Key Management

Chapter 10

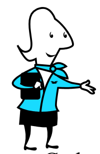
Key Management

- Distribution of cryptographic keys
- Binding identity to a key
- Generation, maintenance, revoking

Session Keys

- More the same symmetric key used, more likely to be broken
- Generate and use a symmetric key for use during a specific communication for data only
- PK schemes good for encrypting random data; not good otherwise - especially if possible plaintext is from a small set
  - Forward search attack
  - Encrypt all possibilities with public key

Communicating Securely



Cathy
Trusted 3rd party

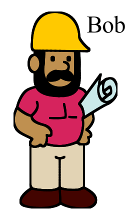
How can Alice send Bob a symmetric key to enable communication?

Alice

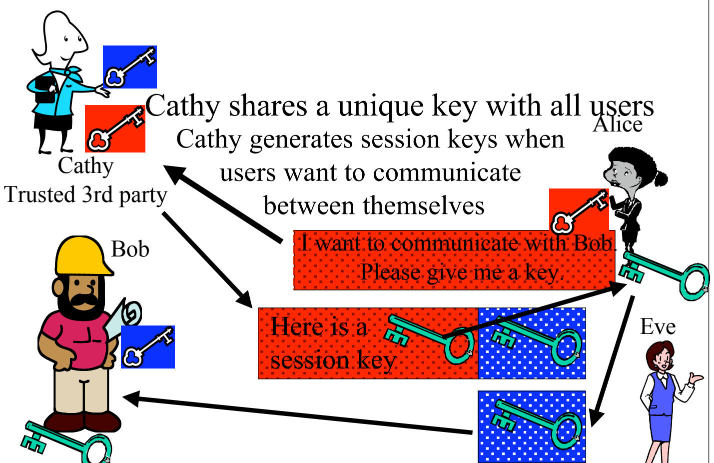
If sent in the clear, Eve can see

Use a *Trusted* 3rd Party

Bob



Eve



Basic Exchange

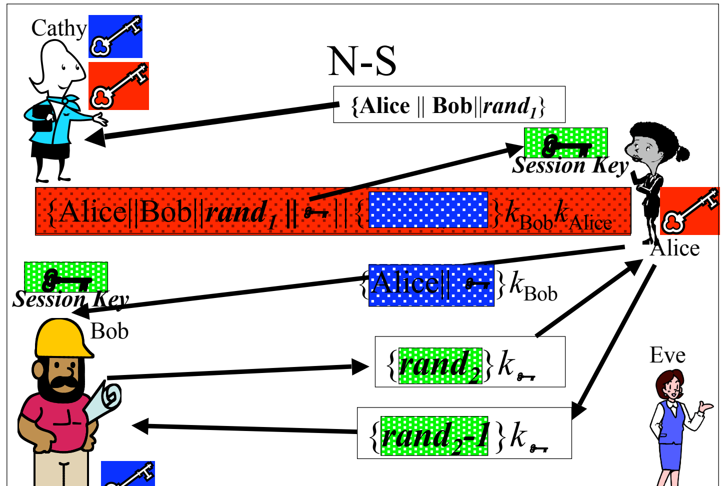
- Vulnerable to replay by Eve
- Eve copies Bob's encrypted key and messages encrypted under the sessions key
  - Eve can't "read" the messages, but Bob will still read (and possibly redo something) it
  - "deposit $500"

Needham-Schroeder

- Added authentication to thwart replay
- Random numbers used

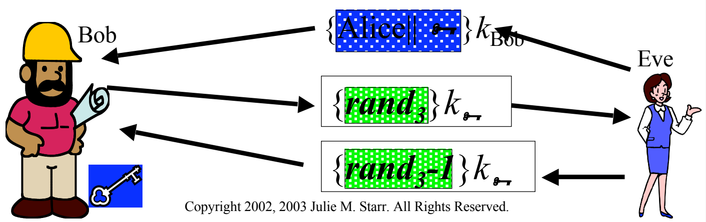
1. Alice □ Cathy : {Alice ||Bob||*rand*$_1$}
2. Cathy □ Alice:
   {Alice ||Bob||*rand*$_1$|| $k_{session}$ {Alice|| $k_{session}$} k_{Bob}} k_{Alice}
3. Alice □ Bob: {Alice || $k_{session}$} k_{Bob}
4. Bob □ Alice: {*rand*$_2$} $k_{session}$
5. Alice □ Bob: {*rand*$_{2-1}$} $k_{session}$

N-S

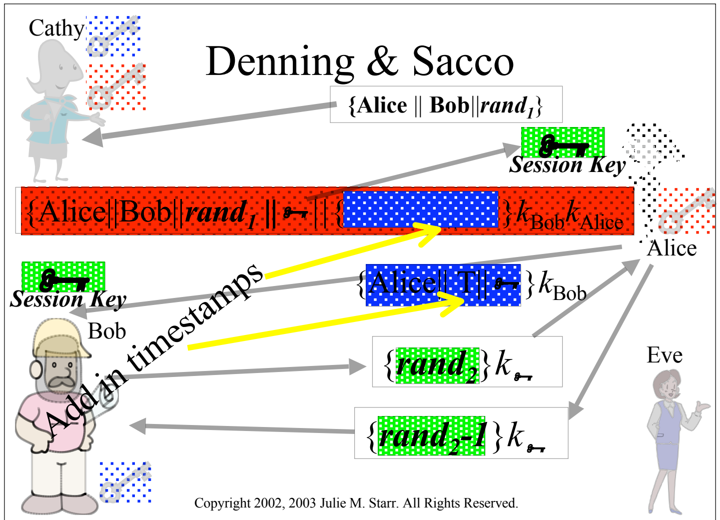


N-S Analysis

- Can’t repeat random numbers
  - AKA *nonces*
- What if session key is known by Eve?



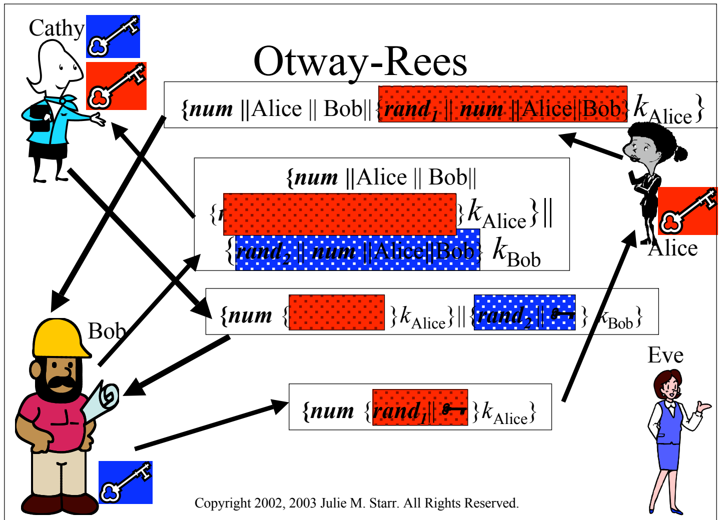
Denning & Sacco



Denning & Sacco Analysis

- If clocks are too fast or too slow, vulnerable

Otway-Rees



Public Key Key Exchange

- Here interchange keys known
  - e_A, e_B Alice and Bob's public keys known to all
  - d_A, d_B Alice and Bob's private keys known only to owner
- Simple protocol
  - k_s is desired session key

Alice —— $\{ k_s \} e_B$ ——→ Bob

Problem and Solution

- Vulnerable to forgery or replay
  - Because *eB* known to anyone, Bob has no assurance that Alice sent message
- Simple fix uses Alice's private key
  - k_s is desired session key

Alice —— $\{ \{ k_s \} d_A \} e_B$ ——→ Bob

Notes

- Can include message enciphered with *ks*
- Assumes Bob has Alice's public key, and *vice versa*
  - If not, each must get it from public server
  - If keys not bound to identity of owner, attacker Eve can launch a *man-in-the-middle* attack (next slide; Cathy is public server providing public keys)
    - Solution to this (binding identity to keys) discussed later as public key infrastructure (PKI)

Man-in-the-Middle Attack

Alice —— send Bob's public key | *Eve intercepts request* ——→ Cathy

Eve —— send Bob's public key ——→ Cathy

Eve ←—— e_B —— Cathy

Alice ←—— e_E —— Eve

Alice —— $\{ k_s \} e_E$ | *Eve intercepts message* ——→ Bob

Eve —— $\{ k_s \} e_B$ ——→ Bob

Key Generation

- Goal: generate difficult to guess keys
- Problem statement: given a set of *K* potential keys, choose one randomly
  - Equivalent to selecting a random number between 0 and K–1 inclusive
- Why is this hard: generating random numbers
  - Actually, numbers are usually *pseudo-random*, that is, generated by an algorithm

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What is "Random"?

- *Sequence of cryptographically ransom numbers*: a sequence of numbers n_1, n_2, … such that for any integer $k > 0$, an observer cannot predict n_k even if all of $n_1, \ldots, n_{k-1}$ are known
  - Best: physical source of randomness
    - Random pulses
    - Electromagnetic phenomena
    - Characteristics of computing environment such as disk latency
    - Ambient background noise

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What is "Pseudorandom"?

- *Sequence of cryptographically pseudorandom numbers*: sequence of numbers intended to simulate a sequence of cryptographically random numbers but generated by an algorithm
  - Very difficult to do this well
    - Linear congruential generators [$n_k = (an_{k-1} + b) \bmod n$] broken
    - Polynomial congruential generators [$n_k = (a_j n_{k-1}^j + \ldots + a_1 n_{k-1}\, a_0) \bmod n$] broken too
    - Here, "broken" means next number in sequence can be determined

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Best Pseudorandom Numbers

- *Strong mixing function*: function of 2 or more inputs with each bit of output depending on some nonlinear function of all input bits
  - Examples: DES, MD5, SHA-1
  - Use on UNIX-based systems:

```
(date; ps gaux) | md5
```

  where "ps gaux" lists all information about all processes on system

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Cryptographic Key Infrastructure

- Goal: bind identity to key
- Classical: not possible as all keys are shared
  - Use protocols to agree on a shared key (see earlier)
- Public key: bind identity to public key
  - Crucial as people will use key to communicate with principal whose identity is bound to key
  - Erroneous binding means no secrecy between principals
  - Assume principal identified by an acceptable name

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Certificates

- Create token (message) containing
  - Identity of principal (here, Alice)
  - Corresponding public key
  - Timestamp (when issued)
  - Other information (perhaps identity of signer)

  signed by trusted authority (here, Cathy)

$$C_A = \{ e_A \parallel \text{Alice} \parallel T \} \, d_C$$

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Use

- Bob gets Alice’s certificate
  - If he knows Cathy’s public key, he can decipher the certificate
    - When was certificate issued?
    - Is the principal Alice?
  - Now Bob has Alice’s public key
- Problem: Bob needs Cathy’s public key to validate certificate
  - Problem pushed “up” a level
  - Two approaches: Merkle’s tree, signature chains

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Key Escrow

- *Key escrow system* allows authorized third party to recover key
  - Useful when keys belong to roles, such as system operator, rather than individuals
  - Business: recovery of backup keys
  - Law enforcement: recovery of keys that authorized parties require access to
- Goal: provide this without weakening cryptosystem
- Very controversial

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Escrowed Encryption Standard

- EES; Capstone; Skipjack
- SymmetricSkipjack cipher, 80 bit
- 1993
- LEAF
  - Law Enforcement Access Field
  - Allowed agencies access to keys to also decrypt
- 2-party systems/protocols are hard enough, 3rd party even more difficult to secure

EES

- LEAF vulnerability
  - Can generate a LEAF and insert into traffic
- Most banks, companies stuck with DES rather than a use a ‘broken’ scheme
- Key escrow
  - LEAF keys held by a Trusted Third Party

PGP ADK

- 1997, Additional Encryption Key
- In even employee no longer had their private key, let company unlock messages
  - Corporate customers wanted this feature
- Alternative to key escrow
- Original implementation allowed users to attach an ADK to their key
- Bug in August 2000 (now fixed)
  - Was not digitally signed
  - Someone else could potentially attach a different ADK to your key