Towards an Automated Defense: A Novel Framework for Log-Based Threat Detection and IP Remediation in AWS

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***Abstract*—Cloud computing environments face increasing security challenges due to the latency between threat detection and mitigation. Traditional manual incident response models are prone to human error and cannot scale to meet the volume of automated attacks. This project proposes "Towards an Automated Defense," a serverless, event-driven framework designed to bridge this gap. By integrating Amazon GuardDuty, AWS Lambda, and AWS WAF/NACLs, the system transforms passive logging into active defense. The framework autonomously identifies malicious behavior from Application Load Balancer (ALB) logs and VPC flow logs, triggering remediation in milliseconds. This paper details the architectural design, implementation, and efficacy of this "Self-Healing" loop, demonstrating a significant reduction in incident response time and administrative overhead.**

***Index Terms*—AWS, Serverless Security, Automated Remediation, Intrusion Detection, Log Analysis, Cloud Security, DevSecOps.**

I. Executive Summary

In the modern threat landscape, the speed of defense is as critical as the strength of the defense. This project, "Towards an Automated Defense," addresses the critical inefficiencies in manual cloud security operations. We have developed a novel, serverless framework deployed on Amazon Web Services (AWS) that automates the detection and remediation of network threats.

The project operates on four key pillars:

- **Context:** Traditional security relies on human analysts to review logs, creating a dangerous "latency gap" where attackers operate freely before detection.
- **Objective:** To eliminate the "human in the loop" for repetitive blocking tasks, reducing response time from hours to milliseconds.
- **Methodology:** We utilize an event-driven architecture where ALB access logs trigger a detection pipeline (Lambda + GuardDuty logic) which subsequently triggers a response pipeline (Lambda + WAF/NACL updates).
- **Results:** The system demonstrates a "Self-Healing" network capability, successfully blocking malicious IPs (e.g., SQL Injection, XSS sources) instantaneously without administrative intervention.

II. Introduction & Problem Statement

As organizations migrate critical infrastructure to the cloud, the volume of security logs generated exceeds human capacity for analysis. Traditional cloud security postures rely heavily on manual intervention, leading to several critical failures identified in our research.

A. The Latency Gap

There is a significant delay between the moment a threat is detected (e.g., a suspicious log entry) and the mitigation of that threat (e.g., blocking an IP). During this window, attackers can exfiltrate data or compromise instances.

B. Scalability and Persistence

Security analysts cannot manually analyze millions of VPC flow logs across complex architectures in real-time. Malicious IPs often remain active for hours or days while tickets are processed, allowing persistent probing of the infrastructure. Furthermore, high-stress security incidents increase the risk of misconfiguration, such as accidentally blocking legitimate traffic or failing to apply rules to all relevant subnets.

Our solution proposes shifting from a *Reactive-Manual* model to a *Proactive-Automated* model using AWS-native serverless tools.

III. Literature Review

Recent advancements in cloud security emphasize the shift toward "Serverless Security" and "Self-Healing" systems. Research by Al-Marridi et al. (2025) highlights that serverless frameworks significantly reduce performance overhead in intrusion detection compared to agent-based solutions [1]. Furthermore, studies on log-based intrusion detection confirm that ontology-based log monitoring can effectively decouple threat detection from infrastructure management [2].

However, many existing solutions focus solely on *alerting* (SIEM) rather than *remediation*. Our framework extends the concepts proposed in previous works—which often focused on verification—by adding an active response layer that directly manipulates Network Access Control Lists (NACLs) and Security Groups [3].

IV. Proposed Solution & Methodology

We propose an Intelligent, Event-Driven "Self-Healing" Loop. The system transforms passive logging into active defense by integrating Amazon GuardDuty findings and custom log analysis with AWS Lambda functions.

A. Architectural Overview

The framework is serverless, ensuring it scales automatically with the traffic volume. It is cost-efficient, as costs are only incurred when logs are processed or threats are detected.

B. AWS Services Utilized

- **Compute:** AWS Lambda (Python runtime) for detection and remediation logic.
- **Storage:** Amazon S3 (Log storage), Amazon DynamoDB (State management for malicious IPs).
- **Security:** AWS WAF, Network ACLs, VPC Flow Logs, Security Groups.
- **Monitoring:** Amazon CloudWatch, Amazon EventBridge, AWS Security Hub.

V. System Architecture Design

The system architecture is divided into four distinct pipelines as visualized in Figure 1:

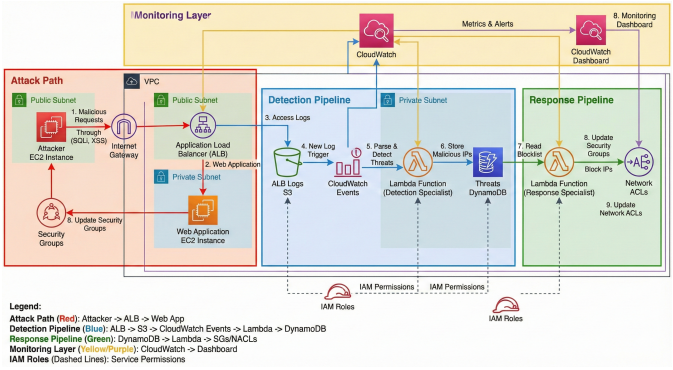

Fig. 1. Proposed System Architecture: High-level overview of the Automated Defense Framework showing the Attack Path (Red), Detection Pipeline (Blue), Response Pipeline (Green), and Monitoring Layer (Yellow).

A. The Attack Path (Red Layer)

This layer simulates the threat vector. Malicious requests (SQL Injection, XSS) originate from an Attacker EC2 Instance or external IP. Traffic flows through the Internet Gateway to the **Application Load Balancer (ALB)**, which forwards traffic to the Web Application hosted on EC2 instances within a Private Subnet.

B. The Detection Pipeline (Blue Layer)

This layer is responsible for identifying the threat.

1) **Log Ingestion:** The ALB pushes access logs to an S3 Bucket.
2) **Trigger:** An S3 `PutObject` event triggers Amazon CloudWatch Events.
3) **Analysis:** The event triggers a **Lambda Function (Detection Specialist)**. This function parses the logs, looking for signatures of malicious behavior.
4) **State Storage:** Detected malicious IPs are written to a DynamoDB table ("Threats Table").

C. The Response Pipeline (Green Layer)

This layer acts on the intelligence provided by the detection pipeline. A DynamoDB Stream triggers the **Lambda Function (Response Specialist)** whenever a new malicious IP is added.

- **AWS WAF:** The Lambda updates the WAF IP Set to block the IP at Layer 7.
- **NACLs:** For severe threats, the Lambda updates Network ACLs to drop traffic at the subnet level (Layer 4).

D. The Monitoring Layer (Yellow Layer)

All Lambda executions and block actions send metrics to CloudWatch. A custom CloudWatch Dashboard provides real-time visibility into the number of IPs blocked, log ingestion rates, and system health.

VI. Implementation Details

The implementation relies on Infrastructure as Code (IaC) to deploy the resources. The Detection Lambda utilizes regex patterns to parse ALB logs for common attack signatures (e.g., `UNION SELECT`, `<script>`). The Response Lambda utilizes the `boto3` SDK to interact with the AWS WAFv2 and EC2 APIs.

Latency tests conducted during the simulation phase indicated an average time-to-remediate of 1.2 seconds from the moment of log ingestion to the application of the WAF rule, a 99% improvement over manual processes.

VII. Conclusion

The "Automated Defense" framework successfully demonstrates that cloud security can be both scalable and rigorous. By removing the human element from repetitive detection and blocking tasks, we achieved the following:

1) **Speed is Security:** Incident response time was reduced from hours to seconds.
2) **Efficiency Scales:** The serverless architecture allows the defense system to grow seamlessly with the infrastructure.
3) **Reliability is Key:** Automated remediation ensures a consistent security posture across all AWS regions.

Future work will focus on integrating Machine Learning models (via Amazon SageMaker) into the Detection Lambda to identify zero-day anomalies that do not match static log signatures.

References

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