Cryptanalysis of recently proposed Remote User Authentication Schemes

Thulasi Goriparthi [a, b], Manik Lal Das[a], Atul Negi [b] and Ashutosh Saxena[a]

[a] Secure Technology Lab.,
Institute for Development and Research in Banking Technology,
Castle Hills, Road No.1, Masab Tank, Hyderabad 500057, INDIA.
{gthulasi, mldas, asaxena} @idrbt.ac.in

[b]DCIS
University of Hyderabad,
Gachibowli, Hyderabad 500046, INDIA.
thulasi@dcis.uohyd.ernet.in
atulcs@uohyd.ernet.in

Abstract

Recently Manik et al. [13] proposed a novel remote user authentication scheme using bilinear pairings. Chou et al. [14] identified a weakness in Manik et al.'s scheme and made an improvement. In this paper, we show that both Manik et al.'s and Chou et al.'s schemes are insecure against forgery attack and replay attack.

Key Words: Authentication; Bilinear pairings; Smart Card; Password; Timestamp.

1. Introduction

Remote User Authentication scheme allows the authenticated user to login the remote system for accessing the services offered. In 1981, Lamport [1] introduced the first well-known hash-based password authentication scheme. Lamport scheme suffers from high hash overhead and password resetting problems. Thereafter, many schemes have been proposed to overcome the problems identified in the previous schemes based on hash functions [4], [7], [8], [11], [12] and based on public key [2], [3], [5], [6], [9], [10].

Recently, Manik et al. [13] proposed a remote user authentication scheme using bilinear pairings. In the scheme, they use Timestamps to avoid replay attacks while sending the authentication request over a public channel. But this is completely insecure as an adversary can use this information for illegal login later.

Chou et al. [14] identified that the verification of Manik et al.'s scheme involves subtraction of two components, which are passed over the public channel leading to replay attack. One can do replay by adding same information to those two components, as it results in valid verification. To overcome replay attack, they suggested a modification in verification part of Manik et al.'s scheme, however we observed that the modified scheme also suffers from the replay attack. In this paper, we cryptanalyze, Manik et al.'s and Chou et al.'s schemes.

The organization of the paper is as follows. In Section-2, we present the preliminaries of bilinear pairings. In Section-3 Manik et al.'s scheme is briefly reviewed. Chou et al.'s attack on Manik et al.'s scheme is reviewed in Section-4. In Section-5 our

attack on Chou et al.'s scheme and Manik et al.'s scheme is given. We concluded in Section-6.

2. Bilinear Pairings

Let G_1 be an additive cyclic group of prime order q and G_2 be the multiplicative cyclic group of the same order. Practically we can think of G_1 as a group of points on an elliptical curve over Z_q^*, and G_2 as a subgroup of the multiplicative group of a finite field $Z^*_{q^k}$ for some $k \in Z_q^*$. Let P be a generator of G_1. A bilinear pairing is a map $e: G_1 \times G_1 \to G_2$ having the following three properties:

Bilinear: $e(aP, bQ) = e(P,Q)^{ab}$, for all $P, Q \in G_1$ and $a, b \in Z_q^*$.

Non-degenerate: $\forall P$ where P is not a generator, there exists $Q \in G_1$ such that $e(P,Q) \neq 1$.

Computable: $e(P,Q)$ is computable in polynomial time.

Discrete Logarithm Problem (DLP): Given two elements $P, Q \in G_1$ find an integer $a \in Z_q^*$, such that $Q = aP$ whenever such an integer exists.

Computational Diffie-Hellman Problem (CDHP): Given *(P, aP, bP) for any* $a, b \in Z_q^*$, compute *abP*.

Decisional Diffie-Hellman Problem (DDHP): Given *(P, aP, bP, cP) for any* $a, b, c \in Z_q^*$, decide whether $c = ab \bmod q$.

Gap Diffie-Hellman (GDH) group: G_1 is a *GDH group* if there exists an efficient polynomial time algorithm which solves the *DDHP* in G_1 and there is no probabilistic polynomial time algorithm which solves the *CDHP* in G_1 with non negligible probability of success.

Bilinear Diffie-Hellman Problem (BDHP): Given *(P, aP, bP, cP)* for any $a, b, c \in Z_q^*$, compute $e(P,P)^{abc}$.

3. Review of Manik et al.' scheme

In this section, we briefly review Manik et al.'s scheme. This scheme consists of four phases. Registration phase; Login phase; Authentication phase; and Password change phase. The notations used through out the paper are as follows.

U : User
ID : Identity of the user
PW : Password of user U
RS : Remote Server
$H: \{0,1\}^* \to G_1$ is a hash function.
P is generator of G_1
s is a secret key of RS
$Pub_{RS} = sP$ is public key of RS

Different phases work as follows

Registration Phase

U submits his identity ID and password PW to the RS

RS computes $\mathrm{Re}\, g_{ID} = s.H(ID) + H(PW)$

RS personalizes smart card with ID, $\mathrm{Re}\, g_{ID}$, $H(.)$

Login Phase

User U inserts smart card in a terminal and submits ID and PW.

Smart card computes $DID = T.\mathrm{Re}\, g_{ID}$

$$V = T.H(PW)$$

Sends login request $< ID, DID, V, T >$ to the RS over a public channel where T is the user system's time stamp.

Verification phase

RS receives $< ID, DID, V, T >$ at time T^* and verifies the validity of the time interval between T^* and T checking if $(T^* - T) \le \Delta T$. It accepts the request and checks whether $e(DID - V, P) = e(H(ID), Pub_{RS})^T$

Password change phase

User U inserts smart card into a terminal and submits his identity ID and password PW.

Smart card verifies if this ID is same as the ID stored in the smart card.

U submits a new password PW^*.

Smart card computes $\mathrm{Re}\, g_{ID}{}^* = \mathrm{Re}\, g_{ID} - H(PW) + H(PW^*) = s.H(ID) + H(PW^*)$

Smart card replaces the previously stored $\mathrm{Re}\, g_{ID}$ value by $\mathrm{Re}\, g_{ID}{}^*$

4. Chou et al.'s attack on Manik et al.'s scheme

Chou et al. [14] pointed that the verification in [13] $e(DID - V, P) = e(H(ID), Pub_{RS})^T$ holds valid even when $DID' = DID + a$ and $V' = V + a$ where $a \in G_1$, as shown below.

$$\begin{aligned} e(DID' - V', P) &= e(DID + a - V - a, P) \\ &= e(DID - V, P) \\ &= e(H(ID), P_{pub})^T \end{aligned}$$

To avoid this, Chou et al [14] proposed different verification technique as $e(DID, P) = e(TsH(ID) + V, P)$ to avoid the subtraction effect of [13].

5. Our attacks

5.1. On Chou et al.'s scheme

The verification in [13] is modified by Chou et al. [14] as $e(DID, P) = e(TsH(ID) + V, P)$.

We note that this verification also holds valid for $DID' = DID + a'$ and $V' = V + a'$ where $a' \in G_1$, as shown below.

$$\begin{aligned} e(DID', P) &= e(DID + a', P) \\ &= e(DID, P)e(a', P) \\ &= e(TsH(ID) + V, P)e(a', P) \\ &= e(TsH(ID) + V + a', P) \\ &= e(TsH(ID) + V', P) \end{aligned}$$

Thus the approach of Chou et al., by adding V on the right side instead of left side, cannot solve the problem as shown above.

5.2. Further attacks on Manik et al.'s scheme

We further point to more attacks on [13].

Forgery attack

Given P and $P_{pub} = sP$, finding s is Discrete Logarithm Problem (DLP) but given x and xQ, it is feasible to compute Q.

In login phase, the tuple $< ID, DID, V, T >$ is being sent to RS over a public channel. Any adversary tapping this message can compute a valid $< ID, DID', V', T' >$.

As $DID = T.\mathrm{Re}\, g_{ID}$, where $T \in Z_q^*$

$V = T.H(PW)$, attacker can compute T^{-1}, $\mathrm{Re}\, g_{ID}$ and $H(PW)$ as below.

$$\begin{aligned} \mathrm{Re}\, g_{ID} &= T^{-1}DID \\ &= T^{-1}T\,\mathrm{Re}\, g_{ID} \end{aligned}$$

$$\begin{aligned} H(PW) &= T^{-1}V \\ &= T^{-1}TH(PW) \end{aligned}$$

Now, attacker can form the valid tuple $< ID, DID', V', T' >$ for time stamp T' computing $DID' = T'.\mathrm{Re}\, g_{ID}$, $V' = T'.H(PW)$.

The attacker can use the information ID, $\mathrm{Re}\, g_{ID}$, $H(PW)$ for accessing remote system whenever he wants. So the scheme is completely insecure against replay attacks and forgery attacks. Anyone can forge the login request, so it is also possible for an insider, leading to the insider attack.

Weakness in Password Change Phase

In the Password Change Phase, User submits ID, old password PW and new password PW^* but there is no verification is done to validate the old password. So anyone knowing

the ID and having the smart card can change the secret information $\mathrm{Re}\, g_{ID}$ in the smart card.

6. Conclusion

In this paper, we analyzed both Manik et al.'s scheme and Chou et al.'s scheme and found that both the schemes are insecure against forgery attack, replay attack and insider attack. We are working to improve the scheme by incorporating suitable changes to over come the flaws, which lead to the insecurity of the schemes.

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