Cryptanalysis of Sun and Cao’s Remote Authentication Scheme with User Anonymity

Dheerendra Mishra*
Department of Mathematics,
Indian Institute of Technology Kharagpur,
Kharagpur 721302, India

Abstract
Dynamic ID-based remote user authentication schemes ensure efficient and anonymous mutual authentication between entities. In 2013, Khan et al. proposed an improved dynamic ID-based authentication scheme to overcome the security flaws of Wang et al.’s authentication scheme. Recently, Sun and Cao showed that Khan et al. does not satisfy the claim of the user’s privacy. Moreover, they proposed an efficient authentication scheme with user anonymity. The Sun and Cao’s scheme achieve improvement over Khan et al.’s scheme in both privacy and performance point of view. Unfortunately, we identify that Sun and Cao’s scheme does not resist password guessing attack. Additionally, Sun and Cao’s scheme does not achieve forward secrecy.

keywords: Smart card; Remote user authentication; Anonymity.

1 Introduction
Advancement in technology has provided a scalable platform for various online services. In these services, a user access the remote servers via a public channel. However, an adversary is considered powerful enough that he can intercept, modify, delete and replace the messages, which transmits via public channel. This increase the threats to data security and integrity. One of
the countermeasure is remote user authentication protocols [3, 5, 6, 8, 10, 11]. Most of the existing remote user authentication schemes ensure mutual authentication and session key agreement where the user and the server can mutually authenticate each other and draw a session key.

To achieve efficient and secure remote user services, low-cost smart card based authentication protocol has been presented to achieve a scalable solution. Most of the existing smart card based schemes face various kinds of attacks such as insider attack, password guessing attack, man-in-the middle attack, impersonation attack, repay attack and many more. Moreover, user anonymity is usually not protected [1, 2]. In 2009, Wang et al. [15] presented an efficient and secure dynamic ID-based remote user authentication scheme to achieve authorized and anonymous communication. However, in 2011, Khan et al. [7] identified the flaws in Wang et al.'s scheme and proposed an improvement to remove these flaws. In recently published paper, Sun and Cao's demonstrated that Khan et al.'s dynamic ID-based remote user authentication scheme claim to provide user anonymity is failing as an adversary can track any legitimate user’s identity by eavesdropping on the mutual authentication session over the public channel. Additionally, they proposed an improved scheme and claimed that their scheme is reasonable in privacy, security and performance aspect.

In this article, we analyze the security of Sun and Cao's smart card based remote user authentication scheme. We identify that Sun and Cao's scheme is vulnerable to the password guessing attack. Moreover, we present the inefficiency of Sun and Cao's scheme to ensure forward secrecy.

The rest of the paper is organized as follows: Section 2 explains the meaning of symbols that are used in this paper. The brief review of Sun and Cao's scheme is given in Section 3. Section 4 demonstrates the flaws in Sun and Cao's scheme. Finally, the conclusion is drawn in Section 5.
2 Notations

Table 1: Meaning of symbols of used notations that used throughout the paper

| Notation | Description |
|----------|-------------|
| $U_i$    | User $i$    |
| $S$      | A trustworthy server |
| $ID_i$   | Unique identity of user $i$ |
| $PW_i$   | Unique password of user $i$ |
| $N$      | Registration time of user |
| $T_U$    | Timestamp generated by $U_i$ |
| $T_S$    | Timestamp generated by $S$ |
| $sk$     | Session key |
| $x$      | Master key of $S$ |
| $h(\cdot)$ & $h_1(\cdot)$ | One-way hash functions |
| $\oplus$ | XOR |
| $||$     | String concatenation operation |

3 Review of Sun and Cao’s Scheme

In 2013, Sun and Cao [14] proposed an improvement of Khan et al.’s scheme [7] dynamic ID-based remote user authentication scheme. This comprises following phases:

a. Registration phase

b. Login Phase

c. Authentication Phase

d. Lost smart card revocation Phase

In this section, we will briefly discuss registration, Login and authentication phases of Sun and Cao’s scheme as we only analyzes these phases in our study.
3.1 Registration Phase

A new user can register with the server and gets the personalized smart card as follows:

Step 1. $U_i$ chooses his identity $ID_i$ and password $PW_i$, and generates a random number $r$. Then, he computes $RPW = h(r||PW_i)$ and sends the message $<ID_i, RPW>$ to $S$ via secure channel.

Step 2. Upon receiving the registration request, $S$ verifies the credentials of $ID_i$ and checks whether $ID_i$ exist or not in its database. If $ID_i$ exist and registers with any other user, it asks new identity. Otherwise, if $U_i$ does not exist in the server’s database, $S$ computes $J = h(x||ID_i||N)$ and $L = J \oplus RPW$, where $N$ is the number of times $U$ registered. Then, $S$ embeds $\{L\}$ into smart card and secretly issues the smart card to $S$.

Step 3. Upon receiving the smart card, $U_i$ stores $r$ into the smart card.

3.2 Login Phase

When a user wants to login to the server, he inserts his smart card into the card reader and inputs the identity $ID_i$ and password $PW_i$, then login phase works as follows:

Step 1. The smart card computes $RPW = h(r||PW_i)$ and $J = L \oplus RPW$.

Step 2. The smart card computes $C_1 = h_1(J||TU)$. Then $U_i$ sends $M_1 = <C_1, TU>$ to $S$.

3.3 Authentication Phase

When server $S$ receives the login message, then server verifies the authenticity of the user. The user also verifies the server authenticity as follows:

Step 1. Upon receiving $U$’s message $M_1$, $S$ verifies the validity of timestamp $TU$. If $TU$ is incorrect, it terminates the session. Otherwise, $S$ searches $ID_i$ among stored identities by verifying the condition $C_1 = ? h_1(h(x||ID_i||N)||TU)$. If $ID_i$ verification does not hold for any identity of the database, $S$ terminates the login session. Otherwise, $S$ accepts the login request.
Step 2. $S$ computes $C_2 = h_1(h(x||ID_i||N)||C_1||T_S)$. Then, $S$ sends the message $M_2 = <C_2, T_S>$ to $U_i$. Moreover, $S$ computes the session key $sk = h_1(J||C_2)$.

Step 3. Upon receiving the message $M_2$, $U_i$ verifies the timestamp $T_S$. If the verification does not hold, it ends the session. Otherwise, it verifies $C_2 =? h_1(J||C_1||T_S)$. If verification does not succeed, the session terminated. Otherwise, $S$ is authenticated and session key $sk = h_1(J||C_2)$ is computed.

4 Security Weaknesses of Sun and Cao’s Scheme

4.1 Off-line password guessing attack

The password guessing attack is the one of the most common attack on password based authentication protocols using smart card. An adversary can perform password guessing attack on Sun and Cao’s scheme as follows:

Step 1. Guess the password $PW_i^*$, and compute $RPW^* = h(PW_i^*||r)$ and $J^* = L \oplus RPW^*$.

Step 2. Verify the condition $C_1 =? h_1(J^*||T_U)$.

Step 3. If the verification holds, the guessing of passwords is succeeding. Otherwise, repeat Step 1 and Step 2.

4.2 Forward secrecy

In Sun and Cao’s scheme, the session key $sk$ is the hashed output of user’s long term secret key $J$ along with $C_2$, i.e. $sk = h_1(J||C_2)$. This shows that Sun and Cao’s scheme doe not ensure forward secrecy, as a compromise of user’s long term secret key $J$ causes compromise of all the established session keys. This is possible as follows:

- An adversary can achieve all the previously transmitted message via public channel, i.e, an adversary can achieve $C_2$.
- The adversary can compute the session key $sk = h_1(J||C_2)$. 
5 Conclusion

An efficient password based remote user authentication scheme should resist all kinds of attack. In this article, we have demonstrated that Sun and Cao’s privacy preserving remote user authentication scheme is vulnerable to off-line password guessing attack and fails to ensure forward secrecy.

References

[1] Boyd, C., Mathuria, A.: Protocols for authentication and key establishment. Springer (2003)

[2] Brier, E., Clavier, C., Olivier, F.: Correlation power analysis with a leakage model. In: Cryptographic Hardware and Embedded Systems-CHES 2004, pp. 16–29. Springer (2004)

[3] Chien, H.Y., Jan, J.K., Tseng, Y.M. (2002). An efficient and practical solution to remote authentication: smart card. Computers & Security 21(4), 372–375

[4] Eisenbarth, T., Kasper, T., Moradi, A., Paar, C., Salmasizadeh, M., Shalmani, M.T.M.: On the power of power analysis in the real world: A complete break of the keeloq code hopping scheme. In: Advances in Cryptology–CRYPTO 2008, pp. 203–220. Springer (2008)

[5] Fan, C.I., Chan, Y.C., Zhang, Z.K. (2005). Robust remote authentication scheme with smart cards. Computers & Security 24(8), 619–628

[6] Jaspher, G., Katherine, W., Kirubakaran, E., Prakash, P. (2012). Smart card based remote user authentication schemessurvey. In: Computing Communication & Networking Technologies (ICCCNT), 2012 Third International Conference on, pp. 1–5. IEEE

[7] Khan, M.K., Kim, S.K., Alghathbar, K. (2011). Cryptanalysis and security enhancement of a more efficient & secure dynamic id-based remote user authentication scheme. Computer Communications 34(3), 305–309

[8] Khan, M.K., Kumari, S., Gupta, M.K. (2013). More efficient key-hash based fingerprint remote authentication scheme using mobile device. Computing pp. 1–24
[9] Kocher, P., Jaffe, J., Jun, B. (1999). Differential power analysis. In: Advances in CryptologyCRYPTO99, pp. 388–397. Springer

[10] Kumari, S., Khan, M.K. (2013). Cryptanalysis and improvement of a robust smart-card-based remote user password authentication scheme. International Journal of Communication Systems

[11] Li, X., Niu, J., Khurram Khan, M., Liao, J. (2013). An enhanced smart card based remote user password authentication scheme. Journal of Network and Computer Applications

[12] Madhusudhan, R., Mittal, R. (2012). Dynamic id-based remote user password authentication schemes using smart cards: A review. Journal of Network and Computer Applications 35(4), 1235–1248

[13] Messerges, T.S., Dabbish, E.A., Sloan, R.H. (2002). Examining smart-card security under the threat of power analysis attacks. Computers, IEEE Transactions on 51(5), 541–552

[14] Sun, D.Z., Cao, Z.F. (2013). On the privacy of khan et al.’s dynamic id-based remote authentication scheme with user anonymity. Cryptologia 37(4), 345–355

[15] Wang, Y.y., Liu, J.y., Xiao, F.x., Dan, J. (2009). A more efficient and secure dynamic id-based remote user authentication scheme. Computer communications 32(4), 583–585

[16] Xu, J., Zhu, W.T., Feng, D.G. (2009). An improved smart card based password authentication scheme with provable security. Computer Standards & Interfaces 31(4), 723–728