Protocols II

Computer Security Lecture 8

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Outline

Introduction

Shared-key Authentication

Asymmetric authentication protocols

Key exchange protocols

Combined key exchange and authentication

Summary

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  - Digital certificates
  - More fun with nonces

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- Nonces prevent replay of *old messages*
- S is included inside the encrypted package to foil a *reflection attack* (impersonation of S to A).
- Also, encrypting random strings can be risky: to prevent a **chosen-text attack** on the encryption scheme in the first case, A may include another random number in the encrypted package.

Shared-key mutual authentication

- This protocol achieves *mutual authentication* using shared keys and nonces:

Message 1. $S \rightarrow A$: N_s
Message 2. $A \rightarrow S$: $\{ N_s, N_a, S \}_{K_{as}}$
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- The second nonce N_a in message 2 serves both as a challenge for message 3 and to prevent chosen-text attacks. On receiving message 2, S checks N_s was the nonce he issued in message 1, and that his name S is included in the encrypted package. He also recovers N_a to send in message 3.

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- Mutual authentication may be obtained by running unilateral authentication twice, but that achieves something slightly weaker: the two authentications are not logically linked by the protocol (TOCTOU).

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Challenge-response with PK decryption

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- First PK approach: Alice demonstrates knowledge of a private key by **decrypting a challenge**.

Message 1. $S \to A$: $h(N_s), S, \{ N_s, S \}_{K_a}$
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  - Alice decrypts, and responds with N_s only if the hash and name both match. When Sam sees his nonce N_s returned, Alice is authenticated.

Challenge-response with digital signatures

- Alice demonstrates knowledge of her signature private key by **signing a challenge**.

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Message 2. $A \rightarrow S$: $N_a, S, \mathbf{S}_A(N_a, N_s, S)$

- Server Sam sends a nonce N_s. Alice replies with a message containing her own nonce N_a, the name S, and the signature for a message with both nonces and the name. She constructs the signature using her private signing function $\mathbf{S}_A$.

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- If the signature verifies for the plaintext N_a, N_s, S, he considers Alice authenticated.
- In both this case, and the previous slide, we assume that Sam already has the (correct) public verification function $\mathbf{V}_A$ to check Alice's signatures (wait for discussion of digital certificates).

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- A new key for each conversation is good practice: if a particular key is used for a long time (or a lot of data), there is more opportunity for attack.

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- Many protocols have been designed for **key-exchange**. Key exchange usually establishes short-term *session keys*, which encrypt individual conversations, usually with conventional crypto.
- A new key for each conversation is good practice: if a particular key is used for a long time (or a lot of data), there is more opportunity for attack.
- Many protocols combine **authentication and key-exchange**.

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  - One solution: use a TTP to create *digital certificates* which are used to securely distribute public keys.

  - Advantages: public key distribution it is only required to preserve authenticity; it can be separated from the key exchange protocol.

Key-exchange using symmetric crypto

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- A particular protocol:

Message 1. $A \rightarrow S$: A, B
Message 2. $S \rightarrow A$: $\{K_{ab}, T\}_{K_{as}}, \{K_{ab}, T\}_{K_{bs}}$
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Here the session key has a timestamp T to indicate its creation time.

Key-exchange using PKC

- **Hybrid cryptography** combines PK crypto for exchanging a session key with conventional crypto to communicate using the session key. Two reasons: (1) PK algorithms are slow, so bad for lots of data; (2) PK cryptosystems are vulnerable to chosen-plaintext attacks (since E_e is public).
- Assume that Alice can generate good session keys, and that she already has Bob's public key K_b. Then she can send him the session key K_{ab} and a message M encrypted with it, in one go (for extra protection, she could sign and date the message):

$$A \rightarrow B : \quad \{ K_{ab} \}_{K_b}, \{ M \}_{K_{ab}}$$

- This requires just a single message (not interactive), so it works on a *store-and-forward* network (e.g., email), or for offline storage.
- Next: how can we be sure that Alice has the right public key?

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- Compared with a secure directory of public keys, this protects against MITM attacks; only the CA's verification function needs to be distributed securely. (But the CA's private signing key becomes a critical vulnerability.)
- X.509 uses this model. Each certificate is signed by one CA, and there is a chain of certificates until a *root* or **self-signed** certificate is reached. Common root certificates are built into web browsers.

Key-exchange using certificates

Here is a way to exchange a session key using certificates. First, Alice asks the server Sam for her certificate and Bob's certificate. Then she generates a session key K_{ab} and a timestamp T_a to send to Bob. She signs these with her signing function $\mathbf{S}_A$, encrypts them with Bob's public key, and sends them to him together with the certificates.

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- Some examples follow. . .

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- Sam decrypts the message from Alice and checks that the message is timely. Then he concatenates a new timestamp, Alice's name, and the key. He encrypts this under the key he shares with Bob, and sends the package along to Bob in Message 2.

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- Bob decrypts this message, and checks that message contains a newer timestamp than any seen before. If so, he accepts the session key.

The Needham-Schroeder protocol (flawed)

A protocol using nonces and a server to generate keys.

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Message 5.	$A \rightarrow B$:	$\{ N_b - 1 \}_{K_{ab}}$

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Message 1. $A \rightarrow S$: A, B, N_a
Message 2. $S \rightarrow A$: $\{N_a, B, K_{ab}, \{K_{ab}, A\}_{K_{bs}}\}_{K_{as}}$
Message 3. $A \rightarrow B$: $\{K_{ab}, A\}_{K_{bs}}$
Message 4. $B \rightarrow A$: $\{N_b\}_{K_{ab}}$
Message 5. $A \rightarrow B$: $\{N_b - 1\}_{K_{ab}}$

(1) A makes contact with the server who **(2)** provides the session key K_{ab} and a package for transmission to B containing the same key. Then **(3)** A transmits the package to B, and B initiates a handshake with A **(4)** using N_b to prevent replay. The final message from A uses $N_b - 1$ to distinguish it from the previous message from B.

Can you guess what the flaw is? (Hint: consider if a session key K_{ab} is broken)

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- Alice contacts TGS S and asks to access B. It grants her a *ticket* for using B with a limited duration. She passes this to B, with an *authenticator*. Optional: B replies for mutual authentication.

Message 1.	$A \rightarrow S$:	A, B
Message 2.	$S \rightarrow A$:	$\{T_s, L, K_{ab}, B, \{T_s, L, K_{ab}, A\}_{K_{bs}}\}_{K_{as}}$
Message 3.	$A \rightarrow B$:	$\{T_s, L, K_{ab}, A\}_{K_{bs}}, \{A, T_a\}_{K_{ab}}$
Message 4.	$B \rightarrow A$:	$\{T_a + 1\}_{K_{ab}}$

Here, T_s and T_a are timestamps, and L is a *lifetime*.

Outline

- Introduction
- Shared-key Authentication
- Asymmetric authentication protocols
- Key exchange protocols
- Combined key exchange and authentication
- Summary

Protocols: summary

- **Weak authentication protocols** (e.g., traditional passwords). Stored *time-invariant* secrets or hashes of secrets. Added salt.
- **Strong authentication protocols**. Challenge-response with time-variant parameters (**nonces** or **timestamps**) to guarantee freshness and prevent **replay attacks**. Shared key and public key protocols, demonstrating knowledge of keys. Another kind of authentication protocol we haven't looked at (yet): **zero-knowledge** protocols, are based on demonstrating knowledge without giving way any further information, provably.
- **Key-exchange protocols**. Using shared keys, public keys, and digital signatures/certificates.
- **Key-exchange and authentication protocols**. Using shared keys, public keys. Well-known ones are Kerberos and Needham-Schroeder.

References

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CRC Press Series on Discrete Mathematics and Its Applications. CRC Press, 1997.
Online version at `http://cacr.math.uwaterloo.ca/hac`.

Recommended Reading

Chapter 10 of HAC (10.1–10.3). Chapter 5 of Anderson.