Cryptography V: Digital Signatures

Computer Security Lecture 12

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[1]Based on original lecture notes by David Aspinall

Outline

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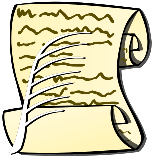
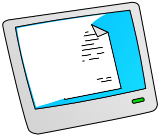
- Note: **electronic signatures** are a more general notion.

Handwritten versus Digital Signatures





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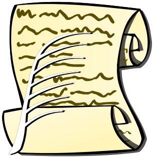

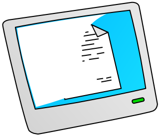

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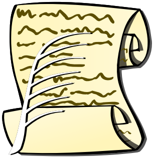

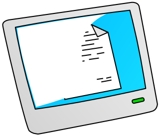

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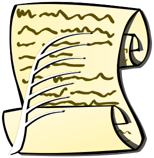

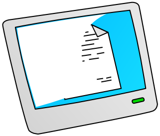

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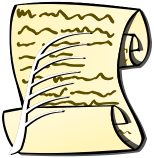

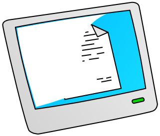

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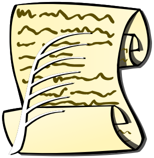

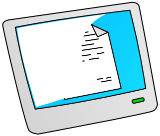

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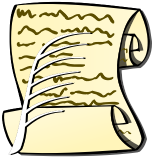

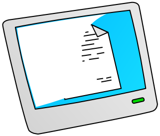

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Signature mechanism

A signature mechanism for principal A is given by:

- A message space $\mathcal{M}$ of messages for signing
- A set $\mathcal{S}$ of *signatures* (e.g. strings $\{0,1\}^n$)
- A secret **signing function** $S_A : \mathcal{M} \to \mathcal{S}$
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1. $V_A(m, s) = \text{true}$ if and only if $S_A(m) = s$.
2. For any principal other than A, it is computationally infeasible to find for any $m \in \mathcal{M}$, an $s \in \mathcal{S}$ such that $V_A(m, s) = \text{true}$.

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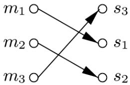
Remark: nobody has proved a signature mechanism satisfying 2 exists, although there are good candidates.

Using a signature scheme



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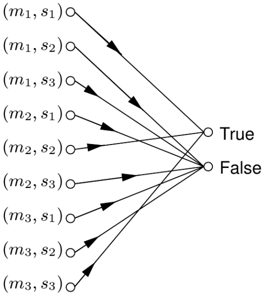

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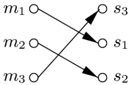

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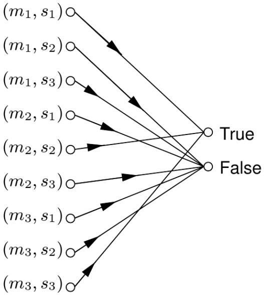

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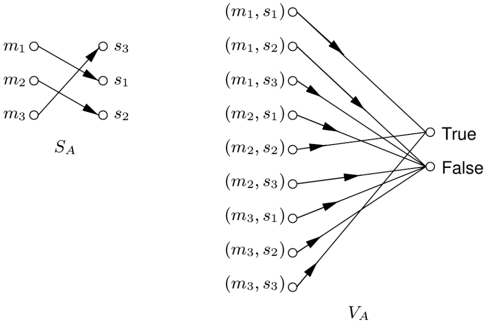

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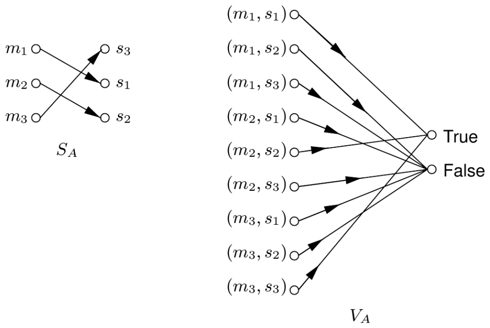

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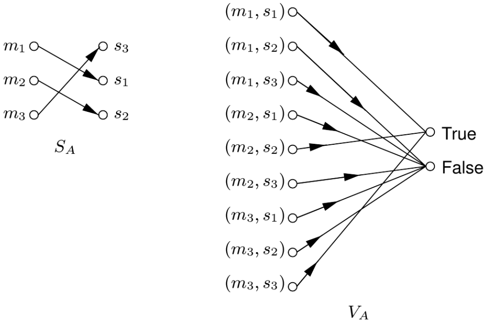

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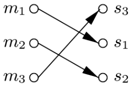

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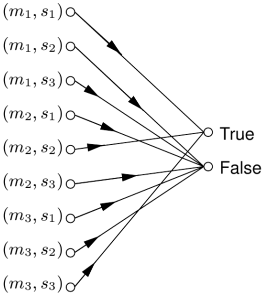

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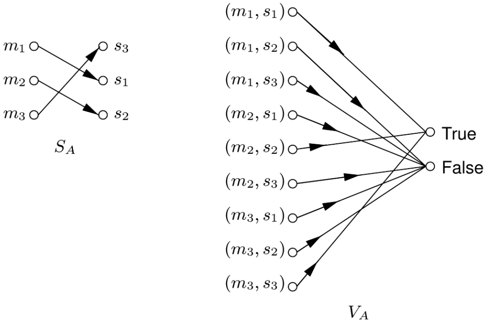

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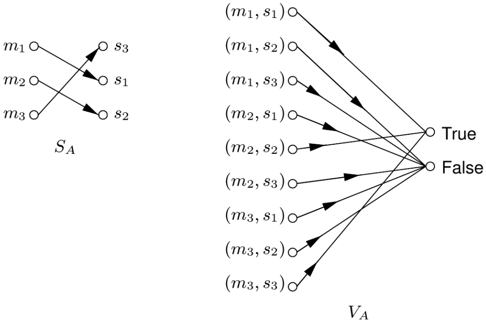

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- If A and B disagree about a signature, a judge Judy can verify the contracts also using S:

  Message 1. $J \rightarrow S$: $\{M\}_{K_{as}}, \{M\}_{K_{bs}}$
  Message 2. $S \rightarrow J$: $\{\textit{yes or no}\}_{K_{js}}$

Digital signatures from PK encryption

- Suppose we have a public-key encryption scheme with $\mathcal{M} = \mathcal{C}$, and (d, e) a key-pair. Then because E_e and D_d are both permutations on $\mathcal{M}$, we have that:

  $$D_d(E_e(m)) = E_e(D_d(m)) = m \quad \text{for all } m \in \mathcal{M}$$

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  2. **Known-message attack**: adversary has signatures for a known (not chosen) set of messages.
  3. **Chosen-message attack**: adversary can obtain signatures for messages of his choosing. Messages may be determined in advance or in **adaptive** way, using signer as oracle.

Existential forgery

- The previous scheme is too simple because signatures are forgeable: a principal B can generate a random $s \in \mathcal{S}$ as a signature, apply the public encryption function to get a message $m = E_e(s)$, and transmit (m, s).

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- But this ability violates property 2 given earlier.

Signatures with redundancy

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- This format is easily recognized by the verifier:

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- This scheme is called a **signature scheme with appendix**.

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- To verify the signature, upon receipt of (m, s), compute $s^e \bmod n$ and verify whether it equals $h(m)$

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- Signatures can optionally be *distributed* so that each of t users contributes to the signature. A trusted party T computes t *shares* such that

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- *Secret sharing* can also be used so that $l < t$ users could be used to construct a signature.

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- Verification works because for a correct signature,

$$(g^d)^e e^s \equiv g^{de+rs} \equiv g^m \pmod{p}.$$

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- **Security** of both ElGamal and DSA schemes relies on the intractability of the DLP.
- Comparison with RSA signature scheme: key generation is faster; signature generation is about the same; DSA verification is slower. Verification is the most common operation in general.

Outline

Summary: Digital Signature Schemes

- **RSA**, **ElGamal**, **DSA** already described. There are several variants of ElGamal, including schemes with message recovery.
- Notice difference between *randomized* and *deterministic* schemes.
- Schemes for **one-time signatures** (e.g., Rabin, Merkle), require a fresh public key for each use.
  - Typically more efficient than RSA/ElGamal methods.
  - But tedious for multiple documents
- E-cash protocols use **blind signature** schemes that prevent the signer (e.g., a bank) linking a signed message (e.g., the cash) with the user.
- For real world security guarantees:
  - **obtaining correct public key** is vital;
  - non-repudiation supposes that **private key has not been stolen**;
  - we may require **secure time stamps**.

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  CRC Press Series on Discrete Mathematics and Its Applications. CRC Press, 1997.
  Online version at `http://www.cacr.math.uwaterloo.ca/hac`.
  Digital signatures covered in Section 1.6 and Chapter 11.

- Nigel Smart. *Cryptography: An Introduction*.
  McGraw-Hill, 2003. Third edition online: `http://www.cs.bris.ac.uk/~nigel/Crypto_Book/`

Recommended Reading

Chapter 14 (14.2–14.4, 14.7) of Smart (3rd Ed).