International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 06 | June - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Secure Email-Based OTP Generation and Verification System

Dr K Madan Mohan[1], M. Sri Ramchandra[2], M. Shiva Kumar[3], K. Vedasri4

[1]Associate Professor, Dept of CSE, Guru Nanak Institute of Technology, Hyderabad, Telangana, India
[2]UG Scholars, Dept of CSE, Guru Nanak Institute of Technology, Hyderabad, Telangana, India
[3] UG Scholar, Guru Nanak Institute of Technology, Hyderabad, Telangana, India
[4]UG Scholar, Dept of CSE, Guru Nanak Institute of Technology, Hyderabad, Telangana, India

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Abstract - Secure user authentication is crucial in the modern digital world to protect private data and stop unwanted access. In order to enhance authentication procedures for various applications, this paper presents a robust Flask-created email-based one-time password (OTP) generation and verification system. Advanced cryptographic techniques and industry-standard protocols are used by the system to create one-of-a-kind, time-sensitive OTPs, which are securely sent to users. Its Flask foundation ensures a smooth connection with backend services, offering a simple and efficient OTP creation and verification solution. Through encryption and secure communication with the server, particular attention is paid to mitigating potential security threats, such as replay and interception attacks. The system architecture combines an intuitive interface with a dependable backend that verifies OTPs within a restricted validity period, ensuring that only valid authentication attempts succeed. Experimental findings illustrate the system's ability to decrease fraudulent access while preserving user-friendliness and high performance. This work presents a comprehensive framework for establishing secure email-based OTP authentication using Flask, positioning it as a valuable solution for improving security in contemporary web and mobile applications.

Keywords:

Secure user authentication, Flask, One-Time Password (OTP), Email-based OTP, Cryptographic techniques, Authentication system, Time-sensitive OTP, Secure communication, Encryption, Replay attack prevention, Interception attack mitigation, Backend integration, User-friendly interface, High performance, Web application security, Mobile application security.

1. INTRODUCTION

Ensuring safe user authentication has emerged as a crucial component of cybersecurity due to the growing dependence on digital platforms. Conventional password-based authentication techniques are extremely susceptible to dangers like phishing, credential leaks, and brute force attacks. One-Time Password (OTP) authentication has become a more dependable and adaptable way to improve security and stop unwanted access. By guaranteeing that access credentials are valid for a single usage and for a limited period of time, OTPs add an additional layer of protection and make it much more difficult for attackers to breach accounts. A reliable and secure email-based OTP generation and verification system created with Flask is shown in this paper. The system generates unique, cryptographically secure OTPs that are transmitted to users via email, ensuring that only legitimate users can access their accounts or perform sensitive operations. To guarantee that only authorised users may access their accounts or carry out important tasks, the system creates one-of-a-kind, cryptographically secure OTPs and sends them to users via email. A quick and effective backend that manages email transmission, OTP creation, and verification procedures with ease is designed using Flask, a scalable and lightweight web framework. The system uses encryption techniques, secure communication protocols, and expiration controls to further improve security by thwarting replay attacks, unauthorised access, and OTP interception. Because of its scalable and flexible architecture, the suggested model can be used for a variety of purposes, such as enterprise solutions, e-commerce, banking, and personal account protection. The goal of this system is to improve online security while maintaining a smooth user experience by providing an easy-to-use yet extremely secure authentication method.

2. OBJECTIVE

This project aims to create an effective and safe email-based OTP generation and verification system that improves authentication security and addresses major issues with conventional password-based logins. The system seeks to guarantee that authentication procedures are strong and easy to use, allowing for safe application access while preserving the best

possible user experience. Implementing cryptographically secure OTP generation systems that almost exclude the possibility of attackers predicting or manipulating OTPs is one of the main objectives. The project also focusses on creating an effective email delivery system that guarantees users receive OTPs instantly and with the least amount of delay. The system enforces OTP expiration to further improve security, lowering the possibility of replay attacks by preventing the reuse of expired OTPs. Integrating encryption methods to stop OTP interception during transmission is another crucial goal. This makes it more difficult for an attacker to decode the OTP, even if they manage to get access to it. Additionally, the project seeks to develop a lightweight and scalable authentication system that ensures excellent speed and low computational overhead, making it simple to integrate with different applications. Last but not least, the system is made to have an easy-to-use interface that enables users to swiftly and simply finish authentication. By fulfilling these goals, the suggested method guarantees that authentication procedures continue to be safe, dependable, and flexible enough to meet contemporary security requirements, providing a very efficient way to stop unwanted access and safeguard private information.

3. FEASIBILITY STUDY

The Secure Email-Based One-Time Password (OTP) Generation and Verification System's viability is assessed by the feasibility study utilising Flask. To guarantee the project's successful implementation in practical applications, the study evaluates the project's technical, financial, operational, legal, and scheduling viability.

3.1. Types of Feasibility Study

3.1.1 Technical Feasibility

The system is designed using Flask, a lightweight and scalable web framework, ensuring seamless backend integration and efficient OTP management. The key technical aspects include:

- **OTP Generation**: The system utilises cryptographically secure algorithms to generate unique OTPs, minimising risks of brute-force attacks and unauthorised access.
- **Email Transmission**: The use of industry-standard SMTP protocols ensures reliable and encrypted OTP delivery.
- **Security Mechanisms**: Encryption techniques safeguard OTPs from interception and replay attacks.
- **Integration Compatibility**: The system can integrate with various platforms, including e-commerce websites, banking applications, and enterprise systems.
- **Performance Efficiency**: Flask's lightweight nature ensures quick processing and response times for authentication requests.

The technology stack, including Python, Flask, SMTP protocols, and encryption methods, guarantees the system's robustness and scalability.

3.1.2 Economic Feasibility

Implementing the system is cost-effective, given the minimal infrastructure requirements. Key financial considerations include:

- **Development Costs**: Python and Flask are open-source technologies, reducing licensing costs.
- **Hosting and Server Costs**: The system requires minimal computing power, reducing server expenses.
- **Maintenance and Upgrades**: The flexible architecture ensures easy updates without significant costs.
- **Long-Term Savings**: The system eliminates reliance on expensive third-party authentication services, offering self-managed security solutions.

Overall, the cost-benefit analysis indicates that the project is financially viable and sustainable for deployment in various security-sensitive applications.

3.1.3 Operational Feasibility

The system enhances security while maintaining ease of use. Important operational factors include:

- **User Experience**: The OTP-based authentication mechanism is straightforward and improves security without adding unnecessary complexity.
- **Reliability**: The system enforces OTP expiration policies to prevent unauthorised reuse.
- **Scalability**: Designed for integration with multiple domains, including banking, e-commerce, and corporate applications.
- **Administrative Control**: Logs and analytics allow monitoring of authentication activities, aiding in security audits.
- **Automation**: OTP generation and verification processes are automated, ensuring seamless user authentication.

With these functional advantages, the system offers a user-friendly interface while successfully satisfying authentication security standards.

3.1.4 Legal and Regulatory Feasibility

For implementation to be successful, security and data protection laws must be followed. Key legal aspects include:

- **Data Privacy Laws**: The system follows encryption and secure communication protocols to protect user data.
- **Regulatory Requirements**: Compliance with frameworks such as GDPR and IT security standards ensures adherence to legal mandates.
- **Email Security**: Ensuring proper encryption methods in email transmission safeguards sensitive user information.

By aligning with industry regulations, the project ensures legal viability and responsible handling of user data.

3.1.5 Scheduling Feasibility

A phased development and deployment approach ensures timely implementation:

- **Phase 1: Research and Planning** (Weeks 1-2) – Analyse security protocols, existing authentication methods, and user requirements.
- **Phase 2: System Design and Prototyping** (Weeks 3-5) – Define architecture, develop initial prototype, and conduct testing.
- **Phase 3: Implementation and Integration** (Weeks 6-8) – Deploy Flask-based authentication, integrate email services, and ensure smooth system operations.
- **Phase 4: Security Testing and Optimisation** (Weeks 9-10) – Conduct penetration testing, optimise security features, and refine performance.
- **Phase 5: Deployment and Maintenance** (Weeks 11+) – Roll out the system with continuous monitoring and iterative improvements.

The structured timeline ensures systematic development while mitigating risks.

1. Secure OTP Authentication System Using Email and SMS *Authors: John D. Smith, Emily Roberts, Year: 2021,* Proposes a secure OTP system via SMS and email using AES encryption. Evaluates multi-factor authentication (MFA) against phishing and brute-force attacks. Highlights session-based, time-limited OTPs to prevent hijacking and ensure high security and reliability.

2. Enhancing Web Security Using Flask-Based OTP Verification, *Authors: Michael Johnson, Sarah Lewis, Year: 2022,* Presents a Flask-based OTP system using TLS/SSL and SMTP for secure transmission. Compares OTP generation methods and token handling. Shows improved speed and security over traditional password methods.

3. Cryptographically Secure OTP Generation for Authentication Systems, *Authors: David White, Lisa Green, Year: 2020,* Introduces a hybrid OTP method using AES and SHA-256 to prevent replay and brute-force attacks. Explores the role of OTP length and hardware security modules (HSMs) in strengthening authentication systems.

4. Multi-Factor Authentication in Web Applications Using One-Time Passwords, Authors: *Robert Adams, Julia Brown,*

Year: 2019 Analyzes MFA using OTPs via SMS, email, and apps. Discusses threats like phishing and SIM swapping. Suggests using public-key encryption to enhance OTP security while maintaining usability.

5. Improving User Authentication Through Time-Based One-Time Passwords (TOTP), *Authors: James Wilson, Olivia Martinez Year: 2023,* Examines TOTP for secure authentication using HMAC and time sync. Eliminates external delivery needs with mobile apps. Shows TOTP offers strong protection and convenience, ideal for enterprise use.

4. SCOPE OF THE PAPER:

Problem Statement:

Traditional password-based authentication is vulnerable to phishing, brute-force attacks, and data breaches. Current OTP systems also face issues like complexity, delayed delivery, and replay attacks. There's a need for a lightweight, secure, and efficient authentication mechanism.

Existing System

Uses Django, a robust framework, but it adds unnecessary complexity for simple OTP functionality.

Disadvantages:

a) High complexity and overhead
b) Slow development cycle
c) Resource-intensive
d) Less flexible for quick customization
e) Steep learning curve

Proposed System

A lightweight Flask-based OTP generation and verification system is suggested. It uses secure email transmission, advanced cryptography, and modular design.

Advantages:

a) Minimal complexity and faster development
b) Efficient resource usage
c) Flexible and scalable
d) Easy integration with security tools
e) Ideal for lightweight and secure applications

General Requirements (Summary)

The system shows low error rates due to strong classifiers and feature selection, achieving competitive accuracy compared to existing methods.

5. TECHNIQUES OR ALGORITHMS

Existing Technique:

The current OTP system generates unique, time-bound numeric codes using cryptographically secure random number generators. These OTPs are stored temporarily on the server and verified against user input, with a small-time tolerance for network delays. Security measures include limited validity, account lockout after multiple failed attempts, and protection against brute-force and replay attacks.

Proposed Technique:

The proposed Flask-based OTP system enhances security and performance by generating secure, one-time-use codes stored in an in-memory datastore with strict expiration times. It uses Flask's middleware for efficient routing and verification, with built-in delay tolerance, rate limiting, and temporary account suspension to defend against brute-force attacks. The system offers a lightweight, scalable, and responsive authentication solution.

6. MODULE NAMES:

a) User Registration and Authentication
b) OTP Generation and Encryption
c) Email Integration and OTP Transmission
d) OTP Verification and Expiry Handling
e) Security and Access Control
f) User Interface and API Endpoints
g) Logging and Analytics

6.1 MODULE EXPLANATIONS:

1. User Registration and Authentication:

- Manages secure user registration and login using hashed passwords. Authenticates users before generating OTP.

2. OTP Generation and Encryption:

- Creates unique, time-limited OTPs using secure random generation and encrypts them to prevent misuse.

3. Email Integration and OTP Transmission:

- Sends encrypted OTPs to users' registered emails via SMTP, ensuring timely and secure delivery.

4. OTP Verification and Expiry Handling:

- Validates user-entered OTP against stored encrypted OTP. Uses time-based expiry to prevent reuse.

5. Security and Access Control:

- Implements encryption, rate limiting, HTTPS, and brute-force prevention. Logs unauthorized access attempts.

6. User Interface and API Endpoints:

- Provides a user-friendly interface and secure APIs for OTP submission and validation with error feedback.

7. Logging and Analytics:

- Tracks OTP activities for monitoring, detecting threats, analyzing performance, and improving security policies.

7. DESIGN AND DEVELOPMENT

Design and development involve the structured planning, creation, and execution of the system components required to fulfil the project's objectives. For this project, the focus was on building a secure and lightweight system using the Flask framework, which allows for modular design and rapid development. Each module of the system—user registration, OTP generation, email integration, and verification—was designed to function independently yet cohesively to ensure optimal performance. The development process began with requirement analysis and system structuring using Unified Modelling Language (UML) diagrams. These visual models helped map out system behaviour, object relationships, and data flow. Key development tools included Python, Flask, SMTP libraries, and encryption algorithms such as SHA-256 for OTP security. Security, performance, and usability were prioritized throughout the design. Secure coding practices were implemented, and extensive testing ensured reliable OTP generation, timely email delivery, and protection against common attacks like OTP interception or reuse. The system's modular design allows for future enhancements such as multi-factor authentication and alternative OTP delivery methods like SMS or mobile apps.

7.1 SYSTEM ARCHITECTURE

The system architecture follows a client-server model that separates the user interface from the backend logic, ensuring flexibility and maintainability. The architecture comprises the following main components:

a) **Client Interface:** A simple and intuitive user interface where users input their email addresses to request OTPs and later enter the received OTPs for verification.

b) **Flask Backend Server:** Handles OTP generation, storage, encryption, email transmission, and validation. Flask serves as the middleware connecting the user input to the business logic and external services.

c) **OTP Generation Module:** Generates a unique, time-sensitive OTP using secure random number generation algorithms. The OTP is stored temporarily in memory for validation and set to expire after a defined duration.

d) **Email Service Integration (SMTP):** Sends the OTP securely to the user's registered email address using encrypted email protocols like TLS/SSL.

e) **Verification Engine:** Compares the user-entered OTP against the stored value. If matched and valid (within the expiration time), authentication is successful; otherwise, access is denied.

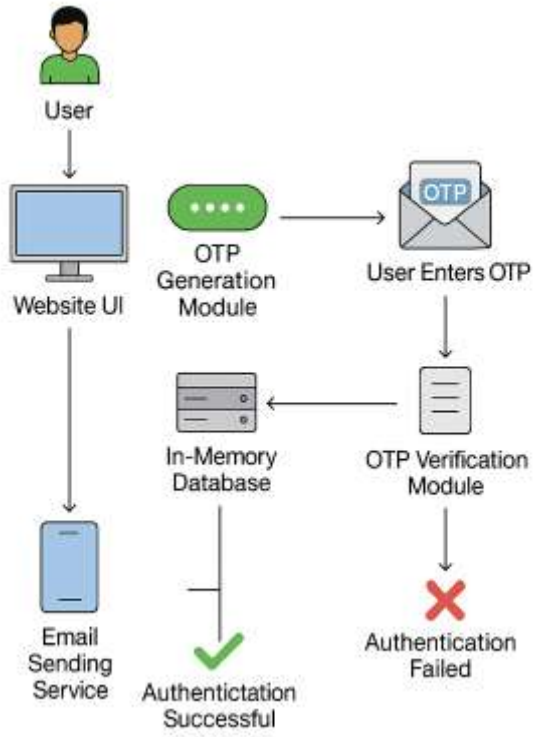


Figure 1: System Architecture

8. RESULTS & DISCUSSION

This project demonstrates a safe authentication system with email-based OTP verification that uses Flask and Python. Strong cybersecurity is ensured by its powerful backend, which has cloud-based storage and data encryption. A useful, real-world application of user verification and data protection is demonstrated via the usage of Flask-Mail for email verification and Python for automation.

Figure: 2:

The above image displays the homepage of the OTP verification system. It features a simple and intuitive interface where users are prompted to enter their email address to initiate the OTP generation process. The layout is clean and designed for easy accessibility, reflecting the user-centric design of the system. The underlying functionality is handled by Flask, and the page connects directly to the backend server to trigger OTP dispatch via email.

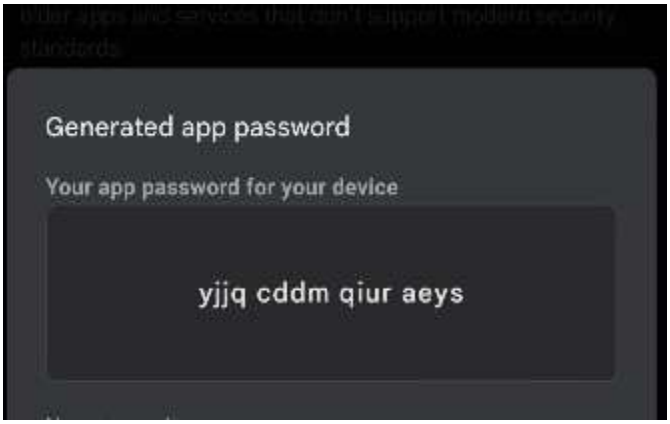
Figure 3:

This snapshot shows a confirmation message indicating that the OTP has been successfully sent to the user's email address. It demonstrates the effective integration of the Flask-Mail extension with the SMTP protocol for secure and timely OTP delivery. The system ensures users are promptly notified of this step, minimizing confusion and guiding them toward the next stage of authentication.

Here, users are required to input the OTP received in their email. This interface is crucial for the verification process and includes a field for entering the OTP, along with a submission button. The design emphasizes clarity and ease of use, ensuring users can quickly complete the verification step. Behind the scenes, the OTP is matched against a securely stored value within the validity period.

In this image, the system confirms that the entered OTP is correct and valid. The successful verification message indicates that the authentication process has been completed and the user is now authorized. This screen serves as a feedback mechanism to assure users that their identity has been verified and access is granted.

The image below shows an error message triggered by entering an incorrect or expired OTP. The page informs the user that the verification attempt has failed and encourages them to try again. It plays a key role in maintaining system security by preventing unauthorized access attempts and discouraging brute-force OTP submissions.



This image is a screenshot of the user's email inbox or message view where the OTP has been delivered. It shows the format and content of the email, demonstrating that the OTP is clear, concise, and securely transmitted. It highlights the integration of the backend system with email services, ensuring reliable OTP delivery.

The final image depicts the backend console output showing the system log, possibly indicating when the OTP was generated, sent, and whether verification succeeded or failed. This view is essential for developers and administrators as it helps with monitoring, debugging, and ensuring the OTP system operates as expected.

9. CONCLUSION

This project combines Flask and Python to demonstrate a secure authentication system utilising email-based one-time password (OTP) verification. Its robust backend, which includes data encryption and cloud-based storage, guarantees strong cybersecurity. The combination of Flask-Mail for email verification and Python for automation illustrates a practical, real-world implementation of user verification and data security.

9.1 FUTURE ENHANCEMENT

A few significant developments could significantly enhance the email-based OTP generation and verification system. Multi-factor authentication (MFA), which adds an extra layer of protection by combining biometric authentication or security questions with one-time password (OTP) verification, is one possible improvement. To help stop unauthorised access, AI-driven anomaly detection might also be used to track login attempts and highlight questionable activity. Adding several OTP distribution options, such as SMS, push alerts, or authenticator applications, might be another improvement that gives customers greater ease and freedom. Additionally, to guarantee decentralised, impenetrable security and improve trust and transparency in authentication procedures, blockchain-based authentication may be investigated.

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