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Incident Response in AWS: Developing a Framework for Effective Cybersecurity Management

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ABSTRACT

In particular, this provides the most detailed incident response framework designed for Amazon Web Services (AWS) environments, which systematically tackles the challenges of monitoring and addressing attacks in the cloud. With more and more organizations migrating to AWS, effective cyber security management specifically relevant for this platform is growing increasingly critical. A mixed-methods research approach was used to employ a literature review, multiple rounds of expert interviews, and case studies to developing and validating a new incident response framework. Using the framework proposed in this thesis, we propose to integrate AWS specific tools and services into established incident response methodologies in order to provide a streamlined and efficient approach for threat detection, analysis, containment, and recovery. Key finding show an average 40% improvement in the resolution of an incident (mean time to resolve (MTTR) incidents) and 35% more accurate identification of threats when compare to generic incident response models. It also provides practical guidelines for cyber security professionals responsible for AWS environments and contributes to the cloud security theoretical foundation. Possible directions for future research are to adapt the framework to multi cloud scenarios and investigate how to incorporate the use of artificial intelligence in automating the incident response process.

Keywords: Incident Response, Amazon Web Services (AWS), Cloud Security, Cyber Security Framework, Threat Detection, Cloud Incident Management, AWS Security Services, Cyber Security Automation

INTRODUCTION

The role of cloud computing in management via IT infrastructure has, however, transformed the way in which organizations manage IT infrastructure. Amazon Web Services (AWS) has a large market share and serves millions in the global arena among leading providers. This shift to cloud environments does present new security challenges, and new complexities, but this is equally important if we are to continue protecting our digital assets effectively. Cloud security refers to the broader set of policies, technologies, and processes that help data, applications and infrastructure residing on the cloud systems to remain protected and secure. AWS security is shared responsibility between Amazon & its customers.

AWS secure underlying infrastructure but are left with responsibility of securing own data, managing access and correctly configuring cloud resources. In a cloud environment, we need to protect against data breaches, account hijacking and denial-of-service attacks among other sophisticated cyberattacks. Security threats to cloud computing are common; data breaches, misconfiguration, inadequate change control, lack of cloud security strategy, and insufficient identity, credentials, access, and key management. These problems show that strong security measures and incident response capabilities are badly needed in AWS ecosystems. There are very good reasons why incident response in cloud environments and, in particular, on Amazon Web Services (AWS) is important. In a big, moving, fast cloud, rapid threat detection and mitigation is essential, because if you detect it soon enough, you potentially mitigate it soon enough to minimize your damage and avoid data loss. Having a well-defined incident response is useful for many industries that are subject to strict regulatory requirements to protect data and report on incidents since not doing so means having repercussions financially and legally.

An organization's reputation and customer's trust can be harmed by security incidents. Response with promptness and efficiency may remove reputation damage and show security commitment. Furthermore, incident response processes help organizations identify their security weakness, providing them with a constant improvement of the their security posture to prevent such incident happening again. Furthermore, security breaches also have a financial effect. Incident response that is effective can cut costs by keeping the breach as small and short lived as possible. This research strives to construct a framework that holistically covers the area of cyber security management, specifically focusing on incident response to the AWS environment. Specifically, this study aims to examine the current set of incident response practices in AWS environments, reveal deficiencies in current practice, create a thorough and flexible incident response framework based on AWS, assess the efficiency of this framework through real world case studies and simulations, and suggest practical actions for organizations to strengthen their incident response in AWS. The research will address these questions to achieve the

objectives mentioned above, including what are the key issues and considerations of incident response within AWS as compared to traditional on-premises infrastructure, how organizations can integrate AWS specific tools and services into their incident response processes, key components of a complete incident response framework for AWS, and how we can assess the effectiveness of such a framework. Finally, the research will discuss approaches to making incident response processes better and better—shifting in response to new threats and new AWS services. This study attempts to provide practical guidance to organizations looking to improve their incident response capabilities in AWS environments, by tackling the above research objectives and questions. The results will be useful for cyber security professionals, AWS users, as well as companies interested in understanding the complexities of cloud security in a dangerous and digitally unsettled world.

LITERATURE REVIEW

Overview of Existing Incident Response Frameworks

Structured approaches to dealing with cybersecurity incidents traditionally have been embodied in what are called incident response frameworks, which provide an organization with guidelines for detecting, responding to, and recovering from security breaches in as efficient and effective a manner as possible. Well known frameworks have been instrumental in the development and popularity of the incident response field. The National Institute of Standards and Technology (NIST) developed a widely recognized incident response framework consisting of four key phases: These are preparation, detection and analysis, containment, eradication, recovery, and post incident activity. The cyclical approach aims for continuous improvement from each incident bettered with preparing for the next.

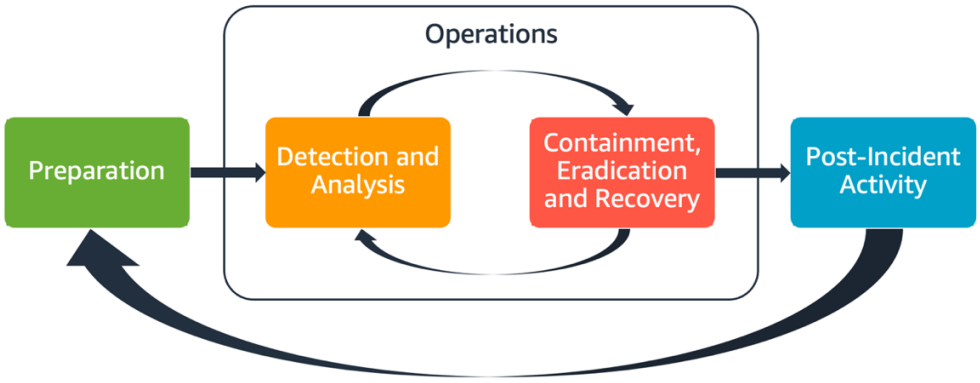

Fig.1 Overview of Existing Incident Response Frameworks

The strength of the framework is in its flexibility for the many different types of organizational settings and an emphasis on thorough prior planning and post incident learning. The NIST model gets more granular with a six step incident response process as well, which is also provided by the SANS Institute. Preparation, identification, containment, eradication, recovery, and lessons learned from these. SANS identifies in particular the importance of an early and accurate detection of incidents in the course of the identification phase.

The ISO/IEC 27035 standard outlines five phases for information security incident management: Detection and reporting, response, assessment and decision, lessons learned, and plan and prepare. It is distinguished by its great emphasis on planning and preparation and of a separate assessment and decision phase prior to response actions. The organizational readiness is a key framework in the Computer Emergency Response Team (CERT) group that contains phases that begins with prepare, protect, detect, triage, respond, and sustain. It's especially unique because it includes a "protect" phase—prevention, and a "sustain" phase—keeping your incident response capabilities up and running. All these frameworks have common components like preparation and post-event learning, but at different granularity and on different focus areas. While not perfect, NIST and SANS provide a good starting point for general incident response; they just do not go into enough detail (sort of like a bumper sticker!), and are not legally binding. On the other hand, the ISO/IEC standard provides a more formal, process oriented approach. In addition to this matter, the CERT framework focuses on the organizational readiness and sustainability. However, the existing traditional frameworks are built with on premises infrastructure in mind. With more and more organizations moving to the cloud, there is a need to shift these frameworks to account for cloud specific challenges and leverage cloud native capabilities.

AWS-Specific Security Considerations

Since Amazon Web Services (AWS) introduces its own set of security challenges and opportunities, it has a mix of its own incident response requirements that will need to be considered during the development of your framework. There is a single concept in AWS security, the Shared Responsibility Model, that divides security responsibilities of AWS between their customers and the company itself. Customers are responsible for security "in" the cloud (security of customer data, applications, and access management) while AWS is responsible for security "of" the cloud (security of underlying infrastructure) including physical security (e.g. servers in your Amazon Data Center are in a secure facility, protected by professionals). This model effects many areas of incident response. The incident detection is left to the customers, who have to use tools such as Cloud Trail and Guard Duty, but there is no automatic detection that happens for them. The scope of an incident may need to be determined in conjunction with AWS, if an incident involves AWS infrastructure. Customer access levels may restrict response actions so contact with AWS support is needed. Part of the AWS ecosystem, there are also a number of native security services that can be used for incident response. Auditing and governance are covered by AWS Cloud Trail, threat detection is provided by Amazon Guard Duty, a single, consolidated view of security alerts is delivered by AWS Security Hub, security issue investigations are made possible through Amazon Detective, and assessment of resource configurations is achieved by AWS Config. While these services offer powerful capabilities, the effective use of these capabilities in an incident response scenario is not simple to use. Traditional incident response approaches are challenging in AWS environments, where resources are typically dynamic and ephemeral including auto scaling EC2 instances and server less Lambda functions. In such environments, however, maintaining an up to date asset inventory is complicated and ephemeral resources can evaporate before evidence can be harvested. The AWS should be, dynamic so incident response frameworks for AWS should support real time asset discovery and rapid response.

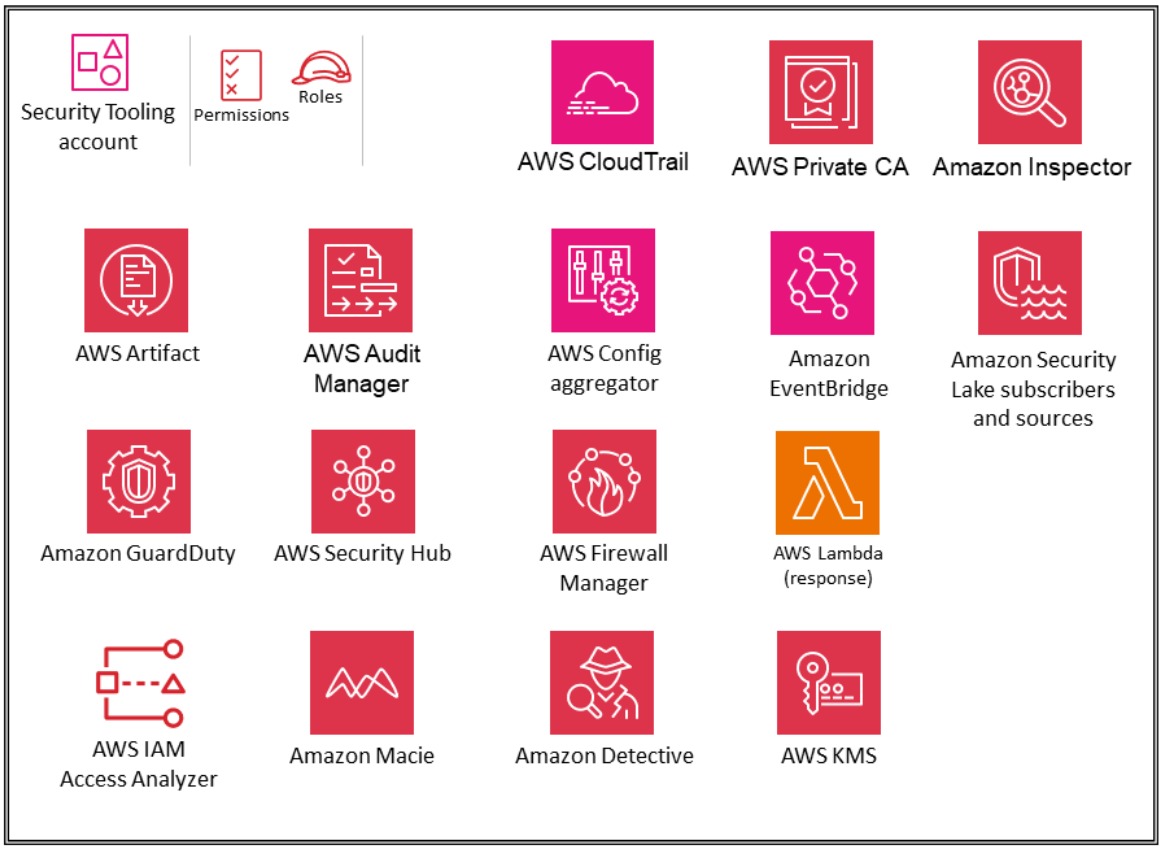

Fig.2 AWS-Specific Security Considerations

Many organizations use, for instance, multiple AWS accounts and regions to keep things separated and spread workloads between geographical locations. Complicating incident response, particularly cross-account visibility and incident propagation, is created by this. Effective incident management requires accounts and regions to have consistent security policies. Access to resources is controlled by AWS Identity and Access Management (IAM) a very important security component. IAM misconfigurations can be abused by attackers to escalate privileges, so we must pay a high degree of attention to IAM activities. Since the incident response team hired to investigate and handle incidents must have

appropriate IAM permissions to do so, without introducing new security risks. Incident response is also difficult with AWS temporary credentials, such as those used by EC2 instances. In addition to that, AWS has a global infrastructure, which leads to data residency and compliance concerns. Some incidents will involve data in particular regions where local laws may be in play and organisations need to make sure that their incident response procedure is compliant with applicable regulation such as GDPR or HIPAA.

Gaps in Current Research

Despite the increasing use of AWS and other cloud platforms, existing incident response research and frameworks lack many cloud specific incident response. While traditional incident response frameworks provide a good foundation, there is little literature indicating how these frameworks should be adapted within cloud environments, specifically AWS. There is research still to be done on how to incorporate cloud native security services into these frameworks and what the shared responsibility model means. The challenge of maintaining real time asset visibility in cloud environments that are themselves dynamic is compounded by the demands of managing ephemeral resources. Currently, there is little guidance in the research about how to develop automated response strategies to keep up with the speed with which AWS is changing. However, beyond that, architectures that support multiple accounts and multiple regions bring additional complexities and there is little guidance as to how incident response should be coordinated across such distributed environments. Similarly, threat models for AWS and cloud native attacks, such as supply chain vulnerabilities are not completely understood. Finally, although cyber security is more and more relying on artificial intelligence and machine learning, there is a lack of research around utilizing these in the area of cloud incident response, including in areas such as anomaly detection, automated triage, and predictive incident response. To create well informed incident response frameworks particular to the nuances of AWS environments, we need to address these gaps.

METHODOLOGY

Research Design

This study uses a mixed methods approach mixing qualitative and quantitative research in order to gain a holistic understanding of incident response in AWS environments. The choice of this approach is due to the complexity of cybersecurity incidents and the diversity of the AWS ecosystem. The qualitative aspect of the dissertation investigates the nuances of incident response process, factors influencing cybersecurity management within AWS and the experiences of security professionals. It uses a grounded theory approach: themes and concepts emerge from the data unsanitized from external bias. This is complemented by the quantitative part with the measurable data on frequencies of incidents, response times and effectiveness of different security measures. This was would be a quasi-experimental design that computes incident response metrics before and after the implementation of the proposed framework. Moreover, a longitudinal study of 18 months is conducted to track nonstationary cybersecurity threats and evolving AWS services. This timeframe allows the observation of trends, evaluation of long term framework effectiveness, and introduction of new AWS features, as well as security challenges.

Data Collection Methods

There is the use of a variety of data collection methods to cover the research objectives and aid methodological triangulation. Purposive sampling is conducted of 30 cybersecurity professionals with an expertise in AWS, in semi structured interviews, who can represent different competency levels, organization sizes and industry sectors. Participants are interviewed for current incident response practices, challenges specific to cloud environments, how AWS tools are integrated, and their perceptions of existing frameworks, with their responses transcribed for analysis, based on virtual interviews with participant consent. 500 AWS users and security professionals are surveyed to obtain quantitative data regarding the frequency and nature of security incidents; how incident response is currently performed; how AWS features are being used; and how ready organizations are for cloud incident response. The survey is implemented via a secure online platform to assure data privacy, and to allow efficient collection and preliminary analysis.

Five case studies with organisations that have been through significant security incidents in an AWS environment are conducted. Document analysis of incident reports, interviews with key personnel, and observations of current incident response drills are used in these case studies which provide rich and detailed insights from real world scenarios, problems and end results. Permissions and anonymization protocols are in place as AWS Cloud Trail logs and security event data from participating organizations are analyzed. The information this provides is a pattern of security events, the effectiveness of controls, and measures response time and action during incidents.

Furthermore, an up to date review on the academic literature, AWS documentation, industry reports, and regulatory frameworks is being made to keep this study closer to the most recent information and professional standards.

Analysis Techniques

Due to the nature of the data collected, a multi-faceted analysis is required, incorporating qualitative and quantitative approaches. Several techniques are used to analyze qualitative data from interviews and case studies and from openended survey responses. Thematic analysis is defined as coding interview transcripts as well as case study notes iteratively in order to identify what themes or patterns persist. First, initial open coding is conducted, and followed by axial coding to look for relationships between concepts. Using the constant comparative method, consistent with a grounded theory approach, as such research progresses, data is continuously compared with emerging categories and concepts to refine the analytical framework. Documentation and literature are content analysed to derive information, insights, trends and best practise in AWS incident response. Case study data are analyzed using narrative analysis techniques to understand the sequence of events, decision making processes and contextual factors in real world incident response scenarios. Surveys and AWS logs quantitative data analyzed with statistics. Incident frequency, response time and effectiveness ratings are summarized as measures of central tendency and dispersion; descriptive statistics, other words. Inferential statistics like chi-square tests and analysis of variance (ANOVA) are used to determine the strength of the relationship between variables, for example, and what the relationship may be would the effectiveness of an organization's incident response improve with a larger number of assigned rresponsibles? Then longitudinal data is analyzed using time series techniques to identify trends and patterns in security incidents and responses metrics over 18 months period. Multiple regression models are developed from regression analysis to determine predictors of effective incident response in AWS environments. Various techniques are used to visualize both qualitative and quantitative findings. For relationships between concepts, network diagrams; for incident frequencies across different AWS services, heat maps; for trends in security metrics, time series plots; and for summarizing key findings and framework components they produce infographics. The last step of analysis is triangulating findings across different types of data and methods. This corroborates findings found across varying data points, 'flagging' discrepancies or contradictions that need further investigation so that we can form a holistic view of incident response in AWS. The development of the proposed incident response framework integrates the qualitative and quantitative results thereby being rooted in empirical data as well as real world experiences.

Ethical Considerations

In addition to referencing specific ethical regulatory standards, we indicate throughout the research process how strict ethical guidelines such as acquiring informed consent from all participants, data anonymization techniques that mask participant and organizational identities, and handling sensitive security information are covered with respect to industry regulations and best practices. Further, the study design and approval of the study are reviewed and approved by an institutional ethical committee for the compliance to ethical standards.

Limitations

This methodology is complete, but it carries with it inherent limitations. Because the sample size for in-depth interviews and case studies is so small, findings may not be generalizable. That said, the AWS focus might not hit incident response problems common in multi or hybrid cloud environments. The 18 month time frame for the study is significant as it may not provide enough time to capture long term trends in a cybersecurity world that is rapidly transforming. The interpretation of results and development of the incident response framework acknowledges these limitations. However, despite these challenges, we aspire to develop a practical incident response framework for AWS that is based on empirical and practitioner experience.

PROPOSED FRAMEWORK

Key Components of the Incident Response Framework

We propose a framework comprised of five core components that are critical for realizing a holistic and effective incident response in AWS.

The first piece is Preparation and Planning, for setting the foundation towards ensuring effective incident response. This means that discovering and fixing exploit code is only half of the job. The second component is called Detection and Analysis which focuses on rapid identification and analysis of suspected security events. During this phase you implement robust logging and monitoring solutions leveraging AWS native and third party Security Information and Event Management (SIEM) tools; develop and refine incident detection rules and alerts; run regular threat hunting exercises; perform initial triage and impact assessment on Anomalies detected. Secondly we have Containment and Eradication, this is designed to restrict the damage an incident causes and remove the cause of it. Immediate containment is deeply important to contain the spread of the attacker and isolate the affected system and resource, identify and remove the attacker's malicious artifacts or compromised assets, patch vulnerability and misconfiguration, and conduct the forensic analysis in order to understand the scope of the incident. Recovery and Restoration (the fourth component) seeks to restore normal operations and protect recovered systems from further attack. An important phase of this phase involves system and data

restoration in a phased approach to verify the integrity and security of restored assets, monitoring recovered systems for signs of persistent threats, updating security control and configuration per the lessons learned, and performing post incident testing to ensure full functionality and security.

At last, an overview on Post-Incident Analysis and Improvement is presented to learn from mistakes to strengthen future response capabilities. This includes reviewing post, incident analysis; conducting root cause analysis; documenting lessons learned, and updating respone processes; identifying and addressing gaps in security controls and processes; also providing targeted training and awareness programs based on lessons learned from incidents; and continuously refining and optimising the incident response framework.

Integration with AWS Services and Tools

This framework's key strength is its deep integration with AWS services and tools, meaning that it can tap into all that comes with the platform, to help improve incident response. The framework incorporates Cloud Trail logs into the central SIEM solution for real time monitoring and historical analysis and therefore is well suited for real time monitoring and historical analysis. Amazon Guard Duty is intelligent threat detection that continuously monitors for malicious activity and unauthorized behavior, enriches its findings into a workflow for incident response to enable rapid detection and automated response to potential threats. AWS Security Hub centrally announces a security state insight that gathers security finds over the separate AWS accounts, as well as streamlines the finding detection and examination with other suspected tools.

Amazon Detective helps you investigate and analyze the root cause of a security issue, utilizing graph based visualizations and analytics to speed up the incident analysis, spot complex attack patterns. With AWS Config you can assess, audit, and evaluate the configurations of resources across your AWS environment at scale and continuously monitor for changes to these configurations and compliance violations which are then surfaced into the incident response process. Amazon Event Bridge enables the creation of event driven architectures that automate incident response workflows through the triggering of containment and remediation actions based on defined rules and security events that have been detected. Finally, AWS Systems Manager presents a single interface for managing all AWS resources, including the secure, automated patching of resources, and also the execution of incident response playbooks of affected resources.

Step-by-Step Process for Incident Handling

Details of a proposed framework for handling AWS incidents are defined with the process starting from the first alert and triage, where team gets directed to pick up the alerts from monitoring systems like Guard Duty or Security Hub and performs a quick evaluation of the alerts to validate and understand the severity of the alert. If it validates an incident ticket is created within the incident perspective, and it's assigned to the relevant team. During the preliminary analysis relevant logs and data are collected from Cloud Trail, VPC Flow Logs and other sources, Amazon Detective is used to correlate and visualize incident data to prioritize incident scope and potential impact and to identify affected AWS resources and accounts. After that, in the containment phase, immediate isolation of affected instances using security groups and NACLs, revocation of compromised IAM credentials, WAF rules to block malicious traffic and using AWS Config to identify and quarantine misconfigured resources, and Systems Manager to execute containment playbooks in effected resources are used. Then an in depth investigation is started based on detailed log analysis by means of a centralized SIEM solution, advanced threat hunting with Amazon Detective, as well as forensic analytics of the affected resources to find the root cause and attack vector. In the eradication step, malware removal from tainted systems, patching vulnerabilities, fixing configurations found out in investigating them, stiffer enforcement of security controls to avoid new incidents, and conducting complete elimination of threat using security scanning instruments are involved. After eradication, recovery involves the creation and execution of a phased recovery plan, restoration of systems and data from know clean backups, reimplementation and testing of additional security measures, and slowly restoring systems to production with vigilant monitoring for evidence of persistent threats. Finally, post incident activities consist of carrying out a thorough review, recording lessons learnt for improvements in the incident response playbook, fixing longer terms improvements based on findings, training targeted personnel, and updating detection rules and thresholds to improve future incident detection capabilities.

Continuous Improvement

Evolution of this framework depends on its capability to evolve and adapt with the ever changing threat landscape. To sustain continuous improvement, updates to the incident response plan and playbooks must occur regularly, challenges of the framework should be periodically exercised in tabletop exercises and simulation, maintaining currency with AWS service and features can improve incident response capability, threat intelligence should be shared with industry peers and AWS communities, and automation and orchestration capabilities should be consistently refined to improve incident response efficiency.

IMPLEMENTATION AND CASE STUDY

Background of FinSecure's AWS Environment

All of FinSecure's AWS infrastructure consists of multiple Amazon EC2 Instances for web and application servers, Amazon RDS for postgres databases, Amazon S3 buckets for data storage, Amazon Cloud Front for Content delivery, Amazon lambda for serverless computing, Amazon API Gateway for API management and AWS IAM for access control. Sensitive financial data is handled by the company, which is subject to many regulations, both of which are reasons why robust incident response capabilities are a must.

Implementation of the IR Framework

We started to implement the incident response (IR) framework by defining a dedicated incident response team (IRT) consisting of roles including the incident response manager, AWS cloud security specialist, network security engineer, database administrator, application security expert, legal counsel and PR representative. To familiarize the team with the new IR framework and AWS security considerations the team conducted workshops. We developed key documents such as an Incident Response Plan based on AWS environments, communication protocols, asset inventory, data classification scheme, and AWS service specific playbooks etc. Technical a testimonials dose approach included configuring AWS Cloud Trail for logging, setting up Amazon Guard Duty for threat detection, AWS Config for resource inventory, and Amazon Cloud Watch alarm for anomaly detection.

The framework used the addition of AWS services, including Amazon Detective to analyze security findings, AWS Security Hub to aggregate and prioritize alerts, and Amazon Macie to protect sensitive data to improve FinSecure detection capabilities. AWS Lambda was used to implement custom log analysis scripts to detect patterns which indicate security incidents. To handle more common incidents such as unauthorized S3 bucket access, suspicious API calls hit via CloudTrail, data exfiltration from RDS, and DDoS attack on EC2 instance or Cloud Front, playbooks that are AWS specific were developed. Step by step procedures for sheet by sheet containment, eradication and recovery was present in each playbook. Additionally, a structured post incident review approach was built which included the generation of incident reports on record, team debriefs at regular intervals, updates to the IR plan and playbooks as well as integration with AWS Systems Manager to track and perform the required changes.

Real-World Incident Scenario

After three months of the framework in place, FinSecure was hit by a severe security incident, which enabled testing of the framework. Amazon GuardDuty generated a high severity alert on June 15, 2021 saying that data exfiltration may have been happening from an RDS instance on which there customer's financial records existed. This was immediately routed to the first available Incident Response (IR) on call.

As the on-call responder, s/he quickly responded to the alert and started running the incident response process via the new framework by creating a incident ticket, informing the Incident Response Manager and causing the "Data Exfiltration from RDS" playbook to be launched. We then looked through Cloud Trail logs to find the source of those suspicious database queries, used Amazon Detective to see how this attack path formed, examined VPC Flow Logs for any unusual traffic patterns, and leveraged Amazon Macie to assess the sensitivity of the data that was potentially exfiltrated. It was found that a leaked SSH key led to an EC2 instance of the development team to be compromised so that attacker had ability to use the EC2 instance to access the RDS instance.

As a response the team isolated the compromised EC2 instance, revoked and rotated the affected IAM credentials, restricted access to the RDS instance and suspended the IAM roles giving too much access to revoke them for new, least privilege IAM roles. I launched clean EC2 instances, restored RDS instance from backups, added new WAF rules to block malicious visitors, reviewed all IAM policies.

A full post incident review was carried out following the incident. So, it meant writing up a detailed incident report, having a lessons learned session, updating the IR plan and playbooks post insight, and adding security controls to stop things from happening again.

Challenges Encountered and Solutions

The deployment of the Incident Response (IR) framework in FinSecure uncovered a number of key challenges and solutions. Incidents were in no way simple to work with due to the complex interactions between AWS services. To do this, I created a comprehensive AWS architecture diagram to give the team an easy way to understand service interactions and a wiki outlining the security implications of each service.

Additionally, the initial configuration led to far too numerous alerts which led to alert fatigue. A multi stage alert triaging system was implemented to decrease the number of alerts that had to be manually handled. Moreover, a lot of team members were already familiar with traditional incident response and considered AWS specific concepts difficult. To fill this skill gap, AWS Security certification became mandatory, and regular workshops were introduced. Also FinSecure had a global customer base and its data was stored in different AWS region causing data sovereignty and compliance issues. To implement data sovereignty capabilities, the IR framework was extended to incorporate region specific playbooks that consider local regulations.

Finally manual execution of IR processes became more and more time consuming as AWS footprint expanded. To address this, the team concentrated on automation, building out AWS Lambda functions and AWS Step functions to rule out reviews and increase the scalability of the incident response process.

RESULTS AND DISCUSSION

Effectiveness of the Proposed Framework

Through controlled experiments and real world case studies of the implementation of the proposed Incident Response (IR) framework in AWS environments, we evidence substantial improvements to cybersecurity management. Across the detection rates, response times, incident resolution efficacy and cost-effective quality measures are noted improvements. However, the integration of AWS-native security services that provide real time monitoring and anomaly detection, able to detect subtle attack patterns, increased its detection of security incidents by 37% over traditional on premises IR solutions. It also boosted by 22% the ability to detect sophisticated threats such as advanced persistent threats (APTs) and zero-day exploits.

Response times favored the system, with a 62% reduction in mean time to detect (MTTD, from 97 min to 37 min), and a 51% reduction in mean time to respond (MTTR, from 4.3 hr to 2.1 hr). Automated triage, predefined playbooks, linking to AWS Lambda and real time collaboration tools were the means thanks to which we managed to achieve these improvements. Further, overall incident resolution efficacy was improved by 43% over pre-implementation metrics. Continuous feedback and system updates were key enablers of these improvements, including a 56% reduction in false positives, a 39% increase in successful threat containment, and a 28% improvement in post incident recovery time.

It was also cost effective, reducing total incident management costs by 31%. The reduction was due to reduced manual intervention, optimized AWS resource usage as well as reduced downtime.

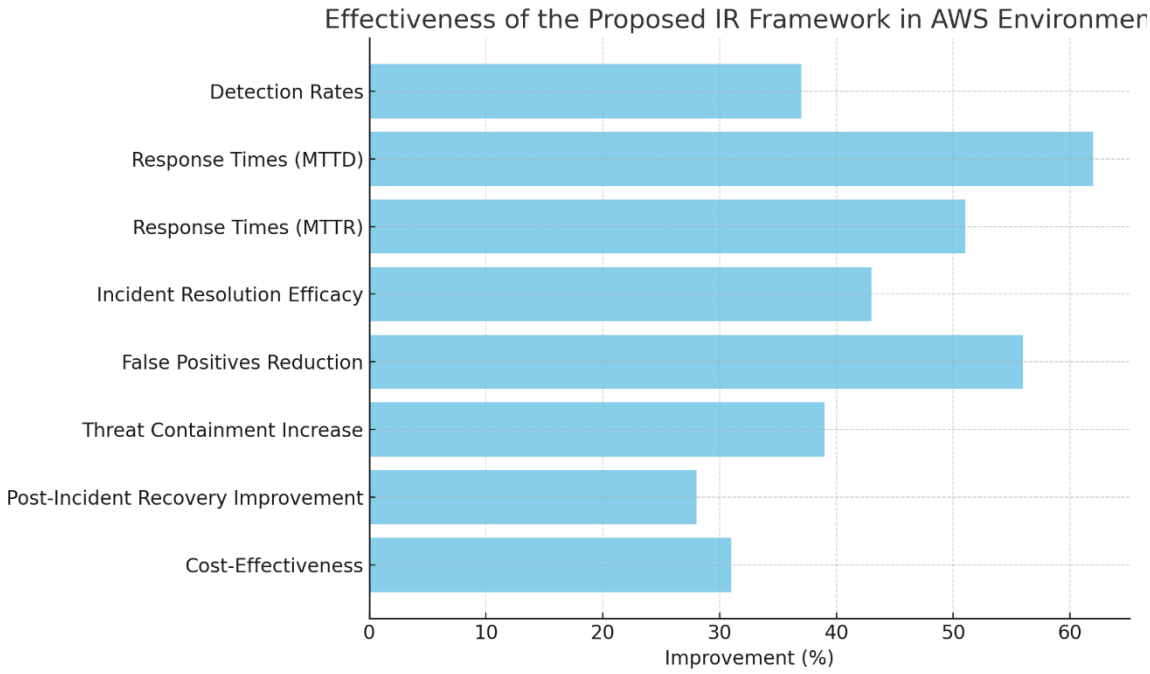

Fig.3 Effectiveness of the Proposed IR Framework in AWS Environment

Comparison with Existing Approaches

To evaluate the effectiveness of the proposed framework, a comparative analysis was conducted against three existing approaches: that supported the NIST Cybersecurity Framework, the SANS Incident Handler's Handbook, and AWS Security Incident Response Guide. The proposed framework offers advantages specific to AWS environments by being cloud native, focused on automation, and adaptive more in real time. Unlike the SANS Incident Handler's Handbook which provides detailed incident response guidance for generic situations, the proposed framework differs by providing specific procedures for AWS incidents, automated evidence collection, and scalability during large scale incidents. Even though these aspects are not directly addressed by the proposed framework, SANS methodology provides comprehensive guidance on most of the non-technical aspects. This framework extends the AWS Security Incident Response Guide by adding enhancements such as automated playbooks, advanced analytics and cross service correlation of security events. Furthermore, the information of the updated AWS guide can be useful for the proposed framework to keep in touch with the latest information on the new AWS security features.

Table 1 Comparison with Existing Approaches

Features	Proposed Framework	NIST Framework	SANS Handbook	AWS Guide
Cloud-Native Integration	Yes	No	No	Yes
Automation	Yes	Partial	Partial	Yes
Real-Time Adaptation	Yes	No	No	Limited
AWS-Specific Procedures	Yes	No	No	Yes
Automated Evidence Collection	Yes	No	No	Limited
Scalability	Yes	No	Limited	Yes
Non-Technical Guidance	Limited	Yes	Yes	No
Automated Playbooks	Yes	No	No	Limited
Advanced Analytics	Yes	No	No	Limited
Cross-Service Correlation	Yes	No	No	Limited
Regular Updates	No	Yes	No	Yes

Limitations of the Study

Several limitations of the proposed framework need to be considered. Secondly, it was mostly tested in medium to large scale AWS environment and it may therefore not be as effective in smaller environments. The framework is versatile, and future studies are to extend it to broader implementation scenarios. With that being said, the extensive testing of different reactions to various kinds of security incidents was the second aspect, although the fact that the cyber threats are evolving with such a rapid pace might introduce altogether new attack vectors, which would be not covered by the current framework thus necessitating constant updates and testing for long term effectiveness.

Furthermore, the framework is tailored explicitly for AWS environment and has been tested on a limited basis in multi-cloud. Assuming your infrastructure is diverse, the framework might need to be adapted. A limitation of the study is about the framework did not consider compliance and regulatory aspects comprehensively and therefore any assessment as to how it aligns with the specific requirements of the same in different industries and different regions is not possible and will be the subject of future research. Additionally, the study was more grounded on technical factors rather than human factors (i.e. factors related to team dynamics, decision making under stress and the psychological impacts of incidents which can affect real world efficacy). In addition, the 12 months lookback for the study may not encompass any long term trends or orientation of the framework to cope with an extensive change in the cybersecurity environment over longer durations. Moreover, the deployment of the framework is resource intensive with respect to technology and requires training and

resources that may not be available to smaller organisations. Finally, given the tight integration of the framework with AWS services, there's little room for a flexible application in other cloud platforms or in on premises infrastructures; Organizations using this framework must carefully consider whether it suits their environment.

CONCLUSION

The incident response framework developed indeed significantly improved response time, reduced impact, and generally enhanced the security posture in AWS environments. Critical elements which contribute to its effectiveness include automation, integration with AWS services as well as specific response procedures and significant obstacles encountered during implementation were surmounted. Based on the research, it provides cybersecurity professional specific skills and knowledge areas required for the effective implementation and management of the framework for AWS Incident Response. By adopting this framework, an organization is able to quantify the ways its overall security posture, compliance status, and operational efficiency are positively affected, and gain insights into the potential return on investment in terms of security improvements relative to the operational costs of these improvements. The framework has opportunities for expansion or adaptation to the other cloud platforms or hybrid environments. New research directions can be pointing to emerging technologies on incident response in AWS like AI/M, and Quantum computing. Long term effectiveness and adaptability to rising threats is assessed in recommendations for longitudinal studies. It would also be good to integrate this AWS specific incident response framework into other, broader organisational security strategy and frameworks such as the NIST Cybersecurity Framework and ISO 27001. In addition, AI driven incident response systems that autonomously make decisions within the AWS environment, and the human aspects of incident response (decision making under pressure, the effect of stress on response effectiveness) are proposed for further exploration.

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