멀티서버를 위한 안전한 동적 ID 기반 원격 사용자 인증 방식에 대한 안전성 분석

Security Analysis of a Secure Dynamic ID based Remote User Authentication Scheme for Multi-server Environment

양형규* 

Hyung-Kyu Yang

Abstract Recently, user authentication schemes using smart cards for multi-server environment have been proposed for practical applications. In 2009, Liao-Wang proposed a secure dynamic ID based remote user authentication scheme for multi-server environment that can withstand the various possible attacks and provide user anonymity. In this paper, we analyze the security of Liao-Wang’s scheme, and we show that Liao-Wang’s scheme is still insecure against the forgery attack, the password guessing attack, the session key attack, and the insider attack. In addition, Liao-Wang’s scheme does not provide user anonymity between the user and the server.

Key Words: Smart card, User authentication, forgery attack, user anonymity, session key attack

I. Introduction

With the rapid development of internet technology, user authentication scheme in e-commerce has been becoming one of important security issues. However, the security weaknesses in the remote user authentication scheme have been exposed seriously due to the careless password management and the sophisticated attack techniques.

If conventional password-based authentication scheme is applied to multi-server environment, each remote user has to login to various servers repetitively and remember many sets of identity/password. It is inefficient and is not secure the authentication scheme

*정회원, 강남대학교 컴퓨터미디어정보공학부 
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*Corresponding Author: hkyang@kangnam.ac.kr
Dept. of Computer Engineering, Kangnam University, Korea
from compromise of the identity and password. Several authentication schemes for multi-server environment have been proposed to improve the security and efficiency\cite{1-9}. In general, a secure and efficient remote user authentication scheme for multi-server environment usually should provide the following basic criteria: single registration, low computation, no verification table, update password securely and freely, mutual authentication, session key agreement, and security.

In 2003, Lin et al. proposed a new remote user authentication scheme for multi-server architecture\cite{2}. However, Juang in 2004 pointed out that Lin et al.’s scheme is not enough efficient for authentication process, and then proposed an efficient multi-server password authenticated key agreement using smart cards\cite{3}. In 2007, Hwang and Shiau showed Juang’s scheme lacks of explicit key authentication and is inefficient with respect to communication costs, and then they proposed provably efficient authenticated key agreement protocol for multi-server\cite{5}. However, their scheme still does not provide forward secrecy. Recently, in 2009, Liao–Wang proposed a secure dynamic ID based remote user authentication scheme for multi-server environment, and they claimed that can withstand the various possible attacks and provide user anonymity\cite{7}.

In this paper, we analyze the security of Liao–Wang’s scheme. And we show that Liao–Wang’s scheme is still insecure against the various known attacks and does not provide user anonymity. To analyze the security, we assume that an attacker could obtain the secret values stored in the smart card by monitoring the power consumption and intercept messages communicating between the user and the server\cite{8-10}.

This paper is organized as follows. In section 2, we briefly review Liao–Wang’s scheme. In section 3, we describe the security analysis of Liao–Wang’s scheme. Finally, conclusions are presented in section 4.

II. Reviews of Liao–Wang’s Scheme

In 2009, Liao–Wang proposed a secure dynamic ID based remote user authentication scheme for multi-server environment. This scheme is composed of four phases: registration phase, login phase, mutual verification and session key agreement phase, and password change phase. The notations used in this paper are listed in Table 1.

### Table 1. Notation and Definition

<table>
<thead>
<tr>
<th>Notation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(U_i)</td>
<td>User (i)</td>
</tr>
<tr>
<td>RC</td>
<td>Registration center</td>
</tr>
<tr>
<td>(S_j)</td>
<td>Server (j)</td>
</tr>
<tr>
<td>(PW_i)</td>
<td>Password of the user (i)</td>
</tr>
<tr>
<td>(ID_i)</td>
<td>Identification of the user (i)</td>
</tr>
<tr>
<td>(SID_j)</td>
<td>Identification of the server (j)</td>
</tr>
<tr>
<td>(h())</td>
<td>A one-way hash function</td>
</tr>
<tr>
<td>(x)</td>
<td>A master secret key of the registration center</td>
</tr>
<tr>
<td>(y)</td>
<td>A secret number shared with the registration center and all servers</td>
</tr>
<tr>
<td>(N_i)</td>
<td>A random number chosen by the user</td>
</tr>
<tr>
<td>(N_j)</td>
<td>A random number chosen by the server</td>
</tr>
<tr>
<td>(A \parallel B)</td>
<td>A concatenates with B</td>
</tr>
<tr>
<td>(A \oplus B)</td>
<td>A exclusive–OR B</td>
</tr>
</tbody>
</table>

1. Registration Phase

This phase works whenever a user wants to register in the multi-server system. The user \(U_i\) submits his identity \(ID_i\) and password \(PW_i\) to the registration center RC via a secure channel. Then the registration center performs the following steps.

R1. The registration center computes \(T_i=h(ID_i \parallel x), V_i=T_i \oplus h(ID_i \parallel PW_i), B_i=h(PW_i) \oplus h(x)\) and \(H_i=h(T_i)\).

R2. The registration center issues the smart card with the secret values \((V_i,B_i,H_i,h(y))\) to the user via a secure channel.
2. Login Phase

This phase works whenever a user wants to login to the remote server. The user Ui inserts his smartcart to the card reader and keys his identity IDi, password PWi and the server identity SIDi. Then the smart card performs the following steps. The login and authentication phase are illustrated in Fig. 1.

L1. The smart card computes \( T_i^* = V_i \oplus h(ID_i \parallel PW_i) \), and then checks whether the computed value \( h(T_i^*) \) equals \( H_i \) stored in the smartcard or not. If it holds, the smartcard performs the next steps.

L2. The smart card generates random nonce \( N_i \) and computes \( CID_i = h(PW_i) \oplus h(T_i^* \parallel y \parallel N_i \parallel SID_i) \) and \( P_{ij} = h(y \parallel N_i \parallel SID_j) \).

L3. The smart card sends the login request message \( \{ CID_i, P_{ij}, Q_i, N_i \} \) to the server Sj.

3. Mutual Verification and session key agreement phase

After receiving the login request message, the server Sj and the user Ui authenticate each other and agree on a session key \( SK \) such as the following steps.

M1. The server computes \( T_i^* = P_{ij} \oplus h(y \parallel N_i \parallel SID_j) \), \( h^*(PW_i) = CID_i \oplus h(T_i^* \parallel y \parallel N_i) \) and \( B_{ij}^* = h^*(PW_i) \oplus h(x) \).

M2. The server checks whether the computed value \( h(B_{ij}^* \parallel y \parallel N_i \parallel SID_j) \) equals \( Q_i \) or not. If it holds, the server performs the next steps.

M3. The server generates random nonce \( N_j \) and computes \( M_{ij1} = h(B_{ij}^* \parallel y \parallel N_j \parallel SID_j) \), and then sends back the reply message \( \{ M_{ij1}, N_j \} \) to the user.

M4. After receiving the reply message, the user checks whether the computed value \( h(B_{ij} \parallel y \parallel N_j \parallel SID_j) \) equals \( M_{ij1} \) or not. If it holds, the user performs the next steps.

M5. The smart card computes \( M_{ij2} = h(B_i \parallel y \parallel N_j \parallel SID_j) \), and then sends back the message \( \{ M_{ij2} \} \) to the server.

M6. After receiving the message, the server checks whether the computed value \( h(B_{ij}^* \parallel y \parallel N_j \parallel SID_j) \) equals \( M_{ij2} \) or not. If it holds, the user is authenticated by the server.

M7. After completing the mutual authentication, the user and the server compute their session key respectively such as \( SK = h(B_i \parallel N_j \parallel N_j \parallel y \parallel SID_j) \).

4. Password Change Phase

This phase works whenever a user wants to update his password without the help of the registration center. The user inserts his smart cart to the card reader, and keys his identity IDi and password PWi. Then the user performs the following steps.

P1. The smart card works as the step 1 of login phase for assuring the legality of the cardholder and allows the cardholder to resubmit a new password \( PW_i^{\text{new}} \).

P2. The smart card computes \( V_i^{\text{new}} = T_i^* \oplus h(ID_i \parallel PW_i^{\text{new}}) \) and \( B_i^{\text{new}} = B_i \oplus h(PW_i) \oplus h(PW_i^{\text{new}}) \).

P3. Then, the smart card updates with \( V_i^{\text{new}} \) and \( B_i^{\text{new}} \) instead of \( V_i \) and \( B_i \) each other.
III. Security Analysis of Liao–Wang’s Scheme

To analyze the security of Liao–Wang’s scheme, we assume that an attacker could obtain the secret values $(B_i, y)$ stored in the smart card by monitoring the power consumption and intercept messages $(P_{ij}, N_i, N_j)$ communicating between the user and the server[8-9].

1. Forgery Attack

With the extracted secret values, an attacker can easily perform the user impersonation attack as the following steps. The procedure of the user impersonation attack is illustrated in Fig.2.

FA1. The attacker computes easily $T_i^*=P_{ij}\oplus h(y \parallel N_i \parallel SID_j)$, $h^*(PW_i)=CID_i \oplus h(T_i^* \parallel y \parallel N_i)$ and $B_i^*=h^*(PW_i) \oplus h(x)$.

FA2. Then, the attacker computes the following equations, where $N_i^*$ is a random number chosen by the attacker.

$$CID_i^*=h(PW_i) \oplus h(T_i^* \parallel y \parallel N_i^*)$$

$$P_{ij}^*=T_i^* \oplus h(y \parallel N_i^* \parallel SID_i)$$

FA3. The attacker sends the forged login request message $(CID_i^*, P_{ij}^*, Q_i^*, N_i^*)$ to the remote server $S_i$.

FA4. Upon receiving the forged message, $S_i$ computes $T_i^{**}=P_{ij}^* \oplus h(y \parallel N_i^* \parallel SID_i)$, $h^{**}(PW_i)=CID_i^* \oplus h(T_i^{**} \parallel y \parallel N_i^*)$ and $B_i^{**}=h^{**}(PW_i) \oplus h(x)$.

FA5. Then, $S_i$ checks whether the computed value $h(B_i^{**} \parallel y \parallel N_i^*)$ equals $Q_i^*$ or not. If it holds, the server performs the next steps.

FA6. $S_i$ generates random nonce $N_j$ and computes $M_{ij1}=h(B_i^{**} \parallel y \parallel N_j \parallel SID_j)$, and then sends back the reply message $(M_{ij1}, N_j)$ to the user.

FA7. After receiving the reply message, the attacker computes $M_{ij2}=h(B_i \parallel y \parallel N_j \parallel SID_j)$, and then sends the forged message $(M_{ij2})$ to the server.

FA8. After receiving the message, the server checks whether the computed value $h(B_i \parallel y \parallel N_j \parallel SID_j)$ equals $M_{ij2}^*$ or not. If it holds, the attacker is authenticated as the legal user by the server.

Also, with the extracted secret values $(B_i, y)$ and the intercepted message $(N_j)$, the attacker can perform the server masquerading attack by computing $M_{ij1}^*=h(B_i \parallel y \parallel N_j \parallel SID_j)$ and sending the reply message $(M_{ij1}^*, N_j^*)$ to the user, where $N_j^*$ is a random number chosen by the attacker. After receiving the reply message from the attacker, the user checks whether the computed value $h(B_i \parallel y \parallel N_j \parallel SID_j)$ equals $M_{ij1}^*$ or not. If it holds, the user can authenticate the attacker as the legal server.

2. Session Key Attack

After mutual authentication is performed, the legal user and the remote server can use the session key $SK$ in the public channel to encrypt/decrypt all the messages. In Liao–Wang’s scheme, the attacker can establish the one–time session key $SK=h(B_i \parallel N_i \parallel SID_i)$ as shown in the session key agreement phase if the attacker can obtain the secret values $(B_i, y)$ stored in the smart card and intercept messages $(N_i, N_j)$ communicating between the server and the user. Thus, we can see that the Liao–Wang’s scheme does
not provide the session key agreement.

3. Password Guessing Attack

With the extracted secret values $(B_i, y)$ stored in the smart card card and the intercepted messages $(M_2, M_3)$ communicating between the user and the server, the attacker can easily find out legal user’s password $PW_i$ in which each guess $PW_i^*$ for $PW_i$.

PA1. The attacker can compute $h(PW_i^*) = CIID_i = h(P_i) + h(y || Ni || SID_i || y || Ni)$ in the login phase.

PA2. The attacker verifies the correctness of user’s password $PW_i^*$.

PA3. The attacker repeats the above steps by replacing another guessed password $PW_i^*$ until the correct password $PW_i$ is found.

Thus, the attacker can perform the off-line password guessing attack, and can successfully impersonate the legal user with the guessed user password.

4. Insider Attack

In the registration phase, if the user’s password $PW_i$ is revealed to the server, the insider of the server may directly obtain the user’s password. With these secret information, the insider as an attacker can impersonate as the legal user to access the user’s other accounts in other server if the user uses the same password for the other accounts.

IV. Conclusion

Liao–Wang, in 2009, proposed a secure dynamic ID based remote user authentication scheme for multi-server environment and they claimed that can withstand the various possible attacks and provide mutual authentication. In this paper, we analyzed the security of Liao–Wang’s scheme. And we showed that Liao–Wang’s scheme is not secure against the user impersonation attack, the server masquerading attack, the off-line password guessing attack and insider attack. In addition, we can see that Liao–Wang’s scheme fails to provide mutual authentication and session key agreement.

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저자 소개

양 형 규(정회원)

- 1995년 2월 : 성균관대학교 석사
- 1996년 2월 : 성균관대학교 정보공학과 공학박사
- 1995년 ~ 현재 : 강남대학교 컴퓨터미디어정보공학부 교수
- 1984년 12월 ~ 1990년 2월 : 삼성전자 컴퓨터부문 선임연구원

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