Authentication
Using Asymmetric Keys

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Authentication

- Problem: How do you prove to someone that you are whom you claim to be?
- Any system with access control must solve this problem.
- Goals:
  - 1. Mutual Authentication: each party authenticates itself to the other party.
  - 2. Key Establishment: establish a session key. This session key will be used to encrypt and decrypt messages between the two parties using symmetric key cryptography.
- Methods
  - Authentication with asymmetric keys
  - Authentication with symmetric keys
  - Human authentication

Authentication Using Asymmetric Keys

- Assumption
  - Everyone knows your public key
  - No one (except you) knows your private key
- Threat Model (i.e., what we assume attackers can do):
  - Message injection
    - Inject a new message into a channel, e.g., TCP poisoning attacks injecting TCP RESET.
  - Message modification
    - Modify a message in a channel
  - Message loss
    - Delete a message in a channel
  - Message replay
    - Replay an old message. The message is authentic, but old.

Version 1

$A, n, \{n\}_{PR_A}$

Alice (Private key PR_A, Public key PU_A)

Bob

- Here n denotes a nounce.
  - An ideal nounce has two properties
    - Freshness (No repetition)
      - Each nounce is used at most once during any infinite execution of a protocol
    - Unpredictability
      - Knowing all nounces used in the past does not help to determine the next nounce to be used
  - In practice, it is simulated using a large random number.
  - Sometimes we only need the freshness property. In this case, we can use:
    - Increasing sequence number. The sender needs to remember the last sequence number. The numbers may increase randomly each time.
    - Real time, i.e., time stamp.

Version 1

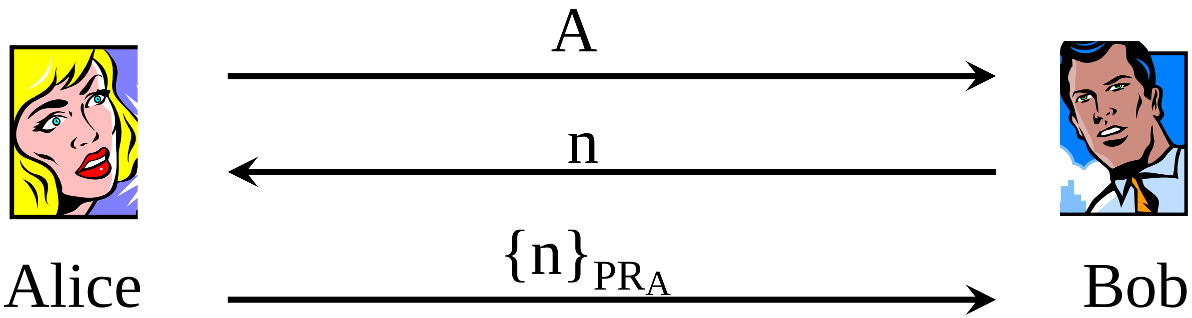
Alice

$A, n, \{n\}_{PR_A}$ ⟶

Bob

- Question 1: Can we replace $\{n\}_{PR_A}$ by $\{n\}_{PU_A}$?
  - Answer: No. Everyone knows PU_A and can compute $\{n\}_{PU_A}$.
- Question 2: What is wrong with this authentication protocol?
  - Answer: No. An attacker can replay this message later to authenticate himself to Bob.
  - How to fix this problem?

Version 2



- Now attackers cannot replay $\{n\}_{PR_A}$.

- Question: What is wrong with this authentication protocol?
  - No session key is established.
  - Authentication= mutual identity verification + session key establishment
  - How to fix this problem?

Version 3

Alice

A →

← n

$\{n, K_{ab}\}_{PR_A}$ →

Bob

K_{ab} denotes a session key

- Question: What is wrong with this authentication protocol?
  - Answer: Attackers can see K_{ab} because they know Alice's public key.
  - How to fix this problem?

Version 4

Alice

$\xrightarrow{A}$

$\xleftarrow{n}$

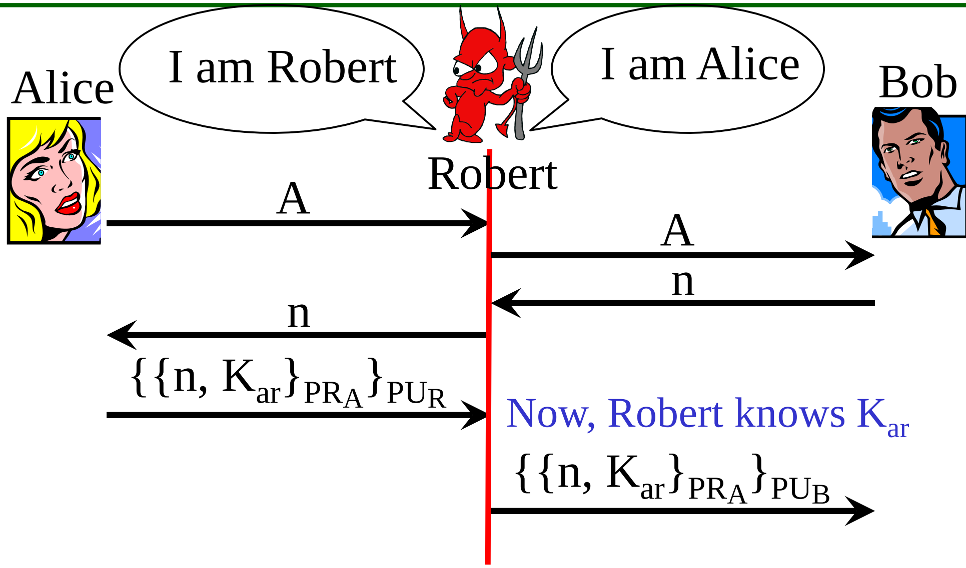
$\xrightarrow{\{\{n, K_{ab}\}_{PR_A}\}_{PU_B}}$

Bob

K_{ab} denotes a session key

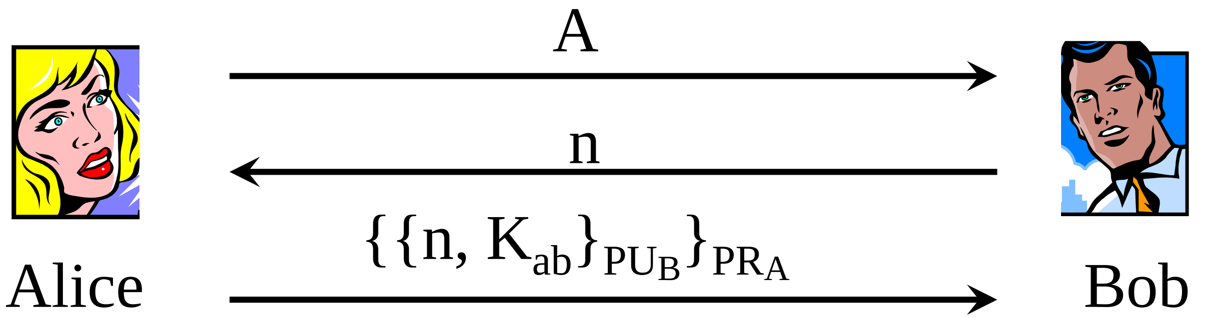
- Only Bob can decrypt $\{\{n, K_{ab}\}_{PR_A}\}_{PU_B}$.
- Denning & Sacco “Time Stamps in Key Distribution Protocols” (1981)
- Question: What is wrong with this authentication protocol?
- Answer: vulnerable to man-in-the-middle attacks:
  - the attacker makes independent connections with the victims and relays/modifies/injects/deletes messages between them.

Man-in-the-middle (MITM) Attack on Version 4



- When Alice begins to talk to Robert, Robert starts to talk to Bob as Alice.
- Question: How to fix this problem?
  - Solution 1: use $\{\{n, K_{ar}\}_{PU_R}\}_{PR_A}$ to replace $\{\{n, K_{ar}\}_{PR_A}\}_{PU_R}$.
  - Solution 2: use $\{\{n, R, K_{ar}\}_{PR_A}\}_{PU_R}$ to replace $\{\{n, K_{ar}\}_{PR_A}\}_{PU_R}$.
- Principle: Encryption should be inside a signature, otherwise we need to include principal's names.

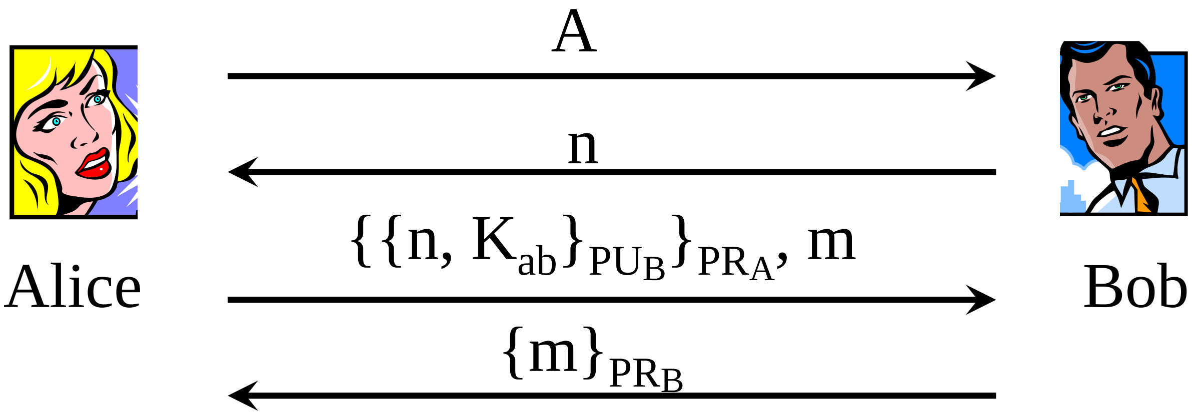
Version 5



K_{AB} denotes a session key

- Now only Alice and Bob can know the session key K_{AB}.
- Question: What is wrong with this authentication protocol?
  - Authentication= mutual identity verification + session key establishment
  - Bob authenticates Alice, but Alice did not authenticate Bob.
  - How to fix this problem?

Version 5



- Now, Bob authenticates Alice, Alice authenticates Bob, and a session key is established.
- Question: which part of this protocol can be made more efficient?
  - Answer: replace $\{m\}_{PR_B}$ by $\{m\}_{K_{ab}}$.
  - Note: an attacker can try to launch man-in-the-middle attack; however, it will not be successful because the attacker cannot learn K_{ab}.

Final Version

Alice

$A \rightarrow$

$\leftarrow n$

$\{\{n, K_{ab}\}_{PU_B}\}_{PR_A}, m \rightarrow$

$\leftarrow \{m\}_{K_{ab}}$

Bob