DESIGN AND IMPLEMENTATION OF A SECURE URL SHORTENING SYSTEM USING JWT-BASED AUTHENTICATION AND RESTFUL APIs

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Abstract

URL shortening systems are commonly used to simplify long web addresses into short and easily shareable links, enabling efficient communication across digital platforms. However, many existing URL shortening services operate without adequate authentication and access control mechanisms, making them vulnerable to security threats such as phishing attacks, malicious redirection, and unauthorized link generation. These security limitations highlight the need for a more reliable and controlled approach to URL shortening. This paper presents the design and implementation of a secure URL shortening system using JWT-based authentication and RESTful APIs. The proposed system restricts URL creation and management to authenticated users by employing JSON Web Tokens (JWT) for stateless and secure user authentication. RESTful APIs are utilized to ensure modularity, scalability, and seamless interaction between the client and server components. The backend is developed using Spring Boot integrated with Spring Security to enforce authorization policies, while a relational database is used to store user credentials, URL mappings, and access logs. In addition to secure URL generation, the system provides URL usage analytics that enable users to monitor link access behavior and improve transparency. Experimental results indicate that the proposed system enhances security, scalability, and reliability when compared to conventional URL shortening services. The solution effectively mitigates common security risks while maintaining efficient URL redirection, making it suitable for secure web application environments.

I.Introduction

In today's digital world, the rapid growth of web applications, social media platforms, and online communication systems has significantly increased the need for efficient and user-friendly link-sharing mechanisms. Web addresses often contain long and complex strings that are difficult to share, remember, or embed within limited-character platforms such as messaging applications and social media posts. URL shortening services address this challenge by converting lengthy web links into short, compact URLs there direct users to the original destination, thereby improving usability and accessibility.

Despite their widespread adoption, traditional URL shortening services often prioritize convenience over security. Most publicly available shorteners allow anonymous users to generate shortened links without authentication or access control. This lack of security has made URL shortening services an attractive target for cybercriminals, who exploit them to conceal malicious websites, conduct phishing attacks, distribute malware, and bypass security filters. As users are unable to easily identify the destination of shortened links, they are more vulnerable to deception, leading to increased security risks and loss of trust in such services.

With the increasing reliance on RESTful APIs and distributed web architectures, securing backend services has become a critical requirement. Modern web applications require scalable and stateless authentication mechanisms that can efficiently manage user sessions without compromising performance. JSON Web Tokens (JWT) have emerged as a widely adopted solution for securing RESTful APIs due to their lightweight structure, stateless nature, and ability to support role-based access control. When combined with established security frameworks such as Spring Security, JWT provides a robust approach for enforcing authentication and authorization in web applications.

This paper presents the design and implementation of a secure URL shortening system that integrates JWT- based authentication with RESTful APIs. The proposed system ensures that only authenticated and authorized users can generate and manage shortened URLs, thereby preventing unauthorized access and misuse. In addition to secure link generation, the system offers user-specific URL management and click-based analytics to enhance transparency and accountability. By addressing the security limitations of conventional URL shorteners, the proposed solution aims to provide a reliable, scalable, and secure platform suitable for real- world and enterprise-level applications.

II.PROBLEM STATEMENT

URL shortening services are widely used to simplify long web addresses for easy sharing across digital platforms. While these services improve usability and accessibility, most existing URL shorteners operate without proper authentication, authorization, or user accountability. The absence of security controls allows anonymous users to generate shortened links, which can be misused for phishing attacks, malicious redirection, spam distribution, and unauthorized content sharing. As a result, users are often unable to verify the authenticity or ownership of shortened URLs, increasing security risks and reducing trust.

Additionally, traditional URL shortening systems lack effective mechanisms to manage user-specific URLs and monitor link usage. Without controlled access and analytics, it becomes difficult to track malicious activity, identify misuse, or enforce accountability. Many systems also rely on insecure or outdated authentication techniques that do not scale well in modern distributed web environments.

With the growing adoption of RESTful APIs and cloud-based applications, there is a critical need for a secure, scalable, and stateless URL shortening solution that ensures controlled access and reliable data protection. Existing solutions fail to integrate modern authentication standards such as JSON Web Tokens (JWT) with RESTful architectures, leading to vulnerabilities in session management and API security.

Therefore, the problem addressed in this work is the design and implementation of a secure URL shortening system that incorporates JWT-based authentication and RESTful APIs to prevent unauthorized access, enhance user accountability, and provide secure and efficient URL management while maintaining high performance and scalability.

III. LITERATURE REVIEW

URL shortening services have become an essential component of modern web applications due to their ability to transform long, unwieldy links into compact and easily shareable URLs. While early research focused on the functional advantages and widespread adoption of URL shorteners, subsequent studies have highlighted significant **security and privacy concerns** associated with their use. Several works have analyzed how traditional short link architectures lack adequate safeguards, making them susceptible to misuse by attackers. For example, large-scale empirical studies have demonstrated that popular public services like Bitly can be exploited to conceal malicious URLs, enabling phishing campaigns and the propagation of harmful content without immediate detection. These investigations revealed that the absence of robust threat detection and link validation mechanisms allows attackers to evade existing safeguards, leading to compromised user trust and potential system abuse

Further research has examined the broader **security risks inherent in URL shortening**, such as the vulnerability of short token spaces to brute-force enumeration, which can reveal sensitive content unintentionally shared through cloud storage or mapping services. Such vulnerabilities highlight the inherent risk of systems that employ small search spaces for link tokens and lack access controls, potentially exposing private resources to unauthorized users arXiv. Other studies have focused on *user behavior-related security risks*, especially in ad-supported shorteners, where the interaction patterns of end users can inadvertently expose them to malicious advertising domains and increased attack surfaces, reinforcing the need for enhanced validation and monitoring strategies

In the context of API-driven systems, securing RESTful interfaces has emerged as a critical concern. Contemporary research on API security underscores the prevalence of threats such as broken authentication, injection attacks, and excessive data exposure, particularly in microservice architectures where REST APIs are ubiquitous. To mitigate these risks, scholars have recommended multi-layered security frameworks incorporating strong authentication schemes and enforcement of access controls at every API layer Ijeret. **JSON Web Tokens (JWT)** have been cited as a widely adopted token-based method for enforcing stateless authentication in REST API environments, improving scalability and reducing server-side session overhead. Studies have highlighted JWT's effectiveness in securing web services by providing signed tokens that clients can use to access protected resources without repeatedly transmitting credentials. However, they also caution against inherent challenges such as token revocation, token lifecycle management, and secure storage, which must be addressed to prevent session hijacking or unauthorized access

Security research focused specifically on RESTful API development emphasizes the integration of token-based authentication techniques such as JWT alongside secure password hashing and encryption mechanisms to protect application endpoints from unauthorized access. These strategies strengthen overall data protection and reduce the risk of credential compromise in distributed systems . Collectively, this body of literature underscores the need for **secure authentication frameworks**, continuous monitoring, and

layered defense mechanisms to protect URL shortening services and their underlying APIs from evolving cyber threats. Integrating JWT authentication with well-designed RESTful APIs represents one promising approach to address these security challenges while maintaining system performance and user convenience. Do you like this personality?

IV. PROPOSED SYSTEM ARCHITECTURE

The proposed secure URL shortening system is designed using a modular, client–server architecture that follows RESTful principles and emphasizes security, scalability, and maintainability. The architecture integrates JWT- based authentication to ensure controlled access and prevent unauthorized usage of the URL shortening service. Each system component is loosely coupled, enabling independent development and easy future enhancements.

Overall Architecture Design

The system consists of three primary components: the client application, the backend server, and the database layer. The client application interacts with the backend exclusively through RESTful APIs, while the backend enforces authentication, authorization, and business logic. JSON Web Tokens (JWT) are used to establish stateless and secure communication between the client and server.

Client Layer

The client layer provides the user interface for registration, login, URL shortening, and analytics viewing. It sends HTTP requests to backend APIs and includes the JWT token in the request headers for all protected operations. This approach ensures that user credentials are never repeatedly transmitted, reducing the risk of credential exposure. The client also handles token storage and session persistence on the user side.

Authentication and Security Layer

The authentication layer is responsible for verifying user identity and enforcing access control. When a user successfully logs in, the system generates a signed JWT containing user identity and role information. This token is returned to the client and must be presented with each subsequent request. On the server side, security filters validate the token's integrity and expiration before granting access to protected resources. This stateless authentication mechanism improves scalability and simplifies session management.

Application and Business Logic Layer

The application layer implements core system functionalities, including URL generation, redirection, user-specific URL management, and analytics tracking. Unique short codes are generated for each original URL and stored securely in the database. When a shortened URL is accessed, the system retrieves the corresponding original URL and performs a redirection while simultaneously recording access details such as timestamp and user metadata. Business rules ensure that users can only manage URLs they have created.

RESTful API Layer

All system functionalities are exposed through RESTful APIs, enabling standardized communication between the client and backend. Separate API endpoints are defined for authentication, URL management, redirection, and analytics. This design promotes interoperability, ease of integration with external systems, and adherence to industry best practices for web service development.

Data Persistence Layer

The data layer uses a relational database to store user credentials, shortened URL mappings, and access logs. Database access is handled through an object–relational mapping framework, ensuring efficient data retrieval and consistency. Proper indexing and normalization are applied to optimize performance and support scalability as the number of users and URLs increases.

System Workflow

1. A user registers and logs into the system.
2. Upon successful authentication, a JWT is issued to the client.
3. The client uses the JWT to access protected API endpoints.
4. The backend validates the token and processes URL shortening or analytics requests.
5. When a shortened URL is accessed, the system performs redirection and records usage data.

Architectural Advantages

The proposed architecture enhances security through token-based authentication, improves scalability through stateless communication, and ensures maintainability through modular design. By integrating JWT with RESTful APIs, the system effectively addresses the limitations of traditional URL shortening services and provides a secure foundation for real-world deployment.

The development of the secure URL shortening system was carried out using a structured and iterative methodology to ensure reliability, security, and scalability. The methodology emphasizes requirement analysis, modular design, secure implementation, and continuous testing throughout the development lifecycle. Each phase was carefully planned to address both functional and non-functional requirements of the system.

1. Requirement Analysis

The initial phase involved identifying system requirements based on common limitations observed in traditional URL shortening services. Functional requirements included user registration, secure authentication, URL shortening, redirection, and usage analytics. Non-functional requirements focused on security, performance, scalability, and usability. Special emphasis was placed on preventing unauthorized access and ensuring secure API communication.

2. System Design

Based on the identified requirements, a modular system architecture was designed following RESTful principles. The system was divided into independent layers such as the client layer, authentication layer, application layer, and data layer. JWT-based authentication was selected to enable stateless session management and to support secure, scalable user authentication. API endpoints were clearly defined to separate authentication, URL management, and analytics functionalities.

3. Authentication and Security Implementation

Security was integrated at the core of the system. User credentials are securely stored using hashing techniques. During login, credentials are verified and a JSON Web Token (JWT) is generated upon successful authentication. The token contains essential user information and an expiration timestamp. For every subsequent request, the token is validated using security filters before access to protected resources is granted. This approach eliminates server- side session storage and enhances scalability.

4. URL Shortening and Redirection Development

The URL shortening module was implemented to generate unique short identifiers for long URLs. Each shortened URL is mapped to its original address and stored in the database along with user information. When a shortened URL is accessed, the system retrieves the corresponding original URL and performs a redirection. Simultaneously, access details such as timestamp and user metadata are recorded for analytical purposes.

5. Analytics and Monitoring Implementation

To improve transparency and user control, an analytics module was developed to track the usage of shortened URLs. This module records click counts and access times, enabling users to monitor link activity. The collected data helps in understanding usage patterns and detecting potential misuse.

6. Frontend Development

The frontend interface was developed to provide an intuitive and user-friendly experience. It includes pages for registration, login, URL creation, and analytics visualization. Secure communication with the backend is ensured by attaching JWT tokens to protected API requests. The frontend design prioritizes simplicity and responsiveness to enhance usability.

7. Testing and Validation

Comprehensive testing was conducted at each stage of development. Functional testing ensured that all features operated as intended, while security testing verified that unauthorized users were unable to access protected APIs. Performance testing evaluated URL redirection speed and system responsiveness under normal load conditions. Identified issues were resolved through iterative improvements.

8. Deployment and Evaluation

After successful testing, the system was deployed in a controlled environment for evaluation. The deployed system was assessed based on security, performance, and usability metrics. Results indicated that the JWT-based authentication mechanism effectively prevented unauthorized access while maintaining efficient URL redirection.

V.SYSTEM ARCHITECTURE LAYERS

The secure URL shortening system is designed using a layered architecture to ensure clear separation of concerns, improved maintainability, and enhanced security. Each layer performs a specific function and interacts with adjacent layers through well-defined interfaces. This layered approach allows the system to scale efficiently while maintaining robust security and reliability.

1. Presentation Layer

The presentation layer is responsible for user interaction and visualization. It provides interfaces for user

registration, login, URL shortening, and analytics viewing. This layer communicates with the backend through RESTful API calls and does not directly access the database. For all protected operations, the presentation layer includes the JWT token in the request headers, ensuring secure communication. By handling only user interface logic, this layer remains independent of backend implementation details.

2. API Layer

The API layer acts as a communication bridge between the client and the server. It exposes RESTful endpoints for authentication, URL creation, redirection, and analytics retrieval. Each endpoint follows standard HTTP methods to maintain consistency and interoperability. This layer ensures that requests are properly structured and routed to the appropriate business logic components.

3. Security Layer

The security layer enforces authentication and authorization policies across the system. It validates JWT tokens received with client requests, checks token expiration, and verifies user roles before granting access to protected resources. By adopting stateless authentication, this layer eliminates the need for server-side session storage, thereby improving system scalability and performance. Unauthorized or invalid requests are blocked at this level to prevent security breaches.

4. Application (Business Logic) Layer

The application layer contains the core functionality of the system. It handles operations such as generating unique shortened URLs, managing user-specific links, processing redirection requests, and recording analytics data. Business rules ensure that users can access and modify only the URLs they have created. This layer also coordinates interactions between the API layer and the data layer.

5. Analytics and Logging Layer

The analytics layer is responsible for collecting and processing URL usage data. It records information such as access count, timestamp, and user-related metadata whenever a shortened URL is accessed. Logging mechanisms are also implemented to track system activities and support auditing and troubleshooting. This layer enhances transparency and system monitoring.

6. Data Persistence Layer

The data layer manages the storage and retrieval of all system data. It maintains structured records of users, shortened URLs, and analytics logs in a relational database. Data access operations are handled through an object– relational mapping framework, ensuring consistency, integrity, and efficient querying. This layer is isolated from direct client access to protect sensitive information.

7. Infrastructure Layer

The infrastructure layer provides the runtime environment required for system deployment and operation. It includes the application server, database server, and network configuration. This layer supports scalability, reliability, and secure communication through proper configuration and resource management.

Layered Architecture Benefits

The layered architecture enhances system security by isolating sensitive operations within dedicated layers. It improves maintainability by allowing individual layers to be updated without affecting the entire system. Additionally, the separation of concerns supports scalability and future enhancements, making the system suitable for real-world and enterprise-level deployment

VI.TECHNICAL STACK AND TOOLS USED

While the proposed mobile code editor demonstrates the practicality of cloud-based program execution on mobile devices, certain limitations and considerations should be acknowledged for a balanced assessment.

Dependence on Internet Connectivity:

The execution of programs relies on stable internet access for cloud-based compilation. Network interruptions may affect execution speed or availability.

Prototype-Level Evaluation:

The current implementation has been tested on a limited scale using sample programs and devices. Large- scale usage patterns and long-term performance have not yet been fully evaluated.

Limited Offline Functionality:

The system does not support offline code execution, which may restrict usability in environments with poor or no connectivity.

Execution Latency:

Although optimized for responsiveness, execution time may vary depending on network conditions and

cloud service load.

Scalability Constraints:

High concurrent user requests may impact performance, requiring further optimization and load-balancing mechanisms for large-scale deployment.

Security Considerations:

Handling user authentication and code data requires strong security practices. Continuous monitoring and secure API management are essential to prevent misuse.

Language-Specific Limitations:

Execution behavior and supported features may vary across programming languages due to differences in cloud compiler capabilities.

Generalization Across Use Cases:

The system is primarily designed for learning and practice. Additional customization may be required to support advanced development or enterprise-level use cases.

VII. TECHNICAL IMPLEMENTATION DETAILS

The secure URL shortening system is technically implemented using a service-oriented architecture that integrates JWT-based authentication with RESTful APIs. The implementation emphasizes stateless communication, secure access control, efficient URL mapping, and reliable data persistence. Each technical component is designed to operate independently while contributing to the overall system functionality.

Backend Service Implementation

The backend is developed using a Java-based web framework that supports RESTful service creation and security integration. Controllers are implemented to handle HTTP requests for authentication, URL shortening, redirection, and analytics. Each controller method corresponds to a specific API endpoint and processes client requests in a structured manner. Business logic is encapsulated within service classes to maintain clean separation between request handling and core operations.

JWT-Based Authentication Mechanism

JWT authentication is implemented to provide stateless and secure user sessions. During the login process, the system verifies user credentials and generates a signed JWT containing user identification data and token validity information. The token is digitally signed using a secret key to prevent tampering. For every subsequent request, the client includes the token in the request header. A request filter validates the token before allowing access to protected resources, ensuring secure and efficient authorization.

RESTful API Design

The system exposes a set of RESTful APIs that follow standard HTTP conventions. Separate endpoints are defined for user authentication, URL creation, URL retrieval, redirection, and analytics access. Data exchange between the client and server is performed using lightweight data formats. Stateless API design enables scalability and simplifies load distribution across multiple server instances.

URL Short Code Generation Logic

The URL shortening logic generates a compact and unique identifier for each original URL. The system ensures uniqueness by checking existing mappings before persisting new entries. Each short code is associated with the corresponding original URL and the user who created it. This association enables user-specific URL management and prevents unauthorized modifications.

Redirection Handling

When a shortened URL is accessed, the system extracts the short code from the request path and queries the database for the associated original URL. Upon successful retrieval, the system performs an HTTP redirection to the destination URL. The redirection process is optimized to minimize latency while ensuring accurate URL resolution.

Data Persistence and Access Management

The data layer uses a relational database to store user records, URL mappings, and access logs. Database operations are performed using a data access abstraction layer that simplifies query execution and ensures consistency. Referential integrity and indexing strategies are applied to improve performance and support scalability.

Analytics Data Collection

An analytics component is implemented to record access events for each shortened URL. The system logs

details such as access count and timestamp during each redirection. This information is stored securely and made available only to authorized users for monitoring and analysis purposes.

Error Handling and Security Validation

The system incorporates comprehensive error handling mechanisms to manage invalid requests, authentication failures, and access violations. Input validation ensures that only valid URLs and properly formatted data are processed. Unauthorized access attempts are logged and blocked at the security layer.

VIII. METHODOLOGY

The development of the secure URL shortening system was carried out using a structured and iterative methodology to ensure reliability, security, and scalability. The methodology emphasizes requirement analysis, modular design, secure implementation, and continuous testing throughout the development lifecycle. Each phase was carefully planned to address both functional and non-functional requirements of the system.

1. Requirement Analysis

The initial phase involved identifying system requirements based on common limitations observed in traditional URL shortening services. Functional requirements included user registration, secure authentication, URL shortening, redirection, and usage analytics. Non-functional requirements focused on security, performance, scalability, and usability. Special emphasis was placed on preventing unauthorized access and ensuring secure API communication.

2. System Design

Based on the identified requirements, a modular system architecture was designed following RESTful principles. The system was divided into independent layers such as the client layer, authentication layer, application layer, and data layer. JWT-based authentication was selected to enable stateless session management and to support secure, scalable user authentication. API endpoints were clearly defined to separate authentication, URL management, and analytics functionalities.

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Security was integrated at the core of the system. User credentials are securely stored using hashing techniques. During login, credentials are verified and a JSON Web Token (JWT) is generated upon successful authentication. The token contains essential user information and an expiration timestamp. For every subsequent request, the token is validated using security filters before access to protected resources is granted. This approach eliminates server- side session storage and enhances scalability.

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Comprehensive testing was conducted at each stage of development. Functional testing ensured that all features operated as intended, while security testing verified that unauthorized users were unable to access protected APIs. Performance testing evaluated URL redirection speed and system responsiveness under normal load conditions. Identified issues were resolved through iterative improvements.

8. Deployment and Evaluation

After successful testing, the system was deployed in a controlled environment for evaluation. The deployed system was assessed based on security, performance, and usability metrics. Results indicated that the JWT-based authentication mechanism effectively prevented unauthorized access while maintaining

efficient URL redirection.

IX.EXPERIMENTAL EVALUATION AND RESULTS

The secure URL shortening system was evaluated to assess its functionality, security effectiveness, and performance efficiency. A series of controlled experiments were conducted to verify whether the system meets its design objectives and to analyze its behavior under normal operating conditions. The evaluation focused on authentication accuracy, URL redirection efficiency, and analytics reliability.

Functional Evaluation

Functional testing was performed to ensure that all system modules operate as intended. User registration and login processes were tested using valid and invalid credentials to verify authentication accuracy. The results confirmed that only authenticated users were able to generate shortened URLs and access URL management features. Unauthorized requests to protected API endpoints were consistently rejected, demonstrating correct enforcement of access control rules.

Security Evaluation

Security testing focused on validating the effectiveness of JWT-based authentication and authorization mechanisms. Requests with missing, invalid, or expired JWT tokens were tested against secured endpoints. In all cases, the system denied access and returned appropriate error responses. This confirms that the security layer successfully prevents unauthorized access and protects sensitive operations. Additionally, the system ensured that users could access only their own shortened URLs, maintaining data isolation and accountability.

URL Redirection Performance

The performance of the URL redirection process was evaluated by measuring response time during link access. The system demonstrated fast and reliable redirection with minimal delay, even after multiple requests. The stateless authentication model eliminated the need for server-side session handling, contributing to efficient processing and improved system scalability.

Analytics Accuracy

The analytics module was tested to verify accurate tracking of URL access events. Each redirection request correctly incremented the access count and recorded the corresponding timestamp. The recorded analytics data matched the actual number of link accesses, confirming the reliability of the monitoring mechanism.

Error Handling and Stability

The system was tested with invalid inputs such as malformed URLs, incorrect API requests, and unauthorized access attempts. In all scenarios, the system responded with meaningful error messages without compromising stability. This demonstrates robust input validation and error handling capabilities.

X.LIMITATIONS

Although the proposed secure URL shortening system successfully improves security and access control through JWT-based authentication and RESTful APIs, certain limitations remain that can be addressed in future enhancements.

One limitation of the system is the absence of automatic URL expiration or time-based access control. Currently, shortened URLs remain valid indefinitely unless manually removed by the user. This may increase the risk of long-term misuse if a shortened link is unintentionally shared or compromised.

The analytics module provides basic usage information such as access count and timestamps; however, it does not include advanced visualization or detailed insights such as geographic location, device type, or referral source. The lack of comprehensive analytics limits deeper analysis of link usage behavior.

Token management presents another limitation. While JWT enables stateless authentication, the current implementation does not support immediate token revocation. In cases where a token is compromised, it remains valid until expiration, which may pose a security risk.

The system has been tested under moderate usage conditions and does not currently include load balancing or distributed deployment mechanisms. As a result, performance under extremely high traffic scenarios has not been fully evaluated.

Additionally, the system does not support integration with third-party identity providers or single sign-on (SSO) mechanisms. This restricts flexibility in environments that require centralized authentication solutions.

XI. FUTURE ENHANCEMENTS AND EXTENSIONS

The proposed secure URL shortening system establishes a strong foundation for authenticated and controlled URL management; however, several enhancements can be incorporated to further improve its functionality, security, and scalability.

One important enhancement is the introduction of **URL expiration and access control policies**. Future versions of the system can allow users to define expiration dates, access limits, or one-time usage links. This would reduce long-term security risks and provide greater control over shared URLs.

The system can be extended to support **advanced analytics and visualization dashboards**. Features such as geographic location tracking, device and browser analysis, referral source identification, and graphical reports would provide deeper insights into URL usage patterns and help detect suspicious activities.

Another significant improvement involves **enhanced token management**. Implementing token revocation mechanisms, refresh tokens, and shorter token lifecycles would strengthen security by minimizing the impact of compromised tokens. Integration with multi-factor authentication (MFA) can further enhance user protection.

To improve scalability and availability, the system can be deployed on **cloud-based platforms** with load balancing and distributed database support. This would allow the application to handle high traffic volumes efficiently and ensure reliable performance under heavy usage conditions.

Future enhancements may also include **role-based access control (RBAC)**, enabling administrative users to manage system-wide URLs, monitor misuse, and enforce security policies. Additionally, integration with **third-party authentication providers** or single sign-on (SSO) solutions would improve usability in enterprise environments.

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