Protokollsicherheit

Protocol Goals and Protocol Design Principles
Motivation
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Simple Example

1. $A \rightarrow B : N_A$
2. $B \rightarrow A : \text{MAC}_{K_{AB}}(B, A, N_A), N_B$
3. $A \rightarrow B : \text{MAC}_{K_{AB}}(A, B, N_B)$

The intention is to check “whether $A$ can communicate with $B$ using the previously exchanged key $K_{AB}$.”
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1. $C(A) \rightarrow B : N_C$
2. $B \rightarrow C(A) : \text{MAC}_{K_{AB}}(B, A, N_C), N_B$
3. $C(B) \rightarrow A : N_B$
4. $A \rightarrow B : \text{MAC}_{K_{AB}}(A, B, N_B), N_A$
5. $C(A) \rightarrow \text{MAC}_{K_{AB}}(A, B, N_B)$
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This seems to be an attack. **But did the protocol fail?** From the sequence above, one could establish that $A$ is willing to communicate with $B$ using $K_{AB}$.
Motivation

A Recent Example [Basin et al. POST’12]

“The ISO/IEC 9798 standard neither specifies a threat model nor defines the security properties that the protocols should satisfy. Instead, the introduction of ISO/IEC 9798 simply states that the protocols should satisfy mutual or unilateral authentication.”
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“The ISO/IEC 9798 standard neither specifies a threat model nor defines the security properties that the protocols should satisfy. Instead, the introduction of ISO/IEC 9798 simply states that the protocols should satisfy mutual or unilateral authentication.”

Unfortunately, there are no general precise definitions for the goals of protocols.
Definitions

One can distinguish some types of goals. The first two are basic goals:

- **User-oriented goals** – concerning entity authentication;
- **Key-oriented goals** – concerning key establishment;
- **Enhanced goals** – some additional goals associated to key establishment;
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**User-Oriented Goals**

**Definition:** Entity authentication is the process whereby one party is assured (through the acquisition of corroborative evidence) of the identity of a second party involved in a protocol, and that party has actually participated.
Definitions

User-Oriented Goals

1. $A \rightarrow B : N_A$
2. $B \rightarrow A : \text{Sign}_B(N_A)$
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However, $B$ has not indicated that she is aware of $A$.

Definition: A principal $A$ is said to have knowledge of $A$ as his peer entity if $A$ is aware of $B$ as his claimed peer entity in the protocol.

1. $A \rightarrow B : N_A$
2. $B \rightarrow A : \text{Sign}_B(A, N_A)$

Definition: Strong entity authentication of $A$ to $B$ is provided if $B$ has fresh assurance that $A$ has knowledge of $B$ as his peer.
Definitions

Key-Oriented Goals
As we have seen, protocols have three entities, which we can use for establishing a key exchange:

- **keys** – which may be long-term or session keys.
- **identifiers** for principals;
- **nonces** which may be random values, timestamps or counters.
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Key-Oriented Goals

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- **keys** – which may be long-term or session keys.
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Session Keys

**Definition**: The shared session key is a *good* key for *A* to use with *B* only if *A* has assurance that:

- the key is **fresh** also called **key freshness**;
- the key is known only to *A* and *B* which are **mutually trusted parties**, also called **key authentication**.
Definitions

**Enhanced Goals**

Combination of user and key goals. Some protocols’ goals are not only to exchange a key but also to establish the **readiness** of a partner.
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**Definition:** **Key confirmation** of A to B is provided if B has assurance that a key K is a good key to communicate with A and that principal A has possession of key K.
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Not really standard definition. In ISO/IEC the following definition appears:

“Key confirmation: the assurance for one entity that another identified entity is in possession of the correct key.”

**Not clear what correct key means.**
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**Definition:** **Explicit key authentication** is the property obtained when both **key authentication** and **key confirmation** hold.
Enhanced Goals

Definition: Mutual belief in the key $K$ is provided for $B$ only if $K$ is a good key for use with $A$ and $A$ wishes to communicate with $B$ using key $K$, which $A$ believes is good for that purpose.
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**Enhanced Goals**

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**Goal Hierarchy**

Mutual Belief in Key

- Good Key
  - Fresh Key
  - Key Exclusivity
- Key Confirmation
  - Far-end Operative
  - Once Authenticated
- Entity Authentication
Abadi-Needham’s 11 Principles
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**Principle 2:** The conditions for a message to be acted upon should be clearly set out so that someone reviewing a design may see whether they are acceptable or not.

**Handshake**

i. $A \rightarrow B : \{N_A\}_K$

i+1. $A \rightarrow B : \{N_A + 1\}_K$

$N_A$ is a challenge nonce and $K$ is the exchanged session key.
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Example

1. $A \rightarrow S : A, B$
2. $S \rightarrow A : C_A, C_B$
3. $A \rightarrow B : C_A, C_B, \{\text{sign}((K_{ab}, T_a), K_a)\}_{K_b}$
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**Attack**

3’. \( B \rightarrow C : C_A, C_C, \{ \text{sign}((K_{ab}, T_a), K_a) \}_{K_c} \)
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3’. $B \to C : C_A, C_C, \{\text{sign}((K_{ab}, T_a), K_a)\}_{K_c}$

**Solution**

3. $B \to C : C_A, C_B, \{\text{sign}((A, B, K_{ab}, T_a), K_a)\}_{K_b}$
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Possible Uses of Encryption

- **Preservation of confidentiality**: \{X\}_K only those that have K may recover X.
- **Guarantee authenticity**: The partner is indeed some particular principal.
- **Guarantee confidentiality and authenticity**: binds two parts of a message – \{X, Y\}_K is not the same as \{X\}_K and \{Y\}_K.
- **Produce random numbers**: This is not really explicit in our symbolic model. In practice, however, encryption techniques can also be used to produce random numbers.
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Kerberos

1. $A \rightarrow S : A, B$
2. $S \rightarrow A : \{T_s, L, K_{ab}, B, \{T_s, L, K_{ab}, A\}_{K_{bs}}\}_{K_{as}}$
3. $A \rightarrow B : \{T_s, L, K_{ab}, A\}_{K_{bs}}, \{A, T_a\}_{K_{ab}}$
4. $B \rightarrow A : \{T_a + 1\}_{K_{ab}}$
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**Message 1**: Although encryption of the message is not necessary, it may allow an intruder to flood the server with request keys.
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**Message 1**: Although encryption of the message is not necessary, it may allow an intruder to flood the server with request keys.

**Message 2**: Double encryption is not really needed. (In later Kerberos versions, the double encryption is not there.)
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Message 1: Although encryption of the message is not necessary, it may allow an intruder to flood the server with request keys.

Message 2: Double encryption is not really needed. (In later Kerberos versions, the double encryption is not there.)

Message 3: The purpose of the encryption with $K_{ab}$ is to prove knowledge of $K_{ab}$ near $T_a$. The same use happens in message 4. However, if $T_a$ is not that different from $T_s$ it could be eliminated. In this case, $B$ uses $T_s$ in message 4.
Principle 5: When a principal signs material that has already been encrypted, it should not be inferred that the principal knows the content of the message. On the other hand, it is proper to infer that the principal that signs a message and then encrypts it for privacy knows the content of the message.
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**Principle 5:** When a principal signs material that has already been encrypted, it should **not be inferred** that the principal knows the content of the message. On the other hand, it is **proper to infer** that the principal that signs a message and then encrypts it for privacy **knows the content** of the message.

1. \(A \rightarrow B : A, \text{sign}((T_a, N_a, B, X_a, \{Y_a\}_{K_b}), K_a)\)

   \(A\) might not know this message!
Principle 6: Be clear what properties you are assuming about nonces. What may do for ensuring temporal succession may not do for ensuring association—and perhaps association is best established by other means.
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Otway-Rees

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Encryption is for binding the messages.
Principle 7: The use of a predictable quantity such as the value of a counter can serve in guaranteeing newness, through a challenge-response exchange. But if a predictable quantity is to be effective, it should be protected so that an intruder cannot simulate a challenge and later replay a response.
**Abadi-Needham’s 11 Principles**

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When completed, $A$ sets his time to $T_s$. 
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When completed, $A$ sets his time to $T_s$.

If $N_a$ is predictable, then the intruder could request the current time using a *future nonce*. Then the intruder could use the returned message in the future to set $A$’s time to the past.
Principle 8: If timestamps are used as freshness guarantees by reference to absolute time, then the difference between local clocks at various machines must be much less than the allowable age of a message deemed to be valid. Furthermore, the time maintenance mechanism everywhere becomes part of the trusted computing base.
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**Principle 9:** A key may have been used recently, for example to encrypt a nonce, yet be quite old, and possibly compromised. Recent use does not make the key look any better than it would otherwise.

Example: Denning-Sacco attack on **Needham-Schroeder**
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**Principle 10:** If an encoding is used to present the meaning of a message, then it should be possible to tell which encoding is being used.
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The purpose of incrementing the nonce is simply for **distinguishing the two messages**.

i. \( A \rightarrow B : \{\text{Message } i : N_A\}_K \)

i+1. \( A \rightarrow B : \{\text{Message } i + 1 : N_A\}_K \)
Principle 11: The protocol designer should know which trust relations his protocol depends on, and why the dependence is necessary. The reasons for particular trust relations being acceptable should be explicit though they will be founded on judgment and policy rather than on logic.
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**Example Kerberos:** Server providing false timestamps leads to an attack.

**Example Certification Authorities (CAs):** CAs are trusted to certify a key only after proper steps have been taken to identify the principal that owns it.