Improved Remote User Authentication Scheme Preserving User Anonymity

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Summary
In 2004, Das et. al proposed a Dynamic ID based remote authentication scheme to authenticate the users while preserving the user’s anonymity. Chein et. al. pointed out that Das et. al scheme fails to protect the user’s anonymity and proposed a new scheme to conquer the weakness in 2005. In this paper, we show that Chein et al scheme is insecure against Insider attack and Man-in-middle attack. An improved scheme is proposed that overcomes the security risk.

Key words: Authentication, Password, Insider attack, Man-in-Middle attack.

1. Introduction
Password authentication with smartcards is one of the convenient and effective two-factor authentication mechanisms. This technology has been widely deployed for various kinds of authentication applications which include remote host login, online banking, access control of restricted vaults, activation of security devices and many more. Several schemes and improvements for remote user authentication schemes using smartcards [1-7, 9, 10] have been proposed.

In 2004, Das et. al. [9] proposed a dynamic ID-based remote user authentication scheme using smartcards which does not maintain any verifier table, allows users to change their password freely and they claimed that their scheme achieves user anonymity. But, in 2005 Chien et. al. [6] pointed out that Das et. al. scheme fails to protect the user’s anonymity, and proposed an improved remote user authentication scheme with user anonymity.

In this paper we show that chien et al scheme is vulnerable to insider attack and man-in-middle attack. The remainder of the paper organized as follows: Section 2 reviews the Chein et. al. scheme, Section 3 points out the weakness of the Chein et. al.’s scheme. In section 4 we propose an improved scheme. In section 5, we analyze the security of our scheme. In section 6 we evaluate the efficiency of the proposed scheme. Finally, section 7 gives a brief conclusion.

2. Review of Chein et. al. Scheme
In this section, we review the Chein et al. scheme. This scheme is composed of 3 phases namely the registration phase, the login phase and authentication phase. These phases are described as follows: The notations used throughout this paper are as follows:

U_i : The user.
PW_i : The password of user U_i.
ID_i : The identity of user U_i.
S : The remote server.
h (.) : A one way hash function.
⊕ : Bitwise XOR operation.
EK[x] : Encryption of x using key k.
DK[x] : Decryption of x using key k.

Registration Phase:
This phase is invoked whenever a user Ui registers with the remote system.
1. Ui selects a password PW_i and submits his identity ID_i and PW_i to the remote system
2. S computes m = h (ID_i ⊕ x) ⊕ h(x) ⊕ PW_i and I = h(ID_i ⊕ x) where x is secret key of the remote system.
3. S issues the smartcard to the user with the parameters m, I and the public parameters (h (.), p).

Login Phase:
The user Ui wants to login to the remote system, he inserts his smart card into the terminal, and inputs his ID_i and PW_i.
1. Generate a random number r_u = g^x mod p.
2. Compute M = m ⊕ PW_i.
3. Compute C = M ⊕ r_u.
4. Computes R = I ⊕ r_u = (h(ID_i ⊕ x) ⊕ r_u.
Ui sends {C, T, E_R, [r_u, ID_i, T]} to Server, where T is timestamp and the E_R [r_u, ID_i, T] is cipher text of encrypted using secret key R.

Authentication Phase:
Upon receiving the message, Server authenticates the user Ui as follows:
1. Computes $R$ with server’s secret key $x$.
   $R = C \oplus h(x)$ then decrypt the message $E_R[r_u, ID_i, T]$.

2. Test the validity of time interval between $T$ and $T'$, where $T'$ is a timestamp when server receives the message.

3. Verify whether following equation holds:
   $R = h(ID_i \oplus x) \oplus ru$.
   If the equation does not hold, reject the service request.

4. Deliver the message $E_R[r_s, r_u + 1]$ to the user, where $r_s = g^y \mod p$.

5. Upon receiving the message $E_R[r_s, r_u + 1]$ and the user checks whether decrypted data contains the value $r_u + 1$.
   if so, the user can generate the session key $K_u = r_s^x = g^{xy}$.
   and delivers the secret information with server.

3. Weaknesses of Chein et. al. Scheme

In this section, we will show that Chein et. al.’s scheme is vulnerable to an insider attack and man-in-middle attack.

1. Insider Attack:
   In the registration phase, user’s password will be revealed to the remote system as the user submits his ID and Password PW. If the user uses password to access several servers for his convenience, the insider of the remote system can impersonate U to access other servers [13].

B. Man-in-Middle Attack: An adversary can imitate user while talking to the server and can imitate server while talking to the user.

The basis of the following attacks is based on the risk of smart card stored information. A legitimate user could extract the values stored in smartcard by some means [12, 13] then he/she could perform the Man-in-Middle attack.

In the registration phase, $m = h(ID_i \oplus x) \oplus h(x) \oplus PWi$ and $I = h(ID_i \oplus x)$ is stored in the $Ui$’s smartcard. Once $Ui$ extracts $m$ and $I$ from smart card by some means [6, 9] then he/she can derive $h(x)$ by computing $h(x) = m \oplus I \oplus PWi$. An adversary with a valid smart card can now perform the attack as follows:

Adversary intercepts the login message of user $Ui$: $\{c, T, E_R[r_u, ID_i, T]\}$to the server, then adversary computes $R = C \oplus h(x)$ and decrypts $E_R[r_u, ID_i, T]$.
Generates $r_u \cdot g^y \mod p$ & computes $R' = R \oplus r_u$ and $C' = C \oplus r_u$ and sends $\{C', T, E_R[r_u, ID_i, T]\}$ to the server. The server authenticates the adversary as user $Ui$ since $R' = h(ID_i \oplus x) \oplus r_u$. Then the server delivers the message $E_R[r_u, r_u + 1]$ where $r_u \cdot g^y \mod p$. Now, the adversary intercepts the message and decrypts it using $R'$ and calculates $K_u = r_s = g^{xy}$, then the adversary generates the message $E_R[r_u, r_u + 1]$ where $r_u \cdot g^y \mod p$ and sends it to $Ui$.

Then, $Ui$ decrypts the received message and checks whether decrypted message contains the value $r_u + 1$ if so, the user generates the session key $K_u = r_s^x = g^{xy}$.

4. The Improved Scheme

In this section, we propose an improved efficient remote user authentication scheme that protects the user’s anonymity using the smart cards and overcomes the above mentioned attacks. The scheme is divided into three phases: the registration phase, the authentication and the password change phase. The notations used in this scheme are same as in Chien et. al. scheme. These phases are described as follows:

Registration Phase
First, the user gives the IDi and $h(PWi)$ to remote system for registration. Next the remote system performs the following steps:

1. Computes $m = h(\text{ID} \oplus x) \oplus h(x) \oplus PWi$
   and $I = h(\text{ID} \oplus x)$ in the $Ui$’s smartcard.
   Once $Ui$ extracts $m$ and $I$ from smart card by some means [6, 9], then $he/she can derive $h(x)$ by computing $h(x) = m \oplus I \oplus PWi$. An adversary with a valid smart card can now perform the attack as follows:

Adversary intercepts the login message of user $Ui$: $\{c, T, E_R[r_u, ID_i, T]\}$to the server, then adversary computes $R = C \oplus h(x)$ and decrypts $E_R[r_u, ID_i, T]$.
Generates $r_u \cdot g^y \mod p$ & computes $R' = R \oplus r_u$ and $C' = C \oplus r_u$ and sends $\{C', T, E_R[r_u, ID_i, T]\}$ to the server. The server authenticates the adversary as user $Ui$ since $R' = h(\text{ID} \oplus x) \oplus r_u$. Then the server delivers the message $E_R[r_u, r_u + 1]$ where $r_u \cdot g^y \mod p$. Now, the adversary intercepts the message and decrypts it using $R'$ and calculates $K_u = r_s = g^{xy}$, then the adversary generates the message $E_R[r_u, r_u + 1]$ where $r_u \cdot g^y \mod p$ and sends it to $Ui$.

User

Adversary

Remote systems

Fig. 1 Man-in-the-middle attack

Thus, the adversary can perform a man in the middle attack and could establish a key with the server and a key with user $Ui$. 

Login phase

Authentication phase

Password change phase

Registration phase
1. Generate a random number
   \[ r_u = g^x \mod p. \]
2. Compute \( M = m \oplus h(PW_i) \).
3. Compute \( C = M \oplus r_u \).
4. Compute \( R = I \oplus r_u = h(ID_i \oplus x) \oplus x \oplus r_u \).

sends the message \( \{ C, T, E_R [r_u, ID_i, T] \} \) to the server, where \( T \) is timestamp and the \( E_R [r_u, ID_i, T] \) is cipher text of encrypted using the secret key \( R \).

**Authentication Phase**

After receiving the message, the server computes as follows:
1. Compute \( R \) with the server’s secret key \( x \).
   \[ R = C \oplus h(x) \oplus x, \]
then decrypts the message \( E_R [r_u, ID_i, T] \).
2. Test the validity of time interval between \( T \) and \( T' \) where \( T' \) is a time stamp when server receive message.
3. Verify whether the following equation holds
   \[ R = h(ID_i \oplus x) \oplus x \oplus r_u. \]
   If the equation does not hold, reject the service request.
4. Deliver the message \( \{ T_1, E_R [r_s, r_u + 1, T_1] \} \) to the user, where \( r_s = g^y \mod p \) and \( T_1 \) is the current timestamp.
5. Upon receiving the message \( \{ T_1, E_R [r_s, r_u + 1, T_1] \} \), user tests the validity of the time interval and checks whether the decrypted data contains \( r_u + 1 \). If so, the user can generate the session key \( K_{us} = g^{xy} \) based on Diffie-Hellman key exchange protocol. So, our scheme can achieve forward secrecy.

6. Server decrypts the received message and checks whether it is equal to \( r_s + 1 \) or not. If yes, the user is authenticated and that the server can be assured of a session key established between the server and the user.

**5. Security analysis of the Improved Scheme**

In this section, we are going to demonstrate that our scheme is secure:

1. **Replay attack:** The replay attacks cannot work in our scheme. That is, replaying neither the login message \( M = \{ C, T, E_R [r_u, ID_i, T] \} \) of login phase nor the response message \( M' = \{ T_1, E_R [r_s, r_u + 1, T_1] \} \) of authentication phase will succeed since the validity of \( M \) and \( M' \) can be checked with the time stamps \( T \) and \( T_1 \) respectively.
2. **Stolen-verifier attack:** Since the scheme had no verification table, nobody could obtain any verifiable information from the server to threaten the protocol. So, the scheme can prevent stolen-verifier attack.
3. **Guessing attack:** Our scheme, don’t send the passwords through communication channel. It is only used by the user to trigger the secret value computation in smart card. So, the adversary can’t verify his guessing from the eavesdropped data.
4. **Forward Secrecy:** The forward secrecy means that even though the shared secret is disclosed at some point, it will not cause the compromise of any earlier session. Suppose the secret key \( x \) is compromised the adversary can intercept the message \( C \) and computes \( R = C \oplus h(x) \oplus x \), then he can’t know the session key \( K_{us} \), because the session key is computed by \( K_{us} = g^{xy} \) based on Diffie-Hellman key exchange protocol. So, our scheme can achieve forward secrecy.
5. **Known-key secrecy:** The known-key security means the compromise of a past session key can’t derive any further session key. If the session key \( K_{us} \) is known by the adversary, he can’t compromise other session key \( K_{us} \), because the session key is generated from random numbers \( r_u = g^x \) and \( r_s = g^y \) based on Diffie-Hellman protocol
6. **Insider attack:** In the registration phase, user submits \( h(PW) \) to the remote system. So, even an insider cannot know the password of a user. Hence, our scheme defends insider attack.
7. **Man-in-the-middle attack:** A registered user with a smart card can not perform this attack as \( h(x) \) or \( x \) cannot be computed from the values stored in the user’s smart card.

**6. Efficiency analysis**

In this section, we show the comparisons of the efficiency between Chien et. al’s scheme and our scheme to demonstrate that our scheme is not only secure but also efficient than Chien et. al’s scheme. Table 1 gives the comparisons of efficiency between our scheme and Chien et. al’s.

It can be viewed that our scheme can defend insider attack and man-in-the-middle attack with one extra XOR operation in registration phase, one extra hash function in Login phase and with two additional XOR operations in authentication phase, these operations do not cost much. In addition session key verification by the server can be achieved with one encryption done by the user and a decryption done by the system.
Table 1: Comparisons of Efficiency between our scheme and Chein et. al.’s

<table>
<thead>
<tr>
<th>Chien et al’s scheme</th>
<th>Our Scheme</th>
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<tbody>
<tr>
<td></td>
<td>Smart card</td>
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<tr>
<td>Computations of RP</td>
<td>0</td>
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<tr>
<td>Computations of LP</td>
<td>3⊕, 1E,</td>
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<tr>
<td>Computations of AP for authenticating users</td>
<td>0</td>
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<tr>
<td>Computations of AP for authenticating server &amp; session key generation</td>
<td>1e, 1E</td>
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<td>Verification of session key by server</td>
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<td>Information kept in the smart card</td>
<td>M.J, h(·), P</td>
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h: Computation operation of the hash function e: exponential computation operation E: Encryption/Decryption operations ⊕: XOR RP: Registration Phase LP: Login Phase AP: Authentication Phase

7. Conclusion

The threat of smart card security [8, 11, 12] is a crucial concern, where some secret information is stored is the memory of smart cards. It is important to judge the financial cost and time to extract the secret data from the smart card. If the cost as well as time is tolerable or higher than the cost of the secret inside the smart card, then one can take that risk while using smart card to store some secret data. If extracting a secret from the card leads to collapse the whole system (e.g., chein et al.’s scheme) then definitely some additional counter measure should be taken while designing the scheme.

We have shown that chain e al’s scheme is insecure against insider attack and man-in-the-middle attack and have proposed a scheme which defends both the attacks, while still maintaining all the benefits of chein et al’s scheme.

References


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