Fundamentals of Computer Security

Spring 2015

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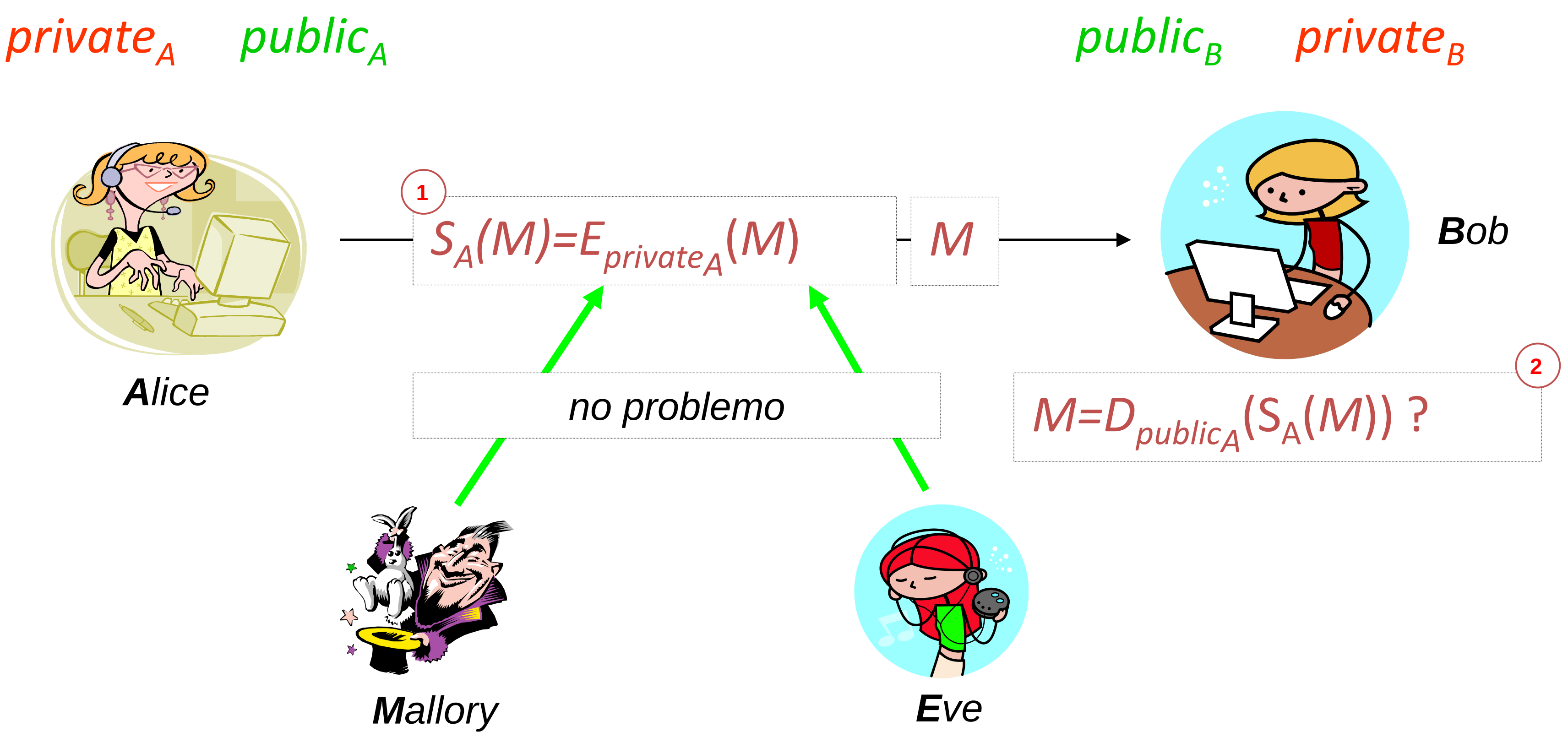
Signatures
Certificate Authorities
Random Number

Signatures: Overview

$$M=D_{private_A}(E_{public_A}(M))=D_{public_A}(E_{private_A}(M))$$



Main idea

Signature …

… something that **only signer can produce**
… and **everybody can verify**

verify = check for a unique association between the signer identity, text to be “signed” and the signature.

Order: encrypt then sign?

- Mallory: replaces signature with own !
- Other problems with RSA !!!
- Not useful: only illegible ciphertext is non-repudiable

When a principal signs material that has already been encrypted, it should not be inferred that the principal knows the content of the message.

If a signature is affixed to encrypted data, then ... a third party certainly cannot assume that the signature is authentic, so non-repudiation is lost.

Order: Sign then encrypt?

- Malicious Bob: sureptitious forwarding
  - decrypts $E_{public_B}(S_A(M))$
  - produces $E_{public_C}(S_A(M))$ and …
  - … sends it to Carol
  - Carol now believes Alice said M (to her)

Fixing the mess?

Computer Security Fundamentals

1. $E_{publicB}(S_A(M;B))$

2. $E_{publicB}(S_A(M;A;B))$

3. $S_A(E_{publicB}(S_A(M)))$

4. $E_{publicB}(S_A(E_{publicB}(M)))$

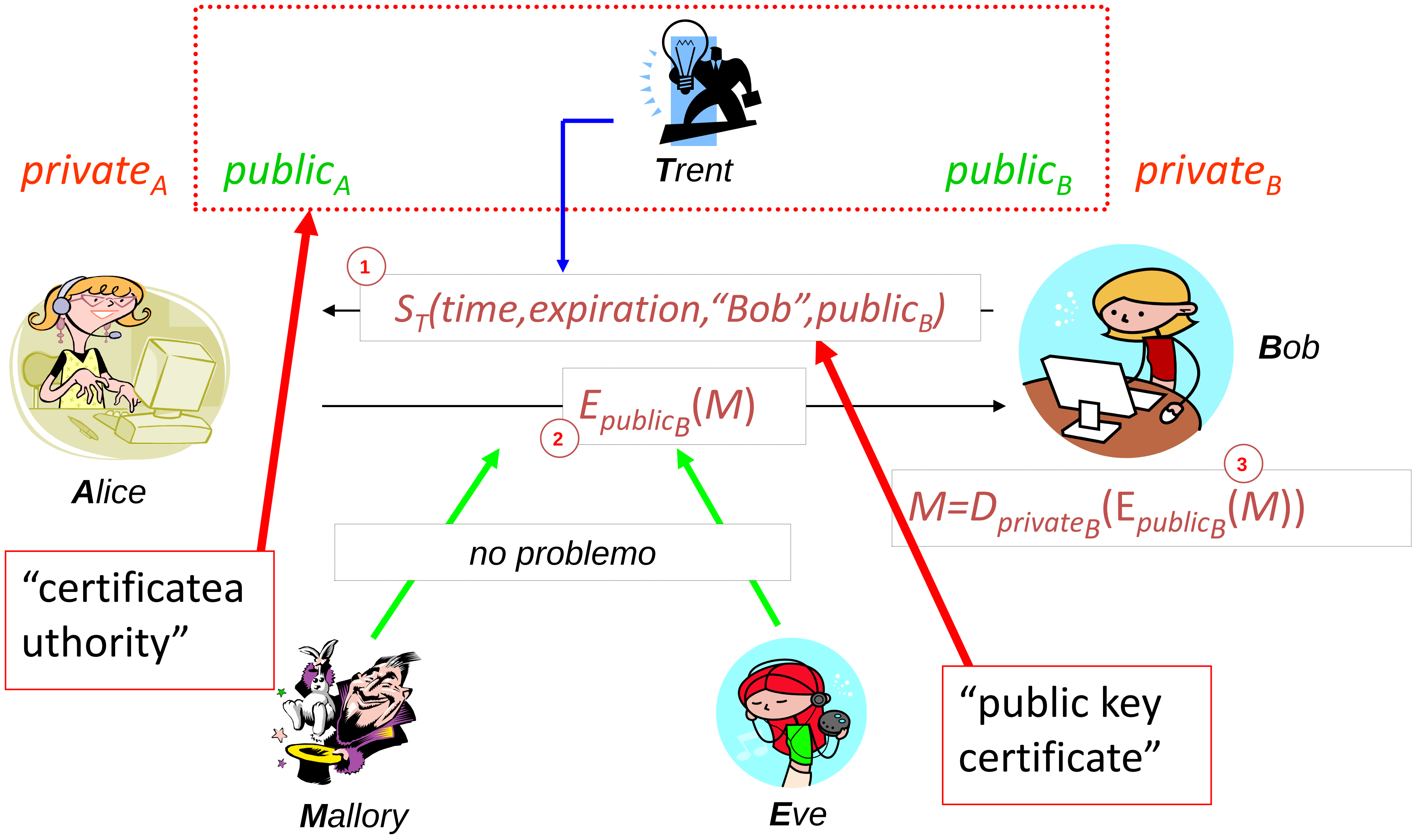
Public Key Cryptography

In RSA S(m)=D(m). If we sign arbitrary stuff, e.g., m=E(M), then in effect we reveal M=D(E(M)) !

If you are a service, do not sign arbitrary stuff. Always sign a hash only !

Do not re-use key pair for different purposes!

Certificate Authority (Trent)



Problem

Alice needs Trent's public key to validate received certificate:

- Needs to verify signature
- Problem pushed "up" a level
- Two approaches:
  - Merkle trees
  - Signature chains (* we discuss this *)

Cross Certification

- Multiple CAs (validation issue)
  - Alice’s CA is Trent; Bob’s CA is Tim; how can Alice validate Bob’s certificate?
  - Have Trent and Tim cross-certify
    - Each issues certificate for the other

Signature Chains

- If we have the following certificates:
  - Trent<<**Alice**>>
  - Tim<<Bob>>
  - Trent<<Tim>>
  - Tim<<Trent>>
- How does **Alice** validate Bob’s certificate ?
  - Get Trent<<Tim>>
  - Use public key of Trent to validate Trent<<Tim>>
  - Use Trent<<Tim>> to validate Tim<<Bob>>

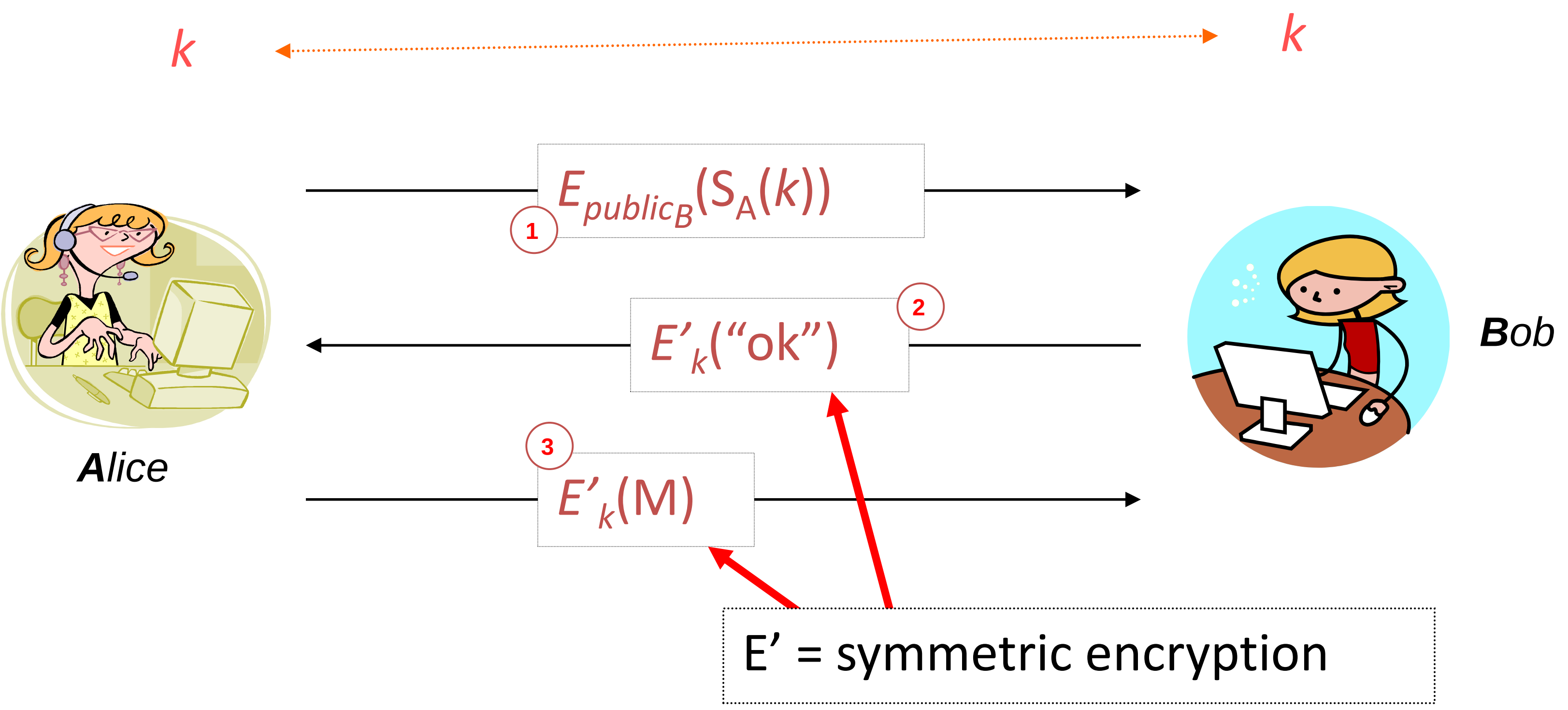
Key Revocation

- Certificates invalidated *before* expiration
  - Usually due to compromised key
  - May be due to change in circumstance (*e.g.,* someone leaving company)
- Problems
  - Is entity revoking certificate authorized to do so ?
  - Does revocation propagate fast enough ?
    - network delays, infrastructure problems

CRLs

- *Certificate revocation list*
- Online Certificate Status Protocol (RFC 2560)
- X.509: only certificate issuer can revoke
- PGP
  - signers can revoke signatures
  - owners can revoke certificates
    - or allow others to do so

PKC is expensive! Use SKC.



What about forward secrecy?

Station to Station protocol. Use PKI for signatures, variant of Diffie Hellman for key exchange.

Authentication vs. Key Exchange

- Which one should come first ?
- Should we maybe couple them ?
- Why ?

"Random"

Cryptographically random numbers: a sequence of numbers X_1, X_2, … such that for any integer $k > 0$, it is **impossible** for an observer to predict X_k even if all of X_1, …, X_{k-1} are known.

Random Number Generators

True RNGs cannot be deterministically algorithmic in a closed system. “Anyone who considers arithmetic methods … is in a state of sin” (von Neuman)

There exists a certain “flow” of randomness/chaos that is preserved within the system.

True randomness can only (arguably) be achieved by a hardware device that extract randomness from real-life processes (e.g. thermal noise, RF).

“Pseudorandom”

Idea: simulate a sequence of cryptographically random numbers but generate them by an algorithm.

Cryptographically pseudo-random numbers: a sequence of numbers X_1, X_2, … such that for any integer $k > 0$, it is **hard** for an observer to predict X_k even if all of X_1, …, X_{k-1} are known.

PRNGs

Approximating randomness (e.g., attempting to achieve a uniform distribution) – will always have period (finite output space), many other defects !

Examples:

- Linear congruential generators: $X_i = (aX_{i-1}+b) \bmod n$
- Mersenne Twister (for Monte Carlo simulations)
  - make it “secure” by using a hash

Best PRNGs

Strong mixing function: function of 2 or more inputs with each bit of output depending on some nonlinear function of all input bits:

- Examples: DES, MD5, SHA-1
- Use on UNIX-based systems:

```
(date; ps gaux) | md5
```

Public Key Cryptography

“pseudo-random number generators exist iff. one-way functions exist”

Johan Håstad, Russell Impagliazzo, Leonid A. Levin, Michael Luby: A Pseudorandom Generator from any One-way Function. SIAM J. Comput. 28(4): 1364-1396 (1999)