Password Authenticated Key Exchange Protocols

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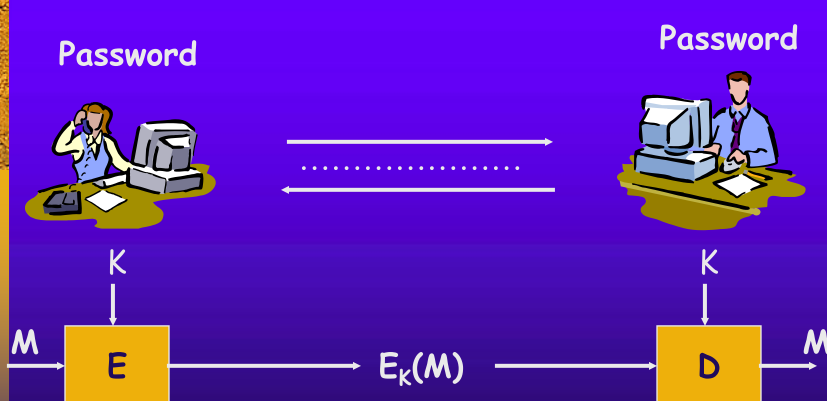
Abstract

- Scenario: client/server model
- Application: password-authenticated key exchange (PAKE)
- Proposals: client/server PAKE protocol from IBE, group PAKE protocol from IBE and IBS

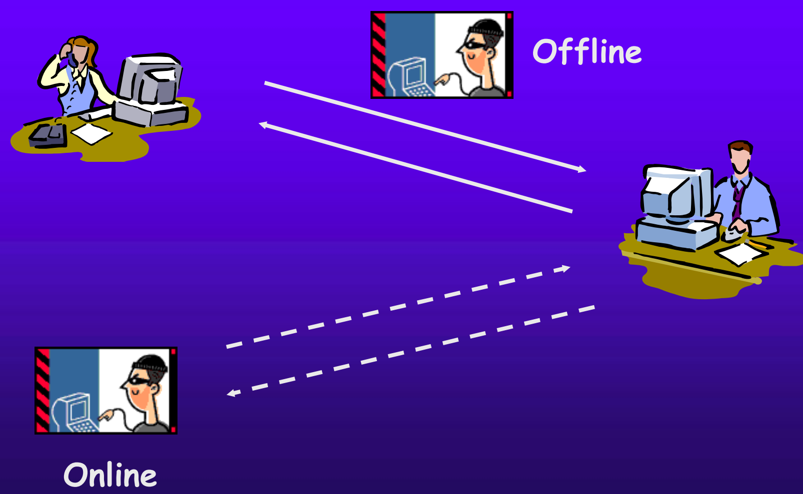
Outline

- Backgrounds
- Client/server PAKE from IBE
- Group PAKE from IBE and IBS
- Security and performance analysis
- Conclusion

What is PAKE?

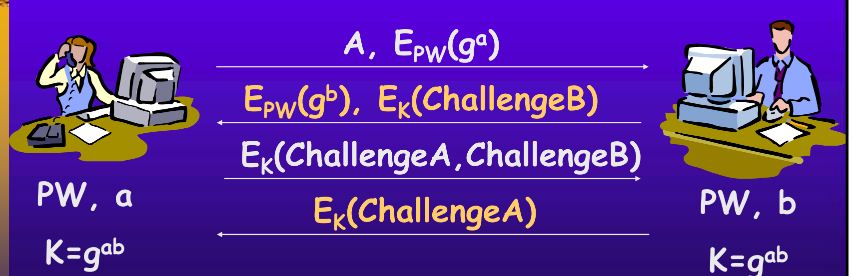


Dictionary Attack



First PAKE

- S. Bellovin and M. Meritt: Encrypted key exchange: Password-based protocols secure against dictionary attacks (1992).
- Built on Diffie-Hellman protocol (1976).



First Formal Model of Security for PAKE

- M. Bellare, D. Pointcheval, and P. Rogaway: Authenticated key exchange secure against dictionary attacks (Eurocrypt 2000).
- V. Boyko, P. Mackenzie, and S. Patel: Provably secure password-authenticated key exchange using Diffie-Hellman (Eurocrypt 2000).
- Random oracle model versus standard model

$$\boxed{Adv_{A,P}(k) \leq Q(k)/N + \varepsilon(k)}$$

First Practical PAKE without Random Oracles

- J. Katz, R. Ostrovsky and M. Yung: Efficient password-authenticated key exchange using human-memorable passwords (Eurocrypt 2001).
- Built on Cramer-Shoup cryptosystem (1998)

PK	SK
$c=g_1^{x1}g_2^{x2}$	x_1,x_2
$d=g_1^{y1}g_2^{y2}$	y_1,y_2
$h=g_1^{z}$	$z\in Zq$

E: $k\in Zq$
$u_1=g_1^k$
$u_2=g_2^k$
$e=h^k m$
$a=H(u_1,u_2,e)$
$v=c^k d^{ka}$

$$S \xrightarrow{u_1,u_2,v,e} R$$

D: $a=H(u_1,u_2,e)$
$u_1^{x1}u_2^{x2}(u_1^{y1}u_2^{y2})^a=v?$
$m=e/u_1^z$

KOY PAKE

Client

$\boxed{\text{Public}: p, q, g_1, g_2, c, d, h, H}$

Server

$(VK, SK), r_1 \in Z_q$
$A = g_1^{r1}, B = g_2^{r1}$
$C = h^{r1} g_1^{pw}$
$a = H(client, VK, A, B, C)$
$D = (cd^a)^{r1}$

$\xrightarrow{\text{Client}, VK, A, B, C, D}$

$x_2, y_2, z_2, w_2, r_2 \in Z_q$
$a' = H(client, VK, A, B, C)$
$E = g_1^{x2} g_2^{y2} h^{z2} (cd^{a'})^{w2}$
$F = g_1^{r2}, G = g_2^{r2}$
$I = h^{r2} g_1^{pw}$
$b = H(server, E, F, G, H)$
$J = (cd^b)^{r2}$

$\xleftarrow{\text{Server}, E, F, G, I, J}$

$x_1, y_1, z_1, w_1 \in Z_q$
$b' = H(server, E, F, G, H)$
$K = g_1^{x1} g_2^{y1} h^{z1} (cd^{b'})^{w1}$
$Sig = Sign_{SK}(b', K)$

$\xrightarrow{K, Sig}$

If $Verify_{VK}(b, K, Sig) = 1$
$C' = C / g_1^{pw}$
$sks = K^{r2} A^{x2} B^{y2} C'^{z2} D^{w2}$

$I' = I / g_1^{pw}$
$sks = E^{r1} F^{x1} G^{y1} I'^{z1} J^{w1}$

Motivations

- Common reference model versus IBE
- Implicit authentication versus explicit authentication
- PAKE security model versus ID-based PAKE security model

Security Model for PAKE from IBE

MasterKey

Private Key Generator

Public Parameters (public key)

Server, SK_S

Client $\xrightarrow{PW}$ Server

Client: PW

Server: SK_S, PW

Client/Server PAKE from IBE

Public Parameters (public key)

Client $\xrightarrow{g^a,\ IBE_{Server}[H(g^a|PW)]}$ Server

Client $\xleftarrow{g^b,\ IBE_{Client^a}[H(g^b|PW)]}$ Server

a: one-time masterkey

Client: PW, a

Server: SK_S, PW, b

Client: $K=e(g^b,g)^{a^2}$ $=e(g,g)^{ba^2}$

Server: $K=e(g^a,g^a)^b$ $=e(g,g)^{ba^2}$

Practical IBE without Random Oracles

- C. Gentry: Practical identity-based encryption without random oracles (Eurocrypt 2006).
- Truncated decisional augmented bilinear Diffie-Hellman exponent (ABDHE) assumption

$q, g, g_1 = g^{\alpha}, h1, h2, h3, H,\ \alpha$: MasterKey

SecretKey

$d_{ID} = \{(r_{ID,i}, h_{ID,i}) : i = 1, 2, 3\}$

$h_{ID,i} = (h_i g^{r_{ID,i}})^{1/(\alpha - ID)}$

E: $s \in Zq$ $u = g^s g_1^{-sID}$

$v = e(g,g)^s$

$w = m \cdot e(g,h_1)^{-s}$

$b = H(u,v,w)$

$Y = e(g,h_2)^s e(g,h_3)^{sb}$

$$S \xrightarrow{u,v,w,y} R$$

D: $b = H(u,v,w)$

$e(u, h_{ID,2} h_{ID,3}^{\ b}) v^{r_{ID,2} + r_{ID,3} b} = y?$

$m = w \cdot e(u, h_{ID,1}) v^{r_{ID,1}}$

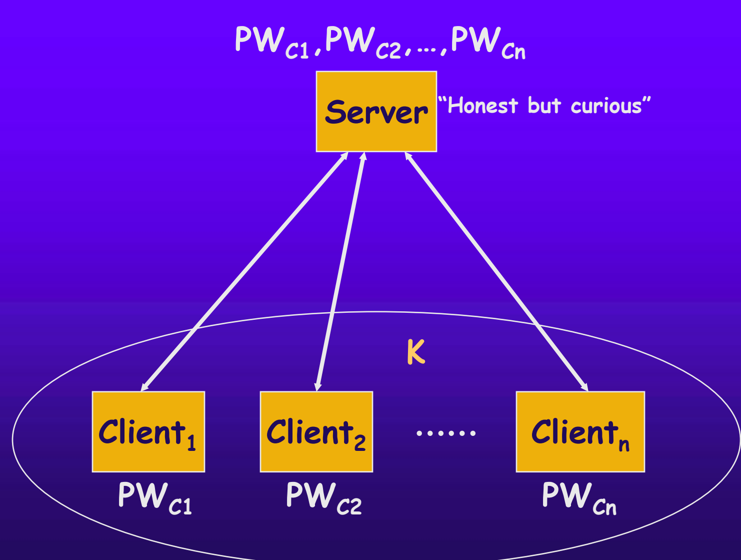
Security of Client/Server PAKE from IBE without Random Oracles

- IBE is secure against the adaptive chosen ciphertext attack.
- A new decisional Diffie-Hellman (NDDH) assumption: given $g, g^a, g^b, Z \in G$, it is hard to decide if $Z = e(g,g)^{ba^2}$
- ABDHE: $(g', g'_{q+2}, g, g_1, \ldots, g_q, Z)$, it is hard to decide if $Z = e(g_{q+1}, g')$ where $g_i = g^{a^i}$
- NDDH is harder than ABDHE because let $g_{(q+1)/2} = g^x$, $g' = g^y$, then $e(g_{q+1}, g') = e(g,g)^{yx^2}$

KOY versus Client/Server PAKE from IBE (Client side)

	KOY	YTO-1
Rounds	3	2
Auth.	Implicit	Explicit
Comm.	12	10
Comp.	16 + 1 Sign	14 + 2 Pair

Extension to Group PAKE



Group PAKE from IBE

- Broadcasting communication model
- Clients run a group key exchange protocol P to obtain K
- Authentication

$IBE_{Server}[H(msg|K)*H(msg|PW_{Ci})]$

$Client_i$ → Server

$Client_i$ ← Server

$Sign_{Server}[H(msg|clients,server),SK_S]$

PW_{Ci} $\quad$ SK_S,PW_{Ci}

Security of Group PAKE from IBE and IBS

- Trust model
- IBE is secure against the adaptive chosen ciphertext attack.
- IBS is existential unforgeability under the chosen message attack.
- Group PAKE from IBE and IBS has been proved to be secure without random oracles.

Abdalla et al's Group PAKE versus ID-based Group PAKE

	Abdalla et al.	YTO-2
Compiler	2-party PAKE, Burmester-Desmedt KE	Group KE, Client/server PAKE
Trusted model	Each user is honest	Server is honest
Auth model	n pairs of users	All clients to server
Rounds	5	4

Conclusion

- Client/server model
- Client/server PAKE from IBE is more efficient than existing 2-party PAKE without random oracles.
- Group PAKE from IBE and IBS is a new way to construct group PAKE protocols.

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