An improved Chang-Lee’s smart card-based authentication scheme

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Abstract. It is useful to verify a legal user from a remote terminal through the Internet with the user authentication schemes based on the smart card. Usually, the remote user has to use his/her identification accompanying the password to access the system. This action is an important scheme to protect the user’s privacy and confidentiality. To achieve the robustness and the efficiency, Chang and Lee proposed a scheme that employs a smart card-based user authentication with the characters of implementation practically and easily. Also, Chang and Lee claim that the scheme could resist the replay attacks, the impersonation attacks, the identity disclosure attacks, and the perfect forward secrecy. However, this work shows that the scheme is in the risk with an on-line guessing identity and password attacks and denial of service attack. Hence, in this paper, it proposes an improved user authentication scheme that holds the capacity to withstand the vulnerability as that in Chang-Lee’s smart card-based scheme.

1. Introduction

With a fast revolution of information technology, to access the Internet becomes convenient. To access the internet service and to download the files becomes easy. In order to identify the authorized users to access the remote server, there some schemes have been proposed [1-4]. Almost schemes meet the requirements of simple, useful, and practical user authentication [5-10].

Traditionally, for the user authentication, the registration table records the pairs of identity and password for each registered user in the server. By this way, the security concerns might be hold with various attacks, such as insider attacks, hacker intrusion, and guessing attacks, and other attacks [11-14]. For the attack defeating, the user authentication scheme based on the smart card has been proposed [15-17]. Within that scheme, the smart card keeps the parameters for the secure verification and the remote server does need to keep the registration table. Hence, these attacks could not be the outbreak for the system. Sequentially, based on the smart card, some user authentications have been
proposed [18-23]. Recently, the robust user authentication scheme is proposed based on the smart card [24]. However, it is weak to resist the on-line guessing ID and password attacks, and DOS attack. This work proposes an improved Chang-Lee’s user authentication scheme to withstand the vulnerability in the scheme.

2. User Authentication by Chang-Lee
Chang-Lee’s scheme is described as the follows [29]. In Chang-Lee’s scheme, there are two major members. One is the user Ui and the other is the server S. Also, there are four phases in the scheme.

2.1 User registration phase
Initially, a new user Ui has to register the system as a legal user. Then, the system will send a valid smart card to the user Ui. The issued smart card contains a message \{R1, R2, R3, SIDi, h( )\}, where h( ) represents a one-way hash function; R1 = h(idi||x||ri); R2 = gxy mod p; R3 = h(idi||R2) ⊕ h(pwi); and SIDi = (idi||sni); ri is a random number, x & y are two secret keys of the server S, g is a primitive root, p is a large prime, and sni is a serial number.

2.2 User login phase
When the user Ui wants to receive the resource from the remote server, the user Ui should input his/her identity id, accompanying with the password pw, to the terminal devise with the smart card. Then, a message \{DIDi, Vi, ni\} is generated by the smart card and is sent to the server S. ni is a random number generating with the smart card; C1 = R3 ⊕ h(pwi); V1 = R1 ⊕ C1; DIDi = h(R2||n1) ⊕ SIDi, where R1, R2, R3, and SIDi are retrieved from the storage of smart card.

2.3 Server authentication phase
According the following steps, the user Ui verifies the server S.
1) The server S retrieves the identity id, and the serial number ni from SIDi: 
   \[ \text{SID}_i = \text{DID}_i \oplus h(g^{xy} \mod p)(n_i) \]
   2) The server S checks the formats for id, and sni. If the formats are correct, the server computes R1*, V2, and V3 and sends \{id, V2, V3\} to the user Ui, here id is the identity of the server. R1* = V1 ⊕ h(id, g^{xy} mod p); V2 = h(R1* || id || ni); V3 = h(h(id, g^{xy} mod p)||ni) ⊕ n2. Here n2 is the random number generating with the server S.
   3) Upon receiving \{id, V2, V3\} from the server, the user Ui computes V2* and check V2, V2* = h(R1 || id || ni). If V2 = V2*, the server is authenticated; otherwise, the user stops the procedure.
   4) Ui send V4 to the server, n2 = V3 ⊕ h(C1 || n2), SK = h(n1 || SIDi || R2 || n2), and V4 = h(SK || (n2 + 1)).

2.4 User authentication phase
According to the following steps, the server S verifies the user Ui.
1) V4* is calculated by S: SK = h(n1 || SIDi || g^{xy} mod p) || n2) and V4* = h(SK || (n2+1)).
2) S checks V4* whether the result is equal to V4. If it is, the user Ui and the session key SK shared with Ui are authenticated; otherwise, the server terminates the connection to the user, and also stops the service to the user.

2.5 User password changing phase
After id, and pw, are input by the user, the smart card executes the procedures to change the current password pw, to a new one pw'.
1) The smart card calculates Q1 = h(id || R2) and Q1* = R3 ⊕ h(pw).
2) The smart card checks Q1 and Q1*. If Q1 ≠ Q1*, it is not allowed to change the password.
3) The new R’3 is calculated by the smart card and, then, the original R3 is replaced.
3. Weakness in Chang-Lee Scheme

Within Chang-Lee’s scheme, for the on-line password guessing attack with user’s smart card and the denial of service attack, it could not effectively withstand these attacks [29].

3.1 Password guessing attack

The adversary might have a chance to use password guessing attack when he steals the user Ui’s smart card or he gets the lost smart card. In the user login phase,

1) The adversary intercepted the message \(\{\text{DID}_i, V_1, n_1\}\) belonging to the user \(U_i\) and the server in this phase. The adversary computes \(V_1\) as follows,

\[
V_1 = R_1 \oplus C_1
\]

\[
= R_1 \oplus R_3 \oplus h(pw_i)
\]

\[
= R_1 \oplus (h(id_i || R_2) \oplus h(pw_i)) \oplus h(pw_i)
\]

\[
= h(id_i || R_2) \oplus h(pw_i)
\]

2) The user \(U_i\)’s smart card is replaced and, then, the adversary uses an arbitrary identity and guesses a password \(PW'_i\).

3). The message \(\{\text{DID}'_i, V'_1, n'_1\}\) is sent to the server \(S\). Here \(n'_1\) is the random number generating by the smart card. The fake message \(\text{DID}_i\) and \(V_1\) are computed as follows,

\[
C'_1 = R_3 \oplus h(pw'_i)
\]

\[
V'_1 = R_1 \oplus C'_1
\]

\[
\text{DID}'_i = h(R_2 || n'_1) \oplus \text{SID}_i
\]

4). The adversary could check \(V'_1\) and \(V_1\),

\[
V'_1 = R_1 \oplus C'_1
\]

\[
= R_1 \oplus R_3 \oplus h(pw'_i)
\]

\[
= R_1 \oplus (h(id_i || R_2) \oplus h(pw_i) \oplus h(pw'_i)) \oplus h(pw'_i)
\]

If the guessing password \(pw'_i\) is equal to the original password \(pw_i\), \(h(pw_i) = h(pw'_i)\), this implies \(V'_1 = V_1\). Otherwise, the guessing password is not correct. The adversary repeats Steps 2 – 4 till the guessing password is correct.

3.2 Identity and password guessing attack

Because of the lost or stolen user \(U_i\)’s smart card, the adversary might have a chance to guess the identity \(id'_i\) and password \(pw'_i\) of the smart card. Also, he might intend to change the password in the login phase.

1) For the password changing, \(Q_1\) and \(Q_1^*\) are calculated by the smart card,

\[
Q_1 = h(id'_i || R_2)
\]

\[
Q_1^* = R_3 \oplus h(pw'_i)
\]

2) The smart card checks if \(Q_1\) is not equal to \(Q_1^*\). If it is, the password changing is not allowed.

3) The original \(R_3\) is replaced with the new \(R'_3\) generating by the smart card,

\[
R'_3 = R_3 \oplus h(pw'_i) \oplus h(pw''_i)
\]

\[
= h(id_i || R_2) \oplus h(pw_i) \oplus h(pw'_i) \oplus h(pw''_i)
\]

\[
= h(id_i || R_2) \oplus h(pw''_i)
\]

4) In the login phase, the guessed identity \(id'_i\) is input and the password \(pw''_i\) is changing. The message \(\{\text{DID}'_i, V'_1, n'_1\}\) is sent to the server by the smart card. Here \(V'_1\) is calculated,

\[
V'_1 = R_1 \oplus C_1
\]

\[
= R_1 \oplus R'_3 \oplus h(pw''_i)
\]

\[
= R_1 \oplus (h(id_i || R_2) \oplus h(pw_i) \oplus h(pw'_i) \oplus h(pw''_i) \oplus h(pw''_i))
\]

When the guessed password \(pw'_i\) is correct (i.e., \(pw'_i = pw_i\)), the hash function \(h(pw_i)\) is equal to \(h(pw'_i)\), \(V'_1\) is calculated,
If $V'1$ is not equal to $V_i$, the adversary repeats to execute Steps 1-4 with re-guessing the identity and password.

### 3.3 Denial of service attack

The message $\{\text{DID}_i, V_i, n_i\}$ belonging to the legal user $U_i$ and the server $S$ could be interrupted in the login phase.

1. The intercepted message $\{\text{DID}_i, V_1, n_1\}$ is sent to the server $S$ in this phase.
2. The server executes the server authentication phase of Chang-Lee’s authentication scheme. The server will cost a large CPU to compute $\text{SID}_i$, $R1^*$, $V2$, and $V3$. The server sends $\{\text{id}_s, V2, V3\}$ to adversary.
3. The adversary sends back an arbitrary $V'4$ to the server. The server needs to computes,$$V4^* = h(\text{SID}_i || (\text{ID}_s^y \text{ mod p}) || n_2)$$and checks $V'4$ and $V4$. In this step, the server could know the user is an adversary. However, the server had spent a large computation for authenticating the user. Therefore, the server is unable to serve other legal users.

### 4. The Proposed Authentication Scheme

In the proposed scheme, the registration phase and the revocation phase are kept as those in Chang-Lee’s scheme.

#### 4.1 User login phase

While the user $U_i$ keys in his/her identity $id_i$ and password $pw_i$ to access the remote server, the user $U_i$ has to keep the smart card in the terminal device.

1. The smart card computes $Q1$ and $Q1^*$,
   \[
   Q1 = h(id_i || R2) \\
   Q1^* = R3 \oplus h(pw_i)
   \]
2. If $Q1$ is not equal to $Q1^*$, the smart card asks the user to repeat his/her identity $id_i$ and password $pw_i$ for three times. If the user does not input the correct identity and password, the smart card stops the connection between the smart card and the terminal device.
3. The login message $\{\text{DID}_i, V_i, T_i\}$ to the server $S$ is sent by the smart card. Here $T_i$ is a time stamp of the smart card. $\text{DID}_i$ and $V_i$ are computed,
   \[
   C1 = R3 \oplus h(pw_i) \\
   V_i = R1 \oplus C1 \\
   \text{DID}_i = h(R2 || T_i) \oplus \text{SID}_i
   \]
   where $R1$, $R2$, $R3$, and $\text{SID}_i$ are obtained from the storage of smart card.

#### 4.2 Server authentication phase

According to the following steps, the user $U_i$ verifies the server $S$.

1. The server $S$ checks if the time stamp $T_i$ is valid. If the time stamp is invalid, the server disconnects the link between the user $U_i$ and the server. Also, it stops to provide the services to the user.
2. The server retrieves the identity $id_i$ and the serial number $sn_i$ from $\text{SID}_i$,$$\text{SID}_i = \text{DID}_i \oplus h(\text{ID}_s^y \text{ mod p} || T_i)$$
3. The server checks the formats for $id_i$ and $sn_i$. If the formats are matched, the server computes $R1^*$, $V2$, and $V3$ and sends $\{\text{id}_s, V2, V3\}$ to the user $U_i$, here $\text{id}_s$ is the identity of the server.
where \( T_s \) is a time stamp of the server.

4) Upon receiving the message \( \{ \text{id}_u, V_2, V_3 \} \), the user \( U_i \) checks if the time stamp \( T_s \) is valid. If \( T_s \) is not valid, the user terminates the connection with the illegal server.

5) The user computes \( V_2^* \) and check \( V_2 \).

\[
V_2^* = h(R_1^* \| id_u \| T_i)
\]

If \( V_2 = V_2^* \), the server is authenticated; otherwise, the user stops the procedure.

6) The user \( U_i \) send \( V_4 \) to the server,

\[
T_s = V_3 \oplus h(C_1 \| T_i)
SK = h(u_i \| SID_i \| R_2 \| T_3)
V_4 = h(SK \| T_3).
\]

### 4.3 User authentication phase

Oppositely, according to the following steps, the server \( S \) verifies the user \( U_i \).

1) The server calculates \( V_4^* \).

\[
SK = h(T_i \| SID_i \| g^v \mod p) \| T_3)
V_4^* = h(SK \| T_s).
\]

2) The server \( S \) compares \( V_4^* \) and \( V_4 \). If \( V_4^* \) is equal to \( V_4 \), the user \( U_i \) and the session key \( SK \) shared are authenticated. Otherwise, the server terminates the connection to the user, and also stops to provide the service to the user.

### 4.4 User password changing phase

When the user \( U_i \) needs to alter the password, after the user inputs his/her id, and pw, the following procedures for password changing are executed.

1) The smart card calculates \( Q_1 \) and \( Q_1^* \).

\[
Q_1 = h(id_i \| R_2)
Q_1^* = R_3 \oplus h(pw_i).
\]

2) The smart card checks if \( Q_1 \) and \( Q_1^* \) are equal. If it is, the smart card asks the user re-inputs his/her identity id, and password pw, for three times. If the identity and the password could not be input correctly, the connection between the smart card and the terminal device is terminated.

3) The smart card computes a new \( R' \) and replaces the original \( R \) with the new \( R' \).

\[
R' = R_3 \oplus h(pw_i) \oplus h(pw'_i)
= h(id_i \| R_2) \oplus h(pw_i) \oplus h(pw'_i)
= h(id_i \| R_2) \oplus h(pw'_i)
\]

5. Conclusion

In summary, this work has shown the weakness of Chang-Lee's smart card-based authentication scheme. That authentication could not withstand the on-line identity and password guessing attacks with a smart card, and denial of service attack. For these weaknesses in the authentication, in this paper, the scheme authentication scheme has been proposed. With the proposed scheme, it improves authentication without the on-line guessing identity and the password attacks and the denial of service attack.

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