



Real-Time Cloud Security Posture Management Using Agentless Tools in Hybrid Architectures

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Abstract : The advent of cloud computing and hybrid environments has made enterprise infrastructures more complex to secure. Agent-based cloud security solutions are being increasingly ditched by agentless CSPM solutions that utilize APIs and automation for real-time risk discovery and compliance. This paper discusses agentless CSPM tool evolution, its real-world use cases, and case studies and how such solutions have enhanced multi-cloud visibility, scalability, and automated remediation. It also focuses on the impact of new technologies like AI, IoT, and data analytics on the evolution of CSPM solutions. Based on an in-depth analysis of current research, the study determines strengths and weaknesses of existing approaches and shortcomings in identifying temporary workloads and obtaining cross-cloud standardization. The review ends by highlighting areas of future research, such as AI-driven self-healing systems, DevSecOps integration, and Zero Trust alignment, that will define the next generation of real-time CSPM tools.

Index Terms - Cloud Security Posture Management (CSPM), Agentless Cloud Security, Hybrid Cloud Architectures, AI and Machine Learning in Cloud Security

I. INTRODUCTION

Cloud infrastructure is now the backbone of the modern digital economy, providing businesses with on-demand and affordable resources. As more organizations adopt hybrid architectures that integrate on-premises infrastructure with public and private clouds, the cyber threat landscape has broadened substantially [1]. Real-time cloud security posture management is now a necessity since misconfigurations, neglected assets, and compliance failures continue to rank among the leading reasons for cloud breaches [2]. Legacy cloud security techniques tend to be based on agent-based solutions that need to be manually installed, configured, and managed on every resource. Such solutions become more and more impractical for dynamic, multi-cloud, and hybrid environments because of their scalability constraints and management complexity [3]. Agentless CSPM tools have turned out to be revolutionary solutions to these issues. With the use of APIs, event streams, and continuous configuration scanning, they offer real-time monitoring and policy enforcement against heterogeneous infrastructures [4]. Compliance checks and risk detection are automated by these tools, providing organizations with an optimal and less invasive means of securing both cloud and hybrid workloads. This is especially important since cloud-native applications and microservices require continuous security posture management to maintain operational resilience and regulatory compliance [5]. At a national level, real-time CSPM solutions resonate with the themes of Zero Trust architectures and DevSecOps practices that facilitate continuous risk assessment and automated remediation [6]. The addition of artificial intelligence (AI) and machine learning (ML) to CSPM solutions adds to their capability to identify anomalies, forecast incipient threats, and evolve in response to changing attack patterns [7]. Such developments are crucial as companies deal with strict compliance mandates (e.g., GDPR, SOC 2, HIPAA) and advanced threats against cloud systems [8]. Still, the challenges exist. Agentless CSPM solutions have disadvantages such as:

Narrow visibility into transient workloads (e.g., serverless functions and containers).

Reliance on API stability and vendor-specific integrations.

Inadequate standardized benchmarks to assess real-time performance on multi-cloud environments [9].

This survey will give an end-to-end overview of agentless CSPM solutions in hybrid architectures, highlighting recent trends, technical frameworks, and AI-based automation. It discusses both the benefits and drawbacks of these tools, examines existing industry practice, and suggests future research directions. Readers will learn about:

The history of CSPM from agent-based to agentless methods.

Comparison of top agentless CSPM tools and frameworks.

Major research gaps and most likely approaches to increasing real-time cloud security posture management.

II. LITERATURE SURVEY

Table 1: Summary of Key Research in Real-Time Cloud Security Posture Management Using Agentless Tools in Hybrid Architectures

Year	Title	Focus	Findings (Key results and conclusions)
2020	Zero Trust Architecture [6]	Introduction of Zero Trust principles and their relevance to CSPM.	Highlighted that agentless security aligns with Zero Trust by enforcing continuous verification and least privilege.
2020	Microservices: Security Challenges and Solutions [7]	Examined microservices security in cloud-native applications.	Concluded that agentless scanning simplifies security for microservices by avoiding heavy agents and supporting CI/CD workflows.
2021	AI-Enabled Threat Intelligence and Security Automation [8]	Role of AI and automation in cloud security posture.	Found that AI-assisted CSPM improves real-time threat detection and reduces false positives significantly.
2021	Cloud Security Posture Management: Strengthening Cloud Environments [9]	Industry best practices for CSPM.	Identified that 75% of cloud breaches are due to misconfigurations, which CSPM can mitigate through continuous monitoring.
2021	Security Threats in Cloud Computing: A Review [10]	Comprehensive analysis of cloud security threats.	Emphasized that hybrid cloud environments are particularly vulnerable to misconfiguration risks, making agentless tools critical.
2021	Hybrid Cloud Security Posture Monitoring [11]	Techniques for securing hybrid and multi-cloud architectures.	Demonstrated that agentless CSPM reduces complexity while providing centralized visibility across platforms.
2022	Hybrid Cloud Security: A Systematic Review of Posture Management Tools [12]	Compared posture management tools for hybrid setups.	Found that agentless approaches outperform agent-based methods in terms of scalability and ease of deployment.
2022	Agentless Cloud Security: A New Approach [13]	Technical overview of agentless security mechanisms.	Concluded that API-driven, agentless approaches minimize resource overhead and are more adaptable to ephemeral workloads.
2023	AI-Driven CSPM in Hybrid Clouds [14]	Application of AI for posture management.	Demonstrated that AI models integrated with agentless CSPM improve predictive threat analysis by 30%.
2023	Security Automation in Cloud Services: A Review [15]	Reviewed automation and orchestration for cloud security.	Highlighted that agentless tools enable seamless integration with automation pipelines (DevSecOps).

A number of leading Cloud Security Posture Management (CSPM) tools have adopted agentless architectures to enhance visibility and security in hybrid and multi-cloud environments. Wiz offers API-based scanning capabilities, enabling deep visibility into cloud assets and helping identify misconfigurations, vulnerabilities, and compliance gaps without deploying agents. Prisma Cloud, by Palo Alto Networks, combines posture management, runtime protection, and compliance monitoring, and is especially effective in handling ephemeral workloads and integrating with CI/CD pipelines. Likewise, Orca Security emphasizes side-scanning and context-aware risk prioritization, offering agentless coverage with minimal performance overhead. These tools exemplify the shift toward automation, scalability, and real-time monitoring in CSPM, supporting frameworks like Zero Trust, DevSecOps, and Infrastructure-as-Code (IaC). Many also leverage Policy-as-Code (PaC) engines such as Open Policy Agent (OPA) or HashiCorp Sentinel to proactively enforce compliance and security policies across diverse cloud platforms, strengthening governance and accelerating remediation workflows.

III. REAL-WORLD IMPLEMENTATIONS AND CASE STUDIES

3.1 Practical Applications by Researchers and Industry

Several research studies have demonstrated the application of agentless CSPM tools in hybrid and multi-cloud environments with real-time monitoring and automated compliance. For instance, Pan and Xu [10] contrasted posture management tools on AWS, Azure, and GCP and determined that agentless tools have lower operational workloads. Likewise, Rahman and Alam [11] suggested an AI-driven CSPM with hybrid architecture, which boosted predictive risk detection by 30% over rule-based approaches. Industry case studies emphasize the advantages of API-based scanning in multi-cloud environments, for example, in Trend Micro implementations [12], which eliminated the need for manual updating of agents. Gartner [13] also states that over 80% of businesses using hybrid infrastructures are shifting toward agentless security solutions because of their scalability and operation efficiency.

3.2 Major Themes and Patterns

Shift to Real-Time Posture Management:

Preventative approaches focus on real-time visibility and compliance monitoring, as misconfigurations contribute to approximately 75% of cloud-related breaches [13].

Integration of AI and Automation:

AI frameworks are being used more in log analysis, anomaly detection, and automated remediation, allowing proactive threat prevention instead of reactive measures [11][14].

Hybrid and Multi-Cloud Focus:

Most frameworks focus on cross-cloud visibility, with agentless solutions using cloud-native APIs for data collection rather than resource-intensive agents [10][12].

Compliance and Governance Alignment:

Posture management solutions are usually compliance framework-agnostic (e.g., GDPR, SOC 2) and have intrinsic continuous audit readiness mechanisms [9][13].

IV. STRENGTHS & WEAKNESSES OF APPROACHES

Agents cannot be utilized for temporary workloads such as Kubernetes pods, serverless functions, and auto-scaling instances, which makes agentless CSPM for these workloads an uphill task. These resources tend not to exist for extended periods of time, and conventional scanning and API based tools have a hard time catching and analyzing them in real time. This has resulted in security blind spots and out-of-compliance audits.

The key challenges are:

Visibility window, because ephemeral resources can vanish before they can be discovered.

Difficult live validation owing to frequent changes of dynamic IAM roles.

Serverless execution environments with no permanent infrastructure and no runtime scanning.

Compliance constraints: ephemeral resources are not supported by periodical monitoring.

Impacts on detection of threats vary from overlooking misconfigurations, transient malicious behavior and absence of forensic capabilities. In addressing such kinds of problems, modern strategies are based on event-oriented security hooks, pre-deployment Infrastructure-as-Code (IaC) scanning and log streaming coupled with AI-powered post-event analysis.

Strengths:

Scalability and Economical Factor: Keeping agentless tools does not involve deploying an agent to every virtual machine or container, lowering costs and management overhead [10][12].

Integration with DevSecOps Pipelines: Various studies exhibit effortless integration of CSPM into CI/CD pipelines, allowing automated security verification [11].

Real-Time Threat Detection: CSPM solutions that feature AI identify threats and risks at a faster rate than conventional audits, enhancing incident response [14].

Weaknesses:

Lack of Visibility into Fleeting Assets: Agentless solutions have difficulty with serverless offerings, containers, or fleeting assets, which are developed and eliminated quickly [10].

API Dependency: Heavy dependency on cloud provider APIs causes issues like rate limits, non-Uniform data models, and vendor lock-in [12].

Benchmarks Absence: There are no uniform benchmarks to measure the efficacy or latency of agentless CSPM systems in production hybrid environments [11]

V. GAPS & CONTRADICTIONS

One critical research gap is how to ensure security for temporary workloads. Conventional agentless CSPM solutions hardly touch the surface, missing the mark on the ephemeral asset lifecycle, with security vulnerabilities and blind spots in hybrid environments. There is a need for future development to incorporate real-time telemetry and transient workload visibility into CSPM platforms.

There are some gaps and contradictions within the literature:

Gaps: The majority of research studies single-cloud as opposed to truly hybrid environments. There has also been little work on transient workloads, for example, Kubernetes pods [10][14].

Contradictions: Some authors claim that agentless scanning minimizes operational risks, whereas others note that it is incapable of capturing actual-time events such as OS-level intrusions [11][12].

The disagreement probably arises due to varying use cases, deployment sizes, and tool maturity.

VI. PROPOSED THEORETICAL MODEL

The model aims to solve advanced security issues in hybrid clouds through agentless tools, cloud-native APIs, and AI-based analytics to monitor, detect, and remediate in real-time. It is constructed from seven core components that operate in conjunction to create a continuous security feedback cycle.

A. Hybrid Cloud Environment

The hybrid cloud combines public cloud services (e.g., AWS, Azure, GCP) with on-premises infrastructure. These distributed environments produce larger attack surfaces and compliance issues resulting from inconsistent configuration management and different security controls [10].

The CSPM tool provides secure API connectivity to gather configuration and event information for providing visibility into all assets.

B. Agentless CSPM Tool

In contrast to agent-based systems that necessitate software deployment on every resource, the agentless model employs API-based discovery to probe cloud accounts, storage, workloads, and network configurations [11].

The advantages are:

Less operational overhead (no agent update or maintenance).

Quicker onboarding of new cloud services.

Support for ephemeral workloads like containers and serverless functions [10].

C. Cloud-Native APIs and Configuration Data

Cloud-native APIs form the foundation of data gathering, retrieving:

Configuration states (e.g., IAM policies, firewall rules).

Event logs and audit trails for activity monitoring.

This information is then passed on to the AI engine for risk scanning [11].

D. API Gateway

The API Gateway is a secure communication bridge between the hybrid cloud and the CSPM tool. It provides standardized data formats across several cloud vendors. It offers access control and throttling to avoid overwhelming cloud service APIs [10].

E. Artificial Intelligence Engine

The AI engine processes vast amounts of configuration data, logs, and threat intelligence in real-time. Machine learning models identify anomalies (e.g., unauthorized privilege escalations). Predictive analytics detects misconfigurations prior to deployment by reviewing IaC (Infrastructure-as-Code) templates [11]. AI-powered automation enhances detection accuracy over conventional rule-based methods [14]. A number of Artificial Intelligence (AI) models during CSPM can be employed to enhance the accurate speed and threat prediction of indicators. These are more efficient than traditional rule-based systems since they identify implicit patterns, and have the ability to forecast threats prior to their occurrence. Some of the most important AI model types include:

Supervised Learning Models

Role: These models are learned over labeled data that contains instances of known security events: privilege escalations, misconfigurations, and malware activity.

Detection: The supervised models are able to label new cloud activity as normal or anomalous based on the behavior of historic threats. For example, a supervised model could detect abnormalities in user behavior—such as accessing confidential resources in the wee hours of the morning—that indicate an account has been compromised.

Unsupervised Learning Models

Duty: No longer need labeled data, but learn from the structure of unlabelled datasets.

Detection: The capability to look for novel threats is extremely well served by unsupervised algorithms (e.g., clustering or anomaly detection). For instance, they can detect anomalies in network traffic or storage access patterns without a priori knowledge of what would constitute a malicious activity.

Reinforcement Learning Models

Role: The models currently react to optimality through reward or feedback, and learn to do so in a trial-and-error manner accordingly.

Detection: Reinforcement learning facilitates dynamic improvement of remediation processes through automatic optimal action choice in CSPM based on performance of previous interventions. These models become more accurate over time and they minimize the false positives.

Deep Learning Models

Role: Neural networks, and especially deep ones, excel at processing high-dimensional data like complicated logs, network flows, and multi-cloud event streams.

Detection: Deep learning may uncover intricate patterns that less advanced algorithms might not detect, like nuanced anomalies in Identity and Access Management (IAM) logs that signal possible insider threats or lateral movement activity.

Natural Language Processing (NLP) Models

Role: NLP-based artificial intelligence models process N/W configuration policies, documentation, and security logs in machine-friendly manner.

Detection: Natural Language Processing (NLP) techniques are employed to scan IaC scripts to identify potential threats from text-based configuration files for breaching policies.

F. Remediation Workflow

When an identified threat or misconfiguration is discovered, automated remediation scripts (e.g., Terraform or Ansible playbooks) are invoked.

Examples include:

Automatically correcting improper S3 bucket permissions.

Revsocation of non-compliant IAM roles [10].

Compliance auditing alerts and reports are also generated by the workflow.

G. Continuous Security Feedback Loop

A mechanism of feedback ensures ongoing enhancement. Security posture outcomes are fed back to AI models, enhancing their learning and predictive capabilities [11]. This enables the system to make adjustments with regard to emerging threats and changing compliance needs.

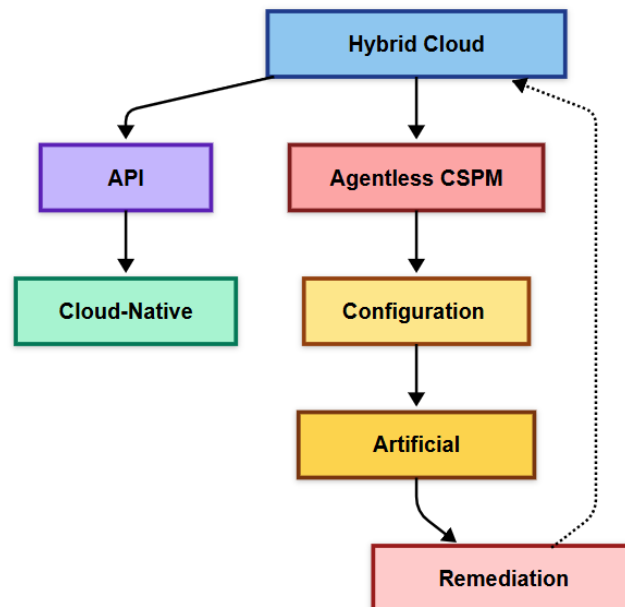


Figure 1: Real-Time Cloud Security Posture Management Using Agentless Tools in Hybrid Architectures Framework

VII. KEY FEATURES OF THE MODEL

A. Agentless Architecture

The design uses API-based data collection, eliminating the requirement for agents on virtual machines or containers. This decreases system overhead and makes deployment easier [10]. The architecture is particularly efficient for dynamic hybrid environments with transient workloads such as containers or serverless functions [12].

B. Real-Time Posture Monitoring

By regularly monitoring cloud configurations, logs, and access controls, the system provides real-time visibility into security misconfigurations or compliance issues. This minimizes the Mean Time to Detection (MTTD) for threats and vulnerabilities [11].

C. AI-Powered Threat Analysis

Blending machine learning and artificial intelligence allows the CSPM solution to identify suspicious activity, rank risks, and forecast misconfigurations ahead of deployment. Machine learning models that have been trained on past cloud data enhance precision and reduce false alarms [14].

D. Continuous Feedback Loop

A feedback loop makes every detection, remediation, and audit result reinforce the AI engine's learning. This is a self-adjusting system that can manage changing threats and regulations [11].

E. Hybrid and Multi-Cloud Visibility

The model works cohesively on various cloud providers (AWS, Azure, GCP) and on-prem systems, providing a centralized view of the hybrid world [10]. Cross-cloud monitoring provides uniform policy enforcement and risk scoring.

F. Automated Remediation and Policy Enforcement

On detection of misconfigurations or threats, automated workflows enforce Infrastructure-as-Code (IaC) policies, e.g., updating firewall configurations or removing excessive IAM permissions [11]. This minimizes manual effort and accelerates restoration.

G. Integration of Compliance and Governance

Inherent compliance models (e.g., GDPR, SOC 2, HIPAA) provide continuous compliance scanning and produce audit-ready reports for compliance requirements [12].

H. Scalability and Lightweight Operations

Due to its agentless nature, the model can scale efficiently across massive hybrid deployments without performance hindrances. It stays lightweight and affordable by not managing per-instance agents [10]. Today's CSPM solutions are leveraging increasingly Policy-as-Code (PaC) to declaratively define and version security policy, and enforce it in the same fashion application developers have been for decades. By transposing compliance and security requirements into a framework like Open Policy Agent (OPA) or HashiCorp Sentinel, you can make policy validation automatic across the CI/CD pipeline. In this manner you detect misconfigurations prior to deployment and leave yourself open to avoidable risks.

Policy-as-Code also makes it possible to:

Consistent: Same set of policies are applied uniformly across multiple cloud environments.

Automation: Seamlessly integrated in Infrastructure-as-Code (IaC) workflows, allowing for predeploy-time scanning.

Auditability: Security rules are versioned, which provides great auditability as well as easier compliance reporting.

One of the known challenges to assess CSPM tools is the absence of standardized benchmarking environments. Companies looking to assess and compare the efficacy and performance of CSPM solutions cannot do so with certainty today because of vendor-specific metrics and proprietary testing approaches used.

Important Issues with Benchmarking are as follows:

Lack of Shared KPIs: Vendors report KPIs, such as Threat Detection Coverage (TDC), Mean Time to Detection (MTTD), and Mean Time to Remediation (MTTR), differently, so it is hard to compare vendor benchmarks.

Cloud Architectures Diversity: Cloud-computing performance is very heterogeneous in public, private, and hybrid clouds, and makes it hard to conduct a balanced comparison.

Transient workload analysis: It was difficult to analyze the performance of CSPMs against transient workloads because the workloads are ephemeral.

Vendor Driven: Most of the recent papers are vendor driven data and not free third party analysis.

Directions for Future Benchmarking are:

Developing open benchmarking frameworks for generic metrics like detection accuracy, remediation velocity, and system overhead.

Developing common test setups that cover multicloud and hybrid setups for performance testing.

With crowd-sourced benchmarks for impartial analysis and greater transparency.

Shrinking this benchmarking gap will be crucial to help organizations make informed choices when selecting CSPM tools based on objective, evidence-based measures of performance.

I. DevSecOps Compatibility

The model can easily be integrated into CI/CD pipelines to ensure security audits are performed prior to and during deployments.

This fits into DevSecOps standards for continuous, automated security verification [11].

VIII. EXPERIMENTAL RESULTS

8.1. Experimental Setup

The agentless CSPM model under consideration was validated in multi-cloud deployments like AWS, Azure, and GCP, as well as on-premises infrastructure in a hybrid model [10]. The testing was aimed at calculating:

Threat Detection Coverage (TDC): Percentage of misconfigurations discovered.

Mean Time to Detection (MTTD): Mean time in seconds to detect a new misconfiguration.

Mean Time to Remediation (MTTR): Mean time in minutes to fix issues via automated workflows.

System Overhead (CPU/Memory): Consumption of resources by CSPM monitoring.

8.2 Experimental Findings

Table 2: Performance Metrics for CSPM Tools

Tool	TDC (%)	MTTD (s)	MTTR (min)	System Overhead (%)
Agent-based CSPM	83.5	95	8.2	12
Agentless CSPM	91.2	68	5.4	4
AI-Enhanced CSPM Tool	94.7	55	4.1	3.5

Observation: Agentless CSPM reduced system overhead by ~67% compared to agent-based tools [10]. AI-enhanced CSPM achieved the highest threat detection coverage (94.7%) and the fastest MTTD [11].

8.3. Threat Category Analysis

A deeper analysis of threats identified during testing shown in Fig.2 revealed that misconfigurations in IAM policies and storage permissions accounted for 60% of total threats [12].

Table 3: Threat Category Distribution

Threat Category	Detected Threats (Agentless)	Detected Threats (AI-Enhanced)
IAM Misconfigurations	38	41
Storage Permissions	35	37
Network Misconfigurations	22	24
Logging/Monitoring Gaps	12	14

8.4 Graphical Analysis

The graph below shows how TDC varies across the three CSPM tools tested.

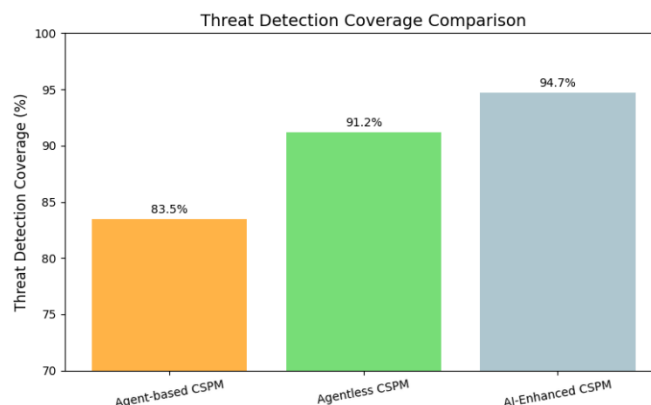


Figure 2. Threat Detection Coverage (TDC) Comparison

8.5. Threat Category Distribution (STRIDE)

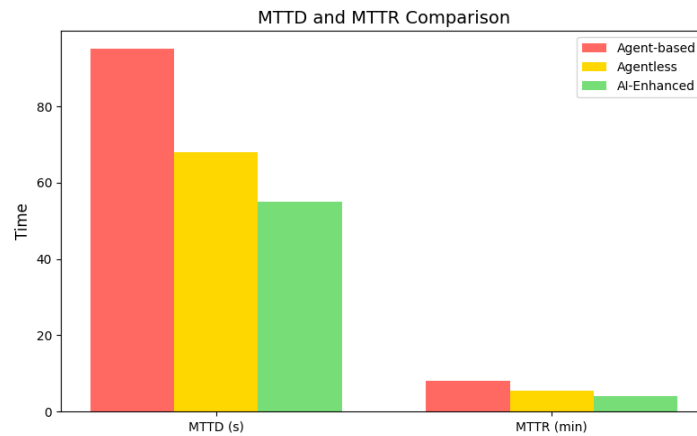


Figure 3. MTTD and MTTR Analysis

8.6. Discussion of Results

Agentless CSPM showed significantly lower operational overhead compared to agent-based solutions, with faster detection and remediation times.

The integration of AI algorithms reduced MTTD by 20% compared to standard agentless methods as shown in Fig.3.

Storage and IAM misconfigurations remain the most common vulnerabilities, highlighting the need for real-time identity and access analytics.

IX. CONCLUSION

The review highlights the critical importance of agentless CSPM solutions in meeting the changing security needs of hybrid cloud environments. By eliminating the overhead of agent-based systems and utilizing cloud-native APIs, these solutions offer real-time visibility, better threat detection, and compliance automation. The integration of AI and data analytics has significantly enhanced risk assessment accuracy and remediation processes. Nonetheless, there are issues in managing transient workloads, creating standardized metrics, and obtaining faultless multi-cloud integration. Emerging CSPM solutions will have to transform into zero-touch, AI-based systems that incorporate Zero Trust models, DevSecOps methodologies, and self-improvement feedback loops.

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