

# Security Weaknesses of Dynamic ID-based Remote User Authentication Protocol

Hyungseob Lee, Donghyun Choi, Yunho Lee, Dongho Won, Seungjoo Kim

**Abstract**— Recently, with the appearance of smart cards, many user authentication protocols using smart card have been proposed to mitigate the vulnerabilities in user authentication process. In 2004, Das *et al.* proposed a ID-based user authentication protocol that is secure against ID-theft and replay attack using smart card. In 2009, Wang *et al.* showed that Das *et al.*'s protocol is not secure to randomly chosen password attack and impersonation attack, and proposed an improved protocol. Their protocol provided mutual authentication and efficient password management. In this paper, we analyze the security weaknesses and point out the vulnerabilities of Wang *et al.*'s protocol.

**Keywords**—Message Alteration Attack, Impersonation Attack

## I. INTRODUCTION

With the increase of users using commercial services through networks, the user authentication protocol has been regarded as a most important security issue. However, many vulnerabilities have been exposed in the user authentication protocol due to the careless password management and the sophisticated attack techniques. Recently, with the appearance of smart card, these vulnerabilities were mitigated.

In 2004, Das *et al.* proposed ID-based authentication protocol to mitigate vulnerabilities of the password-based authentication protocol[3]. This authentication protocol has some advantage that it allows a user to change a password easily, and requires low computations cost by using the hash function, moreover, the server does not need to maintain the password verification table. In 2009, Wang *et al.* pointed out that Das *et al.*'s protocol allowed an attacker to complete the authentication without knowing the password and did not provide the mutual authentication between user and remote server[4]. To improve the previous protocol, Wang *et al.* proposed the secure protocol using dynamic ID and the mutual authentication between user and remote server. The Wang *et al.*'s protocol, however, is not secure against the message alteration attacks and impersonation attacks.

In this paper, we analyze the vulnerabilities of Wang *et al.*'s protocol. This paper is organized as follows. In section II, we briefly review previous protocols. In section III, we describe the vulnerabilities of Wang *et al.*' protocol. and finally the conclusion is presented in section IV.

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## II. RELATED WORKS

### A. Das *et al.*'s Protocol

In 2004, Das *et al.* proposed ID-based remote user authentication protocol. This protocol is divided into the four phases of registration, log-in, verification, and password-changing. The notations used in this protocol are defined in Table I.

#### 1. Registration Phase

User  $U_i$  transmits his or her password before communicating with remote server  $S$ , and the server issues a smart card to  $U_i$ .

1.  $U_i$  transmits password  $PW_i$  to  $S$ .
2.  $S$  computes  $N_i = h(PW_i) \oplus h(x)$  using its secret - variable  $x$ .
3.  $S$  saves  $[h(\bullet), \gamma, N_i]$  in smart card and issues the smart card with  $PW_i$  to  $U_i$ .  $\gamma$  is a secret value to be stored in smart card that is issued to each user.

#### 2. Log-in Phase

User  $U_i$  inputs his or her password  $PW_i$  after inserting the smart card into terminal. The smart card performs the following steps.

1. Compute  $CID_i = h(PW_i) \oplus h(N_i \oplus \gamma \oplus TS)$  using the information stored in smart card.  $TS$  is the time stamp of the present date and time.
2. Compute  $B_i = h(CID_i \oplus h(PW_i))$  using the result from the step 1.
3. Computes  $C_i = h(TS \oplus N_i \oplus B_i \oplus \gamma)$  using the result from the step 2.
4. Transmit the log-in requesting message  $\langle CID_i, N_i, C_i, TS \rangle$  to  $S$ .

#### 3. Verification Phase

After remote server  $S$  received the log-in requesting message  $\langle CID_i, N_i, C_i, TS \rangle$  from  $U_i$  at time  $TS^*$ , he or she performs the following steps.

1.  $S$  checks the validity of the time interval by verifying

the time stamp. If  $TS^* - TS \leq \Delta TS$ , the log-in requesting message of  $U_i$  is accepted, if NOT, the log-in request is rejected.

2.  $S$  computes  $h'(PW_i) = CID_i \oplus h(N_i \oplus \gamma \oplus TS)$ .
3.  $S$  computes  $B'_i = h(CID_i \oplus h'(PW_i))$  using the result from the step 2.
4.  $S$  computes  $C'_i = h(TS \oplus N_i \oplus B'_i \oplus \gamma)$  using the result from the step 3. If the computed  $C'_i$  and  $C_i$  are equal, the log-in request of  $U_i$  is accepted.

#### 4. Password-changing Phase

If user  $U_i$  wants to change password, he or she inputs new password  $PW_N$ . smart card computes  $N_i^* = N_i \oplus h(PW_i) \oplus h(PW_N)$  and replaces  $N_i$  to a new  $N_i^*$ .

#### B. Wang et al.'s protocol

In 2009, Wang *et al.* pointed out the vulnerabilities of the Das *et al.*'s protocol and showed that their protocol allowed an attacker to complete the authentication without knowing the password and did not provide the mutual authentication between user and remote server. To solve these problems, Wang *et al.* proposed secure protocol using dynamic ID and mutual authentication. Their protocol is composed of the three phases of registration, log-in, and verification.

TABLE I  
NOTATION

Item	Description
$U_i$	User
$S$	Remote Server
$ID$	User's ID
$PW_i$	User's Password
$h(\bullet)$	One-way hash Function
$\oplus$	Bitwise XOR Computation
$\gamma$	Secret Value of Server To Be Stored in Smart Card
$x$	Secret Variable of Server
$TS$	Time Stamp

#### 1. Registration Phase

User  $U_i$  only transmits  $ID_i$  to remote server  $S$ .

1.  $U_i$  transmits  $ID_i$  to  $S$
2.  $S$  computes  $N_i = h(PW_i) \oplus h(x) \oplus ID_i$  after choosing its secret variable  $x$  and the  $U_i$ 's password  $PW_i$  for itself.
3.  $S$  saves  $[h(\bullet), \gamma, N_i]$  in smart card and issues the

smart card with  $PW_i$  to  $U_i$ .  $\gamma$  is a secret value to be stored in smart card that is issued to each user.

#### 2. Log-in Phase

User  $U_i$  inputs his or her  $ID_i$  and  $PW_i$  after inserting the smart card into terminal. The smart card performs the following steps.

1. Compute  $CID_i = h(PW_i) \oplus h(N_i \oplus \gamma \oplus TS) \oplus ID_i$  using the information stored in smart card.  $TS$  is the time stamp of the present date and time.
2. Transmit the log-in requesting message  $\langle ID_i, CID_i, N_i, TS \rangle$  to  $S$ .

#### 3. Verification Phase

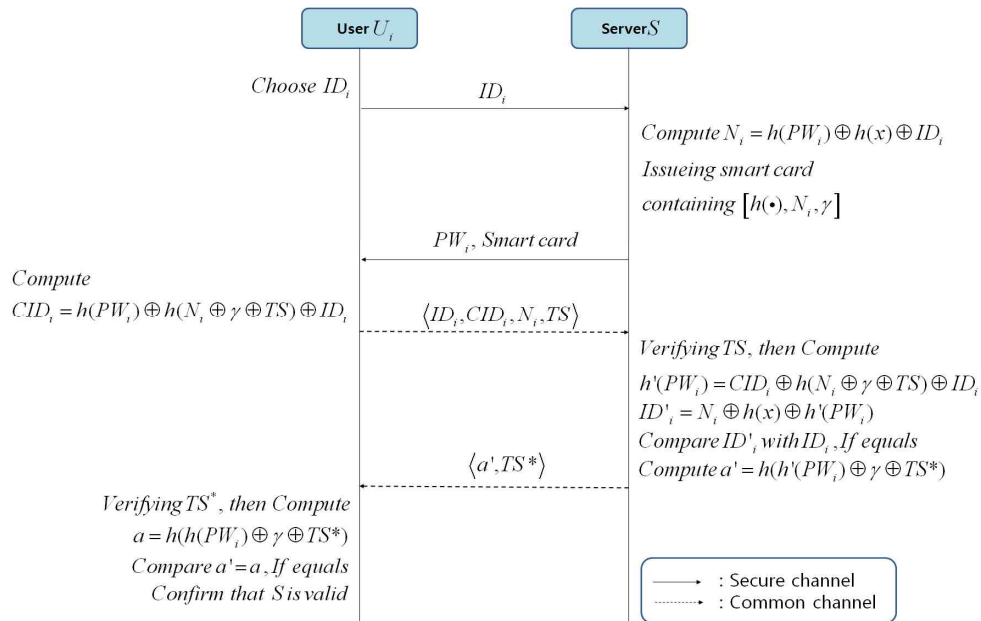
After remote server  $S$  received the log-in requesting message  $\langle ID_i, CID_i, N_i, TS \rangle$  from  $U_i$  at time  $TS^*$ , he or she performs the following steps.

1.  $S$  checks the validity of the time interval by verifying the time stamp. If  $TS^* - TS \leq \Delta TS$ , the log-in requesting message of  $U_i$ 's is accepted, if NOT, the log-in request is rejected.
2.  $S$  computes  $h'(PW_i) = CID_i \oplus h(N_i \oplus \gamma \oplus TS) \oplus ID_i$ .
3.  $S$  computes  $ID'_i = N_i \oplus h(x) \oplus h'(PW_i)$  using the result from the step 2. If the computed  $ID'_i$  and  $ID_i$  are equal, the log-in request of  $U_i$  is accepted.
4.  $S$  computes  $a' = h(h'(PW_i) \oplus \gamma \oplus TS^*)$  using the result from the step 2. If the computed  $C'_i$  and  $C_i$  are equal,  $S$  transmit  $\langle a', TS^* \rangle$  to  $U_i$ .
5. If the Verification message  $\langle a', TS^* \rangle$  is arrived at time  $TS'$ ,  $U_i$  checks the time stamp whether  $TS' - TS^* \leq \Delta TS$ . If it holds,  $U_i$  computes  $a = h(h(PW_i) \oplus \gamma \oplus TS^*)$  and compares  $a$  with  $a'$ .
6. If the two values are equal,  $U_i$  considers  $S$  to be a valid server.

In Wang *et al.*'s protocol, there is no need to alter the password since the user password is generated directly by the server  $S$ .

### III. SECURITY ANALYSIS OF WANG ET AL.'S PROTOCOL

In this section, we point out the vulnerabilities of Wang *et al.*'s protocol.


 Fig. 1 Wang *et al.*'s protocol

#### A. Message Alteration Attack

In Wang *et al.*'s protocol, an attacker can be authenticated as a valid user without knowing the ID and password. If an attacker eavesdrops the log-in requesting message  $\langle ID_i, CID_i, N_i, TS \rangle$  the valid user  $U_i$  transmitted to remote server  $S$ , the attacker  $A$  performs the following steps.

1.  $A$  alters the log-in requesting message  $\langle ID_i, CID_i, N_i, TS \rangle$  into  $\langle ID_j, CID_i, N_i, TS \rangle$  by choosing the random  $ID_j$ .
2.  $A$  transmits altered log-in requesting message  $\langle ID_j, CID_i, N_i, TS \rangle$  to  $S$ .
3.  $S$  computes
 
$$\begin{aligned} h'(PW_i) &= CID_i \oplus h(N_i \oplus \gamma \oplus TS) \oplus ID_j \\ &= h(PW_i) \oplus h(N_i \oplus \gamma \oplus TS) \oplus ID_i \oplus \\ &\quad h(N_i \oplus \gamma \oplus TS) \oplus ID_j \\ &= h(PW_i) \oplus ID_i \oplus ID_j \end{aligned}$$
4.  $S$  computes
 
$$\begin{aligned} ID_i'' &= N_i \oplus h(x) \oplus h'(PW_i) \\ &= h(PW_i) \oplus h(x) \oplus ID_i \oplus h(x) \oplus h(PW_i) \oplus \\ &\quad ID_i \oplus ID_j \\ &= ID_j \end{aligned}$$

As the computed  $ID_i''$  and the  $ID_j$  contained in the altered message are equal,  $S$  accepts the log-in request.
5.  $S$  transmits  $\langle a', TS^* \rangle$  to the attacker after computing  $a' = h(h'(PW_i) \oplus \gamma \oplus TS^*)$ .

Even though attacker  $A$  transmits the log-in requesting message to the server only with the altered ID, he or she is able to complete the authentication process successfully. That is, Wang *et al.*'s protocol is equivalent to the protocol in which the user ID and PW are not needed.

#### B. Impersonation Attack

Although the smart card is equipped with tamper resistance, many researches have shown that the secret values stored in smart card can be extracted by executing the differential power attacks and fault attacks[7][8]. Malicious attacker  $U_m$  participating in protocol as a valid user can execute the impersonation attack because  $U_m$  can extract the secret value of  $\gamma$  server stored in his or her smart card by executing the differential power attacks and fault attacks.  $U_m$  can compute the secret value  $h(PW_i)$  of valid user  $U_i$  by executing the impersonation attack. If  $U_m$  eavesdrops the log-in requesting message  $\langle ID_i, CID_i, N_i, TS \rangle$  the user transmitted, the  $U_m$  performs the following steps.

1.  $U_m$  computes  $h(N_i \oplus \gamma \oplus TS)$  using the secret value  $\gamma$  of server.
2.  $U_m$  computes  $h'(PW_i) = CID_i \oplus h(N_i \oplus \gamma \oplus TS) \oplus ID_i$  from log-in requesting message  $\langle ID_i, CID_i, N_i, TS \rangle$ .
3.  $U_m$  computes  $a'' = h(h'(PW_i) \oplus \gamma \oplus TS^*)$  using the result from the step 2 and transmits the  $\langle a'', TS^* \rangle$  to  $U_i$ .

4.  $U_i$  compares  $a$  within the verification message  $\langle a, TS^* \rangle$  received from  $U_m$  with computed  $a = h(h(PW_i) \oplus \gamma \oplus TS^*)$ .

As the attacker  $U_m$  forges the valid verification message  $\langle a', TS^* \rangle$  using the secret value  $\gamma$  of server, the user  $U_i$  recognizes the attacker  $U_m$  as a valid server.

#### IV. CONCLUSION

In this paper, we have analyzed the security of Wang *et al.*'s protocol. Although Wang *et al.*'s protocol provided mutual authentication and overcame the fatal drawback of Das *et al.*'s protocol, we have shown that Wang *et al.*'s protocol is insecure against the message alteration attack and impersonation attack.

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