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A BLOCKCHAIN-BASED SECURITY MANAGEMENT FRAMEWORK FOR CYBER-PHYSICAL SYSTEMS

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Abstract : The Single sign-on (SSO) is a new authentication mechanism that enables a legal user with a single credential to be authenticated by multiple service providers in a distributed computer network. Recently, Chang and Lee proposed a new SSO scheme and claimed its security by providing well-organized security arguments. In this paper, however, we demonstrative that their scheme is actually insecure as it fails to meet credential privacy and soundness of authentication. Specifically, we present two impersonation attacks. The first attack allows a malicious service provider, who has successfully communicated with a legal user twice, to recover the user's credential and then to impersonate the user to access resources and services offered by other service providers. In another attack, an outsider without any credential may be able to enjoy network services freely by impersonating any legal user or a nonexistent user. We identify the flaws in their security arguments to explain why attacks are possible against their SSO scheme. Our attacks also apply to another SSO scheme proposed by Hsu and Chuang, which inspired the design of the Chang–Lee scheme. Moreover, by employing an efficient verifiable encryption of RSA signatures proposed by Ateniese, we propose an improvement for repairing the Chang–Lee scheme. We promote the formal study of the soundness of authentication as one open problem.

I. INTRODUCION INTRODUCTION

Hospital Single Sign-On (SSO) is a widely used authentication mechanism that allows users to log in once and access multiple services without repeated authentication. In distributed systems, SSO improves usability but introduces security risks such as impersonation attacks and credential leakage Cyber-Physical Systems (CPS) integrate physical processes with computational systems, making them highly sensitive to cyber threats. Therefore, strong authentication and security mechanisms are required.
This paper focuses on analyzing the vulnerabilities of existing SSO systems and proposes a secure framework using cryptographic techniques and blockchain technology to ensure safe authentication.

NEED OF THE STUDY

With the rapid growth of distributed systems and online services, users are required to access multiple platforms frequently. Managing multiple credentials creates complexity and security risks. Existing SSO systems suffer from vulnerabilities such as impersonation attacks, credential recovery attacks, and lack of privacy protection Therefore, there is a need for a secure authentication framework that ensures data privacy, prevents unauthorized access, and provides efficient authentication. This study aims to develop a secure SSO mechanism using advanced cryptographic techniques and blockchain technology.

3.1 Population and Sample

In this study, the population consists of all users and service providers participating in a distributed Single Sign-On (SSO) system. The system includes multiple entities such as users, authentication servers, and service providers within a network environment. The sample considered for this study includes a set of registered users and service providers interacting within the proposed secure SSO framework. These entities are selected to evaluate authentication processes, security mechanisms, and system performance.

The study focuses on analyzing how users access multiple services using a single credential and how the system prevents security threats such as impersonation attacks and credential leakage. The selected sample helps in testing the effectiveness and reliability of the proposed system.

3.2 Data and Sources of Data

The data used in this study is mainly experimental data collected from the implementation of the proposed SSO system. The data includes user credentials, login attempts, authentication logs, encryption keys, and session details. These data elements help in analyzing the behavior of the system during authentication and communication.

3.3 Theoretical framework

The theoretical framework of this study is based on secure authentication mechanisms and cryptographic techniques. The proposed system uses RSA encryption, Diffie-Hellman key exchange, and Non-Interactive Zero Knowledge Proof (NZK) to ensure secure communication and authentication ..RSA encryption is used to generate secure credentials and protect user identity. Diffie-Hellman key exchange is used to establish a secure communication channel between users and service providers. The NZK protocol allows users to prove their identity without revealing sensitive information. .Blockchain technology is integrated into the system to provide decentralization, transparency, and data integrity. The blockchain stores authentication records in a secure and tamper-proof manner.

RESEARCH METHODOLOGY

The methodology of this study focuses on designing and implementing a secure Single Sign-On (SSO) system using advanced cryptographic techniques and blockchain technology. Initially, existing SSO systems are analyzed to identify their weaknesses, including impersonation attacks and credential leakage. Based on this analysis, a secure framework is proposed. The system is implemented using Java for application development and MySQL for database management. The proposed system integrates RSA encryption, Diffie-Hellman key exchange, and Non-Interactive Zero Knowledge Proof to enhance security. The system is tested under various scenarios, including normal login conditions and attack situations. Performance metrics such as response time, authentication accuracy, and system reliability are measured. The results are analyzed to verify the effectiveness of the proposed system in improving security and efficiency.

The research methodology adopted in this study focuses on the design, implementation, and evaluation of a secure Single Sign-On (SSO) system using cryptographic techniques and blockchain technology. Initially, a detailed analysis of existing SSO systems is carried out to identify their limitations and security vulnerabilities such as impersonation attacks, credential leakage, and lack of privacy protection. Based on this analysis, a secure authentication framework is proposed. The proposed system integrates multiple security mechanisms including RSA encryption, Diffie-Hellman key exchange, and Non-Interactive Zero Knowledge Proof (NZK). RSA encryption is used to generate and protect user credentials, ensuring secure identity verification. Diffie-Hellman key exchange is used to establish a secure communication channel between users and service providers over an insecure network.

The system is developed using Java for application implementation and MySQL for database management. The architecture consists of users, service providers, and a trusted authority. Blockchain technology is incorporated to store authentication records in a decentralized and tamper-proof manner, improving data integrity and transparency.The implementation phase involves simulating real-time scenarios where multiple users access different services using a single credential. The system records authentication logs, session details, and response times for analysis. Various testing methods such as unit testing, integration testing, and system testing are performed to ensure the reliability of the system.

The system is also tested under different attack scenarios including impersonation attacks, replay attacks, and denial-of-service attacks. These tests help evaluate the robustness of the proposed system against potential security threats. Performance metrics such as authentication accuracy, response time, and system efficiency are measured and analyzed.
Finally, the results obtained from testing are compared with existing SSO systems to determine the improvements achieved in terms of security and performance. This methodology ensures that the proposed system is practical, secure, and efficient for real-world applications.

3.4 Statistical tools and econometric models

This study uses various statistical and analytical tools to evaluate the performance and security of the proposed Single Sign-On (SSO) system. The analysis focuses on measuring system efficiency, authentication accuracy, and resistance to security attacks.
The primary tools used in this study include performance analysis metrics such as response time, authentication success rate, error rate, and system reliability. These metrics help in understanding how effectively the system handles user authentication and prevents unauthorized access.
In addition, comparative analysis is performed between the proposed system and existing SSO systems to evaluate improvements in security and performance. Graphical representations and tabular analysis are used to present the results clearly.

3.4.1 Descriptive Statistics

Descriptive statistics are used to summarize and analyze the data collected from the system during testing. These statistics provide a clear understanding of system performance and behavior. The key statistical measures used in this study include mean, minimum, maximum, and standard deviation. The mean value represents the average response time and authentication success rate. The minimum and maximum values indicate the best and worst performance of the system under different conditions.Standard deviation is used to measure the variation in system performance, which helps in understanding the consistency of the system. A low standard deviation indicates stable performance, while a high value indicates variability.

.3.4.2 Fama-Mcbeth two pass regression

The Fama–McBeth two-pass regression method is a statistical technique used to analyze the relationship between dependent and independent variables over time. It is commonly used to evaluate how different factors influence a particular outcome by performing regression analysis in two stages.
In the first pass, time-series regression is applied to estimate the relationship between the dependent variable and a set of independent variables for each time period. In this study, system performance metrics such as authentication accuracy and response time are treated as dependent variables, while security parameters such as encryption strength, key exchange mechanism, and authentication protocols are considered as independent variables.

The first-pass regression helps in estimating the sensitivity of the dependent variables to changes in the independent variables. These estimated coefficients represent how strongly each factor affects system performance.In the second pass, cross-sectional regression is performed using the estimated coefficients obtained from the first pass. This step evaluates the overall impact of different factors across all observations. It helps in identifying which factors significantly contribute to improving system security and efficiency.

The Fama–McBeth approach reduces estimation errors and provides more reliable results by separating time-series and cross-sectional analysis. This method is useful in understanding the relationship between multiple variables and validating the effectiveness of the

proposed system.In this study, the model is adapted to analyze how different security mechanisms influence authentication performance and system reliability. The results obtained from this method help in determining the most effective security parameters for enhancing the overall system.

3.4.2.1 Model for CAPM

The Capital Asset Pricing Model (CAPM) is used to determine the relationship between risk and expected return of an asset. It explains how the expected return of an asset is influenced by its systematic risk compared to the overall market.

The CAPM model is expressed as:

$Ri = Rf + \beta (Rm – Rf)$ Where,

Ri = Expected return of the asset Rf = Risk-free rate
Rm = Market return
β (Beta) = Measure of systematic risk

In this study, CAPM is adapted to evaluate system performance by treating the system output as the dependent variable and risk factors as independent variables. The beta value represents how sensitive the system performance is to different influencing factors.

The model helps in understanding the impact of system-level risks on overall performance and provides a simplified way to analyze performance variation. CAPM assumes that only systematic risk affects the outcome, while other risks can be minimized.

This model is useful for analyzing the relationship between risk factors and performance efficiency in a structured manner.

3.4.2.2 Model for APT

The Arbitrage Pricing Theory (APT) is a multi-factor model used to determine the expected outcome based on several influencing factors. Unlike CAPM, which considers only one factor, APT takes into account multiple variables that affect performance.

The APT model is expressed as:

$Ri = Rf + \beta 1F1 + \beta 2F2 + \beta 3F3 + \ldots + \varepsilon$

Where,

Ri = Expected return Rf = Risk-free rate
β = Sensitivity to each factor
F = Factors affecting the system ε = Error term

In this study, APT is used to analyze system performance by considering multiple factors such as authentication accuracy, response time, encryption strength, and system reliability.

Each factor contributes to the overall performance of the system, and their combined effect is evaluated using the APT model. This approach provides a more comprehensive analysis compared to single-factor models.

3.4.3 Comparison of the Models

3.4.3 Comparison of the Models

The CAPM and APT models are compared to evaluate their effectiveness in analyzing system performance. CAPM is a single-factor model that considers only one variable, making it simple and easy to use. However, it may not capture all influencing factors affecting system performance. On the other hand, APT is a multi-factor model that considers multiple variables, providing a more detailed and accurate analysis. It allows the inclusion of various factors such as system reliability, response time, and security parameters. CAPM is useful for basic analysis, while APT is more suitable for complex systems where multiple factors influence the outcome. In this study, APT provides better insights into system behavior due to its ability to handle multiple variables.

3.4.3.1 Davidson and MacKinnon Equation

The Davidson and MacKinnon equation is a statistical method used to compare two non-nested models. Non-nested models are those that do not share the same set of variables and cannot be derived from one another. This method helps in determining which model provides a better explanation of the observed data.In this study, the Davidson and MacKinnon approach is used to compare the CAPM and APT models. The equation combines the predicted values from both models and evaluates their contribution to the actual outcome.

The general form of the equation is:
$Ri = \alpha + \beta 1\ RCAPM + \beta 2\ RAPT + \varepsilon$

Where,
Ri = Actual observed value
RCAPM = Expected value from CAPM RAPT = Expected value from APT
α = Intercept term β1, β2 = Coefficients ε = Error term

.3.4.3.2 Posterior Odds Ratio

The Posterior Odds Ratio is a statistical technique used to compare two competing models based on their probability of explaining the observed data. It provides a quantitative measure to determine which model is more strongly supported.

The Posterior Odds Ratio is calculated as:

$R = (ESS_0 / ESS_1) \times (N - K_0 / N - K_1)$

Where,

ESS_0 = Error sum of squares for Model 0 (APT) ESS_1 = Error sum of squares for Model 1 (CAPM) N = Number of observations
K_0 = Number of independent variables in APT K_1 = Number of independent variables in CAPM

The value of R determines which model is better:

- If R > 1, CAPM is more strongly supported
- If R < 1, APT is more strongly supported

This method is considered more formal and statistically reliable compared to other comparison techniques. It evaluates model performance based on error values and data fitting.

In this study, the Posterior Odds Ratio is used to compare the effectiveness of CAPM and APT in analyzing system performance. The results help in selecting the most suitable model for evaluating the proposed system.

Non-nested models are those that do not share the same set of variables and cannot be derived from one another. This method helps in determining which model provides a better explanation of the observed data.In this study, the Davidson and MacKinnon approach is used to compare the CAPM and APT models. The equation combines the predicted values from both models and evaluates their contribution to the actual outcome.

.IV. RESULTS AND DISCUSSION

4.1 Results of Descriptive Statics of Study Variables
Table 4.1: Descriptive Statics

Metric	Minimum	Maximum	Average	Result
Authentication Accuracy (%)	**92**	**99**	**96**	**High**
Response Time (ms)	**120**	**350**	**210**	**Fast**
System Reliability (%)	**90**	**98**	**95**	**Stable**
Attack Detection Rate (%)	**88**	**97**	**93**	**Effective**
Error Rate (%)	**1**	**8**	**4**	**Low**

Table 4.1 presents the performance analysis of the proposed system. The authentication accuracy is high, indicating that the system correctly verifies legitimate users. The response time is low, which shows that the system processes authentication requests efficiently.The system reliability is also high, demonstrating consistent performance under different conditions. The attack detection rate indicates that the system effectively prevents unauthorized access and security threats. The error rate is minimal, which confirms the stability and robustness of the system.

Overall, the results show that the proposed SSO system provides better security and performance compared to existing systems. The integration of advanced cryptographic techniques significantly enhances the system's ability to handle modern cyber threats.The proposed Single Sign-On (SSO) system was successfully implemented and evaluated under different operating conditions to measure its performance, security, and reliability. The system was tested using multiple users and service providers to simulate real-time scenarios in a distributed environment. The evaluation was carried out using key performance metrics such as authentication accuracy, response time,

system reliability, attack detection rate, and error rate. These metrics help in understanding how efficiently the system performs during authentication and how effectively it handles security threats.The authentication accuracy of the system is observed to be consistently high, which indicates that the system is capable of correctly identifying legitimate users while rejecting unauthorized users. The response time of the system remains low even when multiple users access the system simultaneously, which shows that the system is efficient and scalable.

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