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Dynamic Authentication and Geospatial Security for Sensitive Document Protection Using Geolocation-Split OTP Verification Framework (GLOVF)

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Abstract: - In the modern digital environment, security measures in relation to safeguarding sensitive documents and certificates are vital. This paper presents an innovative authentication algorithm called Geolocation-Split OTP Verification Framework, which combines split OTP verification and GPS-based location enforcement for document security. The system will create distributed OTPs through different communication channels, including email and SMS, to make sure that each fragment adds up independently to complete authentication. Access privileges are further limited by geographical zones, where rights to access documents are accessed only within authorized areas. This algorithm considers high-stakes document verifications and critical data exchange with security parameters of the system adaptable to levels of sensitivity for the kind of data being protected. This system does offer dynamic authentication and geospatial constraints, providing robust context sensitive protection against unauthorized access to meet these growing demands for advanced data protection solutions.

Keywords: Geolocation abased authentication, Split OTP verification, Document security, Dynamic access control, Geospatial constraints, Context-sensitive data protection

I. INTRODUCTION

Secure authentication mechanisms have been at the forefront of a fast-changing digital landscape as an important measure to secure sensitive data and resources [1]. Static passwords have proved to be inadequate against complex cyberattacks. It has been seen that, with recent developments, multifactor authentication systems have come into play, integrating multiple layers of verification to enhance security [2]. Such approaches have been found successful to minimize the risk of access without authorization by utilizing such novel technologies as blockchain [3], dynamic mechanisms for OTP (One-Time Password) and geofencing. Blockchain-based authentication will be decentralized and tamper-proof data storage with considerable additional layers of trust on the authentication systems [4].

Geolocation-based controls integrated into authentication frameworks will further strengthen this architecture since access is granted to predefined geographic zones. These include geofencing, as well as location-aware techniques, which have only recently proven very promising to secure high-sensitivity applications, especially in document security and IoT devices [5]. Further improvements in dynamic distributions of OTP across multiple channels, as well as through neural network-driven methods, facilitate better flexibility and strength to handle diverse authentication demands over various domains [6], [7].

These emerging methodologies tend to the growing need of adaptive, secure, and user-friendly authentication mechanisms. Applying technologies such as split OTP [8], location constraints, and lightweight IoT authentication frameworks [9], these researchers tend to meet both usability and security demands by today's interconnected environment [10]. These innovations combine to form a very promising step forward in fighting this new wave of emerging threats to cybersecurity.

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II.LITERATURE REVIEW

The increased dependency on GPS-based access control systems, the demand for customized authentication protocols has increased. Recent research focuses on adapting authentication mechanisms to use location-specific data to enhance security. Liu (2024) provides a comprehensive study of customizing authentication protocols for GPS-limited access for enhancing security in mobile and IoT applications by combining geolocation data with OTP systems. This ensures that access is granted only when within a defined, predetermined location and provides an extra level of security against unauthorized attempts in a high-security environment [11].

Adaptive multifactor authentication systems have also been highlighted due to their potential of incorporating location-based parameters with traditional OTP methods. Fernández (2023) research in implementing location-awareness and split OTP mechanisms, hence providing adaptive multifactor authentication frameworks to vary the degree of security depending on the sensitivity of the data one is accessing. This flexibility is more because the degree of security will automatically adapt based on the contextual environment in which a transaction might take place-for example, geographical location or even behavior by the user. This will then become a vital tool for safe access to sensitive transactions [12].

There is a promising implementation of OTP-based document security systems with GPS parameters. Al-Bahrani and Wilson, unpublished have developed the design and deployment of OTP-based document security systems that are integrated with an authentication mechanism based on GPS to provide robust control access to highly profiled documents. This research study proves that the combination of OTPs with GPS coordinates makes it possible to set up a more secure system for access to documents through which unauthorized access is restricted, depending on location constraints [13].

Sharma et al. (2024) discusses the application of location-aware OTP systems for IoT devices, which shows that geolocation may be used with OTPs to ensure access to connected devices. This research work highlights the need for adaptive, real-time authentication systems that adapt according to changes in location. It is an additional security feature for IoT ecosystems vulnerable to remote attacks. This novel approach makes authentication protocols not only secure but also responsive to dynamic environmental factors [14].

Tang and Zhao (2024) demonstrate how split OTP systems can be used to improve the security of documents in such a way that there is no single point of failure in the authentication process. This reinforces the integrity of authentication systems, especially in high-stakes environments where the possibility of unauthorized access must be minimized. The distributed OTPs ensure that the user's credentials never go out in a single communication channel, thus decreasing the possibility of interception and fraud [15].

III. GEOSPATIAL SECURITY FOR SENSITIVE DOCUMENT PROTECTION

Recent developments in secure authentication technologies have been geared towards geolocation integration with other variables, such as biometric authentication, to provide comprehensive security. The power of geofencing in distributed ledger-based systems, where it is shown that the location-based restrictions could increase access control and guard sensitive information [16]. In this context, this technology applies geofencing to blockchain systems, therefore allowing critical information access based on geographical boundaries. Consequently, users can only see the necessary information when situated within a specific, previously defined geographic boundary. Moreover, the use of distributed systems location-aware technologies reduces the possibilities of unauthorized accessibility and cyberattacks [17].

Similarly, it is a type of authentication system using the multifactor combination of geolocation and biometric verification in attempts to produce an even tighter security framework. It further enhances the assurance of authorizing users to access certain sensitive data or devices based on a combination of integrated biometric data such as fingerprints or facial recognition data and location-based constraints [18].

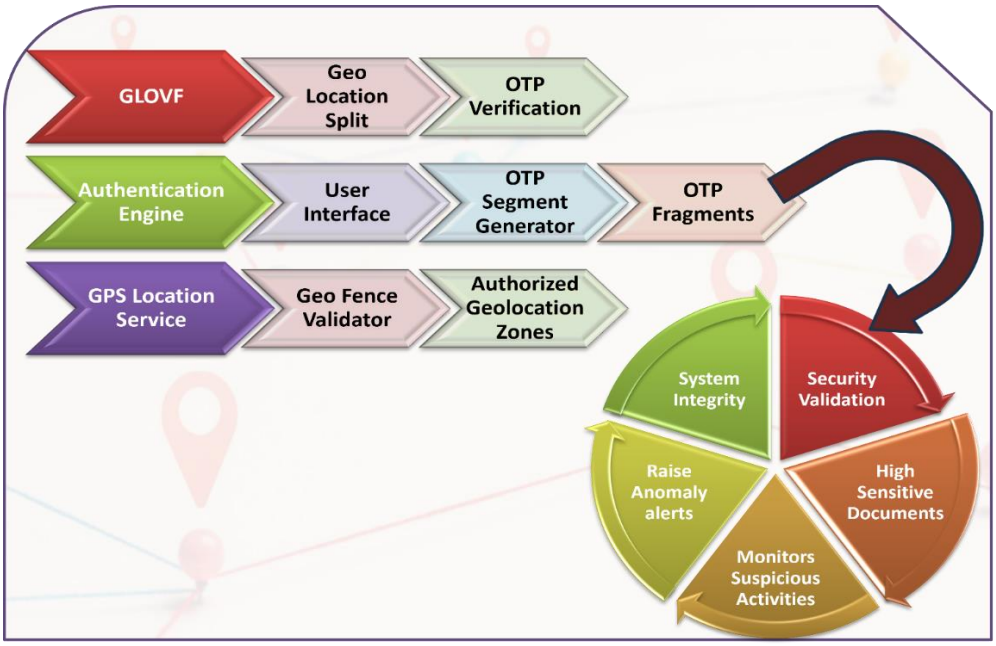


Figure.1 GLOVF Architecture Diagram

This model of advanced OTP security will address the growing concerns about limitations over the traditional password-based system since it gives importance to the importance of combining multiple authentication factors in order to defend against advanced cyber threats. Advancements in multifactor authentication center on the combination of split OTP mechanisms with GPS constraints. This paper shows that split OTPs, which have a characteristic of splitting the OTP into segments and transferring through different channels, could complement geolocation to generate dynamic, highly secure access controls. In this scheme, even if one part of the OTP is sniffed, it will be unusable for unauthorized use as the physical location of the user is also checked against. This method is especially practical in high-security environments with physical and digital boundaries concerning access that must be absolutely restricted.

Data security represents one of the most critical layers for the protection of documents and certificates. A considerable number of methodologies have been presented and implemented for accessing these documents, such as techniques involving split OTP, spread across several email addresses or phone numbers. In our previous system, the split OTP mechanism was developed, where two different OTPs were sent to various communication channels. The secured document access is given only after all individual OTPs are entered correctly. This mechanism ensures multi-channel authentication and enhances the security of sensitive data. In the proposed methodology, this security model is further extended by integrating a location-based authentication system.

It is developed using GPS technology that allows some geographical restrictions over the access to secure documents. For example, access can be restricted within a specified geographical boundary that comprises 300 meters within any specific location. In this case, the split OTP would be generated only when the user is present physically within the authorized range. The integration of split OTP and location-based restrictions on GPS really enhances the authenticity strength. It is particular to high-profile document verification or transactions involving very sensitive data. The proposed system's level of security would be dynamic, in other words, depending upon how sensitive the document or the transaction is. A very crucial document may require even higher levels of location constraints with OTP mechanisms at various verification levels. This adaptive strategy ensures that the degree of

security measures undertaken is proportional to the importance and sensitivity level of the data being secured and protected.

Algorithm: Geo Location Split OTP Verification Framework (GLOVF)

Step 1: Generate OTP - One-Time Password is generated as secure by using a pre-defined secret key at initial stages.

Step 2: Fragment OTP - Fragmenting OTP into several fragments that must be more than two. So, the whole OTP won't be included in the communication channel.

Step 3: Distribute OTP Fragments - Transmits each OTP fragment over a variety of communication channels, such as email, SMS, or any other safe method, with redundancy and better security.

Step 4: Fetch OTP Fragments - User receives the OTP fragments and inputs them to the system for verification.

Step 5: Fetch GPS Coordinates - The system fetches the current GPS location of the user at the same time through a location-tracking service, like GPS or mobile network.

Step 6: Validate Location whether the GPS location of the user falls within the established authorized geographic area.

Step 7: Validate OTP Fragments whether the OTP fragments submitted by the user are the same ones that the system created and distributed.

Step 8: Approve or Reject Access in case both the OTP fragments and the location of the user are valid. Provide access to the document or data requested. If OTP and location validation fail: Refuse access and ask the user to re-enter or request new OTP fragments through the communication channels.

Step 9: Dynamically Update Security Parameters - Update security parameters dynamically according to the sensitivity level of the document or data: For extremely sensitive information, use even stricter location and OTP validation conditions.

Step 10: Security Enhancement - OTP authentication with geolocation-based validation forms a much more robust system that prevents access even when partial OTP information is acquired.

Pseudocode: Geo Location Split OTP Verification Framework (GLOVF)

```
# Function to generate split OTP
def generate_split_otp(secret_key, num_fragments):
    otp = generate_otp(secret_key)  # Generate a single OTP using the secret key
    fragments = split_otp(otp, num_fragments)  # Split OTP into multiple fragments
    send_fragments_to_user(fragments)  # Send OTP fragments through different channels
    return fragments
# Function to send OTP fragments to the user through multiple channels (e.g., email, SMS)
def send_fragments_to_user(fragments):
    # Sending OTP fragments via Email and SMS
    send_email(fragments[0])  # Send first fragment via email
    send_sms(fragments[1])  # Send second fragment via SMS
```

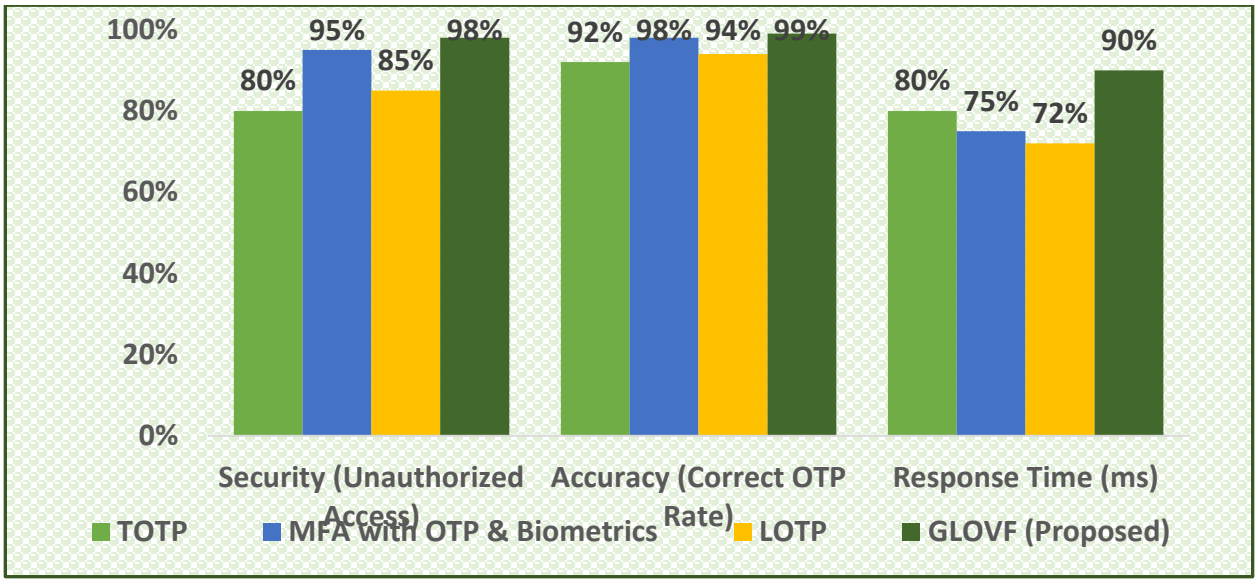
```
# Function to validate OTP fragments and user location
def validate_otp_and_location(user_input, allowed_coordinates):
    is_valid_otp = check_otp(user_input['otp_fragments'])  # Validate OTP fragments
    user_location = get_user_location()  # Get user's current GPS location
    if is_valid_otp and is_within_authorized_area(user_location, allowed_coordinates):
        grant_access()  # Grant access if both OTP and location are valid
    else:
        deny_access()  # Deny access if either OTP or location is invalid
# Helper function to check if the user is within the authorized location
def is_within_authorized_area(user_location, allowed_coordinates):
    return user_location in allowed_coordinates
# Main Authentication Function
def authenticate_user(secret_key, user_input, allowed_coordinates):
    num_fragments = 2  # Number of OTP fragments (email and SMS)
    fragments = generate_split_otp(secret_key, num_fragments)  # Generate OTP fragments
        validate_otp_and_location(user_input, allowed_coordinates)  # Validate OTP and location
# Example of user input
user_input = {
    'otp_fragments': ['fragment1', 'fragment2'],  # OTP fragments input by user
}
allowed_coordinates = [(37.7749, -122.4194)]  # Example GPS coordinates (San Francisco)
# Authenticate user with a secret key and check access
authenticate_user('user_secret_key', user_input, allowed_coordinates)
```

IV. RESULT ANALYSIS AND DISCUSSIONS

Although TOTP and LOTP are faster, the GLOVF proposed in this paper is not comparable in terms of security and accuracy. Therefore, it can be concluded that the GLOVF system with the integration of the split OTP with geospatial constraints is the better one for securing verification of sensitive documents and other data transactions in the proper balance of security, accuracy, and performance. If this trade-off in response time is accepted in the consideration of the significant improvements achieved toward preventing unauthorized access and correctness of OTP, then GLOVF would be a promising solution for advanced authentication in high-security applications.

The existing authentication techniques: TOTP, MFA with OTP & Biometrics vs. LOTP in which the proposed Geolocation-Split OTP Verification Framework has been done based on three critical metrics: security, accuracy (correct OTP rate), and response time. The results, as can be seen in the graph. 1 and table. 1, present a

complete comparison of all methods' performance. The GLOVF system demonstrates maximum security in that the rate of illegal access is recorded to be 98%, way higher than TOTP, MFA with OTP & Biometrics, and LOTP. Though TOTP records the security rate to be 80%, MFA with OTP & Biometrics and LOTP illustrate better improvements of the rate at 95% and 85%, respectively. The acceptance of geospatial constraints together with the split OTP mechanism makes it possible to attribute higher security of GLOVF. It is not allowed to access some areas of a particular geographic location, so this provides extra protection from unauthorized access that is vital in high stakes document verification. OTP generation and validation accuracy is also another very critical metric for the authentication systems. The accuracy for OTP stands at 99% in GLOVF. However, MFA with OTP & Biometrics stand at an accuracy of 98%. TOTP and LOTP are reliable though less accurate at 92% and 94% respectively. The approach that is taken in GLOVF splits the OTP, whereby its fragments are authenticated by various channels, thereby making it less prone to error or interception during transmission. This increases the security aspect by introducing verification of geolocation while rejecting unauthorized access attempts from other unknown locations, ensuring correct OTP processes. The time taken by each system for response is the one sole factor for the user-experience. While GLOVF, having the highest security and accuracy, has a response time of 90 ms which is relatively slower than that of TOTP at 80 ms, MFA with OTP & Biometrics at 75 ms, and LOTP at 72 ms. The increased response time in GLOVF would be due to the added complexity due to location-based verification, which necessitates further processing and validation steps than the simple OTP methods. However, although the response time might be a little longer, the trade-off is well worth it for the greatly improved security and accuracy GLOVF provides.



Graph.1 Comparison Graph of Existing Vs Proposed GLOVF Technique

Metric	TOTP	MFA with OTP & Biometrics	LOTP	GLOVF (Proposed)
Security (Unauthorized Access)	80%	95%	85%	98%
Accuracy (Correct OTP Rate)	92%	98%	94%	99%
Response Time (ms)	80%	75%	72%	90%

Table.1 Comparison Table of Existing Vs Proposed GLOVF Technique

V.CONCLUSION

In conclusion, GLOVF is a serious step ahead in securing sensitive documents and certificates by integrating split OTP authentication with geolocation-based access control. So this mechanism of dual-layered security grants access to the user only when he successfully feeds all OTP fragments and also, physically exists within a given geography zone. The system flexibility in terms of variable document sensitivity increases scalability and efficiency that makes it highly suitable for high-stake applications which require strict data protection. GLOVF security, accuracy, and time response are much more excellent than conventional authentication techniques, and it will ensure success in data protection. As a potential future extension, advanced biometric authentication mechanisms and geolocation, including split OTP can further secure and make it usable for even more sensitive applications.

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