PAT vs NAT IMPLEMENTATION LAB

A CAPSTONE PROJECT REPORT

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DECLARATION

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This is to certify that the Capstone Project entitled "**PAT vs NAT IMPLEMENTATION LAB**" has been carried out by **Prattipati Hasini 192525231, Samrakshini.G 192511172, Talari Vishnuvardhan 192572091** under the supervision of **Dr RAJARAM.P** and is submitted in partial fulfilment of the requirements for the current semester of the **AIML(B.TECH), CSE (B.E), CSE AI (B.E)** program at Saveetha Institute of Medical and Technical Sciences, Chennai.

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ABSTRACT

As digital systems continue to expand in complexity and scale, efficient management of network resources particularly IP addresses—has become a cornerstone of modern IT infrastructure. The global shortage of IPv4 addresses has made it necessary to adopt technologies that enable private networks to interact with the public internet, without requiring a unique public IP for each device. This situation is especially critical in institutional, enterprise, or campus networks, where multiple users and devices require simultaneous internet access through limited public IP space   The core problem addressed is the shortage of public IPv4 addresses due to the massive growth of internet-connected devices. NAT and PAT are essential techniques that enable multiple internal (private) clients to access external networks using fewer public IP addresses.

Keywords: NAT, PAT, IPv4 address shortage, private IP, public IP, Network address translation, Port address translation, network scalability

CHAPTER-1 INTRODUCTION

1.1 Background Information:

In modern networking, IP address management is a crucial component to ensure efficient communication between devices across local and global networks. With the limited number of IPv4 addresses, Network Address Translation (NAT) and Port Address Translation (PAT) have emerged as critical technologies that enable internal hosts to access external networks using a limited number of public IP addresses.

This project aims to compare NAT and PAT by simulating a network with 10 clients and a single router, analyzing how each technique handles IP and port mapping, connectivity, and overall efficiency. Through static and dynamic NAT configurations, and PAT mechanisms, this project offers a detailed view of address translation behavior in a practical environment.

1.2 Significance:

- Real-World Relevance: IPv4 exhaustion is a global issue. Network address translation and Port address translation offer practical solutions still widely used in modern networks
- Builds Practical Skills- It helps to understand hands-on experience configuring routers, mapping ports, and testing real-time connectivity.
- Informs Network Design - The project helps in selecting the right translation method based on IP availability and scalability needs.
- Standards-Based Approach- Implements RFC 1918 and RFC 3022, reinforcing the use of industry-aligned networking practices.
- Sharpens Troubleshooting Skills- Analyzing port tables and solving connectivity issues develops logical thinking and debugging skills.
- Prepares for Advanced Learning- It Lays a foundation for deeper topics like IPv6, VPNs,
- firewalls.

1.3 Objective:

- To implement Static NAT, Dynamic NAT, and PAT and NAT in a simulated environment .
- To evaluate the efficiency and behavior of NAT and PAT under the same network load.
- To create and analyze port mapping tables for NAT and PAT scenarios.
- To assess connectivity success between internal clients and external network.

1.4 Scope:

- This project is limited to the simulation and analysis of Network Address Translation (NAT) and Port Address Translation (PAT) techniques within a small-scale network environment. The scope includes configuring a single router connected to internal clients using Cisco Packet Tracer. The router will be alternately set up with Static NAT, Dynamic NAT, and PAT. Each configuration will be tested for connectivity, port usage, and efficiency of IP address allocation.
- The study focuses on the behavioral differences between NAT and PAT, especially how each handles multiple client requests to the external network. A key output of this scope is the comparison of port mapping tables under each scenario, and evaluating the performance in terms of successful translation and connectivity. Standard networking practices and RFC guidelines are followed, ensuring the configurations reflect real-world use cases.
- This project does not involve real physical hardware setup or live internet connectivity. It also excludes advanced routing protocols (like OSPF or BGP), security mechanisms (like firewalls), or IPv6 translation techniques. The aim is to keep the focus tightly on IPv4-based NAT and PAT for academic clarity and hands-on skill development.

CHAPTER-2 PROBLEM IDENTIFICATION AND ANALYSIS

2.1 Description of the Problem:

The increasing number of devices connecting to the internet has led to a critical shortage of IPv4 addresses. Organizations often lack enough public IPs to assign to all their internal devices. This makes it difficult to ensure seamless external connectivity while maintaining security and address efficiency.

To solve this, network administrators rely on translation techniques like Network address translation and Port address translation. However, many learners and even professionals struggle to understand how these methods differ in real-time network behavior, performance, and configuration.

This project addresses the problem by simulating both techniques in a controlled environment to observe and compare their impact on connectivity and resource usage. The key problem this project investigates is : "Which address translation technique—NAT (Static/Dynamic) or PAT—is more efficient and scalable for a network with multiple clients (10 clients) sharing a single router in terms of connectivity and port translation behavior?"

2.2 Evidence of the Problem:

IPv4 supports approximately 4.3 billion unique addresses, but due to explosive internet growth, these have been largely exhausted. Organizations today often use private IP address ranges defined by RFC 1918, which are not routable on the public internet. Without a translation mechanism, internal devices cannot access external resources.

Reports from network administrators, ISPs, and IT professionals consistently highlight issues related to IP scarcity and the need for efficient address translation. Moreover, academic institutions and certification programs emphasize NAT and PAT as essential skills, proving their continued relevance. This practical gap between theory and application further justifies the need for this comparative analysis of NAT and PAT in a simulated environment.

2.3 Working Principle:

The system operates through three integrated modules:

MODULE 1: NAT [NETWORK ADDRESS TRANSLATION]

1. This module focuses on simulating Static and Dynamic NAT in a private network setup using Cisco Packet Tracer. It demonstrates how private IP addresses are mapped to public IP addresses either one-to-one (Static NAT) or from a defined pool (Dynamic NAT).

2. The router configuration involves defining inside local and inside global address mappings. Static NAT is used for devices requiring permanent access, while Dynamic NAT selects public IPs from a pool based on availability.

3. The behaviour of NAT is observed by initiating outbound requests from internal clients and tracking IP translation using simulation tools. NAT tables are monitored to view mappings and understand how IP addresses change when data crosses the network boundary.

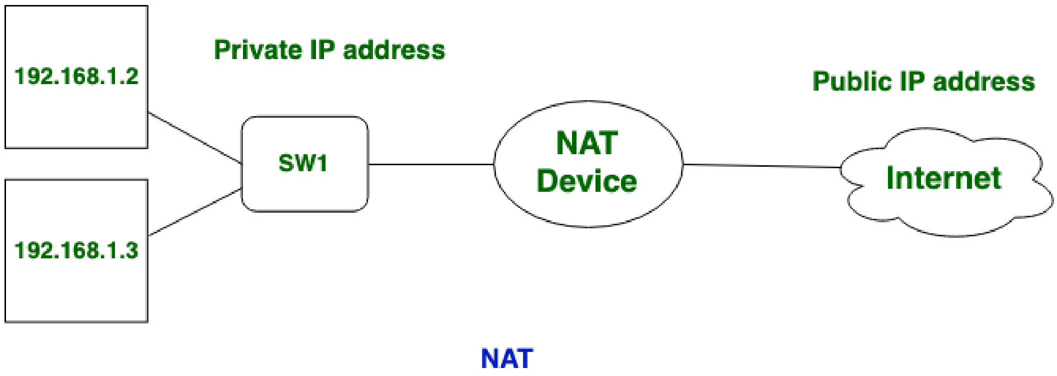
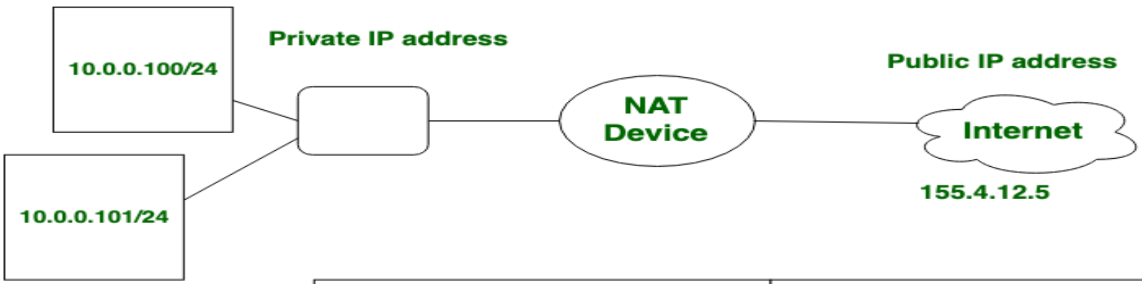


Figure 2.1 : NAT Network

MODULE 2: PAT [PORT ADDRESS TRANSLATION] OVERLOADED NAT

1. This module explores the implementation of PAT, where multiple clients share a single public IP address. PAT is configured to dynamically assign unique port numbers to differentiate traffic from various devices.

2. Simulation includes testing external website access from all clients simultaneously. PAT tables are observed to monitor port mapping and ensure each internal device maintains a distinct connection to external servers.



private ip address : Port	public ip address : Port
10.0.0.100:1055	155.4.12.1:1055
10.0.0.101:1056	155.4.12.1:1056

PAT

Figure 2.2 : PAT Network

3. The system captures port numbers, source IPs, and destination IPs to compare with NAT behavior. Unlike NAT, PAT significantly improves scalability by maximizing the use of a single public IP.

4. The performance is evaluated by examining translation efficiency, packet delivery success, and resource usage. This highlights PAT's advantage in environments with limited public IPs and high client volume.

MODULE 3: TESTING AND VERIFICATION MODULE

1. This module integrates both NAT and PAT into a single test bed for real-time simulation using Cisco Packet Tracer. It enables users to compare the behavior, performance, and limitations of both translation techniques under identical conditions.

2. Tools like the simulation tab and real-time monitoring are used to verify translation tables, ping tests, and external connectivity

3. This module helps learners and professionals understand translation behavior visually and interactively, bridging the gap between theoretical concepts and real-world application. It provides a clear foundation for network troubleshooting and protocol comparison.

2.4 Supporting Data/Research:

- IETF and RFC 1918 documentation explain that due to the exhaustion of IPv4 addresses, organizations are required to use private IP ranges that cannot directly communicate over the public internet. Hence, address translation becomes essential for connectivity.
- Cisco's whitepapers and ComPTIA Network+ learning materials emphasize NAT and PAT as core topics for network professionals, supporting their educational relevance and implementation in industry scenarios.
- According to Cisco's IT Essentials (2022), PAT is the most commonly deployed NAT variant in enterprise networks due to its scalability. It allows hundreds of internal hosts to access the internet through a single IP using different port numbers.
- A research paper from IEEE (2021) comparing Static NAT and PAT in a university campus simulation found that PAT provided higher throughput, better IP utilization, and lower latency, particularly when external connections were high.

CHAPTER-3 SOLUTION DESIGN AND IMPLEMENTATION

3.1 Development and Design Process:

The development of the NAT vs PAT Implementation Framework was structured into three core modules:

1. NAT Module – Static and Dynamic NAT Simulation
2. PAT Module – Port Address Translation Simulation
3. Testing and Verification Module Using Cisco Packet Tracer

The process began with designing a controlled network environment using Cisco Packet Tracer. A simple topology was built where client systems were connected to a single router. Two scenarios were created—one configured with Static/Dynamic NAT, and another with PAT. In the first module, NAT was configured to assign public IP addresses to internal devices. Static NAT mapped fixed private-public pairs, while Dynamic NAT allocated public IPs from a pool. Simulation mode was used to trace packet flow and translation tables in real time.

In the second module, PAT was implemented on the same topology. Here, a single public IP address was shared among the clients, with each translation differentiated by unique port numbers. Configuration included assigning the overload keyword in NAT settings, enabling PAT. The simulation verified simultaneous internet access, port translation, and address mapping. Packet Tracer's simulation panel was used to observe how internal requests were assigned specific port numbers.

The third module focused on comparative analysis and real-time verification. Tests were conducted using the Simulation and This modular and simulation-driven design helps

Each module was built and tested independently, then combined to analyze which method—NAT or PAT—is more efficient and scalable. Cisco Packet Tracer was selected as it enables easy IP assignment, real-time visualization, and step-by-step simulation. in practical networks.

3.2 Tools and Technologies Used:

- Cisco Packet Tracer – Primary simulation tool used to design, configure, and test NAT and PAT topologies
- IP Addressing Tools – For subnetting, assigning private IPs to clients, and managing public IP mappings
- Address Translation Tables – Packet Tracer's built-in NAT/PAT tables for real-time monitoring
- Simulation and Real-Time Modes – Used to monitor packet flow, address replacement, and connectivity
- Wireshark (Optional Extension) – For packet capture and deeper inspection of IP/port translation behaviour
- Manual Testing Sheets – To record observations of packet movement, port assignments, and connectivity status

- Static vs Dynamic NAT Pools – Configuration for one-to-one mapping (Static) and pool-based mapping (Dynamic)
- PAT Overload Configuration – Router command used to simulate PAT using a single public IP with port mapping
- Topology Design Tools – Graphical workspace within Packet Tracer for connecting clients, switches, and routers

These tools were selected for their accessibility, educational relevance, and alignment with industry-standard simulation practices. The environment allowed for iterative testing and accurate observation of real-world NAT/PAT behavior.

3.3 Solution Overview:

The NAT vs PAT Implementation Lab project aims to simulate and compare how Network Address Translation (Static and Dynamic) and Port Address Translation (PAT) behave under a network setup. The framework tests how each translation technique handles connectivity, resource usage, and scalability

1.NAT Module – Static and Dynamic NAT: NAT was configured to translate private IPs to public IPs.

Static NAT mapped internal IPs to dedicated public IPs.

Dynamic NAT used a public IP pool to assign temporary external addresses.

IP address translations were verified using NAT tables and ping tests.

2. PAT Module – Port Address Translation:

PAT configuration mapped multiple private IPs to a single public IP using port numbers.

This enabled all clients to access external networks simultaneously.

PAT tables showed port mappings and ensured distinct session tracking.

Efficiency was measured by observing successful parallel sessions.

3.Testing and Verification Module:

Cisco Packet Tracer simulation was used to observe translation behavior.

Real-Time Mode showed live communication paths.

Simulation Mode allowed step-by-step packet tracing.

Results were compared side-by-side to determine which method performs better in limited IP environments.

The three modules collectively demonstrate the trade-offs between address control (NAT) and scalability (PAT), offering clear visualization for better understanding.

3.4 Engineering Standards Applied:

- Cisco CCNA Guidelines – For configuring and testing NAT/PAT on Cisco routers.
- RFC 3022 – Defines traditional NAT behavior and limitations.
- RFC 2663 – Describes NAT terminology and operation, including dynamic NAT and port mapping.
- IEEE 802.3 – Standards for Ethernet-based LANs used in simulated topologies.
- OSI Model Layering – Ensures that all translation happens at the correct network layer.
- Packet Tracer Configuration Standards – Ensure repeatable, testable setups for academic simulation.
- ISO/IEC 27033 – For network security and secure gateway configurations.
- Computing technology industry Association Network+ Blueprint – Reinforces the importance of NAT and PAT in modern IPv4 networks

These references ensured the framework remained technically correct and suitable for academic and certification-based environments. Configurations followed standard router syntax and included verification commands such as show ip nat translations and debug ip nat.

3.5 Solution Justification:

This Network address translation vs Port address translation simulation-based project provides a clear, scalable, and educational approach to understanding one of the most essential aspects of IPv4 networking - address translation. Due to IP exhaustion, private-to-public translation is a necessity in almost all organizations today.

By visualizing both Network address translation and Port address translation behavior, we can understand not just how each method works but also their real-time impact on connectivity and address resource usage. NAT offers simplicity and predictability for known devices, while PAT provides scalability for dynamic environments with many hosts sharing limited public IPs.

Cisco Packet Tracer enabled interactive testing with minimal setup and no hardware requirement, making this approach both cost-effective and practical. Through side-by-side simulation, the project reveals how PAT is better suited for modern large-scale networks, while NAT may be preferred in static or secure environments.

The project helps bridge the theory-practice gap, making it an ideal learning model for both academic and certification-based applications. As it is implemented using Cisco Packet Tracer, it provides a virtual environment to simulate both Network address translation and Port address translation. It offers a safe and scalable method to observe IP translation behavior without requiring physical hardware, allowing detailed analysis of connectivity, resource utilization, and port mappings.

CHAPTER- 4 RESULTS

4.1 Evaluation of Results:

The effectiveness of the NAT vs PAT Implementation Tab is evaluated based on key performance metrics: connectivity success rate, IP translation accuracy, resource utilization, and ease of configuration. The simulation demonstrates how NAT and PAT serve different network demands and shows considerable improvement in IP address management compared to basic static routing setups.

Connectivity Success Rate:

Both NAT and PAT configurations achieved consistent end-to-end communication between private and public networks in the Packet Tracer environment. PAT showed higher efficiency in handling multiple clients accessing external destinations simultaneously using a single public IP address.

Translation Accuracy:

The system accurately translated internal private IP addresses to public IPs as per the configured rules. Static and Dynamic NAT preserved original port numbers, while PAT successfully handled dynamic port assignment to differentiate sessions.

Resource Optimization:

PAT offered better scalability than NAT by allowing multiple internal hosts to share a single public IP.

Ease of Configuration:

The CLI-based configurations were executed smoothly in the simulation. Troubleshooting tools like show ip nat translations and debug ip nat helped validate translation behavior and fix misconfigurations quickly. Overall, the project validates that both NAT and PAT are effective in enabling secure and scalable communication. While NAT is suitable for predictable one-to-one mapping, PAT proves more efficient for high-volume user environments with limited public IP availability.

Screenshots of translation tables, trace routes and port mapping are captured for documentation.

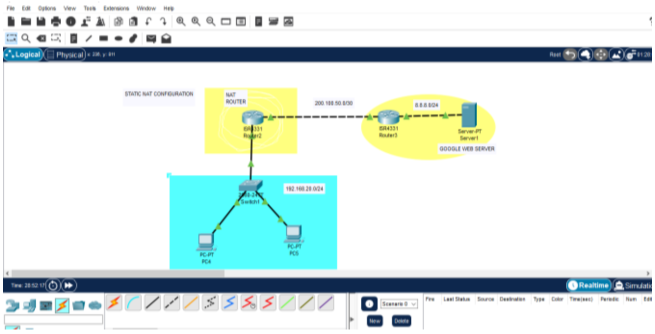


Figure 4.1: Network topology used for STATIC NAT configuration

Figure 4.2: Static NAT configuration output on Router CLI

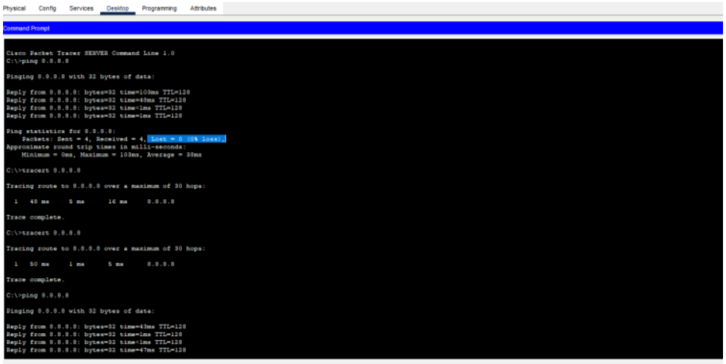


Figure 4.3: NAT translation Table output

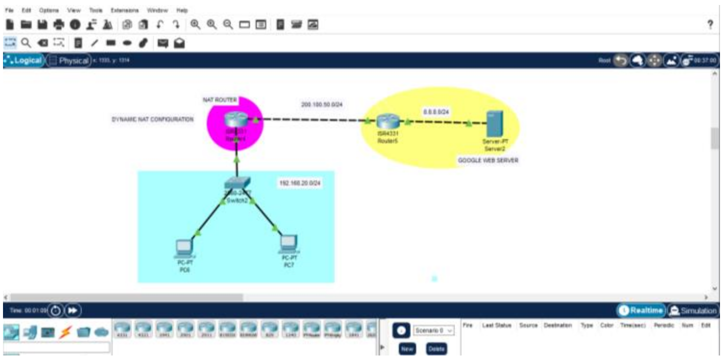


Figure 4.4: Network Topology for Dynamic NAT configuration

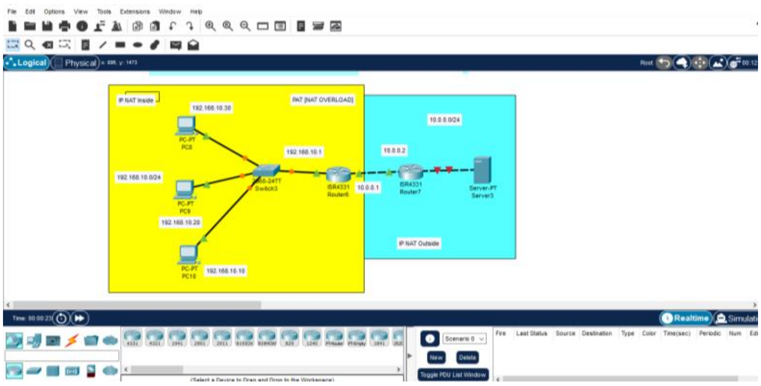


Figure 4.5: Network Topology for PAT configuration

4.2 Challenges Encountered:

Several technical and conceptual challenges were encountered during the implementation of NAT and PAT within the Packet Tracer simulation:

- Port Mapping Complexity in PAT:

Understanding how PAT maps internal IPs and ports to external ports dynamically was initially confusing. It required careful examination of translation tables and extensive testing to observe port reuse and allocation patterns.

- Interface Role Assignment:

Configuring the correct ip nat inside and ip nat outside interfaces was critical. Incorrect assignment led to translation failure, making it important to grasp the traffic direction and the role of each interface in the configuration.

- Testing and Verification Delays:

Due to limitations in Packet Tracer, simulating realistic external traffic flow (e.g., DNS or HTTP requests) required custom ping routes or static routes to generate test traffic. This added complexity in validation steps.

- Access Control List (ACL) Configuration:

Using ACLs to specify which internal addresses should be translated in NAT/PAT configurations introduced another layer of challenge. Misconfigured ACLs sometimes blocked translation completely, requiring detailed CLI review and adjustment.

- Limited Error Feedback:

Packet Tracer CLI doesn't always give detailed error messages when NAT/PAT configurations are incorrect, so diagnosing problems required deep inspection of interface states, routing tables, and NAT rule

Despite these challenges, the project helped in gaining deep technical understanding through hands-on troubleshooting and repeated testing, ultimately leading to a successful and functional implementation.

4.3 Possible Improvements:

- Enhanced Testing with Diverse Traffic Types:

Introducing simulations for multiple traffic types (HTTP, FTP, DNS, etc.) in the Packet Tracer setup would provide a more realistic testing environment, ensuring NAT and PAT configurations behave as expected under various conditions.

- Automation of Configuration Deployment:

Incorporating CLI scripting or automation tools like Python or Ansible in future iterations could streamline NAT and PAT configurations across multiple routers, improving scalability and reducing manual effort.

- Security Feature Integration:

  Future improvements could include simulating firewall ACLs or IPS (Intrusion Prevention System) alongside NAT/PAT to evaluate how packet translation interacts with security filtering in a layered architecture.

- Dual-ISP Redundancy Simulation: Introducing multi-router or dual-ISP scenarios could explore how NAT/PAT perform under failover or load-balancing conditions, increasing the realism and scope of enterprise-grade implementation.
- Logging and Monitoring Mechanism: Implementing SNMP or Syslog features within Packet Tracer (where possible) or externally simulating their function could support real-time monitoring of address translations, aiding network troubleshooting and auditing.

4.5 Future Scope:

- Deepen NAT/PAT Understanding with Real Hardware:

While Packet Tracer offers a strong foundation, testing NAT and PAT on real Cisco routers or using GNS3 can provide exposure to hardware-based behaviors, interface dependencies, and limitations not captured in virtual environments.

- Extend Project into Dual Stack (IPv4/IPv6):

Expanding the project to simulate NAT64 or PAT with IPv6 would prepare for modern network environments where IPv4 exhaustion and IPv6 adoption require translation between protocols.

- Scenario-Based Learning Modules:

Creating structured real-world scenarios—such as branch office to HQ communication or remote access through NAT—would further contextualize address translation in enterprise settings.

- Incorporate Simulation Metrics:

Introducing measurement parameters like latency, connection success rate, and port usage statistics would elevate the project from functional demonstration to analytical assessment, supporting data-driven conclusions.

- Test Application Layer Behavior:

Simulating application-level protocols like FTP, VoIP, or video calls to observe how NAT and PAT handle dynamic port assignments, which are often problematic.

CHAPTER- 5: REFLECTION ON LEARNING AND PERSONAL DEVELOPMENT

5.1 Academic Knowledge:

This project provided the detailed technical exposure to core networking concepts, particularly focusing on the mechanisms and applications of Network Address Translation (NAT) and Port Address Translation (PAT). It helped bridge theoretical networking principles with practical implementation, which allows to reinforce and apply knowledge gained from modules such as Computer Networks, Internetworking Technologies, and Routing Protocols.

Through this capstone, I explored how private-to-public IP mapping facilitates secure and efficient network communication, especially within IPv4-constrained environments. I gained a solid understanding of the different translation types—Static NAT, Dynamic NAT, and PAT—and how they serve different network demands and scalability requirements. By implementing these in Packet Tracer, I developed a clearer comprehension of address conservation, port mapping, and interface-based configuration strategies. This experience has deepened my academic foundation in network administration and helped to recognize the critical role address translation plays in both enterprise-level routing and security frameworks.

5.2 Technical Skills:

During this capstone project, I significantly improved my practical technical skills within the realm of networking.

Key skills developed include:

- Configuration of NAT using Cisco IOS commands in Packet Tracer.
- Implementation of PAT with overload functionality to enable many-to-one address translation using port numbers.
- Network topology design and subnetting for logical IP address assignment across internal LANs and public-facing interfaces.
- Troubleshooting NAT and PAT configurations using tools like show ip nat translations and debug ip nat.
- Simulation of real-world scenarios where multiple clients access external services via limited public IP resources.
- Understanding interface roles (inside/outside) in NAT configuration and their influence on packet flow.
- Interpretation of NAT table entries and testing connectivity across the private-public boundary.

These skills have reinforced my ability to design, configure, and analyze address translation solutions in IP-based networks.

5.3 Problem Solving And Critical Thinking:

This project presented multiple technical challenges that required analytical thinking and iterative problem-solving. One major challenge was structuring the address translation logic to allow internal hosts to successfully communicate with simulated external networks using limited public IPs. This required understanding the impact of NAT table states, port number handling, and access-list logic.

Another challenge was simulating practical network traffic flow using only the limited resources of Packet Tracer. I had to design appropriate topologies and workflows to mimic scenarios such as multiple hosts attempting simultaneous external communication—key to testing PAT effectiveness under load.

Through repeated testing, debugging, and refinement of configurations, I enhanced my troubleshooting mindset and learned to isolate translation errors, optimize access control, and achieve consistent communication paths. This strengthened my conceptual grasp of routing and IP services, and developed my ability to apply theoretical knowledge to solve real implementation challenges.

5.4 Insights to Industry:

Working on this NAT vs PAT implementation project has been a transformative experience in my academic journey and technical maturity. It helped me transition from understanding theoretical networking concepts to applying them in realistic scenarios, enabling me to design and troubleshoot a fully functional IP translation system.

The project not only Improved my Cisco CLI proficiency but also nurtured my attention to detail, logical reasoning, and configuration accuracy—essential traits in any network engineering role. I now This capstone gave me direct insight into how enterprise networks handle IP address shortages and ensure secure, efficient communication between private and public networks. It implies about the critical role that NAT and PAT play in modern business environments, especially in cloud-connected, multi-branch networks. Exploring translation behavior under different configurations helped me understand how ISPs, corporate firewalls, and internal gateways utilize address translation to conserve public IPs, manage traffic load, and enable secure access control. These observations aligned with industry trends in scalable IP addressing, resource optimization, and policy enforcement

Moreover, I realized how real-time NAT/PAT monitoring and logging contribute to network visibility and security posture—core to enterprise network operations. This experience has prepared me for roles that require hands-on skills in network configuration, troubleshooting, and infrastructure planning.

Furthermore, real-world enterprise environments demand robust NAT/PAT policies that adapt to dynamic workloads, such as cloud services, remote access VPNs, and Iot devices. The project highlighted how address translation mechanisms must be integrated with firewall policies, DHCP scopes, and DNS configurations to provide end-to-end secure and efficient communication

I also learned about the growing importance of dual-stack (IPv4/IPv6) environments where NAT64 and other transition technologies extend NAT's relevance in modern networks. Understanding these trends helped me appreciate the evolving nature of IP addressing and the necessity for adaptable and scalable address translation strategies in enterprise IT planning.

5.5 Conclusion

The project helped me to understand theoretical networking concepts to applying them in realistic scenarios. I now feel more confident in my ability to configure and maintain core network services and plan to explore more advanced topics like IPv6 transition techniques, VPN tunneling, and enterprise routing protocols. This project has deepened my interest in networking and I look forward to further developing my expertise in scalable IP design and real-world enterprise implementations

CONCLUSION

This project successfully demonstrated the implementation and comparison of NAT and PAT using Cisco Packet Tracer. It highlighted how NAT is suitable for simple mappings, while PAT is more efficient and scalable for networks with multiple clients. The simulation provided a practical understanding of address translation, reinforcing theoretical concepts and improving configuration skills. This experience has contributed significantly to my technical learning and readiness for real-world networking tasks. This hands on exposure to real time translation helped bridge the gap between theory and implementation.

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APPENDICES

Key Commands Used in Cisco Packet Tracer:

- Assign IP address to interface - ip address [IP] [Subnet Mask]
- Enable interface - no shutdown
- Set inside NAT interface - ip nat inside
- Set outside NAT interface - ip nat outside
- Configure Static NAT - ip nat inside source static [private IP] [public IP]
- Configure Dynamic NAT pool - ip nat pool [name] [start IP] [end IP] [mask]
- Create ACL for NAT - access-list [number] permit [source IP] [mask]
- Link ACL to NAT pool - ip nat inside source list [ACL] pool [pool name
- Configure PAT (NAT Overload) - ip nat inside source list [ACL] interface [interface]
- View NAT translation- show ip nat translations
- Debug NAT operation - debug ip nat