An Improved Remote User Authentication

Scheme Using Smart Cards

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Abstract: In 2000, Hwang and Li proposed a new remote user authentication scheme using smart cards. In the same year, Chan and Cheng pointed out that Hwang and Li's scheme is not secure against the masquerade attack. Further, in 2003, Shen, Lin and Hwang pointed out a different type of attack on Hwang and Li's scheme and presented a modified scheme to remove its security pitfalls. This paper presents an improved scheme which is secure against Chan-Cheng and all the extended attacks.

*Index Terms***:** Authentication, cryptography, remote user, network security, password and smart card.

Introduction: Remote user password based authentication scheme, proposed by Lamport [14] in 1981, is a way to authenticate the remote user over an insecure channel. In Lamport's scheme, the *AS* stores a password table at the server to check the validity of the login request made by the user. However, high hash overhead and the necessity for password resetting decrease the suitability and practical ability of Lamport's scheme. Since then, many similar schemes [18]-[20] have been proposed. They all have a common feature: a verification password table should be securely stored in the *AS*. Actually, this property is a

disadvantage for the security point of view. *U*nfortunately, the *AS* will be partially or totally braked/affected, if the password table is stolen /removed /modified by an antagonist/adversary.

Password authentication schemes with smart cards have a long history in the remote user authentication environment. So far different types of password authentication schemes with smarts cards [2]-[3]-[4]-[5]-[9]-[10]-[11]-[13]-[17]-[21]-[23] have been proposed. In 2000, Hwang and Li [16] proposed a new remote user authentication scheme using smart cards, which was based on ElGamal cryptosystem [22]. This scheme does not maintain the password table to check the validity of the login request. Also, it can withstand message-replaying attack. Chan and Cheng [7] pointed out the security weaknesses of Hwang and Li's Scheme and show that a legitimate user can easily create a valid pair of (*ID* , *PW*) without knowing the secret key x_s of the authentication server. In 2003, Shen-Lin- Hwang [11] discussed a different attack on the Hwang-Li's scheme and they also proposed a modified scheme to remove the security pitfalls of Hwang-Li's scheme. In the same year, Chang and Hwang [1] explained the practical problems of the Chan – Cheng's attack on the Hwang-Li's scheme. Further, Leung - Cheng, - Fong and Chen [12] pointed out that the Shen-Lin-Hwang's scheme is still vulnerable to the attack proposed by Chan and Cheng.

Contributions: This paper presents an improved remote user authentication with smart cards. The improved scheme is secure against Chan – Cheng, Chan-Hwang and Shen-Lin- Hwang's extended attacks.

Organization: Section 2 reviews the Hwang – Li's scheme. Section 3 describes the cryptanalysis of Hwang – Li's scheme. Section 4 reviews the Shen-Lin-Hwang's scheme. Section 5 describes the security pitfall in the Shen-Lin-Hwang's scheme. An improved remote user authentication with smart card is proposed in section 6. Section 7 discusses the security of the improved scheme. Finally, comes to a conclusion in the section 8.

Notations: The notations used through out in this paper can be summarized as follows:

U denotes the remote user.

ID denotes the identity of the remote user *U*.

PW denotes the password corresponding to the registered identity *ID*.

AS denotes the authentication server.

x_s denotes the permanent secret key of the authentication server.

f (.) denotes a cryptographic one way hash function.

↔ denotes a secret channel between the remote user *U* and the authentication server *AS*.

→ denotes a public channel (insecure channel)   between the remote user *U* and the authentication server *AS*.

p denotes a large prime number.

$\oplus$ denotes XORed operation.

μ denotes a random number generated by the *AS* at the time of registration of the user *U*.

REVIEW OF THE HWANG-LI'S SCHEME: There are three phases in the Hwang-Li's scheme: the registration phase, login phase and the authentication phase. In the registration phase, the user *U* sends a request to the *AS* for the registration. The *AS* will issue a smart card and a password to every legal user through a secure channel. In the login Phase, when the user *U* wants to access the *AS*, she/he inserts her/his smart card to the smart card reader and then keys the identity and the password to access services. In the authentication phase, the *AS* checks the validity of the login request.

Registration Phase: A user *U* submits her/his *ID* to the *AS*. *AS* computes the password *PW* for the user *U*, as, $PW = ID^{x_s}$ mod *p*, where, x_s is a secret key maintained by the *AS* and *p* is a large prime number. *AS* provides a password *PW* and a smart card to the user *U* through a secure channel. The smart card contains the public parameters (*f*, *p*), where *f* a one-way function.

*Login Phase: U*ser *U* attaches her/his smart card to the smart card reader and keys *ID* and *PW*. The smart card will perform the following operations:

  Generate a random number *r*.

  Compute $C_1 = ID^r$ mod *p*.

  Compute $t = f(T \oplus PW)$ mod *p* − 1, where *T* is the current date and time of the smart card reader.

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Compute $M = ID^t \bmod p$.

Compute $C_2 = M(PW)^r \bmod p$.

Sends a login request $C = (ID, C_1, C_2, T)$ to the AS.

Authentication Phase: Assume AS receives the message C at time T_c, where T_c is the current date and time at AS. Then the AS takes the following action:

Check the format of *ID.* If the identity format is not correct, then AS will rejects this login request.

Check, whether $T_c - T \leq \Delta T$, where ΔT is the legal time interval due to transmission delay, if not, then rejects the login request C.

Check, if $C_2 (C_1^{x_s})^{-1} \stackrel{?}{=} (ID)^{f(T \oplus PW)} \bmod p$, then the AS accepts the login request. Otherwise, the login request will be rejected.

Cryptanalysis of the Hwang- Li's Scheme: This section discusses the security weakness of the Hwang – Li's scheme.

Chan and Cheng's Attack: Impersonation Attack: According to Chan and Cheng [7], a legal user Alice can easily generate a valid pair of identity and password without the knowledge of secrete key 'x_s' of AS. Alice uses her valid pair (ID_A, PW_A) to generate another valid pair (ID_B, PW_B) as follows:

Alice computes $ID_B = (ID_A \times ID_A) \bmod p$. Then, she can compute the corresponding password $PW_B = ID_B^{x_s} \bmod p = (ID_A \times ID_A)^{x_s} \bmod p = (PW_A \times PW_A) \bmod p.$ As a result, Alice can generate a valid pair (ID_B, PW_B) without knowing the secret key x_s.

Shen-Lin-Hwang's Attack: Masquerading Attack: According to Shen - Lin and Hwang [11] masquerading attack is possible on Hwang- Li's scheme. A user Bob can masquerade another user Alice to login a remote server and gain access right. Bob computes an identity $ID_B = ID_A{}^k \bmod p$, where k is a random number such that gcd $(k, p) = 1$. Then, he submits this identity ID_B to *AS* for registration. *AS* provides a smart card and a password $PW_B = ID_B{}^{Xs} \bmod p$. With the knowledge of PW_B, Bob can compute the password PW_A related to the identity ID_A, as, $PW_A = ID_A{}^{Xs} \bmod p = PW_B{}^{-k} \bmod p$. As a result, Bob can masquerade as Alice to login a remote server and gain access privilege.

Chang- Hwang's Attack: According to Chang and Hwang [1], there is a mistake in the Chan- Cheng's attack. It is not always possible that the square of a legal identity satisfies the specific identity format. Chang and Hwang generalized the Chan- Cheng's attack. They described two attacks.

Attack- I: Alice computes $ID_B = ID_A{}^k \bmod p$, where k is a random number. Then, he can compute the corresponding password $PW_B = PW_A{}^k \bmod p$. As a result, a legal user Alice can impersonate other user Bob with a valid pair of *(ID_B, PW_B)* to login the *AS.* If ID_A is a primitive root of *Zp,* then all the valid identities and their corresponding password can be generated easily.

Attack- II: A group of eavesdroppers may cooperate to generate a valid pair of identity *(ID_G, PW_G)*, as $ID_G = \prod ID_{Aj} \bmod p$ and $PW_G = \prod PW_{Aj} \bmod p$. Chang and Hwang pointed out that in Hwang – Li's scheme, it is still difficult to obtain

the corresponding password for a known arbitrary valid identity, but once the valid identity is generated, its corresponding password will be obtained easily.

Shen, Lin and Hwang's scheme: Shen-Lin-Hwang [11] proposed a modified remote user authentication scheme to solve the security pitfall of the Hwang-Li's scheme. Shen-Lin-Hwang's scheme uses the concept of hiding the identity to prevent the masquerading attack. They modified the registration phase, now a shadow identity *SID* will be issued to the legal user. This modified in the registration phase is described below.

Modified Registration Phase: A user *U* submits her/his identity string *J* to the *AS* for the registration. The string *J* contains the name, address, unique number etc. This information in the string *J* is unique for every user. Then the *AS* computes a pair (*SID, PW*) for the user *U* after the identity *J is identified.* The pair (*SID, PW*) is computed as $SID = Red\ (J)$ and $PW = (SID)^{x_S}\ mod\ p$, where, *Red* (.) is a shadow identity of device which is only maintained in the remote server and *SID* is the shadow identity of the user *U.* Furthermore, the *AS* distributes the smart card and (*SID, PW*) to the user *U* in a secure way. The smart card contains the public parameters (*f, p*). In this scheme, the message sent to the *AS* now contains (*SID, C_1, C_2, T*). Because J_i specially formatted, the evil user cannot compute new identity string J_i via SID_i.

Cryptanalysis of the Shen, Lin and Hwang's Scheme: According to Leung-Cheng-Fong-Chan [12], Shen-Lin-Hwang's scheme [11] defends the attacks of

registration for a new identity ID_B via ID_A for a legal user Alice. They also pointed out that the modified scheme is still vulnerable to the attack described by Chan and Cheng. They showed that the modified scheme is not secure against the attack that is similar to Chan - Cheng and Chang – Hwang's attacks. If we replace ID_A with SID_A, then the Chang and Hwang's attack will work as follows. Alice computes $SID_B = (SID_A)^k \bmod p,$ where k is a random number. Then, he can compute the corresponding password $PW_B = PW_A^{\ k} \bmod p.$ As a result, a legal user Alice can impersonate other user Bob with a valid pair of (SID_B, PW_B) to login the AS. If SID_A is a primitive root of Zp, then all the valid identities and their corresponding password can be generated easily. Since, Chan – Cheng's attack is one case of this attack so it also works well.

An Improved Scheme: This section presents an improved remote user authentication scheme to remove the security pitfalls of the original scheme: Hwang – Li's scheme. This improved scheme overcomes the security flaws of Hwang – Li's scheme, which are described in the previous sections. The improved scheme has four phases: initial phase, registration phase, login phase and verification phase. These phases are described below.

Initial Phase: First, the insider at AS initialized the same public and secret parameters, as in Hwang –Li's scheme.

Registration Phase: For our requirement, we have modified the registration phase of Hwang and Li's scheme. Assume that this phase is executed over a secure channel. The following steps are involved in this phase.

Step R1. $U \leftrightarrow AS$: J. The string J contains the name of the user U, address, identity ID and a unique identification number etc, which are unique for the user U.

Step R2. AS generates a random number μ and then computes $m = f(ID \oplus \mu)$ mod p and the password PW for the user U, as, $PW = [f(ID \oplus \mu)]^{xs}$ mod p.

Step R3. $AS \leftrightarrow U$: a smart card containing the public parameters (f, p) and a pair $(ID \| \mu, PW)$ to the user U.

After the registration, the identity ID of the user has two parts: ID and μ. The second part μ is induced by the AS after registration.

Login Phase: Whenever, the user U wants to gain the access right on the AS, then the following steps are involved for the proper execution of this phase.

Step L1. U attaches her/his smart card to the smart card reader at any time T and keys her/his identity $ID \| \mu$ and the corresponding PW.

Step L2. The smart card of the user U conducts the following computations:

Generate a random number r.

Computes $C_1 = f(ID \oplus \mu)^r$ mod p.

Compute $t = f(T \oplus PW)$ mod $p - 1$.

Compute $M = (ID)^t \bmod p$.

Compute $C_2 = M\,(PW)^r \bmod p$.

Step L3. $U \rightarrow AS$: $L_R = (ID\|\mu,\ C_1,\ C_2,\ T)$.

Verification Phase: Assume that the *AS* receives the login request L_R at time T_c. Then, *AS* does the following computations to check the validity of the login request L_R.

Step V1. Check the specific format of the identity $ID\|\mu$. If the format of the identity is incorrect, then *AS* rejects the login request L_R.

Step V2. Check, whether $T_c - T \leq \Delta T$, where ΔT is the legal time interval due to transmission delay, if not, then *AS* rejects the login request L_R.

Step V3. Check, if $C_2 \overset{?}{=} (C_1{}^{X_s})\,(ID)^{\,f\,(T \oplus PW)} \bmod p$, then the *AS* accepts the login request. Otherwise, the login request will be rejected by *AS*.

Security Analysis of the Improved Scheme: The above scheme is a modified form of the original scheme: *Hwang-Li's scheme*. The security analysis has been already discussed and demonstrated in [16]. Therefore, this section will only discuss the enhanced security features of the proposed scheme.

Chan- Cheng's attack: Impersonation Attack: Consider an antagonist/adversary, Alice wants to create another valid pair $(ID_B\|\mu_B,\ PW_B)$ such that $PW_B = [f\,(ID_B \oplus \mu_B)]^{X_s} \bmod p$, by using her valid pair $(ID_A\|\mu_A,\ PW_A)$, which is provided by the AS to Alice through registration phase. In our scheme, this is infeasible to compute such a valid pair $(ID_B\|\mu_B,\ PW_B)$ due to the one - way property of hash function *f*.

Since, now the computed hash value $[f(ID_B \oplus \mu_B)]$ will not be equal to $[f(ID_A \oplus \mu_A)] \times [f(ID_A \oplus \mu_A)]$, then Chan – Cheng's attack will not work.

Chang- Hwang's Attack: Since, Chang- Hwang's Attack is an extended form of Chen- Cheng's attack, then this attack will also not work.

Shen-Lin-Hwang's attack: In Shen- Lin- Hwang's attack, suppose Bob is an adversary/attacker who wants to masquerade any valid user Alice. To create a favorable results for a successful attack, first the malicious user, Bob has to registered himself at AS. For this purpose, Bob intercepts the logon request $L_R = (ID_A \| \mu_A, C_1, C_2, T)$ from a public network and computes an identity $ID_B = ID_A^k$ mod p or $ID_B = [f(ID_A \oplus \mu_A)]^k$ mod p, where k is a random number such that gcd (k, p) = 1.Then, he submits this identity ID_B to AS for registration. Now, AS provides a smart card and a pair $(ID \| \mu_B, PW_B)$, where, $PW_B = [f(ID_B \oplus \mu_B)]^{x_s}$ mod p to the antagonist user Bob. Now with the knowledge of PW_B, Bob will try to compute the password PW_A related to the identity ID_A. On the one hand, If Bob submits the identity $ID_B = ID_A^k$ mod p, then he can try to computes the password PW_A related to the identity ID_A, by using the relation:

$PW_A^{\ *} = PW_B^{-k}$ mod $p = [f(ID_B \oplus \mu_B)^{x_s}]^{-k}$ mod $p = [f(ID_B \oplus \mu_B)^{-k}]^{x_s}$ mod p,

$$\neq [f(ID_A \oplus \mu_A)]^{x_s} \text{ mod } p \neq PW_A.$$

Thus, the antagonist/attacker can compute only a fictious value $PW_A^{\ *} = [f(ID_B \oplus \mu_B)^{-k}]^{x_s}$ mod p, which is different from the integral/authentic/existing password $PW_A = (ID_A \oplus \mu_A)^{x_s}$ mod p. On the other hand, If antagonist Bob submits the

identity $ID_B = [f\ (ID_A \oplus \mu_A)]^{\ k}$ mod $p,$ then also he can try to computes the password PW_A related to the identity ID_A. With the similar reason, as described above, the antagonist Bob can not compute the integral/authentic/existing password $PW_A = (ID_A \oplus \mu_A)^{x_s}$ mod p. In this way, Bob is not able to compute the actual password PW_A related to the identity ID_A. Thus the antagonist Bob can not masquerade as another user Alice to login a remote server. As a result, the improved scheme successfully withstands the masquerade attack: *Shen-Lin-Hwang's attack*

Conclusion: This paper proposed an improved remote user authentication scheme, which removes the security flaws of the original scheme: Hwang-Li's scheme. The proposed scheme is secure against all the attacks: Shen- Lin-Hwang's attack, Chan- Cheng's attack and Chang- Hwang's Attack.

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