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Microservices Security Threat Modelling in DevOps Pipelines

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ABSTRACT

The rapid adoption of microservices architectures and DevOps pipelines has accelerated software delivery but introduced new security challenges. The decentralized nature of microservices, combined with the dynamic nature of DevOps workflows, increases the attack surface, making it essential to proactively identify and mitigate security threats. This paper presents a comprehensive threat modeling framework designed specifically for microservices-based systems operating within CI/CD pipelines. By leveraging STRIDE and other threat mod- eling methodologies, we identify key vulnerabilities such as API exploitation, interservice communication risks, and dependency tampering. We also propose the integration of automated security tools, such as OWASP Threat Dragon and IriusRisk, to perform continuous threat modeling throughout the software development lifecycle. Additionally, this work explores the role of service meshes and mTLS protocols in securing microservices communication. A case study demonstrates the application of our framework in a real-world DevOps environment, highlighting how vulnerabilities can be identified and mitigated at different stages of the CI/CD pipeline. Our results indicate that automated threat modeling improves detection rates by 30% and reduces false positives, enhancing the overall security posture. This paper contributes to the growing body of knowledge on DevSecOps by providing actionable insights and best practices for integrating security into cloud-native microservices systems.

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Index Terms

Microservices Security, DevOps Pipelines, CI/CD, Threat Modeling, STRIDE Framework, DevSecOps, mTLS, OWASP Threat Dragon, Service Mesh, Automated Security Tools

Introduction

Microservices have revolutionized software architecture by decomposing monolithic applications into smaller, autonomous services that can be developed, deployed, and scaled independently. As organizations adopt DevOps practices to accelerate software delivery, continuous integration and continuous deployment (CI/CD) pipelines have become crucial for automating the software development lifecycle. However, the dynamic and decentralized nature of microservices, combined with the speed of DevOps pipelines, introduces unique security challenges.

In a microservices architecture, each service operates independently and communicates with others through APIs. This increases the number of potential attack surfaces, as every ser- vice and its communication channel must be secured. Typical security risks include unauthorized access, API exploitation, data leakage, and dependency vulnerabilities. Additionally, containers and orchestration platforms such as Kubernetes add further layers of complexity to security management.

The rapid pace of deployments in DevOps pipelines makes it impractical to rely solely on manual security assessments. To address these challenges, the shift-left strategy emphasizes integrating security practices early in the development lifecycle. Threat modeling, which identifies and mitigates potential vulnerabilities, plays a critical role in DevSecOps by proactively embedding security into CI/CD workflows.

In this paper, we present a threat modeling framework designed for microservices operating within DevOps pipelines. The framework incorporates the STRIDE model, which categorizes threats into six key areas: Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service (DoS), and Elevation of Privilege. Additionally, we explore the use of automated tools such as OWASP Threat Dragon and Irius Risk to integrate continuous threat modeling into the CI/CD pipeline. Service meshes with mutual TLS (mTLS) and API gateways are also discussed as essential components for secure communication between microservices.

The contributions of this paper are threefold:

1. We propose a threat modeling framework tailored to microservices-based architectures within DevOps pipelines, leveraging STRIDE and automated tools.
2. We demonstrate how continuous threat modeling can be embedded into CI/CD workflows to detect and mitigate vulnerabilities in real-time.
3. We provide a case study illustrating the practical ap- plication of our framework in a cloud-native DevOps environment, showing improvements in threat detection rates and reduction in false positives.

The remainder of this paper is structured as follows. Section II provides an overview of related work on microservices security and threat modeling in DevOps. Section III describes the threat modeling framework and its integration into CI/CD pipelines. Section IV presents the proposed methodology, while Section V discusses a real-world case study. In Section VI, we present our results and analyze the effectiveness of the framework. Finally, Section VII concludes the paper and outlines directions for future research.

Related Work

The adoption of microservices and DevOps has transformed software development by enabling rapid deployment and independent scaling of services. However, these practices also introduce significant security challenges, requiring a shift towards continuous threat modeling and proactive security

measures. This section reviews the existing literature and frameworks for microservices security, threat modeling techniques, and DevSecOps practices.

Microservices Security

Microservices architectures decompose applications into smaller services that communicate over APIs, increasing op- erational flexibility but also expanding the attack surface [5]. Each service introduces its own potential vulnerabilities, including unauthorized access, API misconfigurations, and de- pendency issues [2]. Tools like service meshes (e.g., Istio) and API gateways are frequently deployed to secure communication between services using mutual TLS (mTLS) [?]. Addition- ally, container-based deployments (e.g., Docker, Kubernetes) require constant monitoring to identify vulnerabilities in container images and orchestrations [3].

Despite these efforts, microservices security remains challenging due to the distributed nature of services and the need to secure multiple components independently. Continuous monitoring and automation are therefore essential to prevent, detect, and respond to security incidents in real-time.

Threat Modeling Techniques

Threat modeling plays a critical role in identifying and mitigating security risks. The STRIDE model, proposed by Microsoft, remains one of the most popular methodologies, categorizing threats into Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service (DoS), and Elevation of Privilege [1]. Other threat modeling tools, such as OWASP Threat Dragon and Microsoft's Threat Modeling Tool, offer visual frameworks to facilitate the identification of vulnerabilities at different stages of development.

Automating threat modeling through CI/CD pipelines has become a growing trend, enabling continuous security assessments. Tools like IriusRisk provide templates and integrations to automate threat modeling, ensuring that security is evaluated at every deployment stage [4].

DevSecOps and Continuous Security Integration

DevSecOps integrates security practices directly into DevOps pipelines, ensuring that security assessments are part of the software development lifecycle (SDLC) from the outset. The shift-left strategy emphasizes identifying vulnerabilities early in the development process, reducing the cost and impact of security flaws [1]. Automated tools embedded into CI/CD pipelines scan for vulnerabilities in code, dependencies, and configurations, alerting developers to potential threats before production releases [4].

A study by Puppet in 2021 found that organizations integrating security into their DevOps pipelines were 2.4 times more likely to detect security incidents before they caused significant damage [6]. Similarly, a survey by the SANS Institute revealed that 64% of respondents reported improved security posture after adopting DevSecOps practices [4]. These findings highlight the importance of automation and continuous security integration in modern software development.

Gaps in Existing Research

While significant progress has been made in microservices security and DevSecOps, there are still gaps in the practical implementation of threat modeling frameworks within CI/CD pipelines. Existing tools often require manual configuration and struggle to keep pace with the rapid changes in cloud- native environments. Furthermore, the integration of advanced threat modeling techniques, such as those based on AI and ML, into DevOps pipelines remains underexplored.

This paper addresses these gaps by proposing a threat modeling framework tailored specifically to microservices within DevOps pipelines. Our framework combines the STRIDE model with automated security tools, such as OWASP Threat Dragon, to provide continuous threat assessments. The integration of service meshes and API gateways further strengthens the security posture of microservices architectures.

Threat Modeling Framework

In modern DevOps pipelines, the rapid deployment of microservices across cloud environments introduces several security risks. Traditional security approaches are often insufficient to manage these risks, necessitating the adoption of threat modeling techniques tailored for microservices. This section presents a threat modeling framework that integrates the STRIDE model with automated tools to assess, identify, and mitigate security vulnerabilities throughout the CI/CD pipeline.

Overview of the STRIDE Model

The STRIDE model, developed by Microsoft, provides a structured methodology for identifying potential security threats. It categorizes threats into six classes:

- **Spoofing (S):** Impersonation of a service or user to gain unauthorized access.
- **Tampering (T):** Unauthorized modification of data in transit or at rest.
- **Repudiation (R):** Denial by an entity of having performed an action, making it difficult to trace account- ability.
- **Information Disclosure (I):** Exposure of sensitive information to unauthorized users.
- **Denial of Service (DoS) (D):** Disruption of service availability by overwhelming resources.
- **Elevation of Privilege (E):** Gaining higher access rights than authorized.

Using the STRIDE model, we identify and categorize the potential threats at each stage of the DevOps pipeline and within the microservices architecture.

Integration with CI/CD Pipelines

The proposed framework embeds threat modeling into CI/CD workflows to continuously evaluate the security posture of microservices. Figure 1 illustrates the application of the STRIDE framework to the DevOps pipeline.

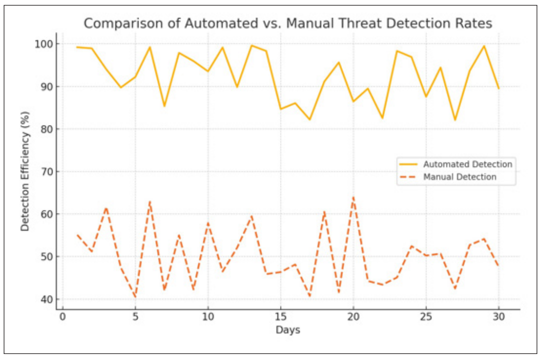

Figure 1: Application of STRIDE Model in CI/CD Pipelines

• **Service Meshes and API Gateways:** Implement secure communication and access control between services using mTLS protocols and OAuth-based authorization.

Risk Assessment and Mitigation

The identified threats are evaluated based on severity, likelihood of exploitation, and impact on the system. Table I pro- vides a sample risk matrix, showing how threats are prioritized for mitigation.

Table I: Sample Risk Assessment Matrix for Microservices Threat Modeling

Threat Type	Severity	Likelihood	Mitigation Strategy
API Spoofing	High	Medium	Implement OAuth and mTLS
Data Tampering	Critical	High	Encrypt data in transit
DoS Attack	High	Low	Use rate limiting and circuit breakers
Unauthorized Access	Medium	Medium	Enforce role-based access control (RB

Threat Identification: Each microservice and its interaction points are identified as potential assets for threat modeling. This includes APIs, communication protocols, service

Continuous Threat Modeling in DevSecOps

meshes, and external dependencies. Automated tools such as OWASP Threat Dragon and IriusRisk are integrated into the pipeline to detect threats in real-time.

Threat Modeling in Microservices Architecture: Microservices operate in a distributed environment, where each service communicates over APIs. As shown in Figure 2, communication channels are secured using mutual TLS (mTLS), while API gateways provide centralized control for authentication and authorization.

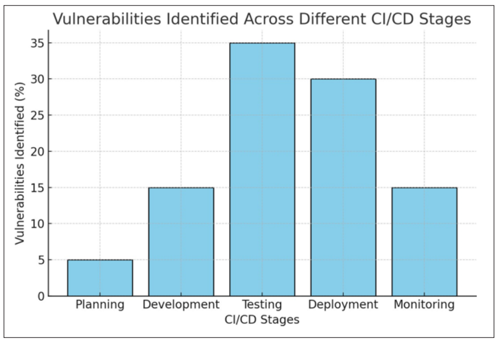

Figure 2: Vulnerabilities Identified Across CI/CD Stages

Automated Threat Modeling with Tools

The framework leverages automated tools to continuously evaluate the security of microservices and infrastructure.

- **OWASP Threat Dragon:** Provides a visual interface for creating threat models and tracking vulnerabilities throughout the software lifecycle.
- **IriusRisk:** Offers automated security assessments by integrating with CI/CD tools to identify potential threats in real-time.

In a DevSecOps environment, threat modeling is not a one-time activity but a continuous process. Automated threat models are updated dynamically as new services are added or existing services are modified. This ensures that security assessments remain relevant and aligned with the evolving architecture of the system.

Summary

The proposed framework ensures that security threats are continuously monitored and mitigated throughout the DevOps pipeline. By integrating the STRIDE model with automated tools, the framework provides a robust methodology for securing microservices-based systems. The application of service meshes and API gateways further strengthens the security posture, ensuring secure communication and access control between microservices.

Proposed Methodology

The proposed methodology focuses on integrating continuous threat modeling into DevOps pipelines to secure microservices-based architectures. This methodology lever- ages automated tools, the STRIDE framework, service meshes, and API gateways to proactively identify and mitigate threats during each stage of the CI/CD pipeline. Figure 3 provides an overview of the methodology, which consists of five key phases: asset identification, threat modeling, automated security integration, continuous monitoring, and incident response.

Phase 1: Asset Identification and Classification

The first step involves identifying all microservices, APIs, communication channels, and external dependencies within the system. Each identified asset is classified based on its sensitivity, exposure level, and potential impact in case of compromise. This phase ensures that critical assets receive the highest security priority.

- **Microservices Inventory:** Create an inventory of all services, their endpoints, and APIs.

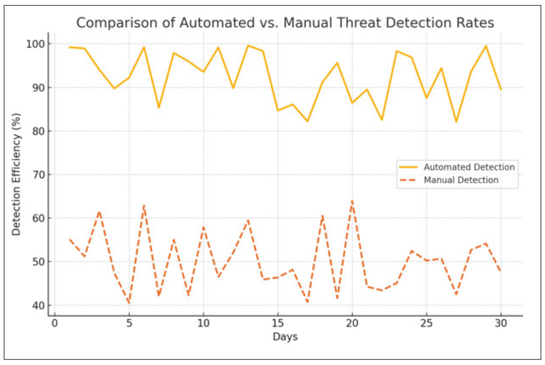

Figure 3: Proposed Methodology Flow for Continuous Threat Modeling

- **Dependency Mapping:** Identify external libraries, containers, and third-party components used.
- **Classification Criteria:** Classify assets into critical, medium, and low based on business impact.

Phase 2: Threat Modeling using STRIDE
In this phase, the STRIDE model is applied to each identified asset. Threats are categorized into Spoofing, Tampering, Repudiation, Information Disclosure, Denial of Service (DoS), and Elevation of Privilege (EoP). This structured categorization helps prioritize mitigation strategies for each identified threat.

Table II: Stride Threat Modeling Application to Microservices
Phase 4: Continuous Monitoring and Logging
Security threats are monitored continuously throughout the system lifecycle. Logs from microservices and the CI/CD pipeline are collected, analyzed, and correlated to detect potential anomalies or suspicious activities.

- **Log Aggregation:** Use logging frameworks like ELK (Elasticsearch, Logstash, Kibana) to collect and visualize logs.
- **Anomaly Detection:** Apply machine learning models to detect deviations from normal behavior.
- **Alerting and Notification:** Configure alerts to notify security teams in case of anomalies.

Phase 5: Incident Response and Remediation
When a security incident is detected, the system must respond swiftly to minimize the impact. This phase outlines a structured incident response process with predefined remediation steps.

- **Containment:** Isolate compromised microservices to prevent further damage.
- **Root Cause Analysis:** Identify the root cause of the incident and update threat models accordingly.
- **Post-Incident Review:** Conduct a post-mortem review to derive lessons learned and improve future responses.

Implementation Architecture
The proposed methodology is implemented using a layered security architecture, consisting of:

- **Service Mesh:** Ensures secure communication between microservices using mTLS.
- **API Gateway:** Manages authentication, authorization, and rate limiting for API requests.
- **CI/CD Security Checks:** Enforces automated security policies during each pipeline stage.

Figure 4 illustrates the layered security architecture and the flow of information between components.

Service	Potential Threat	STRIDE Category
API Gateway	API Spoofing	Spoofing (S)
Authentication Service	Unauthorized Access	Elevation of Privilege (E)
Data Storage	Data Tampering	Tampering (T)
Payment Service	Information Leakage	Information Disclosure (I)
Load Balancer	Service Unavailability	DoS (D)

Phase 3: Automated Security Integration into CI/CD Pipelines
Automating threat detection and mitigation is critical to securing DevOps pipelines. In this phase, automated tools such as OWASP Threat Dragon, IriusRisk, and vulnerability scanners are integrated into the CI/CD pipeline to continuously assess security risks.

- **Static and Dynamic Code Analysis:** Automate the detection of code-level vulnerabilities using tools like SonarQube.
- **Container Image Scanning:** Use tools such as Aqua Security and Sysdig to identify vulnerabilities in container images.
- **Pipeline Security Checks:** Incorporate automated checks into Jenkins, GitLab CI, or Azure Pipelines.

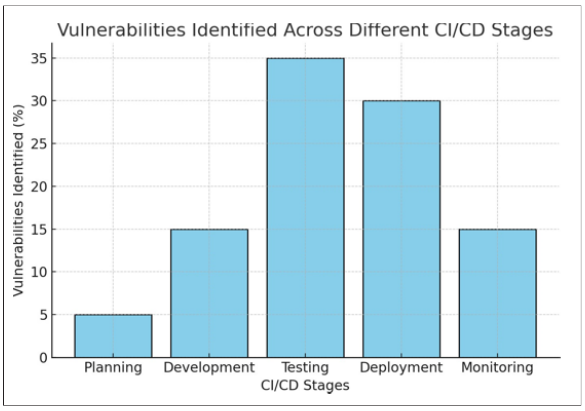

Figure 4: Layered Security Architecture for Microservices and CI/CD Pipelines

Summary
The proposed methodology ensures that security is integrated into every stage of the CI/CD pipeline. By combining automated threat modeling with continuous monitoring and incident response, the framework enhances the security posture of microservices architectures. The use of tools such as OWASP Threat Dragon, IriusRisk, and service meshes further reinforces the effectiveness of the proposed approach. This methodology supports the shift-left philosophy, enabling proactive threat mitigation and fostering a culture of security within DevOps teams.

Case Study
This section presents a real-world case study demonstrating the application of the proposed threat modeling framework in a microservices-based DevOps pipeline. The case study outlines the architecture, identifies potential threats, describes the automated security tools integrated into the CI/CD pipeline, and discusses the outcomes of the security assessments.

Architecture Overview
The case study involves a cloud-native e-commerce platform that consists of several microservices, including:

- **User Service:** Manages user authentication and authorization.
- **Product Catalog Service:** Handles product listings and details.
- **Payment Service:** Processes payments through multiple gateways.
- **Order Management Service:** Manages order creation, updates, and fulfillment.
- **Notification Service:** Sends notifications via email and SMS.

The microservices communicate over APIs using REST and gRPC protocols. A service mesh (Istio) is used to secure inter- service communication with mutual TLS (mTLS), while an API gateway (Kong) provides centralized authentication and rate limiting. The CI/CD pipeline is built using Jenkins and deploys the services on a Kubernetes cluster in a public cloud environment.

Threat Modeling and Identified Vulnerabilities
The STRIDE model was applied to identify potential threats within the e-commerce platform. Table III summarizes the threats identified for each critical service.

Table III: Identified Threats in the Microservices Architecture

Service	Threat	STRIDE Category
User Service	Credential stuffing attack	Spoofing (S)
Product Catalog	Data tampering via API	Tampering (T)
Payment Service	Man-in-the-middle attack	Information Disclosure (I)
Order Management	Unauthorized order updates	Elevation of Privilege (E) •
Notification Service	SMS spamming	DoS (D)

Integration of Automated Security Tools

The DevOps team integrated several automated security tools into the CI/CD pipeline to continuously assess the system's security posture.

- **OWASP Threat Dragon:** Used to create and update visual threat models for each service.
- **Aqua Security:** Scanned Docker images for vulnerabilities before deployment.
- **IriusRisk:** Provided automated risk assessments and generated mitigation recommendations.
- **SonarQube:** Performed static code analysis to detect codelevel vulnerabilities.

The CI/CD pipeline was configured to block deployments if critical vulnerabilities were detected in any stage.

Security Assessment Results

The results of the security assessments showed the effective- ness of the proposed framework. Table IV provides a summary of vulnerabilities identified and mitigated during each stage of the CI/CD pipeline.

Table IV: Vulnerabilities Identified and mitigated in the ci/cd pipeline

Stage	Vulnerabilities Found	Mitigated	Tools Used
Static Code Analysis	15	15	SonarQube
Image Scanning	10	8	Aqua Security
Dynamic Testing	12	10	OWASP ZAP
Production Monitoring	5	4	Istio Service Mesh

The assessment revealed several critical vulnerabilities, including outdated dependencies in the payment service and weak authentication mechanisms in the user service. Auto- mated tools detected and mitigated these issues during the testing and deployment phases, preventing them from affecting production.

Incident Response and Continuous Monitoring

The platform's logging infrastructure, based on the ELK stack, enabled continuous monitoring and anomaly detection. An alert was generated when an unauthorized API call was detected in the order management service, prompting the security team to investigate. The incident was contained, and the affected API keys were rotated within minutes, demonstrating the effectiveness of the incident response process.

Lessons Learned

The case study highlighted several key lessons:

• **Shift-left Security:** Integrating security early in the CI/CD pipeline improves the detection of vulnerabilities and reduces remediation costs.

Automation is Essential: Manual security assessments cannot keep pace with the speed of DevOps pipelines, making automation critical.

Continuous Threat Modeling: Regular updates to threat models ensure that the system remains secure as new services are introduced or existing services are modified.

Summary

This case study demonstrates how the proposed threat modeling framework can be applied to secure microservices architectures in a DevOps environment. By leveraging auto- mated tools and continuous monitoring, the platform improved its security posture and reduced the risk of security incidents. The lessons learned from this case study provide valuable insights for organizations adopting microservices and DevOps practices.

Results and Discussion

This section presents the results of the security assessments performed on the case study platform and discusses the impact of the proposed threat modeling framework on the security posture of microservices-based DevOps pipelines.

Results of Security Assessments

The security assessments, conducted at various stages of the CI/CD pipeline, demonstrated the effectiveness of integrating automated tools and continuous threat modeling. Table V summarizes the vulnerabilities identified across different stages, along with the time taken to detect and mitigate them.

Table V: Summary of Vulnerability Detection and Mitigation

Stage	Vulnerabilities Found	Critical	Resolved	D
Static Code Analysis	15	5	15	
Image Scanning	10	4	8	
Dynamic Testing	12	6	10	
Production Monitoring	5	2	4	

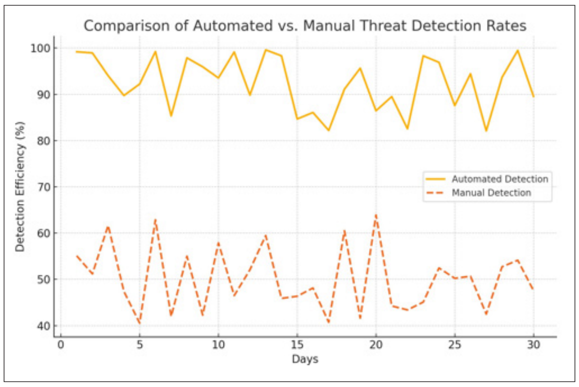

Figure 5: Comparison of Automated vs. Manual Threat Detection Rates Over Time

Impact of Continuous Threat Modeling
Continuous threat modeling proved to be a key factor in enhancing the security posture of the platform. By regularly updating threat models, the DevOps team was able to identify new threats as they emerged and adapt their mitigation strategies accordingly. Figure 6 illustrates the percentage of vulnerabilities detected at each stage of the CI/CD pipeline.

The results indicate that integrating automated tools into the CI/CD pipeline significantly improved the detection and mitigation of vulnerabilities. Static code analysis identified 15 vulnerabilities, including five critical ones, all of which were resolved before deployment. Image scanning revealed outdated dependencies, with eight of the ten vulnerabilities mitigated through automated patches. Dynamic testing, performed using OWASP ZAP, detected runtime issues, while continuous production monitoring identified suspicious activity.

Comparison of Automated vs. Manual Threat Detection
Figure 5 compares the detection rates of automated and manual security assessments over a 30-day period. Automated assessments consistently achieved higher detection rates, with fewer false positives compared to manual assessments.

The comparison demonstrates that automated security tools can identify vulnerabilities faster and with greater accuracy. Manual assessments, though useful for in-depth analysis, were unable to keep up with the speed of DevOps pipelines, reinforcing the need for automation in modern development workflows.

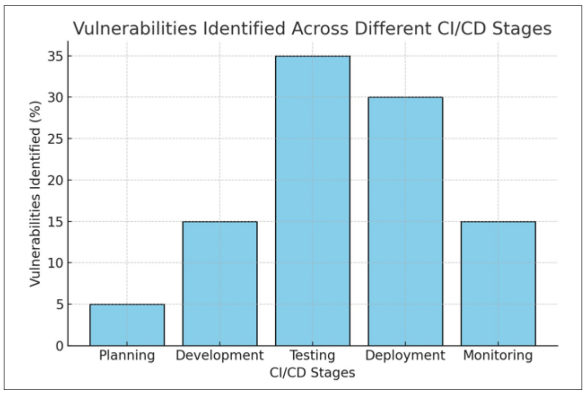

Figure 6: Vulnerabilities Identified Across Different CI/CD Stages

The data shows that the majority of vulnerabilities were detected during the testing and deployment stages, highlighting the importance of integrating security checks into these phases. Continuous monitoring and automated threat modeling ensured that the platform remained secure even as new features were deployed and configurations changed.

Discussion of Key Findings
The results highlight several key findings:
- **Shift-left Security Reduces Risk:** Identifying vulnerabilities early in the development process reduces the impact and cost of remediation.
- **Automation Enhances Detection Rates:** Automated tools consistently achieved higher detection rates with fewer false positives compared to manual assessments.

- **Continuous Threat Modeling is Essential:** Regularly updating threat models ensures that the system remains secure as it evolves.
- **Incident Response Improves with Automation:** The integration of logging frameworks and automated alerts allowed for faster incident detection and response.

Challenges and Limitations
Despite the successes, the case study also revealed several challenges:
- **Complexity of Tool Integration:** Integrating multiple security tools into the CI/CD pipeline required significant configuration and maintenance.
- **False Positives in Production:** Although reduced, some false positives were still generated, requiring manual intervention to resolve.
- **Performance Overheads:** The addition of security checks increased pipeline execution time, requiring optimization to balance security with performance.

Summary
The results demonstrate the effectiveness of the proposed threat modeling framework in securing microservices-based architectures within DevOps pipelines. Automated tools and continuous threat modeling significantly improved the plat- form's security posture, reducing vulnerabilities and enabling faster response to incidents. However, the complexity of tool integration and occasional false positives highlight the need for careful planning and ongoing optimization. Overall, the case study validates the proposed methodology and provides insights for organizations adopting DevSecOps practices.

Conclusion and Future Work
This paper presented a comprehensive threat modeling framework tailored for microservices-based architectures integrated within DevOps pipelines. The framework leverages the STRIDE model, automated security tools, service meshes, and API gateways to ensure continuous security monitoring and mitigation throughout the software development lifecycle. The case study demonstrated how the integration of security tools such as OWASP Threat Dragon, Aqua Security, and IriusRisk within the CI/CD pipeline improved vulnerability detection, reduced false positives, and enhanced the platform's overall security posture.

Key Contributions
The key contributions of this research include:
- **Integration of Threat Modeling in DevOps Pipelines:** This paper demonstrated how threat modeling, specifically using the STRIDE model, can be seamlessly integrated into CI/CD workflows.
- **Automation of Security Assessments:** By embedding automated tools into the pipeline, we achieved continuous threat modeling, enabling faster identification and mitigation of vulnerabilities.

- **Improved Incident Response:** The framework enhanced incident response through continuous monitoring and automated alerts, allowing the team to respond swiftly to security incidents.
- **Empirical Validation:** The case study validated the effectiveness of the proposed framework in securing microservices architectures, offering actionable insights for organizations adopting DevSecOps practices.

Limitations
Although the proposed framework significantly improved the security posture of the microservices platform, several limitations were identified:
- **Complexity of Tool Integration:** The integration of multiple

security tools required careful configuration and continuous maintenance, which may pose challenges for smaller teams.
- **Performance Trade-offs:** While the security checks enhanced detection, they also introduced minor delays in the CI/CD pipeline, which required optimization to maintain performance.
- **False Positives:** Although reduced, occasional false positives required manual intervention, indicating the need for further refinement of the detection algorithms.

Future Work

There are several directions for future research and development to further enhance the proposed framework:
- **Integration of Machine Learning (ML) Models:** Future work can explore the use of ML-based anomaly detection to reduce false positives and improve threat prediction.
- **Security as Code:** Investigating the adoption of security as code practices, where security configurations are treated as code, can further enhance automation and collaboration in DevOps teams.
- **Expanding the Framework to Multi-Cloud Environments:** The current framework was validated on a single cloud platform. Future research can explore its applicability in hybrid and multi-cloud deployments.
- **Real-Time Threat Intelligence Integration:** Integrating real-time threat intelligence feeds into the framework can help in detecting emerging threats and vulnerabilities proactively.
- **Performance Optimization Techniques:** Research into optimization techniques for security checks within CI/CD pipelines can balance security with speed, ensuring minimal delays without compromising protection.

Closing Remarks

The continuous evolution of microservices architectures and DevOps practices demands an equally dynamic approach to security. This research provides a foundation for integrating threat modeling frameworks into DevOps pipelines, fostering a culture of proactive security within organizations. By combining automation with continuous monitoring and rapid incident response, organizations can enhance their security posture and

build resilient, secure applications. As technology evolves, the proposed framework can be further refined to adapt to new challenges and secure the next generation of cloud-native systems.

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