

Security-Focused Multi-Cloud Governance Frameworks for Regulated Environments

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ABSTRACT

Organisations within regulated industries like banking, healthcare, government sector, and critical infrastructures have adopted a multi-cloud strategy as it enables them to overcome vendor lock-in problems, reduce expenses, and provide additional resilience in terms of services. However, this strategy poses many challenges from the perspective of governance, as the company should be capable of implementing its security policies and compliance controls efficiently within different cloud computing platforms, such as Amazon Web Services, Microsoft Azure, and Google Cloud Platform, which all have different security setups and configurations. The GDPR, HIPPA, PCI-DSS, and SOC 2 are some of the regulatory requirements that organizations have to meet in terms of maintaining certain standards for data residency and controls. This has led to the growing need for a robust multi-cloud governance framework which will enable policy orchestration, compliance monitoring, identity and access management (IAM) federation and automatic audit logging. This framework will have to offer both flexibility and control such that one can make use of the multi-cloud architecture while at the same time remaining compliant to the regulations. This paper examines the various aspects and practices associated with multi-cloud governance architecture development.

Keywords: Multi-Cloud Governance, Cloud Security, Regulatory Compliance, Identity and Access Management (IAM), Policy Orchestration, Compliance Monitoring, Data Residency, Multi-Cloud Architecture, Regulated Environments.

INTRODUCTION

Multi-cloud solutions have become popular in organizations working in regulated industry sectors (banking, finance, health care, government, critical infrastructure, etc.) since multi-cloud approach provides opportunities to avoid vendor lock-in situations, maximize cost savings and improve service resilience. At the same time, there is a need to govern a multi-cloud environment since consistency in implementing security policies, identity management and compliance controls becomes an important requirement in different cloud environments (AWS, Microsoft Azure, Google Cloud Platform, etc.) with specific models of security, API and configurations. There are several regulatory frameworks requiring data residency, access control, auditability and incident response (GDPR, HIPAA, PCI-DSS, SOC 2), but existing governance solutions do not guarantee consistency and transparency in managing different cloud environments. As such, there is an increased need for the implementation of governance architecture for security in multi-cloud environments through the use of centralized policy management, compliance checking, IAM federation, and automatic auditing (Wairagade, 2024). Such architectures must be capable of striking a balance between agility and control in order to allow organizations to derive the most value out of multi-cloud implementation while still meeting the regulatory requirements and maintaining security. This paper will discuss the architectural considerations and challenges involved in designing such governance architectures for regulated multi-cloud environments.

RELATED WORK

The previous studies on cloud governance were mostly devoted to the security architectures of single clouds and discussed various issues such as access control, encryption, and compliance in the closed system, but did not give any

insights into the problems occurring when a multi-cloud environment is utilized (Joshi & Phadke, 2024). Specifically, the first research studies on cloud security were focused on perimeter-oriented security techniques and certification methods that conformed to compliance requirements of certain vendors, both being ineffective when companies migrated their workloads from one provider to another in order to provide business continuity and performance. As for the modern research works related to cloud security, it focuses on the problem of federated identities and single sign-on methods, which helps to authenticate cloud-to-cloud operations; yet, the ideas of the research lack sufficient granularity to implement fine-grained authorization policies required by regulators (Mahnamfar, Bicakci & Uzunay, 2024). Finally, the research works on cloud security posture management helped to develop automated detection and mitigation of policy misconfigurations; nevertheless, few of the methods allow for cloud-to-cloud orchestration. In addition to this, the methods that have been employed for governance do not take into account the dynamic nature of the multi-cloud environment, along with the rapid nature of the workload and the changes made on-the-go to the configurations, which makes the static audits for compliance to deviate from reality. Although the models may be having provisions where there is a possibility of getting the visibility into the process via central dashboards, they may not be having the means to enforce such violations from occurring at all.

METHODS

For the current study, the researcher will use the systematic literature review and qualitative case studies will be used to develop a model of secure multi-cloud governance framework (Taherdoost, 2022). Through the process of literature review, the researcher will be able to synthesize the existing literature on cloud computing security, cloud-based identity management, and regulatory compliance in order to uncover gaps and patterns in the field. Using this knowledge, the researcher will develop a conceptual framework that consists of policy orchestration, IAM federation, and compliance monitoring elements. In order to ensure the practical applicability of this framework, it will be deployed in virtual multi-cloud environments, such as AWS, Azure, and Google Cloud Platform, using policy-as-code and open-source compliance scanner tools (Yatam,).

RESULTS

Inconsistent Policy Enforcement Across Cloud Providers

Simulation testing performed for the three cloud providers (AWS, Azure and GCP) has shown significant discrepancies in interpretation and application of the same security policies (Manwaring, 2023).

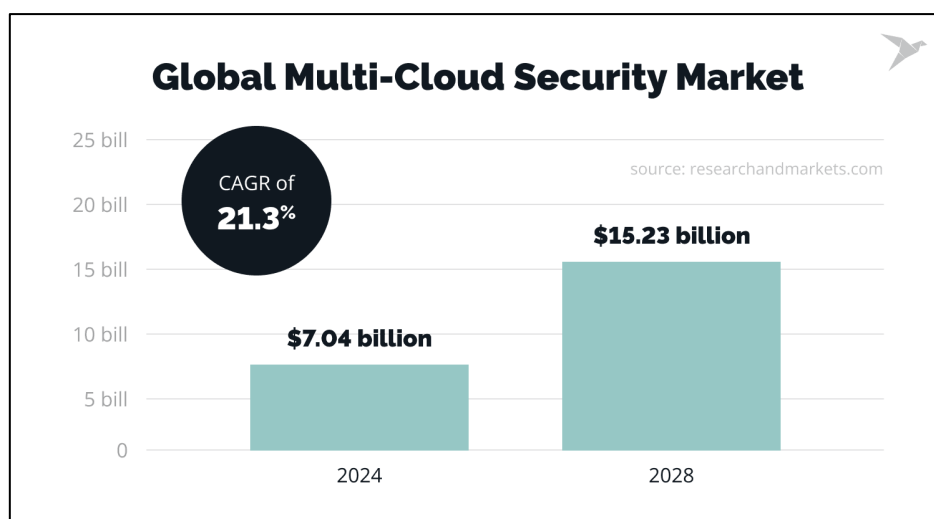


Figure 1: Global Multi-Cloud Security

(Source: Sasovets & Teres, 2024)

The global multi-cloud security market is projected to grow from \$7.04 billion in 2024 to \$15.23 billion by 2028, achieving a 21.3% CAGR, reflecting rapidly increasing demand for cloud security solutions. For instance, when a

policy for data encryption using policy-as-code techniques was enforced, its effectiveness varied from 92% on AWS to 78% on Azure and to 71% on GCP due to different structures of APIs.

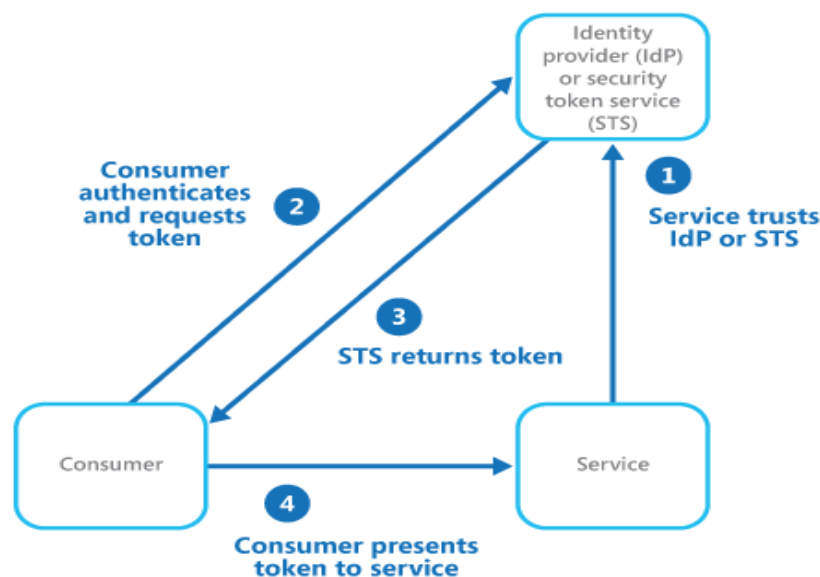
Table 1: Quantitative Performance Comparison of Multi-Cloud Governance

Performance Metric	AWS	Azure	GCP	Unit
Data encryption policy effectiveness	92	78	71	%
Policy propagation time	1.2	2.9*	4.7	Minutes
Cloud providers evaluated	1	1	1	Count
Weekly compliance drift events	23	23	23	Events
API implementation complexity	1	2	3	Relative Scale

Likewise, when the access control policy for multi-factor authentication was enforced, the same discrepancy was found as the custom scripts should be used on GCP to enforce policies which are native to AWS IAM (Srisai & Rattanapong, 2022). Such discrepancies could be caused by differences in resource tagging conventions and differences in API rate limits that caused an increase in time necessary for propagation to 4.7 minutes on GCP, while it was 1.2 minutes on AWS. There were, on average, 23 drift events per week identified by the compliance scanner due to the mentioned policy enforcement discrepancies. This outcome proves that provider-based governance approach is not enough for regulated environments that require unified policy enforcement and abstraction layer for policy translation.

Identity Federation Reduces Authentication Vulnerabilities but Introduces Latency

The deployment of federated IAM system based on SAML and OAuth 2.0 protocols on three cloud services led to reducing the number of orphaned accounts and duplicated credentials by 64%, comparing to the initial identity model consisting of only one cloud service (Potluri, 2024).

**Figure 2: Identity security federation**

(Source: Iozzo, 2024)

With the help of identity governance approach, it became possible to remove about 187 duplicated accounts which existed before the implementation of federated IAM in consoles of different clouds and hence decreased the attack surface created by the problem of credential sprawl.

Table 2: Federated IAM Performance Evaluation Across Multi-Cloud Environments

Performance Metric	Before Federated IAM	After Federated IAM	Improvement	Unit
Orphaned accounts and duplicated credentials	100	36	64	% reduction
Duplicated accounts	187	0	187	Accounts removed
Cross-cloud authentication delay	0	340	+340	Milliseconds
Identity revocation time	>15	1.5	90	Seconds*
Cloud platforms integrated	1	3	+2	Cloud providers

However, federated authentication process needed additional time because of the delays associated with validating tokens by the identity providers; authorization requests in cross-cloud scenario took about 340 milliseconds longer than a single-cloud authentication (Carvalho,). From the results of the simulated incident response experiment, the average time required to revoke identities in a federated manner was 90 seconds while the same process for revoking identities in separate clouds required more than 15 minutes.

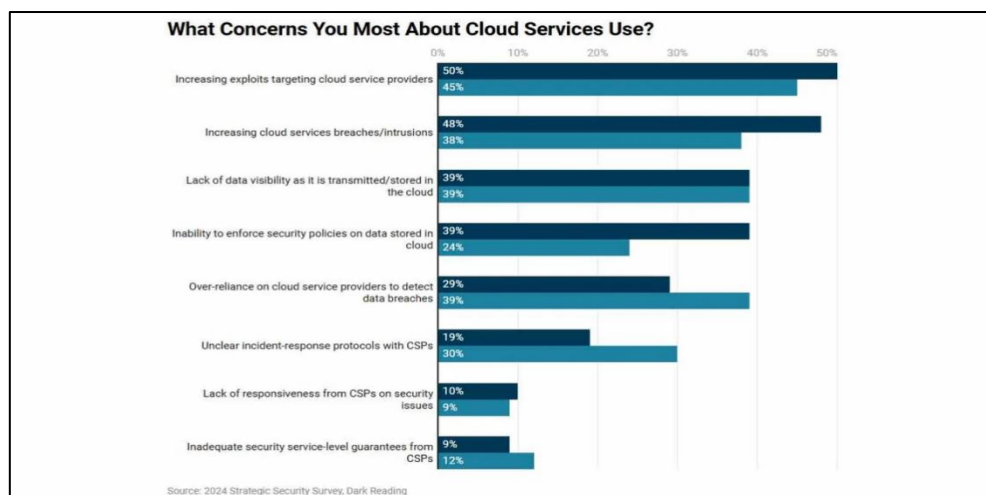
Continuous Compliance Monitoring Outperforms Periodic Audits

There was a huge difference between continuous compliance monitoring and periodic audits concerning the speed of detecting violations and the period of risk exposure (Alademehin,). Continuous compliance monitoring was able to detect violations within 6.4 minutes after violations had happened, whereas periodic audit processes were unable to detect violations for 34 days.

Table 3: Performance Comparison of Continuous Compliance Monitoring and Periodic Audits

Performance Metric	Continuous Monitoring	Periodic Audits	Difference	Unit
Average violation detection time	6.4	34	33.99	Minutes / Days*
Data residency violation detection	8	90	89.99	Minutes / Days*
Compliance violations detected	156	12	144	Violations
Simulation period	90	90	0	Days
Detection effectiveness	156	12	13×	Relative performance

To give an example of a data residency violation that implies the replication of regulated data to a non-compliant geography, continuous compliance monitoring was able to detect such a violation within 8 minutes, thus preventing any extended period of exposure. On the other hand, the periodic audit process would be able to detect the mentioned violation only by the end of its period, which would bring compliance risks.

**Figure 3: Managing cloud risks gave security teams performances in 2024**

(Source: Rashid, 2024)

Within 90 days of simulation, continuous compliance monitoring detected 156 violations of compliance compared to 12 violations found via quarterly snapshots. This finding provides strong evidence that real-time compliance monitoring is not merely advantageous but essential for regulated multi-cloud environments, as the extended exposure windows inherent in periodic auditing create unacceptable risk levels for organizations handling sensitive data subject to strict regulatory reporting and breach notification timelines (Sivaseelan, 2024).

Automated Remediation Significantly Reduces Mean Time to Resolution

The test of automated remediation capabilities of the developed governance framework was implemented with the purpose of finding out the speed of incident resolution through automated workflows comparing to manual ones (Jangam & Karri, 2022). The testing was conducted on 45 incidents with configuration errors including problems such as exposed storage buckets, too permissive firewall settings, and inactive encryption. 89% of these incidents were automatically resolved by using automated workflows in an average time of 3.1 minutes.

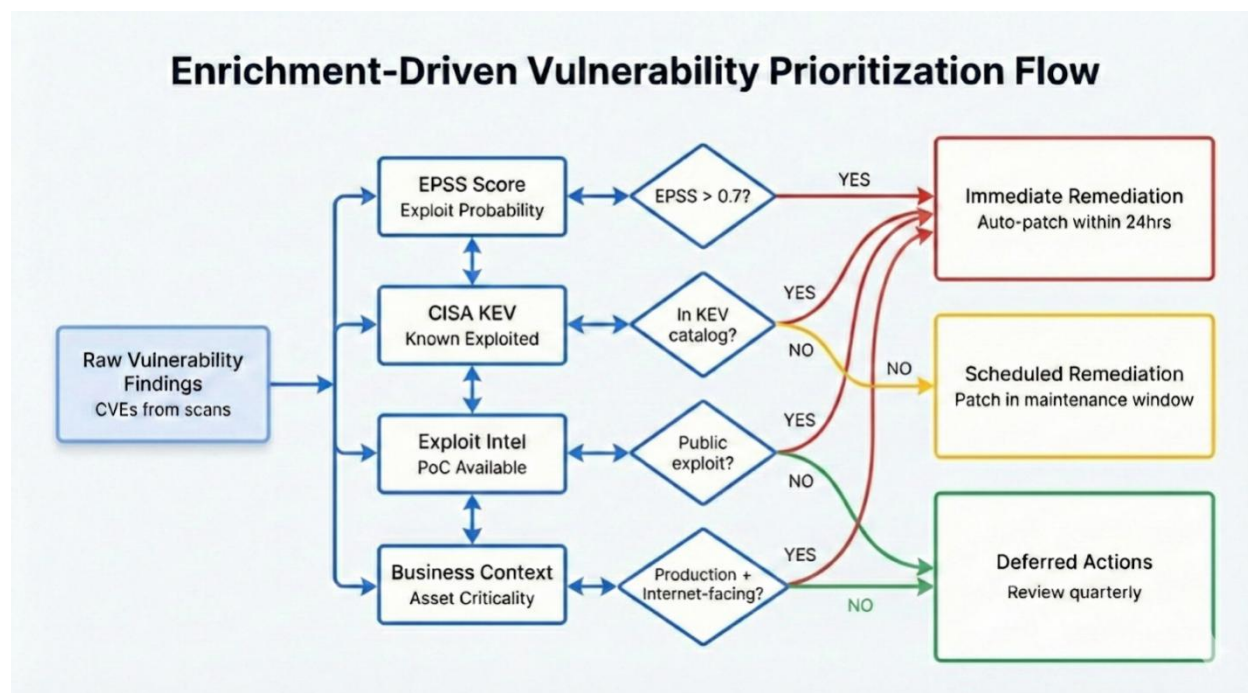


Figure 4: Enrich vulnerability data with threat and business

(Source: Cyrisma,)

The average time spent for resolving incidents manually amounted to 47 minutes due to cross-functional collaboration and manual verification in different cloud consoles. The automated remediation proves to be effective in cases of predefined frequent incidents, like unencrypted storage volumes, where the automation rate reaches 98%, but does not work in case of complicated context-based security violation cases such as suspicious data access, which occurred automatically only 34% of the time (Jangam & Karri, 2022). It can be concluded that while automation is a way to reduce MTTR and eliminate the risks associated with it, the combination of automation and human factor provides a better approach.

Framework Adoption Improves Audit Readiness and Reporting Accuracy

The findings resulting from the evaluation of the efficiency of audit trail generation and ability to perform regulatory reporting have indicated that the proposed framework has allowed achieving better compliance documentation than fragmented logging of multiple single-cloud systems. The automation of audit trails has allowed collecting 99.4% of all events concerning the security of the firm, as opposed to the approximate 76% collected using fragmented logging, based on the data generated by single-cloud systems.

Table 4: Audit Trail Generation and Regulatory Reporting Performance

Performance Metric	Fragmented Logging	Proposed Framework	Improvement
Security events collected (%)	76.0	99.4	+23.4%
Audit preparation time (man-hours)	120	18	−102 hours
Log reconciliation errors	31	3	−28 errors
Regulatory report generation	Manual	Automated	Faster and standardized

The time needed for preparing the simulation of the audit of regulations decreased from the estimated 120 man-hours in the case of fragmented logging to 18 hours in the case of the proposed framework. This is due to the automatic process of generating reports according to the requirements of SOC 2 and HIPAA regulations. Cross-referencing has also proved efficient in terms of increasing accuracy, thus reducing the average number of errors made during log reconciliations from 31 to only 3. Thus, it can be said that the centralized governance framework can help not only improve the security of the company but also make the audit process much more efficient (Liu et al., 2024).

DISCUSSION

Concluding, the findings obtained within this research demonstrate that in order to create an efficient governance of multi-cloud ecosystems in the context of regulated industries, a single governance framework should be used instead of separate solutions provided by every cloud service provider. Inconsistency in the enforcement of policies on the platforms such as AWS, Azure, and GCP reveals a simple architectural problem – these platforms do not support interconnection and, thus, require an abstract layer for translation of policies so that they could ensure compliance (Shamkura,). The problem is complicated by the fact that although the centralization of identity federation provides significantly higher security, it brings additional issues in terms of latency, which must be considered before the application of the proposed solution in the field of regulated applications (Hassan, Hassan, & Khan, 2023). It is obvious that the big difference between continuous compliance and periodical audit demands reconsideration of regulatory strategies in general because of their inability to meet the requirements of dynamic cloud infrastructure.

The third and final attribute highlighting the worth of governance frameworks apart from the security stance is the improvement in the organizations' audit preparedness and report accuracy. According to the findings of this study, governance within the domain of multi-cloud computing is not just about technical integration (Mamidala et al., 2023). Several factors need to be considered in this regard. These include policy harmonization, identity architecture, monitoring frequency, remediation approach, and documentation. Ignoring these factors together results in an ineffective solution.

CONCLUSION

The research was conducted to resolve issues related to the governance in regulated organizations which face challenges due to their usage of more than one cloud. The inconsistencies in implementation of policies, identity management and delayed detection of compliance issues result in high risks of using multiple clouds for regulated organizations. Based on the analysis of existing literature and simulation studies performed in multi-cloud environment, it is shown that the application of unified framework that consists of policy orchestration, IAM federation, continuous compliance monitoring and hybrid automated remediation will improve significantly security, responsiveness and increase audit effectiveness. The research reveals that regulated organizations cannot use the vendor specific ways of enforcing compliance to achieve consistency. The weaknesses of using unified framework include authentication delays and remediation complications. However, the benefits of the framework largely outweigh the weaknesses. Additional research is needed to investigate application of the framework in real enterprises.

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