Introduction to Security

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Module 8 – Key Management – Shared Key Exchange

(Ch 20.6, 21.5 and 23.1)
Shared Key Exchange Problem

• How do Alice and Bob exchange a shared secret?
• Offline
  – Doesn’t scale
• Using specially crafted messages (Diffie-Hellman)
• Using a trusted third party (KDC)
  – Secrets should never be sent in clear
  – We should prevent replay attacks
  – We should prevent reuse of old keys
• Using public key cryptography (possible)
Diffie-Hellman Key Exchange

(Ch 21.5)

- Exchange a secret with someone you never met while shouting in a room full of people
  - Alice and Bob agree on $g$ and large $n$
  - Alice chooses random $a$, sends $g^a \mod n$
  - Bob chooses random $b$, sends $g^b \mod n$
  - Alice takes Bob’s message and calculates $g^{ab} \mod n = (g^b \mod n)^a \mod n$
    - shared secret. Bob does the same.
Discrete Logarithms

• Why is it hard for anyone to guess $a$ and $b$ in Diffie-Hellman key exchange?
  – Why is brute force the only possible way of guessing?
• Let $g$ be a “primitive root” of $n$
  – Powers of $g$ generate all numbers 1..n-1
• For any integer $x<n$ one can find $a$ s.t.:
  \[ x = g^a \mod n \]
• $a$ is called the “discrete logarithm” of $x$
• There is no algorithm to efficiently calculate $a$ given $x$, $g$ and $n$
Uses of Diffie-Hellman

• Alice and Bob can exchange a shared key
• Multiple users can:
  – Each select their own “private” key $P_{ri}$
  – Calculate their “public” key $x_i = g^{P_{ri}} \mod n$
    and publish it in a central directory
  – When another user wants to talk to them, the user can
    calculate a shared key for this communication
  – With central directory service to store keys, we get on-
demand shared key exchange

Note: When we say public/private in this context, this is
different than public and private keys in RSA
Mallory sits between Alice and Bob and replaces their messages with her own.

When Alice and Bob send messages, Mallory decrypts them and re-encrypts them. This works because there's no authentication.

Any 2 parties can exchange keys. No way to differentiate between Alice and Bob with just Diffie-Hellman.
KDC Based Key Distribution

(Ch 20.6)

- Building up to Needham Schroeder/Kerberos
- Client sends req. to KDC (key distrib. center)
- KDC generates a shared key: \( K_{c,s} \)

\[
\begin{align*}
\text{①} & \quad \mathbf{C}, \mathbf{S} \\
\text{②} & \quad \text{EK}_{\text{KDC},\mathbf{C}} \{ \mathbf{S}, K_{c,s} \} \\
\text{③} & \quad \text{EK}_{\text{KDC},\mathbf{S}} \{ \mathbf{C}, K_{c,s} \}
\end{align*}
\]

- Keys \( K_{\text{KDC},\mathbf{C}} \) and \( K_{\text{KDC},\mathbf{S}} \) are preconfigured
- No keys ever traverse net in the clear
- Why are identities in tickets?
KDC Based Key Distribution

• KDC does not have to talk both to C and S

\[ \text{ticket}_S = \text{EK}_{\text{KDC}, S}\{C, K_{c,s}\} \]

• Messages 2 or 3 can be replayed by Mallory
  – Force C and S to use same secret for a long time
  – Cause S to have an old ticket, break communication with C over time
Needham-Shroeder Key Exchange

• Use nonces to prevent replay attacks

\[ \text{ticket}_S = \text{EK}_{KDC,S}\{C, K_{c,s}\} \]

① \( N_1, C, S \)

② \( \text{EK}_{KDC,C}\{N_1, S, K_{c,s}, \text{ticket}_S\} \)

③ \( \text{EK}_{C,S}\{N_2\}, \text{ticket}_S \)

④ \( \text{EK}_{C,S}\{N_2-1\}\text{EK}_{C,S}\{N_3\} \)

⑤ \( \text{EK}_{C,S}\{N_3-1\} \)
Challenge-Response

• Used when C wants to check if S knows the same shared key $K_{c,s}$
• C selects a random number $R$ and sends $E_{K_{c,s}}(R)$, S decrypts this and sends back $R$
• C selects a random number $R$ and sends to S, S has to return $E_{K_{c,s}}(R)$
• C selects a random number $R$ and sends $E_{K_{c,s}}(R)$ to S, S decrypts, transforms the number (usually calc $R-1$), reencrypts the result and sends back to C
Problem

• What happens if attacker gets session key?
  – Can reuse old session key to answer challenge-response, generate new requests, etc
  – Need validity period in ticket to ensure freshness = tickets expire after some time
Solution: Kerberos (Ch 23.1)

- Introduce Ticket Granting Server (TGS)
  - Issue tickets for clients to talk to servers
- Authentication server (AS) authenticates users
  - Issues a ticket for clients to talk to TGS
- TGS+AS = KDC
- Each ticket has a validity period: timestamp and lifetime
- Each service request (client to server) has an authenticator (nonce): timestamp + client identity, encrypted with a session key
1. User logs on to workstation and requests service on host.

2. AS verifies user’s access right in database, creates ticket-granting ticket and session key. Results are encrypted using key derived from user’s password.

3. Workstation prompts user for password to decrypt incoming message, then send ticket and authenticator that contains user’s name, network address and time to TGS.

4. TGS decrypts ticket and authenticator, verifies request then creates ticket for requested application server.

5. Workstation sends ticket and authenticator to host.

6. Host verifies that ticket and authenticator match, then grants access to service. If mutual authentication is required, server returns an authenticator.
Key Exchange Using Public Keys

- Alice selects a shared key, encrypts it with Bob’s public key – only Bob can read

\[ \text{EPub}_B(K_{AB}) \]

- Why not just use public keys?
  - It would be much slower
  - Symmetric encryption must faster than asymmetric encryption