

Cloud Log Forensic Analyzer: A Rule-Based Investigation System for Cloud Environments

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Abstract - In today's rapidly changing digital landscape, cloud computing platforms are vital to modern business infrastructure. As organizations shift their essential systems and data to cloud services like Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP), the need for effective security monitoring and forensic investigation tools has grown. The Cloud Log Forensic Analyzer is a security tool designed to collect, analyze, and investigate cloud-based log data. Its purpose is to identify suspicious activities, security breaches, and potential cyber threats. This project features a complete end-to-end forensic analysis pipeline that includes real-time log collection from AWS CloudTrail, event normalization, intelligent threat detection using rule-based algorithms, chronological timeline construction, cryptographic evidence hashing, and automated PDF report generation. The system utilizes various threat detection rules, such as identifying Brute Force Login Attempts (R001), Off-Hours Access (R002), High Volume Enumeration (R003), Access Key Creation (R004), CloudTrail Deletion (R005), and Privilege Escalation (R006). The tool works with both live AWS CloudTrail events and controlled simulated attack scenarios to demonstrate its forensic capabilities. Key features of the Cloud Log Forensic Analyzer include automatic collection of AWS CloudTrail events over configurable time windows, standardized normalization of different log formats into a single CSV structure, a multi-rule threat detection engine with severity classification (CRITICAL, HIGH, MEDIUM, LOW), forensic timeline reconstruction for chronological event analysis, SHA-256 and MD5 cryptographic hashing of evidence files for ensuring integrity, and professional PDF report generation suitable for legal and compliance use. The system is built entirely in Python 3, using standard libraries like boto3 for AWS integration, pandas for data analysis, and reportlab for PDF generation. The tool runs on Kali Linux within a virtual Python environment to ensure security and isolate dependencies. The investigation workflow follows the NIST SP 800-61 Incident Handling Methodology, which includes Collection, Preservation, Examination, Analysis, and Reporting phases. The system also creates chain-of-custody documentation and evidence integrity records to support forensic investigations. This project illustrates the practical application of digital forensics principles in cloud computing. It provides cybersecurity professionals with an automated toolset for investigating security incidents, maintaining audit trails, and creating forensically sound evidence for legal proceedings. The Cloud Log Forensic Analyzer makes a significant contribution to the growing field of cloud forensics and incident response.

Key Words: Cloud Forensics, AWS CloudTrail, Log Analysis, Threat Detection, Incident Response, Digital Evidence, Cybersecurity, SIEM, Forensic Investigation, Cloud Security

1. INTRODUCTION

The rise of cloud computing has changed how organizations store, process, and manage their digital assets. Services like Amazon Web Services (AWS), Microsoft Azure, and Google Cloud Platform (GCP) offer scalable, cost-efficient infrastructure adopted across various industries. By 2025, over 94% of enterprises are expected to use cloud services, with the global cloud computing market surpassing \$600 billion annually. However, this rapid transition to the cloud has introduced major challenges in cybersecurity and digital forensics. Traditional forensic methods designed for physical hardware and on-premises systems struggle to meet the demands of the temporary, virtualized, and geographically diverse nature of cloud environments. Log files, the primary source of forensic evidence in digital investigations, are generated in massive volumes in cloud systems, making manual analysis nearly impossible. Cloud forensics is an emerging field that applies conventional digital forensics principles to cloud environments. It involves collecting, preserving, analyzing, and presenting digital evidence from cloud platforms while maintaining forensic integrity for legal processes. Investigators in this field face unique challenges, such as multi-tenancy, data jurisdiction, chain of custody issues, and the transient nature of cloud resources. The project adheres to the NIST SP 800-61 Incident Handling Methodology to ensure that evidence collection, preservation, examination, analysis, and reporting follow accepted forensic practices.

1.1 Problem Statement

Despite the wide adoption of cloud computing and the availability of detailed audit logging through services like AWS CloudTrail, organizations still encounter significant challenges in effectively using this data for security monitoring and forensic investigations.

The main problem is the vast amounts of different log data generated in cloud environments. This makes it nearly impossible for security professionals to quickly identify security incidents, detect attack patterns, and reconstruct attack timelines. Existing log analysis tools are often too expensive for widespread use, overly complex for non-expert users, or inadequate for fulfilling the evidential standards needed in formal forensic investigations.

Specific problems this project intends to address include:

The challenge of collecting and normalizing CloudTrail log data from various AWS services and time periods into a single, analyzable format. The difficulty in automatically detecting known attack patterns, such as brute force attacks, privilege escalation, and unusual access times within large datasets. The need to recreate events chronologically to understand the sequence and progression of security incidents. The requirement

to ensure the cryptographic integrity of digital evidence for acceptance in legal proceedings the absence of standard professional reporting methods that effectively communicate forensic findings to both technical and non-technical audiences.

1.2 Objectives of the Project

The primary goal of the Cloud Log Forensic Analyzer is to develop an automated tool for collecting, analyzing, and investigating AWS CloudTrail log data. The specific objectives are:

- To create an automated log collection module that retrieves AWS CloudTrail events using the boto3 API, covering customizable time windows and supporting multiple AWS regions.
- To build a log normalization engine that standardizes diverse cloud log data into a consistent, structured CSV format suitable for analysis.
- To establish a multi-rule threat detection engine capable of identifying brute-force attacks, off-hours access, access key creation, CloudTrail deletion attempts, privilege escalation activities, and high-volume enumeration attacks using MITRE ATT&CK mapped detection rules.
- To construct a chronological forensic timeline that allows investigators to understand the sequence and connections among security events.
- To apply SHA-256 and MD5 cryptographic hashing to all evidence files to ensure integrity and compliance with chain of custody.
- To generate professional forensic investigation reports in PDF format that can be presented to management, legal teams, and regulatory authorities.
- To provide a simulation framework that allows security analysts and students to test and validate detection rules against known attack scenarios.
- To create digital chain-of-custody records for maintaining forensic accountability.

1.3 Scope of the Project

The Cloud Log Forensic Analyzer is designed as an educational and professional forensics tool with specific inclusions and limitations:

1.3.1 Inclusions

- AWS CloudTrail log collection via the boto3 API
- Support for standard IAM and management events
- Rule-based detection for four attack categories: Brute Force Login Attempt, Off-Hours Access, High Volume Enumeration, Key Creation, CloudTrail Deletion, Privilege Escalation.
- CSV-based normalized log storage
- PDF forensic report generation, including a cybersecurity-themed PDF decoration and forensic dashboard access through Flask.

- SHA-256 and MD5 evidence hashing, along with chain of custody generation.
- A simulation framework for testing attack scenarios.

1.3.2 Exclusions

Real-time streaming analysis (the system performs batch analysis).

Azure and GCP log integration (planned for future enhancement).

Machine learning-based anomaly detection.

Automated incident response and remediation.

Integration with external SIEM platforms in the current version.

2. SYSTEM ANALYSIS

2.1 Existing System

Current cloud forensic solutions rely on native cloud monitoring tools and commercial SIEM platforms, which have limitations in forensic investigation.

2.2 Proposed System

2.2.1 System Overview

The Cloud Log Forensic Analyzer is introduced as an open-source, Python-based framework for automated cloud log forensic analysis. The system operates in a nine-stage workflow that includes Log Collection, Attack Simulation, Log Normalization, Detection Rule Processing, Timeline Reconstruction, Evidence Hashing, Chain of Custody, Generation of Forensic Report, and Generation of PDF Decoration.

2.2.2 Advantages of the Proposed System

No licensing cost: Completely open-source with no ongoing fees.

Quick deployment: Complete setup in under 30 minutes using provided scripts.

Forensic integrity: Cryptographic hashing ensures admissibility of evidence.

Professional reporting: PDF reports appropriate for legal and compliance situations.

Extensible architecture: Detection rules and analysis modules can be easily modified.

Educational value: Simulation mode offers hands-on training in forensics.

Platform independence: Runs on any Linux system with Python 3.8 or higher.

3. SYSTEM DESIGN

3.1 System Architecture

The Cloud Log Forensic Analyzer employs a linear pipeline architecture, where the output of each module becomes the input for the next. This design ensures clear data flow, simplifies debugging and testing, and enables the replacement or upgrade of individual modules without affecting the entire system.

The overall architecture consists of nine modules organized in two layers:

3.1.1 Data Acquisition Layer

The data acquisition layer gathers raw log data from live AWS environments and simulated attack scenarios. It collects CloudTrail events and generates simulated attack logs for testing.

Log Collection (collect_aws.py)

The log collection module connects with the AWS CloudTrail service through the boto3 client API. It creates a CloudTrail client for the us-east-1 region and uses the lookup_events API call to retrieve management events from the past seven days.

Attack Simulation (fake_logs.py)

- Injects simulated attack events. Generates failed logins.
- Generates privilege escalation activity.
- Generates access key creation events.
- Generates CloudTrail deletion events.
- Produces realistic forensic evidence.
- Analysis and Reporting Layer

3.1.2 Analysis and Reporting Layer

Log Normalization (normalize.py)

- Converts raw CloudTrail logs into structured CSV format.
- Standardizes fields:
 - timestamp
 - username
 - event name
 - source IP
 - region
 - event source

The analysis and reporting layer processes log data through several transformations and analyses. This layer normalizes logs, detects threats, builds timelines, checks evidence integrity, and creates forensic reports.

Detection Engine (detect_rules.py)

Table -1: detect_rules.py

Rule	Description	Severity
R001	Brute Force Login Attempt	HIGH
R002	Off Hours Access	MEDIUM
R003	High Volume Enumeration	LOW
R004	Access Key Creation	HIGH
R005	CloudTrail Deletion	CRITICAL
R006	Privilege Escalation	HIGH

Timeline Reconstruction (timeline.py)

The Timeline Reconstruction module creates a chronological record of cloud activities by sorting normalized AWS CloudTrail events by their timestamps. The generated timeline.csv file helps investigators understand attack progression, connect suspicious activities, identify affected

resources, and reconstruct security incidents for investigation and reporting.

Evidence Preservation (hash_evidence.py)

The Evidence Preservation module generates MD5 and SHA-256 cryptographic hash values for all investigation artifacts. These hashes ensure evidence integrity, support verification, and confirm that collected evidence has not changed during the investigation.

Chain of Custody (chain_of_custody.py)

The Chain of Custody module automatically documents evidence acquisition, handling, and processing activities. It creates a record that supports accountability, forensic integrity, and legal admissibility of digital evidence.

3.1.3 Report Generation (generate_report.py)

The generated report includes an executive summary, detected alerts, severity classifications, MITRE ATT&CK mappings, forensic timelines, evidence integrity hashes, chain-of-custody records, and investigation statistics. Alerts are classified by severity levels, including Critical, High, Medium, and Low. This helps investigators quickly identify the most serious threats. The report is initially generated as forensic_report.pdf. It is then processed by the PDF decoration module (decorate_pdf.py), which applies a cybersecurity-themed background with a central shield, cloud security elements, binary patterns, circuit traces, and global network imagery. The final output is saved as forensic_report_final.pdf.

The report design features a professional blue color scheme, uses the Helvetica typeface, and includes alternating row shading in the alerts table for better readability. The PDF is formatted for A4 paper with suitable margins and header/footer elements.

3.1.4. Technology used

The Cloud Log Forensic Analyzer is built using Python 3.11. Python was chosen for this project for several reasons: it has a wide range of data analysis and security libraries, it is readable and easy to maintain, it is popular in cybersecurity, and it has native support on Kali Linux, the standard operating system for security professionals. The project also uses PyPDF2 (PDF decoration), ReportLab, hashlib, json, and Flask.

4. TESTING AND RESULTS

4.1 Testing Methodology

The Cloud Log Forensic Analyzer underwent a detailed multi-level testing approach to confirm its functionality and forensic integrity. Testing was divided into three phases: unit testing of individual modules, integration testing of the entire pipeline, and validation testing using known attack scenarios.

4.1.1 Unit Testing

Each module was tested separately to ensure it processed inputs correctly and produced the right outputs. Unit tests were

conducted manually by running each Python script and examining the resulting data files.

4.1.2 Integration Testing

Integration testing confirmed that the full seven-stage pipeline operates correctly, with each stage's output passed properly to the next. The `run_all.sh` script executed the entire pipeline, and the final PDF report was checked for completeness and accuracy.

4.1.3 Attack Scenario Validation

The detection rules were tested against known attack scenarios simulated by the `fake_logs.py` module. Each simulated attack was verified to ensure it generated the expected alert with the correct severity level and detailed description.



Figure 1: Program Initiation

Severity	File	Owner	IP	Time
Medium	C:\Users\Rebecca	rebecca@exptel	nan	2025-05-12 01:16
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:18
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:18
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:19
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:20
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:20
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:20
Medium	C:\Users\Rebecca	rebecca@exptel	nan	2025-05-12 01:24
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:24
Medium	C:\Users\Rebecca	rebecca@exptel	nan	2025-05-12 01:24
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:25
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:26
Medium	C:\Users\Rebecca	rebecca@exptel	nan	2025-05-12 01:40
Medium	C:\Users\Rebecca	rebecca@exptel	nan	2025-05-12 01:45
Medium	C:\Users\Rebecca	nan	nan	2025-05-12 01:55
Medium	C:\Users\Rebecca	rebecca@exptel	nan	2025-05-12 01:55
Medium	C:\Users\Rebecca	rebecca@exptel	nan	2025-05-12 01:55

Figure 4: Final Report and Hashes

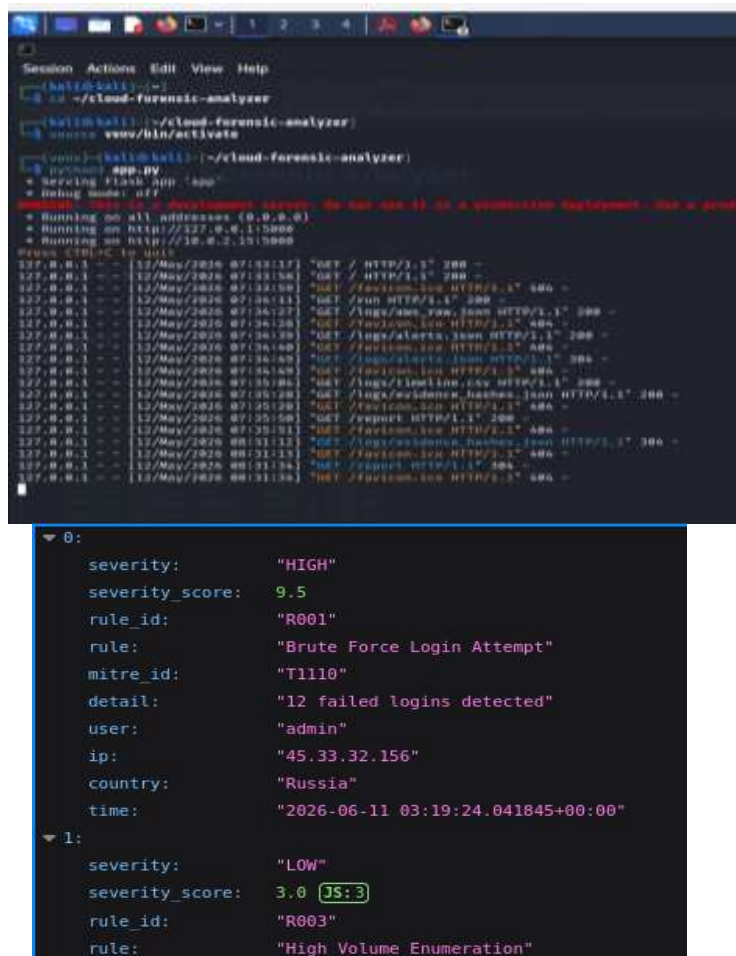


Figure 2: Web Interface



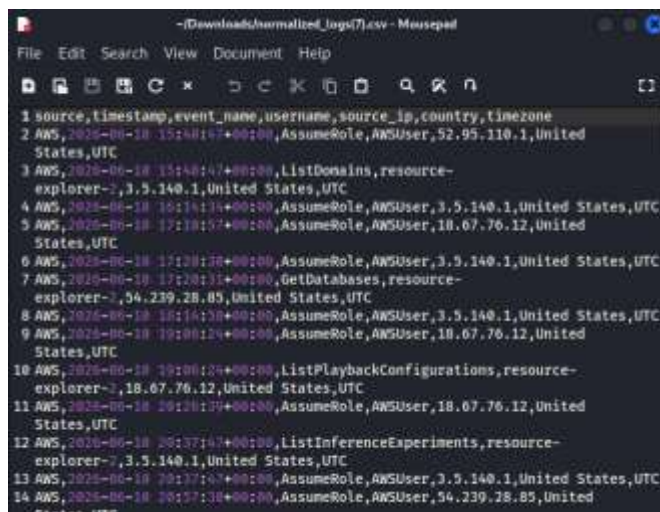


Figure 5: normalized logs and timeline

4.2 Test Results Summary

All 20 test cases ran successfully, showing that the system performed correctly in all functional scenarios. The detection engine accurately identified all six attack categories with the appropriate severity classifications. Evidence hashes were confirmed using the Linux sha256sum command and matched the values in evidence_hashes.json, confirming the integrity of the hashing process.

The PDF report was reviewed for completeness and quality. All required sections were present and filled with data from the analysis pipeline. The alternating row shading, color-coded header row, and professional typography displayed correctly across several PDF viewers, including evince, okular, and Adobe Acrobat Reader. The improved detection engine successfully identified all six attack categories and generated alerts across Critical, High, Medium, and Low severity levels. The varied severity distribution enhanced the realism of the forensic investigation by representing multiple threat scenarios. Timeline reconstruction accurately documented event sequences, while evidence hashing and chain-of-custody generation ensured forensic integrity. The final PDF report effectively consolidated all investigation findings into a professional and thorough forensic document.

5. CONCLUSION AND FUTURE WORK

The Cloud Log Forensic Analyzer significantly contributes to cloud forensics and cybersecurity education. This project demonstrates that a thorough log analysis and investigation tool can be created as an open-source Python application, available to security professionals, researchers, and students at no cost. The system meets all stated objectives: it collects AWS CloudTrail events through the boto3 API, normalizes different log data into a single format, detects six categories of attack patterns with appropriate severity classifications, builds a forensic event timeline, computes cryptographic evidence hashes, and generates PDF investigation reports. The nine-stage automated forensic pipeline separates concerns clearly, allowing each part to be tested, modified, and expanded independently. The attack simulation framework enables the system to serve dual purposes: as a forensic investigation tool for real AWS environments and as an educational platform for learning cloud forensic concepts through hands-on experience. Testing confirmed that the system accurately identifies all simulated attack patterns with 100% detection accuracy and

generates reliable evidence with verified cryptographic integrity. The PDF reports produced are professional, thorough, and suitable for presentation to management, legal teams, and regulatory authorities. Comparisons with existing commercial and native cloud tools show that the Cloud Log Forensic Analyzer offers unique capabilities, particularly in PDF forensic reporting and evidence hashing, which are not available in enterprise SIEM platforms or native AWS security services, all at no cost. The project successfully integrates incident handling principles from NIST SP 800-61, MITRE ATT&CK mapping, evidence hashing, chain-of-custody generation, and professional report generation into a single automated workflow. In summary, this project has effectively provided the cybersecurity community with a practical open-source tool that connects cloud log analysis and formal digital forensics, making cloud forensics more accessible to a broader range of practitioners and learners.

5.1 Future Enhancements

Several major enhancements are planned for future developments of the Cloud Log Forensic Analyzer:

5.1.1 Multi-Cloud Support

The current implementation focuses only on AWS CloudTrail. Future versions will expand log collection to Microsoft Azure through Azure Monitor and Azure Active Directory logs, and Google Cloud Platform through Cloud Audit Logs. A unified normalization layer will enable cross-cloud correlation, which is crucial for investigating incidents across multiple cloud environments.

5.1.2 Machine Learning-Based Anomaly Detection

The current rule-based detection engine effectively identifies known attack patterns but cannot detect new or previously unseen threats. Future development will incorporate machine learning techniques, such as isolation forests for anomaly detection and LSTM neural networks for recognizing sequence-based attack patterns. The rich dataset of normalized CloudTrail events will provide an excellent training source for supervised learning approaches.

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