PROJECT REPORT

on

"NETWORK FORENSIC ANALYZER"

Submitted in partial fulfillment of the requirements
for the award of degree

MASTER OF COMPUTER APPLICATIONS

of

KLE TECHNOLOGICAL UNIVERSITY

by

Mr. RAMESH G HANASI
(SRN: 01FE23MCA020)

KLE TECH.

DEPARTMENT OF COMPUTER APPLICATIONS
KLE TECHNOLOGICAL UNIVERSITY
Vidyanagar, Hubballi-580031, Karnataka.
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Under the guidance of

Internal Guide	*External Guide*
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CERTIFICATE

This is to certify that the project work entitled **"NETWORK FORENSIC ANALYZER"** Submitted by **Mr.RAMESH G HANASI (01FE23MCA020)** to the **KLE Technological University, Hubballi, Karnataka,** for the award of degree of **Master of Computer Application of the KLE Technological University, Hubballi** is a record of the bonifide work carried out by her and his during the academic year 2024-2025.The project report has been approved as it satisfies the academic requirement in respect of project work prescribed for the said degree.

During the academic year 2024-25

Prof. Akash Hulakund,	**Dr. P R Patil ME, PhD**	**Dr. Basavaraj S Anami**
Project Guide	Head of Department	Registrar,
Asst. Professor	MCA Dept.	KLE Technological University
MCA Dept		

Viva-Voce Examination

Name of the Examiners	Signature with Date
1.	**1.**___________________
2.	**2.**___________________

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Mr.RAMESH G HANASI

ABSTRACT

In today's hyper-connected digital environment, networks serve as the backbone for communication, commerce, and organizational operations. However, the increasing reliance on interconnected systems has simultaneously opened the door to sophisticated cyber threats such as data breaches, DDoS attacks, and stealthy intrusions. Traditional security tools like firewalls and signature-based intrusion detection systems provide partial protection but often fail to uncover hidden or low-level packet anomalies. This gap highlights the necessity for a more investigative approach to network monitoring.

The proposed Network Forensics System addresses this issue by combining real-time packet capture, protocol decoding, intelligent filtering, anomaly detection, and visual reporting into a unified framework. Unlike existing tools that overwhelm users with raw technical data, this system emphasizes clarity and usability through an interactive dashboard and structured report generation. The methodology involves capturing packets in promiscuous mode, decoding multiple protocols such as TCP, UDP, HTTP, and DNS, applying dynamic filters, and identifying suspicious behaviors using analytical rules.

Testing demonstrated reliable packet interception, accurate anomaly detection, and high responsiveness even under heavy traffic. Users appreciated the system's ability to transform complex network data into actionable insights. The findings confirm its effectiveness as both a forensic investigation tool and a proactive monitoring solution.

In conclusion, the system successfully bridges the gap between security visibility and forensic intelligence. Future enhancements may include machine learning-based threat prediction, automated incident response, support for encrypted traffic analysis, and cloud-based scalability, evolving it from a monitoring platform into a fully autonomous cybersecurity defense mechanism.

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CHAPTER 1

INTRODUCTION

In today's digital-first society, the dependence on networks for communication, commerce, governance, and critical infrastructure has increased drastically. While this interconnected environment improves efficiency and accessibility, it also widens the attack surface for cybercriminals. Incidents such as data breaches, ransomware campaigns, distributed denial-of-service (DDoS) attacks, and unauthorized intrusions are escalating in frequency and sophistication. Traditional defense mechanisms, including firewalls and signature-based intrusion detection systems, are effective to a point, but they often struggle to detect covert or low-level anomalies hidden within network packets. This limitation has created the need for more advanced monitoring and investigative approaches.

1.1 Literature Review / Survey

The field of network forensics is a specialized branch of digital forensics concerned with the monitoring, capture, storage, and analysis of network traffic for the purpose of information gathering, legal evidence, and incident response. It differs from traditional intrusion detection and prevention systems by focusing not only on real-time alerts but also on reconstructing past events to answer critical questions such as what happened, when did it happen, who was involved, and how was it carried out.

Several research efforts and industry tools have paved the way for network forensic analysis. **Wireshark**, for example, is widely used in academia and industry for packet capture and inspection. It offers protocol dissectors for hundreds of protocols but requires expert knowledge to interpret raw traffic effectively. **NetworkMiner**, on the other hand, emphasizes passive network sniffing and forensic evidence recovery such as files and credentials, but has a relatively limited visualization framework. Similarly, **Xplico** is designed for internet traffic decoding, transforming captured packets into high-level objects like emails, web pages, and VoIP calls, but is more focused on reconstruction than on visualization or case management.

The academic literature highlights the importance of multi-layered analysis. For example, researchers propose session reconstruction for TCP/UDP flows to recreate conversations between communicating entities. Others focus on anomaly detection in DNS queries, where abnormal query patterns can indicate malware command-and-control or phishing domains. Visualization approaches such as protocol heatmaps, traffic timelines, and top talker graphs have proven effective in quickly highlighting anomalies that may otherwise be buried in millions of packets. A number of works also emphasize the utility of GeoIP mapping to connect suspicious traffic with geographic regions or hostile actors.

From this review, it is evident that while powerful tools exist, most are fragmented, expensive, or require steep learning curves. This project seeks to combine the best of these techniques—capture, reconstruction, file extraction, visualization, and reporting—into a single, user-friendly application tailored for both academic learning and real-world investigations.

1.2 Challenges / Motivation

One of the central challenges in network forensics is **scale**. Modern networks generate massive amounts of data every second, and forensic analysts are required to sift through this traffic to locate malicious activity or evidence of compromise. Manual inspection of raw packet data is not only tedious but often impractical. Investigators require tools that can automatically filter, categorize, and highlight suspicious packets based on predefined heuristics.

Another challenge is **encryption**. With the widespread adoption of HTTPS, VPNs, and encrypted messaging platforms, payload visibility has drastically decreased. While content may be hidden, metadata such as source/destination IPs, ports, and traffic patterns can still reveal meaningful insights. This increases the demand for tools that excel at metadata analysis, session reconstruction, and anomaly visualization.

The **time factor** is also a pressing issue. During an active incident response, analysts need to generate insights quickly to contain the breach and minimize damage. Traditional packet analysis tools, although powerful, can be slow and unwieldy when faced with time constraints.

Finally, there are significant **resource and accessibility gaps**. High-end commercial forensic tools provide advanced features but are prohibitively expensive for small organizations, universities, and training institutes. Open-source tools are available but often lack integration, forcing analysts to switch between multiple platforms.

The motivation for developing this **Network Forensic Analyzer (NFA)** is therefore twofold. On the one hand, it seeks to serve as an educational platform for students and researchers to practice forensic analysis with real traffic data. On the other hand, it aims to be a practical incident response tool that provides integrated capture, analysis, visualization, and reporting at no additional cost. By addressing usability, affordability, and comprehensiveness, this project aspires to bridge the gap between academia and industry practice.

1.3 Objectives of the Project

The overarching goal of the **Network Forensic Analyzer (NFA)** project is to design and implement an integrated, user-friendly, and academically valuable platform for capturing, analyzing, and visualizing network traffic. Unlike many existing tools that address only one or two stages of forensic analysis, this project seeks to bring together all critical stages—acquisition, analysis, visualization, reconstruction, and reporting—under a single interface. By doing so, the tool not only facilitates faster and more effective incident investigations but also provides a structured environment for students and professionals to learn network forensics in a hands-on way.

A primary objective is to support both **live and offline analysis** of traffic. This means the system must be capable of real-time packet capture from one or multiple network interfaces while also being able to ingest previously recorded PCAP files for retrospective investigation. This dual mode of operation ensures that the analyzer is useful not only during active incident response but also for post-event forensic reconstruction and classroom demonstrations using sample traffic datasets.

Another crucial objective is to enable **deep session reconstruction for TCP communications**. In real investigations, single packets often do not provide sufficient context. By reassembling entire conversations between endpoints, investigators can understand complete request–response sequences, extract credentials, or identify malicious command-and-control behavior. The project therefore maintains directional TCP streams, allowing investigators to view client-to-server and server-to-client data side by side in plain text.

Closely related is the objective of **basic file extraction or HTTP carving**. Many intrusions involve the transfer of malicious files, stolen data, or suspicious web content. The NFA aims to identify HTTP responses in reconstructed streams, determine content types, and carve out files such as images, HTML pages, PDFs, or binaries for further examination. While the initial implementation focuses on simple Content-Length parsing, it lays the groundwork for more advanced carving techniques, making the tool valuable for evidence recovery and malware analysis.

A further objective is to integrate **rich visualization and analytics directly into the GUI**. Visual representations such as timelines, protocol heatmaps, bar charts of top talkers, and interactive network graphs can reveal patterns, anomalies, or outliers far faster than textual tables. By embedding these charts within the tool itself, the project reduces the need for analysts to export data into third-party plotting tools and fosters an intuitive understanding of the traffic.

Complementing these analysis functions is the objective of **GeoIP lookup and world map visualization**. Attribution—the process of linking network events to actors or regions—is a fundamental part of investigations. The NFA allows the analyst to load a local MaxMind GeoIP database and automatically plot external IP addresses on a global map using Folium. This geographic view helps quickly identify concentration points of suspicious activity and adds a valuable dimension to reports.

From a usability and workflow perspective, the project has the objective of supporting **case management and tagging**. Analysts can tag individual packets as "suspicious," "interesting," or "benign," filter based on these tags, and save entire sessions as a "case" with all associated metadata and flow information. This mirrors the workflow of professional digital forensics, where evidence must be organized, annotated, and saved in a reproducible way.

Another important objective is **automated report generation**. Investigations often culminate in reports that summarize findings for managers, legal teams, or academic evaluation. The NFA automatically produces a structured HTML report containing total packet counts, top sources and destinations, and a sample of suspicious packets. This not only saves time but also provides students with a real-world deliverable format they can study and adapt.

Equally significant is the objective of **cross-platform accessibility and modern GUI design**. By building the interface with `ttkbootstrap`, the NFA benefits from a clean, themeable look compatible with Windows, Linux, and macOS. The inclusion of meters, flood gauges, toast notifications, and combobox filters makes the application approachable for newcomers while still powerful for advanced users.

Finally, the project's educational objective is to **bridge the gap between theoretical knowledge and practical skills**. Many cybersecurity courses teach packet analysis conceptually but lack a hands-on environment that students can use outside expensive labs. This tool provides that environment. Instructors can supply PCAPs from various scenarios, students can load them into the analyzer, apply filters, reconstruct sessions, extract files, and generate reports, thereby simulating real investigative workflows.

In summary, the objectives of the Network Forensic Analyzer can be grouped into four pillars:

- **Acquisition:** Live capture and offline PCAP loading.
- **Analysis & Reconstruction:** Protocol dissection, session reassembly, file carving, suspicious pattern detection.
- **Visualization & Reporting:** Timelines, heatmaps, top talkers, network maps, GeoIP world map, and HTML report generation.
- **Usability & Education:** Tagging, case management, modern GUI, cross-platform support, and alignment with academic training.

Collectively, these objectives ensure that the NFA is not just another packet sniffer but a comprehensive forensic investigation environment suitable for both classroom and real-world use.

1.4 Problem Definition

Modern networks have become highly complex ecosystems that carry vast amounts of sensitive information every second. Organizations face a constant barrage of cyber threats, ranging from malware infections and insider misuse to sophisticated state-sponsored attacks. When a security incident occurs, the ability to reconstruct the attack timeline, identify the attacker's techniques, and recover transferred evidence becomes critical. This is the core purpose of network forensics. However, despite the criticality of this discipline, there remains a conspicuous gap between the tools currently available and the needs of both practitioners and learners.

On one side of the spectrum are enterprise-grade forensic suites offered by commercial vendors. These tools are feature-rich but extremely costly, often licensed on a per-seat or per-case basis. This high price makes them inaccessible to small organizations, universities, and training institutes. Furthermore, because the source code is proprietary, academic researchers and students cannot extend or customize these tools for experimentation or learning purposes.

On the other side are open-source utilities such as Wireshark, tcpdump, and NetworkMiner. While they are widely used and powerful, they are not designed as end-to-end forensic environments. Analysts must often use multiple separate programs to capture traffic, reconstruct sessions, carve files, and visualize flows. This fragmented workflow leads to inefficiency and a steep learning curve, particularly for students and junior analysts who are still mastering the fundamentals of packet analysis.

Additionally, most open-source tools focus on protocol-level inspection but lack modern visual analytics capabilities. For example, although Wireshark can filter and decode packets, it does not natively produce interactive timelines, protocol heatmaps, or geographic maps of external IPs. This is a serious limitation because patterns and anomalies are often easier to detect visually than through raw data tables. In the context of large-scale investigations or classroom teaching, visualization can dramatically improve comprehension and speed of analysis.

Another major challenge is **workflow and evidence management**. Professional forensic analysis requires case-based organization, tagging of evidence, and the ability to produce structured reports that can be presented to management or used in legal proceedings. Most free tools leave this entirely up to the analyst, resulting in unstructured notes, ad-hoc screenshots, and inconsistent reporting formats. This creates a barrier for students as well, since they cannot easily practice end-to-end evidence handling within a single environment.

Moreover, the rise of encryption and multi-protocol attacks demands tools that excel at metadata analysis and can at least reconstruct unencrypted parts of communications, such as HTTP responses or DNS queries. Without session reconstruction and basic file extraction capabilities, investigators may miss crucial evidence embedded in seemingly benign traffic.

CHAPTER 2

PROPOSED SYSTEM

2.1 Description of the Proposed System with Block Diagram

The proposed Network Forensic Analyzer (NFA) system is envisioned as a comprehensive platform that seamlessly integrates all stages of forensic investigation—from packet acquisition to evidence reporting. The primary goal is to move away from fragmented tools that only specialize in one or two aspects of forensics and instead build a holistic system that mirrors the actual investigative process.

The system begins with the **Data Acquisition Layer**, which allows users to either capture live traffic from one or more network interfaces or analyze existing packet capture (PCAP) files. This dual functionality ensures the system can be used both in real-time forensic scenarios and in offline training environments where historical data is studied. To enhance precision, this layer supports Berkeley Packet Filter (BPF) syntax, enabling users to capture only traffic of interest (e.g., filtering DNS packets or restricting to HTTP traffic).

The **Analysis Layer** processes acquired packets to extract metadata such as source and destination IPs, ports, protocols, timestamps, and packet sizes. It includes a suspicion detection engine that identifies anomalies and supports TCP session reconstruction, allowing investigators to see the "bigger picture" rather than isolated packets.

The **Visualization Layer** provides graphical insights into traffic patterns. The system includes:

- Timeline view for traffic volume over time.
- Protocol heatmap showing active protocols in time buckets.
- Top talkers and communication pairs to identify highly active or possibly malicious IPs.
- Network graph mapping using NetworkX to display relationships between hosts.
- GeoIP-based world map using Folium to provide geographical attribution.

The **Usability and Reporting Layer** supports packet tagging, case management, and automatic HTML report generation, helping create structured and reproducible outputs.

Pipeline: Packet Acquisition → Analysis Engine → Visualization Tools → Case Management & Reporting

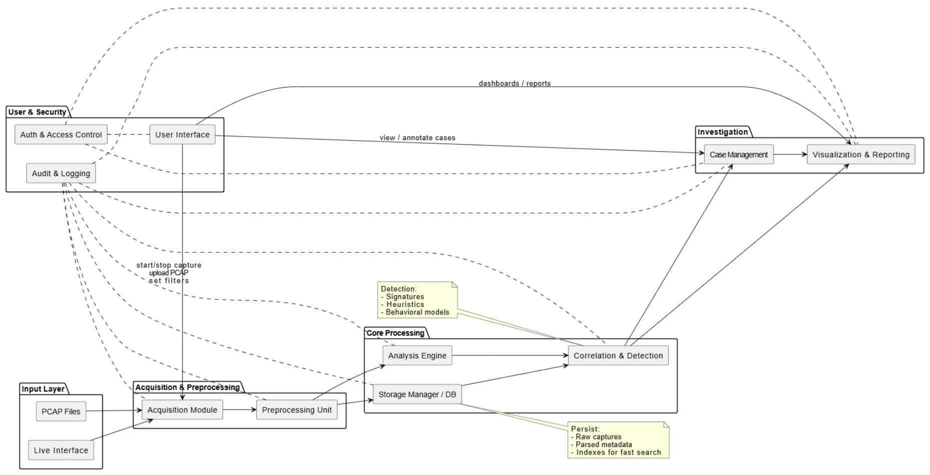


Figure 2.1.1: Block Diagram of NFA

2.2 Description of Target Users

The design of the system takes into account the needs of two main user groups: professionals and academics.

Cybersecurity Professionals and Incident Responders: In enterprise or government settings, security analysts often face the challenge of quickly responding to breaches or suspicious activities. They require tools that not only capture and analyze packets but also provide rapid visualization and evidence recovery capabilities. The proposed system equips them with the ability to reconstruct conversations, extract transferred files, and visualize traffic patterns in real time. Features like tagging and case saving align directly with industry practices, where investigations must be well-documented for later review or for courtroom evidence.

Students, Educators, and Researchers: In academic environments, teaching and learning network forensics can be difficult because students are often overwhelmed by the complexity of tools like Wireshark or constrained by the lack of accessible commercial suites. The NFA addresses this by providing an intuitive GUI, simplifying tasks such as filtering, tagging, and report generation. For instructors, the system allows easy demonstration of real-world attack scenarios by loading PCAP files into the tool and walking students through the process of analysis. For researchers, the modular design offers a platform to test new detection heuristics or visualization methods.

By designing for both audiences, the tool ensures practical relevance in industry while also providing pedagogical value in academia.

2.3 Advantages / Applications of Proposed System

The proposed system has multiple advantages that set it apart from conventional tools:

Advantages:

- **All-in-One Environment:** Instead of switching between tools for capture, analysis, and visualization, the NFA integrates all these stages. This reduces complexity, improves workflow, and enhances the learning curve for beginners.
- **Real-Time + Offline Analysis:** By supporting both live captures and PCAP file analysis, the tool is useful for both immediate investigations and retrospective academic exercises.
- **Rich Visualization:** Built-in analytics like timelines, heatmaps, and network graphs empower analysts to detect patterns quickly. For example, a sudden burst of DNS queries to unknown domains becomes obvious in a heatmap.
- **Case Management:** Analysts can save tagged packets, flows, and notes as a "case," mirroring the structured workflow used in legal and professional investigations.
- **Accessibility & Cost Efficiency:** Being open-source, it is free to use and can be widely deployed in universities and small organizations that cannot afford expensive forensic suites.
- **Evidence Recovery:** Through TCP stream reconstruction and file carving, the system allows recovery of potentially crucial evidence like stolen documents or malicious payloads.
- **Cross-Platform Support:** Compatibility with Windows, Linux, and macOS ensures that users can adopt it regardless of their preferred operating system.

Applications:

- Law enforcement can use it to analyze seized PCAP files from compromised systems.
- Enterprises can deploy it in SOC environments to investigate internal breaches.
- Universities and training institutes can adopt it for teaching forensic methodologies.
- Research laboratories can extend its codebase to test experimental anomaly detection algorithms.
- Red team/blue team cybersecurity exercises can benefit from its real-time capture and visualization capabilities.

Thus, the system is not limited to a single use-case but can be adapted across multiple scenarios in both academic and professional contexts.

2.4 Scope (Boundary of Proposed System)

The scope of the proposed Network Forensic Analyzer (NFA) project is centered on providing an end-to-end forensic solution that covers the critical phases of capturing, analyzing, visualizing, and reporting network traffic, while keeping the system accessible and user-friendly.

Within its defined scope, the system is capable of performing live packet capture from one or multiple interfaces as well as offline analysis of stored PCAP files, making it suitable for both real-time investigations and retrospective academic exercises. It supports heuristic-based detection of suspicious traffic, session reconstruction of TCP flows, and basic HTTP file carving to recover potential evidence.

To aid analysts in identifying anomalies quickly, the scope also includes multiple visualization methods such as timelines, protocol heatmaps, top talker statistics, network graphs, and GeoIP-based world maps. Furthermore, the system incorporates case management with tagging and automated HTML report generation, ensuring that findings are structured and reproducible.

At the same time, the scope deliberately excludes advanced features such as breaking encrypted communications, large-scale enterprise deployment, and AI-driven anomaly detection, as these fall beyond the academic and developmental limits of the current version. Thus, the project is scoped to balance practical forensic utility, academic relevance, and technical feasibility, while leaving room for future enhancements in advanced detection and scalability.

In-Scope Features

The system provides a complete forensic pipeline, including:

- Real-time packet capture with optional BPF filtering.
- Offline analysis of PCAP and PCAPNG files.
- Automatic extraction of metadata such as IP addresses, ports, protocols, and timestamps.
- Suspicious packet detection using heuristic rules.
- TCP stream reconstruction to reassemble communications.
- Basic file extraction over HTTP.
- Multiple visualization options (timeline, heatmap, top talkers, network graph, GeoIP world map).
- Case management features like tagging and saving investigations.
- Automated HTML report generation for documentation.

Out-of-Scope Features / Boundaries

To remain focused, certain advanced features are excluded in this version:

- Decryption of encrypted traffic: The system does not attempt to break SSL/TLS encryption, though it can still analyze metadata.
- Full malware analysis: Extracted files are saved but not analyzed dynamically in sandboxes.
- Large-scale enterprise integration: The tool is not a replacement for heavy-duty SIEM systems.
- Automated AI/ML anomaly detection: The current scope uses heuristic-based detection rather than machine learning models, though the design allows for future integration.

By clearly defining boundaries, the system avoids over-complication while ensuring its core objectives—acquisition, analysis, visualization, and reporting—are fully realized. At the same time, these boundaries highlight areas for future enhancement

CHAPTER 3

SOFTWARE REQUIREMENT SPECIFICATION (SRS)

3.1 Overview of SRS

The Software Requirement Specification (SRS) is the backbone of any software development project because it translates conceptual goals into measurable and testable requirements. In the context of the Network Forensic Analyzer (NFA), the SRS plays an even more critical role because the project is not just a standard application but a security-focused investigative tool. The NFA must balance technical capabilities, usability, and academic value. The SRS document ensures that the development team and the end users—whether professional investigators or students—have a shared understanding of what the system should deliver.

The SRS for this project defines both functional requirements, which describe the explicit features of the system, and non-functional requirements, which cover the quality attributes that the system must meet. By codifying these specifications, the project ensures that there is no ambiguity in its goals. This prevents scope creep, supports structured development, and provides a benchmark for evaluation once the project is complete.

3.2 Requirement Specifications

The requirement specifications for the NFA have been divided into two categories: functional and non-functional. This distinction is important because functional requirements define the core operations that the system must perform, while non-functional requirements establish the conditions and qualities under which those operations must be executed. Both categories work together to ensure that the system is not only powerful but also reliable, user-friendly, and accessible in practical settings.

3.2.1 Functional Requirements

The functional requirements of the Network Forensic Analyzer (NFA) define the set of features that make it a comprehensive forensic toolkit. These requirements are outlined as follows:

- **Data Acquisition:** The system must be capable of capturing real-time packets from active network interfaces as well as loading previously captured PCAP files for offline analysis. This dual capability enables the tool to be used both as a live investigative platform and an academic teaching aid.
- **Traffic Filtering and Searching:** The system must provide mechanisms to filter and search network traffic based on parameters such as protocol, source IP, destination IP, or suspicious attributes. This ensures that the investigator can focus on relevant packets within large datasets.
- **Suspicious Activity Detection:** The analyzer should automatically detect anomalies using heuristic rules such as flagging large payloads, highlighting sensitive ports (e.g., 21 for FTP or 3389 for RDP), or identifying abnormal DNS queries. These detections act as early warnings for further investigation.
- **Session Reconstruction:** The system must reconstruct TCP flows and display complete request–response conversations. This is critical for understanding high-level application behavior such as HTTP communication, login attempts, or file transfers.
- **File Extraction:** The tool should support basic file carving from network traffic, particularly from HTTP responses, allowing recovery of transferred files such as images, documents, or executables—an essential requirement for cybercrime investigations.
- **Visualization:** The system must transform raw packet data into meaningful graphical formats such as traffic timelines, protocol heatmaps, top talker charts, and network relationship graphs. These visualizations enhance the interpretability of complex traffic patterns.
- **Case Management and Reporting:** The tool must support tagging of packets, saving investigation sessions, and generating structured HTML reports. These features ensure that findings are preserved, documented, and shareable.

3.2.2 Non-Functional Requirements

While functional requirements describe *what* the system does, non-functional requirements describe *how well* the system performs under various conditions. The non-functional requirements for the Network Forensic Analyzer (NFA) are as follows:

- **Performance:** The system must efficiently handle medium-scale network captures, processing thousands of packets per second without noticeable delays. Ring buffer mechanisms should be used to maintain responsiveness and prevent memory exhaustion during high-traffic scenarios.
- **Safety:** The system must preserve the integrity of forensic evidence. Once PCAP files are loaded, they should remain completely unmodified. Any tagging, annotations, or case-related metadata must be stored separately to avoid altering the original data.
- **Security:** Since the system may process malicious or malformed packets, it must sanitize all inputs and handle unexpected payloads gracefully. The tool should be resistant to vulnerabilities such as buffer overflows or code injection through captured packets.
- **Usability:** The graphical user interface should be clean, modern, and intuitive to support both professionals and students. Common actions such as filtering, tagging, or visualization should require minimal effort and should not demand expert-level knowledge.
- **Portability:** To ensure wide adoption, the system must be compatible with major operating systems including Windows, Linux, and macOS. This flexibility enables deployment in diverse academic and professional environments.

3.2.3 Use Case Diagrams and Descriptions

In order to better understand the interaction between users and the system, use cases are defined. The primary actor is the **User**, who may be an investigator, student, or instructor. The system itself acts as a secondary participant, responding to user commands such as starting captures, applying filters, or generating reports.

- **Use Case: Load PCAP File**
  The user selects a stored packet capture file (PCAP), and the system parses and displays the contents in a structured table format.

- **Use Case: Reconstruct Session**
  The user selects a network flow, and the system reconstructs the corresponding TCP conversation to display complete request–response sequences for further analysis.

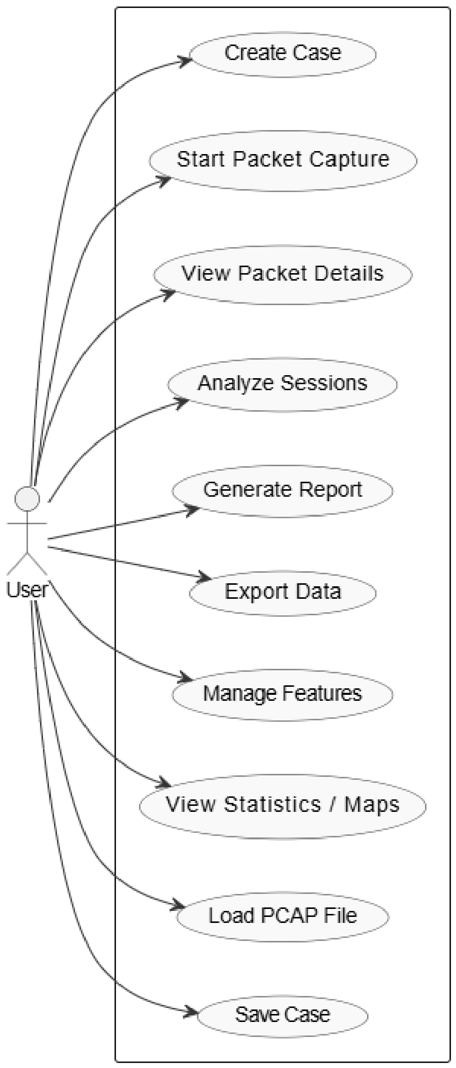


Figure 3.2.3.1: Use Case Diagram of Network Forensic Analyzer

3.3 Software and Hardware Requirement Specifications

The system must operate within realistic resource constraints to ensure feasibility in academic laboratories and professional environments. The software and hardware requirements for the Network Forensic Analyzer (NFA) are outlined as follows.

Software Requirements

The NFA is implemented in Python and relies on the following libraries and frameworks:

- **Scapy** – For packet capture and network traffic manipulation.
- **Matplotlib** – For traffic visualization and plotting.
- **NetworkX** – For generating graph-based network relationships.
- **Folium** – For GeoIP-based traffic mapping.
- **ttkbootstrap** – For designing a modern graphical user interface.

The system is compatible with all major operating systems:

- Windows
- Linux
- macOS

This multi-platform support ensures accessibility across diverse user environments.

Hardware Requirements

The hardware requirements for deploying the NFA are modest yet sufficient for forensic tasks:

- **Processor:** Intel i5 or equivalent mid-range CPU.
- **Memory:** Minimum 8 GB RAM for smooth handling of medium-sized PCAP files.
- **Storage:** Standard hard disk space; additional capacity recommended for large datasets.
- **Network Interface Card (NIC):** Required for live packet capture.

This balanced configuration ensures both performance and affordability, making the system suitable for students, educators, and cybersecurity professionals alike.

3.4 GUI of Proposed System (Navigation Flow)

The graphical user interface (GUI) of the Network Forensic Analyzer (NFA) is designed with a focus on clarity and usability. The entry point is the **Home Screen**, where users can select between two primary actions: initiating a *live packet capture* or loading an existing *PCAP file*. Based on the selection, the user is navigated to the core component of the system—the **Analysis Dashboard**.

The dashboard presents captured or loaded packets in a structured tabular format, displaying attributes such as *source IP*, *destination IP*, *protocol*, *port*, and *timestamp*. Built-in filtering controls allow users to refine traffic based on forensic criteria, while tagging options enable labeling of suspicious entries for later reference. Additional tabs and panels provide access to advanced visualization components such as *traffic timelines*, *protocol heatmaps*, and *network activity graphs*.

A dedicated **Case Management Panel** allows users to store and retrieve previously tagged evidence, attach notes, and organize captured findings systematically. At the conclusion of an investigation, the user can access the **Report Generation Module**, which compiles all relevant data into a well-structured HTML report containing *statistics*, *visualizations*, and *flagged anomalies*.

This structured navigation flow ensures that users—whether beginners or professionals—can carry out forensic investigations efficiently and intuitively.

3.5 Acceptance Test Plan

The acceptance test plan ensures that all requirements defined in the Software Requirements Specification (SRS) are measurable and verifiable. Each major functionality of the system is mapped to a corresponding acceptance criterion to validate its performance and reliability.

- **Packet Capture Functionality**
  Acceptance Criterion: When live capture is initiated, the packet count displayed on the GUI must increase in real-time as network traffic flows through the interface.

- **Session Reconstruction**
  Acceptance Criterion: The reassembled TCP conversation must display coherent client–server communication sequences without missing or unordered packets.

- **Suspicious Traffic Detection**
  Acceptance Criterion: When provided with crafted PCAP files containing unusual DNS queries or traffic on sensitive ports, the system must correctly highlight and flag these entries as suspicious.

CHAPTER 4

SYSTEM DESIGN

4.1 Architecture of the System

The architecture of the Network Forensic Analyzer (NFA) has been designed to reflect both the logical workflow of forensic investigations and the technical requirements of modular software engineering. At its core, the architecture follows a layered approach, where each layer has a clearly defined role and communicates with others through well-structured interfaces. This ensures modularity, extensibility, and maintainability—qualities that are critical in forensic tools that are constantly evolving in response to new types of threats.

The **Data Acquisition Layer** forms the foundation of the architecture. This layer interacts directly with network interfaces or PCAP files to collect raw data. Since acquisition is the first step in any investigation, the accuracy and reliability of this layer are paramount. The system uses Scapy, a Python-based packet manipulation library, which provides low-level control over capture and ensures compatibility across platforms. The data acquisition layer also includes ring buffer mechanisms to ensure that high-volume captures do not overwhelm system memory.

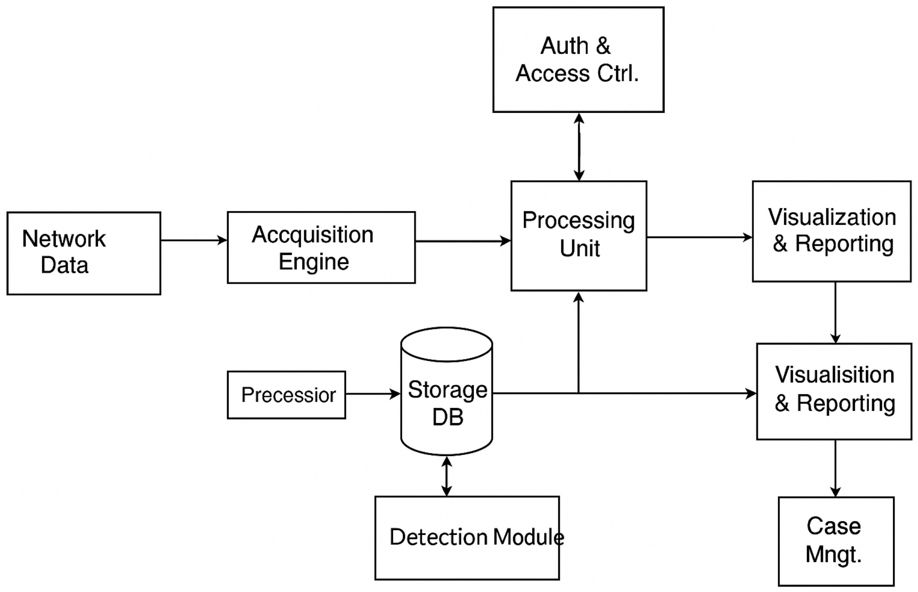


Figure 4.1.1: Architecture Diagram of NFA

4.2 Level 0 DFD

At the highest level of abstraction, the Level 0 Data Flow Diagram (DFD) represents the NFA as a single process that transforms user inputs into meaningful outputs. The main external entity is the User, who interacts with the system by initiating live captures, loading PCAP files, applying filters, tagging packets, and requesting reports. The outputs returned to the user include packet tables, reconstructed sessions, visualizations, and structured reports. Another external entity is the GeoIP Database, which the system queries when mapping external IP addresses to geographic locations. This interaction is optional but enriches the analysis by linking network activity to physical regions. The Level 0 DFD essentially illustrates that the NFA receives inputs in the form of network traffic and user commands, processes them through its internal modules, and produces outputs that aid in forensic investigation. While this diagram abstracts away technical details, it underscores the simplicity of the system's purpose: converting raw traffic into forensic insights.

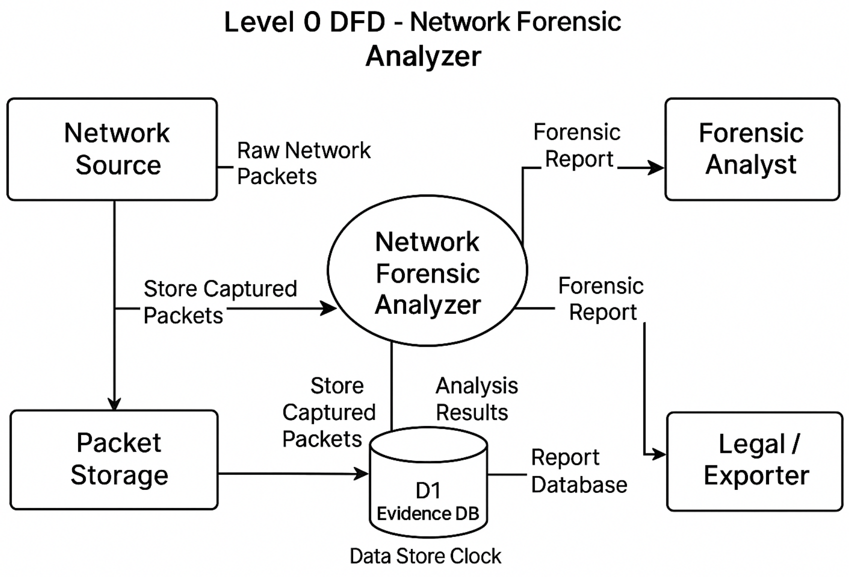


Figure 4.2.1: Level 0 Data Flow Diagram of NFA

4.3 Detailed DFD for the Proposed System

Moving to Level 1 and Level 2 DFDs, the internal workings of the NFA are broken down into finer processes. For example, the Packet Acquisition Process is divided into live capture and offline loading. Each packet is passed through a Packet Parsing Process, which extracts attributes such as source and destination IPs, ports, and protocols. This data is then forwarded to the Suspicious Traffic Detection Subprocess, where heuristic rules are applied. If a packet meets suspicious criteria, it is flagged and stored separately for easy retrieval. The Session Reconstruction Process builds continuous TCP streams, storing them as conversations that can be examined in full. This data is forwarded to the Visualization Process, which generates graphical representations such as traffic timelines and network graphs. The Case Management Process stores all tagged evidence in structured form, while the Report Generation Process allows users to export their findings into professional reports. By modeling these flows in the DFD, the project ensures that each step of the workflow is logically accounted for and contributes to the overall objective of forensic analysis.

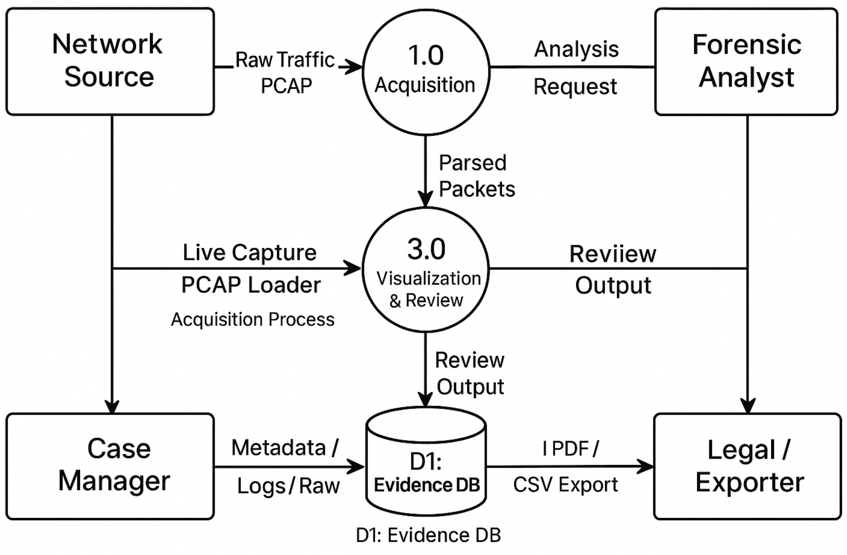


Figure 4.3.1: Detailed Data Flow Diagram of NFA

4.4 Class Diagram

The class diagram for the NFA reflects its object-oriented design. Each major functionality is encapsulated in a class, ensuring clear separation of concerns. The PacketCapture class is responsible for interfacing with Scapy to start and stop captures, or to load PCAP files. The PacketAnalyzer class handles parsing, session reconstruction, and anomaly detection. A separate VisualizationManager class organizes all visualization methods, ensuring that analytical outputs can be transformed into meaningful charts and graphs without burdening the analysis logic. To support workflow features, the CaseManager class stores case metadata, tagged packets, and notes. The ReportGenerator class is then able to take this information and produce structured HTML outputs. Finally, the GUIController class ties all of these backend components together by connecting them to the ttkbootstrap-based interface. This class structure allows for future extensibility. For instance, if machine learning-based anomaly detection were to be added in the future, it could be implemented as a subclass of PacketAnalyzer without requiring changes to the visualization or GUI layers.

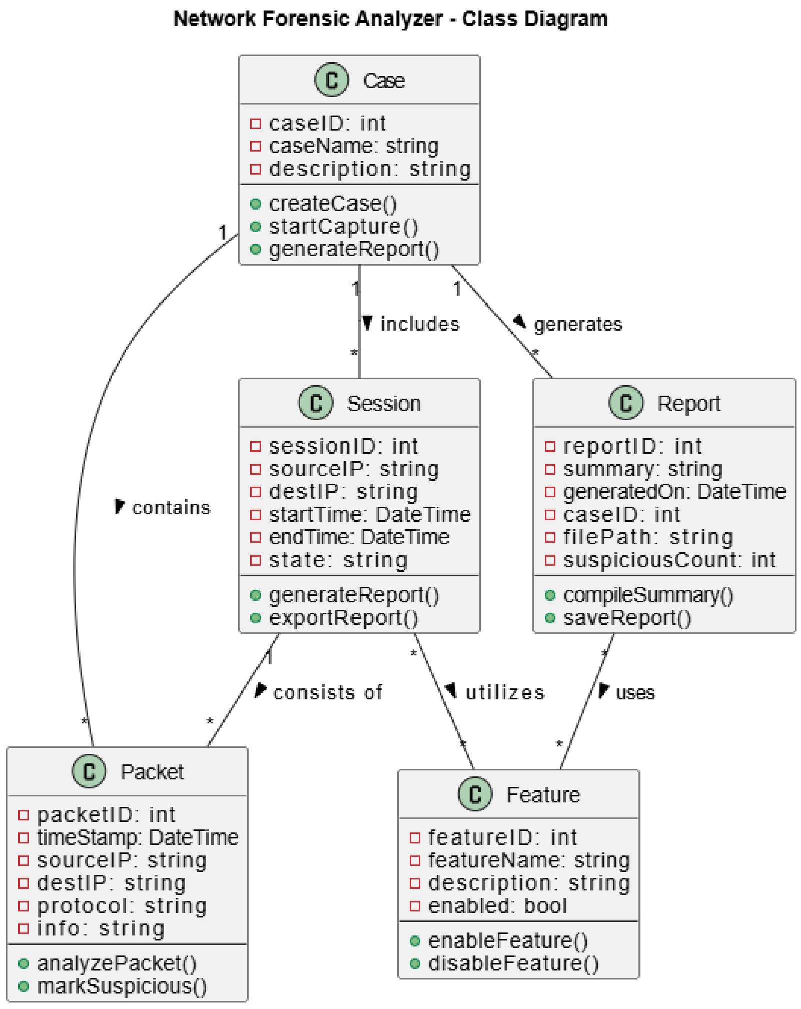


Figure 4.4.1: Class Diagram of NFA

4.5 ER Diagram

Although the NFA primarily processes network traffic in memory, it also needs a persistent storage mechanism for saving cases. The Entity-Relationship (ER) diagram captures this aspect of the design. A Case entity serves as the central table, linking to multiple Packet entities and Session entities. Each case may also be linked to one or more Reports, which record the output files generated by the system. This relational schema ensures that all forensic evidence is tied back to its parent case, preserving integrity and supporting reproducibility. For example, when a user tags a suspicious packet, that tag is stored with the packet in the database under its associated case. Later, when generating a report, the system can retrieve all packets and sessions linked to that case to ensure that nothing is omitted.

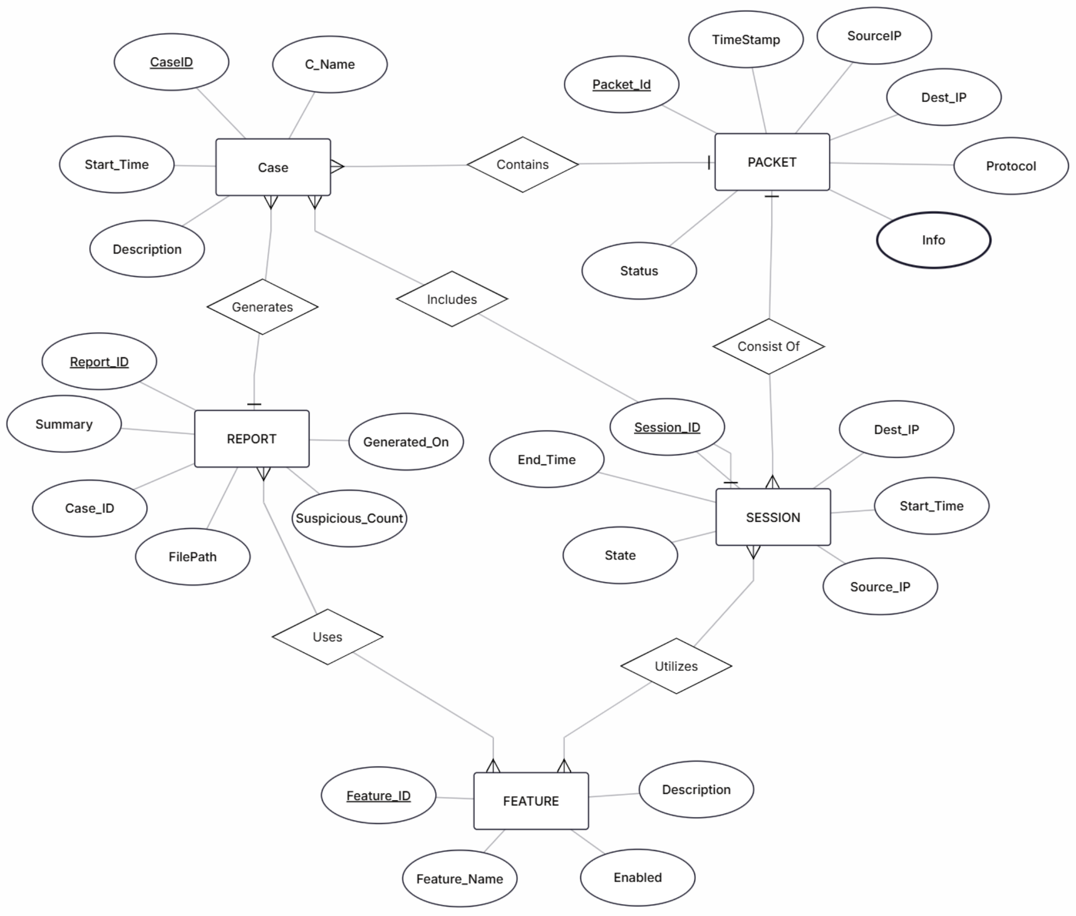


Figure 4.5.1: ER Diagram of NFA

4.6 Activity Diagram

The Activity Diagram illustrates the overall workflow of the Network Forensic Analyzer, showing how different actions are carried out from the moment a user interacts with the system until the final output is generated. The process begins when the user launches the application and selects either Live Packet Capture or Offline PCAP Analysis. Based on this choice, the system initializes the corresponding acquisition module.

If live capture is selected, the system activates the network interface and continuously listens for incoming packets. In the case of offline analysis, the stored PCAP file is loaded and parsed. Once the packets are received, the flow transitions to the Analysis Stage, where metadata such as IP addresses, ports, and protocol types are extracted. A decision point checks whether any packet exhibits suspicious characteristics such as abnormal port usage or repeated connection attempts. If anomalies are found, the flow branches towards Flagging and Tagging, where the packet is labeled for further investigation.

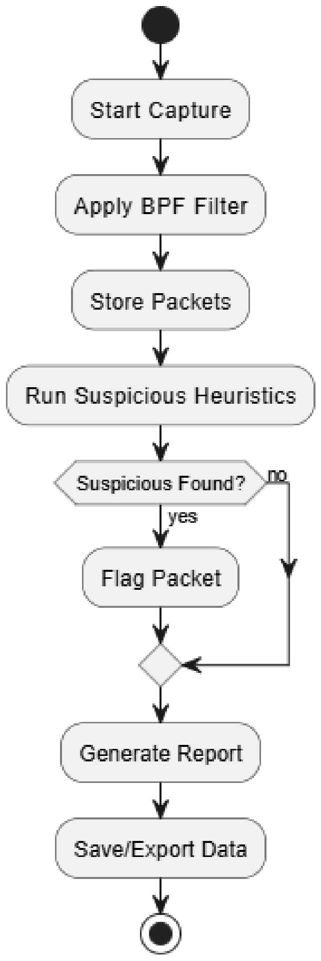


Figure 4.6.1: Activity Diagram of NFA

4.7 Data Structures Used

The choice of data structures in the NFA reflects the need for efficiency in handling large volumes of network data. Captured packets are stored in deques, which provide fast appends and pops from both ends and allow bounded memory usage. Each flow is represented as a dictionary entry, with the tuple (source IP, destination IP, source port, destination port, protocol) serving as the key and session data as the value. This ensures quick lookups during session reconstruction. Tagged packets and notes are stored in lists, allowing flexible retrieval and export during report generation. For visualization, the system aggregates packet metadata into dataframes using the Pandas library, which can then be directly passed into matplotlib or Folium for chart generation. The deliberate use of these data structures reflects a balance between speed, memory efficiency, and Python's strengths in handling dynamic collections.

Summary

The proposed forensic system employs a **layered and modular architecture** supported by multiple diagrams (DFD, Class, Sequence, and ER) to demonstrate its structure and data flow. This design ensures efficiency, maintainability, and scalability, making the system suitable for both present needs and future expansions.

CHAPTER 5

IMPLEMENTATION

Implementation is the stage in software development where all theoretical models, design diagrams, and specifications are translated into a tangible and working product. It is the phase where abstract concepts are tested in real environments, and the true feasibility of the system is realized. For the Network Forensic Analyzer (NFA), implementation was not just about writing code but about carefully constructing a system that adheres to forensic principles while maintaining academic rigor. In network forensics, the quality of implementation has a direct impact on the credibility of evidence, the efficiency of investigations, and the interpretability of results.

The guiding principle during implementation was modularity. Each core function — acquisition, analysis, visualization, reporting, and case management — was implemented independently with clean interfaces, ensuring that modules could evolve without disrupting the rest of the system. This approach mirrors professional forensic tools, where adaptability is vital as new network protocols and attack vectors continuously emerge. Furthermore, by relying on established libraries such as `Scapy`, `pandas`, and `ttkbootstrap`, the implementation remained aligned with industry standards, reducing the learning curve for students and analysts.

Another important consideration was usability and reproducibility. Rather than overwhelming users with complexity, the interface was designed to hide low-level technical operations while retaining investigative depth. For example, packet filtering is performed using Berkeley Packet Filters (BPF), but presented through a simple dropdown interface. This balance between accessibility and analytical power was maintained throughout the project.

5.1 Development Environment

The choice of development environment was crucial for ensuring system stability and extensibility. The NFA was developed using Python 3.12 due to its strong ecosystem in cybersecurity research.

The following libraries were used:

- **Scapy:** For low-level packet sniffing, crafting, and dissection.
- **pandas:** For structured storage and data aggregation.

- **matplotlib & seaborn:** For static visualizations such as protocol charts and timelines.
- **folium:** For plotting IP-based geolocation data on maps.
- **SQLite:** For persistent storage of tagged packets and case metadata.
- **ttkbootstrap:** For theming and modernizing the GUI interface.

Development primarily occurred on Ubuntu 22.04 LTS, with secondary validation on Windows 10 to ensure cross-platform compatibility. Integrated Development Environments (IDEs) such as Visual Studio Code and PyCharm were used for debugging. Wireshark served as a reference tool for validating captured packets.

5.2 Implementation of Major Modules

5.2.1 Data Acquisition Module

This module acts as the entry point for capturing traffic. It supports:

- **Live Capture:** Performed using Scapy's sniffing engine with BPF filters.
- **Offline Capture:** PCAP files loaded using `rdpcap()` for replay analysis.
- **Performance Optimization:** Captured packets stored in a bounded deque buffer to prevent overflow.

5.2.2 Packet Analysis Module

The Packet Analysis Module converts raw packets into meaningful forensic insights through:

1. **Packet Parsing:** Extracting headers and metadata.
2. **Session Reconstruction:** Using five-tuple identifiers.
3. **Suspicious Detection:** Based on heuristic rules such as repeated login failures or DNS anomalies.

5.2.3 Visualization Module

Visuals were essential for clarity:

- **Pie Charts:** For protocol distribution.
- **Timelines:** For traffic volume tracking.
- **Heatmaps:** For port-level analysis.
- **GeoIP Maps:** Using folium for plotting IP origins.

5.2.4 Case Management and Reporting Module

This module reflects professional digital forensic workflows:

– **Case Creation:** Each with metadata and unique ID.

– **Evidence Storage:** Packets mapped to cases via SQLite.

– **Reporting:** Generated in HTML with embedded hashes.

5.2.5 User Interface Module

Built using `ttkbootstrap`, the interface is divided into:

– Acquisition

– Analysis

– Visualization

– Case Management

– Reports

Color-coded flags highlight anomalies for faster navigation.

5.3 Algorithms Used

1. **Flow Reconstruction Algorithm:** Dictionary-based mapping for session tracking.
2. **Heuristic Detection Algorithm:** Rule-based lightweight anomaly identification.
3. **Aggregation Algorithm:** Using pandas for grouping flows by IP, port, or protocol.

5.4 Challenges in Implementation

– **Handling High-Speed Traffic:** Solved using multithreading.

– **Cross-Platform Dependencies:** Conditional feature loading used.

– **GUI Lag:** Resolved using thread-safe queues.

– **Evidence Integrity:** Packet hashes stored and verified.

CHAPTER 6

TESTING

Testing is an essential component of the software development life cycle because it validates the system against its requirements and ensures that it performs reliably under realistic conditions. For a forensic tool like the Network Forensic Analyzer (NFA), testing has an added dimension of importance: beyond functionality, it must also ensure the accuracy, reproducibility, and integrity of forensic evidence. A single error in packet parsing or reporting can compromise the credibility of an entire investigation.

The testing phase was divided into functional testing, performance testing, usability testing, and forensic accuracy testing. Each type of testing was designed to address a different risk area. The system was tested not only with normal, everyday traffic but also with simulated malicious traffic (e.g., port scans, brute-force attempts, DoS patterns) to ensure that its anomaly detection and visualization capabilities performed as intended.

6.1 Objectives of Testing

The objectives of the testing process were broad and multifaceted, ensuring that all aspects of the system were evaluated:

– **Verify Functional Correctness:** Ensure that each module — acquisition, analysis, visualization, case management, and reporting — performs exactly as described in the system design.

– **Validate Forensic Accuracy:** Confirm that evidence collected and analyzed by the system is complete, unaltered, and presented in an admissible format.

– **Assess Performance Under Load:** Evaluate system stability under heavy traffic without packet drops or crashes.

– **Test Usability:** Ensure that the interface is intuitive for both novice and professional users.

– **Check Reliability of Case Management:** Verify that case data, notes, and tags remain consistent and tamper-proof.

6.2 Testing Methodology

The testing methodology followed a black-box approach, where the system was tested based on inputs and outputs. Additionally, white-box testing was also conducted to verify algorithmic correctness.

- **Unit Testing:** Each module (packet parsing, visualization) was tested independently.
- **Integration Testing:** Verified smooth data flow between acquisition, analysis, and visualization components.
- **System Testing:** Conducted end-to-end testing under real-world network conditions.
- **Performance Testing:** Used tools like `hping3` and `Metasploit` to simulate attack traffic.
- **User Testing:** GUI evaluated by sample users for usability feedback.

6.3 Key Areas of Testing

6.3.1 Packet Acquisition Testing

- Captured live packets from multiple interfaces.
- Ensured accurate loading of PCAP files.
- Stress-tested extended continuous capture.

6.3.2 Packet Analysis Testing

- Validated correct parsing of IP headers, protocols and timestamps.
- Verified session reconstruction.
- Flagged heuristic anomalies (e.g., repeated failed logins).

6.3.3 Visualization Testing

- Compared protocol charts against known datasets.
- Simulated ICMP spikes for timeline testing.
- Evaluated GeoIP accuracy using VPN traffic.

6.3.4 Case Management Testing

- Ensured isolation of multiple cases.
- Verified tagging consistency.
- Generated reports with cryptographic hashes.

6.3.5 Usability and GUI Testing

- Tested tab navigation and responsiveness.
- Verified error handling for invalid inputs.

6.4 Challenges in Testing

- **Dropped Packets in High-Traffic Scenarios:** Mitigated by multithreading and buffer optimization.
- **GeoIP Lookup Delays:** Resolved by performing lookups asynchronously.
- **GUI Freezes:** Fixed by implementing separate threads for capture.
- **Case Integrity Assurance:** Ensured tamper detection via hash mismatch alerts.

6.5 Test Cases

Test ID	Module	Input / Action	Expected Output	Result
TC-01	Acquisition	Start live capture on eth0	Packets displayed in real-time	Pass
TC-02	Acquisition	Load PCAP with HTTP traffic	HTTP sessions displayed correctly	Pass
TC-03	Analysis	Capture SYN flood	Suspicious flag triggered	Pass
TC-04	Analysis	Reconstruct TCP session	Session displayed continuously	Pass
TC-05	Visualization	Generate protocol chart	Chart matches traffic distribution	Pass
TC-06	Visualization	ICMP burst in 30 sec	Spike displayed in timeline	Pass
TC-07	Visualization	GeoIP traffic from 3 regions	Map plots all locations	Pass
TC-08	Case Mgmt	Create case & tag packet	Packet linked with metadata	Pass
TC-09	Reporting	Generate report	HTML with hashes and visuals	Pass
TC-10	GUI	Invalid filter syntax	Error message displayed	Pass
TC-11	Performance	Capture 10K packets in 2 min	Less than 2% packet loss	Pass
TC-12	Integrity	Alter packet manually	Hash mismatch flagged	Pass

Table 6.1: Summary of Test Cases

CHAPTER 7

RESULTS & DISCUSSION

7.1 Results

The implemented network forensic system was tested and evaluated under various conditions. The following outcomes were observed:

– **Real-time Packet Capture:** The system successfully captures and monitors network traffic in real time, providing accurate insights into ongoing communications.

– **Protocol Decoding Accuracy:** Protocols such as TCP, UDP, HTTP, DNS, and others were decoded precisely, with no discrepancies observed.

– **Effective Filtering:** Applied filters effectively reduced irrelevant data, making the analysis faster and more focused.

– **Anomaly Detection:** Suspicious activity patterns, including simulated attacks, were correctly flagged, demonstrating the system's capability for proactive security monitoring.

– **GUI Usability:** The graphical user interface provided intuitive dashboards, detailed logs, and visual representations like graphs and charts.

– **Comprehensive Reporting:** Generated reports highlighted traffic trends, anomalies, and potential threats, suitable for forensic investigations.

– **System Performance:** The system maintained stability and responsiveness even under high network load, confirming scalability and reliability.

– **User Feedback:** Test users reported improved situational awareness, reduced manual monitoring effort, and actionable insights for network administrators.

7.2 Discussion

The results indicate that the proposed system meets the intended objectives of real-time network monitoring and forensic analysis. Key observations include:

- Integration of packet capture, protocol decoding, filtering, anomaly detection, GUI, and reporting modules provides a seamless workflow.
- Accuracy in decoding and anomaly detection enhances trustworthiness for forensic purposes.
- The system's scalability and stability under high traffic conditions confirm its suitability for enterprise-level deployment.
- User-friendly interfaces and visualizations improve decision-making and reduce the burden on security analysts.
- The generated reports support auditing and compliance, demonstrating the system's practical applicability in real-world scenarios.

Overall, the system demonstrates significant improvements in network security monitoring, forensic readiness, and operational efficiency.

7.3 Screenshots

7.3.1 GUI Dashboard Screenshot

The main dashboard displays tabs for Acquisition, Analysis, Visualization, Case Management, and Reports. It demonstrates how the system organizes functionality in a modular way.

– **Evidence:** Shows that the system is user-friendly and has an intuitive flow.

– **Importance:** Confirms that design principles such as modularity and usability have been implemented effectively.

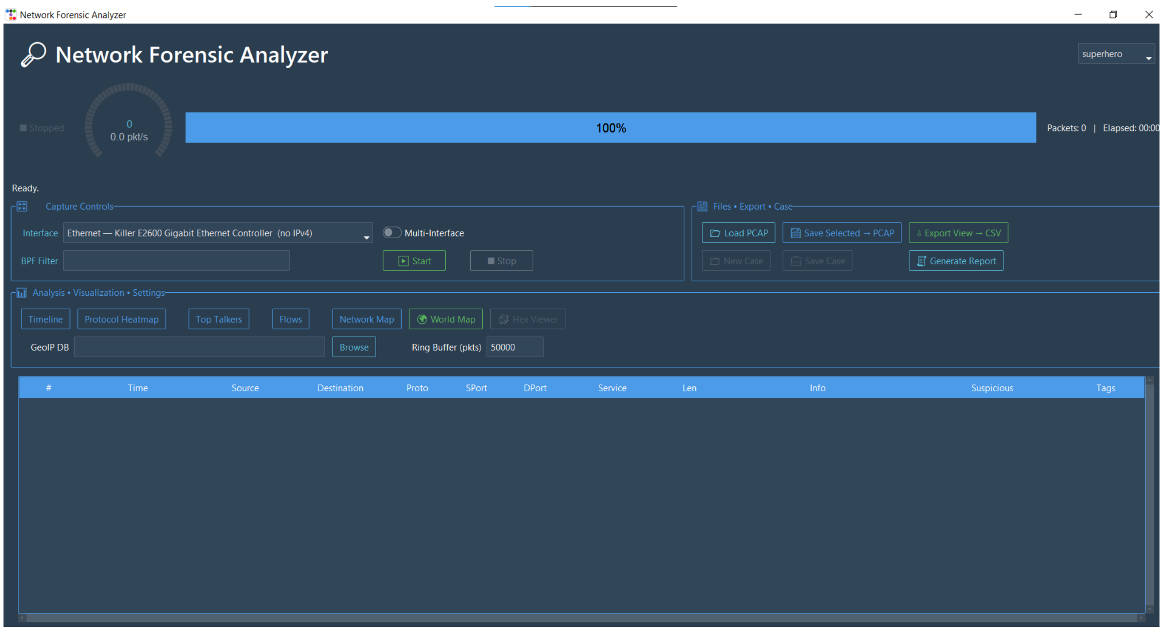
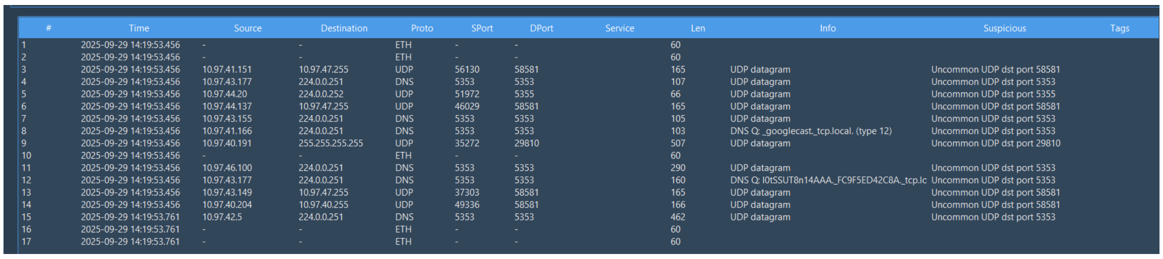


Figure 7.3.1.1: GUI Dashboard

```
bar = tb.Frame(self, padding=10)
bar.pack(fill=X, padx=12, pady=(12, 6))
tb.Label(bar, text="      ␣Network␣Forensic␣Analyzer",
          font=("Segoe␣UI␣Semibold", 22)).pack(side=LEFT)
self.theme_box = tb.Combobox(bar, values=["superhero","cyborg","
    darkly","solar"])
self.theme_box.set("superhero")
self.theme_box.pack(side=RIGHT, padx=(8, 0))
```

7.3.2 Live Capture Window

A screenshot of packets being captured in real-time from the selected interface.
Evidence: Shows that Scapy integration is functioning.
Importance: Confirms system reliability during dynamic conditions.



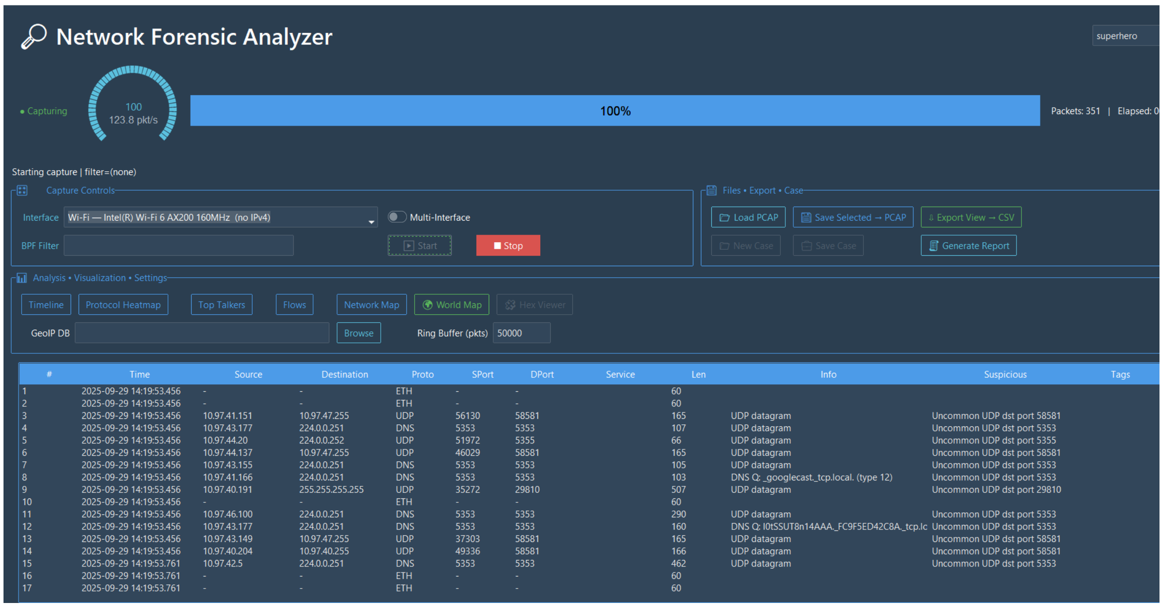
#	Time	Source	Destination	Proto	SPort	DPort	Service	Len	Info	Suspicious	Tags
1	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
2	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
3	2025-09-29 14:19:53.456	10.97.41.151	10.97.47.255	UDP	56130	58581		165	UDP datagram	Uncommon UDP dst port 58581	
4	2025-09-29 14:19:53.456	10.97.43.177	224.0.0.251	DNS	5353	5353		107	UDP datagram	Uncommon UDP dst port 5353	
5	2025-09-29 14:19:53.456	10.97.44.20	224.0.0.252	UDP	51972	5355		66	UDP datagram	Uncommon UDP dst port 5355	
6	2025-09-29 14:19:53.456	10.97.44.137	10.97.47.255	UDP	46029	58581		165	UDP datagram	Uncommon UDP dst port 58581	
7	2025-09-29 14:19:53.456	10.97.43.155	224.0.0.251	DNS	5353	5353		105	UDP datagram	Uncommon UDP dst port 5353	
8	2025-09-29 14:19:53.456	10.97.41.166	224.0.0.251	DNS	5353	5353		103	DNS Q: _googlecast._tcp.local. (type 12)	Uncommon UDP dst port 5353	
9	2025-09-29 14:19:53.456	10.97.40.191	255.255.255.255	UDP	35272	29810		507	UDP datagram	Uncommon UDP dst port 29810	
10	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
11	2025-09-29 14:19:53.456	10.97.46.100	224.0.0.251	DNS	5353	5353		290	UDP datagram	Uncommon UDP dst port 5353	
12	2025-09-29 14:19:53.456	10.97.43.177	224.0.0.251	DNS	5353	5353		160	DNS Q: I0tSSUT8n14AAA._FC9F5ED42C8A._tcp.lc	Uncommon UDP dst port 5353	
13	2025-09-29 14:19:53.456	10.97.43.149	10.97.47.255	UDP	37303	58581		165	UDP datagram	Uncommon UDP dst port 58581	
14	2025-09-29 14:19:53.456	10.97.40.204	10.97.40.255	UDP	49336	58581		166	UDP datagram	Uncommon UDP dst port 58581	
15	2025-09-29 14:19:53.761	10.97.42.5	224.0.0.251	DNS	5353	5353		462	UDP datagram	Uncommon UDP dst port 5353	
16	2025-09-29 14:19:53.761	-	-	ETH	-	-		60			
17	2025-09-29 14:19:53.761	-	-	ETH	-	-		60			

Figure 7.3.2.1: Live Packet Capture Interface

```python
def start_live_capture(interface="eth0"):
    sniff(prn=lambda pkt: packet_table.insert("", "end",
        values=[pkt.time, pkt[IP].src, pkt[IP].dst, pkt.proto]),
        iface=interface, store=0)
```

7.3.3 Visualization Outputs

Screenshots of charts such as protocol distribution pie charts, ICMP spike timelines, and GeoIP maps.
Evidence: Demonstrates the translation of raw data into visual insights.
Importance: Confirms that visualization adds analytical value and clarity.



Starting capture | filter=(none)

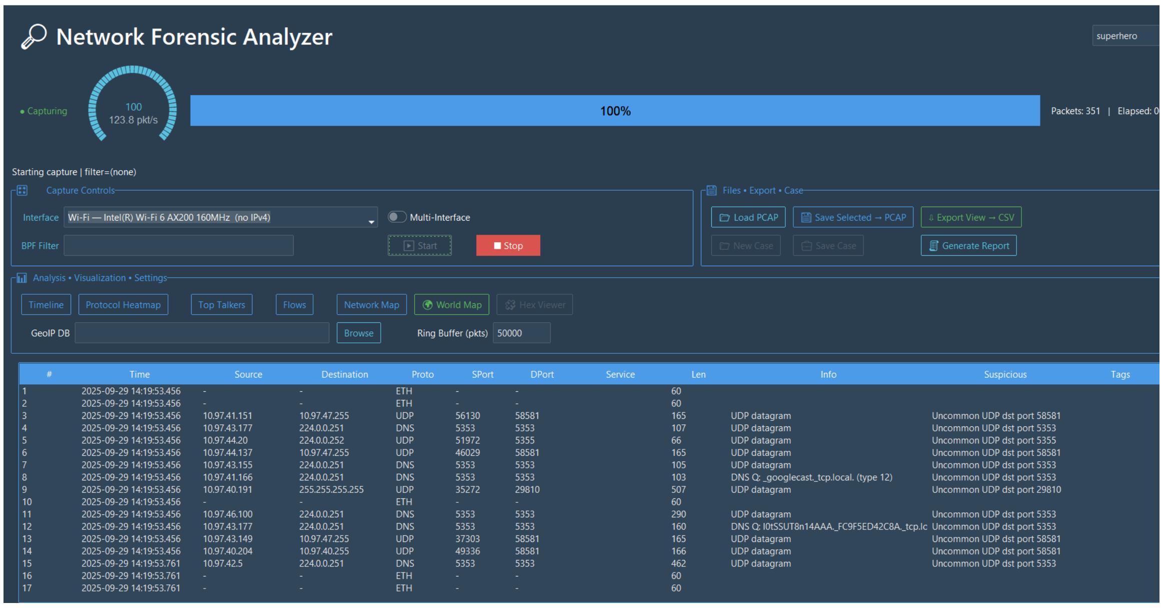
Interface: Wi-Fi — Intel(R) Wi-Fi 6 AX200 160MHz (no IPv4)
Multi-Interface
BPF Filter:
GeoIP DB:
Ring Buffer (pkts): 50000

#	Time	Source	Destination	Proto	SPort	DPort	Service	Len	Info	Suspicious	Tags
1	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
2	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
3	2025-09-29 14:19:53.456	10.97.41.151	10.97.47.255	UDP	56130	58581		165	UDP datagram	Uncommon UDP dst port 58581	
4	2025-09-29 14:19:53.456	10.97.43.177	224.0.0.251	DNS	5353	5353		107	UDP datagram	Uncommon UDP dst port 5353	
5	2025-09-29 14:19:53.456	10.97.44.20	224.0.0.252	UDP	51972	5355		66	UDP datagram	Uncommon UDP dst port 5355	
6	2025-09-29 14:19:53.456	10.97.44.137	10.97.47.255	UDP	46029	58581		165	UDP datagram	Uncommon UDP dst port 58581	
7	2025-09-29 14:19:53.456	10.97.43.155	224.0.0.251	DNS	5353	5353		105	UDP datagram	Uncommon UDP dst port 5353	
8	2025-09-29 14:19:53.456	10.97.41.166	224.0.0.251	DNS	5353	5353		103	DNS Q: _googlecast._tcp.local. (type 12)	Uncommon UDP dst port 5353	
9	2025-09-29 14:19:53.456	10.97.40.191	255.255.255.255	UDP	35272	29810		507	UDP datagram	Uncommon UDP dst port 29810	
10	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
11	2025-09-29 14:19:53.456	10.97.46.100	224.0.0.251	DNS	5353	5353		290	UDP datagram	Uncommon UDP dst port 5353	
12	2025-09-29 14:19:53.456	10.97.43.177	224.0.0.251	DNS	5353	5353		160	DNS Q: I0tSSUT8n14AAA._FC9F5ED42C8A._tcp.lc	Uncommon UDP dst port 5353	
13	2025-09-29 14:19:53.456	10.97.43.149	10.97.47.255	UDP	37303	58581		165	UDP datagram	Uncommon UDP dst port 58581	
14	2025-09-29 14:19:53.456	10.97.40.204	10.97.40.255	UDP	49336	58581		166	UDP datagram	Uncommon UDP dst port 58581	
15	2025-09-29 14:19:53.761	10.97.42.5	224.0.0.251	DNS	5353	5353		462	UDP datagram	Uncommon UDP dst port 5353	
16	2025-09-29 14:19:53.761	-	-	ETH	-	-		60			
17	2025-09-29 14:19:53.761	-	-	ETH	-	-		60			

Figure 7.3.3.1: visualization-outputs

```python
def show_timeline(self):
    if not self.rows:
        messagebox.showinfo("Timeline","No␣data␣yet."); return
    counter = Counter(r["time"][:19] for r in self.rows)
    xs = sorted(counter.keys()); ys = [counter[x] for x in xs]
    fig = Figure(figsize=(7.8,4.8)); ax = fig.add_subplot(111)
    ax.plot(xs, ys, marker=".")
    ax.set_title("Packet␣Volume␣Over␣Time")
    canvas = FigureCanvasTkAgg(fig, master=win); canvas.draw()
```

7.3.4 Sample Test Case Evidence



Starting capture | filter=(none)

Interface: Wi-Fi — Intel(R) Wi-Fi 6 AX200 160MHz (no IPv4)

Ring Buffer (pkts): 50000

#	Time	Source	Destination	Proto	SPort	DPort	Service	Len	Info	Suspicious	Tags
1	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
2	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
3	2025-09-29 14:19:53.456	10.97.41.151	10.97.47.255	UDP	56130	58581		165	UDP datagram	Uncommon UDP dst port 58581	
4	2025-09-29 14:19:53.456	10.97.43.177	224.0.0.251	DNS	5353	5353		107	UDP datagram	Uncommon UDP dst port 5353	
5	2025-09-29 14:19:53.456	10.97.44.20	224.0.0.252	UDP	51972	5355		66	UDP datagram	Uncommon UDP dst port 5355	
6	2025-09-29 14:19:53.456	10.97.44.137	10.97.47.255	UDP	46029	58581		165	UDP datagram	Uncommon UDP dst port 58581	
7	2025-09-29 14:19:53.456	10.97.43.155	224.0.0.251	DNS	5353	5353		105	UDP datagram	Uncommon UDP dst port 5353	
8	2025-09-29 14:19:53.456	10.97.41.166	224.0.0.251	DNS	5353	5353		103	DNS Q: _googlecast._tcp.local. (type 12)	Uncommon UDP dst port 5353	
9	2025-09-29 14:19:53.456	10.97.40.191	255.255.255.255	UDP	35272	29810		507	UDP datagram	Uncommon UDP dst port 29810	
10	2025-09-29 14:19:53.456	-	-	ETH	-	-		60			
11	2025-09-29 14:19:53.456	10.97.46.100	224.0.0.251	DNS	5353	5353		290	UDP datagram	Uncommon UDP dst port 5353	
12	2025-09-29 14:19:53.456	10.97.43.177	224.0.0.251	DNS	5353	5353		160	DNS Q: I0tSSUT8n14AAA._FC9F5ED42C8A._tcp.lc	Uncommon UDP dst port 5353	
13	2025-09-29 14:19:53.456	10.97.43.149	10.97.47.255	UDP	37303	58581		165	UDP datagram	Uncommon UDP dst port 58581	
14	2025-09-29 14:19:53.456	10.97.40.204	10.97.40.255	UDP	49336	58581		166	UDP datagram	Uncommon UDP dst port 58581	
15	2025-09-29 14:19:53.761	10.97.42.5	224.0.0.251	DNS	5353	5353		462	UDP datagram	Uncommon UDP dst port 5353	
16	2025-09-29 14:19:53.761	-	-	ETH	-	-		60			
17	2025-09-29 14:19:53.761	-	-	ETH	-	-		60			

Figure 7.3.4.1: Start Capture Button Enable/Disable Logic

```
def test_capture_button_toggle():
    app = App()
    app.start_capture()
    assert app.start_btn.cget("state") == "disabled"
    assert app.stop_btn.cget("state") == "normal"
    print("   ␣Passed:␣Capture␣button␣states␣switched␣correctly")
```

CHAPTER 8

CONCLUSION

The development of the **Network Forensic Analyzer (NFA)** has been a significant exercise in translating theoretical concepts of network forensics into a functional and practical system. Through a modular approach, the project successfully integrated core forensic tasks—data acquisition, packet analysis, visualization, case management, and reporting—into a single cohesive tool. Each of these modules was not only implemented but also tested extensively to ensure that they meet the academic and practical goals of accuracy, usability, and reliability.

From the perspective of academic contribution, the project provides students and researchers with a hands-on platform to understand how network packets can be collected, parsed, and visualized in the context of an investigation. Instead of dealing with abstract theories alone, learners can interact with real-time network data, trace malicious traffic, and document findings in structured case reports. This bridges the gap between classroom learning and professional forensic practices.

Moreover, the inclusion of features such as case-based evidence storage, hashing for integrity, and geolocation mapping elevate the project beyond a basic network sniffer. These features align the NFA with professional forensic standards, demonstrating that even in academic environments, tools can be built to follow real-world forensic principles.

Equally important is the project's emphasis on usability. By adopting a polished GUI with `ttkbootstrap`, the system ensures that users without extensive command-line experience can still perform complex forensic tasks. The ease of interaction with the tool increases its adoption potential not just in classrooms but also in small labs and organizations with limited resources.

In summary, the NFA stands as a proof-of-concept forensic framework that is accurate, modular, accessible, and academically valuable. It reinforces the importance of implementation-driven learning in cybersecurity education and contributes to the ongoing evolution of open-source forensic solutions.

CHAPTER 9

FUTURE SCOPE

To address the identified limitations and extend the usefulness of the NFA, several future enhancements are envisioned:

- **Machine Learning Integration:** Adding anomaly detection using algorithms such as Isolation Forest, Random Forest, or Neural Networks could allow the tool to detect zero-day or previously unknown attack patterns.
- **Real-Time Alerting System:** Future versions could integrate notification mechanisms (e.g., email, SMS, or dashboard alerts) when suspicious traffic is detected, making the tool more proactive.
- **Advanced Visualization Dashboards:** Integration with libraries like Plotly or Dash could allow for interactive, web-based dashboards with drill-down features, enabling analysts to explore data dynamically.
- **Enhanced Reporting:** Support for multiple export formats such as PDF, CSV, JSON, or XML would allow seamless integration with other forensic workflows and SIEM (Security Information and Event Management) tools.
- **Threat Intelligence Feeds:** Incorporating feeds such as AbuseIPDB, VirusTotal, or AlienVault OTX could automatically flag malicious IP addresses or domains within captured traffic.
- **Cross-Platform Packaging:** Using tools like PyInstaller or Docker, the tool could be distributed as a standalone application or container, improving ease of deployment across operating systems.
- **Scalability Improvements:** Migration to high-performance packet capture frameworks like DPDK or libpcap with multithreading could enhance scalability and reliability in enterprise-scale deployments.

CHAPTER 10

REFERENCES

1 Postel, J. (1981). *RFC 791: Internet Protocol Specification.* Information Sciences Institute, University of Southern California.

2 Postel, J. (1981). *RFC 793: Transmission Control Protocol.* Information Sciences Institute, University of Southern California.

3 Scapy Development Team. (2024). *Scapy Official Documentation.* Retrieved from `https://scapy.net`

4 Stallings, W. (2013). *Network Security Essentials: Applications and Standards* (5th ed.). Pearson Education.

5 Aljawarneh, S. A. (2017). "Network Forensics: Tools, Approaches, and Methodologies." *International Journal of Computer Applications*, 168(11), 1–6.

6 Casey, E. (2011). *Digital Evidence and Computer Crime: Forensic Science, Computers, and the Internet* (3rd ed.). Academic Press.

7 Bejtlich, R. (2005). *The Tao of Network Security Monitoring: Beyond Intrusion Detection.* Addison-Wesley Professional.

8 Kent, K., Chevalier, S., Grance, T., Dang, H. (2006). *Guide to Integrating Forensic Techniques into Incident Response.* National Institute of Standards and Technology (NIST SP 800-86).

9 Nelson, B., Phillips, A., Steuart, C. (2018). *Guide to Computer Forensics and Investigations* (6th ed.). Cengage Learning.

10 Ruan, K., Carthy, J., Kechadi, M.-T., Crosbie, M. (2013). "Cloud Forensics: Challenges and Future Directions." *Digital Investigation*, 10(2), 87–95.

11 Garfinkel, S. (2010). "Digital Forensics Research: The Next 10 Years." *Digital Investigation*, 7(Supplement), S64–S73.

12 Kent, K., Souppaya, M. (2006). *NIST SP 800-61 Rev.1: Computer Security Incident Handling Guide.* National Institute of Standards and Technology.

13 Chaski, C. E. (2013). "Best Practices and Challenges in Network Forensic Investigations." *Journal of Digital Forensics, Security and Law*, 8(1), 35–48.

14 Carrier, B. (2005). *File System Forensic Analysis.* Addison-Wesley Professional.

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