CSCI 667: Concepts of Computer Security

Lecture 9

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Derived from slides by William Enck, Micah Sherr, Patrick McDaniel, Peng Ning, and Vitaly Shmatikov

Authentication

Three Flavors of Credentials

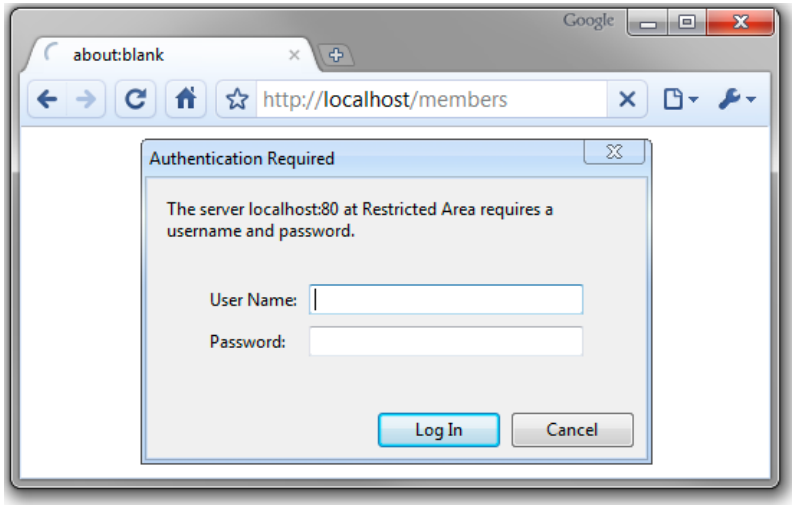
- … are evidence used to prove identity
- Credentials can be
  1. **Something I am**
  2. **Something I have**
  3. **Something I know**

Web Authentication

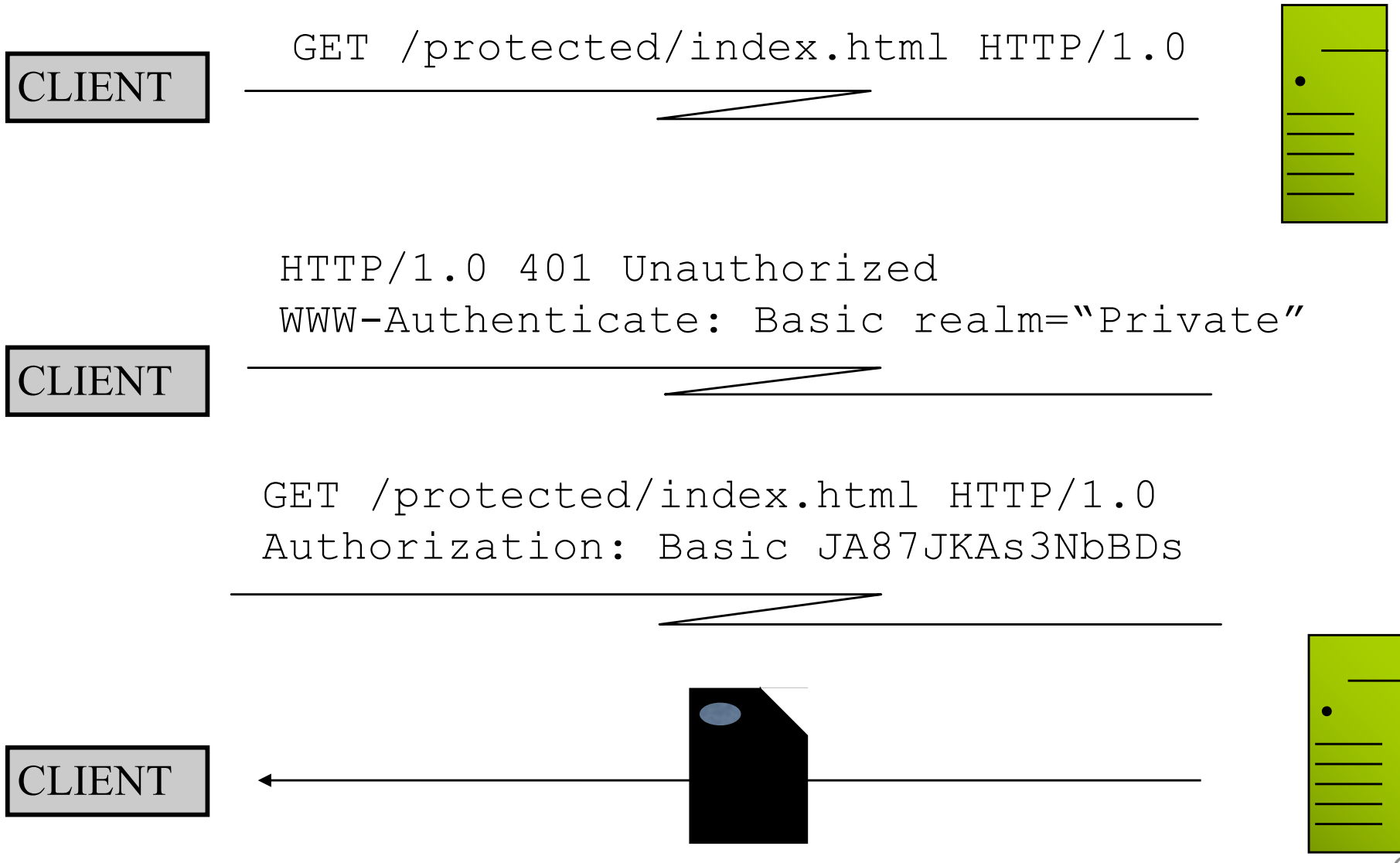
(still based on“something you know”)

Web Authentication

- Authentication is a bi-directional process
  - Client
  - Server
  - Mutual authentication
- Several standard authentication tools
  - Basic (client)
  - Digest (client)
  - Secure Socket Layer (server, mutual)



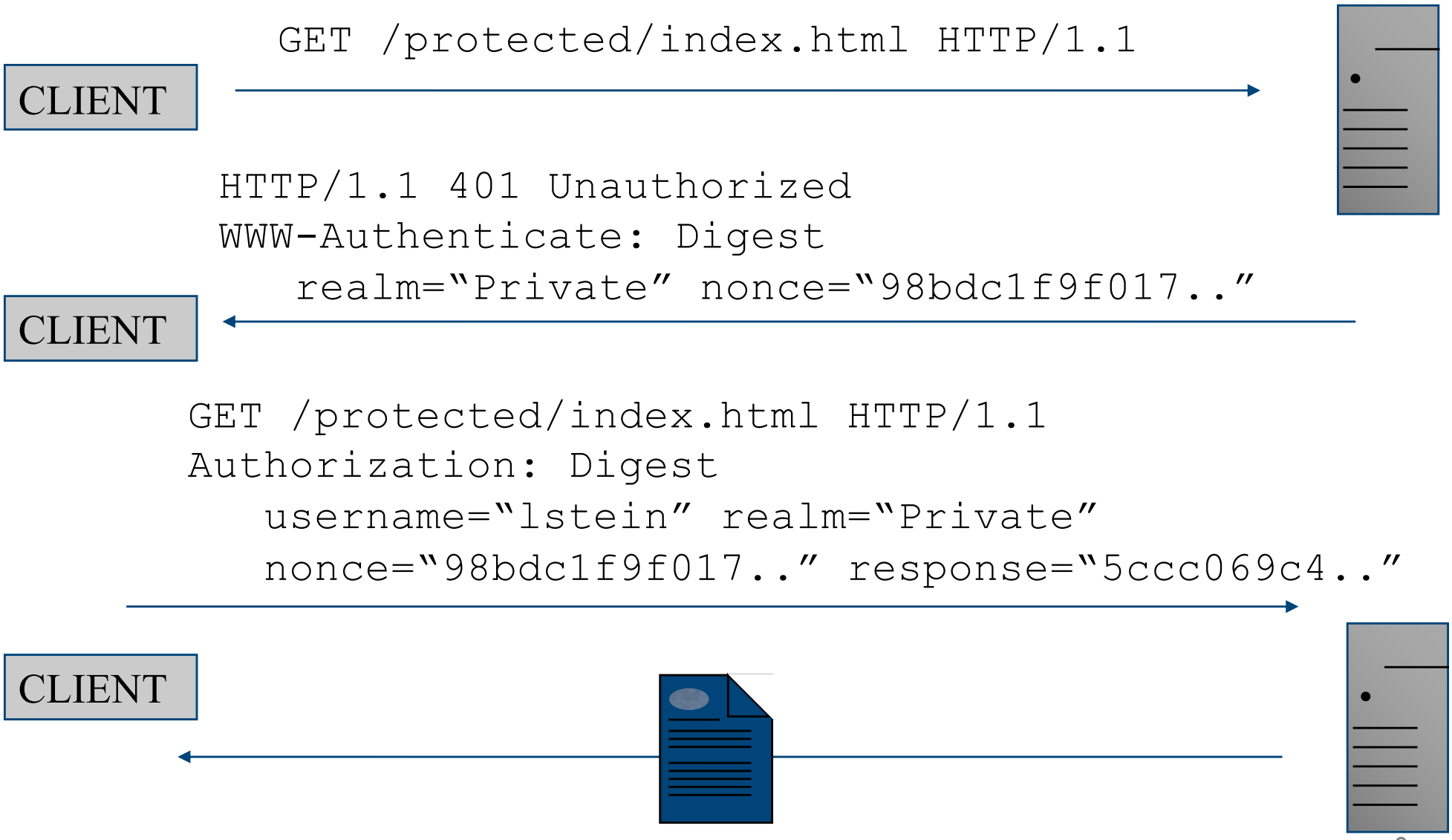
Basic Authentication



Basic Authentication -- is this secure?

- Encoded ! = Encrypted https://gchq.github.io/CyberChef/
  - Passwords easy to intercept (base-64 encoded; not encrypted)
- Passwords:
  - easy to guess
  - easy to share
- No server authentication - easy to fool client into sending password to malicious server

Digest Authentication



Challenge/Response

- Challenge nonce is a one time random string/value

$$\text{nonce} = H(\text{IPaddress} : \text{timestamp} : \text{server secret})$$

  - more generally, a **nonce** is number or string (often randomly or pseudorandomly chosen) that is **only used once**

- Response: challenge hashed with username and password

$$response = H(H(name : realm : password) : nonce : H(request))$$

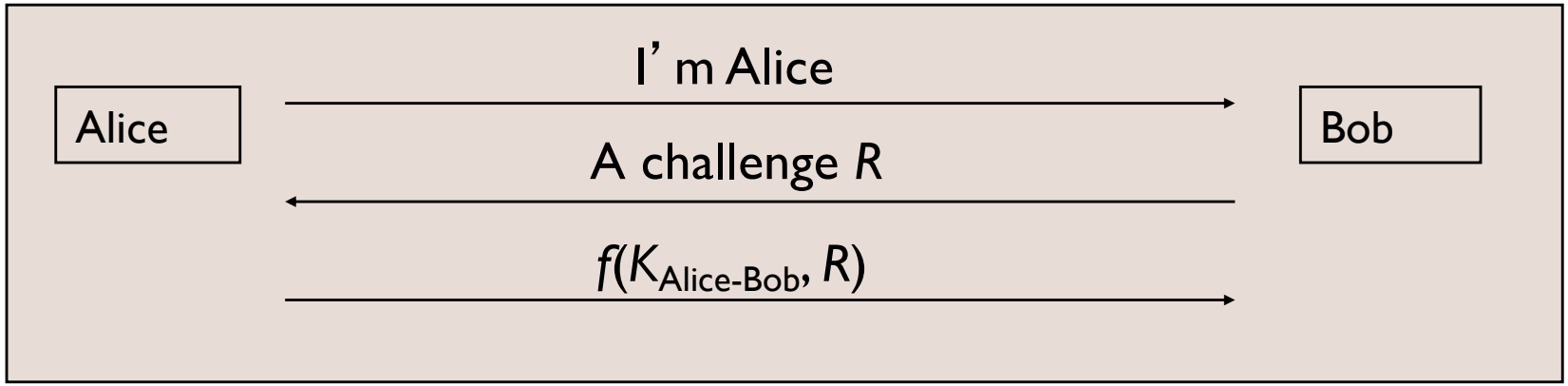
Advantages of Digest over Basic

- Cleartext password never transmitted across network
- Cleartext password never stored on server
- **Replay attacks** difficult
- Intercepted response only valid for a single URL
- Shared disadvantages
  - Vulnerable to man-in-the-middle attacks (no server-side auth)
  - Document itself can be sniffed

Authentication Handshakes

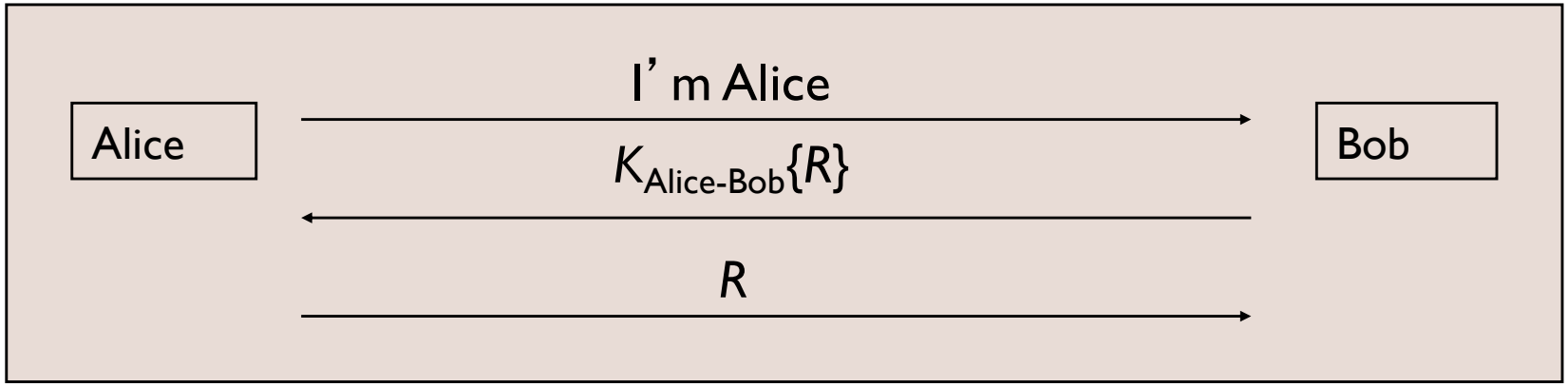
- Secure communication almost always includes an initial authentication handshake.
  - Authenticate each other
  - Establish session keys
  - *This process is not trivial; flaws in this process undermine secure communication*

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)

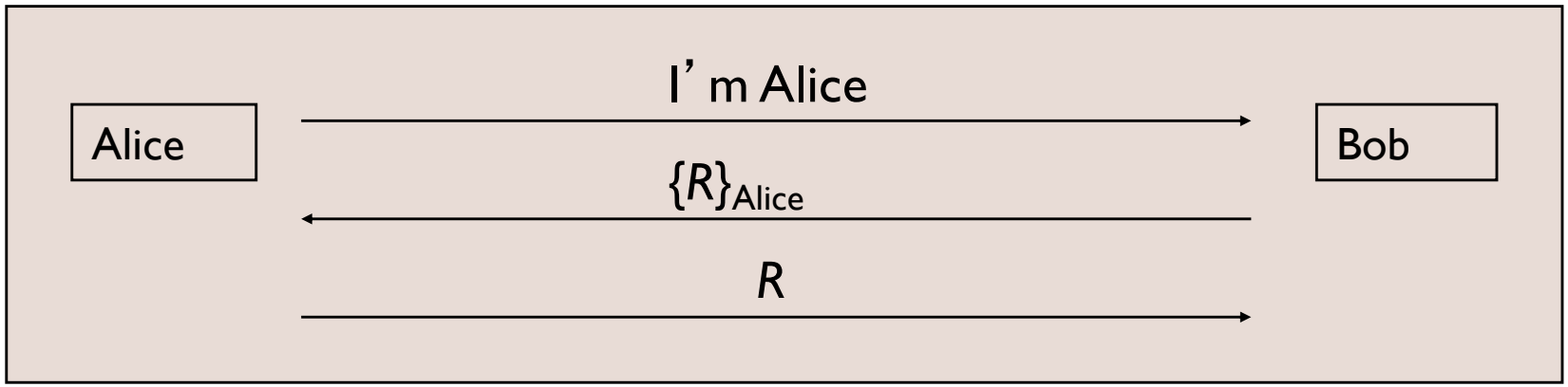


- A variation
  - Requires reversible cryptography
  - Other variations are possible
- Weaknesses
  - All the previous weaknesses remain
  - Trudy doesn't have to see R to mount off-line password guessing if R has certain patterns (e.g., concatenated with a timestamp)
    - Trudy sends a message to Bob,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

Authentication with Public Key

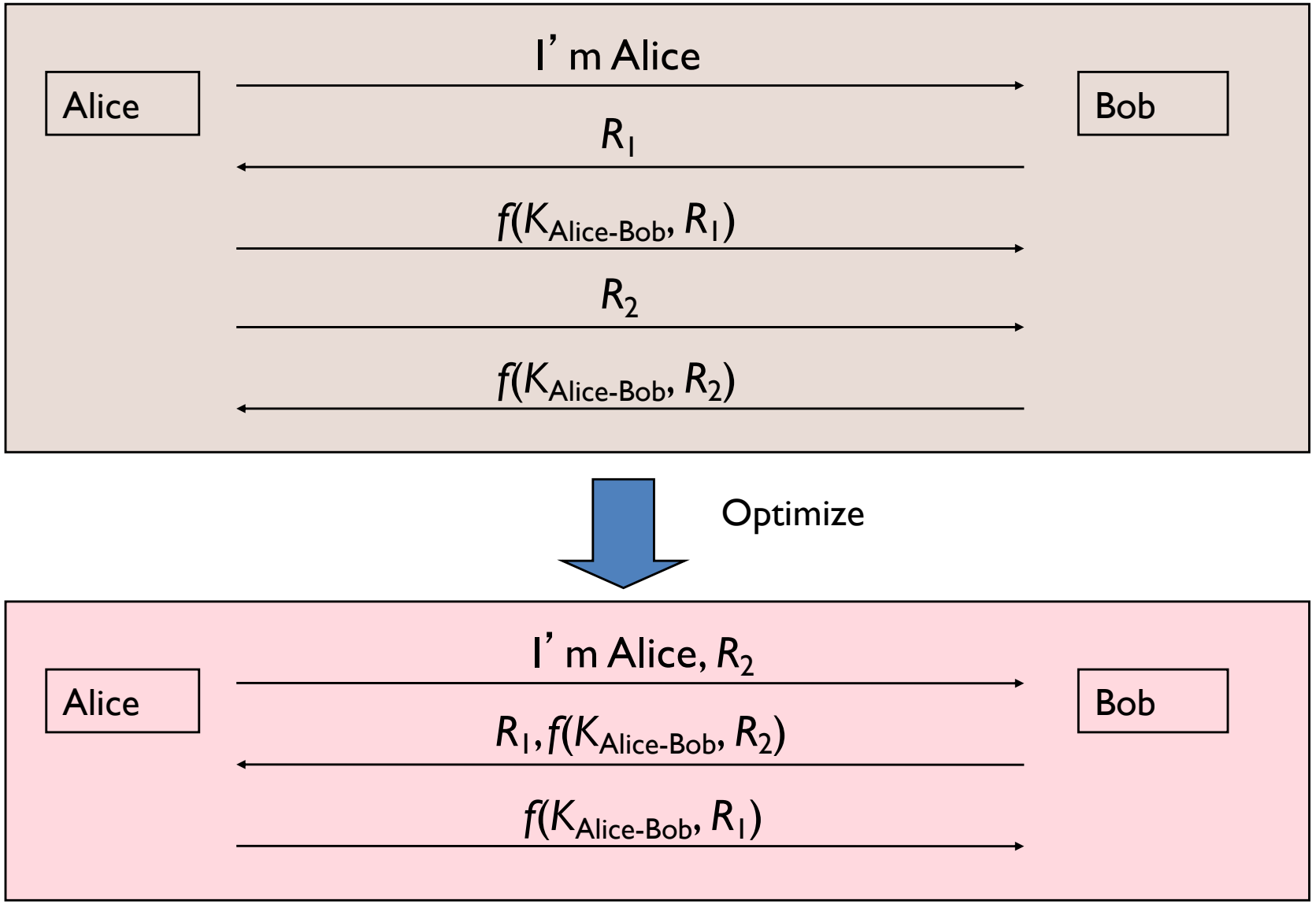
- Bob's database is less risky
- Weaknesses
  - Authentication is not mutual; Trudy can convince Alice that she is Bob
  - Trudy can hijack the conversation after the initial exchange
  - Trudy can trick Alice into signing something
    - Mitigation: Use different private key for authentication

Authentication with Public Key (Cont'd)



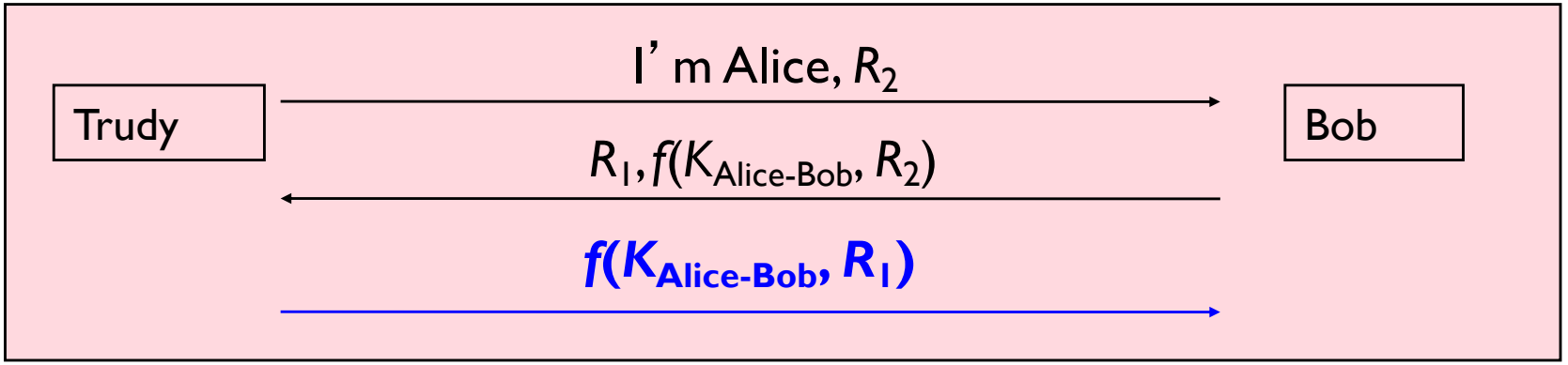
A variation

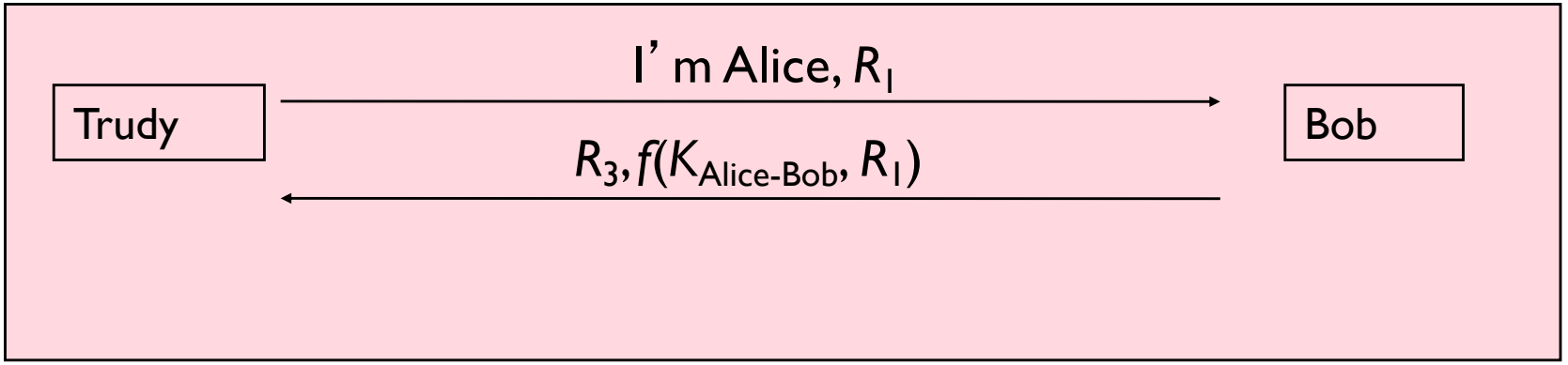
Mutual Authentication



Mutual Authentication (Cont'd)

- Reflection attack



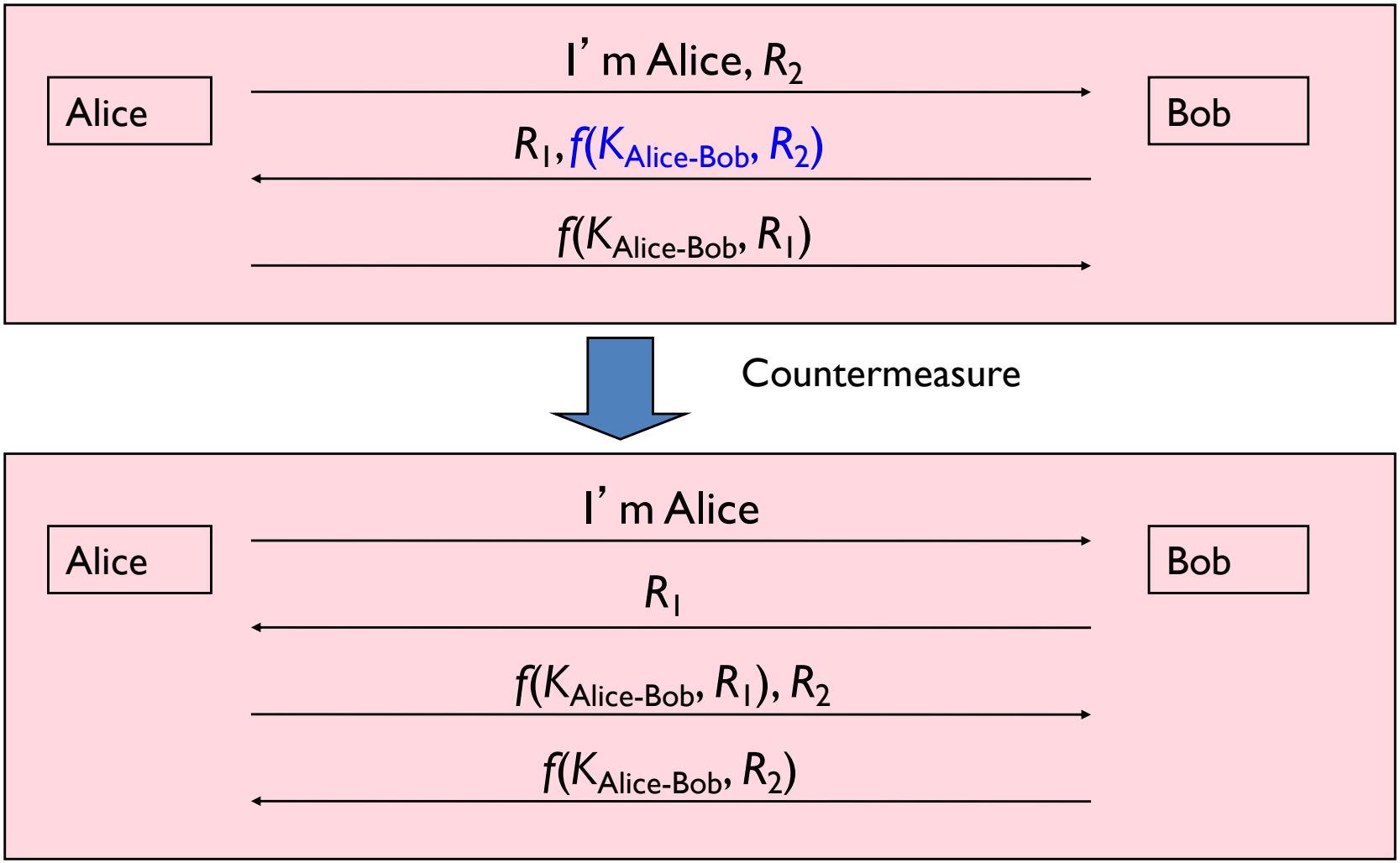


Reflection Attacks (Cont'd)

- 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

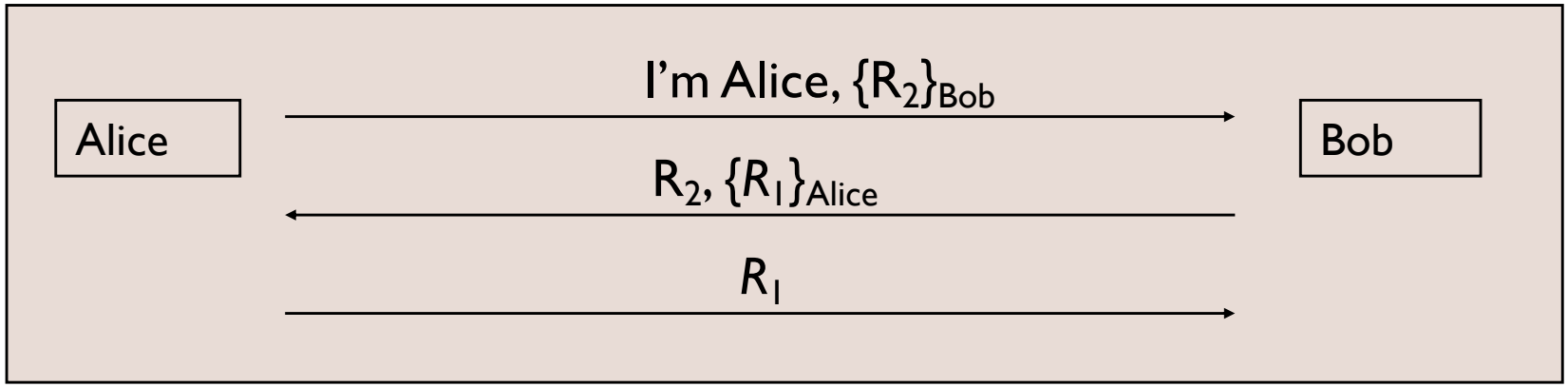
Mutual Authentication (Cont'd)

- Password guessing



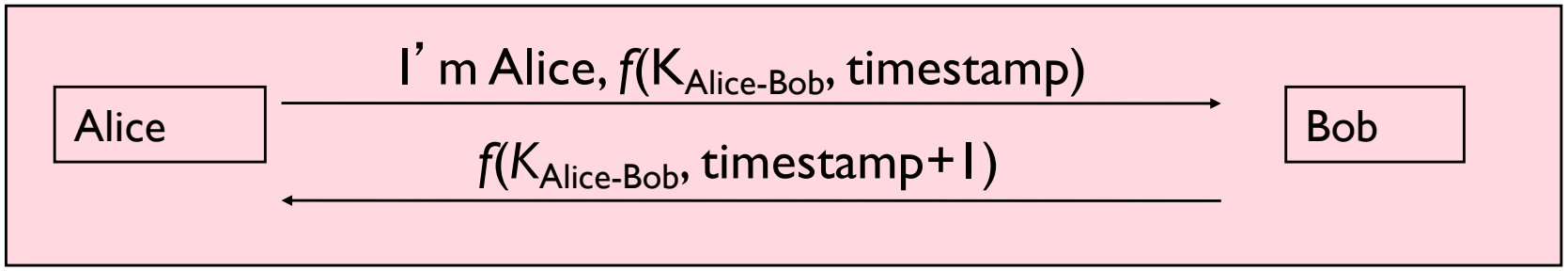
Mutual Authentication (Cont'd)

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



Mutual Authentication (Cont'd)

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

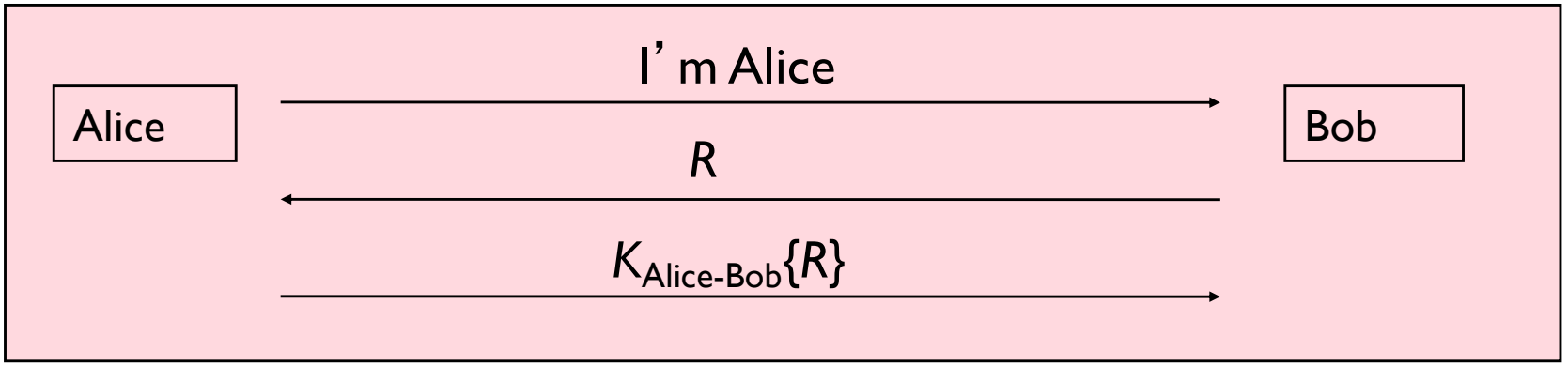


Integrity/Encryption for Data

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

Establishment of Session Keys

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



Establishment of Session Keys (Cont'd)

- Two-way *public key* based authentication
  1. Alice chooses a random number R, encrypts it with Bob's public key, result used as session key.
     - Trudy may hijack the conversation
  2. 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)

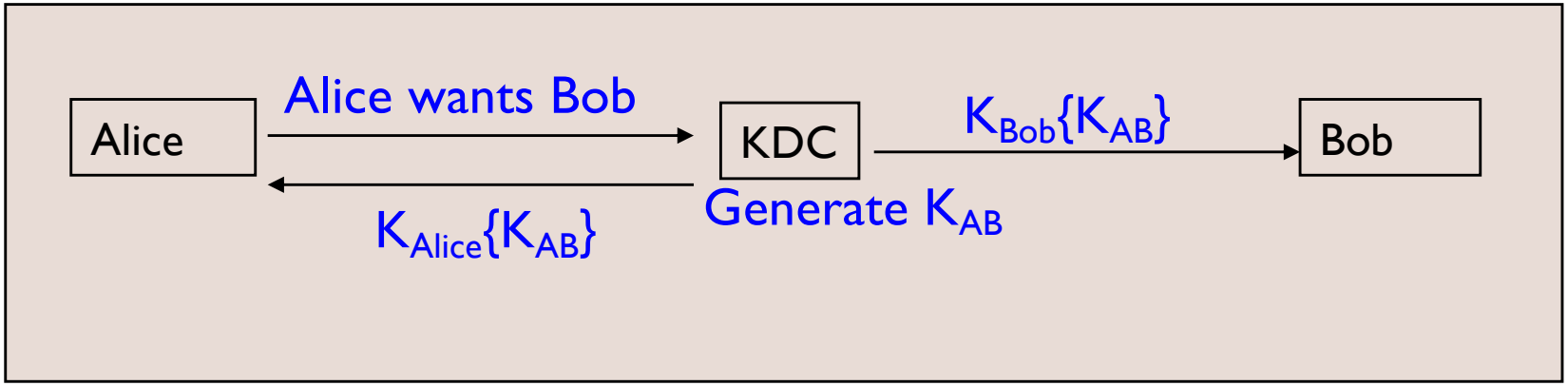
- A better approach
  - Alice chooses and encrypts R_1 with Bob's public key
  - Bob chooses and encrypts R_2 with Alice's public key
  - Session key is $R_1 \oplus R_2$
  - Trudy will have to compromise both Alice and Bob
- An even better approach
  - Alice and Bob establish the session key with Diffie-Hellman key exchange, and then throw away their secrets
  - Alice and Bob sign 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

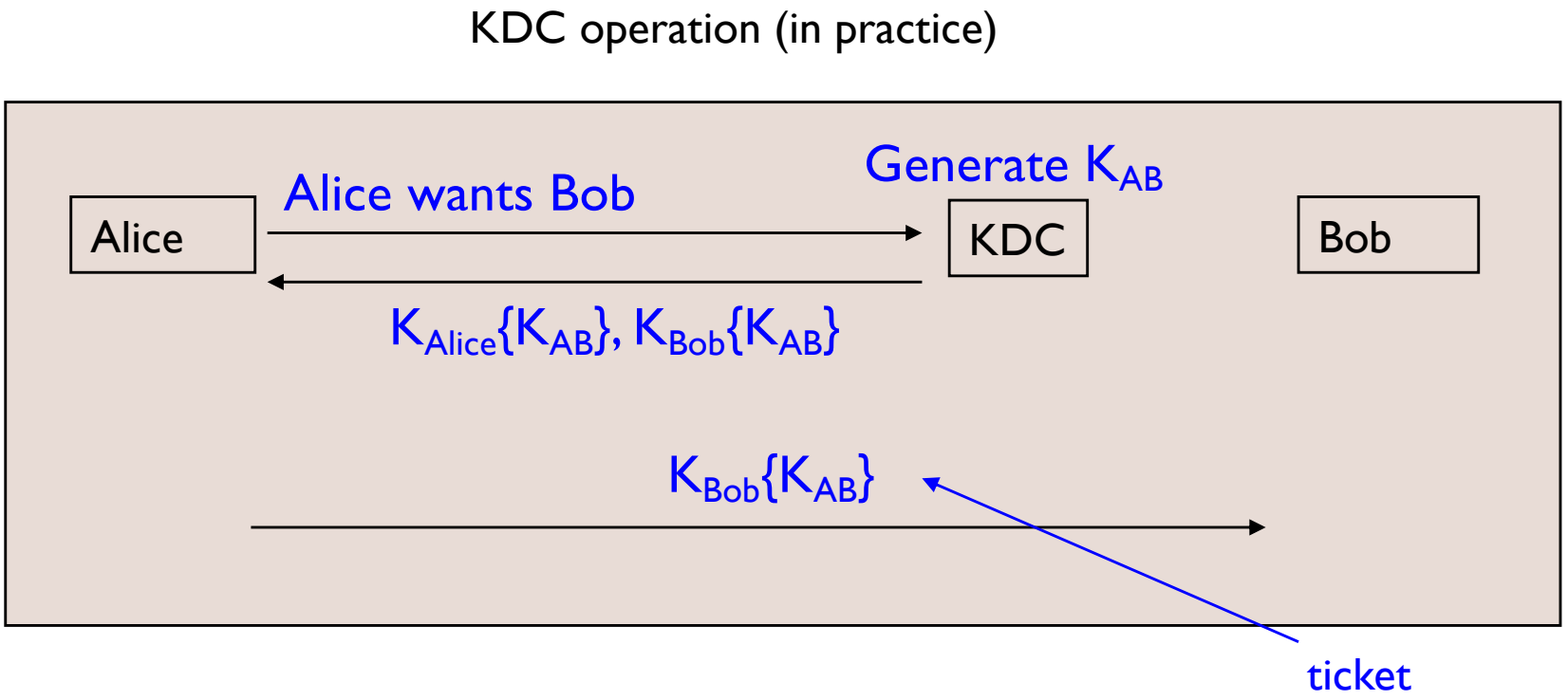
Mediated Authentication (With KDC)

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

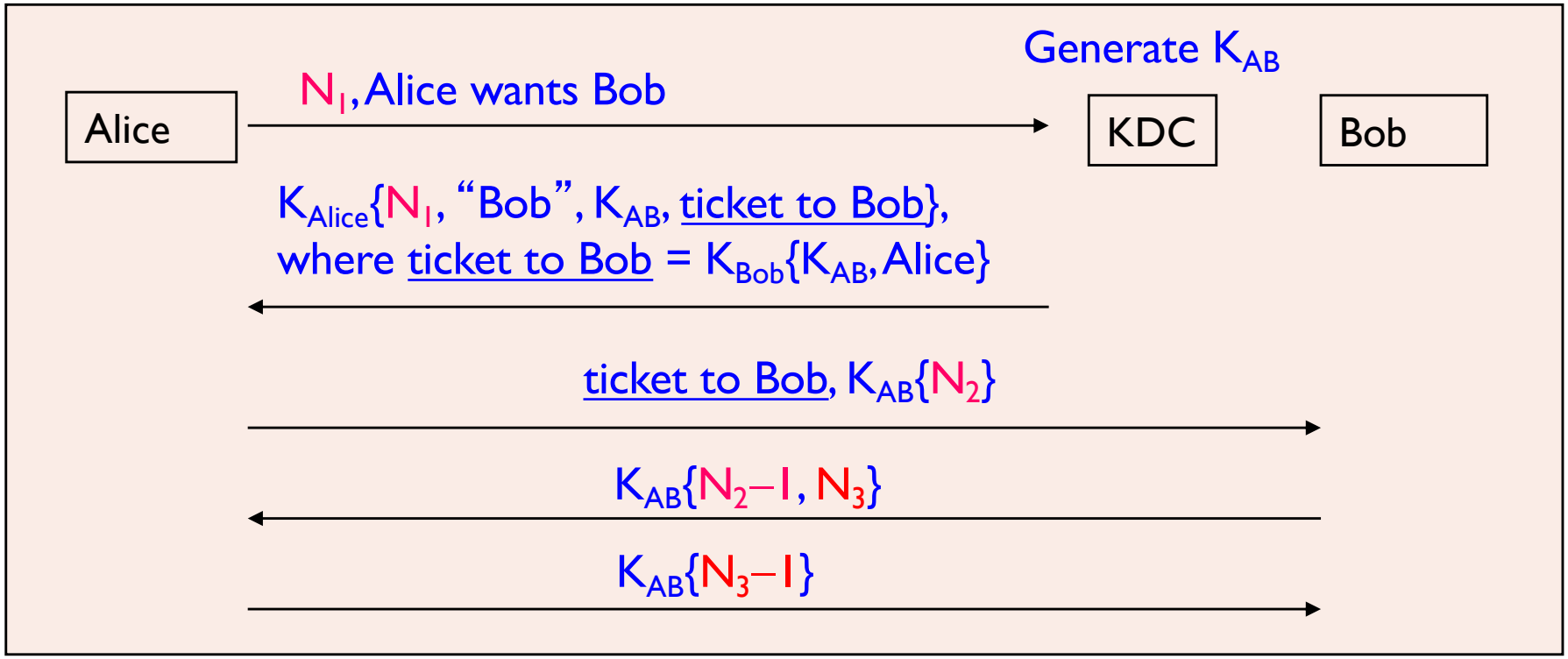
Mediated Authentication (With KDC)



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

Needham-Schroeder Protocol

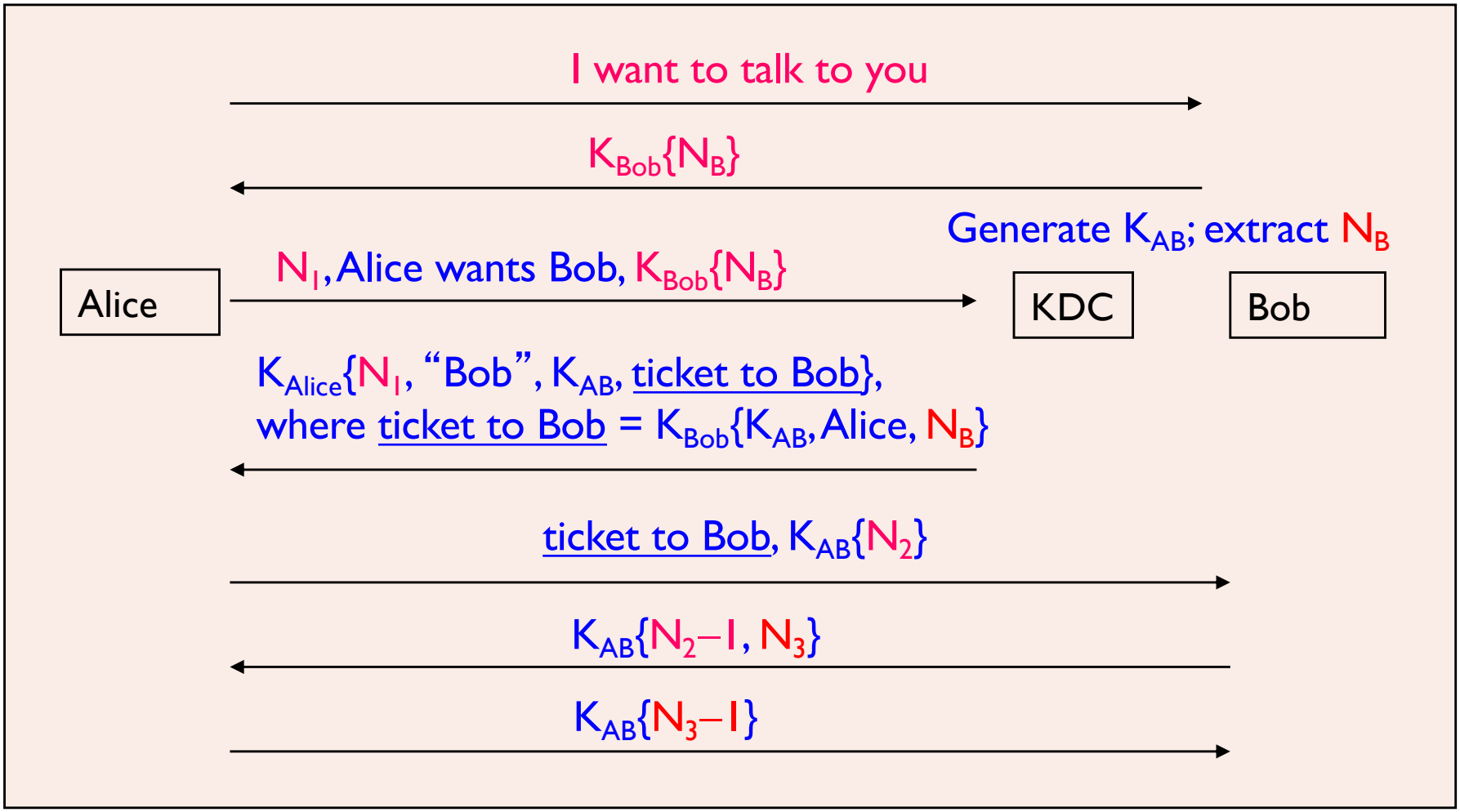
- Classic protocol for authentication with KDC
  - Many others have been modeled after it (e.g., Kerberos)
- Nonce: A number that is used only once
  - Deal with replay attacks



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



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