CIS 551 / TCOM 401

# Computer and Network Security

Spring 2007

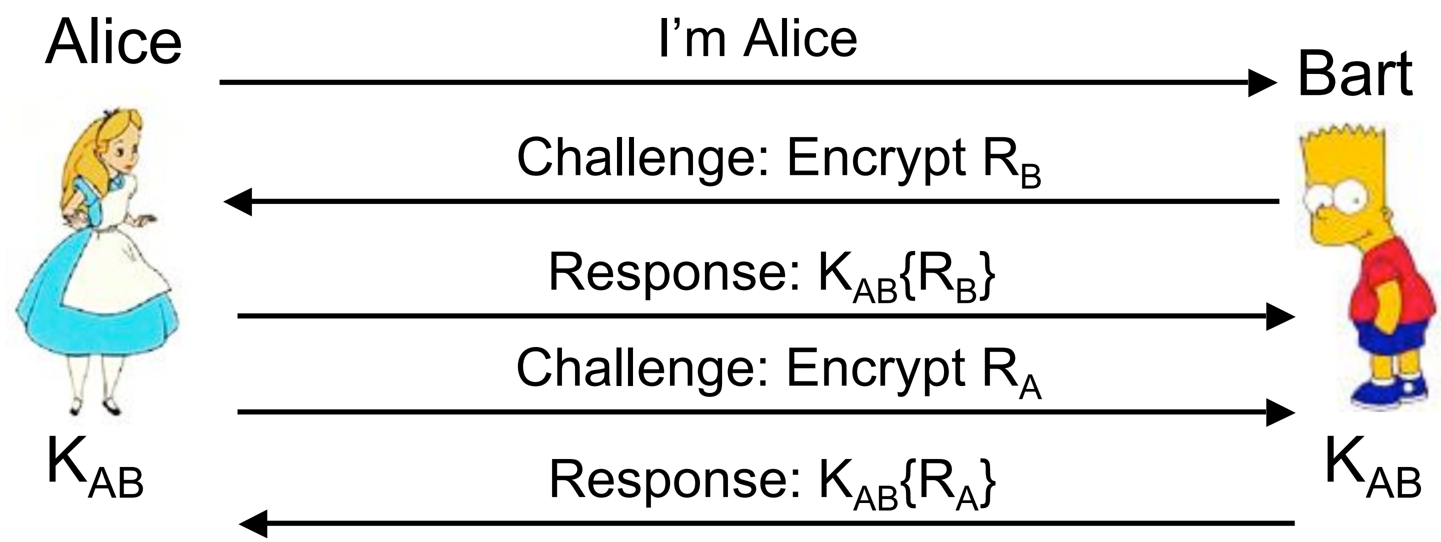
Lecture 17

# Announcements

- Project 2 is due today at 11:59 pm.

- Midterm II
  – Thursday, March 22

# Recap: Challenge Response




- Protocol doesn't reveal the secret.
- *Challenge/Response*
  - Bart requests proof that Alice knows the secret
  - Alice requires proof from Bart
  - $R_A$ and $R_B$ are randomly generated numbers

# Lessons

- Protocol design is tricky and subtle
  - “Optimizations” aren’t necessarily good
- Need to worry about:
  - Multiple instances of the same protocol running in parallel
  - Intruders that play by the rules, mostly

# Threats

- *Transferability:* B cannot reuse an identification exchange with A to successfully impersonate A to a third party C.

- *Impersonation:* The probability is negligible that a party C distinct from A can carry out the protocol in the role of A and cause B to accept it as having A's identity.

# Assumptions

- A large number of previous authentications between A and B may have been observed.
- The adversary C has participated in previous protocol executions with A and/or B.
- Multiple instances of the protocol, possibly instantiated by C, may be run simultaneously.

# Primary Attacks

- Replay.
  - Reusing messages (or parts of messages) inappropriately
- Interleaving.
  - Mixing messages from different runs of the protocol.
- Reflection.
  - Sending a message intended for destination A to B instead.
- Chosen plaintext.
  - Choosing the data to be encrypted
- Forced delay.
  - Denial of service attack -- taking a long time to respond

# Primary Controls

- Replay:
  - use of challenge-response techniques
  - embed target identity in response.
- Interleaving
  - link messages in a session with chained nonces.
- Reflection:
  - embed identifier of target party in challenge response
  - use asymmetric message formats
  - use asymmetric keys.

# Primary Controls, continued

- Chosen text:
  - embed self-chosen random numbers (“confounders”) in responses
  - use “zero knowledge” techniques.

- Forced delays:
  - use nonces with short timeouts
  - use timestamps in addition to other techniques.

# Replay

- *Replay*: the threat in which a transmission is observed by an eavesdropper who subsequently reuses it as part of a protocol, possibly to impersonate the original sender.
  - Example: Monitor the first part of a telnet session to obtain a sequence of transmissions sufficient to get a log-in.
- Three strategies for defeating replay attacks
  - Nonces
  - Timestamps
  - Sequence numbers.

# Nonces: Random Numbers

- *Nonce*: A number chosen at random from a range of possible values.
  - Each generated nonce is valid only once.
- In a challenge-response protocol nonces are used as follows.
  - The verifier chooses a (new) random number and provides it to the claimant.
  - The claimant performs an operation on it showing knowledge of a secret.
  - This information is bound inseparably to the random number and returned to the verifier for examination.
  - A timeout period is used to ensure “freshness”.

# Time Stamps

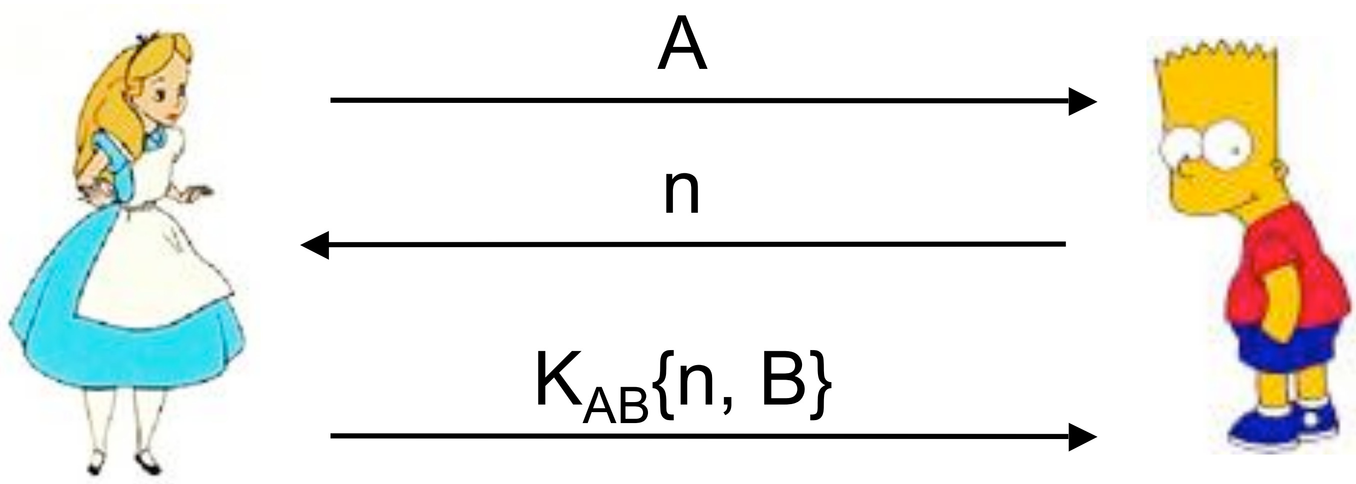
- The claimant sends a message with a timestamp.
- The verifier checks that it falls within an acceptance window of time.
- The last timestamp received is held, and identification requests with older timestamps are ignored.
- Good only if clock synchronization is close enough for acceptance window.

# Sequence Numbers

- Sequence numbers provide a sequential or monotonic counter on messages.
- If a message is replayed and the original message was received, the replay will have an old or too-small sequence number and be discarded.
- Cannot detect forced delay.
- Difficult to maintain when there are system failures.

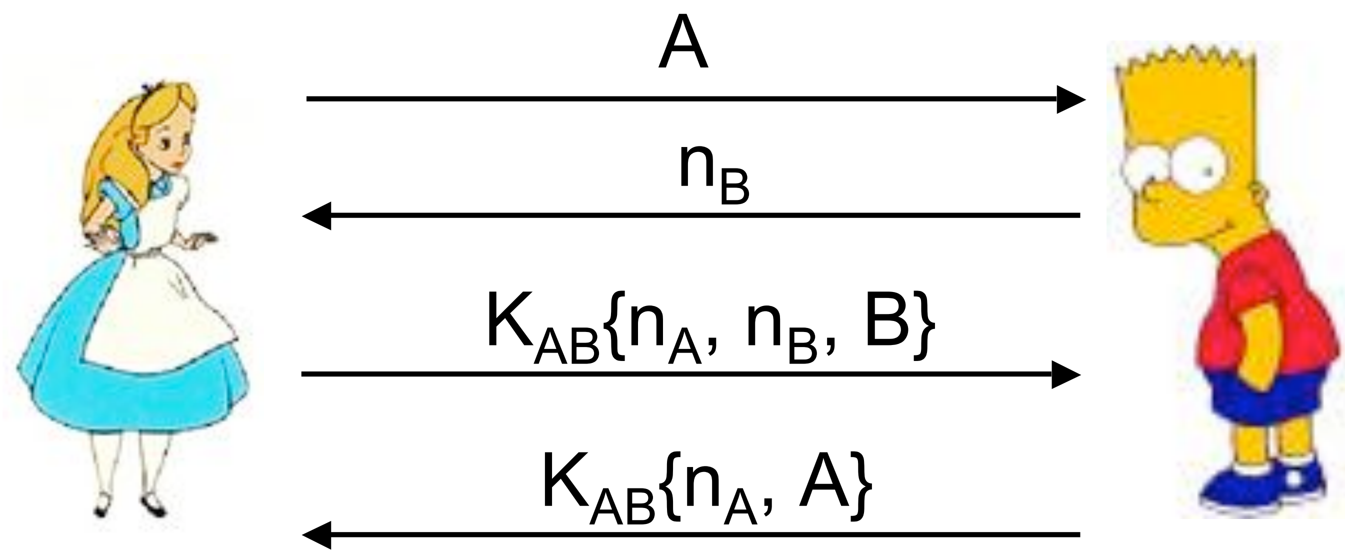
# Unilateral Symmetric Key

- Unilateral = one way authentication
- Unilateral authentication with nonce.



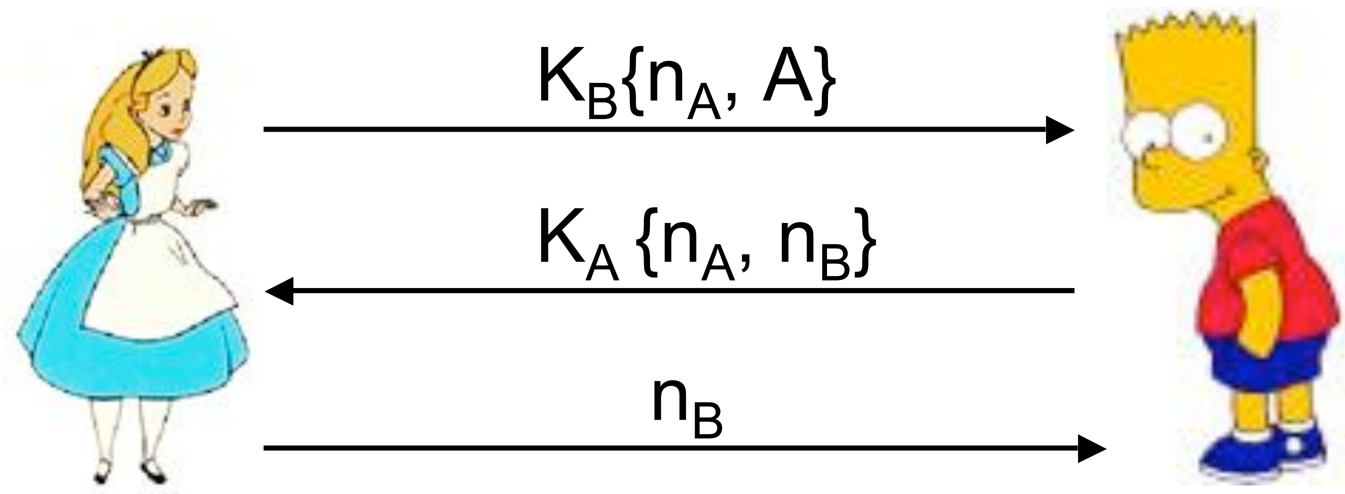
# Mutual Symmetric Key

- Mutual = two way authentication
- Using Nonces:



# Mutual Public Key Decryption

- Exchange nonces



# Usurpation Attacks

- Identification protocols corroborate the identity of an entity only at a given instant in time.
  - An attacker could "hijack" a session after authentication.
- Techniques to assure ongoing authenticity:
  - Periodic re-identification.
  - Tying identification to an ongoing integrity service. For example: key establishment and encryption.

# General Principles

- Don’t do anything more than necessary until confidence is built.
  - Initiator should prove identity before the responder does any “expensive” action (like encryption)
- Embed the intended recipient of the message in the message itself
- Principal that generates a nonce is the one that verifies it
- Before encrypting an untrusted message, add “salt” (i.e. a nonce) to prevent chosen plaintext attacks
- Use asymmetric message formats (either in “shape” or by using asymmetric keys) to make it harder for roles to be switched

# Physical Signatures

- Consider a paper check used to transfer money from one person to another
- Signature confirms authenticity
  - Only legitimate signer can produce signature
- In case of alleged forgery
  - 3rd party can verify authenticity
- Checks are cancelled
  - So they can't be reused
- Checks are not alterable
  - Or alterations are easily detected

# Digital Signatures: Requirements I

- A mark that only one principal can make, but others can easily recognize
- Unforgeable
  - If P signs a message M with signature $S_P\{M\}$ it is impossible for any other principal to produce the pair (M, $S_P\{M\}$).
- Authentic
  - If R receives the pair (M, $S_P\{M\}$) purportedly from P, R can check that the signature really is from P.

# Digital Signatures: Requirements II

- Not alterable
  - After being transmitted, $(M, S_P\{M\})$ cannot be changed by P, R, or an interceptor.
- Not reusable
  - A duplicate message will be detected by the recipient.
- Nonrepudiation:
  - P should not be able to claim they didn't sign something when in fact they did.
  - (Related to unforgeability: If P can show that someone else could have forged P's signature, they can repudiate ("refuse to acknowledge") the validity of the signature.)

# Digital Signatures with Shared Keys

Alice — Tom — Bart

$K_{AT}\{msg\}$ →

$K_{TB}\{Alice,msg,K_{AT}\{msg\}\}$ →

$K_{AT}$ — $K_{AT}$ $K_{TB}$ — $K_{TB}$

Tom is a trusted 3rd party (or arbiter).

**Authenticity:** Tom verifies Alice's message, Bart trusts Tom.

**No Forgery:** Bart can keep msg, $K_{AT}\{msg\}$, which only Alice (or Tom, but he's trusted not to) could produce

# Preventing Reuse and Alteration

- To prevent reuse of the signature
  - Incorporate a *timestamp* (or sequence number)
- Alteration
  - If a block cipher is used, recipient could splice-together new messages from individual blocks.
- To prevent alteration
  - Timestamp must be part of each block
  - Or… use *cipher block chaining*

# 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

$k_A\{msg\}$ →

$k_A, K_A, K_B$

$k_B, K_B, K_A$

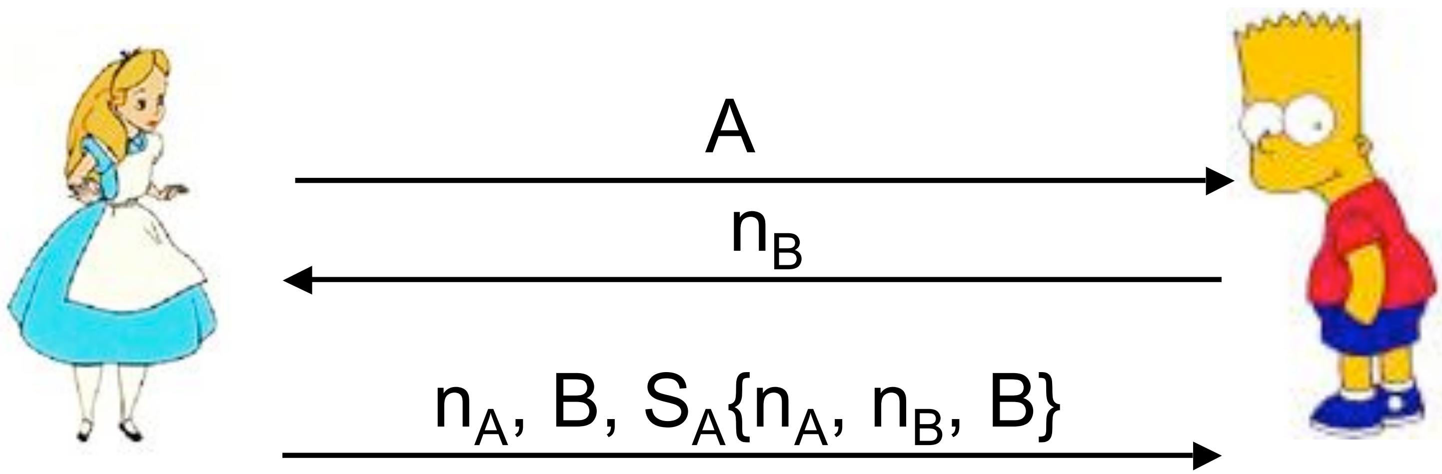
- No trusted 3rd party.
- Simpler algorithm.
- More expensive
- No confidentiality

# 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 $K_B\{k_A\{msg\}\}$ to Bart
- Combined with hashes:
  - Send (msg, $k_A\{MD5(msg)\}$)

# Unilateral Authentication: Signatures

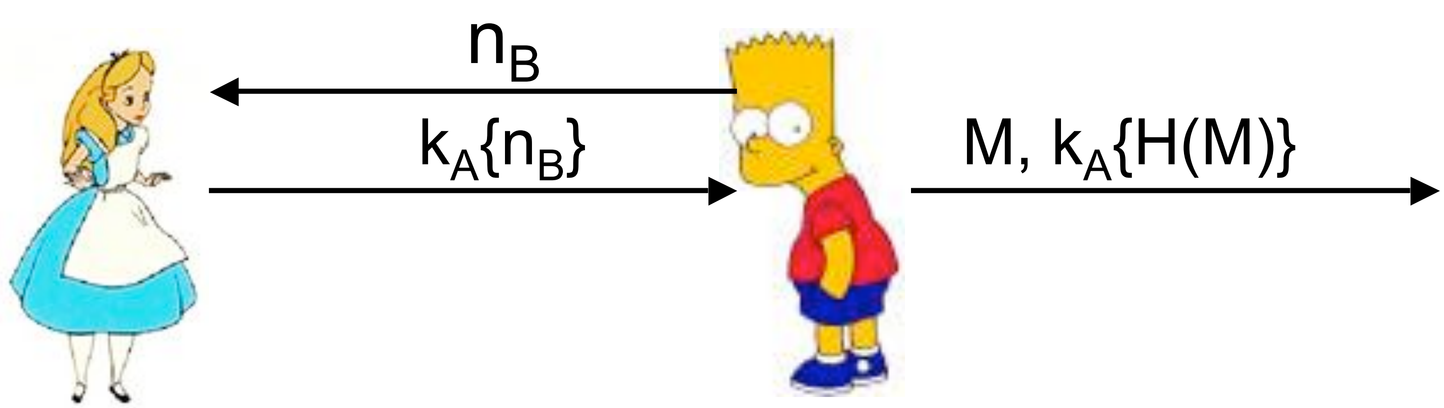
- $S_A\{M\}$ is A's signature on message M.
- Unilateral authentication with nonces:




The $n_A$ prevents chosen plaintext attacks.

# 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