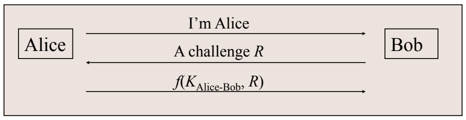
CSCI 454/554 Computer and Network Security

Topic 6.2 Authentication Protocols

Authentication Handshakes

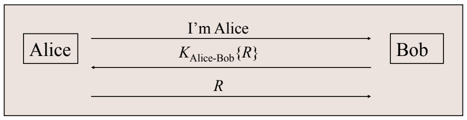
- Secure communication almost always includes an initial authentication handshake.
  - Authenticate each other
  - Establish session keys
  - *This process is not trivial; flaws in this process undermine secure communication*

Authentication with Shared Secret



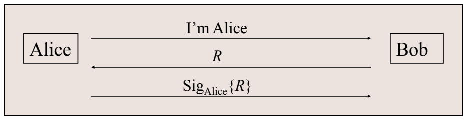
- Weaknesses
  - Authentication is not mutual; Trudy can convince Alice that she is Bob
  - Trudy can hijack the conversation after the initial exchange
  - If the shared key is derived from a password, Trudy can mount an off-line password guessing attack
  - Trudy may compromise Bob's database and later impersonate Alice

Authentication with Shared Secret (Cont'd)



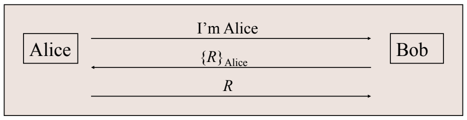
- A variation
  - Requires reversible cryptography
  - Other variations are possible
- Weaknesses
  - All the previous weaknesses remain
  - Trudy doesn't have to see R to mount off-line password guessing if R has certain patterns (e.g., concatenated with a timestamp)
    - Trudy sends a message to Bob, pretending to be Alice

Authentication with Public Key

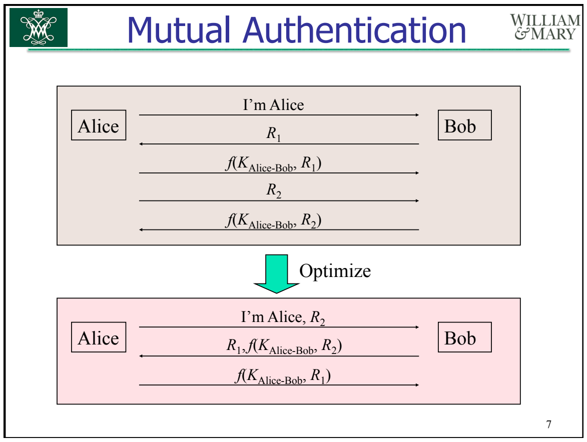


- Bob's database is less risky
- Weaknesses
  - Authentication is not mutual; Trudy can convince Alice that she is Bob
  - Trudy can hijack the conversation after the initial exchange
  - Trudy can trick Alice into signing something
    - Use different private key for authentication

Authentication with Public Key (Cont'd)



A variation



Mutual Authentication

Alice

Bob

I'm Alice

R_1

$f(K_{Alice\text{-}Bob}, R_1)$

R_2

$f(K_{Alice\text{-}Bob}, R_2)$

Optimize

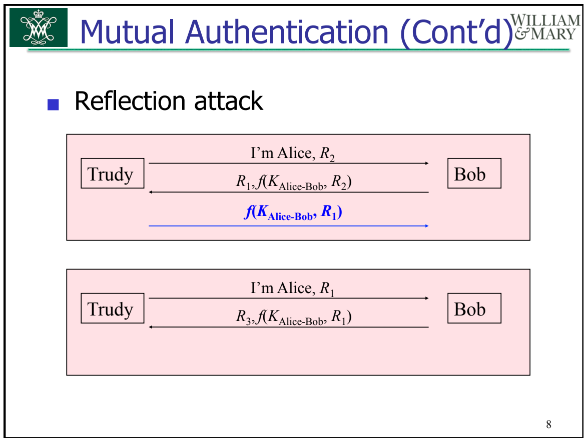
Alice

Bob

I'm Alice, R_2

$R_1, f(K_{Alice\text{-}Bob}, R_2)$

$f(K_{Alice\text{-}Bob}, R_1)$



Mutual Authentication (Cont'd)

- Reflection attack

Trudy

Bob

I'm Alice, R_2

$R_1, f(K_{Alice\text{-}Bob}, R_2)$

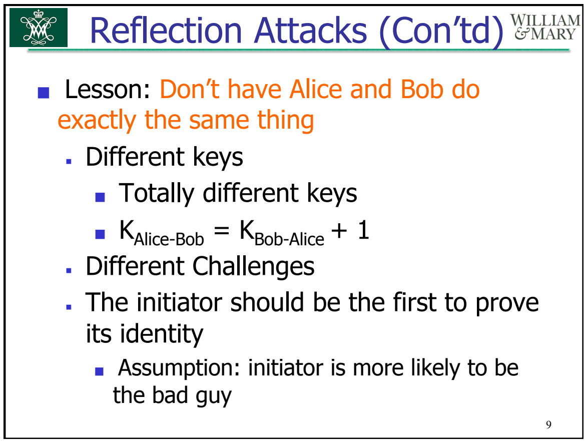
$\boldsymbol{f(K_{Alice\text{-}Bob}, R_1)}$

Trudy

Bob

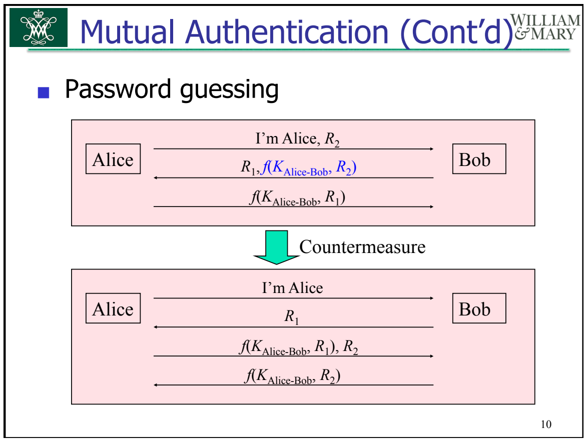
I'm Alice, R_1

$R_3, f(K_{Alice\text{-}Bob}, R_1)$



Reflection Attacks (Con'td)

- Lesson: Don't have Alice and Bob do exactly the same thing
  - Different keys
    - Totally different keys
    - $K_{Alice\text{-}Bob} = K_{Bob\text{-}Alice} + 1$
  - Different Challenges
  - The initiator should be the first to prove its identity
    - Assumption: initiator is more likely to be the bad guy



Mutual Authentication (Cont'd)

- Password guessing

Alice

I'm Alice, R_2

R_1, $f(K_{Alice\text{-}Bob}, R_2)$

$f(K_{Alice\text{-}Bob}, R_1)$

Bob

Countermeasure

Alice

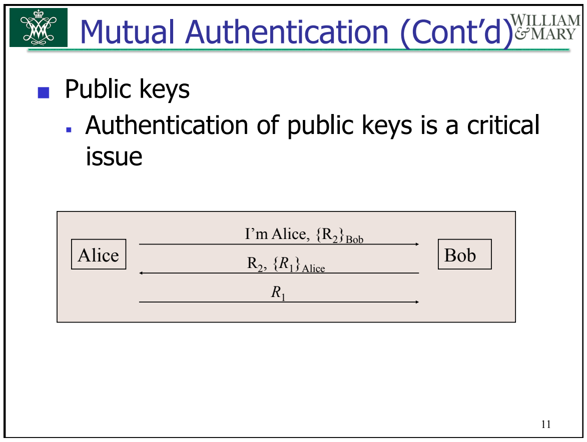
I'm Alice

R_1

$f(K_{Alice\text{-}Bob}, R_1), R_2$

$f(K_{Alice\text{-}Bob}, R_2)$

Bob



Mutual Authentication (Cont'd)

- Public keys
  - Authentication of public keys is a critical issue

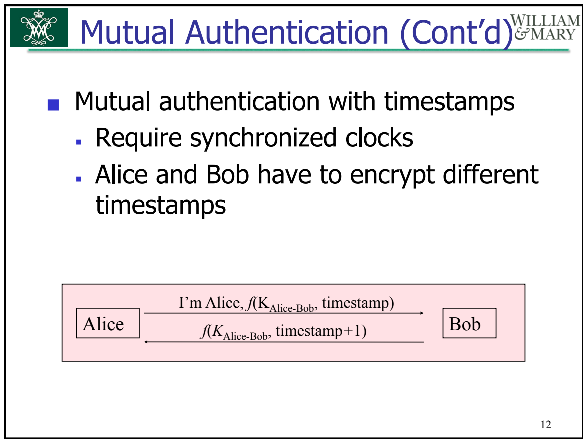
Alice

I'm Alice, $\{R_2\}_{Bob}$

R_2, $\{R_1\}_{Alice}$

R_1

Bob



Mutual Authentication (Cont'd)

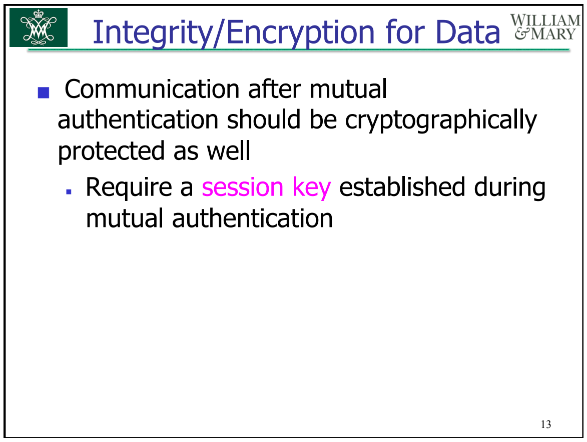
- Mutual authentication with timestamps
  - Require synchronized clocks
  - Alice and Bob have to encrypt different timestamps

Alice

I'm Alice, $f(K_{Alice\text{-}Bob}$, timestamp)

$f(K_{Alice\text{-}Bob}$, timestamp+1)

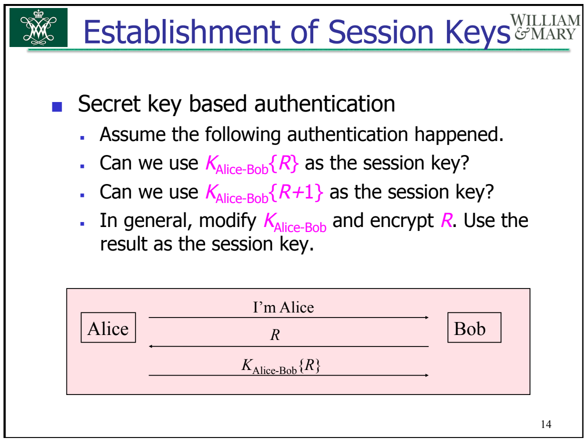
Bob



Integrity/Encryption for Data

WILLIAM & MARY

- Communication after mutual authentication should be cryptographically protected as well
  - Require a session key established during mutual authentication



Establishment of Session Keys

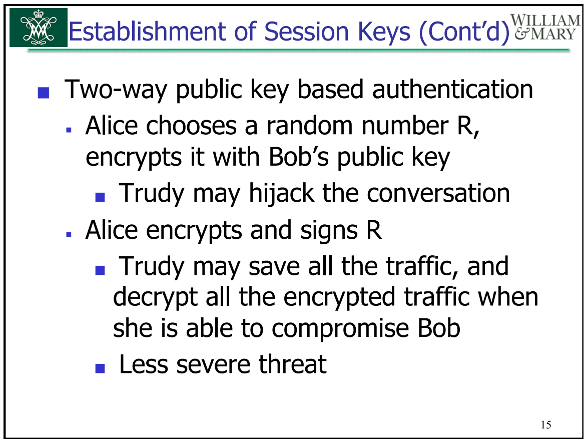
WILLIAM & MARY

- Secret key based authentication
  - Assume the following authentication happened.
  - Can we use $K_{\text{Alice-Bob}}\{R\}$ as the session key?
  - Can we use $K_{\text{Alice-Bob}}\{R+1\}$ as the session key?
  - In general, modify $K_{\text{Alice-Bob}}$ and encrypt R. Use the result as the session key.

Alice → Bob: I'm Alice

Bob → Alice: R

Alice → Bob: $K_{\text{Alice-Bob}}\{R\}$



Establishment of Session Keys (Cont'd)

WILLIAM & MARY

- Two-way public key based authentication
  - Alice chooses a random number R, encrypts it with Bob's public key
    - Trudy may hijack the conversation
  - Alice encrypts and signs R
    - Trudy may save all the traffic, and decrypt all the encrypted traffic when she is able to compromise Bob
    - Less severe threat

Two-Way Public Key Based Authentication (Cont'd)

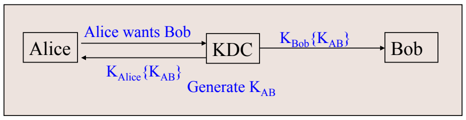
- A better approach
  - Alice chooses and encrypts R_1 with Bob's public key
  - Bob chooses and encrypts R_2 with Alice's public key
  - Session key is $R_1 \oplus R_2$
  - Trudy will have to compromise both Alice and Bob
- An even better approach
  - Alice and Bob estatlish the session key with Diffie-Hellman key exchange
  - Alice and Bob signs the quantity they send
  - Trudy can't learn anything about the session key even if she compromises both Alice and Bob

Establishment of Session Keys (Cont'd)

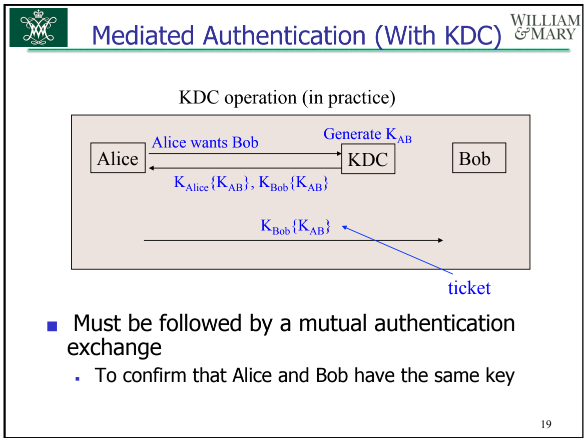
- One-way public key based authentication
  - It's only necessary to authenticate the server
    - Example: SSL
  - Encrypt R with Bob's public key
  - Diffie-Hellman key exchange
    - Bob signs the D-H public key

Mediated Authentication (With KDC)

KDC operation (in principle)



- Some concerns
  - Trudy may claim to be Alice and talk to KDC
    - Trudy cannot get anything useful
  - Messages encrypted by Alice may get to Bob before KDC's message
  - It may be difficult for KDC to connect to Bob



Mediated Authentication (With KDC)

KDC operation (in practice)

Alice wants Bob

Generate K_{AB}

Alice

KDC

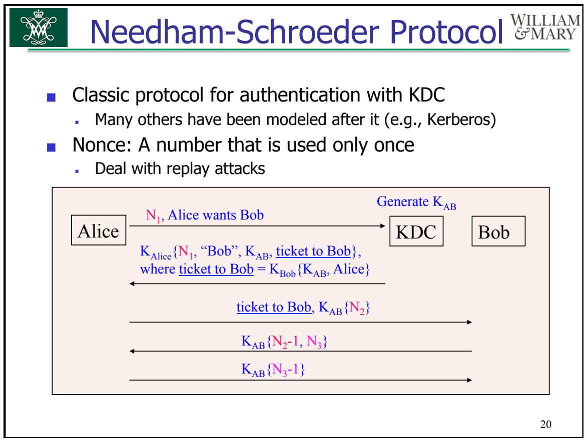
Bob

$K_{Alice}\{K_{AB}\}$, $K_{Bob}\{K_{AB}\}$

$K_{Bob}\{K_{AB}\}$

ticket

- Must be followed by a mutual authentication exchange
  - To confirm that Alice and Bob have the same key



Needham-Schroeder Protocol

- Classic protocol for authentication with KDC
  - Many others have been modeled after it (e.g., Kerberos)
- Nonce: A number that is used only once
  - Deal with replay attacks

Generate K_{AB}

N_1, Alice wants Bob

Alice

KDC

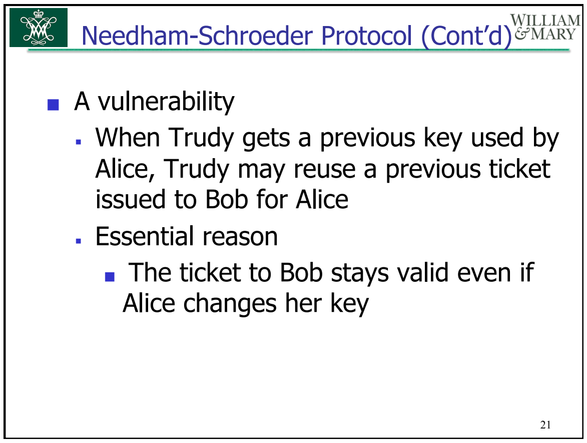
Bob

$K_{Alice}\{N_1$, "Bob", K_{AB}, ticket to Bob$\}$,
where ticket to Bob = $K_{Bob}\{K_{AB}$, Alice$\}$

ticket to Bob, $K_{AB}\{N_2\}$

$K_{AB}\{N_2\text{-}1, N_3\}$

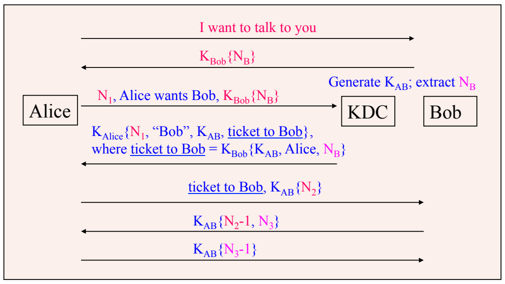
$K_{AB}\{N_3\text{-}1\}$



Needham-Schroeder Protocol (Cont'd)

- A vulnerability
  - When Trudy gets a previous key used by Alice, Trudy may reuse a previous ticket issued to Bob for Alice
  - Essential reason
    - The ticket to Bob stays valid even if Alice changes her key

Expanded Needham-Schroeder Protocol



Alice

KDC

Bob

I want to talk to you

$K_{Bob}\{N_B\}$

Generate K_{AB}; extract N_B

N_1, Alice wants Bob, $K_{Bob}\{N_B\}$

$K_{Alice}\{N_1$, “Bob”, K_{AB}, ticket to Bob$\}$,
where ticket to Bob = $K_{Bob}\{K_{AB}$, Alice, $N_B\}$

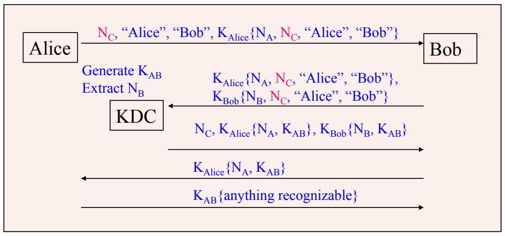
ticket to Bob, $K_{AB}\{N_2\}$

$K_{AB}\{N_2\text{-}1, N_3\}$

$K_{AB}\{N_3\text{-}1\}$

- The additional two messages assure Bob that the initiator has talked to KDC since Bob generates N_B

Otway-Rees Protocol



Alice

Bob

KDC

N_C, “Alice”, “Bob”, $K_{Alice}\{N_A, N_C$, “Alice”, “Bob”$\}$

Generate K_{AB}
Extract N_B

$K_{Alice}\{N_A, N_C$, “Alice”, “Bob”$\}$,
$K_{Bob}\{N_B, N_C$, “Alice”, “Bob”$\}$

N_C, $K_{Alice}\{N_A, K_{AB}\}$, $K_{Bob}\{N_B, K_{AB}\}$

$K_{Alice}\{N_A, K_{AB}\}$

$K_{AB}\{$anything recognizable$\}$

- Only has five messages
- KDC checks if N_C matches in both cipher-texts
  - Make sure that Bob is really Bob