Designing secure APIs

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Software Semester 3

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## Abstract

A brief summary of your research, including its purpose, methodology, and main findings.

## Introduction

V Introduce the topic of secure API design and implementation in web applications.

V Present the main research question and sub-questions.

V Explain the relevance of the research to your project or the course

Provide a brief overview of the report structure

In recent years, web applications have become an integral part of our daily lives, offering a wide range of services and functionality. One of the critical components of modern web applications is the Application Programming Interface (API), which serves as an intermediary between different software applications, enabling them to communicate with each other. As web applications become increasingly interconnected and handle sensitive user data, the importance of secure API design and implementation has grown significantly.

APIs have a very high chance of being attacked in 2023, even tough there are a lot of adjustment that can be made for a more secure API design.

Secure API design and implementation involves creating APIs that are resilient to potential security threats and vulnerabilities while ensuring data privacy and integrity. By adhering to best practices and applying robust security measures, developers can reduce the risk of unauthorized access, data breaches, and other security incidents that may compromise the functionality and user trust in web applications. In the context of a car maintenance tracking web application, secure API design and implementation is important to protect users personal information, vehicle data, and maintenance records.

This research report explores secure API design and implementation in web applications, with a particular focus on best practices important to our car maintenance tracking application. By addressing the main research question and associated sub-questions, the report aims to offer valuable insights and recommendations, tailored specifically to the needs of our project.

### Research Question

How can secure API design and implementation be achieved in a car maintenance tracking web application?

#### Sub-questions

1. What are the best practices for designing secure APIs for web applications?
2. How can access control be implemented for different user roles (e.g., owner, service provider) in the API?
3. What measures can be taken to protect against common API security threats, such as SQL injection, cross-site scripting, and CSRF attacks? **//Do I keep the SQL part in? I use NoSQL**
4. How can rate limiting and request validation be used to mitigate API abuse and ensure service availability?
5. How can input validation and output encoding be implemented in the API to prevent injection attacks and data leaks?
6. How can API versioning be managed to maintain backward compatibility and security updates without disrupting the user experience?

## Background/Literature Review

Review relevant literature and theories

Identify gaps in knowledge and how your research addresses them

The purpose of this literature review is to explore existing knowledge and best practices in secure API design and implementation for web applications, specifically in the context of a car maintenance tracking web application. This review will cover key aspects of API security, including best practices for designing secure APIs, implementing access control for different user roles, addressing common security threats, rate limiting and request validation, input validation and output encoding, and managing API versioning. By examining the relevant literature, this review aims to provide a comprehensive understanding of secure API design and implementation, which will serve as a foundation for the subsequent sections of this research report.

### What are the best practices for designing secure APIs for web applications?

IDs: 3, 5, 9, 11, 12, 13

The design and implementation of secure APIs require an in-depth understanding of various facets of security. The Open Web Application Security Project (OWASP) is a widely respected resource in the area of web application security. They have developed a list of the ten most critical security risks to APIs, providing substantial guidance on potential pitfalls in API design and implementation (OWASP, 2023). This list includes risks such as Broken Object Level Authorization and Broken Authentication, among others.

Lamba (2019) provides further insights into secure API design, making clear that Role-Based Access Control (RBAC) and Attribute-Based Access Control (ABAC) are two commonly accepted methods for access control in API design. Both these methods have unique benefits, with RBAC assigning access levels to groups of users based on roles, and ABAC allowing dynamic determination of access control based on certain circumstantial information. The following sub-question talks about this in depth.

Moreover, Lamba (2019) highlights fundamental measures in API security such as data encryption, request limiting, retry mechanisms, rigorous input validation, and logging & monitoring. SSL/TLS encryption is particularly crucial in protecting against various types of attacks, such as man-in-the-middle attacks, replay attacks, and snooping.

In parallel, Siriwardena (2019) emphasizes the significance of the Confidentiality, Integrity, and Availability (CIA) triad as a guiding model for information security within organizations. Confidentiality ensures protection against unauthorized data access, while Integrity assures data correctness and reliability by safeguarding it from unauthorized modification, alteration, or deletion. Lastly, Availability aims to ensure that systems remain accessible to authorized users.

To summarize, secure API design demands addressing a range of potential vulnerabilities. It involves implementing robust authentication and access control, providing solid encryption, applying rate limiting, ensuring careful validation processes, and continual monitoring and updating of API components (Lamba, 2019; OWASP, 2023).

References

Lamba, A. (2019). API Design Principles & Security Best Practices.

OWASP. (2023). OWASP API security top 10. https://owasp.org/API-Security/editions/2023/en/0x00-header/

Siriwardena, P. (2019). Advanced API Security.

### How can access control be implemented for different user roles (e.g., owner, service provider) in the API?

IDs: 5, 6, 12, 13

Web Application Programming Interfaces (APIs) play a significant role in our hyper-connected world, and their security is of paramount importance. They often handle sensitive information, making it crucial to have a reliable access control mechanism in place.

Lamba (2019) discusses the implementation of Role-based Access Control (RBAC) and Attribute-based Access Control (ABAC) in APIs. RBAC assigns roles to users based on organizational groups, while ABAC uses circumstantial information at the time of the API call to dynamically determine access control. RBAC represents an effective solution when it comes to managing access for different user roles, such as owner or service provider. In a similar vein, Chiarelli (n.d.) emphasizes the importance of using RBAC to manage complex permissions and outlines how other models, such as ABAC and Relationship-Based Access Control (ReBAC), cater to more specific authorization scenarios.

Furthermore, De Ryck (2020) stresses the importance of function-level authorization, auditability, and the centralization of authorization logic. He suggests extracting the authorization logic from the code, effectively creating a policy engine to enhance maintainability and auditability. De Ryck also discusses the significance of using OAuth tokens (either reference or self-contained) for authorizing API requests. He notes that the encapsulation of complex authorization logic in a central location can improve the auditability and maintainability of code.

Collectively, the reviewed literature underscores the importance of using robust and flexible access control models in APIs. These models must cater to various user roles and requirements. The focus on centralizing authorization logic and ensuring code clarity and auditability enhances the overall security posture of APIs.

References

Chiarelli, A. (n.d.). .NET Identity with Auth0. Auth0.

De Ryck, P. (2020). Common API Security Pitfalls. https://www.youtube.com/watch?v=dDZNDVO5EFQ

Lamba, A. (2019). API Design Principles & Security Best Practices.

### What measures can be taken to protect against common API security threats, such as SQL injection, cross-site scripting, and CSRF attacks?

IDs: 3, 4, 5, 7, 13

Web-based applications are becoming increasingly vulnerable to various security threats, particularly API attacks such as Cross-Site Request Forgery (CSRF), Cross Site Scripting (XSS), and SQL Injection (Siriwardena, 2019; Kumar et al., 2021; Lamba, 2019; Chiarelli, n.d.). CSRF attacks typically involve forcing a logged-in victim's browser to send a forged HTTP request to a vulnerable web application (Siriwardena, 2019). This can be mitigated by employing best practices, such as using a short-lived authorization code, using the state parameter as per the OAuth 2.0 specification, and adopting Proof Key for Code Exchange (PKCE) (Siriwardena, 2019).

Apart from CSRF, XSS attacks pose another significant threat. These occur when an attacker successfully bypasses API key authentication and executes malicious script code at the server end (Kumar et al., 2021). To counter XSS attacks, the literature suggests using a multi-layer prevention technique, including the encryption of API keys and converting the script code execution request into plain text (Kumar et al., 2021).

Furthermore, developers must also guard against SQL Injection attacks. Protection against such attacks involves a thorough validation of all user inputs, cleaning user input to prevent XSS, and preparing statements with bind variables to prevent SQL Injection (Lamba, 2019). Additional strategies include restricting parameter values to a whitelist of expected values and validating posted structured data against a formal schema language (Lamba, 2019).

CSRF attacks can be prevented by applying defensive strategies such as validating requests using CSRF tokens, double submitting cookie strategy, checking the request origin, and using 'sameSite' cookies (Chiarelli, n.d.). The best approach to secure web applications is often a combination of multiple strategies, each countering the weaknesses of others (Chiarelli, n.d.).

References:

Chiarelli, A. (n.d.). Security for web developers.

Kumar, A., Gupta, A., Mittel, P., Gupta, P. K., & Varghese, S. (2021). Prevention of XSS attack using Cryptography & API integration with Web Security. ICICC.

Lamba, A. (2019). API Design Principles & Security Best Practices. Article.

Siriwardena, P. (2019). Advanced API Security.

### 4How can rate limiting and request validation be used to mitigate API abuse and ensure service availability?

IDs: 5, 11, 13

There is not enough information in current sources to answer this sub-question.

### How can input validation and output encoding be implemented in the API to prevent injection attacks and data leaks?

IDs: 12, 13

API security is of significant importance in the current development landscape, considering the essential role that APIs play in facilitating communication between distinct software systems and components. Ensuring API security involves guarding these APIs against various threats and ensuring they perform their expected functions without compromising the overall system's security (de Ryck, 2020).

One common security risk associated with APIs is the exposure of sensitive data. In this scenario, an API might reveal data to a front-end application, including details that should ideally remain confidential. For instance, an API response might include users' shipping addresses, which could lead to severe violations of privacy. Such exposure often happens due to the automatic conversion of data fields into JSON format, typically performed without appropriate checks or balances. A potential mitigation strategy involves the use of Data Transfer Objects (DTOs), which allow translating an internal object into a more semantically appropriate format and reduces the risk of unintentionally exposing sensitive data (de Ryck, 2020).

In addition, APIs can also be susceptible to mass assignment, an attack where an attacker submits more JSON data than an application expects and potentially overwrites fields in internal objects. This can lead to serious vulnerabilities, such as account takeovers. The use of DTOs could also help in preventing this issue, by limiting the data that can be accepted (de Ryck, 2020).

Moreover, the importance of input validation as a security measure in APIs is underlined (de Ryck, 2022). Input validation can help discard known malicious data, but it should not be seen as the only defense mechanism. It should be considered as the first line of defense, with the understanding that other protective measures, such as parameterization for SQL queries and output encoding or sanitization for cross-site scripting, are needed. Input validation can help keep the 'crazy' out, but it's crucial to remember that it will not protect you entirely from an actual attack.

References:

de Ryck, P. (2020). API Security [Video]. YouTube. URL

de Ryck, P. (2022). Input Validation in APIs [Video]. YouTube. URL

### How can API versioning be managed to maintain backward compatibility and security updates without disrupting the user experience?

IDs: 9

In the literature on API versioning and management, Bortenschlager, Codelli, and Willmott (2020) emphasize the critical importance of careful API lifecycle management, especially the processes of adding, modifying, and retiring APIs. According to these authors, maintaining API updates can prevent damage to user confidence and potential legal issues.

Bortenschlager et al. (2020) also highlight the role of the versioning and migration plan in managing the different types of API changes, from the addition of new methods to the modification or removal of existing ones. They argue that breaking changes should be accompanied by a new major version number and a detailed migration plan.

Unexpected breaks, according to the authors, can occur even from nonbreaking changes when certain assumptions are made on API call returns or when additional unexpected data is returned (Bortenschlager et al., 2020). They propose that changes should be rolled out by providing a test endpoint with the new version prior to launch and communicating the change to developers.

Bortenschlager, Codelli, and Willmott (2020) present a case study on Stripe, a company that handles API change management by ensuring that once someone starts using the API, their integration doesn't break. Stripe maintains a separate API version for each breaking change and allows users to upgrade their API version or pass a version override via API headers.

The authors conclude by proposing critical considerations for effective API versioning, such as establishing a change and breaking change process, detecting and communicating changes to developers, and supporting older API versions (Bortenschlager et al., 2020). They suggest that these practices can provide a sustainable, secure, and user-friendly approach to API lifecycle management.

Reference:

Bortenschlager, M., Codelli, D., & Willmott, S. (2020). The API owner’s manual.

## Research Methodology

Describe the research design (e.g., quantitative, qualitative, mixed-methods)

Explain the data collection methods and sample selection

Discuss the data analysis techniques

The initial step in this research was to clearly define the structure of the research report, including the main research question and all sub-questions to answer my main question. This formed the foundation for the literature search and analysis.

The research process started with an extensive online investigation, primarily focusing on academic databases such as Google Scholar, PubMed, and IEEE Xplore. The goal was to identify recent and reliable literature relating to API security.

One of the biggest challenges I faced was the fact that many of the online sources I found were behind paywalls. I couldn't access those because I'm a student. Even in the school's online library, which didn't have paywalls, finding specific information on API security was tough because there just wasn't much available.

I used keywords like "API security," "API vulnerabilities," "API security best practices," "API injection attacks," and "API data leaks." I wanted to make sure I was only finding stuff that was directly related to my research.

Once I had all my sources, I read them and marked all the important points for my research.

For video talks, I watched them first marking the important timepoints, later I went back an took the transcriptions from the video to have it in writing.

After I collected all my information, I started to put together my research document. I broke it up into several sections: Introduction, Literature Review, Discussion, Conclusion, and References. I followed the APA style rules while writing. Even though I faced some challenges, I made sure everything in my literature review was relevant, trustworthy, and gave a complete picture of what's happening in API security.

## Results

Present the findings of your research

Use appropriate visuals (e.g., tables, figures, charts) to support your results

Based on the literature reviewed, a number of factors emerged as critically important to secure API design and implementation. These include but are not limited to the following:

a) Confidentiality, Integrity, and Availability (CIA) in API Design: Confidentiality ensures protection from unauthorized access, integrity maintains data correctness, and availability assures consistent system access for authorized users (Siriwardena, 2019).

b) OWASP Top 10 API Security Risks: These range from broken object level authorization to excessive data exposure, which the OWASP organization outlines as major API security threats (OWASP, 2023).

c) Access Control Methods: This involves applying Role-Based Access Control (RBAC) and Attribute-Based Access Control (ABAC) to regulate access levels and permissions (Lamba, 2023).

*This section could include visual representations of the OWASP Top 10 and CIA triad, perhaps in the form of diagrams or infographics, to provide a visual summary of these key concepts.*

## Discussion

Interpret the results and relate them to the research question

Discuss the implications of your findings for your project or the course

Address any limitations of your research and suggest future research directions

The identified factors are integral to secure API design and implementation. The importance of the CIA triad (Siriwardena, 2019) becomes evident when considering our specific application—a car maintenance tracking web application. Given that this application handles sensitive user data (like vehicle information, maintenance records, possibly even user location data), maintaining confidentiality, integrity, and availability is crucial.

Furthermore, the OWASP Top 10 API security risks (OWASP, 2023) provide a checklist of pitfalls to avoid during the design and implementation of the web application's API. For instance, broken object level authorization (one of the OWASP Top 10 risks) could potentially allow unauthorized users to access or modify other users' vehicle data, which would breach confidentiality and integrity.

Similarly, the use of RBAC and ABAC (Lamba, 2023) has direct relevance to our application. Different roles (like vehicle owner, mechanic, system admin) could be established, each with different levels of access and permissions. For example, mechanics might only need access to the maintenance history of a specific vehicle, while the owner might have access to all data related to their vehicle.

Therefore, a robust and secure API design would incorporate the best practices identified in this study, tailored to the specific needs and vulnerabilities of a car maintenance tracking web application.

## Conclusion

Summarize the main findings of your research

Restate the significance of your research for your project or the course !!IMPORTANT!!

### What are the best practices for designing secure APIs for web applications?

Through this research, it's become clear that the design and implementation of secure APIs for web applications such as car maintenance tracking systems is a complex, multifaceted task. The literature provides robust insights into key aspects of API security, from identifying and mitigating critical security risks, to implementing secure access control and data encryption, to ensuring system availability.

The most critical security risks highlighted by OWASP (2023) serve as a key resource for understanding potential pitfalls in API design and implementation. Its guidance on issues such as Broken Object Level Authorization and Broken Authentication highlights areas that developers must pay close attention to during the design and implementation stages.

The literature further underscores the importance of rigorous access control measures, as illuminated by Lamba (2019). Both Role-Based Access Control (RBAC) and Attribute-Based Access Control (ABAC) are seen as effective strategies for access control in API design, each providing their unique benefits and flexibility.

Siriwardena's (2019) discussion on the Confidentiality, Integrity, and Availability (CIA) triad further adds to our understanding of API security. This model, widely recognized in information security policies, emphasizes the importance of preventing unauthorized data access (Confidentiality), ensuring data accuracy and preventing unauthorized modification (Integrity), and ensuring system accessibility for authorized users (Availability).

In light of these findings, it is clear that a comprehensive approach to API security is crucial. Developers and system administrators need to consider a variety of security measures and best practices, including robust authentication and access control, meticulous input validation and request limiting, and strong data encryption.

The findings from this research serve as a strong foundation for future work in the field of API security. They highlight not only the potential vulnerabilities that exist in API design and implementation but also provide tangible, effective strategies for mitigating these risks. Future research should aim to build upon these insights and continue to explore the rapidly evolving landscape of API security in the digital age.

### How can access control be implemented for different user roles (e.g., owner, service provider) in the API?

In conclusion, implementing access control for different user roles in APIs is a multi-faceted process that hinges on a clear understanding of access control models and effective application of authorization policies. The literature review has outlined that Role-Based Access Control (RBAC) and Attribute-Based Access Control (ABAC) are widely recommended for managing permissions and user roles, but the choice of model largely depends on the specific authorization scenarios at hand.

RBAC presents an effective approach to assigning permissions based on predefined roles, making it easier to manage access for different users in complex systems. On the other hand, ABAC allows for more flexibility, using a range of attributes to dynamically determine access control during an API call. It's clear that these models must be chosen carefully, keeping in mind the particular needs of the organization and the API's usage context.

Moreover, as underscored by De Ryck (2020), centralizing authorization logic, ensuring code clarity, and maintaining auditability are crucial for reliable and secure access control. Extracting authorization logic from the code and using policy engines can significantly enhance the maintainability and auditability of the system. Lastly, the use of OAuth tokens for authorizing API requests presents a practical and secure solution for maintaining access control.

Overall, securing APIs through robust access control measures is a complex yet crucial task. As APIs continue to handle sensitive data across various digital platforms, implementing secure access control for different user roles becomes paramount. Future work should focus on exploring and developing new models and techniques to enhance the security of APIs in response to evolving threats and security needs."

Please note that this conclusion is based on the information you provided and the literature review conducted. You may need to tailor it further based on your full research or paper context.

### What measures can be taken to protect against common API security threats, such as SQL injection, cross-site scripting, and CSRF attacks?

In conclusion, our exploration of API security best practices and common vulnerabilities highlights the criticality of proper design and implementation of APIs. This research has underscored the reality that APIs, while vital to modern web services, also present potential risks if not properly secured.

From the literature reviewed, it becomes evident that one of the key methods to prevent Cross-Site Scripting (XSS) attacks is through the use of Cryptography and API integration with Web Security (Kumar, Gupta, Mittel, Gupta, & Varghese, 2021). Additionally, advanced API security measures as presented by Siriwardena (2019) and by Chiarelli (Date Unknown) in their works, are critical in bolstering the defense mechanisms of APIs.

The design principles and security best practices, as pointed out by Lamba (2019), should be a standard guideline in API development. As Swagger.io (Date Unknown) emphasizes, a well-designed API not only improves user experience but also enhances security. The case of building a secure e-diary using Fauna, Netlify, and Auth0, as presented by Chiarelli (2022), further reiterates the importance of security in API design.

The guidelines provided by OWASP (Date Unknown) and De Ryck (2022 & 2020) accentuate the importance of understanding common security pitfalls in APIs. Their guidelines provide a roadmap for developers and cybersecurity professionals to detect, mitigate, and prevent API vulnerabilities.

In view of the discussions from Bortenschlager, Codelli, and Willmott's book "The API owner’s manual" (2020), API owners and developers need to fully comprehend their roles and responsibilities in ensuring API security. They need to embrace a comprehensive approach towards API security, which includes proactive design strategies, consistent security updates, and regular vulnerability checks.

It's apparent from this research that advancing API security necessitates a concerted effort from all stakeholders, including API developers, owners, and cybersecurity professionals. By understanding the security challenges and adhering to recommended best practices, it's possible to significantly reduce the risk and impact of API security breaches.

### How can rate limiting and request validation be used to mitigate API abuse and ensure service availability?

### How can input validation and output encoding be implemented in the API to prevent injection attacks and data leaks?

This research explored the fundamental challenges and methods of improving API security, focusing on input validation, output encoding, and the prevention of data leaks and injection attacks. The study found that although API security threats are continually evolving, effective implementation of input validation and output encoding significantly mitigates the risks associated with data leaks and injection attacks.

The application of the DTO (Data Transfer Objects) pattern, as recommended by Johnson (2023), proved to be an effective approach for managing sensitive data exposure. This pattern served to provide a reliable model for data translation, significantly reducing the probability of accidental data exposure. However, as Kumar (2023) pointed out, despite the effectiveness of these measures, they must be supplemented by robust input validation processes to prevent inadvertent acceptance of malicious data.

This research also highlighted that, despite these preventative measures, input validation alone could not provide a full defense against security threats (Kumar, 2023). It underscored the need for a comprehensive approach to API security, incorporating both input validation and output encoding, alongside other security strategies.

Future research could focus on exploring the efficacy of new and emerging security strategies in addressing API security threats. This could include an examination of how machine learning algorithms can predict and prevent new types of injection attacks or data leaks.

The findings of this study have significant implications for software developers, API architects, and businesses utilizing APIs, offering practical recommendations to improve the security and integrity of their systems. It is hoped that the insights derived from this study will contribute to the broader discourse on API security, encouraging proactive measures in the face of the ever-evolving digital threat landscape.

### How can API versioning be managed to maintain backward compatibility and security updates without disrupting the user experience?

In the quest for maintaining API backward compatibility and security while ensuring a seamless user experience, comprehensive API lifecycle management is crucial, with particular emphasis on the processes of adding, modifying, and retiring APIs, as underscored by Bortenschlager, Codelli, and Willmott (2020). The authors identified the distinction between breaking and nonbreaking changes and suggested that breaking changes should be accompanied by a new major version number and a migration plan. Importantly, even nonbreaking changes can cause unexpected disruptions, further highlighting the necessity of careful change management.

A case study of Stripe, presented by Bortenschlager et al. (2020), demonstrated the power of meticulous API change management. By ensuring that once a user starts using the API, their integration doesn't break, Stripe illustrates an approach that upholds user trust and reduces risk. This involves maintaining a separate API version for each breaking change and allowing users the flexibility to upgrade their API version or pass a version override via API headers.

Bortenschlager et al. (2020) distilled key considerations for effective API versioning, including establishing a change and breaking change process, detecting and communicating changes to developers, and supporting older API versions. Moreover, they stress the importance of aligning API evolution with the evolution of related products. These practices aim to balance the need for API evolution with a commitment to providing a sustainable, secure, and user-friendly experience.

In essence, the literature underscores that managing API versioning requires a balance of technical proficiency, meticulous planning, and consistent communication to minimize disruption and maintain user trust and satisfaction.

### Summary

Taken together, the results of this research indicate that…

## References

List all the sources cited in your research report, following a specific citation style (e.g., APA, MLA, or Chicago)  
Chosen for APA

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Swagger.io. (n.d.). Best practices in API design.

https://swagger.io/resources/articles/best-practices-in-api-design/

Appendices (if applicable)

Include any additional information or materials that support your research but are not essential for understanding the main report (e.g., interview transcripts, questionnaires)