Autonomous and Secure Cloud Infrastructures using AI: A Unified Framework for ML-Driven Auto-Healing and DevSecOps Threat Detection

Nitanshu Tak
B.Tech CSE (Cloud & Virtualization)
UPES, Dehradun
nitanshutak070105@gmail.com

Daksh Mehrotra
B.Tech CSE (Cloud & Virtualization)
UPES, Dehradun
mehrotradaksh2005@gmail.com

Saumil Mishra
B.Tech CSE (Cloud & Virtualization)
UPES, Dehradun
Saumil2214@gmail.com

***Abstract*—Cloud environments demand high availability and strong security simultaneously. This represents a high-availability and high-security cloud environment. This paper proposes a unified framework that combines ML-driven auto-healing and DevSecOps-integrated threat detection techniques to generate autonomous self-managing cloud infrastructures. Eventually, the framework aims at prediction and identification of failures and threats and triggering remediation (auto-healing) with minimal human intervention, conversing on service continuity. We describe the problem motivation, literature context, proposed architecture, and the validation plan.**

***Index Terms*—autonomous cloud, auto-healing, anomaly detection, DevSecOps, ML-driven security, cloud resilience**

I. Introduction

Cloud computing powers modern digital services, yet cloud systems are increasingly complex and exposed to sophisticated attacks. Outages and breaches produce severe financial and reputational damage; therefore, there is an urgent need for systems that not only detect anomalies and threats but also react autonomously. This work proposes integrating ML-driven predictive models with DevSecOps pipelines to create a unified, proactive platform for resilience and security.

II. Literature Survey

Recent work on anomaly detection and cloud resilience demonstrates the promise of ML for spotting abnormal patterns in metrics such as CPU usage, This opening paragraph introduces the opportunities presented by ML to identify abnormal patterns in metrics, anomalies in CPU usage, network flow, and authentication events [1]. Other approaches seek to improve the traceability and deployment-time security by mixing immutable logging, say, blockchain-based logs and continuous security integration [2]. AI-based auto-scaling and reinforcement learning-based auto-scaling approaches showed improved resource optimization and resilience [3], [5]. Nevertheless, a more comprehensive solution that integrates ML auto-healing and DevSecOps threat detection across the entire lifecycle has yet to be looked into in substantial detail. [4].

III. Problem Identified

From the nature of the literature and practical observations, we gather four major gaps:

1) **Reactive posture toward security:** Numerous systems act following an incident rather than predicting and preventing it [1].
2) **Separated operations and security:** Operations and security workflows remain separate in many cases, thus leading to delays and a lack of complete visibility during incidents [4].
3) **Lack of autonomy:** Most of the existing automations cannot respond to unforeseen failures nor assimilate contextual threat intelligence without human intervention [3].
4) **Scalability of Threat Detection:** Detecting new threats at cloud scale with low false positive rates still remains a challenge [1].

IV. Research Objectives

The objectives that are targeted for the research are as follows:

- **O1:** To construct ML models that have the ability to precipitate manual and automatic self-healing upon predicting failure modes of a system.
- **O2:** Embed the ML detections in DevSecOps pipelines to ensure security in real-time for both CI/CD and runtime environments.
- **O3:** With quick detection and mitigation of known and zero-day threats, ensure that cloud security posture is improved.
- **O4:** Validation of the framework would be performed through measurements of downtime reductions, accuracy of detection, latencies in response, and drop in human intervention from these experiments.

V. Proposed Framework

The high-level architecture is shown in Figure 1 (you can insert a diagram). Key components include:

1) **Telemetry Collector:** Collects metrics, logs, traces, and events from cloud services (CloudWatch/Prometheus/ELK).
2) **Feature Engine:** Aggregates and converts telemetry into features for the ML models.
3) **Anomaly & Threat Models:** Supervised/unsupervised models for resource anomalies and classifiers for suspicious behaviors (unauthorized login patterns, for example).
4) **Decision Engine:** Scores incidents on severity and confidence and uses policy rules to decide whether to auto-heal, escalate, or block.
5) **Auto-Healing Orchestrator:** Takes care of remediation workflow (service restart, scale nodes, rollback deployment) infrastructure-as-code (Terraform/CloudFormation) and orchestration (AWS Lambda, SSM, Ansible).
6) **DevSecOps Integration:** The passive detection is put into the CI/CD pipeline to stop vulnerable builds, trigger other static-dynamic scans, and update policies on the fly.
7) **Alerting & Audit:** Uses SNS/email/immutable logs for audit and human-in-the-loop escalation when needed.

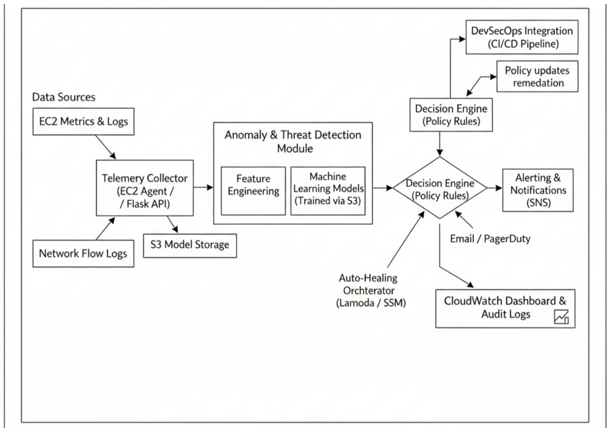
Data Sources
EC2 Metrics & Logs
Telemery Collector (EC2 Agent / / Flask API)
Network Flow Logs
S3 Model Storage
Anomaly & Threat Detection Module
Feature Engineering
Machine Learning Models (Trained via S3)
Decision Engine (Policy Rules)
DevSecOps Integration (CI/CD Pipeline)
Policy updates remedation
Decision Engine (Policy Rules)
Alerting & Notifications (SNS)
Email / PagerDuty
Auto-Healing Orchterator (Lamoda / SSM)
CloudWatch Dashboard & Audit Logs

Fig. 1. High-level architecture of the unified framework.

VI. Validation Methodology

We propose a two-phase validation:

1) **Simulation and Synthetic Fault Injection:** Inject faults (CPU spike, network partition, credential leaking simulation). Measure detection latency, false positives, and time-to-remediate.
2) **Realistic Testbed:** Deploy on a small cloud environment (e.g., AWS test account/local Kubernetes cluster). Measure downtime and mean time to recovery of baseline (no auto-healing) versus system-on (auto-healing + DevSecOps, MTTR).

The evaluation metrics: precision/recall of detection, false positives, MTTR, number of human interventions saved, and system availability.

VII. Discussion and Limitations

Challenges include model drift, adversarial evasion, and incorrect remediation (unsafe automated actions). Mitigations: retraining of the model, conservative policies for action selection (e.g., staged remediation), and human-in-the-loop verification of actions in high-impact cases.

VIII. Conclusion

We presented an architecture for a combined ML and DevSecOps pipeline toward enabling postmodern autonomous cloud infrastructure. This will, given its validation, reduce downtime and speed incident response while actually improving the overall security stance. The later work involves the prototype implementation, thorough evaluation of the system, and possibly exploring explainable ML avenues for it to gain operator trust.

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