Proof of Plaintext Knowledge and (Deniable) Authentication

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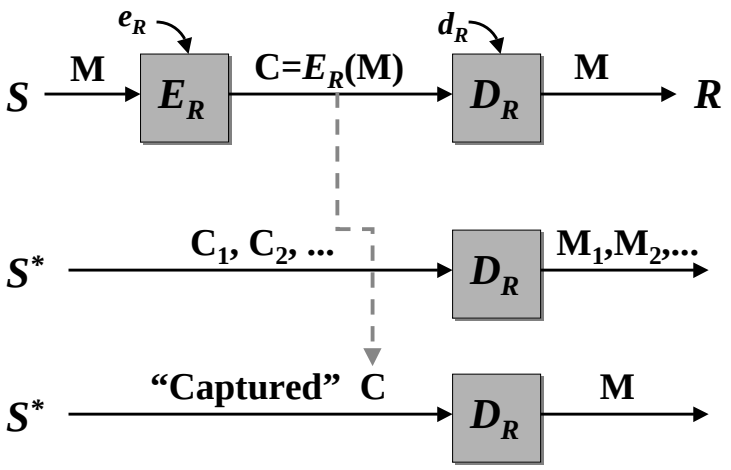
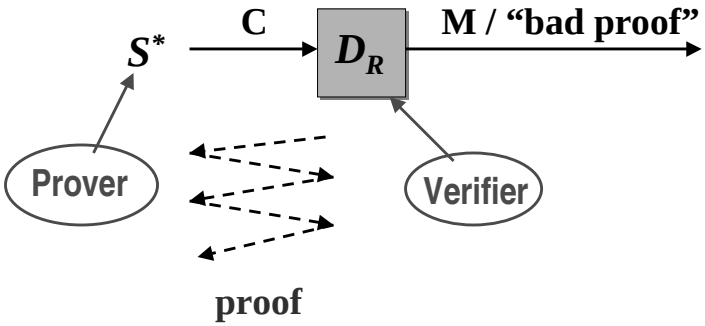
Plan

- *Proof of PlainText Knowledge (PPTK)*
- Efficient Encryption Enhancement to PPTK for any public key encryption scheme
- Efficient protection against Chosen Ciphertext Attacks
- Efficient Authentication of long messages
- Deniable Authentication
- Classification of Adversaries

Chosen Ciphertext Attacks



Proof of PlainText Knowledge



Properties of PPTK

- If S^* proper (C=E_R(M)) then S^* can prove PlainText Knowledge.
- With probability > 1-(7/8)^n, S^* can compute D_R's output on her own:
  - If D_R outputs $\mathbf{M}=D_R(\mathbf{C})$ then S^* can compute $\mathbf{M}$ on her own.
  - If D_R outputs **"bad proof"** then S^* knows this in advance.

Encryption Enhancement

- Generic transformation

$$E_R \Rightarrow ENE_R \quad \textit{The Enhanced } E_R$$

***Theorem*:** For any semantically secure PK system $E_R(\bullet)$, the system $ENE_R(\bullet)$ is also semantically secure and has an efficient PPTK.

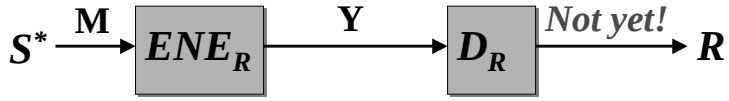
Cost: 4n computations of E_R .

Encryption Enhancement Procedure

$E_R(\bullet)$ - R's public key encryption

1. $M < p$ prime
2. n - security parameter, $m=4n$.
3. S randomly chooses

   $f(t)=a_{n-1}t^{n-1}+ \ldots + a_1 t + M$ } Shamir Secret Sharing
4. $X_i=f(i)$, $Y_i= E_R(X_i)$, $i=1,\ldots, m$
5. $ENE_R(M)=Y=(Y_1,\ldots,Y_m)$



Proof of PlainText Knlowlege

Phase I:

1. $S^* \xrightarrow{Y=(Y_1,\ldots,Y_m)} D_R$
2. Verifier D_R decodes $D_R(Y_i)=X_i$, $i=1,\ldots,m$.
   Sets $X=\{(1,X_1),\ldots,(m,X_m)\}$
3. Verifier (with Prover) randomly chooses

   $I=(i_1,\ldots,i_{n-1})$, $S^* \xleftarrow{I=(i_1,\ldots,i_{n-1})} D_R$
4. $S^* \xrightarrow{X_{i_1},\ldots,X_{i\ n-1}} D_R$

   s.t. $E_R(X_{ij})=Y_{ij}$, $j=1,\ldots,n-1$
5. If S^* fails then D_R aborts

Phase II:

$$H=\{ (i_1, X_{i_1}) , \ldots , (i_{n-1} , X_{i_{n-1}}) \}$$

- D_R checks if exists EH

  $H \subset EH \subset \{(1,X_1), \ldots , (4n,X_{4n})\}$

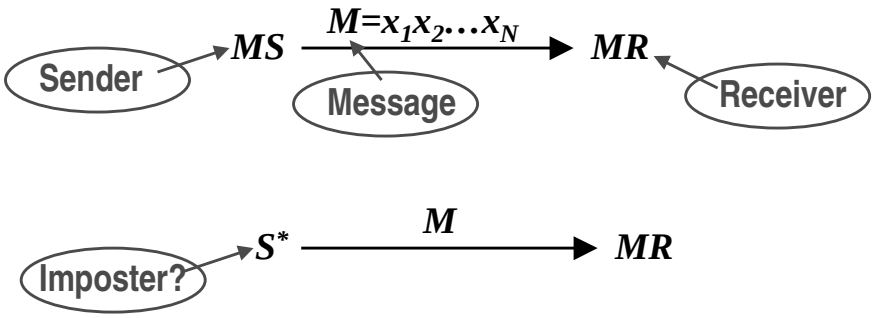
  such that:

  1. $|EH| = 3n$
  2. All $3n$ points of EH are on the curve of some polynomial $f(t)$ of degree $n-1$
- If yes, D_R outputs constant term M of $f(t)$.
- Otherwise, D_R outputs "Failed proof".

Key points of correctness proof

- If S^* was able to decode $Y_{i_1}, \ldots, Y_{i_{n-1}}$ (with work W), then with probability $1-(7/8)^n$ S^* can decode $3.5n$ Y_j's (with work $4nW$).
- By use of these $3.5n$ points (j,X_j), with overwhelming probability, S^* can know on her own D_R's reply in S^* Phase II.

Message Authentication

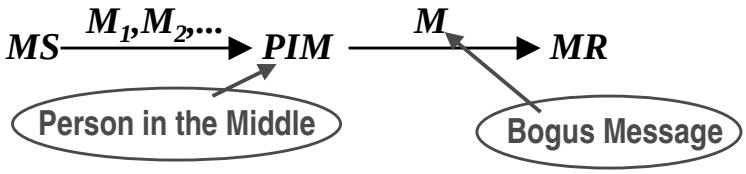


- ***MR*** wants to authenticate ***M*** as being authored by ***MS*** for ***MR, at this time***.

Our Solution

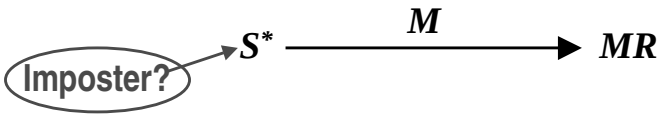
- Generic
- Efficient
- Long messages
- Resilient against Person-in-the-Middle attacks
- No cryptographic hashing
- Deniable Authentication

Person in the Middle Attack

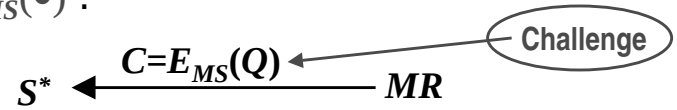


- ***PIM*** will not be able to authenticate ***M*** to ***MR*** , unless for some ***i, M=M***$_i$.

Strategy



- ***MR*** will pose to ***S**** a question ***Q*** about ***M*** .
- The question ***Q*** is sent to S* encrypted by $E_{MS}(\bullet)$.



- By correctly responding ***S**** proves ***S**=**MS*** , and authenticates ***M*** .

Authentication Protocol

1. $MS \xrightarrow{M} MR$

2. MR randomly chooses:
   - Irreducible polynomial $f(t)=t^{64}+b_1t^{63}+\ldots+b_{64}$
   - random $pad=c_1c_2\ldots c_{64}$.

3. $MS \xleftarrow{C=E_{MS}(f,\,pad)} MR$ (Challenge)

   with PPTK.

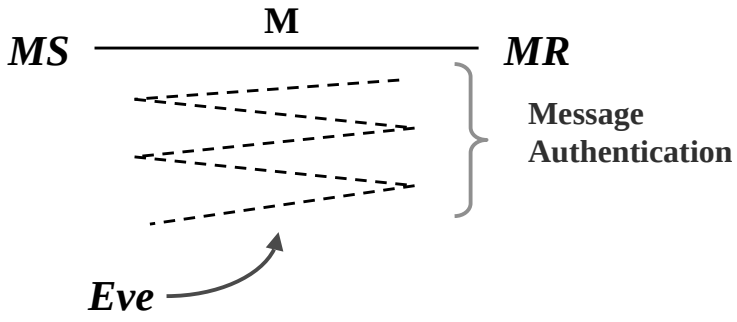
4. $MS \xrightarrow{(M \bmod f)\oplus pad} MR$ (Reply)

[Ra80]

Properties

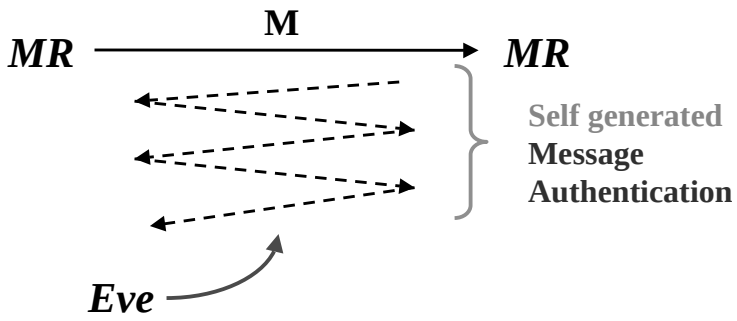
- Assuming E_{MS} is *non-melleable*: **Prob(cheating)** $\leq N/2^{64}$, $N=|M|$
- Computing $M \bmod f$ takes $|M|$ XOR operations.
- As secure as E_{MS}

Deniable Authentication



Eve: On line all powerful adversary, wants proof that *MS* authored *M*.

MS can deny authorship of ***M.***

MS will claim:

- Because of PPTK , ***MR*** *knows* question ***Q*** = **(*f* , *pad*).**
- ***MR*** created ***M*** and gave the correct responses.