networks. Numerous studies are dedicated to addressing routing challenges by enhancing load-balancing processes and optimizing routing strategies to achieve more effective methods and improved Quality of Service in CNs. These research efforts aim to optimize network traffic distribution, improve resource utilization, and enhance overall network performance. These studies often involve the development of mathematical models and methodologies for routing technologies, proposing tailored improvements for various network architectures [4-7]. In addition, several publications [8,9] have extensively studied routing protocols, including OSPF, RIP, and EIGRP. These studies performed a comparative analysis of the protocols. They evaluated their performance in networks with different topologies and data transfer rates using simulation tools such as Riverbed Modeler and GNS3.

Under increasingly complex network conditions, administrators must carefully design and select routing protocols to achieve optimal performance. Key factors determining network performance effectiveness are throughput, latency, jitter, and packet loss. The selection and implementation of routing protocols significantly impact network performance. Therefore, this work aims to implement and configure the EIGRP and OSPF routing protocols in an enterprise network. The study specifically focuses on investigating the load-balancing mechanisms employed by both protocols.

A simulated laboratory environment is designed to investigate the performance of the proposed network model when implementing load balancing using the EIGRP and OSPF routing protocols. The environment simulates an enterprise network using virtual routers, switches, and servers. GNS3, a widely used network software tool, is used for device emulation. Virtual machines running Windows and Ubuntu servers are hosted using VirtualBox to enable the testing of various applications. Cisco IOS images are used to accurately replicate the behavior and features of Cisco devices, providing a cost-effective means to study and experiment with Cisco networking technologies. The lab's network topology is shown in Figure 1 below.

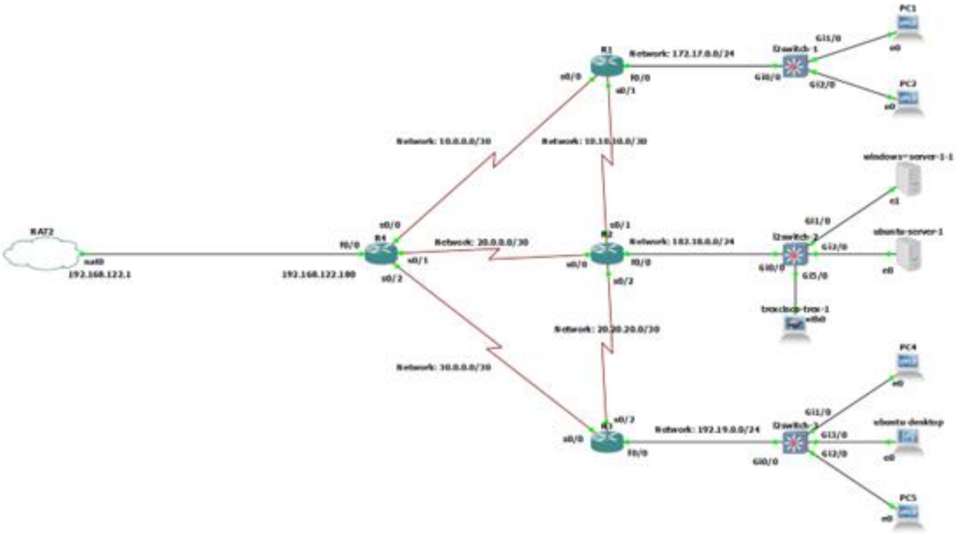

Figure 1 – The enterprise network topology

Two scenarios were implemented in the lab environment. The first scenario involved implementing the EIGRP routing protocol. Multiple routers were interconnected using different interfaces, with each router configured to use EIGRP. The second scenario implemented a single-area OSPF protocol. The routers were configured to participate in OSPF by specifying the process ID and enabling OSPF on the desired interfaces. Both routing protocols in this network topology use an equal-cost load balancing mechanism to increase scalability and flexibility. This approach ensures that traffic is distributed across multiple equal-cost links. The advantage of this setup is that if any path experiences problems or fails, traffic can be automatically rerouted through alternative paths that maintain the same bandwidth and delay.

The experimental study aimed to evaluate the QoS indicators, including latency, throughput, jitter, and packet loss, in pre-designed scenarios. Performance analysis was conducted using tools such as Wireshark, Cisco TRex, and Iperf, with ICMP and TCP packets generated and transmitted at various intervals.

Cisco TRex, an open-source tool developed by Cisco Systems, was employed to understand network traffic comprehensively. It dynamically generates high-volume, realistic network traffic, making it valuable for testing and validating network devices and applications [10]. With the ability to simulate numerous endpoints and support diverse network protocols, TRex's graphical interface, as illustrated in Figure 2 below, provides meaningful graphs and facilitates traffic management.

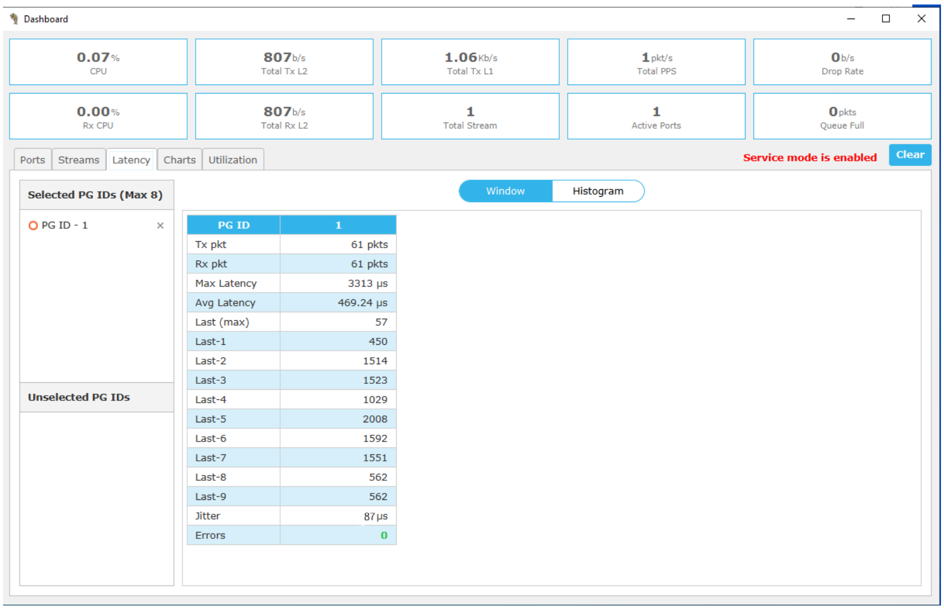

Figure 2 – Cisco TRex graphical interface

For bandwidth measurement, the open-source tool, Iperf, was utilized. Iperf is a speed test and network performance measurement tool that sends TCP and UDP traffic between hosts. Swiftly, Iperf establishes a client-server structure. In this case, the server, which is the Ubuntu server, listens for connections while both the client and the Ubuntu server generate traffic. This arrangement allows for the bandwidth calculation between the two entities. Packet loss is another crucial parameter that can be quantified using another tool, Wireshark. This process involves navigating the "Statistics" menu and selecting "Capture File Properties." Within the "Capture File Properties," relevant statistics related to the captured packets can be found. These include the total number of packets captured and displayed.

The numerical results indicated that EIGRP and OSPF performed nearly equally in load-balancing scenarios. EIGRP exhibited an average latency of 934 microseconds, while OSPF recorded an average latency of 1054 microseconds, indicating acceptable latency levels for both protocols in load-balanced networks.

Bandwidth measurements showed EIGRP achieving a throughput of 2.35 Mbps and OSPF achieving a slightly higher throughput of 2.4 Mbps, demonstrating effective utilization of network resources by both protocols. Further analysis revealed EIGRP achieving a throughput rate of 1.35 Mbits/sec, slightly higher than OSPF's rate of 1.1 Mbits/sec, indicating consistent data delivery rates.

Jitter, a measure of the variation in packet delay, was evaluated, with EIGRP showing a jitter value of 90 microseconds and OSPF showing a slightly higher value of 98 microseconds. Both protocols demonstrated the ability to handle load-balancing situations while maintaining relatively stable packet delay characteristics. Packet loss measurements showed EIGRP with a loss rate of 4.82% and OSPF with a slightly lower rate of 4%, demonstrating reasonable packet delivery reliability in load-balanced networks for both protocols.

Overall, the evaluation of these QoS metrics demonstrated the comparable performance of EIGRP and OSPF in equal load-balanced network scenarios. Both routing protocols effectively handled load balancing while maintaining acceptable latency, bandwidth utilization, throughput, and packet loss characteristics. These results contribute to a deeper understanding of the QoS performance of EIGRP and OSPF in load-balanced environments, helping network administrators and researchers make informed decisions about selecting routing protocols for specific network configurations.

In conclusion, this study has conducted a comprehensive investigation and comparative analysis of the EIGRP and OSPF routing protocols, contributing to a thorough understanding of their features, metrics, and load-balancing mechanisms. Simulations performed in enterprise network scenarios have provided practical insights into the implementation and effectiveness of EIGRP and OSPF in load balancing. These simulations have enhanced our understanding of the protocols' capabilities and limitations in real-world network environments. In addition, a comparative evaluation of Quality of Service (QoS) performance was conducted, considering metrics such as latency, bandwidth, throughput, jitter, and packet loss. The analysis revealed that EIGRP and OSPF perform similarly when managing load-balanced networks. However, EIGRP exhibits slightly better latency and throughput performance than OSPF, indicating potential advantages in specific network contexts.

Based on the research findings, it is recommended that future studies address the potential enhancement of existing flow-based mathematical models of these routing protocols and the investigation of unequal-cost load balancing mechanisms of the EIGRP protocol.

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