A PBL-II (AIM2270) **PROJECT REPORT** on

Network Intrusion Detection System

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CERTIFICATE

This is to certify that the project entitled “Network Intrusion Detection System” is a Bonafide work carried out as part of the course AIM2270, under my guidance from Jan 2025 to May 2025 by Ashwarya Pradhan (23FE10CAI00268) & Kasmya Bhatia (23FE10CAI00010), student of B. Tech (hons.) Computer Science and Engineering (AIML), 4th Semester at the Department of Artificial Intelligence and Machine Learning, Manipal University Jaipur, during the academic semester 4th in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Computer Science and Engineering (AIML), at MUJ, Jaipur.

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ABSTRACT

With the rapid expansion of digital connectivity, the frequency and sophistication of cyberattacks have escalated significantly, posing serious threats to the security of networked systems. This has created a pressing need for robust, adaptive, and cost-effective solutions that can monitor, detect, and mitigate malicious activities in real-time. In response to this need, the present project focuses on the development of a Python-based Network Intrusion Detection System (NIDS), designed to enhance network defense capabilities by enabling proactive threat detection across a variety of environments.

The proposed system utilizes a combination of powerful packet inspection libraries, including Scapy and Pyshark, to capture and analyze live network traffic. These tools facilitate deep packet inspection, protocol dissection, and traffic monitoring. To augment threat detection, the system integrates YARA rules for pattern-based matching, allowing it to identify known threats through signature recognition. This modular approach enables users to define custom rules and receive real-time alerts upon detection of suspicious activity, ensuring responsiveness and flexibility.

Designed with scalability and extensibility in mind, the system supports seamless integration of additional components such as machine learning models for anomaly detection or visualization tools for traffic analysis. Its lightweight architecture ensures minimal resource overhead, making it suitable for deployment in diverse settings including enterprise networks, academic institutions, home networks, and cloud infrastructures. The report provides an in-depth overview of the system's architecture, core functionalities, implementation strategy, and its applicability in real-world cybersecurity scenarios.

This project demonstrates how open-source technologies can be effectively leveraged to create a practical, educational, and production-ready network security solution. By empowering users with real-time visibility and control over their network traffic, the system contributes to the broader objective of strengthening cybersecurity awareness and preparedness in today's digital age.

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CHAPTER 1

INTRODUCTION

1.1 Scope of the Work

The exponential growth of digital communication and interconnected systems has heightened the risk of sophisticated cyber threats targeting both enterprise and personal networks. In this context, the present work aims to develop a Python-based Network Intrusion Detection System (NIDS) capable of monitoring network traffic in real-time to identify and mitigate potential security breaches. The system is engineered to perform four primary functions: live packet capture, rule-based filtering, deep packet analysis, and YARA-rule integration for anomaly detection and threat identification.

A key objective of the project is to deliver a lightweight, modular, and scalable security solution that can be adapted across a wide range of network environments, including corporate infrastructures, virtualized cloud systems, and academic research networks. By emphasizing real-time performance, minimal resource overhead, and extensibility, the system seeks to address pressing cybersecurity challenges through a proactive and adaptable detection framework.

1.2 Product Scenarios

The versatility of the proposed NIDS enables its deployment across diverse operational contexts, each benefiting from its real-time threat detection and flexible architecture:

- **Enterprise Networks**: The system acts as a frontline defense by inspecting incoming and outgoing traffic to detect unauthorized access attempts, malicious payloads, and suspicious behavioral patterns, thereby safeguarding sensitive corporate data and infrastructure.
- **Cloud Environments**: In dynamically scaling cloud platforms, where traditional security models often face visibility limitations, the NIDS provides continuous traffic analysis and anomaly detection to enhance cloud-native security measures.
- **Educational Institutions**: As a pedagogical tool, the system offers cybersecurity students and researchers a practical environment to explore and experiment with intrusion detection concepts, packet-level analysis, and real-time network monitoring techniques.
- **Residential Networks**: For individual users, the NIDS facilitates active monitoring of personal network activity, identifying threats such as phishing attempts, unauthorized devices, and malware infiltration, thereby enhancing digital safety at the consumer level.

CHAPTER 2

REQUIREMENT ANALYSIS

2.1 Functional Requirements

The functional requirements define the essential capabilities that the proposed Network Intrusion Detection System (NIDS) must fulfill to operate effectively in a real-time network environment:

- **Packet Capture**: The system shall continuously monitor live network traffic and capture data packets using Python-based libraries such as Scapy and Pyshark. This functionality serves as the foundation for all subsequent analysis and detection processes.
- **Rule-Based Filtering**: The system must support the integration of YARA rules to facilitate signature-based filtering. These rules enable the identification of malicious patterns or payloads by matching packet contents against predefined threat signatures.
- **Packet Analysis**: Each captured packet shall be subject to detailed inspection, including analysis of header fields and payload content, to detect anomalies, suspicious behaviors, or protocol violations.
- **Real-Time Alerting**: Upon identification of malicious or anomalous activity, the system must generate immediate alerts to notify administrators or end users, ensuring prompt response to potential threats.

2.2 Non Functional Requirements

The non-functional requirements specify the qualitative attributes that govern the system's performance, usability, and maintainability:

- **Scalability**: The system should efficiently process high volumes of network traffic without degradation in performance, ensuring reliability under varying network loads.
- **Modularity**: Each functional component — including packet capture, rule filtering, and analysis — must be designed as an independent module to facilitate ease of maintenance, testing, and future enhancements.
- **Security**: Communication between internal components should be encrypted to safeguard against data interception, tampering, or unauthorized access during runtime operations.
- **Usability**: The system must provide a user-friendly interface that allows for intuitive configuration of detection rules and real-time monitoring of network activity, thereby improving accessibility for both technical and non-technical users.

2.3 Use Case Scenarios

To demonstrate the practical applicability of the system, the following representative use cases are considered:

- **Scenario 1: Detecting Unauthorized Access Attempts**
  A user within a corporate network attempts to access restricted resources without valid credentials. The NIDS captures associated traffic, applies YARA-based pattern matching to detect repeated failed authentication attempts, and issues an alert to the network administrator.
- **Scenario 2: Filtering Malware Traffic**
  The system intercepts incoming traffic containing payloads that match known malware signatures defined in the YARA ruleset. The NIDS proactively filters the suspicious packets, logs the incident, and prevents the payload from reaching its intended target.
- **Scenario 3: Analyzing Suspicious Traffic Patterns**
  The system monitors network sessions and detects anomalous TCP behavior, such as an excessive number of SYN packets in a short time span, which may indicate the onset of a SYN flood attack. An alert is generated, and the event is logged for further analysis.

2.4 Software Engineering Methodologies

An **Agile development methodology** was adopted for this project due to its iterative nature and adaptability to evolving requirements. The development cycle was structured into sprints, each focusing on the implementation and testing of specific functional components such as packet capture, YARA-based filtering, and real-time alerting.

Sprint planning sessions were conducted to prioritize features based on feasibility and impact, while continuous integration practices ensured incremental development and validation. Frequent testing cycles were employed to verify the functionality of each module independently prior to system integration, thereby ensuring robust performance and maintainability throughout the project lifecycle.

CHAPTER 3

SYSTEM DESIGN

3.1 Design Goals

The primary design objectives of the Network Intrusion Detection System (NIDS) focus on delivering a robust, adaptable, and high-performance solution capable of safeguarding diverse network environments. The following goals guided the overall system architecture and implementation:

- **Accuracy**: The system must reliably detect malicious activities with minimal false positives or negatives, ensuring actionable and trustworthy alerts.
- **Efficiency**: The system should process large volumes of network traffic with low latency, maintaining real-time performance even under high throughput conditions.
- **Modularity**: The architecture must support modularity, allowing individual components — such as packet capture mechanisms, rule engines, or analysis logic — to be independently developed, tested, and upgraded without impacting the entire system.
- **Scalability**: The system should be scalable across deployment scenarios ranging from personal home networks to enterprise-level infrastructures, ensuring adaptability to varying performance and security requirements.

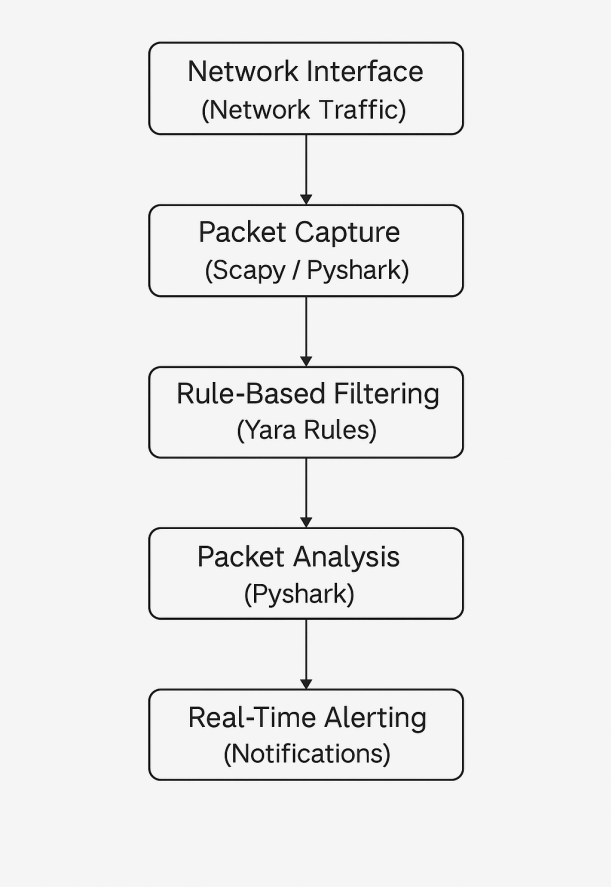
3.2 System Architecture

The system is structured around a modular, layered architecture composed of four primary components, each responsible for a distinct aspect of intrusion detection:

- **Packet Capture Module**: Utilizes Python libraries such as Scapy and Pyshark to continuously monitor and capture live network traffic at the interface level. This module forms the entry point of the system and supplies raw packet data for further processing.
- **Rule-Based Filtering Module**: Implements YARA rule integration for pattern matching and threat detection. This module dynamically loads signature rules at runtime to identify packets exhibiting known malicious characteristics, filtering out benign traffic.
- **Packet Analysis Module**: Performs deep inspection of filtered packets using Pyshark, examining header fields (e.g., IP addresses, ports, protocols) and payload data for anomalies, protocol violations, or embedded threats.
- **Real-Time Alerting System**: Generates and dispatches immediate alerts to administrators upon the detection of suspicious or malicious activity. This component ensures timely response to potential intrusions.

These components work in tandem to enable continuous, real-time monitoring and detection of threats, ensuring that the system operates efficiently and responsively under varying conditions.

Figure 1- System Architecture



3.3 Data Flow Sequence

The data flow in the modular architecture of the Network Intrusion Detection System (NIDS) is outlined as follows

- **External Entities**:
  - The User interacts with the system by viewing alerts and logs.The **Network**
  - Interface serves as the source of live packet data.

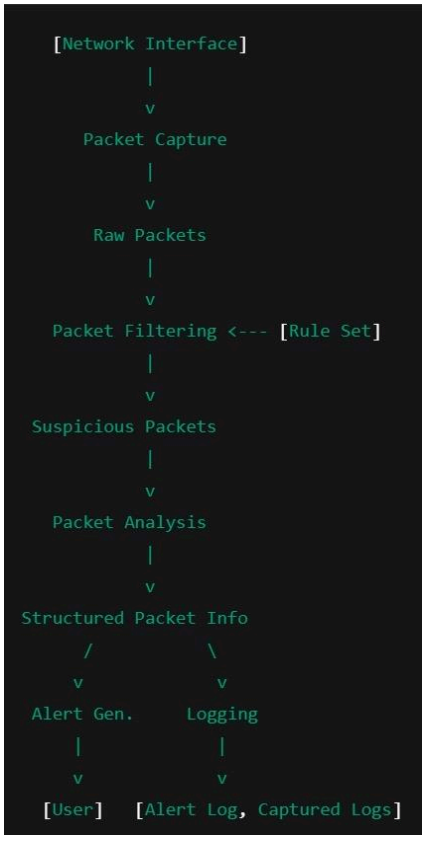
• **Processes**:

1. **Packet Capture**: Captures live network traffic and outputs raw packets.
2. **Packet Filtering**: Filters raw packets using predefined YARA rules to identify suspicious packets.
3. **Packet Analysis**: Analyzes suspicious packets to extract structured information such as IP addresses, ports, and payloads.
4. **Alert Generation**: Generates real-time alerts based on the structured packet information. These alerts are displayed to the user.
5. **Logging**: Logs all detected threats and analysis results into the **Alert** Log and Captured Logs for future reference.

• **Data Stores**:

- **Rule Set**: Stores the YARA rules used by the Packet Filtering module to detect threats.
- **Alert Log**: Stores historical alerts generated by the system.
- **Captured Logs**: Stores full packet data for potential forensic analysis.

Figure 2 - Data Flow



3.4 Detailed Design Methodologies

- **Packet Capture**: Implemented using the Scapy library, this module captures real-time traffic by listening to specified network interfaces. It operates at configurable intervals to ensure continuous data acquisition with minimal packet loss.
- **Rule Application**: YARA rules are dynamically imported into the system during runtime, enabling flexible rule management and facilitating the identification of threats based on established signature patterns. This design also allows for easy rule updates without halting system operation.
- **Packet Analysis**: Leveraging the Pyshark library, this stage inspects filtered packets at both header and payload levels. Header analysis includes examination of source and destination IP addresses, ports, and protocol types, while payload analysis focuses on identifying embedded malicious content or irregular data structures.
- **Suspicious Packet Filtering**: The system applies a two-tiered filtering mechanism, where only packets matching suspicious criteria defined by YARA rules are subjected to deeper analysis. This ensures efficient use of computational resources while maintaining high detection accuracy.

3.5 User Interface Design

1. Control Panel: This section manages the core capture and analysis operations:

- **START** – Begins packet sniffing using Scapy or Pyshark backends.
- **STOP** – Terminates live packet capture.
- **RULES** – Opens the rule editor to define or modify detection rules.
- **SAVE** – Saves current configurations and custom rules.
- **STATS** – Displays real-time network statistics (packet counts, protocol distribution).
- **YARA** – Integrates YARA rules for pattern-based malware detection.

2. Active Rules Panel: Displays active packet inspection rules based on custom logic. Rules are likely evaluated using Pyshark for filtering and Scapy for inspecting packets.

3. Network Traffic Panel: Real-time capture and display of packet metadata

- Shows packet ID, Ethernet/IP/UDP/TCP headers.
- Displays source/destination IPs and ports.
- Shows transport protocol and traffic type (e.g., Raw, mDNS, http).
- Powered by **Pyshark** for deep packet inspection and protocol parsing.

4. Security Alerts Panel: Lists triggered alerts that match defined rules:

- Packet index
- Protocol layers
- Source and destination IP and ports
- Alert messages (e.g., "MSG: HTTP TRAFFIC")
- Likely updated via Scapy's packet sniffing callbacks or Pyshark's display filters.

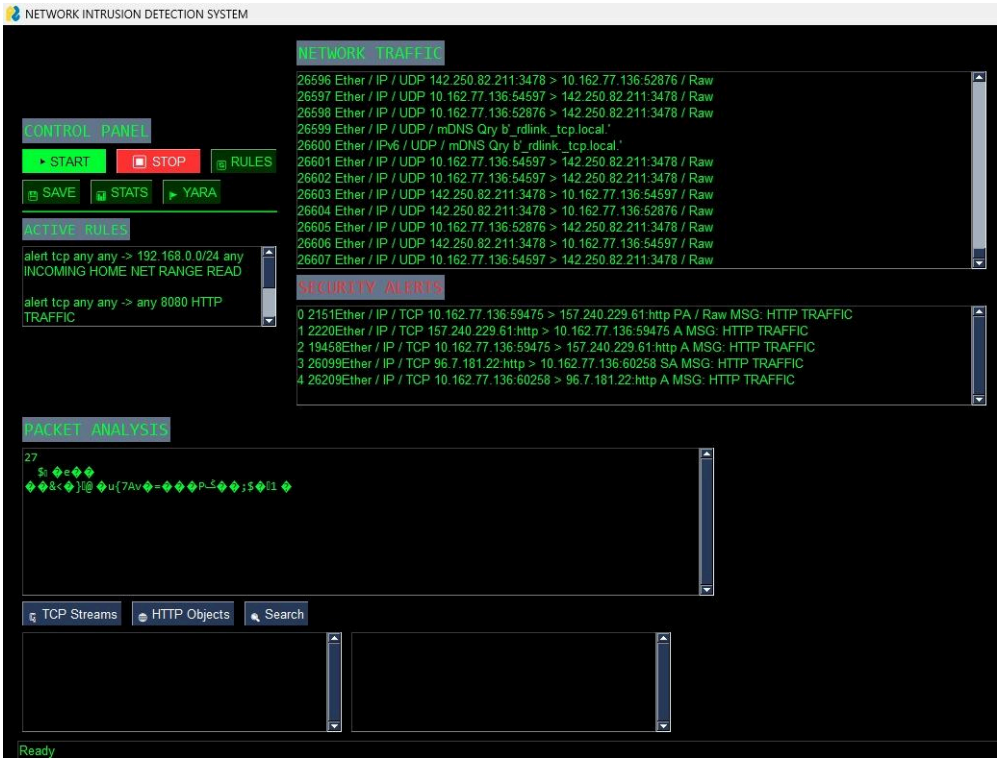
5. Packet Analysis Panel: Displays raw packet content

- Hexadecimal or ASCII views of packet payloads.
- Useful for malware analysis, protocol anomalies, or forensic tasks.
- Extracted using **Scapy** for raw packet data parsing.

6. Bottom Function Buttons:

- **TCP Streams** – Reconstructs full TCP conversations using Pyshark's stream index.
- **HTTP Objects** – Extracts HTTP-transmitted objects (e.g., images, files).
- **Search** – Enables search across captured packet payloads or headers.

Figure 3 - Interface Design



CHAPTER 4

CONCLUSION

The Network Intrusion Detection System (NIDS) developed in this project achieves its core objective of providing real-time traffic monitoring, rule-based threat filtering, and in-depth packet analysis through the effective utilization of open-source Python libraries such as Scapy, Pyshark, and YARA. The system's modular architecture not only enhances maintainability and extensibility but also ensures seamless scalability across a wide range of deployment environments — from home networks to large-scale enterprise infrastructures.

This work highlights the practical potential of open-source technologies in addressing real-world cybersecurity challenges. By combining lightweight packet inspection techniques with customizable rule-based filtering, the system provides a cost-effective and adaptable solution for proactive network defense. Furthermore, the design emphasizes minimal resource overhead while maintaining high accuracy in threat detection.

Looking ahead, the system offers significant opportunities for enhancement. Future work could involve the integration of machine learning models for dynamic anomaly detection, allowing the system to identify previously unseen threats. Additionally, expanding protocol support beyond the TCP/IP stack would further improve the system's versatility in heterogeneous network environments.

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