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RESEARCH ARTICLE **Open Access**

Analysis of Networking Tools Using Cisco Packet Tracer (CPT)

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Abstract: This study aims to evaluate the performance and effectiveness of network devices using Cisco Packet Tracer (CPT) as a simulation tool. CPT is a widely utilized network simulation software, commonly employed for designing and testing network configurations prior to real-world implementation. This research investigates various network topologies to assess the performance of devices such as routers, switches, and end devices. The research methodology encompasses the design of network scenarios, device configuration, and testing of various network protocols. The analysis reveals that CPT is capable of accurately replicating most functions and behaviors of network devices, providing a clear depiction of network performance under different conditions. The findings suggest that CPT serves as an effective and efficient tool for both educational purposes and network planning, despite certain limitations in features and realism when compared to actual hardware. This study is expected to offer valuable insights for professionals and academics in understanding and optimizing network design before deployment in real-world environments.

Keywords: Cisco Packet Tracer; Network Simulation; Network Device Analysis.

1. Introduction

In today's digital landscape, computer networks have become essential components across various sectors, including business, education, and critical aspects of daily life. The demand for reliable and efficient network infrastructure is crucial to ensure the rapid and secure transmission of data, which supports productivity and innovation within these sectors. As highlighted by Hovik and Hanssen (2014), effective network management is not merely a technical requirement but a key factor in organizational success, enabling efficient coordination in increasingly complex environments [1]. The intricate nature of modern networks, with their diverse components and protocols, requires sophisticated management strategies to maintain operational efficiency.

As network environments become more complex, the need for advanced management approaches grows. Research indicates that well-designed network management strategies can significantly enhance interaction quality and operational efficiency, which are vital in today's interconnected systems [2]. However, designing and managing such networks requires a deep understanding of various tools and protocols. For example, Software-Defined Networking (SDN) has emerged as an innovative solution, enabling the separation of control and data planes. This separation allows for greater flexibility in network management, improving visibility and enabling dynamic optimization of resources, as well as the implementation of stronger security policies to meet the evolving challenges of modern network environments [3][4].

Given these developments, it is essential for network professionals to continually update their knowledge and skills, particularly regarding the latest tools and techniques in network management. Cisco Packet Tracer (CPT) is one such tool that has gained widespread popularity in both educational and professional contexts. CPT is a network simulation software that allows users to create virtual network topologies, configure devices, and simulate network traffic without the need for physical hardware. According to Kusuma (2020), CPT's ability to replicate real-world network environments makes it an invaluable resource for both professionals and students who need to test and validate network designs [5]. CPT provides an interactive platform for students to grasp fundamental networking concepts, such as IP addressing, routing, and switching. Simargolang *et al.* (2021) emphasize that simulation tools like CPT play a crucial role in enhancing students' understanding of complex networking topics, offering a practical approach to learning that is both effective and engaging [6]. Moreover, CPT allows users to experiment freely without the risk of damaging physical hardware, promoting exploration and innovation, which are critical aspects of learning and professional development [3].

For professionals, CPT serves as a powerful tool for testing new configurations or planning changes in network infrastructure. CPT's advanced simulation features enable detailed analysis of network performance, allowing users to identify potential issues before implementing changes in a live environment [7][8]. This capability is particularly important in managing complex networks, where configuration errors can lead to significant downtime and financial losses [9]. Additionally, Maulana and Mariam (2021) highlight that CPT supports collaborative efforts by enabling users to share projects and work together on network simulations [8], fostering a cooperative environment that benefits both individual skill development and team-based problem-solving.

This research aims to analyze network devices using CPT. By utilizing this software, various network scenarios will be created and tested to evaluate the performance of devices such as routers, switches, and end devices. The study will also examine how CPT can assist in refining network design before real-world implementation. The primary objective of this research is to identify the strengths and limitations of CPT in simulating network environments and to assess how well the tool can replicate the functions and behaviors of actual network devices. This study seeks to offer valuable contributions to both professionals and academics in the field of computer networking, ultimately leading to more effective and efficient network design and management.

2. Research Method

The research methodology for designing and analyzing computer networks involves several critical steps that must be systematically executed to achieve valid and reliable results. These steps include designing network scenarios, configuring devices, testing network protocols, and conducting performance analysis.

2.1 Network Scenario Design

Designing network scenarios is the foundational step in this research. The scenarios must encompass various elements, such as network topology, the types of devices used, and the protocols that will be applied.

Prior research has demonstrated that well-structured design can significantly influence network performance, particularly in terms of management and analysis [10]. Therefore, it is crucial to consider factors such as user requirements and research objectives when designing these scenarios. This step ensures that the scenarios are realistic and align with the goals of the study, providing a solid basis for subsequent stages of the research.

2.2 Device Configuration

Following the design of the network scenarios, the next step involves configuring the devices, including routers, switches, and end devices. This configuration must be carried out according to the predefined scenarios, paying close attention to the relevant parameters for each device. Research indicates that proper configuration can enhance network efficiency and effectiveness while minimizing potential issues during operation [11]. Moreover, the use of simulation tools such as Cisco Packet Tracer (CPT) facilitates this process by allowing users to test configurations before implementing them in a real environment. This step is critical in ensuring that the network operates as intended and that any potential configuration issues are addressed in a controlled, simulated environment [12].

2.3 Network Protocol Testing

Once the devices are configured, the next phase involves testing the network protocols that have been implemented. The primary objective of this testing is to verify that the protocols function as expected and can effectively manage network traffic. The testing methodology may include analyzing protocol performance under different conditions, as well as measuring latency and throughput [13]. Comprehensive testing is essential for identifying potential problems and improving overall network performance [14]. This step is vital for ensuring that the network protocols are robust enough to handle real-world network demands and that they perform efficiently under various operational scenarios.

2.4 Performance Analysis

The final step in this methodology is the performance analysis of the network. This analysis involves measuring various performance metrics such as data transfer speed, latency, and packet loss rate. By utilizing appropriate analytical tools, researchers can evaluate the effectiveness of the configurations and protocols applied, and identify areas that require improvement [15][16]. The results of this analysis provide valuable insights into the network's performance and can guide future network development efforts. Additionally, these findings assist in making informed decisions regarding network management and optimization [17].

3. Result and Discussion

3.1 Results

3.1.1 Network Scenario Design

To establish an effective and efficient computer laboratory for network testing and experimentation, three different network topologies were designed and evaluated. These topologies—Bus, Mesh, and Star—were selected to determine which best suits the laboratory's requirements based on various performance criteria.

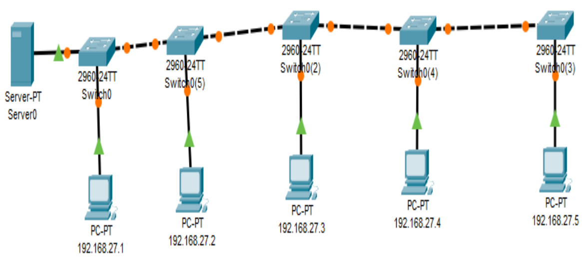

Figure 1. Bus Topology

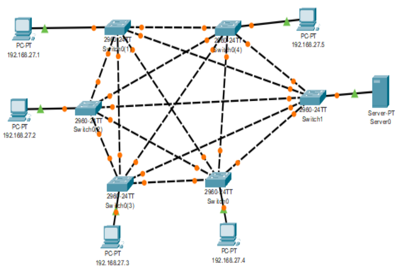

Figure 2. Mesh Topology

The Bus topology (see Figure 1) is characterized by a simple network structure where all devices are connected to a single central cable, known as the bus. This configuration includes client computers, switches, and routers, all directly linked to the bus. The main advantage of the Bus topology lies in its simplicity and cost-effectiveness, making it relatively easy to configure. However, it is highly vulnerable to disruptions because a failure at any point along the bus affects the entire network, potentially leading to significant downtime and degraded performance as the number of connected devices increases. The Mesh topology (see Figure 2) offers a more complex structure, where each device is directly connected to every other device in the network. This topology provides extremely reliable and redundant connections, as there are multiple paths for data to travel. If one path fails, another can take over, ensuring continuous network operation. The components of a Mesh network include multiple interconnections between devices, which significantly enhances reliability. However, this comes with increased costs for implementation and maintenance, as well as greater complexity in configuration and management due to the extensive number of connections that must be maintained.

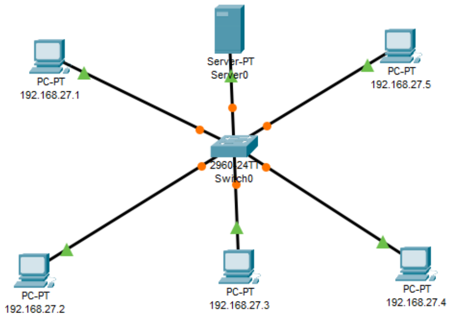

Figure 3. Star Topology

The Star topology (see Figure 3) strikes a balance between simplicity and reliability. In this configuration, all devices are connected to a single central hub, such as a switch or hub. This central hub manages the network's communication, simplifying troubleshooting and expansion. The Star topology is advantageous because a failure in one connection does not affect the rest of the network, making it easier to isolate and resolve issues. However, the network's dependence on the central hub means that if the hub fails, the entire network can go down. Additionally, the Star topology typically requires more cabling than the Bus topology, leading to higher installation costs. After designing these topologies, the next step was to configure the network devices according to the specific requirements of each scenario.

3.1.2 Device Configuration

Following the design phase, the network devices were configured based on the scenarios previously outlined. This involved configuring essential elements such as IP addressing, routing protocols, VLANs, and other necessary network settings to ensure optimal performance.

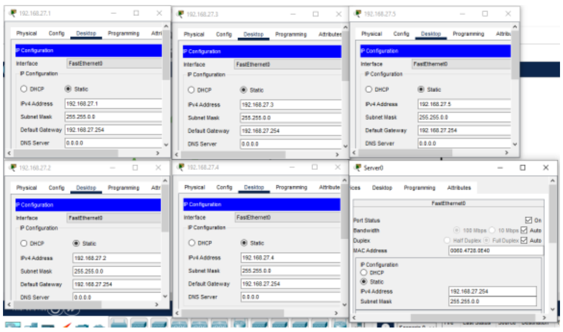

Figure 4. Bus Topology Configuration

For the Bus topology (see Figure 4), the configuration process involved assigning IP addresses to all devices and setting up the necessary routing protocols to facilitate proper communication across the network. Although the configuration was relatively straightforward due to the simplicity of the topology, care was taken to ensure that the central bus, as the critical point of failure, was adequately secured to minimize potential disruptions.

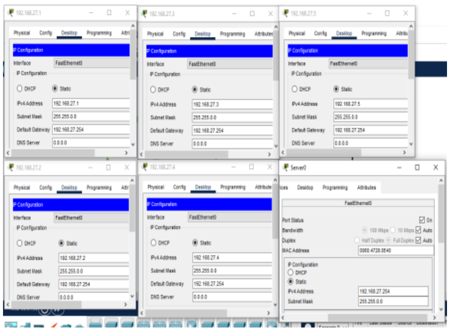

Figure 5. Mesh Topology Configuration

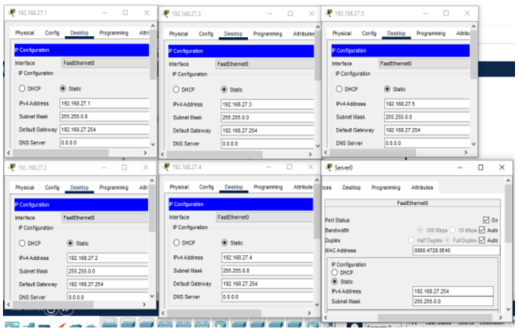

Figure 6. Star Topology Configuration

In the Mesh topology (see Figure 5), the configuration was notably more complex. Each device required multiple connections to communicate with every other device in the network. This requires careful planning of IP addresses and routing protocols to prevent conflicts and ensure efficient data flow. VLANs were also implemented to segment the network, enhancing management capabilities and security. For the Star topology (see Figure 6), configuration is focused on the central hub and the connections to each device. IP addresses and routing protocols were set up to enable seamless communication through the hub. VLANs were configured to manage network traffic more effectively and to provide additional layers of security. Ensuring that the central hub can handle the expected network traffic without becoming a bottleneck is critical in this configuration.

3.1.3 Network Protocol Testing

After configuring the network devices, the next step was to test various network protocols within the simulated environment to assess their performance and behavior under different conditions. The protocols tested included sending messages between devices and conducting ping tests to measure response times and data integrity.

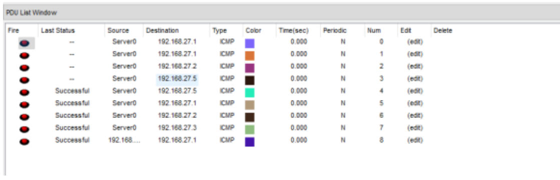

Figure 7. Send Message Test Results Bus Topology

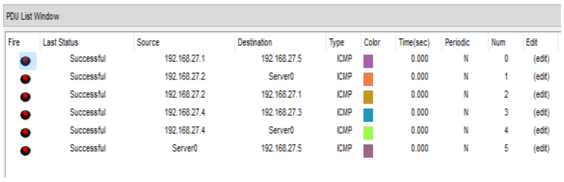

Figure 8. Mesh Topology Send Message Test Results

In the Bus topology (see Figure 7), testing revealed that while the network could handle basic communication tasks effectively, an increase in the number of devices or data load significantly impacted performance, resulting in increased latency and potential data loss. This finding confirmed the Bus topology's susceptibility to performance degradation as network demands grow. The Mesh topology (see Figure 8) demonstrated high reliability and consistent performance, even under heavy data loads. The redundancy inherent in the topology allowed for continuous communication despite simulated failures in individual connections. However, this reliability comes with increased complexity and required robust management tools to handle the numerous connections.

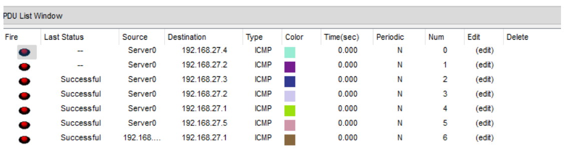

Figure 9. Test Results for Sending Messages on Star Topology

Testing of the Star topology (see Figure 9) showed that it offered a good balance between reliability and simplicity. The network maintained stable communications, and failures in individual connections did not affect overall network performance. However, the tests highlighted the network's critical dependence on the central hub, which, if compromised, would lead to total network failure.

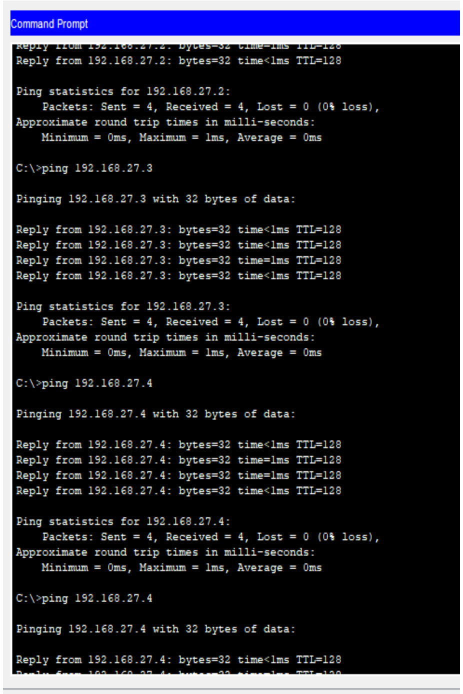

Figure 10. Ping Results on One of The Network Topologies

The ping tests conducted on each topology (see Figure 10) further illustrate the differences in response times and data transmission efficiency across the three topologies.

3.4 Performance Analysis

The final step involved a comprehensive performance analysis of the configured network devices within the simulated environment. Key performance metrics such as latency, throughput, and packet loss were monitored and analyzed. The analysis of the Bus topology indicated that it is best suited for smaller networks with a limited number of devices. Its simplicity and low cost make it an economical choice for environments with minimal network demands. However, the Bus topology's vulnerability to a single point of failure and limited scalability were significant drawbacks, especially in larger or more dynamic network environments. For the Star topology, the analysis shows that it provides a reliable and easy-to-manage solution for medium-sized networks. The ability to isolate failures to individual connections makes troubleshooting straightforward, and the network's overall stability is maintained. However, the dependence on a central hub and the need for more cabling can increase both costs and complexity compared to the Bus topology. The Mesh topology outperformed the other two topologies in terms of reliability and fault tolerance. The ability to reroute traffic in case of a failure makes it ideal for networks requiring high availability and performance. Nevertheless, the complexity of implementing and managing a Mesh topology, along with the higher costs associated with its deployment, make it more suitable for environments where these factors are justified by the network's critical role. This analysis underscores the importance of selecting the appropriate topology based on specific network requirements, including cost, complexity, scalability, and reliability. Each topology has distinct advantages and limitations that must be carefully considered to ensure optimal network performance in various scenarios.

3.2 Discussion

The results from the network simulations and performance analysis provide critical insights into the suitability of different network topologies—Bus, Mesh, and Star—for varying scenarios in a computer laboratory setting. Each topology presents unique strengths and weaknesses that must be considered when designing or optimizing a network infrastructure. The Bus topology, as the simplest and most cost-effective network design, demonstrated several key advantages in scenarios with limited network demands. Its straightforward structure, where all devices connect to a single central cable, makes it particularly attractive for small-scale implementations where ease of configuration and minimal hardware costs are priorities. However, the Bus topology's most significant limitation is its vulnerability to disruptions. As the analysis highlighted, a failure in the central bus affects the entire network, leading to potential downtime and reduced performance, especially as the network expands. This characteristic makes the Bus topology less suitable for larger networks or environments where high availability is critical. The inherent limitation of scalability further restricts its application to scenarios where the network size remains small and static.

The Mesh topology exhibited the highest level of reliability and redundancy among the topologies tested. By connecting each device directly to every other device, the Mesh network provides multiple paths for data transmission, ensuring that communication can continue even if one or more connections fail. This redundancy is particularly beneficial in environments that demand high availability, such as critical infrastructure or large-scale networks where uptime is essential. The performance tests confirmed that the Mesh topology can handle substantial data loads with minimal latency and packet loss, making it ideal for scenarios that require robust network performance under heavy usage. However, the Mesh topology's complexity and cost are significant drawbacks. The extensive cabling and configuration required to establish direct connections between all devices not only increase installation costs but also complicate network management. The complexity of maintaining such a network means that it requires more sophisticated management tools and expertise, which may not be justified in smaller or less critical network environments. Therefore, while the Mesh topology offers superior performance and reliability, it is best suited for scenarios where these benefits outweigh the associated costs and complexities.

The Star topology offers a balance between the simplicity of the Bus topology and the reliability of the Mesh topology. In a Star network, all devices are connected to a central hub, which manages the communication between devices. This setup makes the Star topology relatively easy to configure and manage, especially in medium-sized networks where the number of devices and the network complexity are moderate. One of the main strengths of the Star topology is its resilience to individual connection failures. If a single device or its connection to the hub fails, the rest of the network remains unaffected, which simplifies troubleshooting and maintenance. Additionally, the Star topology supports easy scalability; new devices can be added to the network without disrupting the existing connections. However, the central hub remains a potential single point of failure. If the hub fails, the entire network goes down, which underscores the importance of ensuring that the hub is robust and reliable. The performance analysis of the Star topology indicated that it provides a good compromise between cost, complexity, and reliability, making it a versatile choice for a wide range of network environments. It is particularly well-suited for scenarios where ease of management and moderate scalability are important, but where the risks associated with a single point of failure can be mitigated through the use of reliable, high-performance hub devices.

The findings from this study emphasize the importance of selecting a network topology that aligns with the specific needs of the environment in which it will be deployed. The Bus topology, while economical and simple, is best reserved for small, low-demand networks where budget constraints are a primary concern. The Star topology offers a practical middle ground, providing a balance of reliability, manageability, and scalability for medium-sized networks. On the other hand, the Mesh topology, with its superior fault tolerance and performance, is ideal for critical networks where uptime and redundancy are paramount, despite its higher costs and complexity. When designing a network, it is crucial to consider not only the current needs but also potential future growth and the importance of network availability. The choice of topology should reflect these considerations, ensuring that the network can meet both present and future demands effectively. While no single topology is universally superior, the decision should be guided by a thorough understanding of the specific requirements and constraints of the intended network environment. The insights gained from this analysis can inform network design decisions, helping to optimize performance, reliability, and cost-effectiveness based on the unique characteristics of each topology.

4. Related Work

This study concludes that Cisco Packet Tracer (CPT) is a highly effective tool for network simulation, education, and planning. Previous research has consistently demonstrated that simulation tools like CPT significantly enhance the understanding of networking concepts among both students and professionals [18][19]. Furthermore, CPT's ability to facilitate the design and testing of various network topologies at a relatively low cost makes it particularly suitable for educational and training environments [20]. The analysis and implementation of different network topologies—bus, star, and mesh—have been thoroughly examined in existing studies, each revealing distinct advantages and limitations. For networks with limited budgets and smaller scale requirements, the bus topology is often favored due to its straightforward design and low implementation costs. This topology is ideal for scenarios where network size is minimal and the need for advanced performance and redundancy is not critical.

In contrast, the star topology is recommended for networks requiring greater stability and ease of maintenance. This topology supports simpler management and reduces the risk of a total network failure, as individual device failures do not impact the entire system [21]. The centralized configuration of the star topology allows for easier troubleshooting and expansion, making it a popular choice for medium-sized networks where a balance between performance and manageability is necessary. For larger networks where high reliability and fault tolerance are essential, the mesh topology is regarded as the most appropriate choice. This topology offers enhanced redundancy and can manage node failures without disrupting overall network operations [22]. Studies show that the mesh topology improves network performance in situations where reliability is crucial, such as in Internet of Things (IoT) applications and sensor networks [23]. The mesh network's capability to reroute traffic through alternative paths when failures occur makes it especially suitable for critical applications where continuous uptime is required. Thus, selecting the appropriate network topology depends heavily on the specific needs of the application, budget constraints, and available resources. This study provides important insights for professionals and academics in the design and implementation of efficient and effective networks. The findings presented here complement existing literature by offering practical considerations and emphasizing the importance of aligning network design with the operational requirements and limitations of the intended environment.

5. Conclusion and Recommendations

This study concludes that Cisco Packet Tracer (CPT) is an effective and efficient tool for network simulation, education, and planning. Based on the analysis of the three network topologies, each topology presents distinct advantages depending on the specific requirements and constraints of the network. For networks with limited budgets and smaller-scale usage, the bus topology is a practical choice due to its simplicity and low implementation costs. This topology is best suited for environments where the network demands are minimal, and there is no critical need for advanced performance or redundancy. In cases where stability and ease of maintenance are more critical, the star topology proves to be an optimal choice. Its centralized structure facilitates easier troubleshooting and network expansion, making it ideal for medium-sized networks that require a balance between performance and manageability. For larger networks that demand high reliability and fault tolerance, the mesh topology is the most suitable option. This topology provides superior redundancy and can maintain network operations even in the event of node failures, making it the best choice for environments where continuous uptime and robust performance are essential.The insights gained from this research are expected to be valuable for both professionals and academics in the field of computer networking. By aligning the choice of network topology with the specific needs of the network environment, stakeholders can optimize network performance, reliability, and cost-effectiveness. It is recommended that future studies continue to explore and refine the application of these topologies in different scenarios to further enhance the practical use of CPT in network design and education.

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