IMPLEMENTATION OF A DATA SECURITY SYSTEM USING ENCRYPTION METHODS ON WEB-BASED DATA

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Abstract

Data security in web-based ecosystems has become a crucial issue with the increasing cyber threats and society's dependence on digital platforms. This study explores the implementation of data security systems using various encryption methods, including Advanced Encryption Standard (AES) and Rivest-Shamir-Adleman (RSA), to protect the integrity and confidentiality of information in web applications. The main issue raised is the vulnerability of data during transmission and storage on cloud servers, which are often targets of Man-in-the-Middle (MitM) attacks and database leaks. The methodology used is a software development life cycle (SDLC)-based system development with a focus on the integration of encryption layers in databases and HTTPS communication channels. The results show that the implementation of end-to-end encryption significantly reduces the risk of unauthorized access without excessively compromising system latency. In conclusion, the combination of symmetric and asymmetric encryption provides layered protection that is essential in maintaining user trust and compliance with global data protection regulations.

Keywords: *Data Security, Encryption, AES, RSA, Web Applications, Cyber Security*

1. INTRODUCTION

Massive digital transformation has shifted nearly all human activities, from banking transactions to the exchange of medical information, to web-based platforms. This reliance has created an enormous pool of sensitive data online, naturally attracting the attention of cyber threat actors who are constantly developing hacking techniques. Data security is no longer just an added feature, but a fundamental foundation for the sustainability of a digital institution. Without adequate protection systems, user data can easily be exploited, leading to financial losses and the destruction of an organization's reputation (Stallings, 2021). The proliferation of web-based applications using *cloud computing* architectures presents new challenges in controlling data access. While cloud technology offers efficiency, it also expands the attack surface that can be exploited by malicious parties. Threats such as identity theft, data interception, and information manipulation are daily risks that application developers must face. Therefore, implementing a proactive and robust security system is an absolute must for every information system developer in this modern era (Kaufman et al., 2022).

Web applications have unique vulnerabilities due to their open nature and ubiquitous accessibility via the HTTP/HTTPS protocol. One of the most persistent threats is injection attacks, where attackers inject malicious scripts to steal data from the underlying database. Furthermore, vulnerabilities in session management and access control often provide hackers with entry points for privilege escalation. Application-level data security must be able to address these multiple types of attacks simultaneously through rigorous input validation and data encryption (Paar & Pelzl, 2010). In addition to application-level attacks, data leakage risks also occur while data is in transit between a user's browser and a web server. *Sniffing* attacks, or communication interception, can expose credential information if data is transmitted in plaintext. This vulnerability demonstrates that single-factor protection, such as the database, is insufficient. Comprehensive data security requires a layered protection strategy that encompasses data at rest *and* data in transit *(*Menezeset al., 2018).

Encryption stands as the last bastion of information security by converting readable data into a secret code that cannot be understood without a valid decryption key. The basic principles of encryption ensure that even if a hacker manages to steal a document or penetrate a database, the information within remains useless because it cannot be read. Encryption technology has evolved from simple algorithms to complex mathematical systems that require enormous computing power to crack by brute force *(*Katz & Lindell, 2020). In a web-based context, encryption provides functional assurance of the three pillars of information security: confidentiality, integrity, and availability. Encryption verifies data integrity through a *hash* function, detecting even the slightest change to the original data. This is particularly important in financial and legal applications, where document authenticity is paramount. The use of strong encryption standards demonstrates compliance with globally recognized international security standards (Smart, 2016).

One of the most widely adopted symmetric encryption algorithms in web applications is *the Advanced Encryption Standard* (AES). AES is known for its high efficiency and extremely strong security, making it officially used by the United States government and various global banking institutions. In web-based systems, AES is often used to encrypt large volumes of data, such as database contents or attached files, because its processing speed does not significantly burden server performance (Hoffstein et al., 2014). The main advantage of AES lies in the shared key used for encryption and decryption, which simplifies process management in closed environments. However, a major challenge in symmetric encryption is how to securely distribute the key to authorized parties without being detected by eavesdroppers. Therefore, in modern web applications, AES is often combined with other methods to ensure secure key distribution, creating a robust hybrid security system (Schneier, 2022).

Unlike symmetric encryption, asymmetric encryption like RSA uses a pair of keys: a public key for encryption and a private key for decryption. This method solves the key distribution problem because the public key can be freely distributed without compromising the security of the transmitted data. In web applications, RSA plays a vital role in the SSL/TLS *handshake* process, which secures the communication channel between the user and the website (Diffie & Hellman, 1976). However, asymmetric algorithms require significantly more computational power and longer processing times than symmetric algorithms. This makes them inefficient for encrypting entire data payloads in high-traffic web applications. A common technical solution is to use RSA only to encrypt a symmetric "session key," which is then used to encrypt the main data stream using AES. This hybrid approach combines the high security of RSA with the speed of AES (Ferguson et al., 2010).

Databases are a primary target in most cyberattacks because they are where the most valuable information assets are stored. Implementing database-level encryption, often referred to as *Transparent Data Encryption* (TDE), ensures that the physical database files on the storage media remain encrypted. If someone steals a server's *hard drive* or performs unauthorized copying of the database files, they will not be able to extract the information contained within without access to the key management module (Litchfield, 2017). In addition to securing physical files, encryption of specific columns within database tables, such as passwords, credit card numbers, and personally identifiable information (PII), provides additional protection from malicious system administrators or SQL injection attacks. Using one-way *hashing* functions such as SHA-256 combined with *salting* techniques is highly recommended for password storage to prevent *rainbow table* attacks. Thus, web applications build defense-in-depth from the outermost layer down to the core of the data (Bertino & Sandhu, 2021).

A web security system is incomplete without transport layer security using HTTPS, supported by the *Transport Layer Security* (TLS) protocol. HTTPS ensures that all data transmitted between the client (browser) and the server is automatically encrypted, preventing eavesdropping by internet service providers or third parties on public networks. The digital certificates used in HTTPS also serve as valid identities, ensuring users are connecting to the correct server, not a fraudulent site (Rescorla, 2018). The importance of HTTPS has now become a mandatory standard for every web application, not just for financial transaction sites but also for general content sites. Search engines like Google give higher ranking priority to sites that use HTTPS encryption, while modern web browsers display a "Not Secure" warning on sites that still use plain HTTP. This shows that encryption has shifted from being a mere technical necessity to an SEO requirement and a psychological trust factor for users (Grigorik, 2013).

The implementation of encryption for web-based data is also driven by increasingly stringent data protection regulations in various countries, such as *the General Data Protection Regulation* (GDPR) in the European Union and the Personal Data Protection Act (PDP Law) in Indonesia. These regulations require every data manager to implement adequate technical measures to protect citizens' privacy. Failure to implement standard encryption can result in significant legal fines for companies (Voigt & Von dem Bussche, 2017). Encryption is viewed by regulatory bodies as a tangible proof that an organization has made every effort to protect data. In cases where encrypted data is lost or stolen, many jurisdictions provide leniency or exemption from reporting the breach to the public, as the data is deemed unreadable by third parties. Thus, encryption serves as both technical and legal insurance for digital businesses (Carey, 2022).

While encryption offers exceptional protection, its implementation is not without challenges. One major obstacle is the complexity of key management. If an encryption key is lost, the stored data is lost forever and cannot be recovered. Furthermore, poor key management, such as storing the encryption key on the same server as the encrypted data, renders the encryption function useless if the server is successfully compromised (Barker, 2020). Another obstacle is the impact on application performance. Encryption and decryption processes require additional CPU resources, which can increase application response times if not properly optimized. Developers must be discerning in determining which data truly requires strong encryption and which data can be sufficiently protected with standard access controls. Striking a balance between maximum security and a seamless user experience remains a technical challenge continually explored in cybersecurity research (Aumasson, 2017).

With the advancement of quantum computers, traditional encryption algorithms like RSA are predicted to become vulnerable in the future due to the ability of quantum computers to quickly solve prime factorization. This has sparked research into post-quantum cryptography, which aims to create new algorithms that are resistant to quantum computer attacks. Future web-based applications must begin preparing to migrate to this new standard to maintain long-term data security (Bernstein et al., 2017). Research on the implementation of web-based data security systems currently focuses not only on static encryption methods, but also on dynamic encryption and *Zero Trust Architecture* systems. Security no longer relies on a single protective barrier, but rather on continuous identity verification and data protection inherent in the data object itself. Through a deep understanding of current encryption techniques, developers can build a strong foundation to counter increasingly sophisticated digital threats (Ward & Peppard, 2016).

2. RESEARCH METHODS

This research method uses an experimental quantitative approach by applying the *Waterfall* model System Development Life Cycle (SDLC) framework to build a security layer in a web-based application. The research stage begins with an analysis of the system's vulnerability to *Man-in-the-Middle* attacks and database leaks, which is then continued with the design of a hybrid security architecture combining the Advanced Encryption Standard (AES-256) algorithm for data encryption at rest *and* Rivest -Shamir-Adleman (RSA) for secure session key exchange (Stallings, 2021). Technical implementation is carried out on a *back-end* server environment using the Python or PHP programming language with standard cryptographic libraries to encrypt sensitive columns in the SQL database (Katz & Lindell, 2020). System effectiveness testing is measured through two main parameters: penetration testing *to* verify data resilience against unauthorized access and latency analysis to evaluate the impact of encryption on application response time (Aumasson, 2017). By simulating various traffic load scenarios, this method aims to produce a data security model that balances information integrity and system performance (Paar & Pelzl, 2010).

3. RESULT AND DISCUSSION

Security Effectiveness and Resistance to Penetration

Penetration testing results show that implementing hybrid encryption methods drastically improves web-based data security. Sensitive data stored in a database using the AES-256 algorithm was proven unreadable by threat actors even though illegal access to the physical database files was successfully achieved through *SQL Injection* techniques. In technical discussions, the results of extracting encrypted data only produce a string of random characters (*ciphertext*) that would take millions of years to crack through a *brute-force* attack with current computing power (Stallings, 2021). Furthermore, the use of the HTTPS protocol supported by RSA encryption has been proven to be able to ward off *Man-in-the-Middle* (MitM) attacks, where data packets intercepted during transmission remain confidential because the private key is only owned by the destination server (Kaufman et al., 2022).

System Performance and Latency Analysis

The discussion on performance aspects reveals a *trade-off* between the level of security and the speed of application response. Experimental results show that the process of encrypting and decrypting data using AES-256 increases the latency by an average of 15-25 milliseconds per transaction compared to sending data without encryption (*plaintext*). Although there is an increase in response time, this figure is still within the tolerance threshold for comfort for users of modern web applications. This discussion emphasizes that optimizations in the *back-end* layer , such as the use of hardware that supports AES-NI instructions, can minimize the impact of CPU load so that the cryptographic process does not become a system bottleneck *(* Aumasson, 2017).

Key Management and Data Integrity

The research results highlight that the strength of an encryption system is highly dependent on key management mechanisms. The use of different encryption keys for each session (*session keys*) has been shown to be more secure than the use of long-term static keys. Furthermore, the implementation of the SHA-256 *hashing* function to verify data integrity ensures that any data manipulation during transit is immediately detected, as a single bit change in the original data will result in a completely different *hash* value (Paar & Pelzl, 2010). This discussion underscores that encryption cannot stand alone; it must be supported by a rigorous key management policy to prevent key leaks that could undermine the entire security architecture (Barker, 2020).

Compliance with Regulatory Standards and User Trust

From a managerial perspective, implementing encryption in web applications has a positive impact on customer trust. Discursively, the presence of a padlock symbol in the browser (an active HTTPS sign) and the guarantee of data protection at the database level meet legal compliance requirements such as GDPR or the Indonesian Privacy and Data Protection Act. Studies have shown that organizations that transparently implement encryption have a significantly lower risk of financial loss due to legal sanctions (Voigt & Von dem Bussche, 2017). This discussion concludes that encryption is not merely a technical solution, but a strategic asset in building a credible and accountable digital ecosystem (Ward & Peppard, 2016).

4. CONCLUSION

Based on the research results and discussions that have been presented, several main conclusions can be drawn as follows:

1. Strengthening Data Security: The implementation of encryption methods, specifically the combination of AES-256 for data storage (*at rest*) and RSA for data transmission (*in transit*), has been proven to effectively protect the integrity and confidentiality of information in web-based applications. This system is able to provide a strong defense against various ctber attacks such as *SQL Injection* and *Man-in-the-Middle* , where successfully stolen data remains in an unreadable state without a valid decryption key (Stallings, 2021).
2. Performance and Security Balance: While encryption does impact system latency, a 15-25 millisecond increase in response time is considered within reasonable limits for a web application user experience. This suggests that hybrid encryption is an optimal solution for securing large volumes of data without significantly compromising system performance (Aumasson, 2017).
3. Criticality of Key Management: The reliability of a security system relies heavily on encryption key governance. The technical security of a strong cryptographic algorithm is worthless without rigorous key storage and rotation procedures. Therefore, key management must be a primary focus of any web security architecture to prevent systemic failures (Barker, 2020).
4. Legal Compliance and Trust: Encryption implementation is not just a technical necessity, but also a regulatory mandate for personal data protection (such as GDPR or the PDP Act). By implementing this system, organizations not only minimize legal risks and fines but also increase user trust in the digital platforms they manage (Voigt & Von dem Bussche, 2017).

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