CIS 551 / TCOM 401

Computer and Network Security

Spring 2007

Lecture 18

Announcements

- Midterm II
  - Thursday, March 22
  - In class, format similar to Midterm I

- Project 3 is available on the web pages
  - Handout for SDES needed for the project
  - Due: April 3rd
  - (Don't worry, it's shorter than the previous projects.)

Plan for Today

- Complete Digital Signatures
- Talk about Key Distribution Protocols
  - Needham Schroeder
  - Kerberos

Digital Signatures with Public Keys

- Assumes the algorithm is *commutative*:
  - D(E(M, K), k) = E(D(M, k), K)
- Let K_A be Alice's public key
- Let k_A be her private key
- To sign msg, Alice sends D(msg, k_A)
- Bart can verify the message with Alice's public key

- Works! RSA: $(m^e)^d = m^{ed} = (m^d)^e$

Digital Signatures with Public Keys

Alice

Bart

$A, k_A\{msg\}$ →

k_A, K_A, K_B

k_B, K_B, K_A

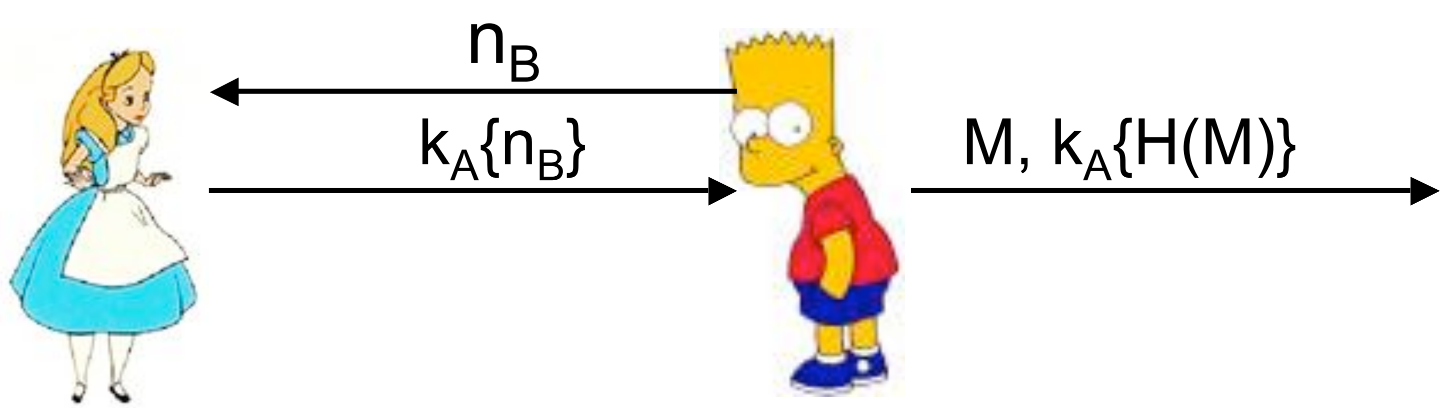
- No trusted 3rd party.
- Simpler algorithm.
- More expensive
- No confidentiality

Variations on Public Key Signatures

- Timestamps again (to prevent replay)
  - Signed certificate valid for only some time.
- Add an extra layer of encryption to guarantee confidentiality
  - Alice sends $A, K_B\{k_A\{msg\}\}$ to Bart
- Combined with hashes:
  - Send $(A, msg, k_A\{MD5(msg)\})$

Multiple Use of Keys

- Risky to use keys for multiple purposes.
- Using an RSA key for both authentication and signatures may allow a chosen-text attack.
- B attacker/verifier, n_B=H(M) for some message M.



B, pretending to be A

Key Establishment

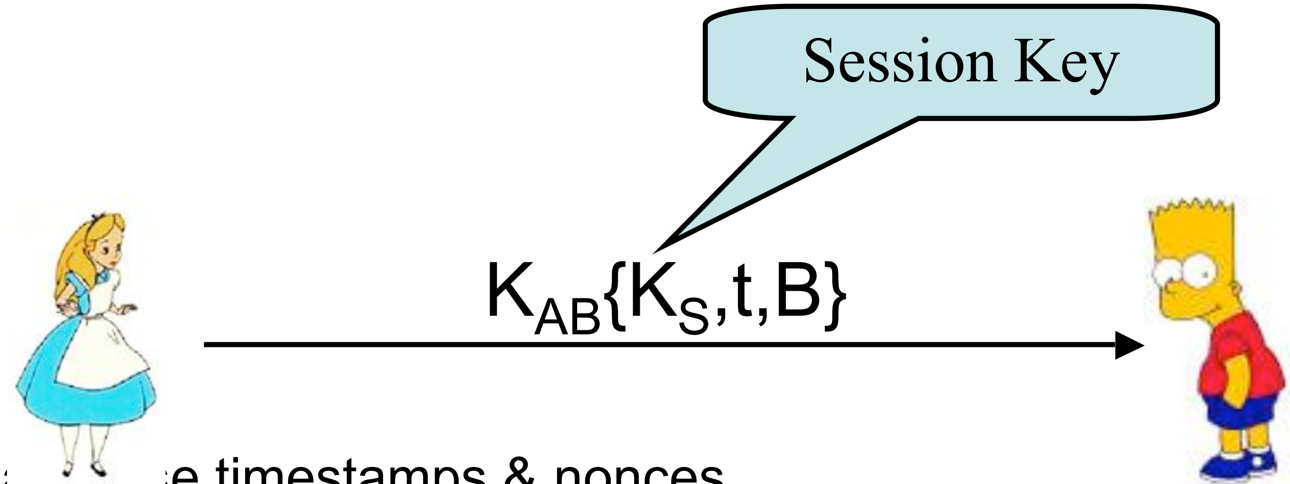
- Establishing a "session key"
  - A shared key used for encrypting communications for a short duration -- a session
  - Need to authenticate first
- Symmetric keys.
  - Point-to-Point.
  - Needham-Schroeder.
  - Kerberos.

Symmetric Keys

- Key establishment using only symmetric keys requires use of pre-distribution keys to get things going.

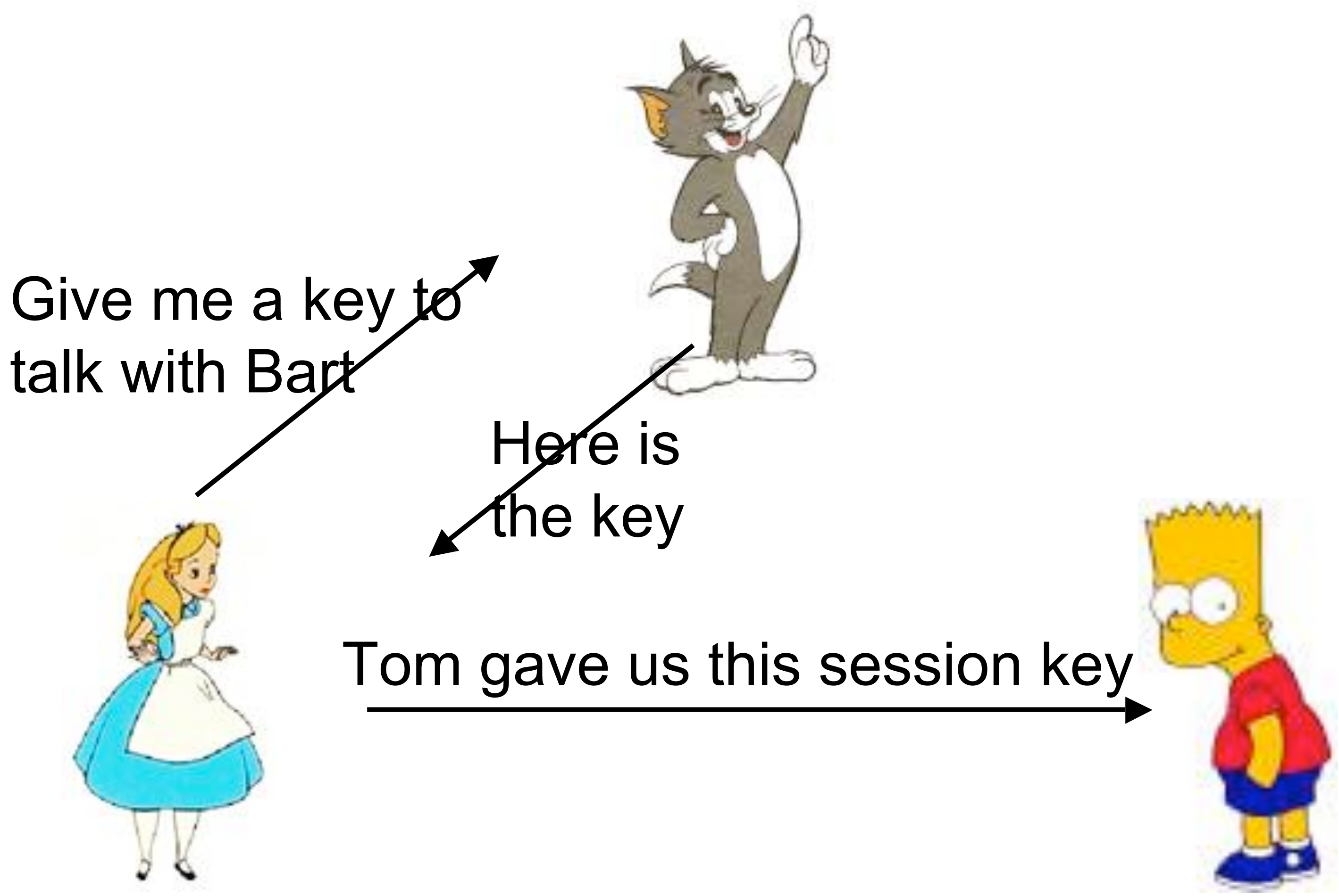
- Then protocol can be based on:
  - Point to point distribution, or
  - Key Distribution Center (KDC).

Point-to-Point



- Should also use timestamps & nonces.
- Session key should include a validity duration.
- Could also use public key cryptography to
  - Authenticate
  - Exchange symmetric shared key

Key Distribution Centers



Distribution Center Setup

- A wishes to communicate with B.
- T (trusted 3rd party) provides session keys.
- T has a key K_{AT} in common with A and a key K_{BT} in common with B.
- A authenticates T using a nonce n_A and obtains a session key from T.
- A authenticates to B and transports the session key securely.

Needham-Schroeder Protocol

1. $A \rightarrow T$: A, B, n_A
2. $T \rightarrow A$: $K_{AT}\{K_S, n_A, B, K_{BT}\{K_S, A\}\}$

   A decrypts with K_{AT} and checks n_A and B. Holds K_S for future correspondence with B.
3. $A \rightarrow B$: $K_{BT}\{K_S, A\}$

   B decrypts with K_{BT}.
4. $B \rightarrow A$: $K_S\{n_B\}$

   A decrypts with K_S.
5. $A \rightarrow B$: $K_S\{n_B - 1\}$

   B checks n_B-1.

Attack Scenario 1

1. $A \rightarrow T$: A, B, n_A
2. $T \rightarrow C(A)$: $K_{AT}\{k, n_A, B, K_{BT}\{K_S, A\}\}$

   C is unable to decrypt the message to A; passing it along unchanged does no harm. Any change will be detected by A.

Attack Scenario 2

1. $A \rightarrow C\ (T)$: A, B, n_A
2. $C\ (A) \rightarrow T$: A, C, n_A
3. $T \rightarrow A$: $K_{AT}\{K_S, n_A, C, K_{CT}\{K_S, A\}\}$

Rejected by A because the message contains C rather than B.

Attack Scenario 3

1. $A \rightarrow C (T)$: A, B, n_A
2. $C \rightarrow T$: C, B, n_A
3. $T \rightarrow C$: $K_{CT}\{K_S, n_A, B, K_{BT}\{K_S, C\}\}$
4. $C (T) \rightarrow A$: $K_{CT}\{K_S, n_A, B, K_{BT}\{K_S, C\}\}$

A is unable to decrypt the message.

Attack Scenario 4

1. $C \rightarrow T$: C, B, n_A
2. $T \rightarrow C$: $K_{CT}\{K_S, n_A, B, K_{BT}\{K_S, C\}\}$
3. $C (A) \rightarrow B$: $K_{BT}\{K_S, C\}$

B will see that the purported origin (A) does not match the identity indicated by the distribution center.

Valid Attack

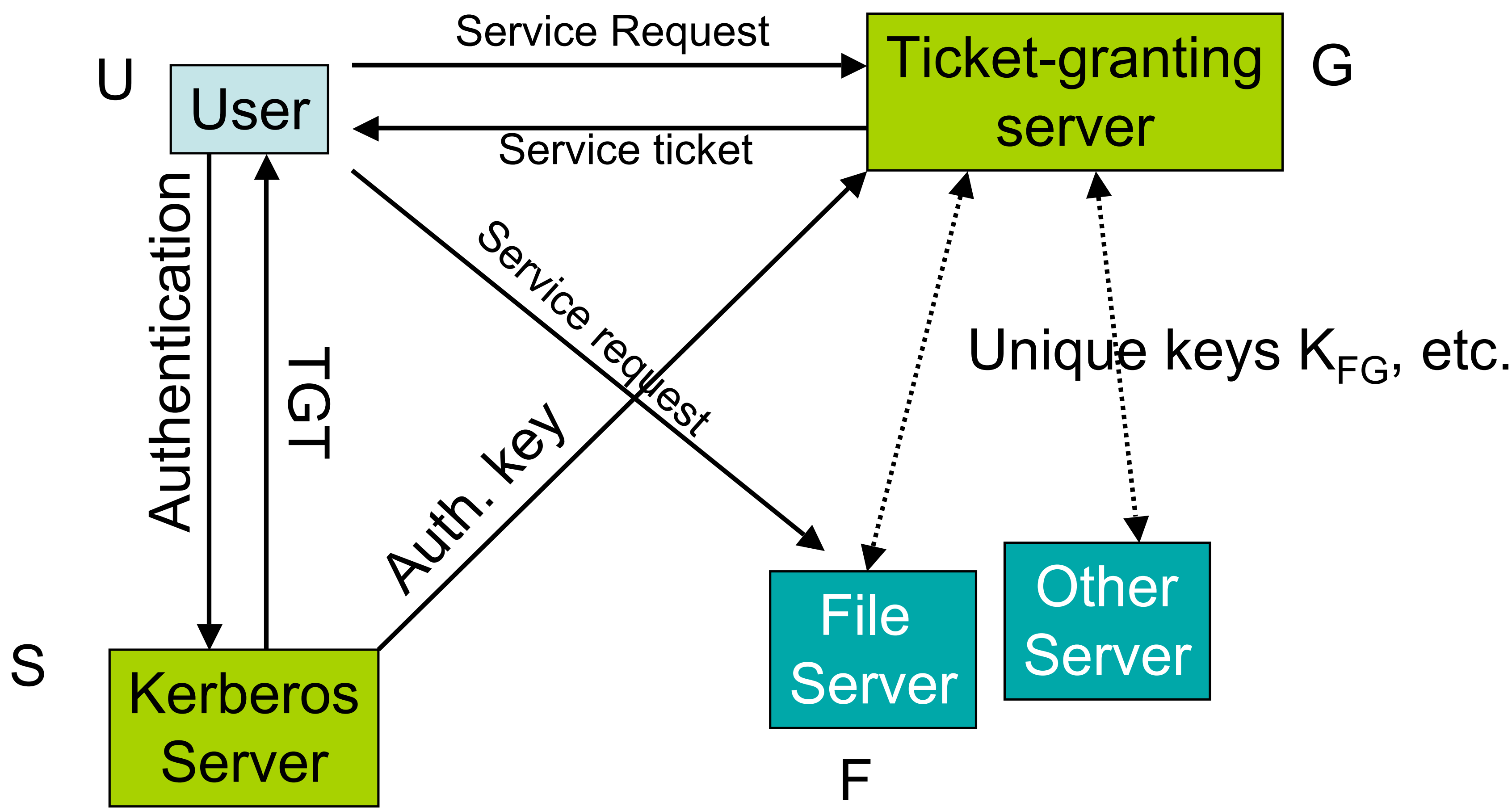
- The attacker records the messages on the network
  - in particular, the messages sent in step 3
- Consider an attacker that manages to get an old session key K_S.
- That attacker can then masquerade as Alice:
  - Replay starting from step 3 of the protocol, but using the message corresponding to K_S.

- Could be prevented with time stamps.

Kerberos

- Key exchange protocol developed at MIT in the late 1980's
- Central server provides "tickets"
- *Tickets* – (also known as *capabilities*):
  - Unforgeable
  - Nonreplayable
  - Authenticated
  - Represent authority
- Designed to work with NFS (network file system)
- Also saves on authenticating for each service
  - e.g. with ssh.

Kerberos



Service Request
U
User
Ticket-granting server
G
Service ticket
Authentication
TGT
Service request
Auth. key
Unique keys K_{FG}, etc.
S
Kerberos Server
File Server
F
Other Server

Kerberos Login

- U = User's machine
- S = Kerberos Server
  - Has a database of user "passwords": userID $\rightarrow k_{pwd}$
- G = Ticket granting server

- $U \rightarrow S$: userID, G, n_U
- $S \rightarrow U$: $k_{pwd}\{n_U, K_{UG}\}, K_{SG}\{T(U,G)\}$
- $S \rightarrow G$: $K_{SG}\{K_{UG}$, userID$\}$

Kerberos ticket granting ticket

- $T(X,Y) = X, Y, L, K_{XY}$

Session key

Ticket lifetime

Kerberos Service Request

- Requesting a service from server F
- $U \rightarrow G$: K_{UG}\{userID,timestamp\}, K_{SG}\{T(U,G)\}, req(F), n'_U
- $G \rightarrow U$: $K_{UG}\{K_{UF}, n'_U\}$, K_{FG}\{T(U,F)\}
- $U \rightarrow F$: K_{UF}\{userID,timestamp\}, K_{FG}\{T(U,F)\}

Kerberos Benefits

- Distributed access control
  - No passwords communicated over the network
- Cryptographic protection against spoofing
  - All accesses mediated by G (ticket granting server)
- Limited period of validity
  - Servers check timestamps against ticket validity
  - Limits window of vulnerability
- Timestamps prevent replay attacks
  - Servers check timestamps against their own clocks to ensure “fresh” requests
- Mutual authentication
  - User sends nonce challenges

Kerberos Drawbacks

- Requires available ticket granting server
  - Could become a bottleneck
  - Must be reliable
- All servers must trust G, G must trust servers
  - They share unique keys
- Kerberos requires synchronized clocks
  - Replay can occur during validity period
  - Not easy to synchronize clocks
- User’s machine could save & replay passwords
  - Password is a weak spot
- Kerberos does not scale well
  - Hard to replicate authentication server and ticket granting server
  - Duplicating keys is bad, extra keys = more management