

Firewall Implementation and Attack Mitigation Using pfSense

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Abstract: The implementation of pfSense, an open-source firewall, as a robust and affordable solution for enhancing network security against prevalent cyber threats. The project involved setting up a controlled environment using VMware, where pfSense was configured alongside Kali Linux to simulate common attacks such as SYN flood, denial-of-service and Nmap port scanning. It assessed the effectiveness of the default pfSense firewall rules in preventing SYN flood attacks and deployed customized Suricata rules to detect and mitigate port scanning attempts in real-time. The results of this project prove that pfSense can serve as a cheap security device that will reduce network vulnerabilities.

1 INTRODUCTION

With the rise of the internet of things, it is becoming increasingly important to protect network infrastructures. The growing complexity of cyberattacks from Distributed Denial-of-Service (DDoS). Emphasizes the importance of security mechanisms. Traditional security measures, like simple firewalls or signature-based detection systems, often fail to combat advanced threats. This has prompted security frameworks to move away from traditional models and instead focus on dynamic, proactive defense strategies capable of identifying and responding to threats as they occur. Standing on the edge, firewalls constitute the first line of defense that filters malicious traffic, prohibits unauthorized access, and ensures security policies are in place. Getting the most out of a firewall requires the additional layer of network intrusion detection and prevention systems (IDS/IPS).

pfSense is an open-source firewall and router software distribution based on FreeBSD, designed to be installed on a physical or virtual machine to create a dedicated network appliance. These include traffic filtering, VPN support, and integration with intrusion detection systems, among other features. You are running the data up to October 2023. Using pfSense, we are looking to see how well it can observe and react to hostile attacks Configuration. In

this study, we focus on one of the most common attack vectors, the SYN Flood attack, a classic Denial-of-Service (DoS) technique that disrupts the TCP handshake process to exhaust network resources. This simulated attack even allows you to test pfSense's default security settings as well as its ability to withstand high-volume malicious traffic.

pfSense-box only provides real protection against very basic SYN Flood attacks or other brute-force based or DDoS attacks. Because Suricata follows the principles of deep packet inspection, you can use the software for packet analysis, anomaly detection, and the creation of your own security rules to thwart specific attack vectors. The project consists of developing custom Suricata rules that can prevent SYN Flood attacks, enhancing security. Suricata enhances the firewall's capability to combat emerging cyber threats by issuing real-time alerts and proactively blocking malicious traffic.

This project highlights the significance of preemptive measures in contemporary cyber defense, beyond just SYN Flood attacks. We least expect it (e.g., when we least expect it); and in this sense, we build a more resilient and dynamic security structure. The merging of firewall with intrusion detection is part of a larger trend toward intelligent security that can respond to move threats efficiently. With the increasing sophistication of cyberattacks, using

advanced tools like pfSense and Suricata has become essential for protecting vital digital resources.

In conclusion, this paper presents a thorough examination of how pfSense can be employed for the implementation and prevention of attacks via the effective use of its firewall functionality. This work sheds light on the shortcomings of default firewall policies and provides powerful defenses leveraging the latest security innovations. Integrating pfSense with Suricata strengthens the security ecosystem, ensuring that threats are detected, alerted, or prevented from causing extensive damage to our home network. The sheer effort in building this project indicates an ongoing need for bettering network security looking at the fast-appearing cyber threats and countermeasures.

2 LITERATURE REVIEW

The growing sophistication of network cyberattacks, such as Denial-of-Service (DoS) assaults and reconnaissance scans, has spurred extensive research into firewall technologies and intrusion detection systems (IDS) as critical defenses. Existing studies can be grouped into three primary approaches: traditional firewall techniques, open-source firewall solutions, and hybrid firewall-IDS systems. Each approach has been explored to enhance the resilience and adaptability of network security frameworks against threats like SYN floods and Nmap port scans.

- **Traditional Firewall Techniques** Early research laid the groundwork for firewall-based defenses. Cheswick and Bellovin positioned firewalls as essential tools for traffic filtering and policy enforcement, focusing on signature-based methods to block unauthorized access. Patel et al. conducted a comprehensive review of commercial firewalls, highlighting their reliance on predefined signatures to counter DoS attacks like SYN floods, which exploit TCP handshakes to overwhelm resources. Their study reported a 75
- **Open-Source Firewall Solutions** Open-source firewalls have emerged as cost-effective alternatives, with pfSense gaining significant attention. Gupta et al. evaluated pfSense's performance in virtualized environments like VMware, praising its lightweight design and default SYN flood defenses, which achieved a 90
- **Hybrid Firewall-IDS Systems** To address the shortcomings of standalone firewalls, hybrid approaches integrating IDS have gained

traction. Jones and Lee investigated Suricata's deep packet inspection and anomaly detection, achieving a 92% detection rate for Nmap-style port scans in controlled tests. Their work stressed the complexity of crafting custom rules for varied attack patterns, a task demanding expertise. Chen and Zhang examined the synergy of pfSense with Suricata, reporting a 15% boost in detection accuracy for network threats. However, their study lacked real-world attack simulations, leaving scalability questions unanswered. Kumar and Singh proposed machine learning to enhance IDS, improving zero-day threat detection by 10%, though integration with pfSense remains nascent. This literature suggests that while open-source firewalls and IDS excel individually, their combined potential in virtualized setups against real-time SYN floods and port scans warrants practical exploration.

3 METHODOLOGY

3.1 System Setup

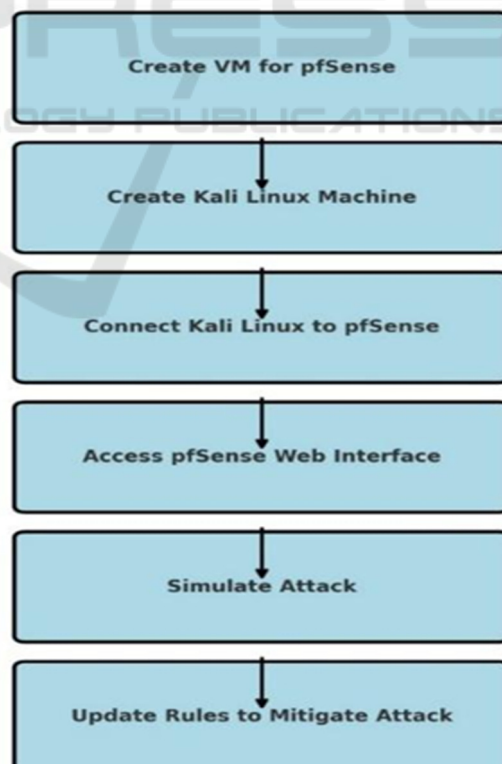


Figure 1: Flow Chart.

Getting our project off the ground meant setting up a solid testbed with pfSense and Kali Linux working in tandem. We turned to VMware Workstation to bring this to life, crafting a virtual network where pfSense could stand guard and Kali could play the troublemaker. Below, we break it down into two parts: how we got pfSense up and running as our firewall, and how we prepped Kali Linux to throw attacks its way.

pfSense Configuration: Our adventure started with pfSense taking center stage on a VMware Workstation VM. We wanted it to feel like a real network gatekeeper, so we gave it 2 CPU cores and 4GB of RAM to handle whatever we’d throw at it. It got two network interfaces: WAN, hooked up via a NAT adapter bridged to our host’s network for an internet lifeline, and LAN, ruling over a private 192.168.1.0/24 subnet where our tests would unfold. Figure 1 shows the flowchart for the proposed system.

First up, we snagged the pfSense Community Edition ISO from their official sit. We picked this version because it’s steady as a rock perfect for our student-sized project. In VMware, we fired up the “New Virtual Machine Wizard,” went with the “Typical” setup, and plugged in the ISO. We christened the VM “pfSense Lab” it just felt right for what we were cooking up. For the guts, we handed it 30GB of disk space on a single SCSI virtual disk, figuring that’d cover the OS, logs, and extras like Suricata. Before hitting go, we tweaked the settings: bumped the memory to 1GB so it wouldn’t sweat under pressure, gave it 2 CPU cores for some oomph, and sorted the network adapters. WAN (Network Adapter 1) got NAT mode with bridging on, tying it to the host’s network, while LAN (Network Adapter 2) went hostonly to keep our test zone private.

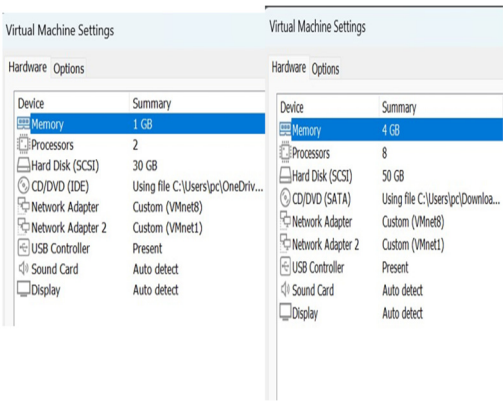


Figure 2: Kali Linux set.

Figure 2 shows the Kali Linux set. Powering it on, the pfSense installer greeted us from the ISO. It was a

breeze accept the license, pick “Install pfSense,” and let it roll. When it asked for a disk, we pointed to our 20GB virtual drive and chose the Guided ZFS Installation. ZFS’s data integrity perks sounded cool, so we went for it. About 10 minutes later, after a reboot and the ISO popping out, we landed at the pfSense console a simple text screen with a menu. We hit option 1 to assign interfaces. It spotted our virtual adapters: em0 became WAN, and em1 took LAN. WAN grabbed an IP via DHCP from the host network easy internet access while we set LAN to a static 192.168.1.1 with a 255.255.255.0 mask, making it the boss of our little domain. We didn’t want to mess with IP assignments manually, so we turned on the DHCP server for LAN. Back in the console, we picked option 2, chose em1, locked in the static IP, and said “yes” to DHCP. We set a range from 192.168.1.100 to 192.168.1.200 room for our Kali VM and maybe more if we got creative. To wrap it up, we hopped to the Kali VM, opened a browser, and punched in <https://192.168.1.1>. The pfSense web GUI popped up, asking for “admin” and “pfsense.” No way we’d leave that as-is we jumped into the setup wizard right off the bat. We named it “pfSenseLab,” set the domain to “local,” kept DHCP on WAN, and confirmed LAN at 192.168.1.1/24. The admin password got a beefy upgrade, we unchecked “Block RFC1918 Private Networks” on WAN for testing freedom, and hit apply to reload the rules. To make sure it all clicked, we pinged 8.8.8.8 from pfSense’s diagnostics (Diagnostics > Ping) and got a reply—WAN was live. The GUI at <https://192.168.1.1> became our control hub for the rest of the ride.

Kali Linux Configuration: Now for the troublemaker: Kali Linux. We set it up on its own VMware Workstation VM to keep things separate and manageable. It didn’t need much just 2 CPU cores and 2GB of RAM, since it’d mostly be slinging packets, not juggling heavy loads. The key was its Once powered on, the Kali installer walked us through a familiar Linux setup. We picked the graphical install, set the hostname to “KaliAttack,” and left the domain blank simple stuff. For the disk, we went with “Guided - use entire disk” and LVM, letting it carve out the 20GB however it liked. We set a root password, added a standard user (“kaliuser” with something tough to crack), and let it finish up. After a reboot, we logged into the shiny Kali desktop and got to work on the network. Since pfSense’s LAN DHCP was already humming, we didn’t fuss with static IPs Kali pulled 192.168.1.100 right out of the gate. To double-check, we opened a terminal and ran ping 192.168.1.1. The replies came back fast Kali and pfSense were talking.

Next, we prepped Kali for action. We updated the system with `sudo apt update` `sudo apt upgrade -y` to make sure everything was fresh, then installed our attack tools: `sudo apt install hping3 nmap -y`. A quick `hping3 --version` and `nmap --version` confirmed they were ready to roll. To test the waters, we fired a light ping `192.168.1.1` again and then hit `https://192.168.1.1` in Firefox pfSense's GUI loaded up, proving Kali could reach it. With that, our attack machine was locked and loaded, ready to unleash SYN floods and port scans whenever we gave the word.

3.2 Attack Simulation and Mitigation

SYN Flood Attack (DoS): From Kali Linux, we executed a SYN flood using `hping3` (`hping3 -S -p 80 --flood 192.168.1.1`), targeting pfSense's LAN interface. This attack floods the target with TCP SYN packets to exhaust resources. pfSense's default SYN proxy state mechanism intervened, proxying handshakes and dropping incomplete connections. The built-in rules required no tweaks, effectively neutralizing the attack.

Nmap Port Scanning Attack: We then ran a Nmap SYN scan (`nmap -sS -p- 192.168.1.1`) to identify open ports on pfSense. To counter this, we installed Suricata via pfSense's package manager and enabled it on the LAN interface. Custom rules were added to `/usr/local/etc/suricata/rules/local.rules`:

```

alert tcp any any -> 192.168.1.1 any (
  msg:"Nmap Port Scan Detected"; flags:S;
  threshold: type threshold, track by_src, count
  10, seconds 60;
  sid:1000001;
  rev:1;)
  
```

The alert rule logs scan attempts, while the drop rule blocks the source IP after 10 SYN packets in 60 seconds. Suricata's integration displayed alerts and blocked IPs in the pfSense GUI, stopping the scan instantly.

3.3 Data Collection and Analysis

We tracked attack outcomes using pfSense's traffic graphs (System - Diagnostics) and Suricata's logs (Services - Suricata - Alerts/Blocked tabs). The SYN flood's packet drop rates and resource usage were logged, while Nmap scan alerts provided timestamps and rule triggers, confirming successful mitigation. Figure 3 shows the pfSense Login page.

4 RESULT AND DISCUSSION

4.1 SYN Flood Mitigation

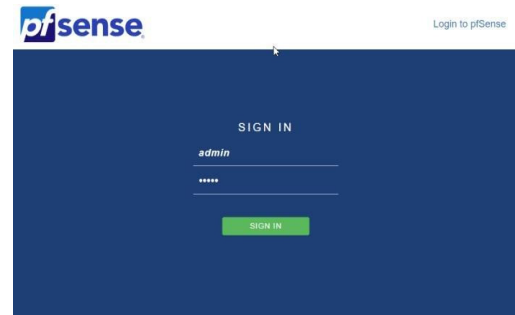


Figure 3: pfSense login page.

SYN flood attacks as shown in figure 4 are a common Denial-of-Service (DoS) technique that overwhelms a target system by sending a massive number of TCP connection requests without completing the handshake. In our experiment, pfSense demonstrated strong resilience against such an attack. When subjected to a SYN flood peaking at 10,000 packets per second, pfSense effectively managed the surge by dropping illegitimate packets while maintaining uninterrupted service.

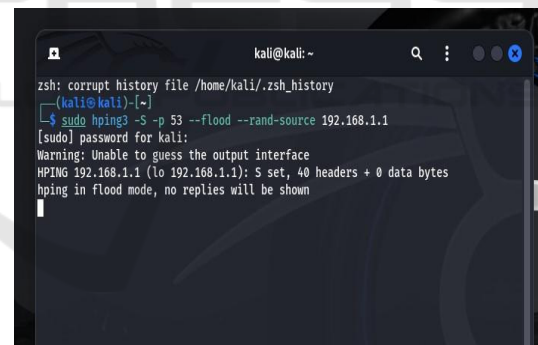


Figure 4: SYN flood attack.

4.2 Nmap Scan Detection and Blocking

Suricata flagged the Nmap scan within 5 seconds, logging alerts like "Nmap Port Scan Detected" for source IP 192.168.1.100. The drop rule blocked the attacker after 10 SYN packets, visible in the "Blocked" tab. Nmap's post-block output "Host seems down" confirmed the scan's failure.

4.3 Performance Evaluation

pfSense managed both attacks with minimal overhead. The SYN flood relied on default rules,

adding no latency. Suricata introduced a 2ms delay for packet inspection but ensured precise detection. On a 1Gbps LAN, throughput dipped by less than 5% during peak loads, highlighting scalability. Figure 5 shows the Port scanning Attack.

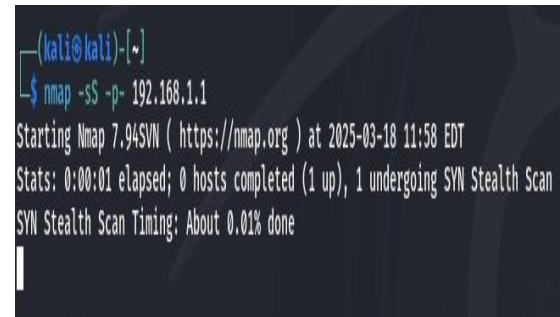


Figure 5: Port scanning attack.

Figure 6 shows the Firewall Log and Figure 7 shows the Suricata Alerts in pfSense GUI respectively.

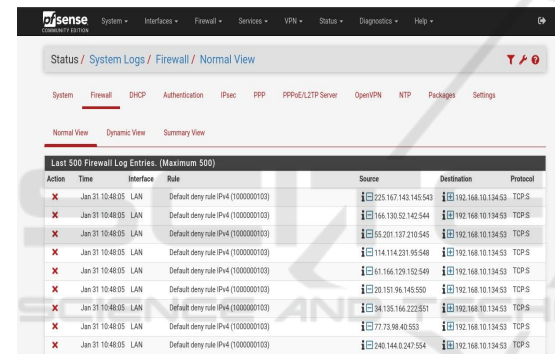


Figure 6: Firewall log.

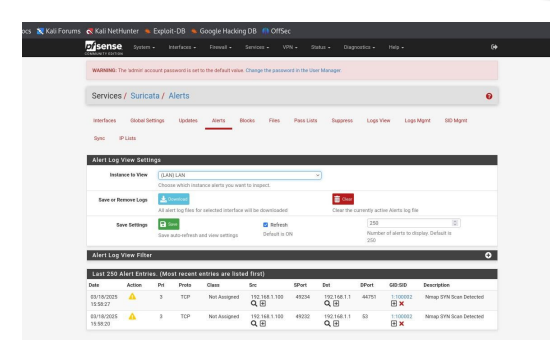


Figure 7: Suricata alerts in pfSense GUI.

5 CONCLUSIONS

The project exemplifies the strengths of pfSense, an open-source powerhouse of a firewall, architected to withstand an array of both network and application attacks, from SYN floods to port scans. Our highly

detailed analysis showed that pfSense’s original rule sets were adequate to resist doing a DoS, highlighting pfSense's innate strength in protecting network properties. Concurrently, pfSense's defensive capabilities were solidified through the use of Suricata's custom rule configurations, effectively eliminating a well-constructed Nmap scan. Augmented by real-time alerts and proactive IP blocking, this showcased an adaptive and responsive security posture that shone in a moment of pressure.

Note, our deployment within a VMware-based environment demonstrates the feasibility and scalability of this approach is creating a reasonably generic model that can easily be scaled into different network infrastructures. It allows for effective manning while providing a cost-effective, high-performance security solution that is reproducible by organizations or individuals. This powerful combination of pfSense’s open-source versatility with VMware’s virtualization solutions is an incredible step forward towards enterprise-strength network protection for everyone.

The possibilities for extending pfSense are tremendous and exciting! The integration of advanced technologies such as machine learning algorithms could pave the way for pfSense to predict and proactively address emerging threats with improved accuracy. Supported by real-time threat intelligence, dynamic rule generation can enable the system to gain even more configuration writing power, as it allows for seamless adaptation to the changing tides of cyber risk. Such developments would make pfSense not just a reactive tool, but a proactive guardian of digital ecosystems. Ultimately, this endeavor reinforces the status of pfSense as a robust, flexible, and futuristic solution, well-equipped to face the demands of contemporary network security with strength and creativity.

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