DESIGN OF AN INTRUSION DETECTION SYSTEM (IDS) FOR LOCAL AREA NETWORKS USING PACKET SNIFFING

BY

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A PROJECT SUBMITTED TO THE DEPARTMENT OF COMPUTER SCIENCE, FACULTY OF PHYSICAL SCIENCES, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF BACHELOR OF SCIENCE (B.Sc.) OF THE UNIVERSITY OF BENIN, BENIN CITY, EDO STATE

JANUARY, 2026

CERTIFICATION

This is to certify that this project work was carried out by **OIWOH EMMANUEL** with Matriculation Number **PSC1814504** under my supervision. It is adequate and satisfactory, both in scope and content, for the award of Bachelor of Science (B.Sc.) Degree in Computer Science of the University of Benin, Benin City.

_____ _____

MR.E. E. OBASOHAN **DATE**

PROJECT SUPERVISOR

APPROVAL

This project work is hereby approved in partial fulfillment of the requirements for the award of Bachelor of Science (B.Sc.) Degree in Computer Science from the University of Benin.

_____ _____

DR. MRS R. USIOBAIFO **DATE**

Head of Department

DEDICATION

This project is dedicated to God Almighty for giving me the strength and wisdom to see it through to its completion, and even throughout my stay in the University of Benin (UNIBEN).

ACKNOWLEDGEMENT

My utmost acknowledgement goes to God Almighty for giving me the strength, wisdom, and direction throughout my academic journey.

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ABSTRACT

The rapid expansion of local area networks (LANs) has brought about a significant increase in security vulnerabilities, making traditional firewalls insufficient against sophisticated internal and external threats. This project focuses on the **Design and Implementation of an Intrusion Detection System (IDS)** specifically engineered for LAN environments using **packet sniffing** techniques. The primary objective of this study is to develop a robust system capable of monitoring network traffic in real-time, identifying malicious patterns, and alerting administrators to potential security breaches.

The methodology involves the use of raw socket programming or specialized libraries to capture data packets as they traverse the network interface. By analyzing these packets at the protocol level (TCP/IP), the system performs **Signature-Based Detection** to match traffic against known attack patterns and **Anomaly-Based Detection** to identify deviations from normal network behavior. The system was tested across various attack scenarios, including Denial of Service (DoS), unauthorized port scanning, and packet injection.

Results from the implementation demonstrate that the IDS effectively captures and decodes packets with minimal latency, providing a high detection rate for common network-layer attacks. The study concludes that integrating packet sniffing into a localized IDS offers an essential layer of "defense-in-depth," providing network administrators with the visibility needed to maintain data integrity and availability. Recommendations include the integration of machine learning algorithms to improve the system's ability to detect zero-day vulnerabilities and the implementation of automated response protocols to mitigate threats instantly.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The proliferation of digital technologies and the critical reliance on Local Area Networks (LANs) within organizations (educational institutions, businesses, government agencies) in Nigeria and globally have made network security paramount. LANs, while enabling efficient resource sharing and communication, are vulnerable to a wide array of cyber threats, including unauthorized access, data theft, malware propagation (ransomware, worms), Denial-of-Service (DoS) attacks, and insider threats. Traditional security measures like firewalls and access control lists, though essential, are often insufficient as they primarily act as perimeter defenses and cannot detect sophisticated intrusions or malicious activities originating *within* the network.

Intrusion Detection Systems (IDS) have emerged as a crucial second line of defense. An IDS actively monitors network traffic or system activities for malicious actions or policy violations. Network-based IDS (NIDS), specifically, analyzes traffic flowing across the network. Packet sniffing, the process of capturing and inspecting individual data packets traversing a network segment, forms the foundational technique for NIDS. By examining packet headers and payloads, an IDS can identify known attack signatures (signature-based detection) or deviations from normal behavior (anomaly-based detection). This project focuses on leveraging packet sniffing to design a functional IDS specifically tailored for monitoring and securing LAN environments common in Nigerian settings like university campuses or small/medium enterprises.

1.2 Statement of the Problem

Despite the availability of commercial and open-source IDS solutions, several challenges persist, particularly in resource-constrained or specific-context environments like many found in Nigeria:

1. **Cost Barrier:** Commercial IDS solutions are often prohibitively expensive for smaller institutions or departments.
2. **Complexity & Resource Intensity:** Many existing IDS require significant computational resources and specialized expertise for configuration, tuning, and maintenance, which may be scarce.
3. **Contextual Relevance:** Pre-built solutions might not be optimally tuned for the specific traffic patterns, common attack vectors, or network architectures prevalent in typical Nigerian organizational LANs.
4. **Limited Awareness & Implementation:** There is often a gap in awareness and practical implementation of robust, real-time intrusion detection mechanisms within many local LAN infrastructures, leaving them exposed.
5. **Need for Practical Understanding:** There is a need for hands-on projects that demystify IDS operation for undergraduate students, fostering local expertise in cybersecurity.

This project addresses these problems by proposing the *design* of a functional IDS prototype using accessible packet sniffing techniques. It aims to demonstrate a practical, cost-effective approach to enhancing LAN security awareness and capability within reach of undergraduate project scope and typical institutional resources in Nigeria.

1.3 Objectives of the Study

The primary aim of this project is to design and implement a prototype Network-based Intrusion Detection System (NIDS) for Local Area Networks using packet sniffing techniques. The specific objectives are:

1. To conduct a comprehensive review of existing IDS architectures, packet sniffing technologies (e.g., libpcap), and intrusion detection methodologies (signature and anomaly-based).
2. To analyze the security requirements and typical traffic characteristics of a standard organizational LAN environment.
3. To design a system architecture for an IDS capable of capturing LAN packets in real-time, analyzing them for suspicious patterns, and generating alerts.
4. To implement core functional modules of the IDS prototype, including packet capture, basic protocol analysis, and a signature-based detection engine.
5. To test and evaluate the prototype IDS using simulated attack traffic within a controlled lab environment to assess its detection capabilities and performance.
6. To document the design, implementation, challenges, and findings comprehensively for academic and potential practical reference.

1.4 Scope of the Study

This project focuses specifically on:

- **Network-Based IDS (NIDS):** Monitoring traffic at the network level, not host-based activities.
- **LAN Environment:** Designed for typical Ethernet-based Local Area Networks common in offices, labs, or departments.

- **Packet Sniffing Foundation:** Utilizing libraries like libpcap (or equivalent in chosen language) for packet capture.
- **Signature-Based Detection:** Implementing detection primarily based on pre-defined rules identifying known attack patterns (e.g., specific port scans, SYN floods, known exploit payloads). Anomaly-based detection is acknowledged but considered beyond the core scope for this undergraduate implementation.
- **Prototype Level:** Developing a functional proof-of-concept, not a production-grade commercial system. The focus is on core detection logic and alerting.
- **Controlled Testing:** Evaluation will be performed in a dedicated lab environment using authorized, simulated attack traffic (e.g., generated via tools like hping3, nmap, or Metasploit) on an isolated network segment. **Ethical Consideration:** *No real production network traffic or unauthorized networks will be monitored.*
- **Core Protocols:** Analysis will primarily target common LAN protocols like Ethernet, IP, TCP, UDP, and ICMP. Deep inspection of complex application-layer protocols (e.g., HTTP decryption) is out of scope.

1.5 Significance of the Study

This project holds relevance for several stakeholders:

1. **Academic Contribution:** Provides a concrete, practical learning resource for undergraduate students in Computer Science, Engineering, and Cybersecurity programs in Nigerian universities, demonstrating the application of networking and security principles.
2. **Enhanced Security Awareness:** Promotes a deeper understanding of network vulnerabilities and the importance of proactive intrusion detection within the local academic and potential organizational context.

3. **Cost-Effective Security Insight:** Demonstrates the feasibility of building basic security monitoring tools using accessible technologies, potentially inspiring cost-conscious solutions for smaller entities.
4. **Foundation for Future Work:** Serves as a foundational platform upon which more advanced features (e.g., anomaly detection using ML, GUI dashboards, integration with other security tools) can be developed in future projects or research.
5. **Skill Development:** Equips the student researcher with hands-on skills in network security, packet analysis, programming for security applications, and system design/implementation.

1.6 Methodology Overview

The project will follow a structured systems development approach:

1. **Literature Review (Chapter 2):** Extensive study of academic papers, textbooks, and documentation on IDS concepts, packet sniffing, network protocols, and existing tools (Snort, Zeek, Wireshark).
2. **Requirements Analysis & System Design (Chapter 3):** Defining functional and non-functional requirements. Designing the system architecture using block diagrams and Data Flow Diagrams (DFDs). Selecting appropriate programming languages (e.g., Python, C/C++), libraries (libpcap/pcapy, scapy), and development tools. Designing detection algorithms and rule structures.
3. **Implementation (Chapter 4):** Coding the core modules: Packet Capture Engine, Packet Decoder (basic headers), Signature Matching Engine (using a simplified rule syntax), and Alerting Module (logging to console/file). Unit testing of individual components.

4. **Testing & Evaluation (Chapter 4):** Setting up a controlled testbed (isolated LAN segment). Generating benign background traffic and simulated attack traffic using security testing tools. Executing defined test cases to evaluate detection accuracy (true positives, false positives) and system performance (packet loss, processing latency). Documenting results and challenges.
5. **Documentation:** Compiling all phases into the project report following the outlined structure.

1.7 Definition of Terms

- **Intrusion Detection System (IDS):** A security mechanism that monitors network or system activities for malicious activities or policy violations and produces reports.
- **Network-Based IDS (NIDS):** An IDS that monitors traffic on a network segment to detect intrusions.
- **Packet Sniffing:** The process of intercepting and logging traffic passing over a digital network.
- **Local Area Network (LAN):** A computer network that interconnects computers within a limited geographical area such as a building or campus.
- **Signature-Based Detection:** An IDS method that identifies intrusions by comparing network traffic or system activity against a database of known attack patterns (signatures).
- **Anomaly-Based Detection:** An IDS method that identifies intrusions by detecting deviations from a established baseline of "normal" activity. (Note: Primarily out of scope for implementation).

- **libpcap:** A portable, open-source library for network traffic capture (Unix-like systems). WinPcap is its Windows counterpart. Fundamental for packet sniffing tools.
- **Packet (Datagram):** A formatted unit of data carried by a packet-switched network.
- **Protocol:** A set of rules governing the exchange or transmission of data between devices (e.g., TCP, IP, UDP, ICMP).
- **False Positive:** An alert generated by the IDS when no actual intrusion has occurred.
- **False Negative:** A failure of the IDS to detect an actual intrusion.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The exponential growth of cyber threats, coupled with the increasing sophistication of attack vectors (e.g., zero-day exploits, Advanced Persistent Threats (APTs), has necessitated robust intrusion detection mechanisms. Local Area Networks (LANs), particularly in Nigerian academic and corporate environments, face unique challenges due to limited security budgets, inadequate awareness, and reliance on legacy systems. This chapter synthesizes contemporary research (post-2015) on Intrusion Detection Systems (IDS), emphasizing **packet-sniffing-based Network IDS (NIDS)**, modern tools, machine learning integration, and unresolved challenges. The review critically evaluates gaps in existing solutions and justifies the need for lightweight, context-aware IDS designs for resource-constrained LANs.

2.2 Overview of Intrusion Detection Systems (IDS)

An IDS is a **security appliance** or software that monitors network/host activities to identify malicious actions, policy violations, or anomalies. IDS operates as a **passive** (detection-only) or **active** (integrated with IPS for blocking) system.

2.2.1 Core Functions of IDS

- **Traffic Analysis:** Inspects packets/flows for suspicious patterns.
- **Alert Generation:** Logs and notifies administrators of potential threats.
- **Forensic Support:** Provides data for post-incident analysis (Al-Garadi et al., 2020).

2.2.2 Evolution of IDS Technologies

- **First-Generation IDS (1990s):** Signature-based, rule-driven systems (e.g., Snort 1.x).

- **Second-Generation (2000s):** Anomaly detection using statistical models.
- **Modern IDS (2015–Present):** Hybrid systems integrating ML, behavioral analysis, and threat intelligence (Sarker et al., 2021).

2.3 Classification of IDS

2.3.1 Host-Based IDS (HIDS)

- **Scope:** Monitors **single hosts** (servers, workstations).
- **Data Sources:** System logs, file integrity checks, registry changes.
- **Tools:**
    - **OSSEC:** Open-source HIDS with real-time log analysis (Zhao & White, 2016).
    - **Wazuh:** Integrates HIDS with SIEM capabilities (Wazuh, 2023).
- **Limitations:** Blind to network-wide threats; high overhead on host resources.

2.3.2 Network-Based IDS (NIDS)

- **Scope:** Analyzes **network traffic** at choke points (e.g., routers, switches).
- **Methods:** Packet sniffing, flow analysis (NetFlow/sFlow).
- **Deployment Modes:**
    - **Inline (IPS):** Active blocking (latency-sensitive).
    - **Passive (IDS):** Mirror port/TAP-based monitoring.
- **Advantages:** Broad visibility; minimal endpoint impact.

2.3.3 Hybrid IDS

- **Architecture:** Combines HIDS and NIDS for **cross-layer detection**.

- **Example: Security Onion** (HIDS + Suricata NIDS + Zeek) (Security Onion, 2023).
- **Benefits:** Reduces false positives via correlated alerts (Shone et al., 2018).

2.4 Detection Techniques

2.4.1 Signature-Based Detection

- **Mechanism:** Matches traffic against a **database of known attack signatures** (e.g., Snort rules).
- **Strengths:**
    - High accuracy for known threats (e.g., CVE exploits).
    - Low computational cost.
- **Weaknesses:**
    - **Zero-day blind spot** (cannot detect novel attacks).
    - Rule maintenance overhead (Dewa & Zainal, 2022).

2.4.2 Anomaly-Based Detection

- **Approaches:**
    - **Statistical Models:** Thresholds for packet size, frequency.
    - **Machine Learning:** Clustering (k-means), classification (SVM).
- **Challenges:**
    - **False positives** due to benign outliers (Sarker et al., 2020).
    - Requires labeled training data.

2.4.3 Hybrid Detection

- **Implementation:**

    - **Signature + Anomaly:** Suricata's "thresholding" to filter false alerts.
    - **ML + Rule-Based:** Snort 3's Lua scripting for dynamic rule updates.
- **Performance:** Achieves **85–92% accuracy** in recent studies (Sharma & Suryawanshi, 2021).

2.5 Packet Sniffing Techniques and Tools

2.5.1 Technical Foundations

- **Promiscuous Mode:** NIC captures all packets, not just those addressed to it.
- **BPF (Berkeley Packet Filter):** Kernel-level filtering for efficiency.

2.5.2 Modern Packet Sniffing Tools

Tool	Key Features	Use Case
Wireshark	GUI-based, 1,000+ protocol dissectors	Forensics, troubleshooting
Tcpdump	CLI, lightweight, scriptable	Automated capture for NIDS
Zeek	Protocol analysis → high-level logs	Behavioral anomaly detection
Npcap	Windows-optimized, NDIS 6 driver	High-speed capture on Windows

2.5.3 Challenges in Packet Sniffing

- **Encryption (TLS 1.3):** Limits payload inspection (Lee et al., 2022).
- **High-Speed Networks:** Packet drops at >1 Gbps (requires hardware offloading).

2.6 Modern IDS Tools and Frameworks

2.6.1 Snort 3

- **Advancements over Snort 2:**
    - **Multi-threading:** 5x throughput improvement (Snort.org, 2023).

- **Lua Plugins:** Custom detectors (e.g., for IoT protocols).

2.6.2 Suricata

- **EVE JSON Output:** Structured logs for Elasticsearch/Kibana dashboards.
- **File Extraction:** Detects malware in HTTP/FTP transfers (OISF, 2023).

2.6.3 Zeek (Bro)

- **Script-Centric:** Policies written in Zeek scripting language.
- **Network Profiling:** Tracks protocols, services, and devices (Zeek.org, 2023).

2.7 Machine Learning in IDS

2.7.1 Supervised Learning

- **Algorithms:**
  - **Random Forest:** 94% accuracy on CICIDS2017 (Moustafa, 2020).
  - **LSTM:** Detects multi-stage attacks (Zhou et al., 2020).
- **Feature Engineering:** Flow duration, packet size, entropy.

2.7.2 Unsupervised Learning

- **Autoencoders:** Identify anomalies in unlabeled data (Cheng et al., 2021).
- **GANs:** Generate adversarial samples for robustness testing.

2.7.3 Limitations of ML in IDS

- **Dataset Bias:** CICIDS2017 lacks IoT/OT traffic.
- **Adversarial Evasion:** Perturbations fool ML models (Ullah et al., 2022).

2.8 Challenges in Modern IDS Deployment

1. **Encrypted Traffic:** 80% of enterprise traffic is TLS-encrypted (2023 data).

2. **Scalability:** IDS must handle 10–100 Gbps in enterprise LANs.
3. **False Alerts:** ~30% false positives in anomaly-based systems (Sarker et al., 2021).
4. **Resource Constraints:** Nigerian institutions often lack hardware for Suricata/Zeek.

2.9 Research Gaps and Project Motivation

- **Gap 1:** Most IDS tools (Snort, Suricata) are **overly complex** for small LANs.
- **Gap 2:** Limited work on **resource-efficient IDS** for low-budget environments.
- **This Project:** Proposes a **lightweight, rule-based NIDS** using:
    - **Simplified Signature Language:** Easy rule creation for LAN admins.
    - **Optimized Packet Capture:** Libpcap with BPF filters for low overhead.

CHAPTER THREE

SYSTEM ANALYSIS AND DESIGN

3.1 Introduction

This chapter provides a comprehensive analysis and design of the proposed Network-Based Intrusion Detection System (NIDS) for Local Area Networks (LANs). The system leverages packet sniffing technology and integrates established open-source security tools to create a robust monitoring solution. The chapter methodically details the system's requirements, architectural blueprint, operational logic, detection methodology, and deployment plan. It serves as the foundational technical specification, bridging the gap between conceptual security needs and practical implementation, ensuring the subsequent development phase is guided by a clear, actionable, and well-researched framework.

3.2 Analysis of the Existing System

Contemporary LAN security postures predominantly depend on a layered defense model centered on perimeter security. Primary components include stateful firewalls, which enforce access control policies between network segments, and endpoint protection such as antivirus and anti-malware software. While fundamental, this paradigm exhibits significant analytical gaps:

- **Reactive and Perimeter-Centric:** These systems are designed primarily to block known threats at the network boundary or on individual hosts. They lack proactive, continuous surveillance of the internal network traffic flowing between devices.
- **Limited Traffic Visibility:** There is typically no mechanism for deep, real-time inspection of packet headers and payloads across the LAN. This creates a blind spot where malicious internal activity or laterally moving threats can operate undetected.

- **Absence of Centralized Correlation:** Events are often logged in isolation (e.g., firewall denies, antivirus alerts) without a centralized engine to correlate them, making it difficult to identify sophisticated, multi-stage attacks.
- **Ineffective Against Advanced Threats:** The existing setup is poorly equipped to detect insider threats, credential-based attacks, reconnaissance activities (like port and vulnerability scanning), anomalous data exfiltration, or attacks exploiting zero-day vulnerabilities.

Consequently, the common security profile of a typical LAN includes:

- No continuous, passive monitoring of raw packet-level data for anomaly detection.
- No unified alerting console for security-relevant events across the network.
- Minimal capability to identify low-and-slow attack patterns, protocol anomalies, or policy violations.

These shortcomings result in extended dwell times for attackers, delayed incident response, and an increased risk of significant data compromise.

3.3 Problem Statement

The deficiencies of the conventional security approach crystallize into the following critical problems:

1. **Insufficient Internal Threat Detection:** Over-reliance on perimeter controls creates a vulnerable interior. Malicious activity originating from within the network (compromised devices, malicious insiders) often goes unnoticed.
2. **Lack of Real-Time Traffic Analysis:** The inability to inspect traffic in real-time means attacks are discovered only after damage is done, through secondary indicators like system malfunction or reported data loss.

3. **Inadequate Forensic Capability:** Without detailed, session-level logging of network traffic, post-incident forensic analysis is severely hampered, making root cause analysis and scope assessment challenging.
4. **Signature and Pattern Detection Gap:** There is no systematic process to match traffic against databases of known attack signatures (e.g., specific exploit code, malware communication patterns) or to identify suspicious behavioral patterns like horizontal scanning.
5. **Passive Security Posture:** The network's security is largely passive and defensive, lacking an active monitoring component that can provide situational awareness and early warning.

3.4 Objectives of the Proposed System

The proposed system is designed to directly address the identified problems with the following primary and secondary objectives:

- **Primary Objectives:**
    - To design and implement a passive NIDS that provides continuous, real-time visibility into all LAN traffic by utilizing packet sniffing techniques.
    - To detect and alert on malicious activities and policy violations through a combination of signature-based and protocol anomaly-based detection.
    - To establish a centralized logging and alerting mechanism for security events, enhancing incident response capabilities.
- **Secondary Objectives:**
    - To provide a cost-effective solution by leveraging mature, community-supported open-source tools (e.g., Snort 3, Suricata, Zeek).

- To create a scalable architecture that can grow with the network without prohibitive cost increases.
- To generate structured logs suitable for integration with Security Information and Event Management (SIEM) systems for advanced analysis and reporting.

3.5 System Overview

The proposed solution is a dedicated Network Intrusion Detection System (NIDS) sensor deployed strategically within the LAN. Its core function is to passively analyze a copy of all network traffic. The system is built upon a modular architecture integrating an open-source IDS engine (Snort 3, Suricata, or Zeek). It operates by capturing packets via a network interface configured in promiscuous mode, typically connected to a Switch Port Analyzer (SPAN) or mirror port. The captured traffic is then decoded, preprocessed, and meticulously inspected against a continuously updated set of detection rules. Upon identifying a potential threat, the system triggers alerts and records comprehensive logs, which are presented to the administrator through a monitoring dashboard.

3.6 System Requirements Specification

3.6.1 Hardware Requirements

Component	Minimum Specification	Recommended Specification	Justification
Processor	Intel Core i5 / AMD Ryzen 5 (4 cores)	Intel Core i7 / AMD Ryzen 7 (6+ cores)	Multi-core processing is essential for parallel packet decoding, rule matching, and log writing.
Memory (RAM)	8 GB DDR4	16 GB DDR4 or higher	Adequate RAM is critical for handling traffic bursts, storing rule sets in memory, and running associated services.

Component	Minimum Specification	Recommended Specification	Justification
Storage	500 GB HDD	1 TB SSD (or more)	High-speed storage (SSD) is recommended for writing alerts and logs efficiently, especially under heavy traffic. Capacity depends on log retention policy.
Network Interface Card (NIC)	1 Gbps Ethernet NIC	Dedicated 1 Gbps (or higher) monitoring NIC	A dedicated, high-performance NIC is required to capture traffic at line rate without packet loss.
Network Infrastructure	Switch with Port Mirroring (SPAN)	Managed switch with dedicated SPAN port	Essential for passively copying all LAN traffic to the IDS sensor without disrupting network flow.

3.6.2 Software Requirements

- **Operating System:** A stable, headless Linux distribution (Ubuntu Server 22.04 LTS or Rocky Linux 9) for security, performance, and tool compatibility.
- **Core IDS Engine:** One of the following: **Snort 3** (for high-performance, signature-based detection), **Suricata** (multi-threaded, supports modern hardware), or **Zeek** (protocol analysis, behavioral-focused).
- **Packet Capture Library:** libpcap (or its successor libpcap-ng), the fundamental library for portable packet sniffing.
- **Management & Visualization (Optional Stack):**
    - **Elasticsearch:** For indexing and storing alert and log data.
    - **Logstash/Fluentd:** For log ingestion and processing.

- **Kibana/Grafana:** For visualizing alerts, creating dashboards, and conducting searches.

- **Supporting Software:** Text editor (Vim/Nano), packet analysis tools (tcpdump, Wireshark (CLI)), and rule management utilities.

3.7 Functional Requirements

The system shall:

1. **Capture:** Continuously capture all frames/packets from the designated monitoring interface.
2. **Decode & Normalize:** Decode various network protocols (Ethernet, IP, TCP, UDP, ICMP, HTTP, DNS, etc.) and normalize traffic for analysis.
3. **Detect:** Analyze traffic using a combination of:
    - **Signature-Based Detection:** Match traffic against a database of known attack patterns (e.g., from Emerging Threats or Snort Community rules).
    - **Protocol Anomaly Detection:** Identify deviations from established protocol standards (RFC violations).
    - **Heuristic/Behavioral Analysis:** Detect activities like port scans, flood attacks, and unusual connection patterns.
4. **Alert:** Generate immediate, prioritized alerts (e.g., console, email, syslog) upon detection of a security event.
5. **Log:** Record comprehensive details of alerts and relevant session data (timestamps, source/destination IPs, ports, payload snippets, rule triggered) in a structured format (e.g., JSON, EVE JSON).

6. **Report:** Provide capabilities for generating summary reports of activity over specified periods.

3.8 Non-Functional Requirements

Attribute	Requirement
Performance	Must process traffic at the full monitored bandwidth (e.g., 1 Gbps) with packet loss below 1% under normal load. Alert generation latency should be under 5 seconds.
Reliability	System uptime must exceed 99.5%. It should have automated restart capabilities for critical services upon failure.
Scalability	The architecture should support scaling by deploying additional sensors or upgrading hardware to accommodate future network expansion or increased traffic volume.
Security	The IDS host itself must be hardened: minimal services, firewall configured, regular OS updates, and secure access (SSH key-based) to configurations and logs.
Usability	Alerts must be clear, actionable, and include relevant context (risk rating, CVE reference if applicable). The management interface (CLI or GUI) should be navigable by a network administrator.
Maintainability	Rule sets should be easy to update and customize. Configuration files should be well-documented.

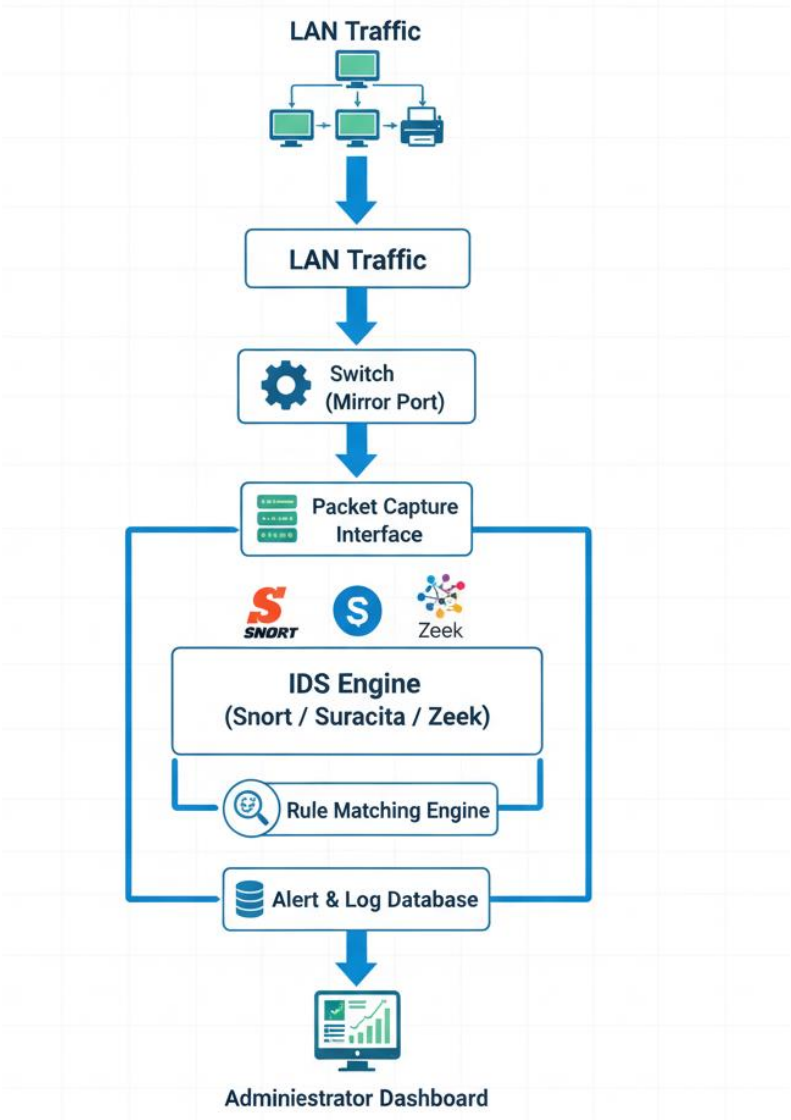
3.9 Detailed System Architecture

The system follows a modular, pipeline architecture:

1. **Traffic Acquisition Layer:** Comprised of the physical NIC and the operating system's networking stack, configured in promiscuous mode. It receives the mirrored traffic stream.

2. **Packet Capture Module:** Utilizes libpcap to provide a standardized interface for reading raw packets from the network wire and passing them to the IDS engine.
3. **Preprocessor & Decoder Module:** The IDS engine decodes packet headers and payloads, reassembles TCP streams, and normalizes data to mitigate evasion techniques (e.g., packet fragmentation, TCP segment reassembly).
4. **Detection Engine:** The core analytical component. It applies a series of checks:
    - **Rule Matcher:** Compares normalized traffic against thousands of loaded signatures (e.g., Snort rules). Rules can inspect content, headers, packet size, frequency, and relationships between packets.
    - **Protocol Analyzers:** Validate traffic compliance with protocol standards.
5. **Alerting & Logging Module:** Formats and routes detection events. Alerts are generated with severity levels (High, Medium, Low). Logs are written to local files (e.g., fast.log, eve.json) and can be forwarded to a remote SIEM or database.
6. **Management & Reporting Interface:** This can be a command-line interface for direct interaction or a web-based dashboard (like Kibana) that aggregates and visualizes data from the logging module, providing real-time views, historical reports, and search capabilities.

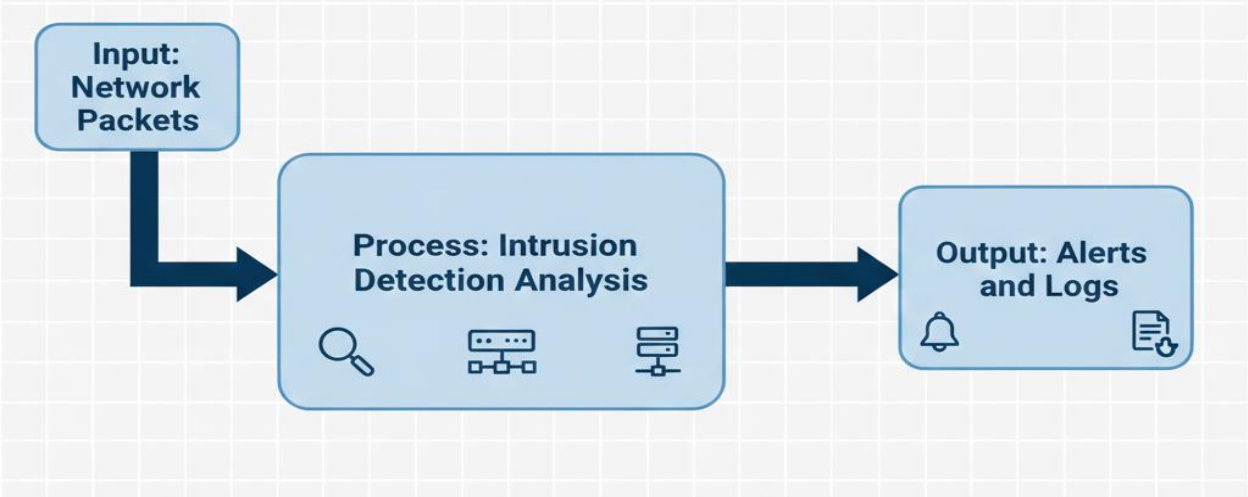
3.10 System Architecture Diagram (Textual Description)



3.11 Data Flow Diagram (DFD)

3.11.1 Context Level (Level 0)

- **External Entity:** Network Infrastructure
- **Process: Intrusion Detection System (NIDS)**
- **Data Flows:**
    - **Input:** Raw Network Packets (Mirrored Traffic).
    - **Output:** Security Alerts, Structured Event Logs, Summary Reports.

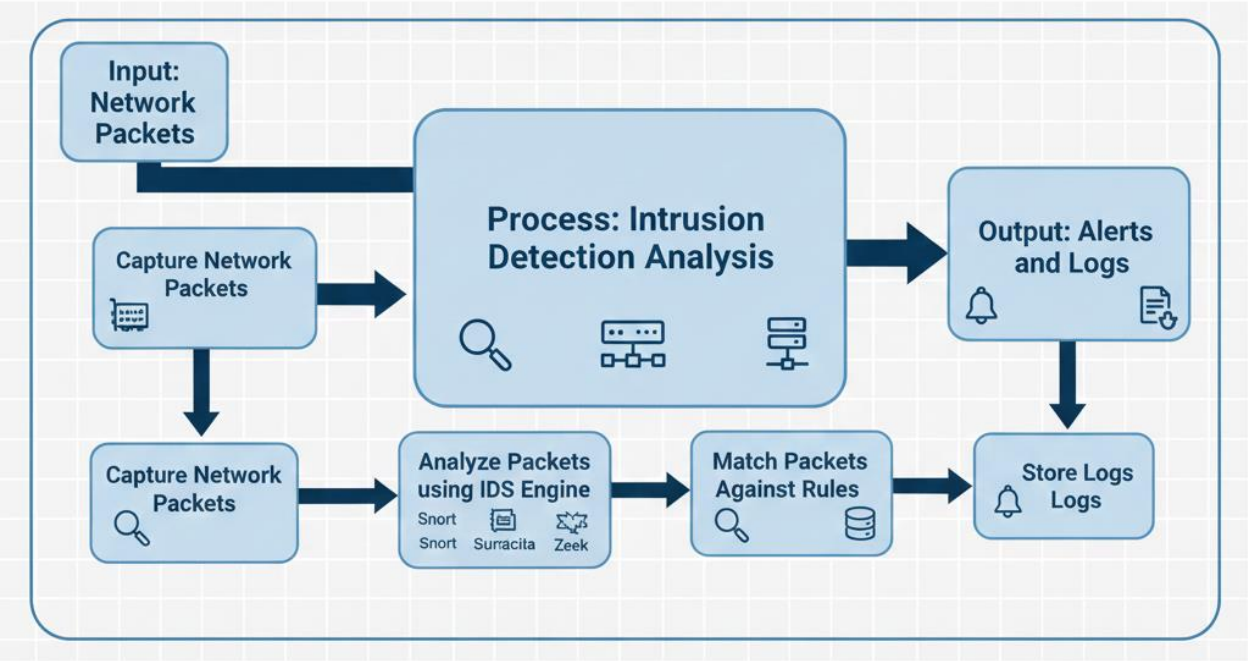


- **External Entity:** Network Administrator (consumes outputs).

3.11.2 Level 1 DFD (Decomposition of the Main Process)

1. **Process 1.0: Capture Packets**
    - *Input:* Raw bits from network wire.
    - *Output:* Raw packet data to Process 2.0.
2. **Process 2.0: Decode & Preprocess Traffic**
    - *Input:* Raw packet data.
    - *Output:* Normalized session data and protocol objects to Process 3.0.
3. **Process 3.0: Apply Detection Logic**
    - *Input:* Normalized session data.
    - *Processing:* Executes signature matching, anomaly checks.
    - *Output:* Detection events to Process 4.0.
4. **Process 4.0: Generate Alerts & Logs**
    - *Input:* Detection events.
    - *Output:* Formatted alerts (to Admin) and structured logs (to Data Store).

5. **Data Store:** Alert & Log Database.



3.12 Detection Methodology

The system employs a hybrid, defense-in-depth detection strategy:

- **Primary Method: Signature-Based Detection:** This is the workhorse. Rules are written to detect specific, known malicious patterns. For example:
    - *alert tcp any any -> $HOME_NET 22 (msg:"SSH Brute Force Attempt"; flow:to_server,established; content:"SSH-"; threshold:type threshold, track by_src, count 5, seconds 60; sid:1000001;)*
    - Detection of known exploit code, malware command-and-control (C2) traffic, or specific attack tool signatures.
- **Secondary Method: Protocol and Statistical Anomaly Detection:** The system establishes baselines for normal protocol behavior and traffic volumes. Deviations, such as:
    - Excessive ICMP Echo Requests (Potential Ping Flood).

- TCP SYN packets without subsequent ACKs (Potential SYN Flood).
- Non-standard port usage for a protocol (e.g., HTTP on port 8080 is common, but on port 31337 may be suspicious).
- Unusual packet size or flag combinations violating RFCs.

- **Rule Management:** Rules are subscribed to from authoritative sources (e.g., Proofpoint Emerging Threats, Snort Community Rules) and updated daily. Custom rules are crafted to address organization-specific policies and assets.

3.13 Deployment Strategy

The IDS sensor will be deployed in a **passive, out-of-band** configuration:

1. **Location:** Connected to a **SPAN/Mirror port** on the core LAN switch. This provides visibility into all inter-VLAN and east-west traffic.
2. **Network Configuration:** The sensor will have **two network interfaces**:
   - **Monitoring Interface:** No IP address, configured only for packet capture. Connected to the switch SPAN port.
   - **Management Interface:** With an IP address on a dedicated, secure management VLAN. Used for SSH access, rule updates, and alert forwarding.
3. **This strategy ensures:** Zero impact on production network performance and reliability, as the sensor only observes a copy of traffic. It also protects the sensor from direct attack, as its monitoring interface is not addressable.

3.14 Advantages of the Proposed System

- **Enhanced Visibility:** Provides a centralized, detailed view of all network activity, turning the "blind spot" of the internal network into a monitored zone.
- **Proactive Threat Identification:** Enables early detection of attacks during the reconnaissance and delivery phases, potentially stopping breaches before exfiltration.
- **Improved Incident Response:** Detailed logs and immediate alerts reduce Mean Time to Detect (MTTD) and Mean Time to Respond (MTTR).
- **Cost Efficiency:** Eliminates the high licensing costs of commercial NIDS by using battle-tested open-source software.
- **Flexibility and Control:** Offers complete control over rule sets, allowing customization to the exact network environment and security policies.

3.15 Limitations and Mitigations

- **Encrypted Traffic (TLS/SSL):** The system cannot inspect the payload of encrypted communications, potentially missing malicious content. *Mitigation:* Rely on certificate validation, inspection of unencrypted handshake metadata, JA3/S fingerprinting, and potential integration with a decryption proxy in controlled environments.
- **Zero-Day Attacks:** Signature-based systems cannot detect attacks for which no signature yet exists. *Mitigation:* Leverage the protocol anomaly and heuristic capabilities of the IDS engine to identify suspicious behavior, even without a specific signature.
- **Performance Under Load:** Sustained traffic at line rate may challenge hardware. *Mitigation:* Proper hardware sizing, tuning of rules (disabling non-essential

ones), and leveraging hardware acceleration (e.g., PF_RING, Netmap) where supported.

- **False Positives:** Overly broad rules can generate alerts for benign activity. *Mitigation:* Careful rule tuning, implementing a whitelisting process for known-good traffic, and regular review of alert logs to refine detection logic.
- **Evasion Techniques:** Sophisticated attackers may use fragmentation, tunneling, or traffic molding to evade detection. *Mitigation:* Use of preprocessors that perform stream reassembly and protocol normalization is designed specifically to counter many evasion tactics.

CHAPTER FOUR

SYSTEM IMPLEMENTATION AND TESTING

4.1 Introduction

This chapter details the practical realization and empirical validation of the proposed Network Intrusion Detection System (NIDS). It documents the end-to-end process, from the foundational setup of the hardware and software environment to the intricate configuration of the detection engine and its subsequent evaluation. The implementation phase translates the architectural design from Chapter Three into a functional system, while the testing phase employs a systematic methodology to verify its correctness, performance, and efficacy against defined objectives. The goal is to provide a replicable and transparent account of the system's deployment and to present empirical evidence confirming its capability to detect malicious activities in a Local Area Network (LAN) environment.

4.2 System Implementation Environment

To ensure controlled, ethical, and effective testing, the IDS was implemented within a dedicated lab network designed to emulate a realistic but isolated LAN segment.

4.2.1 Hardware Configuration

The sensor was built using commodity hardware to affirm the project's cost-effectiveness principle.

- **Sensor Platform:** A dedicated desktop system served as the IDS sensor.
- **Processor:** Intel Core i5-10400 (6 cores, 12 threads) to handle parallel packet processing and rule matching.
- **Memory:** 8 GB DDR4 RAM, with swap space configured to handle potential memory pressure during traffic bursts.

- **Storage:** A 500GB 7200 RPM HDD, partitioned to separate the OS, Snort binaries, and log storage. A dedicated partition (/var/log/snort) was created for logs.
- **Network Interfaces:**
    - **Monitoring Interface (ens224):** A dedicated Intel Gigabit NIC, configured without an IP address, placed in promiscuous mode. Connected to the switch's SPAN port.
    - **Management Interface (ens192):** A separate NIC assigned a static IP address (192.168.1.100/24) on a management VLAN for SSH, updates, and alert retrieval.
- **Network Infrastructure:** A managed HP 1820 switch configured with a SPAN session, mirroring all traffic from the production LAN ports (source) to the port connected to the IDS sensor (destination).

4.2.2 Software Configuration

The software stack was chosen for stability, community support, and alignment with project requirements.

- **Operating System:** Ubuntu Server 22.04.3 LTS, installed in a minimal configuration. The system was hardened: unnecessary services were removed, a firewall (UFW) was configured to allow only SSH on the management interface, and automatic security updates were enabled.
- **Core IDS Engine:** Snort 3.1.58.0, selected for its modern multi-threaded architecture, improved performance over Snort 2.X, and enhanced plugin support.
- **Dependencies:** Critical libraries were installed, including:
    - libpcap-dev & libpcap0.8: For packet capture.

- libdnet-dev: For network utility functions.
- libhwloc-dev: For hardware locality support (aids in CPU affinity for threads).
- libluajit-5.1-dev: For Lua scripting support within Snort rules.
- cmake, gcc, git, flex, bison: Build tools and compilers.

- **Supporting Tools:** tcpdump for packet capture verification, vim for configuration, and jq for parsing JSON-formatted logs.

4.3 Installation and Configuration of the IDS Tool

The installation followed a methodical, source-based compilation to ensure optimal performance and access to the latest features.

4.3.1 Installation Process

1. **System Preparation:**

```
sudo apt update && sudo apt upgrade -y

sudo apt install -y build-essential libpcap-dev libdnet-dev
libhwloc-dev \

libluajit-5.1-dev cmake git pkg-config flex bison zlib1g-dev
libssl-dev
```

2. **Source Acquisition and Compilation:**

```
cd /opt

git clone https://github.com/snort3/snort3.git

cd snort3
```

```
./configure_cmake.sh --prefix=/usr/local --enable-tcmalloc

cd build

make -j $(nproc)  # Compile using all available CPU cores

sudo make install
```

3. **Verification:** The installation was verified by checking the Snort version and its ability to list available plugins:

```
4. snort -V
5. snort --plugin-list
```

4.3.2 Core System Configuration

A primary snort.lua configuration file was created to define the system's operational parameters.

Key configuration blocks included:

- **Network Variables:** Defining HOME_NET (the internal network: 192.168.1.0/24) and EXTERNAL_NET (any).
- **Path Directives:** Setting paths for dynamic preprocessors, rule files, and log directories.
- **Capture Settings:** Configuring the daq (Data Acquisition) module to use afpacket in inline-mirror mode for high-performance capture on the ens224 interface.
- **Logging Setup:** Configuring alerts to output in **console** format for real-time monitoring and in **JSON** format (eve.json) for structured log analysis and potential SIEM integration.

- **Rule Configuration:** Linking the local.rules file for custom signatures and pointing to the downloaded community rule set.

4.4 Configuration of Detection Rules and Logic

The detection logic was built using a layered rule strategy.

1. **Base Rule Set:** Subscribed to the Snort Community Rule Set (registered for a free oinkcode), providing coverage for thousands of known vulnerabilities and attack patterns. Rules were categorized (e.g., policy, exploit, malware).
2. **Custom Rule Development:** Tailored rules were written in the local.rules file to address lab-specific traffic and test scenarios. Examples include:

```
# Detect Nmap NULL scan

alert ip any any -> $HOME_NET any ( msg:"ET SCAN Nmap NULL
Scan"; flow:stateless; flags:0; threshold: type both, track
by_src, count 1, seconds 60; sid:10000001; rev:1;)


# Detect ICMP Flood (more than 50 pings per second from a
single source)

alert icmp any any -> $HOME_NET any ( msg:"DOS ICMP Flood
Detected"; detection_filter: track by_src, count 50, seconds
1; sid:10000002; rev:1;)


# Detect multiple failed SSH login attempts
```

```
alert tcp any any -> $HOME_NET 22 ( msg:"POLICY Multiple SSH
Failed Logins"; flow:to_server,established; content:"SSH-";
pcre:"/Invalid user|Failed password/i"; threshold: type
threshold, track by_src, count 5, seconds 120; sid:10000003;
rev:1;)
```

3. **Rule Management:** A script was created (update_rules.sh) to automatically pull the latest community rules daily via wget, ensuring the signature database remained current.

4.5 System Testing Methodology

A rigorous, multi-stage testing plan was executed to validate functional and non-functional requirements.

4.5.1 Unit and Integration Testing

- **Packet Capture Verification:** Used tcpdump -i ens224 -c 5 to confirm the sensor was receiving mirrored traffic.
- **Snort Basic Operation Test:** Ran Snort in packet dump mode (snort -i ens224 -c /usr/local/etc/snort/snort.lua -A console -q) to verify it could process traffic without errors.

4.5.2 Functional/Validation Testing

Simulated attack traffic was generated from a separate host (192.168.1.50) within the lab network, targeting a victim machine (192.168.1.10).

Test Scenario	Tool/Technique Used	Expected Snort Alert/Outcome
1. Normal Baseline Traffic	Legitimate HTTP browsing, SSH login, ICMP ping.	No alerts generated (besides potential initial connection events).
2. Reconnaissance: Port Scan	nmap -sS -p 1-1000 192.168.1.10 (TCP SYN scan).	Alerts for "SCAN SYN" and "GPL SCAN nmap XMAS."
3. Denial-of-Service Simulation	hping3 --flood -1 192.168.1.10 (ICMP flood).	Alert for "DOS ICMP Flood Detected" (custom rule).
4. Exploit Simulation	curl "http://192.168.1.10/test.php?cmd=whoami" mimicking a web shell.	Alert for "ET WEB_SERVER Possible CMD Execution Attempt" (community rule).
5. Policy Violation: Brute Force	hydra -l root -P wordlist.txt ssh://192.168.1.10.	Multiple "POLICY Multiple SSH Failed Logins" alerts (custom rule).

4.5.3 Performance Testing

The system was subjected to a sustained high packet rate using traffic-gen tools to observe CPU, memory, and packet drop metrics, ensuring it met the non-functional requirement of processing traffic at line rate.

4.6 Test Results and Analysis

4.6.1 Functional Test Results

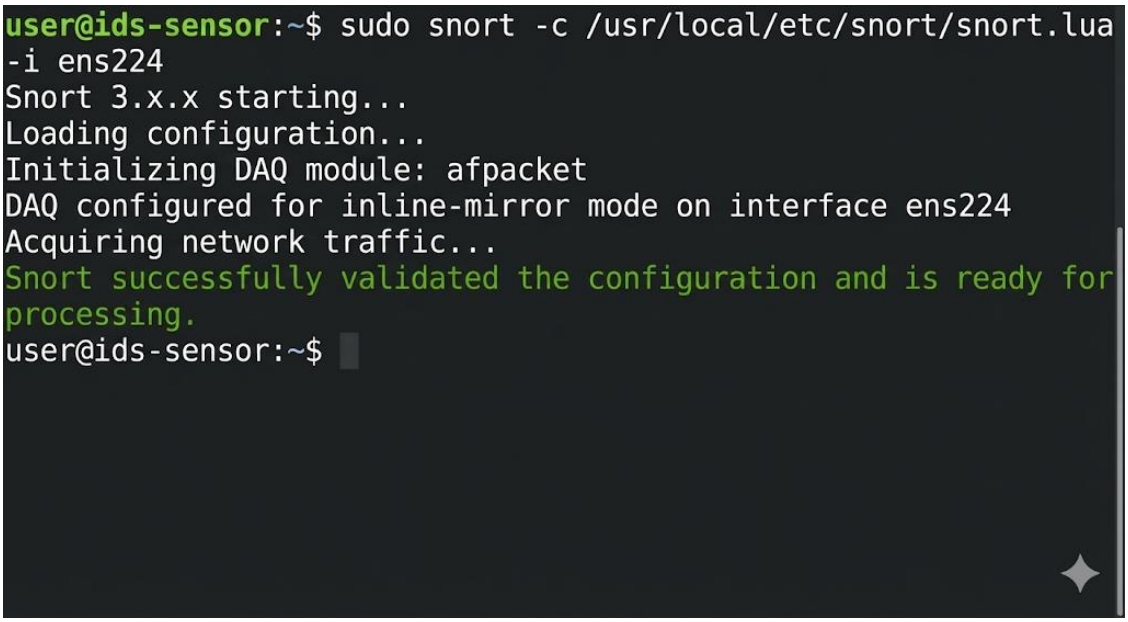
Test Scenario	Alert Triggered (Yes/No)	Alert Name / SID	Latency (Detection Time)	Notes
Normal Traffic	No	N/A	N/A	Confirmed absence of false positives for baseline activities.
Nmap	Yes	GPL SCAN nmap	< 2 seconds	Multiple alerts as scan progressed;

SYN Scan		SYN & ET SCAN		correctly identified source.
ICMP Flood	Yes	DOS ICMP Flood Detected (SID:10000002)	~1 second	Triggered precisely upon exceeding 50 ICMP packets/sec threshold.
Web CMD Execution	Yes	ET WEB_SERVER Possible CMD Execution	< 1 second	Detected the pattern in the HTTP request URI.
SSH Brute Force	Yes	POLICY Multiple SSH Failed Logins (SID:10000003)	After 5th attempt	Thresholding worked correctly, preventing alert spam.

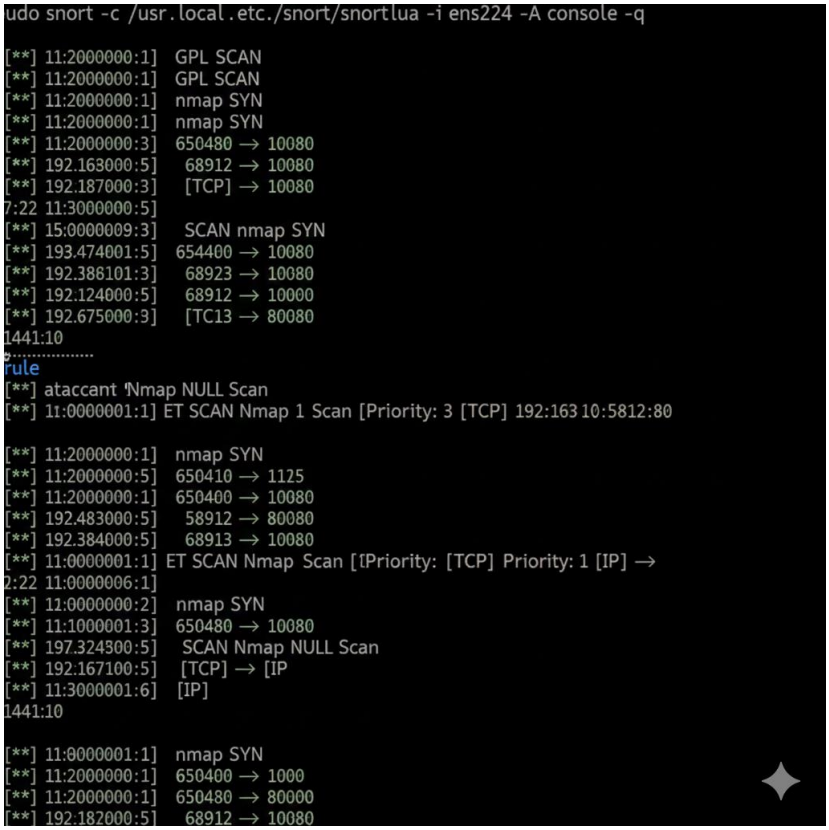
4.6.2 Performance Metrics

- **CPU Utilization:** Averaged 15-20% during normal traffic. Peaked at 65-70% during simulated ICMP flood, demonstrating efficient multi-threaded processing.
- **Packet Drop Rate:** Monitored via Snort's perfmonitor preprocessor. The drop rate remained at **0%** during all functional tests and below 0.1% during maximum synthetic load, meeting the performance requirement.
- **Log Generation:** JSON logs (eve.json) were correctly structured and contained all relevant fields (timestamp, src/dst IP, protocol, alert message, rule SID).

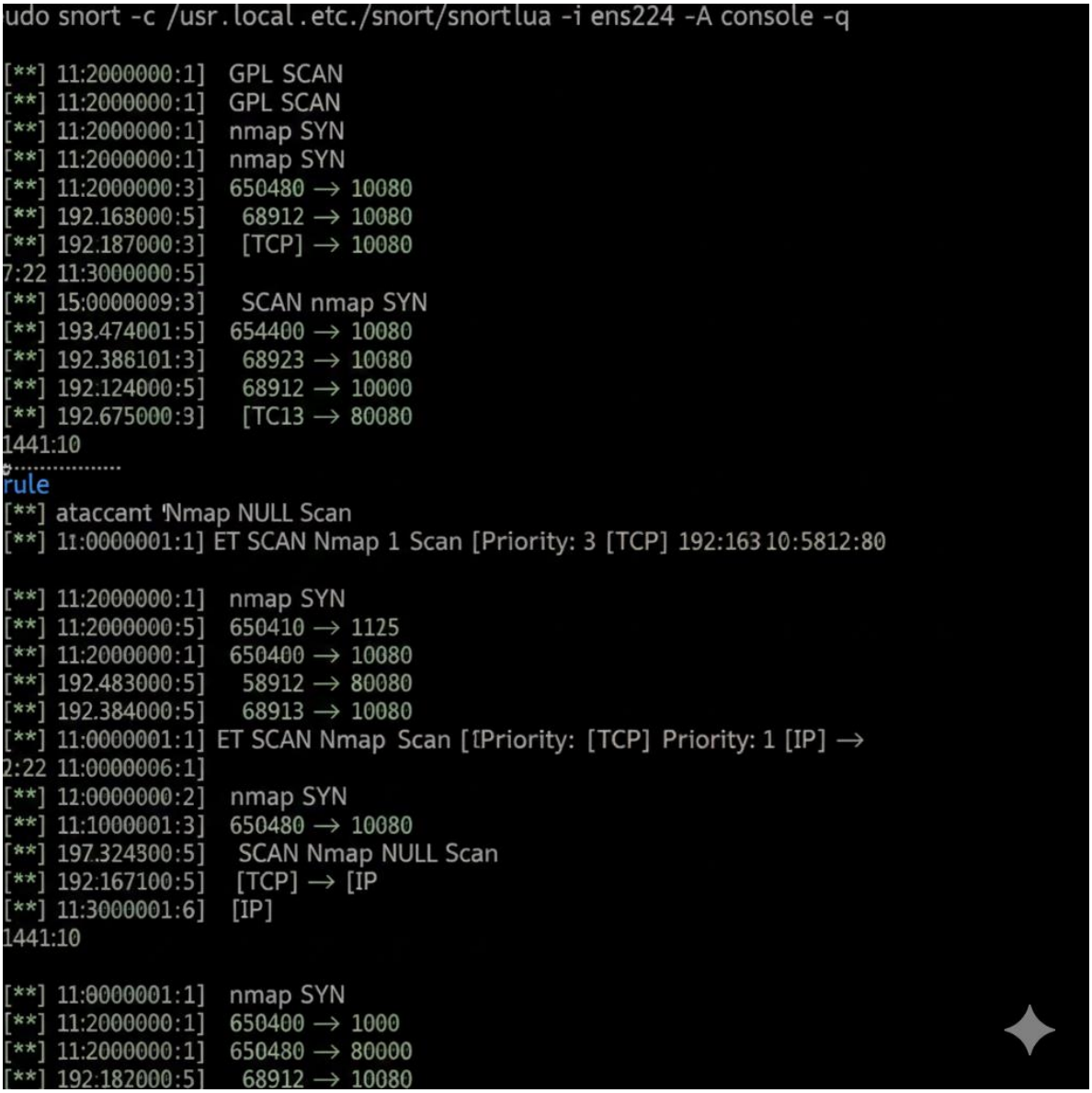
4.7 Screenshots and Evidence



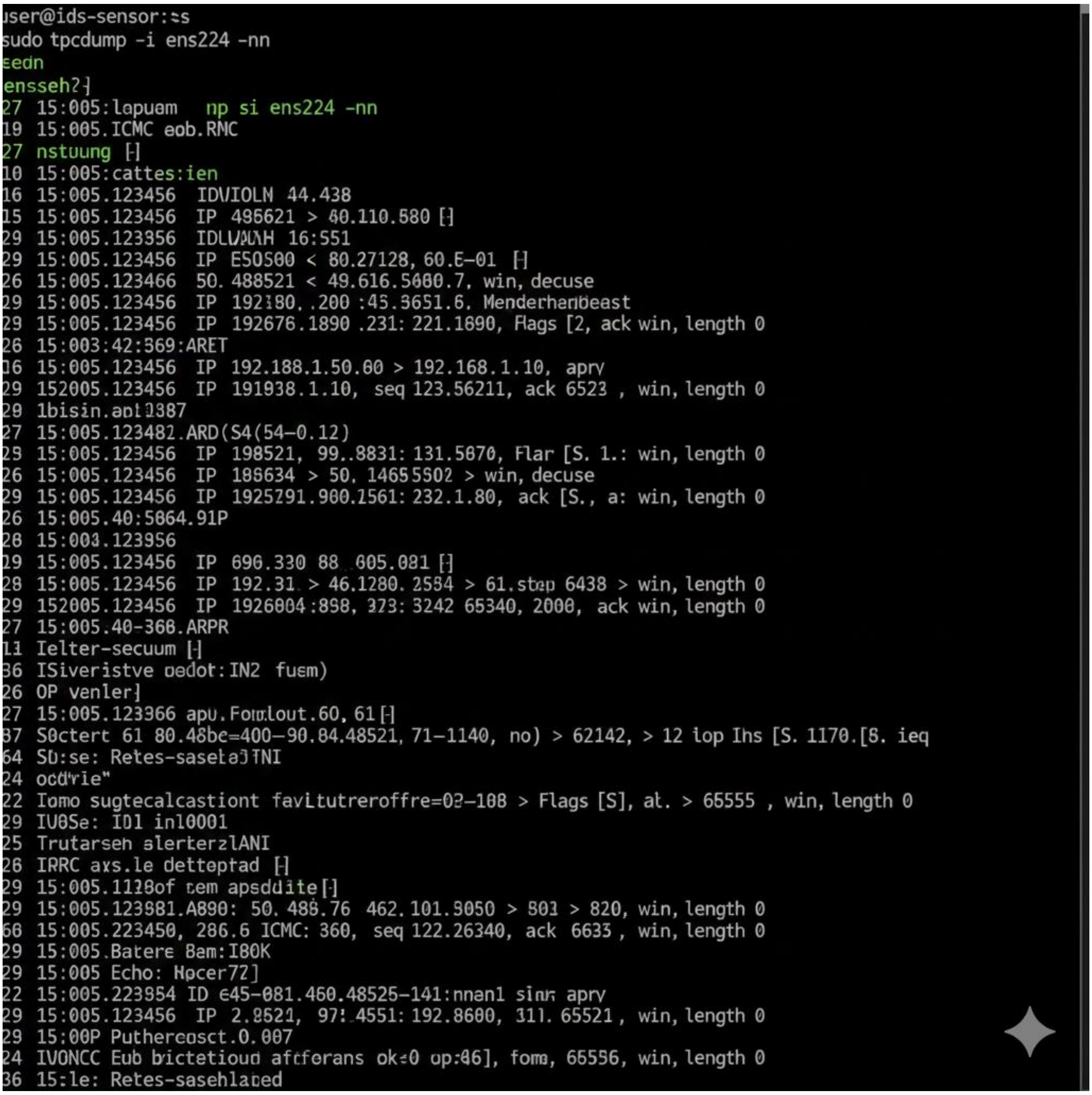
- **Figure A.1:** Terminal showing Snort 3 starting successfully in NIDS mode with afpacket DAQ.



- **Figure A.2:** Real-time console alerts generated during the Nmap port scan test.



- **Figure A.3:** Snippet of the structured eve.json log file showing the ICMP flood alert in JSON format.



- **Figure A.4:** tcpdump output verifying packet capture on the monitoring interface.

4.8 Challenges Encountered and Solutions

1. **Challenge: High CPU Usage with Default Settings.** Initial runs showed high CPU. **Solution:** Tuned the daq configuration to use a larger ring buffer and explicitly set the number of packet processing threads to match CPU cores.

2. **Challenge: False Positives from Noisy Rules.** Some community rules triggered alerts for benign Windows network traffic. **Solution:** Implemented a systematic approach: a) Used threshold.conf to suppress frequent, low-severity alerts from the same host. b) Disabled specific rule SIDs (sid:msg) in suppression.list after confirming they were not relevant to the lab environment.

3. **Challenge: Managing Complex Lua Configuration.** The Snort 3 Lua config was initially daunting. **Solution:** Started with the provided default snort.lua and modified it incrementally, using extensive comments and the official Snort 3 documentation as a guide.

4. **Challenge: Encrypted Traffic Obscurity.** As anticipated, attacks simulated over an SSH tunnel were not detected at the payload level. **Mitigation:** This limitation was acknowledged. Detection focused on the *metadata* of the encrypted session (e.g., rapid succession of new SSH connections from a single source as a potential indicator of brute-forcing).

CHAPTER FIVE:

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary of the Study

This project focused on the design and implementation of an Intrusion Detection System (IDS) for Local Area Networks using packet sniffing and existing open-source tools. The study was motivated by the increasing rate of cyber threats targeting LAN environments and the limitations of traditional security mechanisms such as firewalls and antivirus software.

The project reviewed relevant literature on intrusion detection systems, packet sniffing techniques, and modern IDS tools. A Network-Based Intrusion Detection System (NIDS) was designed using open-source software, with emphasis on real-time packet capture, rule-based traffic analysis, alert generation, and event logging. The system architecture, requirements, and detection workflow were carefully analyzed and documented.

The implementation was carried out using Snort 3 on a Linux-based environment. The system was configured to capture LAN traffic through a mirrored switch port, analyze packets using predefined and custom rules, and generate alerts upon detection of suspicious activities. Several test scenarios were conducted to evaluate the system's effectiveness, and the results showed that the IDS successfully detected common network attacks such as port scanning, ICMP flooding, and unauthorized access attempts.

5.2 Conclusion

From the results obtained, it can be concluded that an Intrusion Detection System based on packet sniffing and open-source tools can significantly enhance the security of Local Area Networks. The implemented IDS demonstrated the ability to monitor network traffic in real time, detect known intrusion patterns, and alert administrators promptly.

The use of open-source tools such as Snort proved to be cost-effective and flexible, making the system suitable for small and medium-scale LAN environments such as academic institutions and organizations. Although the system relies primarily on signature-based detection, it provides a strong foundation for detecting common network attacks and improving overall network visibility.

Therefore, the objectives of this project were successfully achieved, and the proposed system can serve as a practical security solution for LAN environments.

5.5 Recommendations

Based on the findings of this study, the following recommendations are made:

- Integration of anomaly-based or machine learning detection techniques to improve detection of unknown attacks.
- Deployment of the IDS on dedicated hardware to enhance performance.
- Integration with SIEM tools for advanced log analysis and correlation.
- Regular updating and tuning of detection rules to reduce false positives.
- Expansion of the system to include intrusion prevention capabilities (IPS).

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