ENEE 457: Computer Systems Security

Lecture 7
Certificates and Web of Trust

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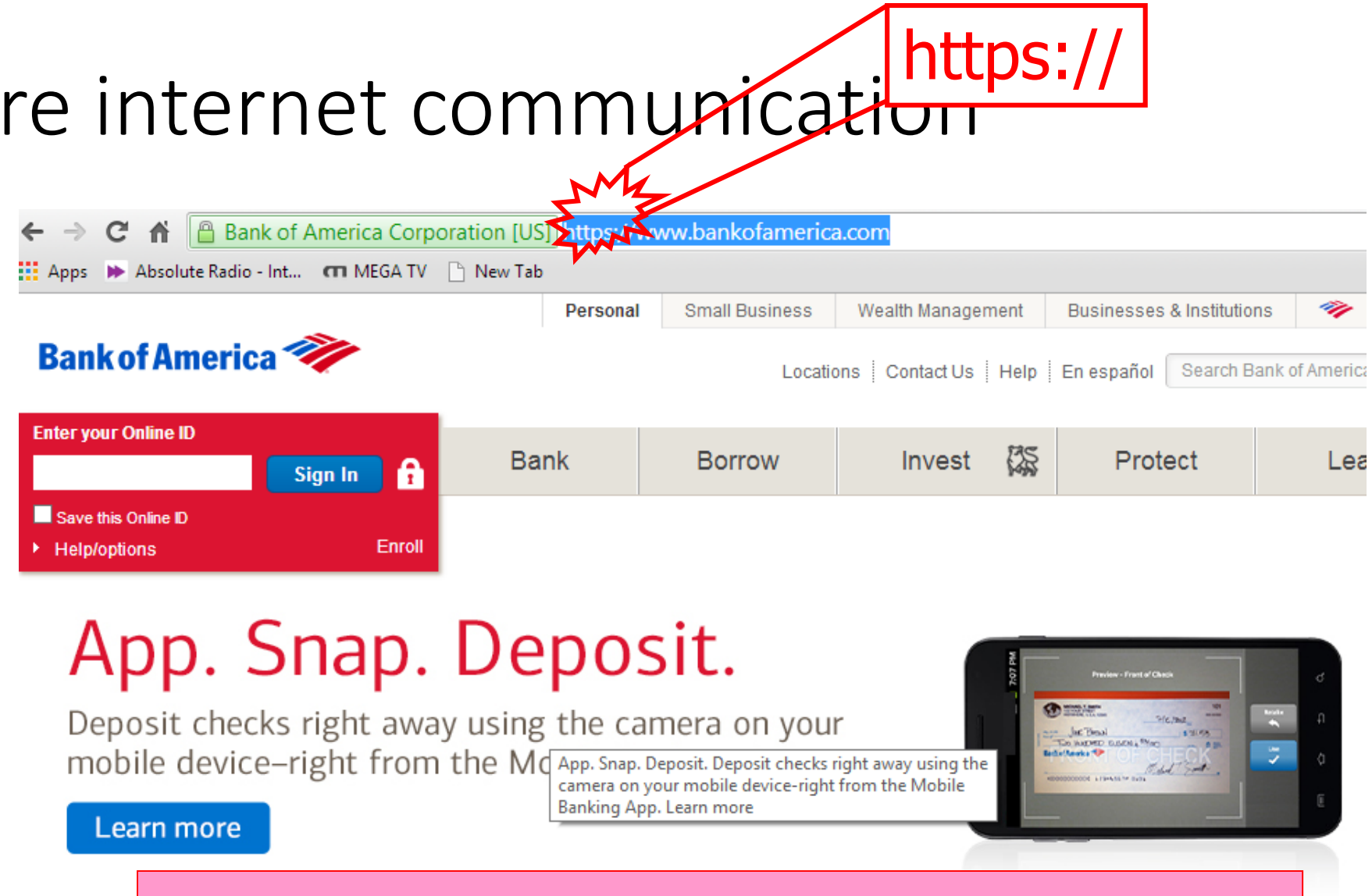
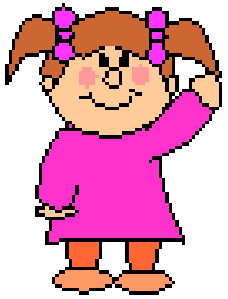
Secure internet communication



What cryptographic keys are used to protect communication?

Public Keys and Trust



Public Key: P_A
Secret key: S_A

Public Key: P_B
Secret key: S_B

How are public keys stored?

How to obtain the public key?

How does Bob know or 'trusts' that P_A is Alice's public key?

Distribution of Public Keys

- **Public announcement**: users distribute public keys to recipients or broadcast to community at large

- **Publicly available directory**: can obtain greater security by registering keys with a public directory

- Both approaches have problems, and are vulnerable to forgeries

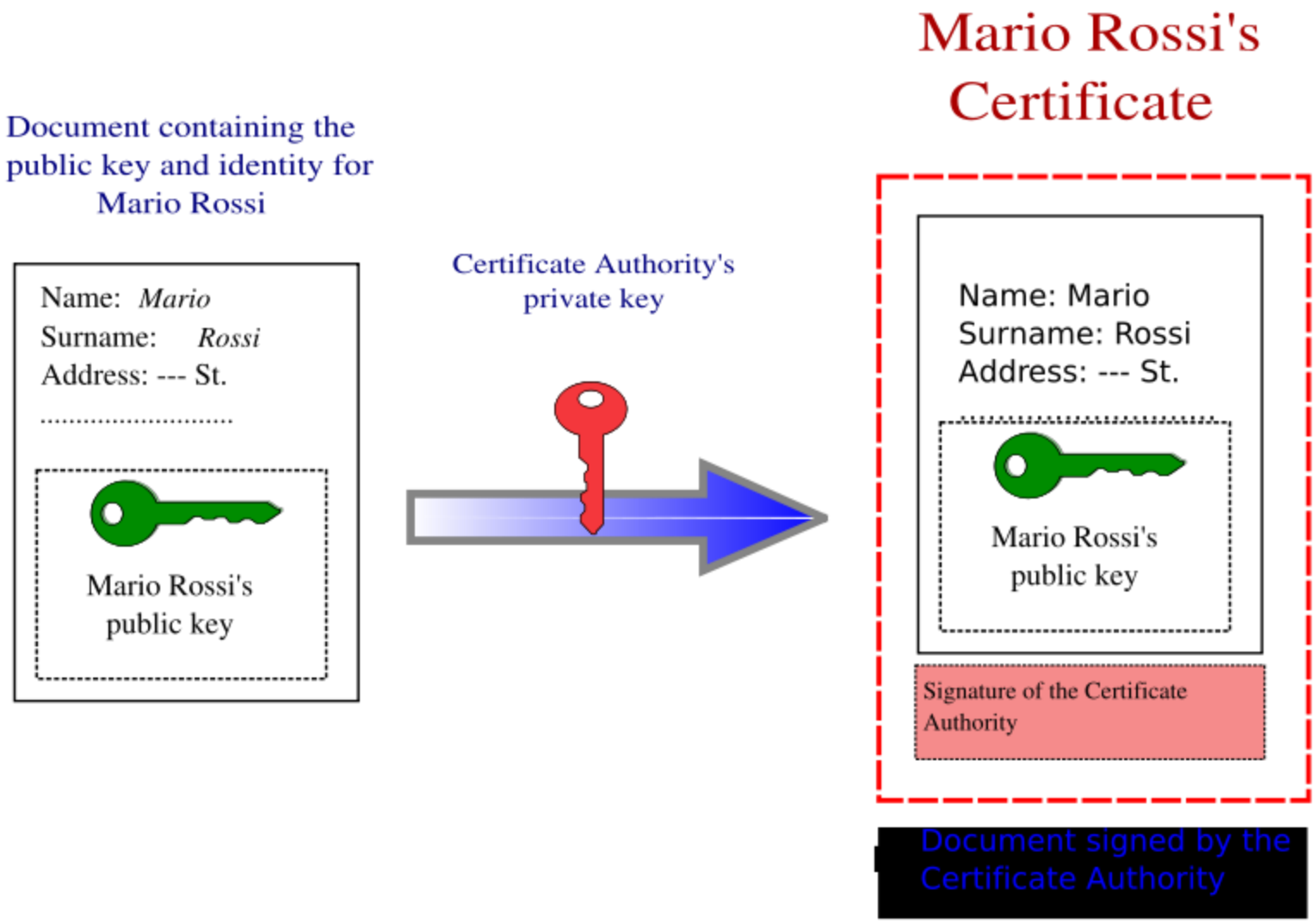
Public-Key Certificates

- A certificate binds identity (or other information) to public key
- It is a signature on a statement “Paul’s public key is 1032xD”

- Contents digitally signed by a trusted Public-Key or Certificate Authority (CA)
  - Can be verified by anyone who knows the authority’s public-key

- For Alice to send an encrypted message to Bob, obtains a certificate of Bob’s public key

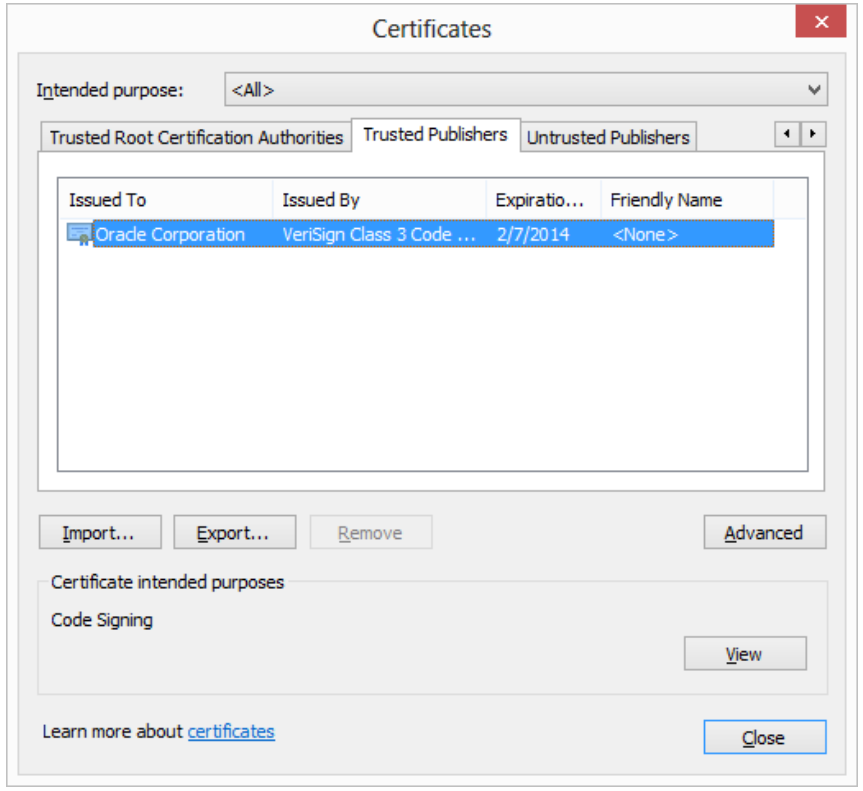
Details

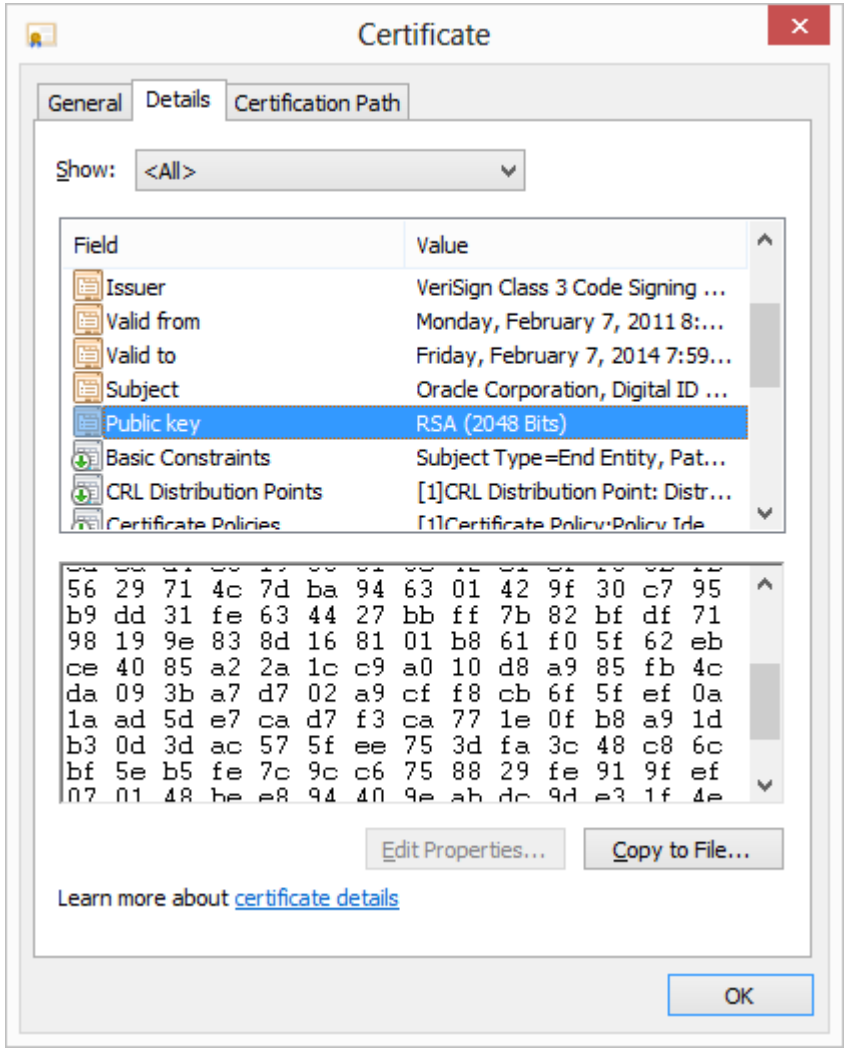

Document containing the public key and identity for Mario Rossi
Name: Mario
Surname: Rossi
Address: --- St.
Mario Rossi's public key
Certificate Authority's private key
Mario Rossi's Certificate
Name: Mario
Surname: Rossi
Address: --- St.
Mario Rossi's public key
Signature of the Certificate Authority
Document signed by the Certificate Authority

X.509 Certificates

- Defines framework for authentication services:
  - Defines that public keys stored as **certificates** in a public directory.
  - Certificates are **issued and signed** by an entity called **certification authority (CA)**
- Used by numerous applications: SSL
- Example: see certificates accepted by your browser

Example: Oracle's certificate

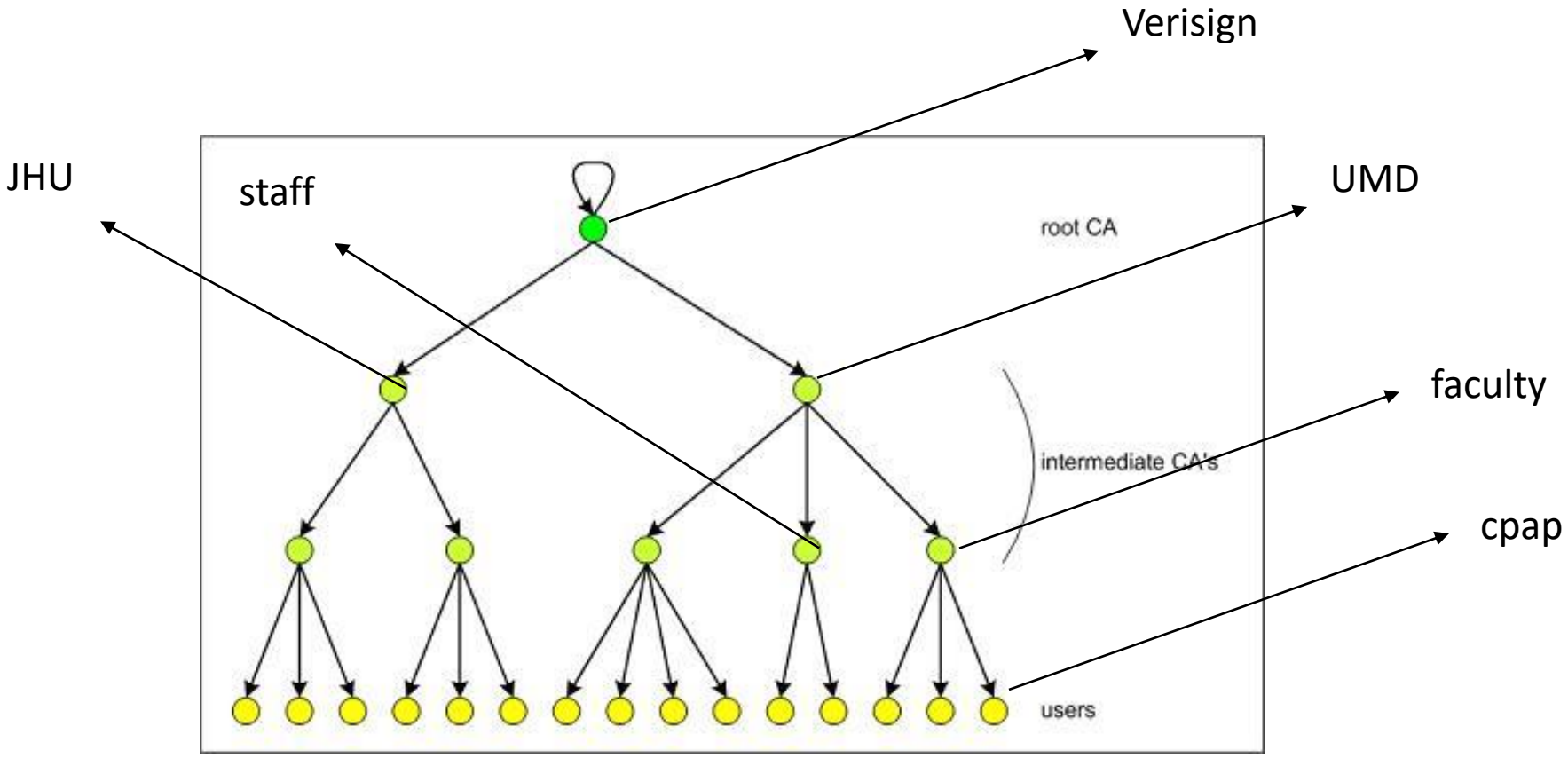




Method 1: Certificate Hierarchy

- Single CA certifying every public key is impractical
- Instead, use trusted root authorities
- Root CA signs certificates for intermediate CAs, they sign certificates for lower-level CAs, etc.
  - Certificate "chain of trust"
    - $sig_{Verisign}$("UMD", PK_{UMD})
    - sig_{UMD}("faculty", $PK_{faculty}$)
    - $sig_{faculty}$("cpap", PK_{cpap})

Example



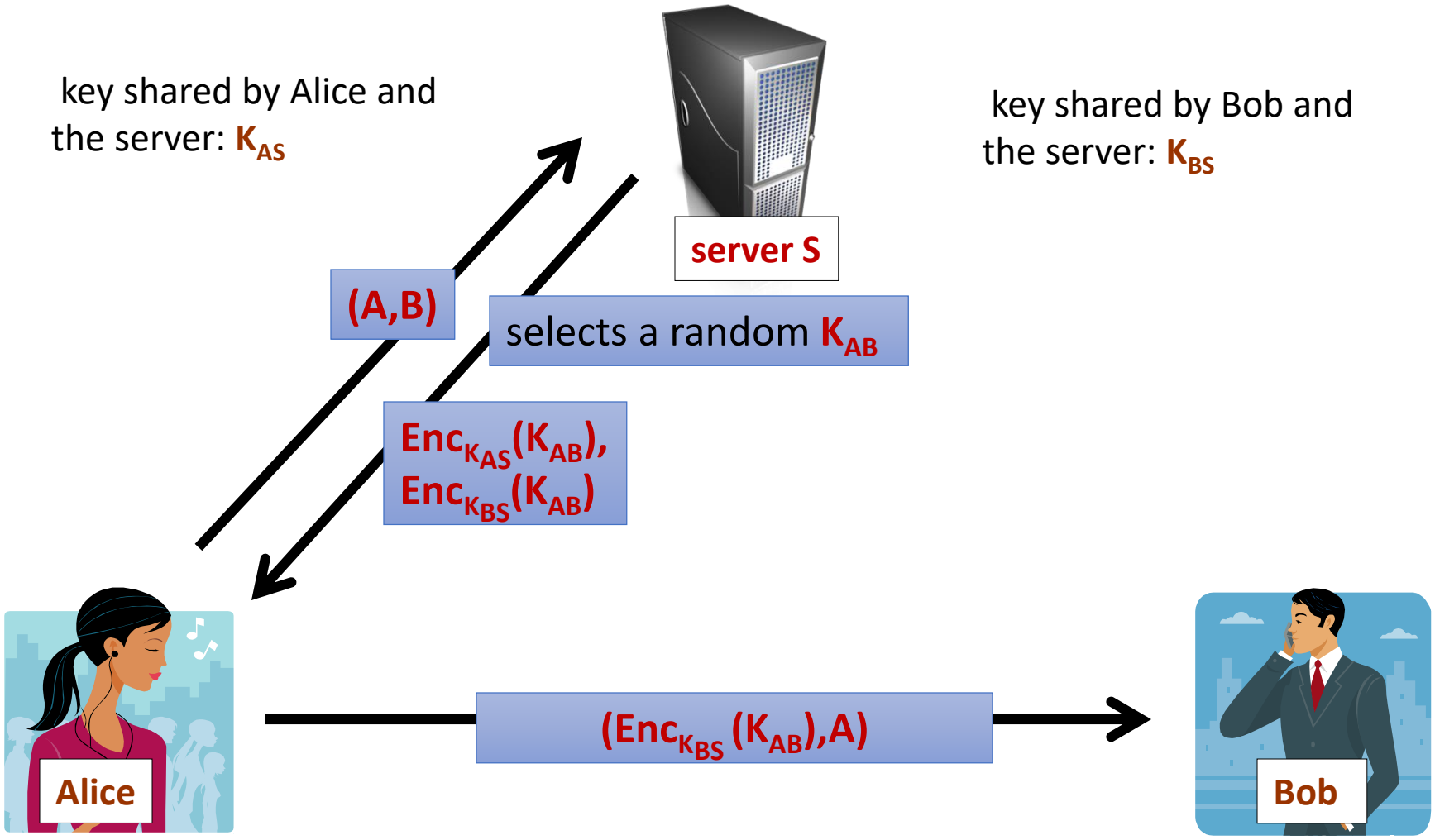
What bad things can happen if the root CA system is compromised?

Method 2: Web of Trust

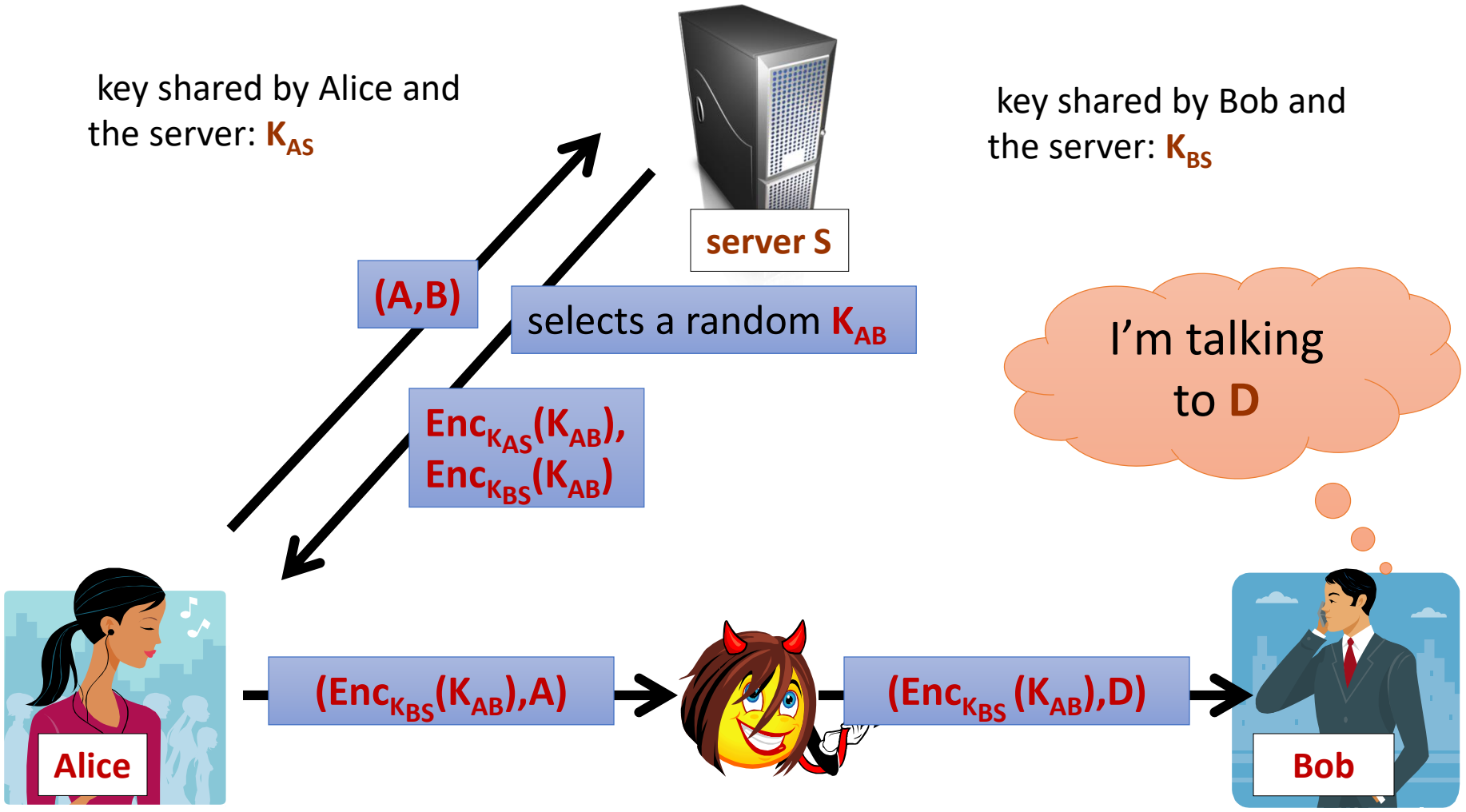
- No centralized authority
- Individuals sign one another's public keys, these "certificates" are stored along with keys in key rings.
- PGP computes a *trust level* for each public key in key ring.
- Users interpret trust level for themselves.
- Original intention was that all e-mail users would contribute to web of trust.
- Reality is that this web is sparsely populated.
- How should security-unaware users assign and interpret trust levels

What if we do not want to use PKI to share a key?

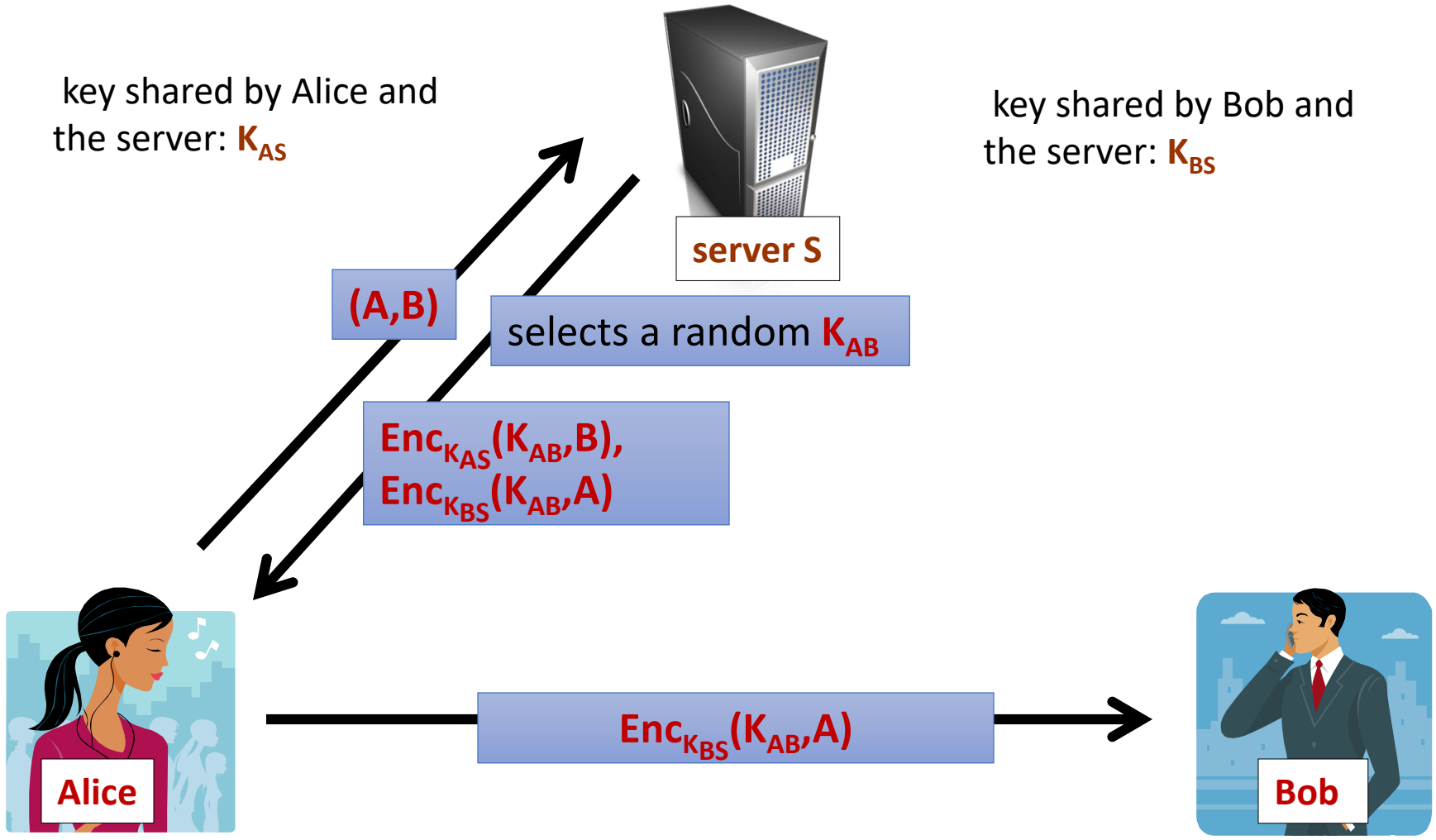
An idea (1)


key shared by Alice and the server: K_{AS}
key shared by Bob and the server: K_{BS}
server S
(A,B)
selects a random K_{AB}
$Enc_{K_{AS}}(K_{AB})$, $Enc_{K_{BS}}(K_{AB})$
Alice
$(Enc_{K_{BS}}(K_{AB}),A)$
Bob

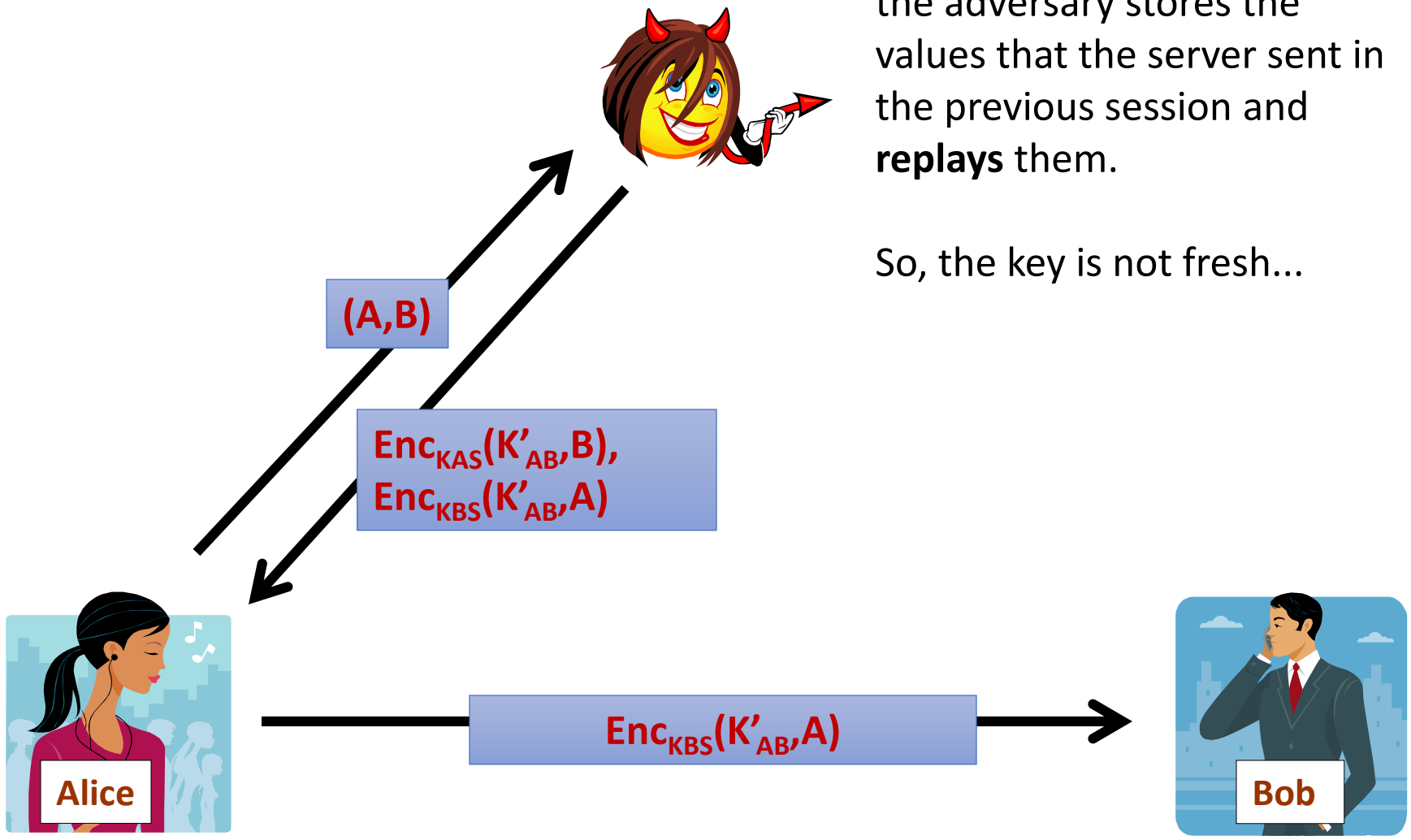
An attack


key shared by Alice and the server: K_{AS}
key shared by Bob and the server: K_{BS}
server S
(A,B)
selects a random K_{AB}
$Enc_{K_{AS}}(K_{AB})$, $Enc_{K_{BS}}(K_{AB})$
I'm talking to D
Alice
$(Enc_{K_{BS}}(K_{AB}),A)$
$(Enc_{K_{BS}}(K_{AB}),D)$
Bob

An idea (2)


key shared by Alice and the server: K_{AS}
key shared by Bob and the server: K_{BS}
server S
(A,B)
selects a random K_{AB}
$Enc_{K_{AS}}(K_{AB},B)$, $Enc_{K_{BS}}(K_{AB},A)$
Alice
$Enc_{K_{BS}}(K_{AB},A)$
Bob

A replay attack



the adversary stores the values that the server sent in the previous session and **replays** them.

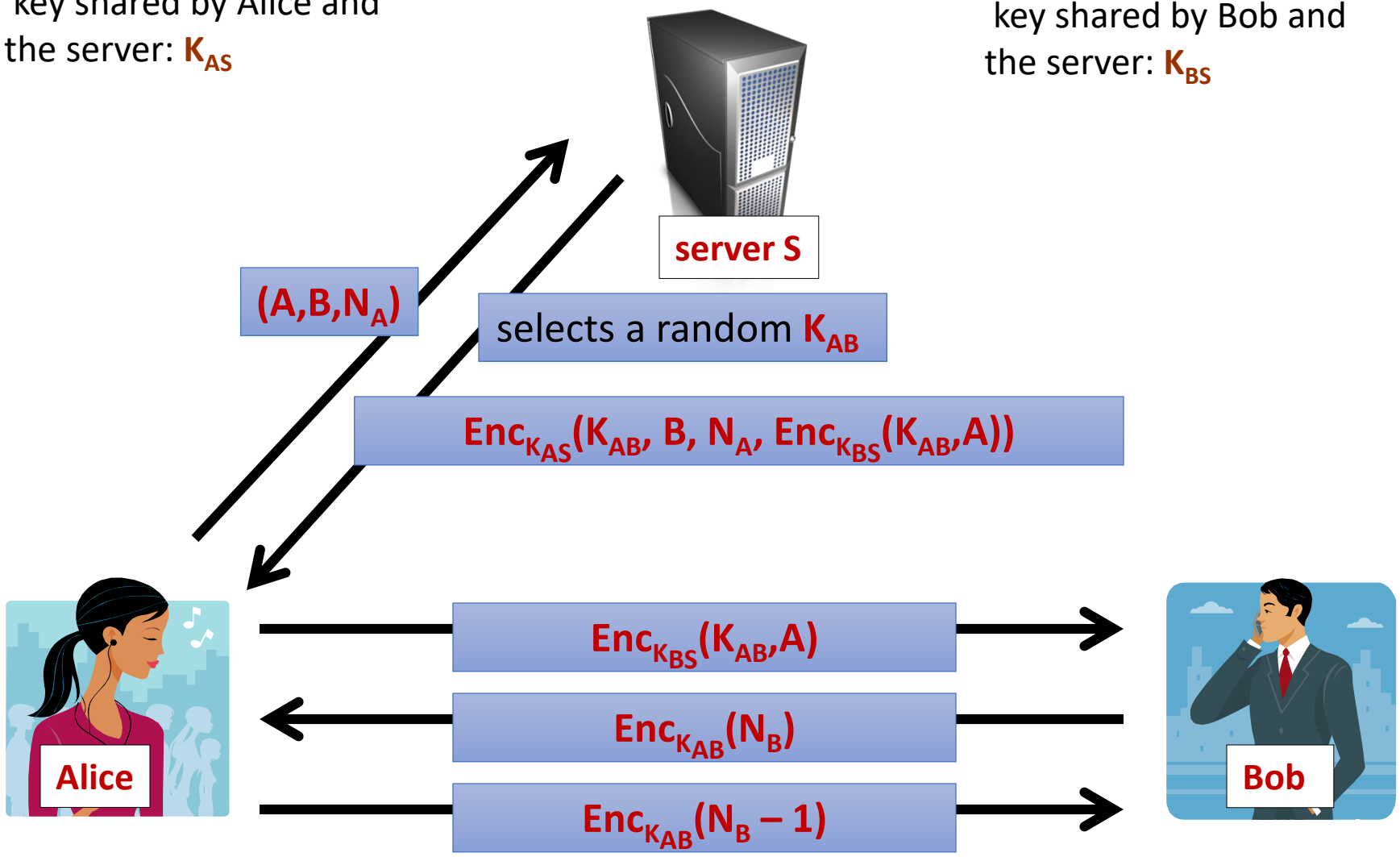
So, the key is not fresh...

How to protect against the replay attacks?

Nonce – “number used once”.

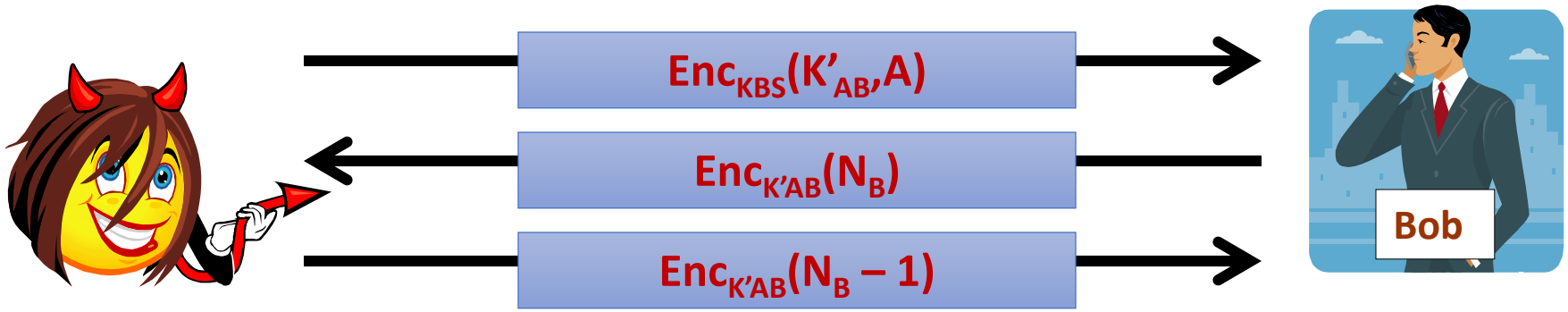
Nonce is a random number generated by one party and returned to that party to show that a message is newly generated.

An idea (3): Needham Schreoder 1972.



An attack on Needham Schroeder

Assume that an old session key K'_{AB} is known to the adversary.



The final solution

key shared by Alice and the server: K_{AS}

key shared by Bob and the server: K_{BS}

server S

(A,B,N_A,N_B)

selects a random K_{AB}

$Enc_{K_{AS}}(K_{AB}, B, N_A)$
$Enc_{K_{BS}}(K_{AB}, A, N_B)$

Alice

(B,N_B)

$Enc_{K_{BS}}(K_{AB}, A, N_B)$

Bob