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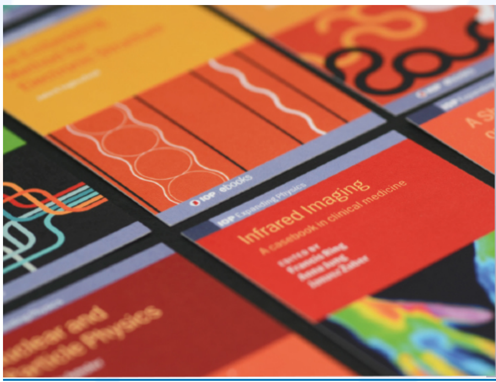

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The Weakness of Moon et al.'s Password Authentication Scheme

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Abstract. Using smart cards make remote transactions easier for users in Internet. It's important to identity the legal users to have the access right to obtain the resources. In 2017, Liu *et al.* proposed an efficient and secure smart card based password authentication scheme. Recently, Moon *et al.* pointed some weaknesses of Liu *et al.*'s scheme. They also proposed a password authentication scheme to overcome Liu *et al.*'s weaknesses. They claim that their scheme is more secure and practical as a remote user authentication scheme. However, we find that some weaknesses of Moon *et al.*'s scheme. In this article, we will show that Moon *et al.*'s scheme is vulnerable to the guessing identity and impersonation attacks.

1. Introduction

Security is the need for everyone at home, at the office, on the street, and in every place, because it makes a person safely use security systems and prevent things that should not happen. The security system should be flexible, inexpensive and work continuously without being limited by working hours [1-3]. Smartcard-RFID is an advanced information technology embedded into a card as an information storage medium [4-8]. Implementation of smartcards has currently spread almost in all areas, whether it is used in hotels, homes, attendance at offices and educational institutions, as tough data security [9-12]. Many schemes were applied a smart card to authenticate the legal users in multi-server environment [13-18]. Other schemes are list in [19-34].

In this paper, we propose modifications to the schemes provided by Moon *et al.*'s [35]. In their papers, we find a weakness during the phase registration, login and authentication, which attacks the security of data transmitted. We have made improvements by modifying the mathematical equations in the 3rd phase. From the given scheme, it can handle the problem of weaknesses during anonymous attacks and impersonation attacks.

This paper, we find that the security weaknesses of the two-factor authentication scheme by Moon et al. After careful analysis, we demonstrate that their scheme does not actually resist anonymous intercepts and user impersonation attacks. To overcome these security vulnerabilities, we propose a new biometrics-based authentication and key agreement scheme using a smart card. In addition, we demonstrate that the proposed authentication scheme is highly more resistant to various attacks, compared with other related schemes.

For more details we divide this paper into 4 Sections as follows: We briefly introduce some cryptographic definitions In Section 2, where we briefly review Moon et al.'s smart card-based password authentication scheme. In Section 3 its weaknesses is analyzed. Finally, we make a conclusion of the paper in Section 4.

2. Review of Moon *et al.*'s Scheme

In this section, we show that Moon *et al.*'s scheme, Secure Smart Card Based Password Authentication [35], is insecure. Their scheme is an improvement of Liu *et al.*'s scheme [36]. In the scheme, there are two participants, the user U_i and the server S. The scheme consists of four phases: registration, login, authentication, and password changing phase. Some notations used in the scheme are described in Table 1.

Table 1. The notations of Moon *et al.*'s scheme.

Notation	Meaning
U_i	The *i*th user
ID_i, PW_i	The identity and password of the user *i*
S	The server
x	The master secret key stored in the *S*
P	The base point of the elliptic curve *E*
rP	The point multiplication defined as $rP = P + P + \cdots + P$.
T_i	The timestamp of the user U_i
T'_i	The time of receiving the login request message
T_s	The timestamp of the *S*
T'_s	The time of receiving the mutual authentication message
R_i, P_i	The U_i's nearly random binary string and auxiliary binary string
$h(\cdot)$	A collision-resistant hash function
$\oplus$	Exclusive-or operation
$\|$	Concatenation operation
sk	The shared session key

2.1. Registration Phase

The server S selects the master secret key *x*, the base point *P* of the elliptic curve *E* and a collision-resistant one-way hash function *h(·)*. Then, the user U*i* registers to the server S by the way below:

Step 1. The U_i imprints the personal biometric information BIO_i at the device sensor. The device sensor then scans the BIO_i, extracts (R_i, P_i) from Gen (BIO_i) → (R_i, P_i), and stores P_i in the memory. Next, U_i selects the identity ID_i and password PW_i, and calculate $RPW_i = h(PW_i||R_i)$. Lastly, the U_i sends the registration request message {ID_i, RPW_i} to the S over a secure channel.

Step 2. After receiving the registration **request** message from the U_i, the server S verifies whether ID_i is valid, and computes the following parameters:

$$A_i = h(ID_i \oplus x),$$
$$B_i = h(A_i) \oplus RPW_i,$$
$$C_i = h(ID_i||RPW_i),$$
$$D_i = x \oplus A_i \oplus h(x).$$

Step 3. The server S stores the data {B_i, C_i, D_i, h(·), P} on a new smart card and issues the smart card to the user Ui over a secure channel.

Step 4. The user U_i stores the random string P_i into the smart card.

2.2. Login Phase

After performing the registration phase, then the user proceeds on the login phase invoke U_i user to log into server S. The steps of this phase are done as follows.

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Step 1. The U_i inserts his/her smart card into the card reader and enters the identity ID_i and password PW_i, and imprints the biometrics BIO_i^* at the sensor. The sensor then sketches BIO_i^* and recovers R_i from $Rep(BIO_i^*, Pi) \rightarrow R_i\ BIO_i^*$.

Step 2. The smart card first computes two parameters: $RPW_i = h(PW_i||R_i)$ and $C'_i = h(ID_i||RPW_i)$. The smart card then examines whether C'_i is equal to the stored C_i. If this holds, the smart card continues to perform **Step 3**; otherwise, the smart card terminates this session.

Step 3. The smart card randomly generates a number α and n_i, and computes the following parameters: $h(A_i) = B_i \oplus RPW_i$, $AID_i = ID_i \oplus h(A_i)$, $E_i = \alpha P$, $F_i = h(ID_i||h(A_i)||E_i||T_i)$, where T_i is the current timestamp of the user U_i.

Step 4. The smart card sends the login request message $\{AID_i, D_i, E_i, F_i, T_i\}$ to the server S.

2.3. Authentication Phase

Completing this phase, the user U_i and the server S could mutually authenticate each other and establish a shared session key for the subsequent secret communication. These steps of the authentication phase are shown as follows:

Step 1. The server S verifies whether $T'_i - T_i \leqslant \Delta T$, where T'_i is the time of receiving the login request message and ΔT is a valid time threshold. If both conditions are true, the server S continues to execute **Step 2**; otherwise, the server S rejects the login request.

Step 2. The server S computes the following parameters:

$$A'_i = D_i \oplus x \oplus h(x),$$
$$ID'_i = AID_i \oplus h(A'_i),$$
$$F'_i = h(ID'_I \,||\, h(A'_i) \,||\, E_i \,||\, T_i).$$

The server S then compares whether F'_i is equals F_i. If this holds, the server S confirms that the user U_i is valid and the login request is accepted; otherwise, the server S rejects the login request.

Step 3. Next, the server S randomly generates a number β and computes the following parameters:

$$F_i = \beta P,$$
$$G_i = h(ID'_i \,||\, h(A'_i) \,||\, F_i \,||\, T_s),$$

where T_s is the current timestamp of the server S.

Step 4. The server S sends the mutual authentication message $\{F_i, G_i, T_s\}$ to the user U_i.

Step 5. Upon receiving the message $\{F_i, G_i, T_s\}$ from the S, the user Ui checks the validity of the T_s. If $T'_s - T_s \leqslant \Delta T$, where T'_s is the time of receiving the mutual authentication message, the user U_i continues to perform **Step 6**; otherwise, the user U_i terminates this connection.

Step 6. The user U_i computes $G'_i = h(ID_i \,||\, h(A_i) \,||\, F_i \,||\, T_s)$, then checks whether G'_i is equal to the received G_i. If this holds, the validity of the server S is authenticated; otherwise, the session is terminated.

Step 7. Finally, the user U_i and the server S construct a shared session key:

$$sk = \alpha\beta P$$

to ensure the secret communication.

3. Cryptanalysis of Moon et al.'s Scheme

Moon *et al.*'s scheme is based on the elliptic curve cryptosystem (ECC). There are two weaknesses: Guessing identity and user impersonation attacks.

- Gussing Identity Attack:
  Moon *et al.*'s scheme [35] did not hide the ID user U_i in the login phase and authentication phase. The attacker could intercept AID_i, ID'_i, F_i, T_s, and G_i from the login and authentication phases:

  User → Server: $\{AID_i, D_i, E_i, F_i, T_i\}$,
  Server → User: $\{F_i, G_i, T_s)$.

The attacker can guess or steal it easily from an unsecure public channel. Then the attacker could check with guessing identity ID'_i to hold the following equation:

$$h(ID'_i \,||\, (AID_i \oplus ID'_i) \,||\, F_i \,||\, T_s) = G_i.$$

In general, the identity was named by the user and the length of the identity is between 6 - 12 characters (26 alphabets and 10 digits). Therefore, the probability of guessing the identity is $1/(36^{12})$ in the worse cases.

- User Impersonation

After knowing the user identity U_i, AID_i, and D_i by the guessing identity attack, the attacker could impersonate the user U_i as follows:

Steps 1 & 2: The attacker by passes Steps 1 and 2 of the login phase.

Step 3: The attacker randomly generates a number α' and n_i, and computes the following parameters:

$$h(A_i) = AID_i \oplus ID_i,$$
$$E'_a = \alpha' P,$$
$$F'_a = h(ID_i||h(A_i)||E'_i||T_a),$$

where T_a is the current timestamp of the attacker.

Step 4: The attacker sends the login request message $\{AID_i, D_i, E'_a, F'_a, T_a\}$ to the server S.

Next, the server authenticates the identity of the attacker (an impersonated user) and establishes a shared session key for the subsequent secret communication. These steps of the authentication phase are shown as follows:

Step 1. The server S verifies whether $T_s - T_a \leqslant \Delta T$, where T_s is the time of receiving the login request message and ΔT is a valid time threshold. If both conditions are true, the server S continues to execute **Step 2**; otherwise, the server S rejects the login request.

Step 2. The server S computes the following parameters:

$$A'_i = D_i \oplus x \oplus h(x),$$
$$ID'_i = AID_i \oplus h(A'_i),$$
$$F'_a = h(ID'_I \,||\, h(A'_i) \,||\, E_a \,||\, T_a).$$

The server S then compares whether F'_a is equals F_a. If this holds, the server S confirms that the attack is a legal user U_i and the login request is accepted; otherwise, the server S rejects the login request.

Step 3. Next, the server S randomly generates a number β and computes the following parameters:

$$F_s = \beta P,$$
$$G_s = h(ID'_i \,||\, h(A'_i) \,||\, F_s \,||\, T_s),$$

where T_s is the current timestamp of the server S.

Step 4. The server S sends the mutual authentication message $\{F_s, G_s, T_s\}$ to the user U_i.

Step 5. Upon receiving the message $\{F_s, G_s, T_s\}$ from the S, the attacker checks the validity of T_s. If $T_a - T_s \leqslant \Delta T$, where T_a is the time of receiving the mutual authentication message, the attacker continues to perform **Step 6**.

Step 6. The attacker computes $G'_s = h(ID_i \,||\, h(A_i) \,||\, F_s \,||\, T_s)$, then checks whether G'_s is equal to the received G_s. If this holds, the validity of the server S is authenticated.

Step 7. Finally, the attacker and the server S construct a shared session key:

$$sk = \alpha'\beta P$$

to ensure the secret communication.

4. Conclusion

In this paper, we have shown that the weaknesses of Moon et al.'s Scheme. Their scheme could not against the guessing identity attack and the user impersonation attack. In general, the probability of guessing the identity is $1/(36^{12})$ in the worse cases, if the user selects his/her identity with 12 characters (26 alphabets and 10 digits).

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