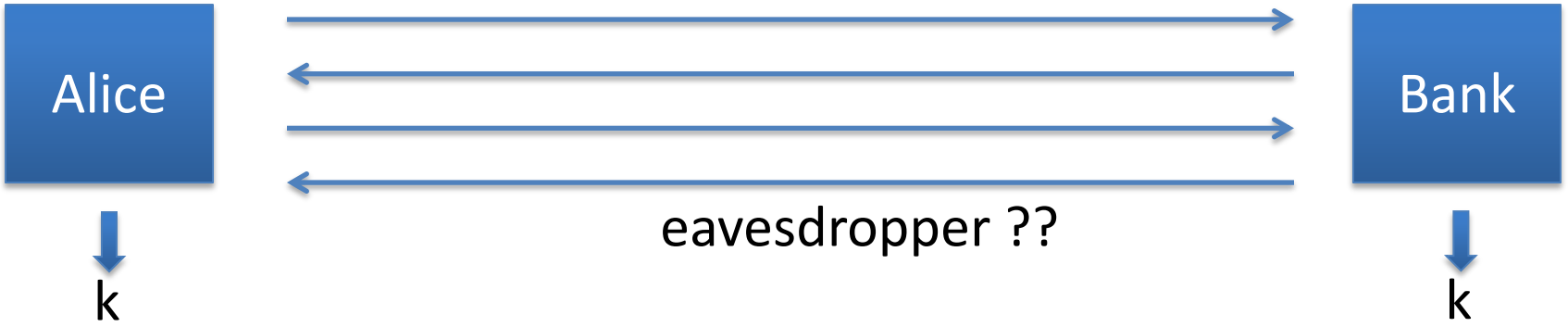
Auth. Key Exchange

Review: key exchange

Alice and Bank want to generate a secret key

- So far we saw key exchange secure against eavesdropping



- This lecture: **Authenticated Key Exchange (AKE)**

  key exchange secure against <u>active</u> adversaries

Active adversary

Adversary has complete control of the network:

- Can modify, inject and delete packets
- Example: man-in-the-middle

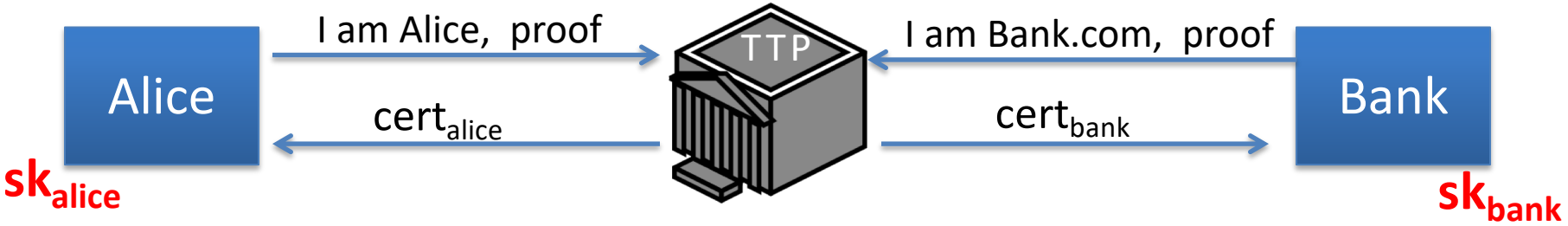
Moreover, some users are honest and others are corrupt

- Corrupt users are controlled by the adversary
  - Key exch. with corrupt users should not "affect" other sessions

Trusted Third Party (TTP)

All AKE protocols require a TTP to certify user identities.

Registration process:



Two types of TTP: (here, we only consider offline TTP)

- **Offline TTP (CA)**: contacted only during registration (and revocation)
- **Online TTP**: actively participates in every key exchange (Kerberos)

  Benefit: security using only symmetric crypto

AKE: syntax

Followed by Alice sending E(k, “data”) to Bank and vice versa.

Basic AKE security (very informal)

Suppose Alice successfully completes an AKE to obtain **(k, Bank)**

If Bank is not corrupt then:

Authenticity for Alice: (similarly for Bank)

- If Alice's key k is shared with anyone, it is only shared with Bank

Secrecy for Alice: (similarly for Bank)

- To the adversary, Alice's key k is indistinguishable from random (even if adversary sees keys from other instances of Alice or Bank)

Consistency: if Bank completes AKE then it obtains **(k, Alice)**

AKE security levels (very informal)

Three levels of (core) security:

- **Static security**: previous slide
- **Forward secrecy**: static security, and if adv. learns sk_{bank} at time T then all sessions with Bank from time t<T remain secret.
- **HSM security**: if adv. queries an HSM holding sk_{bank} n times, then at most n sessions are compromised.
  Moreover, forward secrecy holds.

Several other AKE requirements …

Hardware Security Module (HSM)

One-sided AKE: syntax

Used when <u>only</u> one side has a certificate.

- Similarly, three security levels.

Things to remember …

Do not design AKE protocol yourself …

Just use latest version of TLS

Building blocks

$cert_{bank}$: contains pk_{bank} . Bank has **sk_{bank}** .

$E_{bank}((m,r)) = E(pk_{bank}, (m,r))$ where E is *chosen-ciphertext secure*

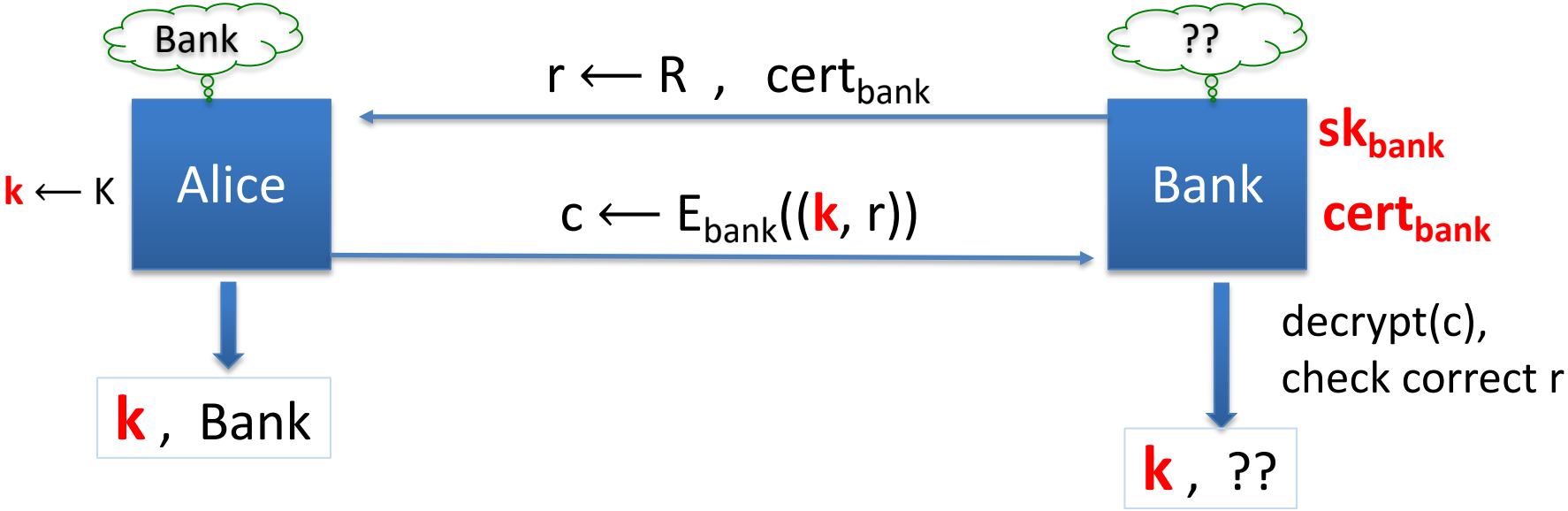
- Recall: from $E_{bank}((m,r))$ adv. cannot build $E_{bank}((m,r'))$ for $r' \neq r$

$S_{alice}((m,r)) = S(sk_{alice}, (m,r))$ where S is a secure signing alg.

R: some large set, e.g. $\{0,1\}^{256}$

Protocol #1

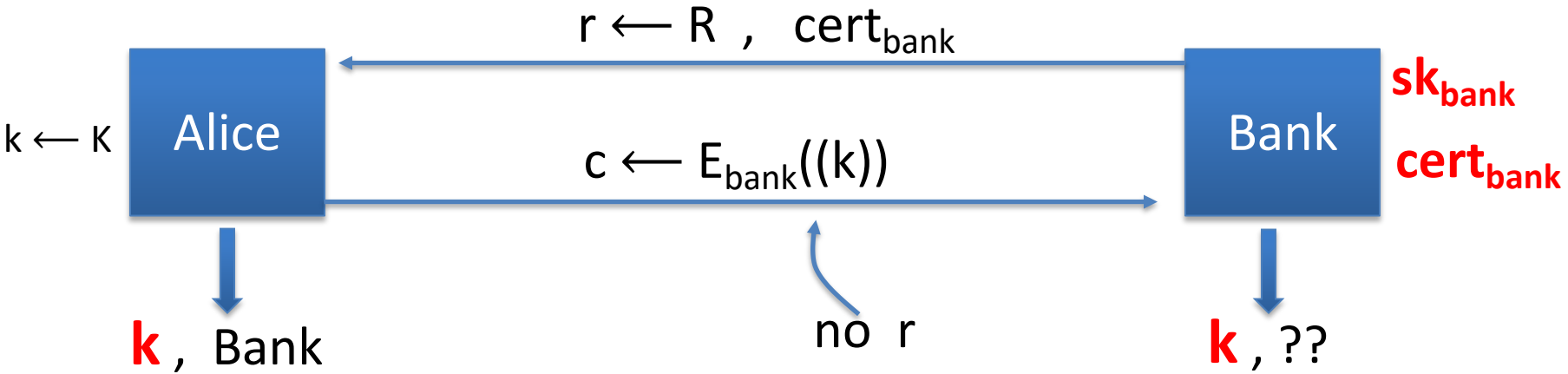
Simple one-sided AKE protocol



"Thm": protocol is a statically secure one-sided AKE

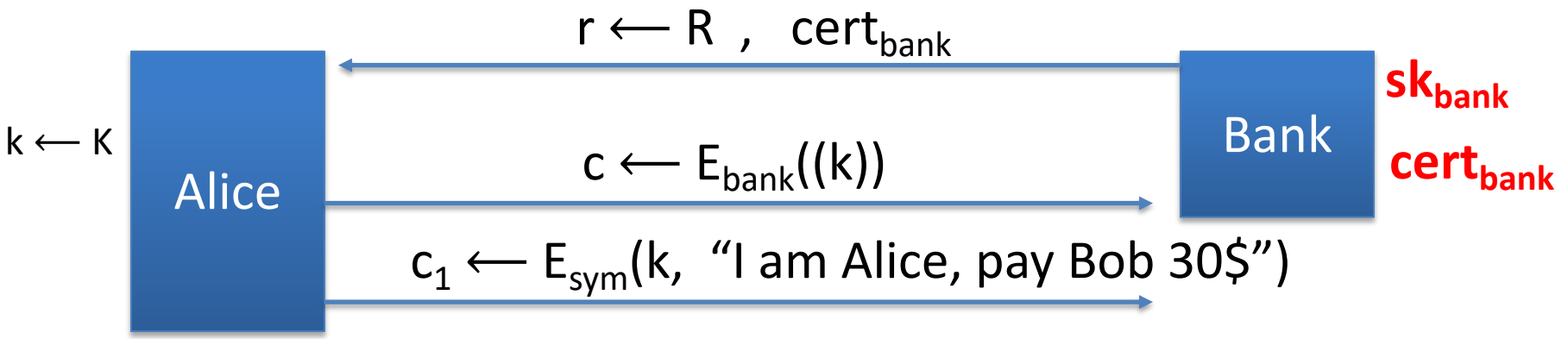
Informally: if Alice and Bank are not corrupt then we have
(1) secrecy for Alice and (2) authenticity for Alice

Insecure variant 1: r not encrypted

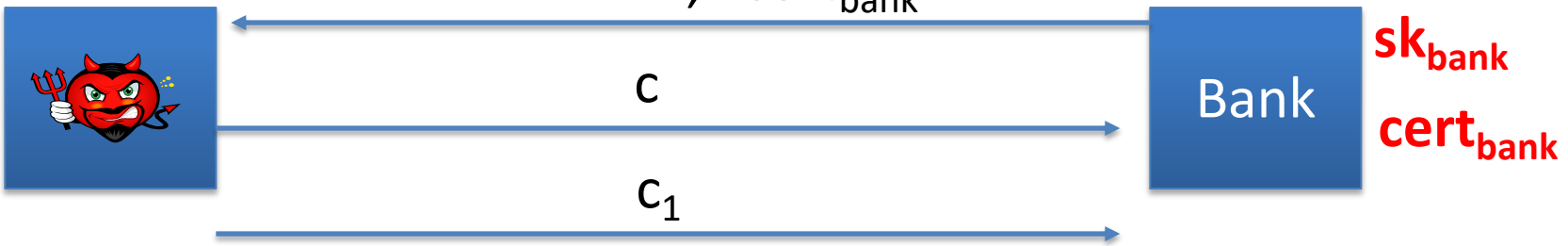


Problem: replay attack

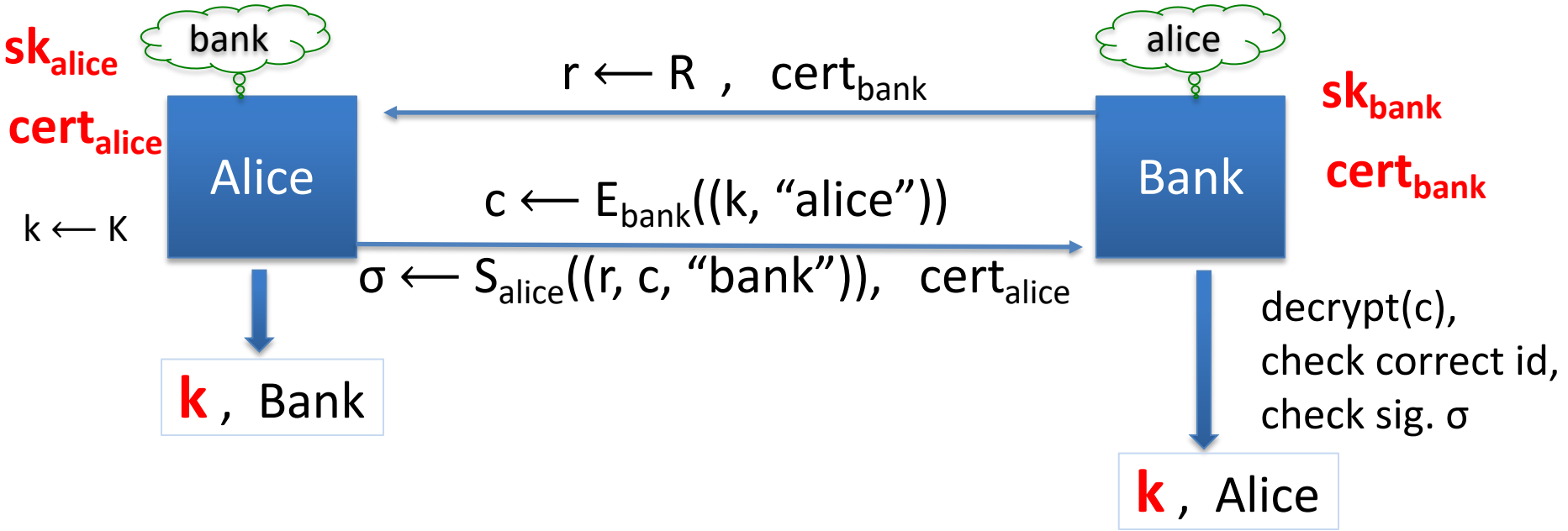
Replay attack



Later:



Two-sided AKE (mutual authentication)

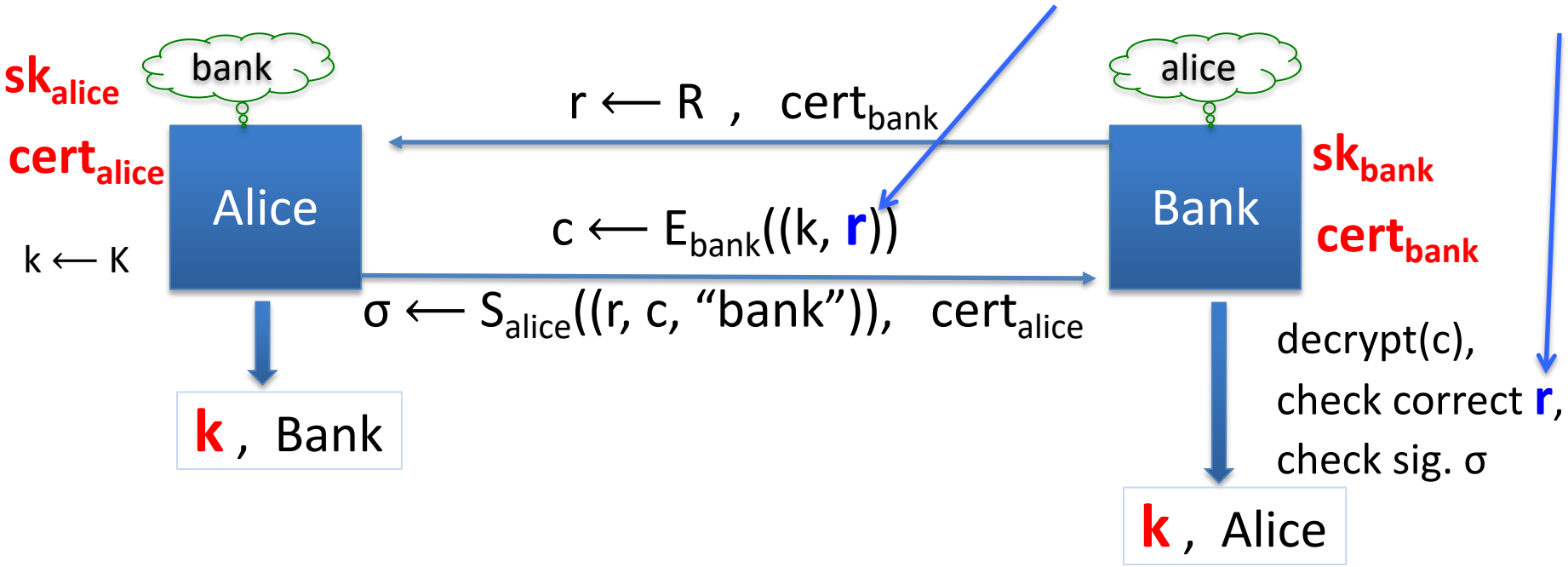


“Thm”: this protocol is a statically secure AKE

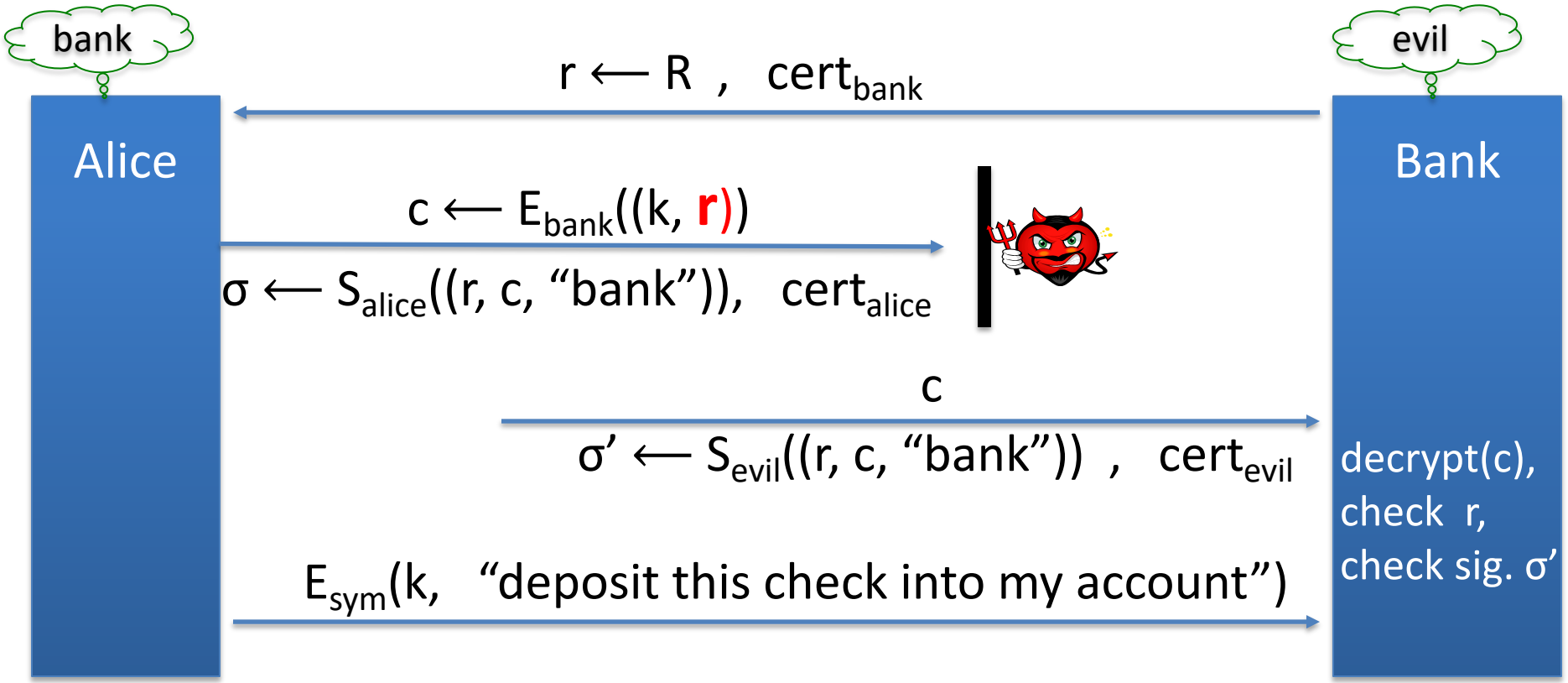
Insecure variant: encrypt **r** instead of "Alice"

Any change to protocol makes it insecure, sometime in subtle ways

Example:

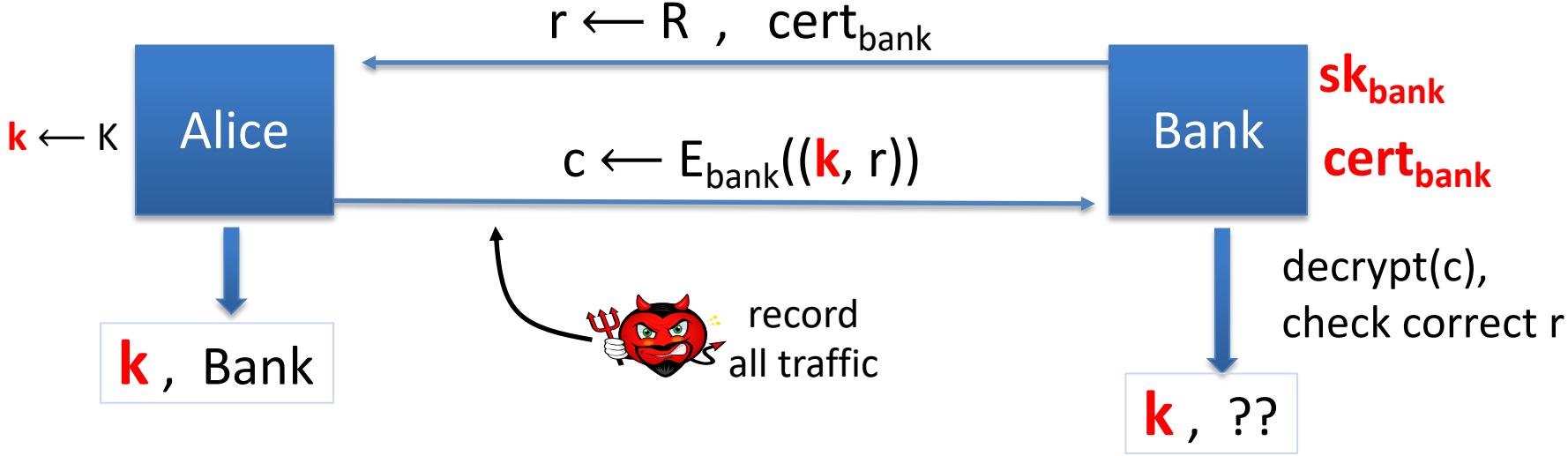


Attack: identity misbinding



Problem: no forward secrecy

Recall the one-sided AKE:



Suppose a year later adversary obtains sk_{bank}

⇒ can decrypt all recorded traffic

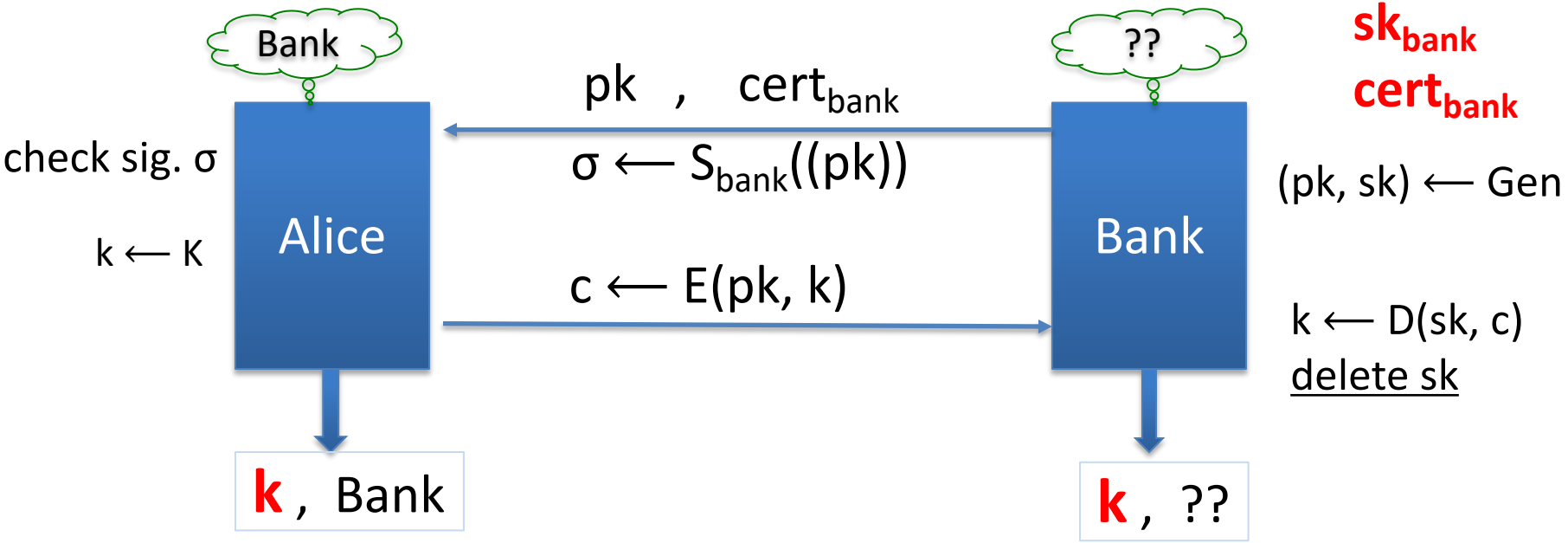
Same attack on the two-sided AKE

This protocol is used in TLS 1.2, deprecated in TLS 1.3

Protocol #2: forward secrecy

Server compromise at time T should not compromise sessions at time t<T

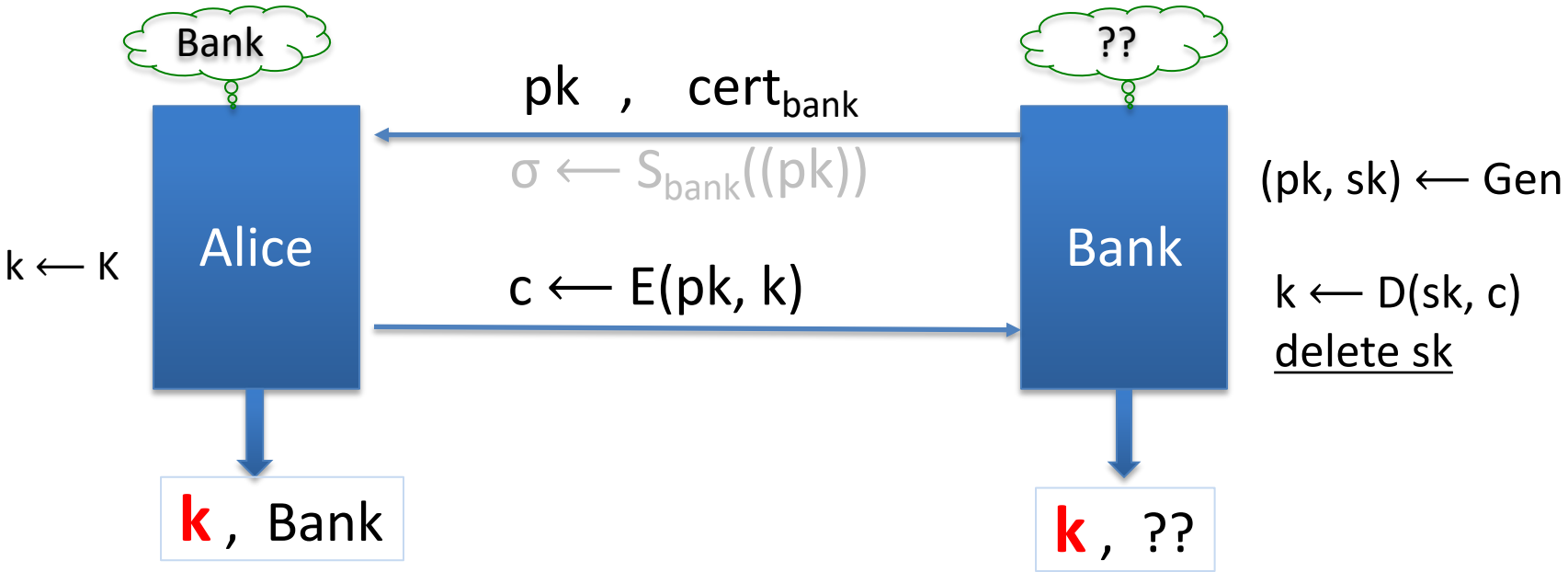
Simple one-sided AKE with forward-secrecy



(pk, sk) are ephemeral: sk is deleted when protocol completes

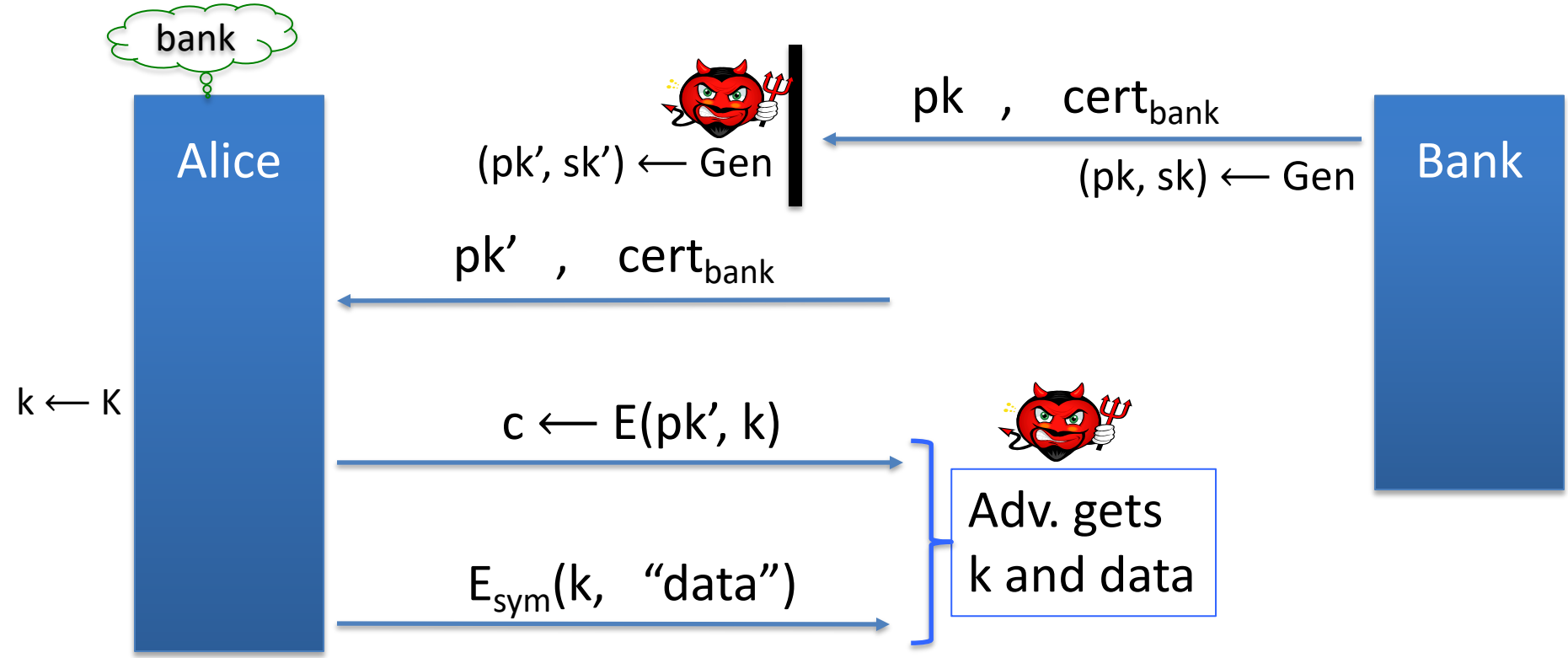
Compromise of Bank: past sessions are unaffected

Insecure variant: do not sign pk

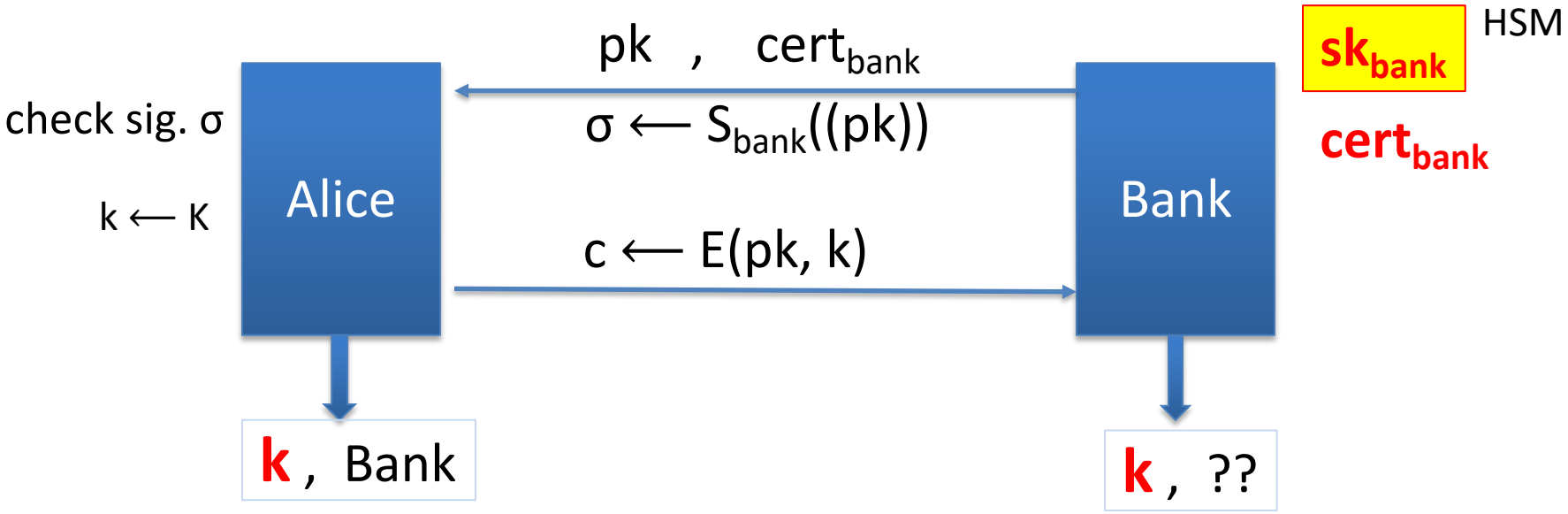


Attack: complete key exposure

Attack: key exposure



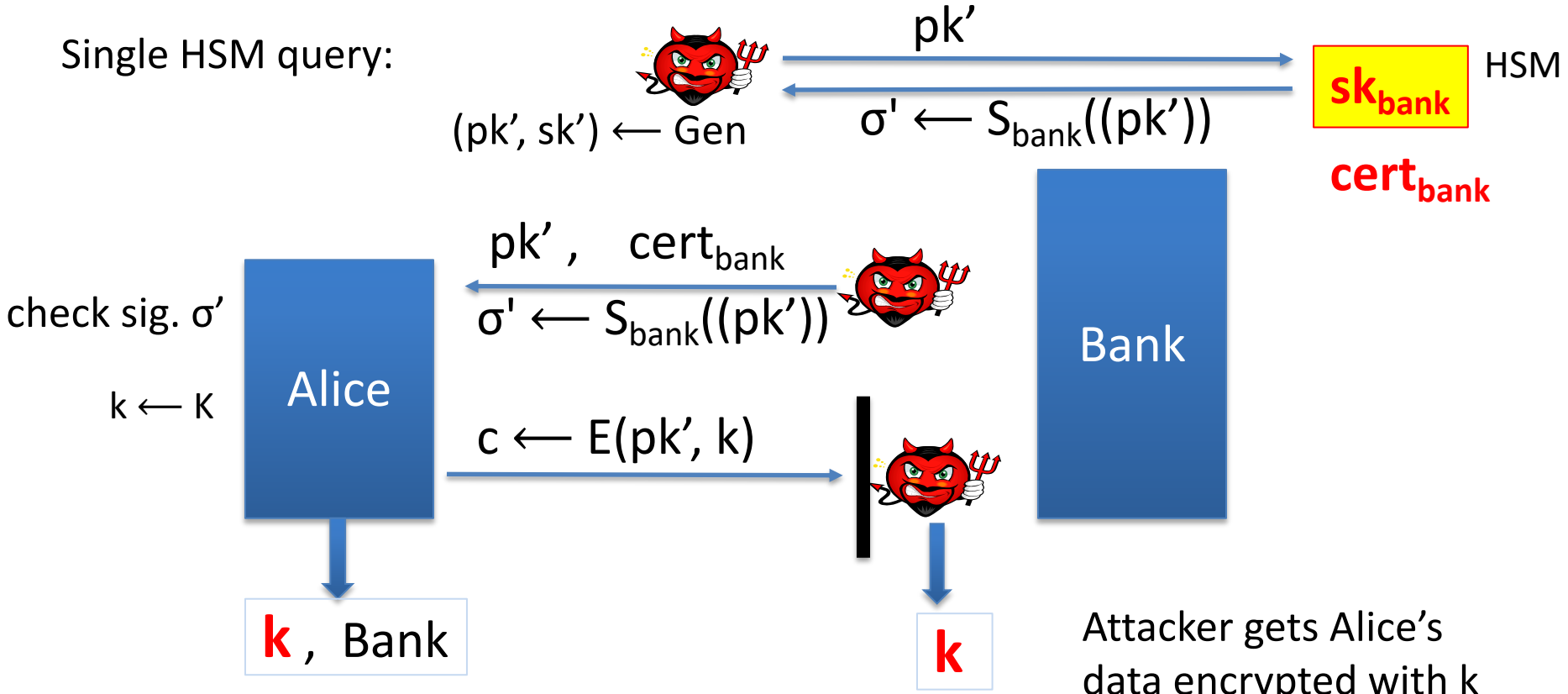
Problem: not HSM secure



Suppose attacker breaks into Bank and queries HSM <u>once</u>

⇒ complete key exposure <u>forever</u> !

Problem: not HSM secure

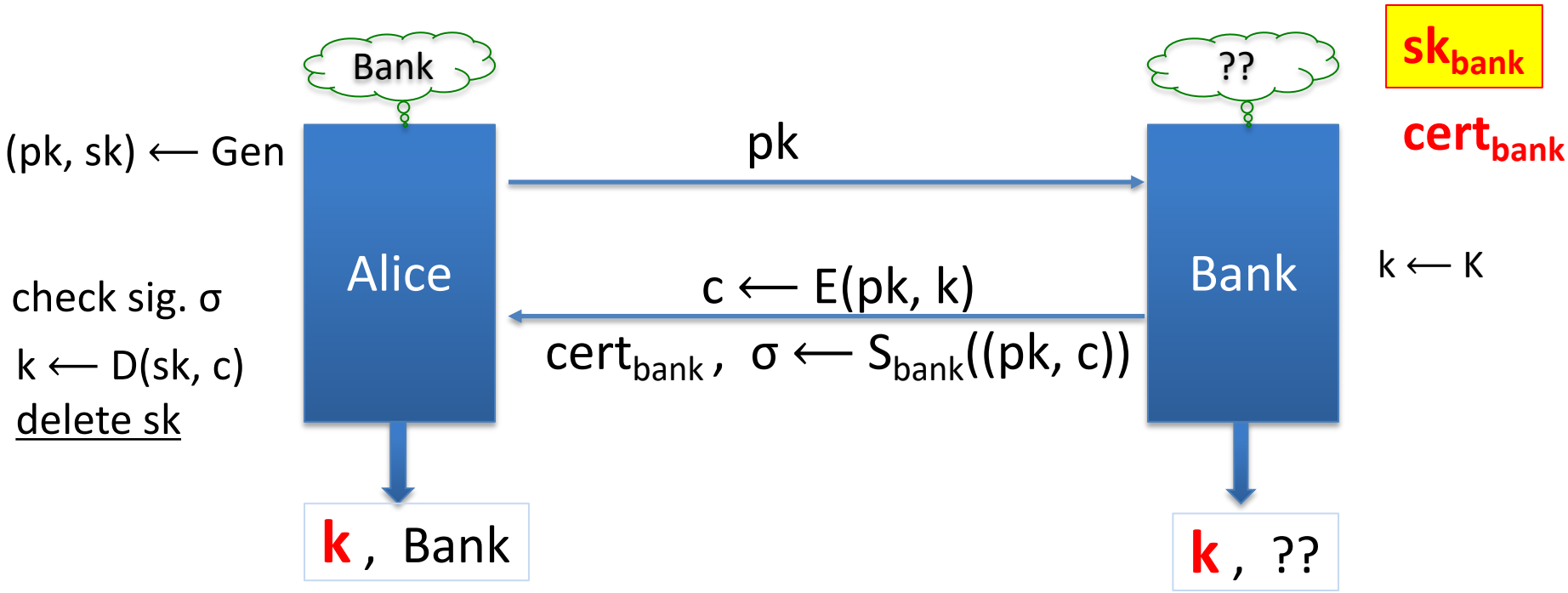


Protocol #3: HSM Security

Forward secrecy, and

n queries to HSM should compromise at most n sessions

Simple HSM security (one-sided)

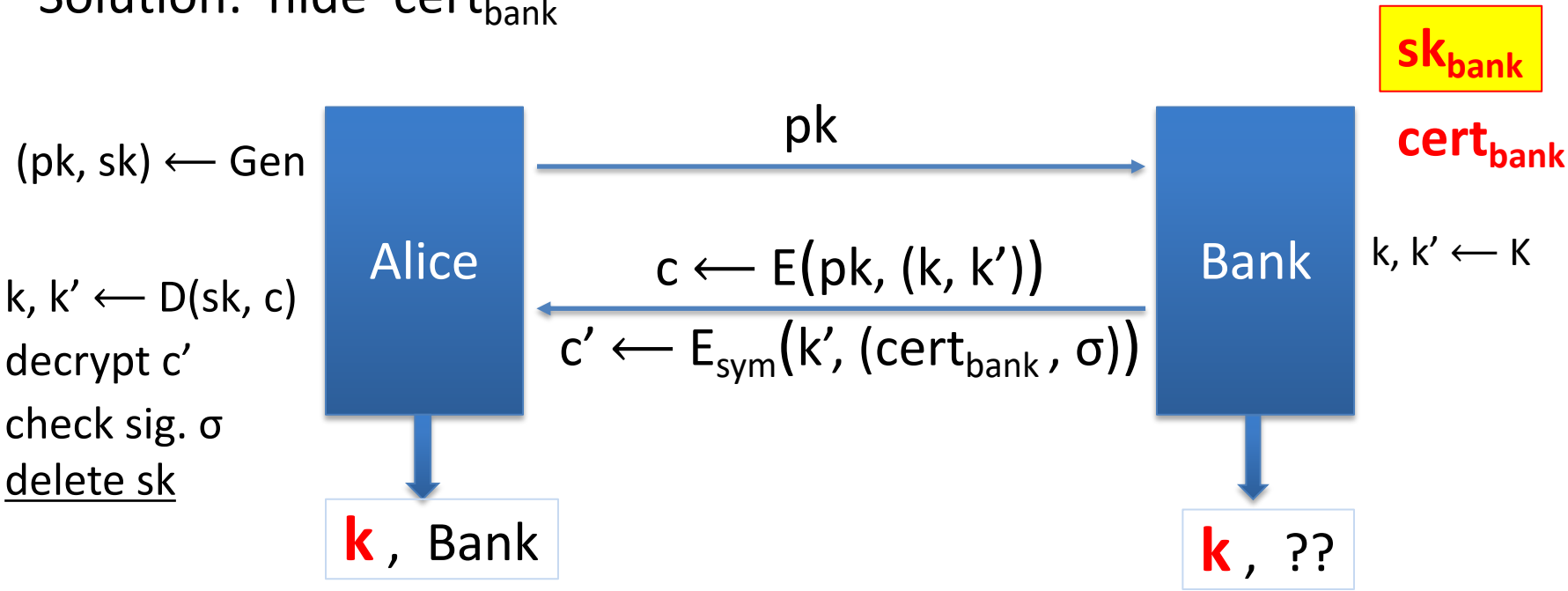


Main point: HSM needed to sign ephemeral pk from client
⇒ past access to HSM will not compromise current session

Final variant: end-point privacy

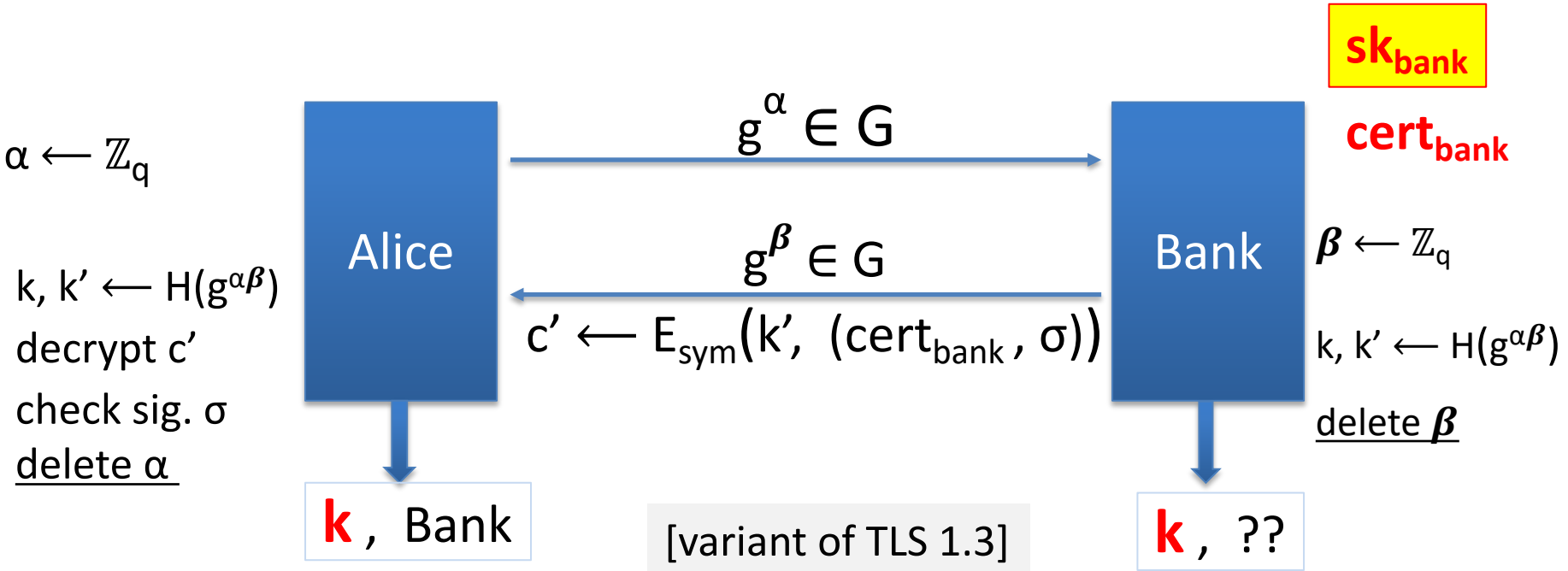
Protocol #3: eavesdropper learns that Alice wants to talk to Bank.

Solution: hide $\text{cert}_{\text{bank}}$



Using Diffie-Hellman: DHAKE (simplified)

We can use Diffie-Hellman instead of general public-key encryption



Many more AKE variants

AKE based on a pre-shared secret between Alice and Bank:

- High entropy pre-shared secret: ensure forward secrecy
- Password: ensure no offline dictionary attack (PAKE)

Deniable:

- Both sides can claim they did not participate in protocol
- In particular, parties do not sign public messages

Auth. key exchange

TLS 1.3 Session Setup

RFC 8446 (Aug. 2018)

TLS 1.3 Session Setup

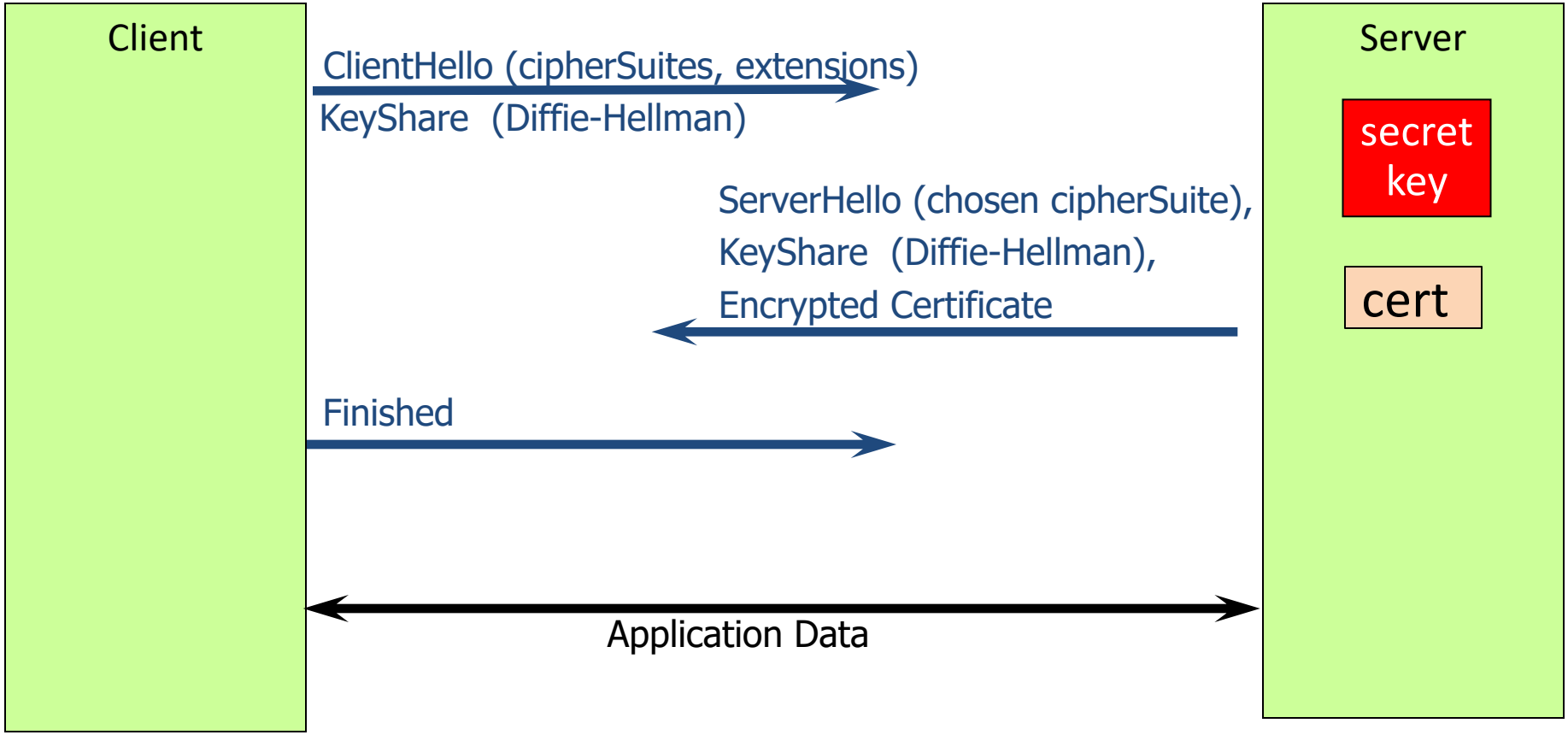
Generate unidirectional keys: $k_{b \rightarrow s}$ and $k_{s \rightarrow b}$

Security goals:

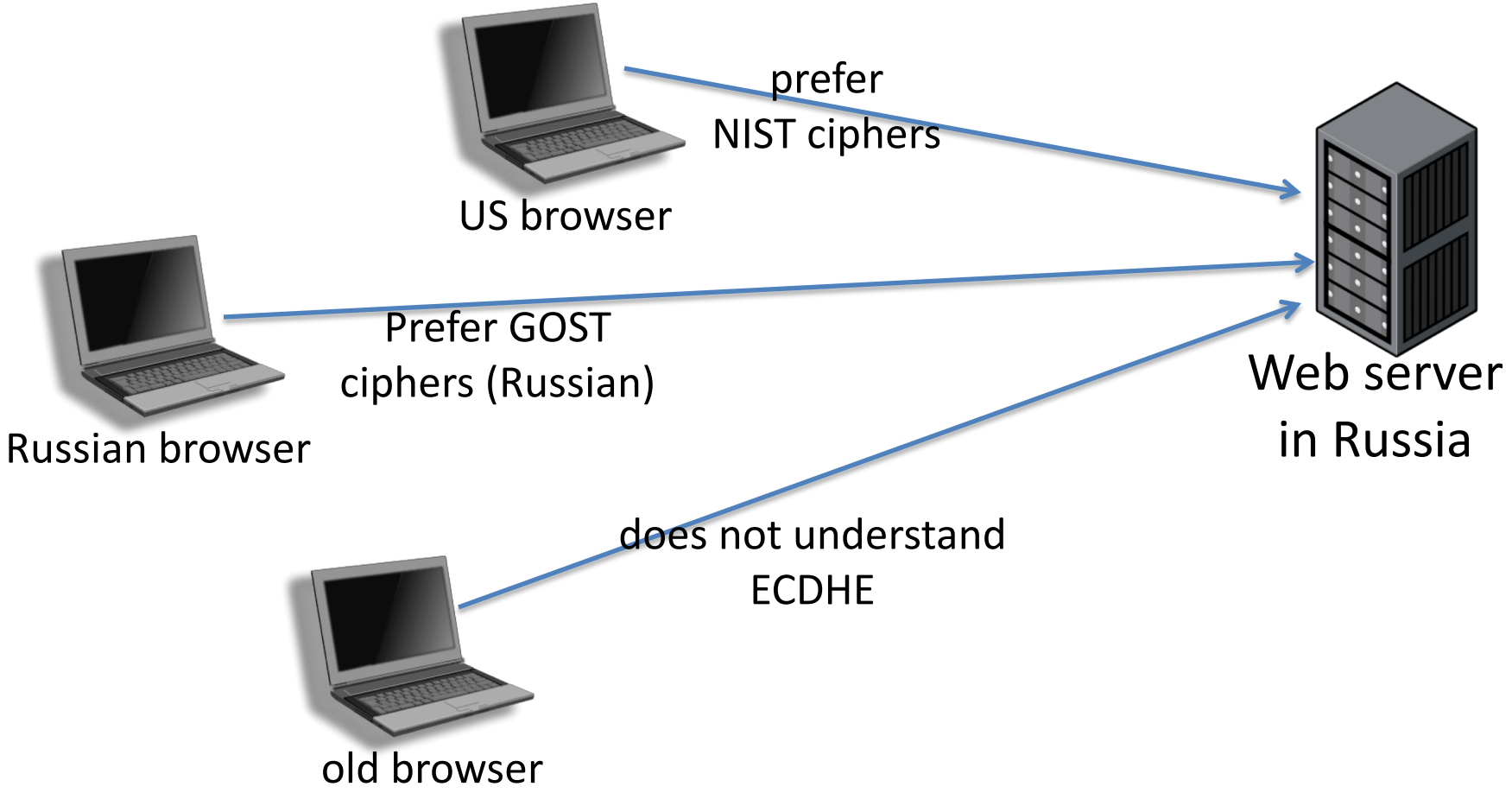
- Support for one-sided and two-sided AKE
- HSM security (including forward secrecy and static security)
- End-point privacy against an eavesdropper

Protocol is related to the Diffie-Hellman protocol DHAKE above

TLS 1.3 session setup (full handshake, simplified)

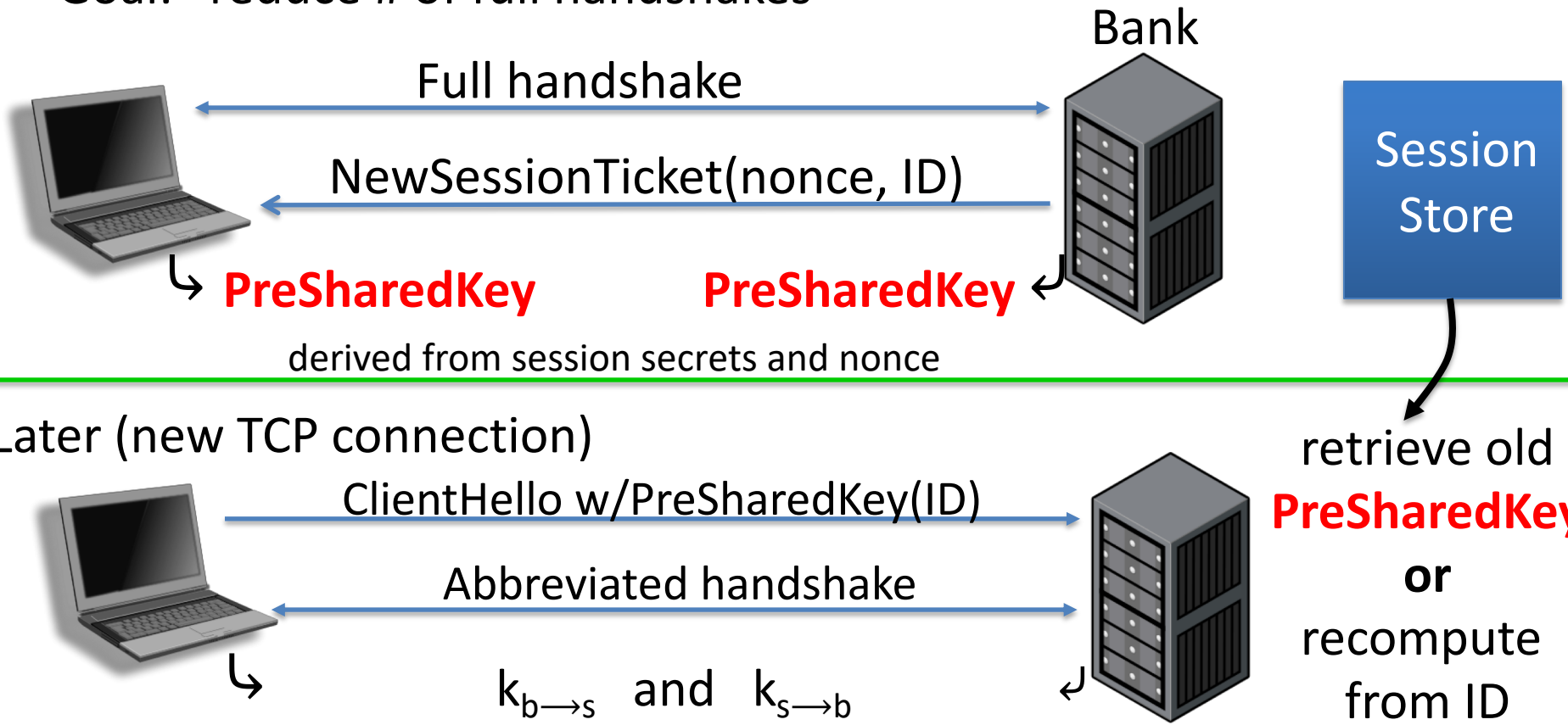


The need for negotiating ciphers

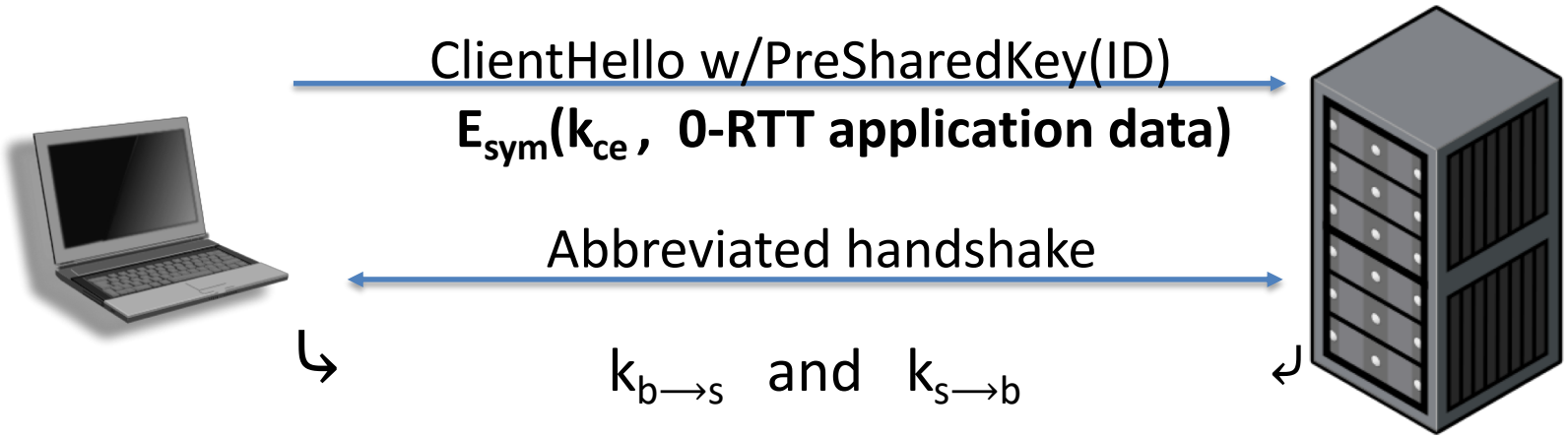


Session setup from pre-shared keys

Goal: reduce # of full handshakes



PSK 0-RTT



k_{CE} : client early key-exchange key.
derived from PSK (and other ClientHello data)

Problem: 0-RTT app data is vulnerable to replay.

THE END