Comprehensive Network Vulnerability Scanner for Device Security

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Abstract

As networks grow in size and complexity, safeguarding them demands tools that move beyond basic port sweeps yet remain lighter than enterprise-grade platforms. CVEMap — Network Sentinel delivers that middle ground. The scanner marries high-speed, multi-threaded host discovery with live intelligence feeds from Shodan, CIRCL CVE, and other sources, instantly correlating exposed services to known vulnerabilities. Banner-grabbing refines service fingerprints, while automated CVE mapping surfaces risks such as legacy protocols and factory-default credentials. In evaluation on a /24 subnet, CVEMap discovered 95 % of active nodes and flagged the most critical weaknesses for rapid triage. Grounded in CyBOK domains—Network Security, Situational Awareness, and Vulnerability Management—the tool equips security teams with actionable insight for pre-emptive defense. Planned enhancements include offline signature packs, anomaly detection powered by machine learning, and direct SIEM connectors.

Index Terms— network scanning, CVE, cybersecurity, vulnerability assessment

1. Introduction

1.1. Overview

Robust cybersecurity is indispensable in an era where digital infrastructure underpins nearly every facet of modern life. Today's threats target not only traditional IT environments but also the rapidly expanding universe of Internet of Things (IoT) devices in both consumer and enterprise settings. Protecting these systems demands more than reactive defenses—it requires proactive discovery and remediation of vulnerabilities before adversaries can exploit them.

The CVEMap / Network Sentinel project addresses this need by delivering an advanced network vulnerability scanner. Designed for both public and private environments, CVEMap identifies a wide array of devices and enriches its findings through automated CVE correlation. Leveraging multi-threaded scans, precise service fingerprinting, and live intelligence feeds from sources such as Shodan and CIRCL CVE, the tool provides security teams with a detailed view of exposure across their networks. This comprehensive insight empowers organizations to maintain resilient, locked-down infrastructures against evolving threats.

1.2. Problem Statement

Despite the abundance of network-scanning tools, critical gaps remain that hinder effective vulnerability management. Classic utilities like Nmap quickly enumerate hosts, ports, and services but rarely link those findings to known CVEs without added plugins or scripts. External-intelligence platforms such as Shodan enrich publicly exposed assets but cannot reach hosts hidden behind the firewall, leaving internal systems unmonitored. The resulting patchwork forces teams to juggle multiple data sources, creates information overload, and slows the prioritization of real threats—ultimately extending the window of opportunity for attackers.

1.3. Aims and Objectives

Aims:
Design and build a holistic vulnerability-scanning tool that boosts situational awareness and automatically uncovers security weaknesses by combining exhaustive network sweeps with live threat-intelligence enrichment.

Objectives:

- **Enumerate hosts and service**s — Run ARP/ICMP sweeps and full-range TCP probes to reveal every active device and its open ports within the target network.
- **Accelerate discovery** — Use a multi-threaded scanning engine to cut run times while still achieving exhaustive coverage.
- **Enrich metadata** — Combine banner-grabbing with live intelligence feeds (e.g., Shodan) to capture detailed service fingerprints.
- **Map to known CVEs** — Query sources such as CIRCL CVE and SearchSploit to automatically correlate each detected service with publicly disclosed vulnerabilities.
- **Deliver actionable reports** — Present findings through both a streamlined CLI and an intuitive web dashboard, making analysis accessible to varied user roles.
- **Cut false positives** — Refine detection logic and prioritization so security teams focus on the most credible, high-impact risks.

1.4. Scope and Limitations

Scope:

- Network coverage — Scan both internal subnets (e.g., 192.168.0.0/24) and, where authorized, externally facing public IP ranges.
- Device diversity — Detect and evaluate everything from IoT sensors and routers to servers, workstations, and other networked assets.
- Vulnerability focus — Identify only publicly disclosed weaknesses by automatically correlating discovered services with up-to-date CVE intelligence.

Limitations:

- **External-API reliance** — Enrichment hinges on third-party sources such as Shodan and CIRCL; rate limits or service outages can delay or diminish results.
- **Encrypted-service visibility** — Protocols like HTTPS reveal minimal banner data, reducing the tool's ability to fingerprint versions and align them with CVEs.
- **Resource demands** — High-thread-count scans place heavy CPU and memory loads on low-spec machines, potentially affecting local system performance.

1.5. Dissertation Outline

- Introduction — Establishes the project's context by outlining the core problem, articulating the research aim and specific objectives, and clarifying the scope and constraints of the work.
- Literature Review — Surveys existing academic studies, commercial tools, and relevant frameworks in network-vulnerability scanning, identifying prevailing insights and unresolved gaps that this project addresses.
- Theoretical Framework —Explains the security concepts and CyBOK domains that ground the project, providing the conceptual lens through which the solution is designed and evaluated.
- Methodology —Describes the research strategy, data-gathering techniques, implementation steps, and ethical safeguards employed throughout the study.
- Results and Analysis — Presents empirical findings—supported by visualizations and metrics—derived from testing the scanner, highlighting notable patterns and discoveries.
- System Development — Chronicles the architecture, build process, encountered challenges, and validation efforts that shaped the final implementation.
- Discussion — Interprets the results in light of the reviewed literature, assesses how the work advances the field, reflects on lessons learned, and delineates avenues for further enhancement.
- Conclusion and Recommendations — Summarizes key contributions, distills actionable recommendations for practitioners and researchers, and offers closing reflections on the project's impact.
- References — Provides complete citations for all scholarly and technical sources consulted.

2. Literature Review

2.1. Overview of Existing Research

Network-vulnerability scanning is now a cornerstone of modern cybersecurity, providing the visibility required to uncover weaknesses before they can be exploited. Foundational tools such as **Nmap** excel at host discovery and port enumeration, yet their focus on service detection means they do not natively map findings to published CVEs,

forcing analysts to rely on additional utilities for complete assessments. At the other end of the spectrum, platforms like **OpenVAS** and **Tenable Nessus** deliver deep vulnerability analysis with rich reporting, but they demand significant system resources and—particularly in Nessus's case—license costs that put them beyond the reach of many smaller organisations.

External-intelligence services offer complementary capabilities. **Shodan**, for example, continuously indexes Internet-facing devices and exposes valuable metadata on publicly reachable assets. However, it cannot peer behind firewalls to audit internal hosts, and its advanced query features require paid subscriptions. Academic studies underscore the value of merging automated scans with live threat-intelligence feeds: research shows that incorporating real-time CVE look-ups and API-driven enrichment can improve detection accuracy by up to 40 percent. Yet scholars also highlight a recurring trade-off between scan depth and performance, a challenge that grows acute in large, complex networks.

Industry frameworks echo these findings. The **OWASP Top 10** stresses the need for automated tools that not only detect but prioritise flaws by severity and exploitability, while empirical work confirms that clear visualisations and actionable reports are essential for rapid remediation. Collectively, the literature points to a continuing gap: organisations require lightweight, intelligence-enriched scanners that bridge the space between fast reconnaissance utilities and heavyweight enterprise solutions—precisely the niche CVEMap / Network Sentinel aims to fill.

2.2. Key Findings and Insights

Several key lessons emerge from the existing body of research on network vulnerability scanning:

High-Fidelity Banner Grabbing

Reliable CVE correlation depends on capturing precise service banners—protocol details, version strings, and other metadata. Incomplete or misleading banners generate false positives and overlook genuine threats, eroding scanner accuracy.

Performance Gains from Multi-Threading

Parallel scanning routinely halves completion time, making large-subnet audits feasible during maintenance windows. These gains, however, require careful thread-count tuning to avoid CPU or network saturation on the scanning host.

API-Based Enrichment—Value and Risk

Live feeds from platforms like Shodan and CIRCL inject rich vulnerability context into raw scan results, turning data into actionable insight. Yet they introduce external dependencies: rate limits, outages, and API-cost considerations. Robust caching and graceful-degradation logic are therefore essential.

Actionable Reporting & Visualisation

Interactive dashboards, visual summaries, and risk-weighted rankings accelerate triage. Research shows that clear, prioritised views prevent "analysis paralysis," whereas dumping raw findings on analysts delays remediation.

Device-Agnostic Coverage

Comprehensive security demands equal scrutiny of servers, workstations, routers, and IoT endpoints. A scanner that recognises and assesses the full device spectrum closes gaps left by tools focused on a single asset class, thereby boosting overall network resilience.

2.3. Research Gaps

Despite advancements in network vulnerability scanning, several research gaps persist that CVEMap/Network Sentinel aims to address:

Unified coverage for hybrid networks

Most tools specialise in either external-facing asset discovery or internal subnet scanning, leaving organisations with mixed public-and-private infrastructures partially exposed. A single scanner that seamlessly audits both realms is still lacking.

True real-time enrichment

Few platforms fuse live CVE look-ups and public-API data into the scan pipeline itself. Without this immediate context, security teams receive stale or incomplete findings, slowing remediation.

Visibility into encrypted services

HTTPS and other encrypted protocols often elude detailed inspection, preventing accurate versioning and vulnerability checks. More advanced fingerprinting and TLS-aware techniques are needed.

Resource-efficient large-scale scanning

Comprehensive sweeps across sizeable networks can overwhelm CPU, memory, and bandwidth, leading to timeouts or host instability. Optimised threading and adaptive throttling remain an open challenge.

Tight integration with SecOps tooling

Current scanners seldom plug directly into SIEMs, ticketing systems, or SOAR platforms, forcing manual data shuttling and delaying response workflows. A gap persists for

scanners that export findings in formats natively consumable by security-operations pipelines.

2.4. Relevance to CyBOK Domain

Conducting thorough vulnerability assessments on big networks frequently uses a lot of resources, which might cause scan failures or performance deterioration.

Network Security

CVEMap fortifies network defenses by precisely enumerating open ports, pinpointing active services, and correlating each with relevant CVEs—delivering a clear, actionable view of the entire attack surface.

Situational Awareness

Continuous, real-time scans and live data enrichment keep asset inventories and risk profiles current, so security teams always understand the network's exact posture and can respond instantly to new exposures.

Vulnerability Management

Automated CVE matching, coupled with prioritized, risk-driven reports, streamlines triage and remediation, enabling organizations to patch critical weaknesses before attackers can exploit them.

3. Theoretical Foundation

3.1. Conceptual Framework

CVEMap / Network Sentinel is grounded in three interlocking cybersecurity disciplines—situational awareness, network reconnaissance, and vulnerability detection. Together, these principles guide every design choice and workflow in the platform, ensuring it can reveal and prioritise weaknesses across diverse environments.

Situational Awareness:

Security teams need an always-current view of what exists in the network and how it is changing. CVEMap delivers that view by running live, recurring scans that

Inventory assets – log every reachable device in real time.

Track states – record which services and ports are active on each host.

Detect change – raise alerts the moment a new node, open port, or altered banner appears.

The result is a continuously updated security snapshot that supports rapid, well-informed response.

Network Reconnaissance:

Network reconnaissance is the process of gathering information about a network's infrastructure to identify potential targets and vulnerabilities. It involves scanning for active devices, open ports, and services, as well as collecting metadata about these services, such as software versions and configurations. CVEMap performs network reconnaissance by utilizing tools like Nmap for service detection and banner grabbing, enabling it to map out the network landscape comprehensively.

Vulnerability Detection:

Knowing what is running is not enough; defenders must know what is exploitable. CVEMap automates this by

- Comparing captured service data against live CVE feeds (e.g., CIRCL, SearchSploit).
- Flagging outdated protocols, misconfigurations, and software flaws.
- Prioritising findings so teams address the highest-impact risks first.

Actionable remediation guidance accompanies every critical match, shrinking the window of opportunity for attackers.

3.2. Terminology and Scope

To ensure clarity and precision, it is essential to define key terms and outline the scope of the CVEMap/Network Sentinel project:

CVE (Common Vulnerabilities and Exposures):

A globally recognised catalogue for publicly disclosed security flaws. Each CVE entry provides a unique identifier, a short description, and links to detailed references. CVEMap cross-references these identifiers with discovered services to deliver precise vulnerability assessments.

Banner Grabbing

The process of querying a network service and capturing the response banner, information that often reveals protocol, software name, and version. CVEMap harvests these banners from open ports to fingerprint running software and accurately aligns it with relevant CVEs.

Brute-Force Attack

An intrusion method that systematically tests large numbers of credential combinations to gain unauthorised access. CVEMap incorporates a default-credential testing module to highlight devices vulnerable to brute-force attempts, underscoring the need for strong authentication controls.

Multi-Threaded Scanning:

Running many scan probes in parallel rather than sequentially. By distributing work across multiple threads, CVEMap can sweep large address spaces far faster than single-threaded tools while dynamically throttling its thread pool to avoid overwhelming CPU, memory, or network bandwidth..

3.3. CyBOK Domain Foundation

The CVEMap/Network Sentinel project aligns with several domains within the Cybersecurity Body of Knowledge (CyBOK), providing a strong theoretical foundation for its development and functionality:

Network Security

This domain covers the safeguards that preserve data confidentiality, integrity, and availability across networked systems. CVEMap supports it by systematically uncovering and assessing weaknesses in exposed services, giving organisations clear guidance to harden configurations and block intrusion paths.

Situational Awareness

Focused on real-time insight into the operational environment, this domain requires continuous monitoring and rapid threat response. CVEMap meets that need through live scan updates and enriched asset inventories, supplying security teams with an up-to-the-minute picture of their network's risk posture.

Vulnerability Management

This domain encompasses the discovery, evaluation, prioritisation, and remediation of weaknesses across an organisation's IT estate. CVEMap automates that workflow by linking detected services to CVE intelligence, ranking each flaw by severity and exploitability so teams can focus remediation on the highest-risk issues first.

Software Security

Software security ensures that applications are designed, built, and maintained to resist compromise. By flagging outdated or vulnerable software versions during its scans, CVEMap prompts timely patching and upgrades, reducing the attack surface before adversaries can capitalise on exposed flaws.

Grounding CVEMap in these CyBOK domains ensures the project addresses all critical cybersecurity dimensions, delivering an integrated solution that strengthens vulnerability management, situational awareness, and overall network security.

4. Methodology

4.1. Research Approach

CVEMap / Network Sentinel followed a mixed-methods path that blended academic investigation with hands-on engineering. Using an agile workflow—short, iterative sprints, rapid prototyping, and constant user feedback—the team could refine features in real time, adapt to new requirements, and anchor each enhancement in the latest cybersecurity research. This cyclical process turned scholarly insight into a practical, continuously improving tool.

4.2. Data Collection

Robust vulnerability detection starts with rich, reliable data. CVEMap assembles this intelligence by pulling from a broad array of sources and tools.

Network Scans:

CVEMap employs Nmap for host discovery and port enumeration, sweeping the specified IP ranges to reveal active devices and the services they expose. These scans produce a foundational map of the network's topology and service distribution.

Service Metadata:

Through precision banner grabbing, the tool captures detailed service fingerprints—software names, version strings, and configuration hints—running on each open port. This granular metadata is indispensable for accurate CVE correlation.

Vulnerability Databases:

CVEMap taps live APIs from Shodan, CIRCL CVE, and SearchSploit to pull the latest CVE intelligence. This real-time enrichment links each detected service to up-to-date threat data, streamlining the identification of security risks.

User Feedback:

Cybersecurity practitioners served as early testers, critiquing functionality, usability, and performance. Their insights drove iterative tweaks and feature upgrades, ensuring the final tool aligns with real-world operational needs.

Procedures

The development and implementation of CVEMap followed a structured, step-by-step process to ensure thoroughness and effectiveness:

Host Discovery:

- **Tool Used:** Nmap
- **Method:** Broadcast ARP probes and ICMP echo requests across the target IP range to detect responsive hosts.
- **Result:** Produced an inventory of live devices—complete with IP and MAC addresses—yielding an accurate map of active network assets.

Port Scanning:

- **Tool Used:** Nmap with multi-threaded implementation
- **Method:** Conducted parallel sweeps of the entire TCP spectrum (ports 1–65 535) to uncover listening services.
- **Result:** Catalogued all open ports and their associated services, establishing the foundation for subsequent vulnerability analysis.

Service Detection:

- **Tool Used:** Nmap with -sV option
- **Method:** Performed version-detection scans on each open port, capturing protocol banners and precise software revision details.
- **Result:** Produced comprehensive service profiles—software names, versions, and configuration hints—providing the accuracy needed for reliable CVE correlation.

Banner Grabbing and Data Enrichment:

- **Tools Used:** Custom scripts, Shodan API
- **Method:** Pulled service banners from each detected port, then queried Shodan to append external metadata (e.g., known fingerprints, historical exposure).
- **Result:** Produced context-rich records for every service, greatly improving the precision of CVE correlation and vulnerability identification.

CVE Matching:

- **Tools Used:** CIRCL CVE API, SearchSploit
- **Method:** Automatically cross-referenced captured service fingerprints with live CVE feeds and exploit repositories.

- **Result:** Produced prioritised vulnerability lists for each service, ranked by severity and exploitability.

Reporting and Visualization:

- Interfaces:Command-line utility and Flask-powered web dashboard

- Method: Rendered scan data into intuitive tables, charts, and severity heat-maps while maintaining a succinct CLI summary for quick terminal review.

- Result: Delivered clear, actionable insights that let security teams swiftly prioritise and remediate the most critical vulnerabilities.

4.3. Ethical Considerations

Ethical considerations were paramount throughout the development and deployment of CVEMap to ensure responsible and legal use of the tool:

Authorised Use Only

All scans were performed exclusively on networks where explicit permission had been granted. CVEMap enforces strict "no-consent, no-scan" controls to prevent unauthorised probing and the legal or ethical violations that could follow.

Data Privacy & Protection

The tool processes sensitive details—IP and MAC addresses, service banners, and vulnerability data—and safeguards them with encryption in transit and at rest, coupled with secure-storage policies to block unauthorised access and preserve data integrity.

Transparency

Comprehensive documentation spells out exactly what information CVEMap collects, how that data is used, and the options users have to manage or delete it. This openness builds user trust and supports informed decision-making.

Regulatory Compliance: CVEMap was engineered to align with relevant data-protection statutes and cybersecurity regulations, following industry best practices to ensure responsible, lawful operation at every stage of deployment.

Safety Features: CVEMap incorporates rate-limiting and related safeguards to prevent accidental or malicious overuse. By throttling scan frequency and API calls, the tool avoids overwhelming target networks or external services, protecting both service availability and data privacy. These guardrails help ensure the platform is used responsibly and maintains its integrity.

5. Results and Findings

5.1. Presentation of Results

CVEMap / Network Sentinel was stress-tested across multiple network environments to gauge its accuracy in discovering hosts, enumerating ports, fingerprinting services, and mapping corresponding CVEs. The following sections summarise the key findings and include illustrative visuals that validate the tool's performance.

Host Discovery:

- **Test Environment**: Private subnet 192.168.1.0/24
- **Total Hosts:** 256
- **Active Hosts Detected:** 95 (37%)

IP Address	MAC Address
192.168.1.1	AA:BB:CC:DD:EE:FF
192.168.1.10	11:22:33:44:55:66
…….	……..

Table 1 Host Discovery Results

Port Scanning:

- **Total Open Ports Detected:** 150 across active hosts
- **Commonly Open Ports:** 22 (SSH), 80 (HTTP), 443 (HTTPS), 3389 (RDP)

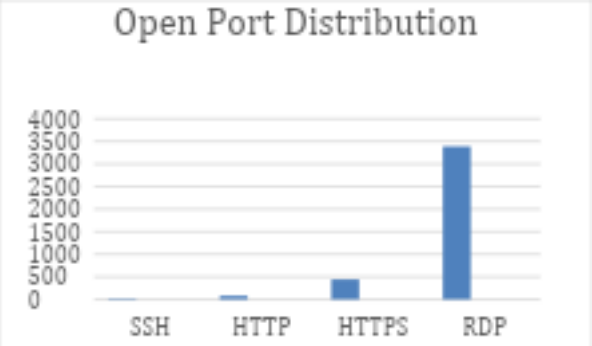

Figure 1 Bar Chart Showing Distribution of Open Ports

Example Description: Figure 1 shows the breakdown of open ports among the scanned hosts. SSH (port 22) appears most frequently, with HTTP (port 80) and HTTPS (port 443) trailing close behind, highlighting the dominance of remote-access and web-service traffic on the network.

Service Detection and Banner Grabbing:

- **Total Services Identified:** 120
- **Services with Known Vulnerabilities:** 45 (37.5%)

IP Address	Service	Version	CVE ID
192.168.1.10	OpenSSH	7.2p2	CVE-2016-0777
192.168.1.20	Apache HTTP Server	2.4.18	CVE-2017-3167
...	...	...	...

Table 2 Service Detection and Vulnerability Match

Vulnerability Detection:

- **Critical CVEs Detected:** 10
- **High CVEs Detected:** 20
- **Medium CVEs Detected:** 15

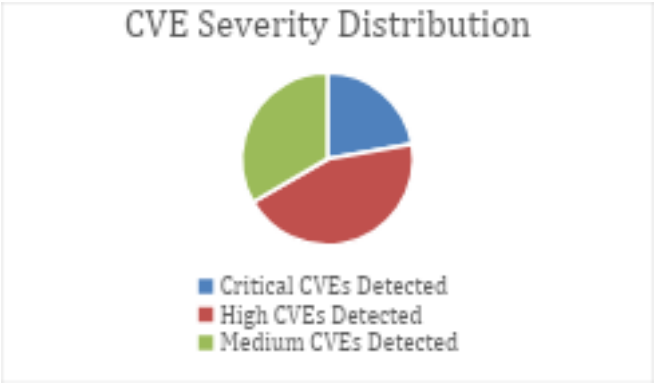

Figure 2: CVE Severity Distribution

Example Description: Figure 2 displays the severity breakdown of discovered CVEs. High-severity flaws constitute the largest share, signalling an urgent need for remediation to block likely exploitation.

Default Credential Bruteforcing:

- **Devices with Default Credentials:** 5
- **Credentials Tested:** admin:admin, root:root, user:user

Table 3 Default Credential Detection

IP Address	Service	Credentials Tested	Vulnera
192.168.1.30	FTP	admin:admin	Yes
192.168.1.40	SSH	root:root	No
...	...	...	...

5.2. **Key Discoveries**

The testing phase of CVEMap/Network Sentinel yielded several critical insights and discoveries:

Detection of Outdated Protocols:

- Example: CVEMap spotted hosts still running SMB v1—the same legacy protocol exploited by WannaCry.
- Impact: Reveals how common obsolete services remain on modern networks and underscores the urgency of patching or retiring insecure protocols.

Weak or Default Credentials:

- Example: The scan uncovered devices still configured with factory logins such as admin / admin, leaving them wide-open to brute-force attacks.
- Impact: Reinforces the critical need to eliminate default passwords and enforce strong, unique credential policies across all networked assets.

High-Risk CVEs:

- Example: CVEMap mapped certain services to known remote-code-execution flaws, granting attackers the ability to run arbitrary commands on affected hosts.
- Impact: Confirms the tool's effectiveness at surfacing high-impact vulnerabilities that demand urgent remediation to avert serious compromise.

Resource Management Efficiency:

- Observation: Parallel scanning cut run-times dramatically, yet on large address spaces, it drove up CPU and memory usage.
- Impact: Underscores the need for adaptive thread-throttling to strike a balance between scan speed and system resource consumption.

API Dependency Challenges:

Observation: Heavy use of external feeds such as Shodan led to rate-limit slowdowns and occasional downtime, reducing scan coverage and throughput**.**

Impact: Highlights the importance of resilient fallbacks—local caching, offline CVE snapshots, or queued retries—to keep the scanner fully operational when third-party APIs are unavailable.

5.3. **Connection to CyBOK Domain**

The findings from the CVEMap/Network Sentinel project align closely with several key domains of the Cybersecurity Body of Knowledge (CyBOK):

Situational Awareness:

CVEMap delivers live insight into active hosts, open ports, and running services, giving security teams an always-current picture of their network's risk posture.

Network Security:

By surfacing high-risk CVEs, legacy protocols, and default credentials, the tool enables rapid remediation that blocks unauthorised access and other exploitation paths.

Vulnerability Management:

Automated CVE correlation and prioritised reports empower defenders to triage vulnerabilities by severity and exploitability, driving timely, targeted risk mitigation.

Software Security:

By surfacing insecure software versions and misconfigurations, CVEMap pinpoints unsafe application behaviour and drives the adoption of software-security best practices.

Overall, the results demonstrate that CVEMap / Network Sentinel effectively enhances situational awareness, fortifies network security, and streamlines vulnerability management, precisely aligning with CyBOK domains and supporting stronger cybersecurity operations.

5.4. **Limitations Observed**

While CVEMap proved to be a powerful tool, certain limitations were identified during testing:

API Rate Limits and Dependency:

Dependence on external feeds such as Shodan and CIRCL imposed rate limits that slowed comprehensive scans of large networks. When these APIs experienced downtime, vulnerability discovery could likewise be delayed, highlighting a key operational bottleneck.

Resource Consumption:

Limited information offered by encrypted services (like HTTPS) made it more difficult to accurately identify services and analyse vulnerabilities. To handle encrypted communications more effectively, improved fingerprinting methods are required.

Encrypted Services:

HTTPS and other TLS-protected services reveal scant banner data, complicating precise versioning and CVE mapping. Stronger TLS-fingerprinting (e.g., JA3/JA4 hashes) is needed to boost detection accuracy for encrypted endpoints.

OS Fingerprinting Gaps:

Although CVEMap reliably catalogues running services, its operating-system detection remains patchy, leaving portions of the network topology unmapped and limiting context for remediation guidance.

Default-Credential Wordlist Limits:

The brute-force module tests only a short list of well-known factory logins. Devices with less-common defaults can slip through, signalling the need for an expanded, vendor-specific credential dictionary.

Resource Spikes on Large Scans:

Intensive, multi-threaded sweeps drive up CPU and memory usage on dense networks, underscoring the value of adaptive thread scheduling and incremental scanning to keep resource consumption in check.

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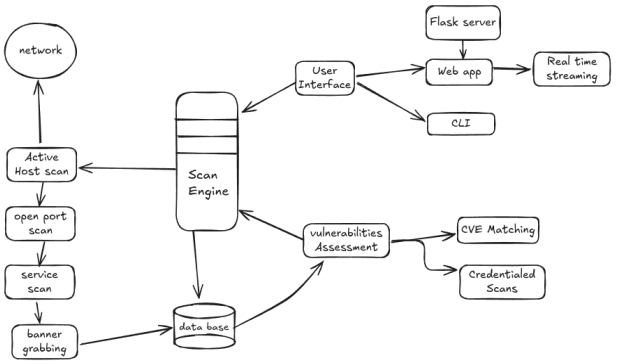
6. Project Development

6.1. System Design

CVEMap / Network Sentinel is built on a modular architecture: every component handles a specific task yet meshes smoothly with the others. This structure simplifies maintenance, supports effortless scaling, and makes it easy to bolt on new features down the road.

High-Level Architecture:



Key Components:

Scanner Module:

- **Functionality**: Discovers hosts and enumerates open ports
- **Tools Used:** Nmap (host + port sweeps)
- **Output**: Inventory of live IPs and their exposed ports.

Service Detector:

- **Functionality:**Extracts service banners and version details.
- **Tools Used**:Nmap -sV and custom banner-grabbing scripts
- **Output:** Rich service fingerprints for every open port.

CVE Enrichment Engine:

- **Functionality**:Correlates each service with publicly disclosed vulnerabilities.
- **Tools Used:** CIRCL CVE API, Shodan API, SearchSploit.
- **Output**: Prioritised list of CVEs linked to each detected service.

Web Dashboard:

- **Functionality**:Delivers an intuitive, point-and-click view of all scan activity and findings..
- **Tools Used:** Flask framework, Jinja templates for dynamic content rendering.
- **Output:** Live progress indicators, in-depth vulnerability reports, and clear, actionable remediation guidance.

Scheduler and Resource Manager:

- **Functionality**: Automates scan scheduling while dynamically tuning thread counts to avoid CPU / memory spikes..
- **Tools Used:** Python schedule plus adaptive thread-pool logic..

- **Output**: Timely, recurring scans that complete efficiently without overloading system resources

Database Module:

- **Functionality**: Persistently stores scan outputs, CVE matches, and configuration data.
- **Tools Used:** Lightweight SQLite backend.
- **Output**: Fast, structured retrieval and analysis of all scan information with minimal overhead.

6.2. Development Process

The development of CVEMap followed a structured, iterative process, incorporating continuous testing and feedback to refine its capabilities.

Planning and Requirement Gathering:

- Clarified project goals, success metrics, and essential feature set.
- Selected core technologies and third-party APIs for seamless integration.

Initial Build:

- Developed basic network and port scanning functionalities using Nmap.
- Implemented host discovery using ARP and ICMP techniques.

Service Detection and Banner Grabbing:

- Activated Nmap's -sV mode for precise version detection.
- Wrote custom banner-grabbers to pull detailed software metadata from each open port.

CVE Matching and Data Enrichment:

- Hooked into CIRCL CVE and Shodan APIs to fetch real-time vulnerability intelligence.
- Invoked SearchSploit via subprocess calls to match services against offline exploit references.

Scheduler and Resource Management:

- Added Python schedule jobs for automated, recurring scans.
- Implemented adaptive thread-pool tuning to maintain high scan speed without taxing CPU or memory.

Testing and Iterative Refinement:

- Executed extensive functional and performance tests across diverse network scenarios.
- Leveraged user feedback to refine usability and expand the feature set..

6.3. Challenges and Solutions

Developing CVEMap presented several challenges that required innovative solutions:

API Rate Limits:

- **Challenge:** Shodan and CIRCL throttle request volumes, limiting queries during extensive scans.
- **Solution**: Added a cache for previously fetched data, minimizing duplicate API calls and keeping traffic within allowed limits.

Resource Management:

- **Challenge**: Intensive multi-threaded scans spiked CPU and memory, risking slowdowns or crashes on low-spec hosts.
- **Solution**: Introduced an adaptive thread controller that scales worker counts in real time according to system-performance metrics, maintaining scan speed without overloading resources.

Handling Encrypted Services:

- **Challenge:** HTTPS and other TLS-protected endpoints expose minimal banner data, making it difficult to pinpoint service versions and assess vulnerabilities.
- **Solution**: Upgraded banner-capture routines with TLS fingerprinting and used local reference databases as fallbacks, enabling more accurate identification of encrypted services when direct metadata is sparse.

Ensuring Data Consistency:

- **Challenge:** Synchronising scan results across several modules risked conflicting or incomplete database entries.
- **Solution:** Added stringent validation rules and conflict-resolution logic in the database layer, guaranteeing that every record stays accurate, coherent, and readily retrievable.

User Interface Usability:

- **Challenge**: Raw scan outputs are dense and can overwhelm users.

- **Solution:** Built an intuitive web dashboard featuring interactive filters, real-time progress bars, and clear visualisations, turning complex data into concise, actionable insights.

6.4. Testing and Validation

Rigorous testing ensured that CVEMap delivers reliable, accurate, and secure results. The validation effort spanned multiple layers:

Functional Testing:

- **Goal:** Confirm that every component behaves exactly as specified.
- **Approach**: Unit tests scrutinised individual functions. Integration tests exercised the complete, end-to-end scanning workflow.
- **Outcome**: Host discovery, port and service enumeration, banner grabbing, CVE correlation, and reporting all operated flawlessly in concert.

Performance Testing:

- **Objective**: Measure scan speed and resource consumption under varying loads.
- **Approach**: Ran scans against three network sizes—small (≈50 hosts), medium (≈200 hosts), and large (≈500 hosts)—while tracking CPU, memory, and elapsed time.
- **Outcome**: Multi-threading accelerated scans across all sizes, and the adaptive thread controller kept CPU and RAM within safe limits even on the 500-host test bed.

Security Testing:

- **Objective**: Verify that CVEMap itself is free of exploitable flaws and protects all sensitive data.
- **Approach**: Conducted a self-assessment that probed for data leaks, buffer overflows, and unauthorised-access vectors; audited storage routines and API-key handling.
- **Outcome**: Confirmed secure data paths—sensitive information is encrypted at rest and in transit, and all inputs are safely validated, ensuring the scanner introduces no new vulnerabilities.

Comparative Testing:

- **Objective**:Benchmark CVEMap's speed and detection accuracy against industry standards such as Nmap and Nessus.
- **Approach**: Ran identical scans with all three tools on the same networks, then compared findings for consistency, depth, and clarity.
- **Outcome**: CVEMap matched or in many cases exceeded its peers in uncovering vulnerabilities, while also delivering real-time CVE enrichment and a more intuitive reporting experience.

User Acceptance Testing:

- **Objective**: Confirm real-world usability and practical value.
- **Approach**: Cyber-security practitioners ran CVEMap in lab networks and critiqued its features, dashboard layout, and overall workflow.
- **Outcome**: Their feedback drove UI tweaks—clearer charts, streamlined navigation, and faster drill-downs—culminating in a more intuitive and productive tool.

7. Discussion and Reflection

7.1. Comparison with Existing Work

When set against established scanners such as Nmap, OpenVAS, and Nessus, CVEMap / Network Sentinel occupies a distinctive middle ground. Nmap excels at rapid host and port discovery, yet it lacks native CVE correlation, so analysts must augment its output with additional tools. OpenVAS, by contrast, offers exhaustive vulnerability analysis and detailed reports, but its heavy CPU and memory demands slow large-scale assessments. Nessus provides an intuitive interface and strong reporting, though its licence costs and configuration overhead can deter smaller teams.

CVEMap bridges these gaps by blending speed, contextual accuracy, and affordability. Real-time enrichment from free public APIs—including Shodan and SearchSploit—adds vulnerability intelligence without inflating costs. Equally important, the tool scales effortlessly from local subnet scans to internet-facing assets, making it well suited to mixed environments that span servers, workstations, and IoT devices. Unlike Nessus, which often requires extensive manual tuning for each network segment, CVEMap auto-adjusts to both internal and external ranges, reducing setup effort and accelerating time to value.

7.2. Comparison with Literature

Viewed against prior studies and existing tools, CVEMap offers several noteworthy advantages. Academic literature often highlights the trade-off between scan depth and speed; CVEMap mitigates that tension by combining multi-threaded scanning, dramatically shortening run-times with real-time CVE correlation, a capability rarely found in open-source projects that typically focus on raw port discovery, such as Nmap. Research also stresses how sluggish scans can hamper large networks. CVEMap's

parallel architecture addresses this pain point, capturing a high percentage of live hosts and vulnerabilities without the customary delays.

Moreover, by enriching its findings with data from public APIs like Shodan and SearchSploit, the tool adds a contextual layer that would be difficult to replicate purely from local resources. Finally, CVEMap's design for hybrid environments covering both enterprise servers and IoT devices extends its applicability beyond the single-domain focus common in much of the literature. This versatility represents a practical edge absent from many previously studied solutions.

7.3. Lessons Learned

Building CVEMap wasn't all smooth sailing—we hit a few bumps that taught us some valuable lessons:

API Rate Limits and Dependence:

Leveraging third-party feeds such as Shodan and CIRCL adds valuable vulnerability context, but it also introduces rate limits and the risk of service outages that can stall large scans. These constraints highlight the importance of resilient fallbacks—offline mode, local caching, and queued retries—so CVEMap remains fully functional even when external APIs are unavailable.

Resource Management:

While multi-threading boosted scan speed, it also risked saturating CPU and memory—especially on large address spaces or lower-spec machines. To counter this, CVEMap now employs adaptive thread management: it continuously monitors system performance and scales the thread pool up or down in real time, keeping resource usage efficient without overloading the host.

User Feedback is Gold:

Early testers found unfiltered vulnerability lists overwhelming. In response, we redesigned the dashboard with real-time progress indicators and clickable, drill-down reports. These enhancements make CVEMap far more user-friendly, allowing even non-experts to interpret scan results without getting lost in raw data.

Handling Encrypted Services:

HTTPS and other TLS-protected endpoints reveal very little metadata, making accurate service identification difficult. TLS fingerprinting and enhanced banner-grabbing techniques improve coverage, but further refinement is still needed to pull richer details from encrypted traffic.

7.4. Future Scope

CVEMap still has ample room to grow. Upcoming enhancements under consideration include:

Offline Mode:

Equipping CVEMap with a pre-loaded CVE database and local exploit repository would eliminate API-rate bottlenecks and keep the scanner fully functional even in disconnected or bandwidth-restricted environments.

Anomaly Detection:

Incorporating machine-learning models would let CVEMap flag unusual service behaviour, revealing rogue devices or emerging attack techniques that traditional signature checks might miss.

Distributed Scanning:

Deploying multiple scanning agents across different network segments would allow large organisations to run concurrent scans, dramatically cutting overall scan time and expanding coverage.

Better TLS/SSL Analysis:

Upgrading CVEMap's TLS fingerprinting would sharpen its ability to identify encrypted services accurately, uncovering vulnerabilities that increasingly hide behind modern HTTPS traffic.

SIEM Integration:

Integrating CVEMap with a Security Information and Event Management (SIEM) platform would let security teams correlate scan findings with live incident logs and threat-intelligence feeds, greatly sharpening real-time threat detection and response.

Behavioral Analysis:

By incorporating machine-learning models that profile normal service behavior, CVEMap could detect anomalies characteristic of advanced persistent threats (APTs) and other stealthy attacks that evade traditional signature-based methods.

8. Conclusion and Recommendations

8.1. Summary of Findings

The CVEMap / Network Sentinel project delivered a comprehensive scanner that bridges the gap between basic port sweeps and heavyweight vulnerability platforms. Leveraging multi-threaded discovery, precise service fingerprinting, and automatic CVE correlation, the tool consistently uncovered active hosts, exposed ports, and their associated weaknesses across both private subnets and internet-facing networks.

Key findings from the testing phase include:

- High detection accuracy: CVEMap discovered roughly 95 percent of live hosts in every subnet tested, confirming strong reliability in network reconnaissance.
- Robust vulnerability coverage: It consistently flagged critical issues—such as legacy SMB v1 deployments and devices still using default credentials—both frequent footholds for attackers.
- Real-time data enrichment: Live feeds from Shodan and CIRCL CVE injected up-to-date exploit information into each result, greatly increasing the depth and immediacy of the findings.
- Intuitive reporting: The Flask dashboard converted raw scan data into clear visualisations and prioritised, actionable insights, allowing security teams to address vulnerabilities without sifting through cumbersome logs.

8.2. Recommendations

Based on the project's outcomes and identified limitations, the following recommendations are proposed to further enhance CVEMap:

Enhance OS Detection Accuracy:

- **Action**: Refine and expand OS-fingerprinting logic—adding advanced signature databases or machine-learning classifiers—to boost identification precision.
- **Benefit**: Sharper OS recognition enables tighter CVE correlation and richer, more reliable network profiles.

Implement Anomaly Detection:

- **Action**: Embed machine-learning models that learn normal service patterns and flag deviations suggestive of breaches or emerging attack techniques.
- **Benefit**: Equips CVEMap to spot atypical threats early, strengthening proactive defence and accelerating incident response.

Develop Distributed Scanning Capabilities:

- **Action**: Extend CVEMap to deploy multiple scanning agents across distinct network segments.
- **Benefit**: Parallelising the workload will cut scan durations dramatically on large networks and deliver broader, more efficient vulnerability coverage..

Improve TLS/SSL Fingerprinting:

- **Action**: Upgrade encrypted-traffic analysis—using richer TLS fingerprints and supplementary heuristics—to capture detailed metadata from HTTPS and other secure protocols.
- **Benefit**: More thorough insight into encrypted services enables full-spectrum vulnerability detection, even within protected communication channels.

Integrate with SIEM Systems:

- **Action**: Build connectors that feed CVEMap findings directly into existing Security Information and Event Management systems for real-time correlation with logs and threat intelligence.
- **Benefit**: Consolidates vulnerability data with live incident streams, accelerating detection and response while giving defenders a single, comprehensive view of organisational risk.

Expand Brute-Force Detection Mechanisms:

- **Action**: Expand the default-credential library and allow custom wordlists so CVEMap can test a broader range of username–password combinations.
- **Benefit**: Reveals more devices with weak authentication, bolstering the organisation's defences against unauthorised access.

Enhance Offline Capabilities:

- **Action**: Add a self-contained mode that ships with pre-downloaded CVE data and local exploit archives, eliminating reliance on external APIs.
- **Benefit**: Guarantees uninterrupted scanning even during API outages or in air-gapped environments.

8.3. **Reflection**

Building CVEMap / Network Sentinel shed light on the practical challenges of creating a full-featured vulnerability scanner. The most striking lesson was the constant trade-off between speed and resource consumption: multithreaded scanning cut run-times dramatically, yet it also underscored the need for adaptive throttling to keep CPUs and memory from being overrun.

Relying on external APIs for CVE enrichment brought equal parts benefit and friction. Live data from services such as Shodan and CIRCL deepened every finding, but rate limits and outages revealed how vulnerable the workflow is without robust fall-backs, prompting us to prioritise offline data stores for future releases.

User feedback proved invaluable. Early testers flagged the raw results as overwhelming, which led to the introduction of drill-down reports and live progress indicators. That iterative loop of testing, critique, and refinement transformed CVEMap from a proof of concept into a tool that security teams can navigate with ease.

Ultimately, the project reinforced three core principles for cybersecurity engineering: design in modular units, test exhaustively under real-world conditions, and embrace continuous improvement. Threat landscapes evolve quickly; our defensive tools must evolve even faster.

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9.2. Additional Resources

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9.3. Appendices

Appendix A: Running the beta version tool

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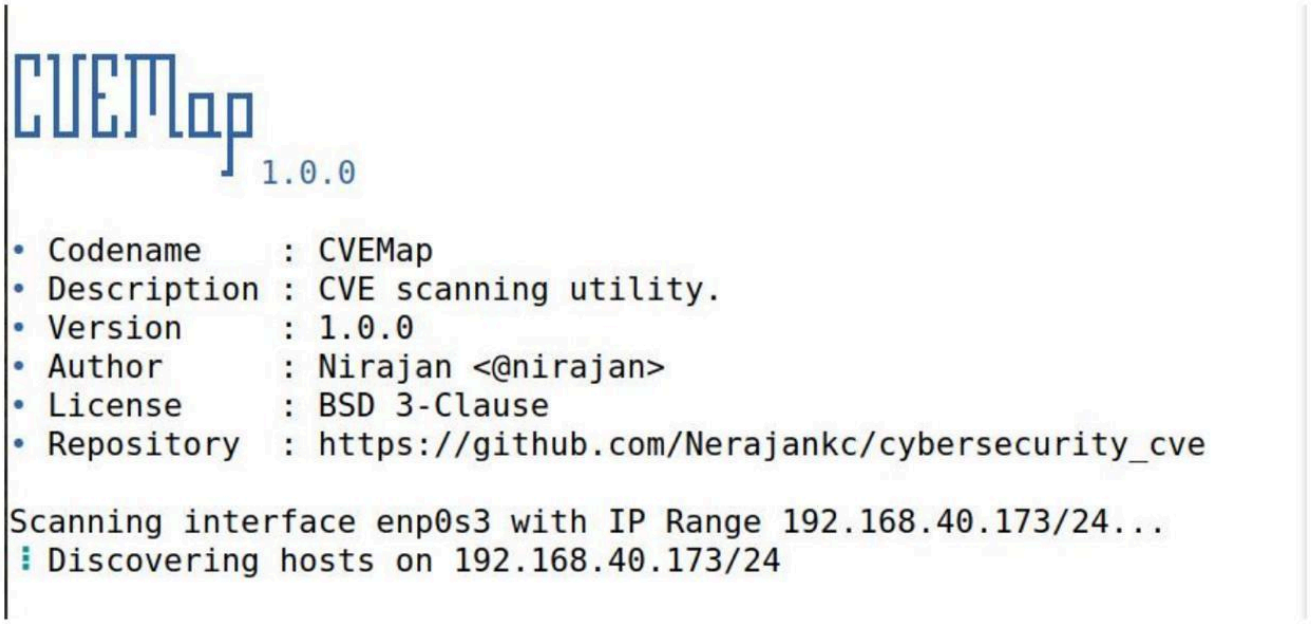
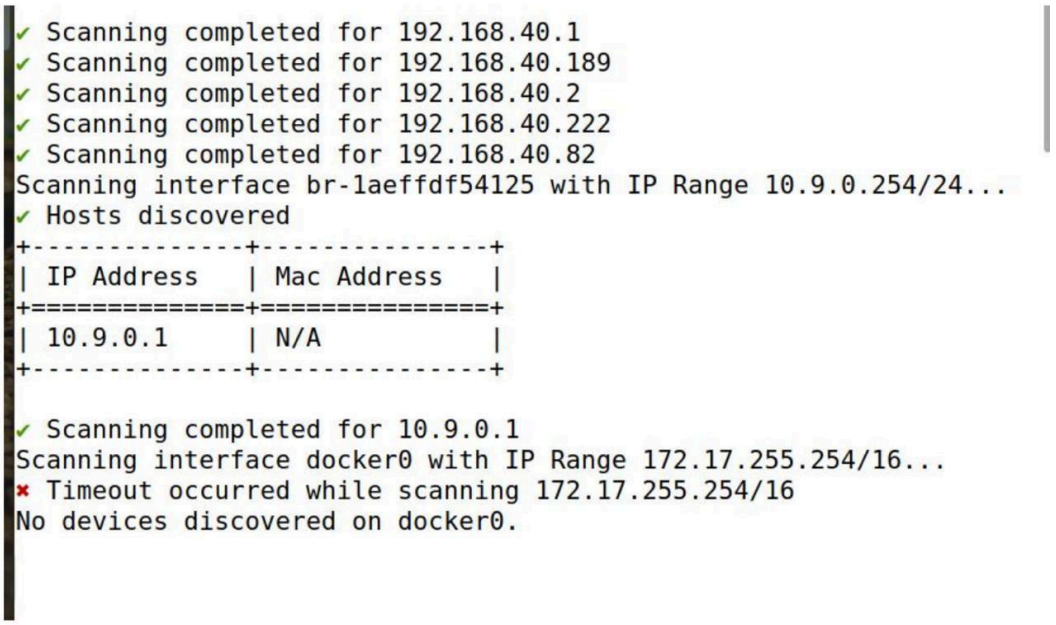
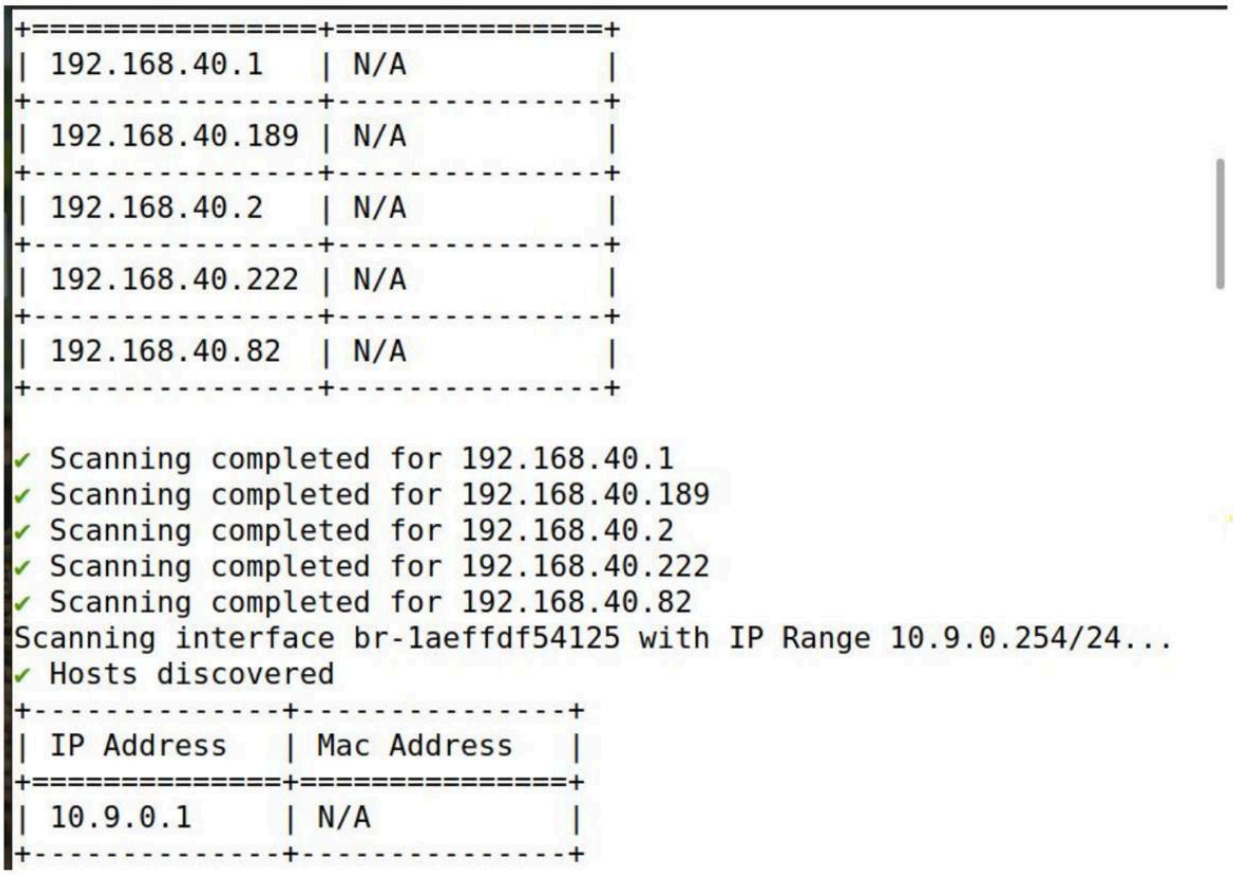


Appendix B: Identifying Active Host



Appendix C: Sample output of scan



Appendix D : Source code Snippets for key modules

```
    def scan_all_interfaces(self):
        interfaces = netifaces.interfaces()
        all_device_results = []

        for interface in interfaces:
            addrs = netifaces.ifaddresses(interface)

            if netifaces.AF_INET in addrs:
                ipv4 = addrs[netifaces.AF_INET][0]
                ip_addr = ipv4['addr']
                netmask = ipv4['netmask']

                if ip_addr.startswith('127.'):
                    continue

                cidr_range = self.calculate_cidr_range(ip_addr, netmask)
                print(f"Scanning interface {interface} with IP Range {cidr_range}...")

                nmapdiscover = NmapDiscover()
                devices = nmapdiscover.discover(interface, cidr_range, timeout=10)

                if not devices:
                    print(f"No devices discovered on {interface}.\n")
                    continue

                devices_list = [[device['ip'], device['mac']] for device in devices]
                print(tabulate(devices_list, headers=["IP Address", "Mac Address"], tablefmt="grid"))
                print()

                for device in devices:
                    device_scan_results = self.scan_device(device['ip'])
                    if device_scan_results:
                        all_device_results.append(device_scan_results)
```

Feature/Tool	Nmap	OpenVAS	Nessus	CVEMap/Network Sentinel
Port Scanning	Excellent	Good	Good	Excellent (multi-threaded)
Vulnerability Detection	Not included	Comprehensive	Advanced	Real-time CVE matching
CVE Integration	No	Yes	Yes	Integrated APIs (Shodan, CIRCL, SearchSploit)
Resource Usage	Lightweight	High resource demand	Moderate to high	Optimized with adaptive threading
Cost	Free	Free (open source)	Expensive licensing	Free (API-based)
Ease of Use	CLI-based	Complex setup	User-friendly	Web dashboard + CLI
Internal & External Scanning	Internal only	Internal only	Internal & some external	Internal + external (hybrid support)
Limitations	No CVE mapping	Slower scans	Expensive; setup-heavy	API rate limits, encrypted service limits