Key Management/Distribution

Cryptography in Use
- Provides foundation for security services
- But can it bootstrap itself?
  - Must establish shared key
  - Straightforward plan
    - One side generates key
    - Transmits key to other side
    - But how?

Security Through Obscurity?
- Caesar ciphers
  - Very simple permutation
  - Only 25 different cases
  - Relies strictly on no one knowing the method

Administrivia
- Snafu on books
  - Probably best to buy it elsewhere
- Paper assignment and first homework
  - Next week (9/24)

Two Problems
- Peer-to-peer key sharing
- Prob 1: Known peer, insecure channel
- Prob 2: Secure channel, unknown peer

Passwords
- Reduces permutation space to key space
- Caesar cipher: one-letter “key”
- 10-letter key for MSC reduces 26! (~$4 \times 10^{26}$) to $26 \cdot C_{10}$ (~$2 \times 10^{11}$)
- 8-byte key for DES reduces $2^{64}$ (~$10^{26}$) to $2^{25}$ (~$10^{12}$)
The Enigma Machine

- Broken first by Polish, then by English
  - Not as easily as widely regarded
- Weaknesses in key distribution
  - Day keys plus scramblers
  - "Session keys" encrypted in duplicate
- Enigma did not use OFB/CFB

Peer-to-Peer Distribution

- Technically easy
- But it doesn’t scale
  - Hundreds of servers...
  - Times thousands of users...
  - Yields ~ million keys
- Centralized key server
  - Needham-Schroeder

Basic Idea

- User sends request to KDC: \{s\}
- KDC generates a random key: \(K_{c,s}\)
  - Encrypted twice: \(\{K_{c,s}K_c\ K_{c,s}\}\)
  - Typically called ticket and credentials, resp
  - Ticket forwarded with application request
- No keys ever traverse net in the clear

Problem #1

- How does user know session key is encrypted for the server? And vice versa?
- Attacker intercepts initial request, and substitutes own name for server
  - Can now read all of user’s messages intended for server

Solution #1

- Add names to ticket, credentials
  - Request looks like \(\{c, s\}\)
  - \(\{K_{c,p} \ s\}K_c\) and \(\{K_{c,p} \ c\}K_p\) resp
  - Both sides can verify intended target for key sharing
- This is basic Needham-Schroeder

Problem #2

- How can user and server know that session key is fresh?
- Attacker intercepts and records old KDC reply, then inserts this in response to future requests
  - Can now read all traffic between user and server
Solution #2
- Add nonces to ticket, credentials
  - Request looks like \( \{ c, s, n \} \)
  - \( \{ K_{c,r}, s, n \} K_s \) and \( \{ K_{c,r}, c, n \} K_s \)
- Client can now check that reply made in response to current request

Solution #3
- Add challenge-response
  - Server generates second random nonce
  - Sends to client, encrypted in session key
  - Client must decrypt, decrement, encrypt
- Effective, but adds second round of messages

Solution #4
- Replace (or supplement) nonce in request/reply with timestamp [Denning, Sacco]
  - \( \{ K_{c,r}, s, n, t \} K_s \) and \( \{ K_{c,r}, c, n, t \} K_s \) resp
  - Also send \( \{ t \} K_{s,s} \) as authenticator
- Prevents replay without employing second round of messages as in challenge-response

Problem #3
- User now trusts credentials
- But can server trust user?
- How can server tell this isn’t a replay?
- Legitimate user makes electronic payment to attacker; attacker replays message to get paid multiple times
- Requires no knowledge of session key

Problem #4
- What happens if attacker does get session key?
  - Answer: Can reuse old session key to answer challenge-response, generate new requests, etc

Problem #5
- Each client request yields new known-plaintext pairs
- Attacker can sit on the network, harvest client request and KDC replies
Solution #5
- Introduce Ticket Granting Server (TGS)
  - Daily ticket plus session keys
  - (How is this different from Enigma?!)  
- TGS+AS = KDC
  - This is modified Needham-Schroeder
  - Basis for Kerberos

Problem #6
- Active attacker can obtain arbitrary numbers of known-plaintext pairs
  - Can then mount dictionary attack at leisure
  - Exacerbated by bad password selection

Solution #6
- Preauthentication
  - Establish weak authentication for user before KDC replies
  - Examples
    - Password-encrypted timestamp
    - Hardware authentication
    - Single-use key

Public Key Distribution
- Public key can be public!
  - How does either side know who and what the key is for? Private agreement? (Not scalable.)
- Must delegate trust
  - Why?
  - How?

Certification Infrastructures
- Public keys represented by certificates
- Certificates signed by other certificates
  - User delegates trust to trusted certificates
  - Certificate chains transfer trust up several links

Examples
- PGP
  - “Web of Trust”
  - Can model as connected digraph of signers
- X.500
  - Hierarchical model: tree (or DAG?)
  - (But X.509 certificates use ASN.1!)

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