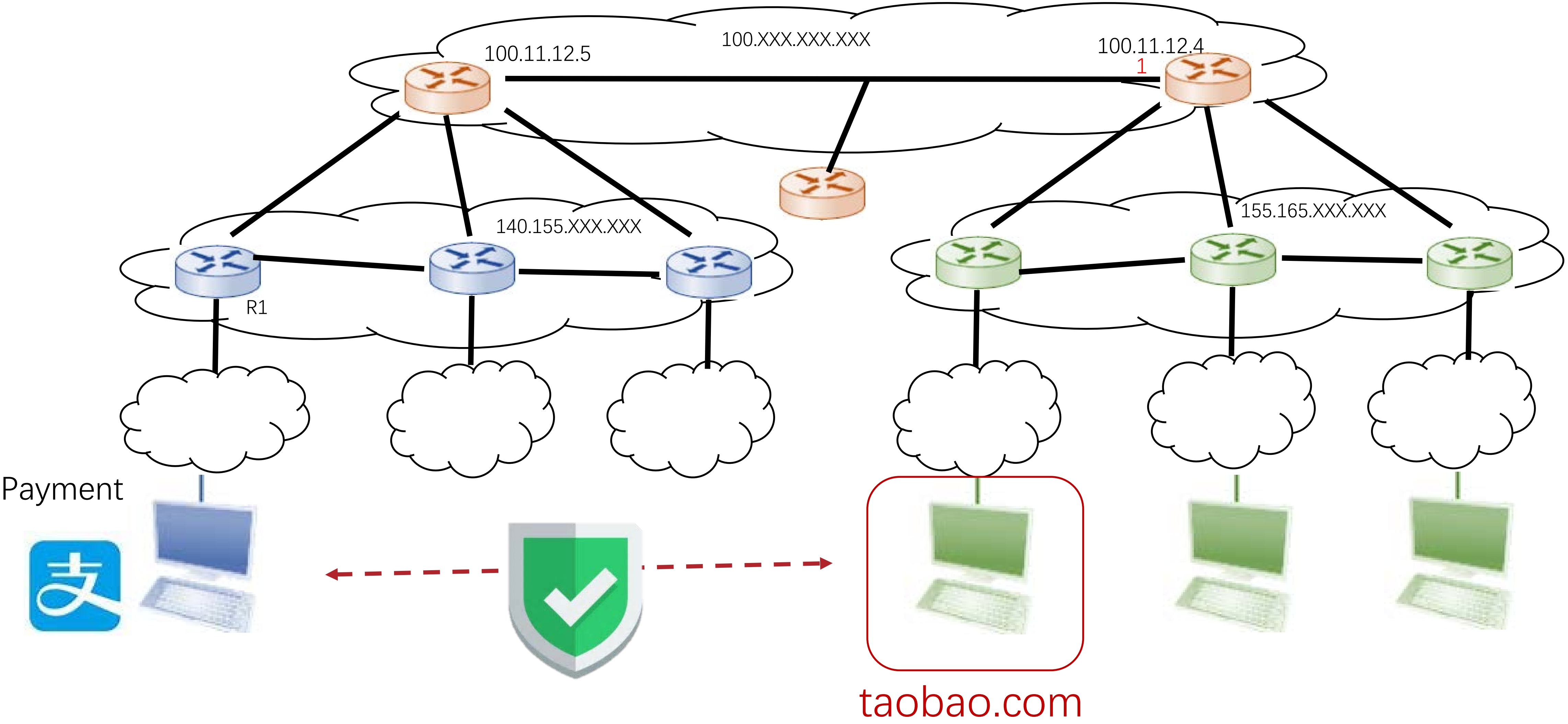
CS120: Computer Networks

Lecture 27. Network Security 1

Zhice Yang

How to Secure the Internet?



What is Network Security

- Confidentiality
  - To encrypt messages so as to prevent an adversary from understanding the message contents
- Integrity
  - To prevent an adversary from modifying the message contents.
- Availability
  - services must be accessible and available to users
- Authentication
  - To confirm identity of each other
- Timeliness
  - To identify delayed messages

Guarantee	Primitive
Confidentiality	Encryption
Integrity	Hash
Authentication	Signatures

Security Risks in Networks

- Eavesdrop
- Injection
- Impersonation
  - can fake (spoof) source address in packet (or any field in packet)
- Hijacking
  - “take over” ongoing connection by removing sender or receiver, inserting himself in place
- Denial of Service (DoS):
  - prevent service from being used by others (e.g., by overloading resources)
- …

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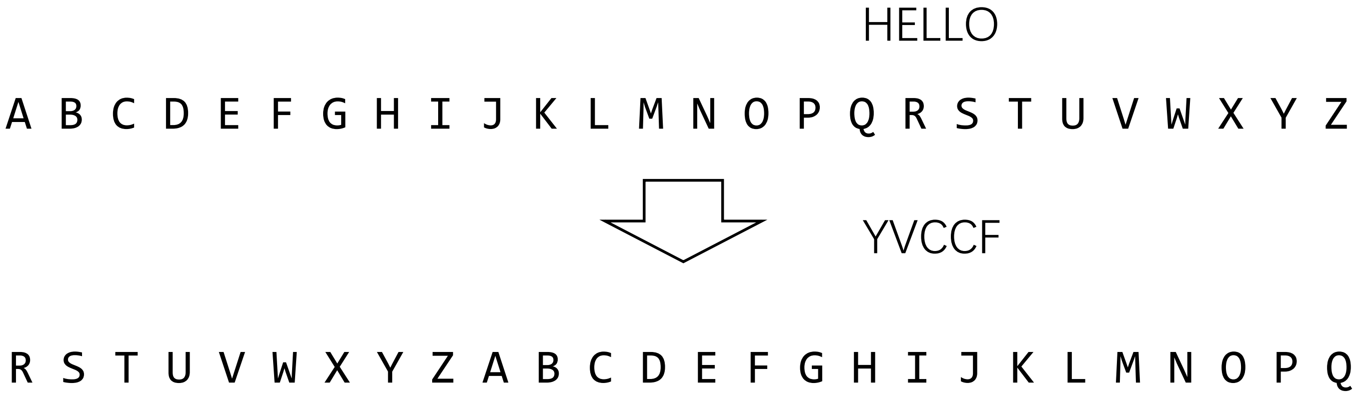
Cipher

- Cipher: the Cryptographic Algorithm for Encryption or Decryption



HELLO

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

YVCCF

R S T U V W X Y Z A B C D E F G H I J K L M N O P Q

Cipher

- Ciphers are normally parameterized by **keys**
  - Message: x
  - Key: k1, k2
  - Encryption function: y=En(x, k1)
  - Decryption function: x=De(y, k2)
- Key is the secret
  - The encryption function and decryption function are public known

put the valuable in

take the valuable out

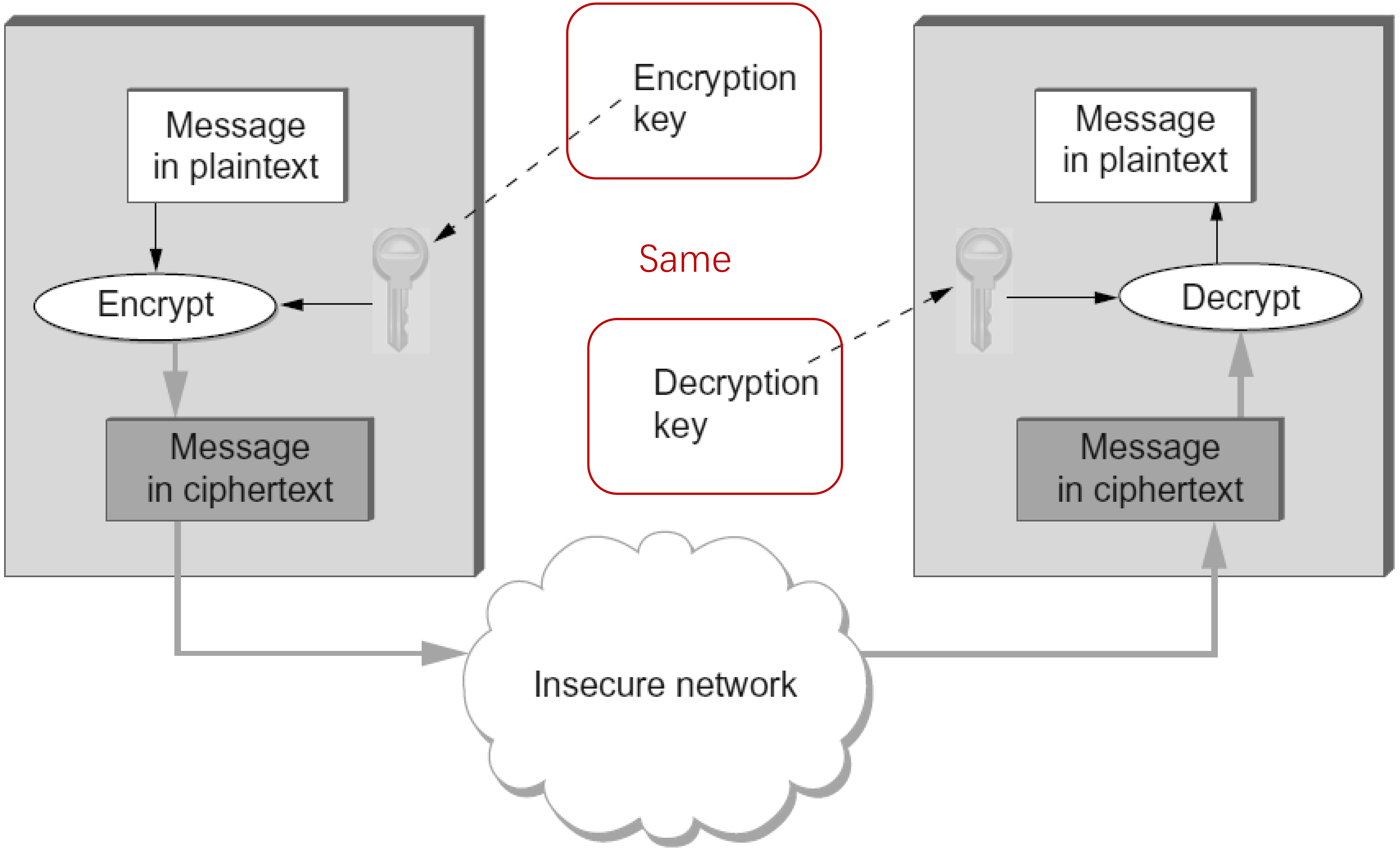
Cipher as a Secret ?

Obtain the secret by unlocking the block

Not Scalable
Not secure after the cipher is cracked

The mechanism of the locker is public known, but the key unknown

Symmetric-Key Cipher

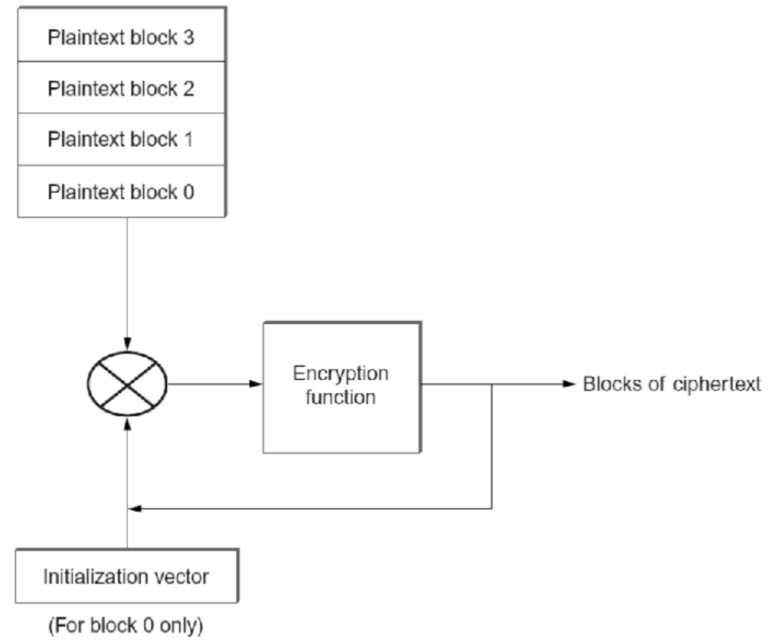


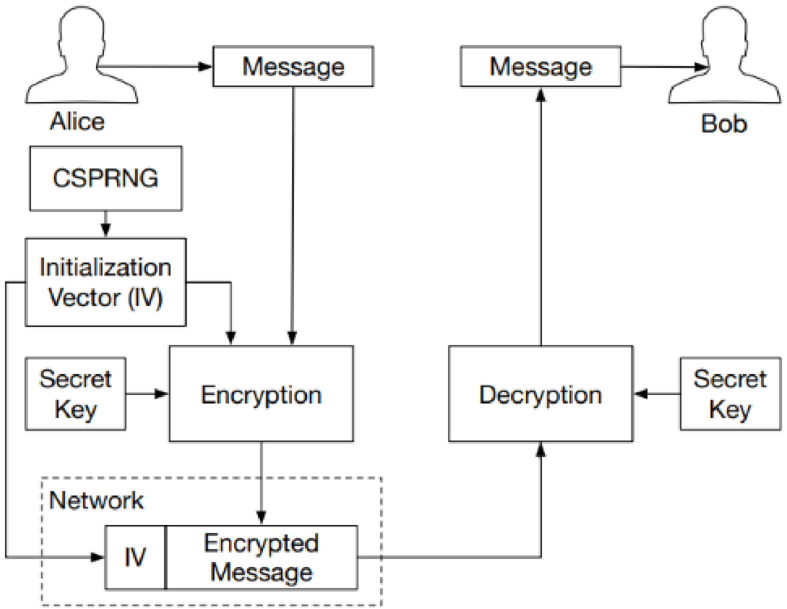
Symmetric-Key Cipher

- Examples:
  - Advanced Encryption Standard (AES)
    - Block size: 4*4 = 16 Byte (128 bit)
    - Operation: a permutation of the 128 bits according to the key
    - key size: 128, 192, 256 bit
    - https://aesencryption.net/

Symmetric-Key Cipher

- Ciphers are under various attacks
    - e.g., word frequency, known plaintext, etc.
- Cipher designs
    - Prevent attackers from knowing key even the attacker knows plaintext
        - Initialization Vector (IV)
        - Cipher Block Chaining to prevent same output under same input





Symmetric-Key Cipher

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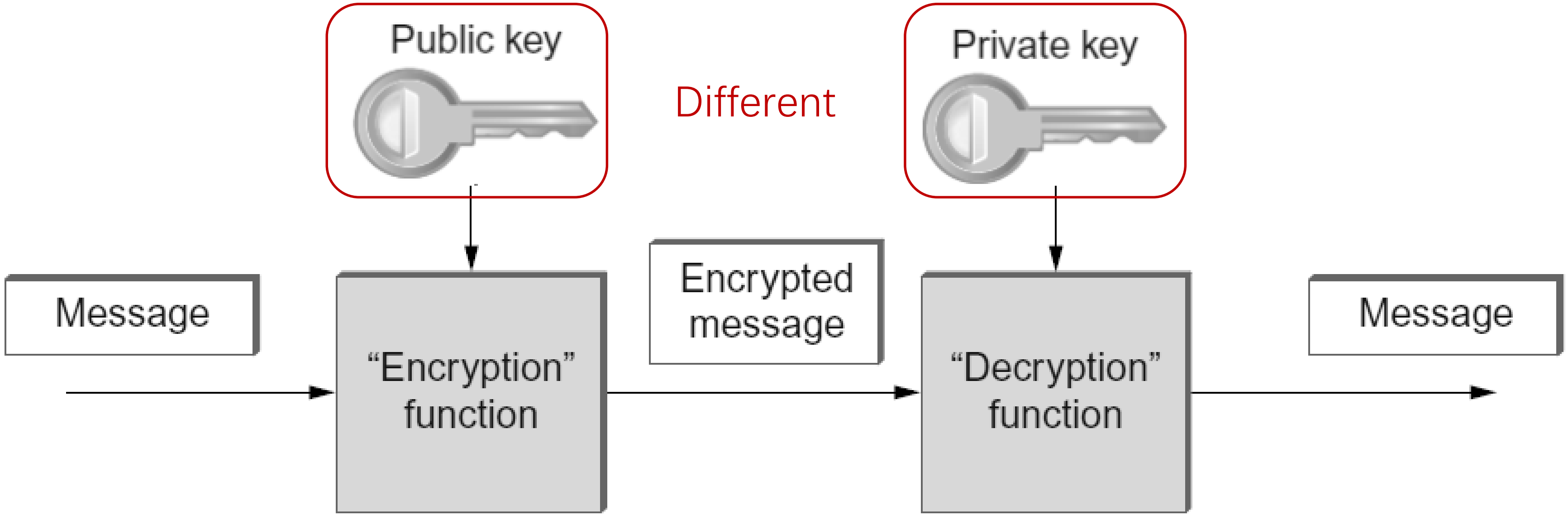
  - Advanced Encryption Standard (AES)
    - Block size: 4*4 = 16 Byte (128 bit)
    - Operation: a permutation of the 128 bits according to the key
    - key size: 128, 192, 256 bit
    - https://aesencryption.net/
  - Operation Mode
    - e.g., AES-CTR
    - Initialization Vector (IV)
    - Block chaining
      - e.g., Counter (CTR) and Cypher Block Chaining (CBC)

Symmetric-Key Cipher

- Problem
  - Sender and receiver have to share the secret key
  - Q: how to agree on the key in first place (particularly if never “met”)?
- This problem haven’t been solved until very recently (70s)
  - -> Public-Key Cipher

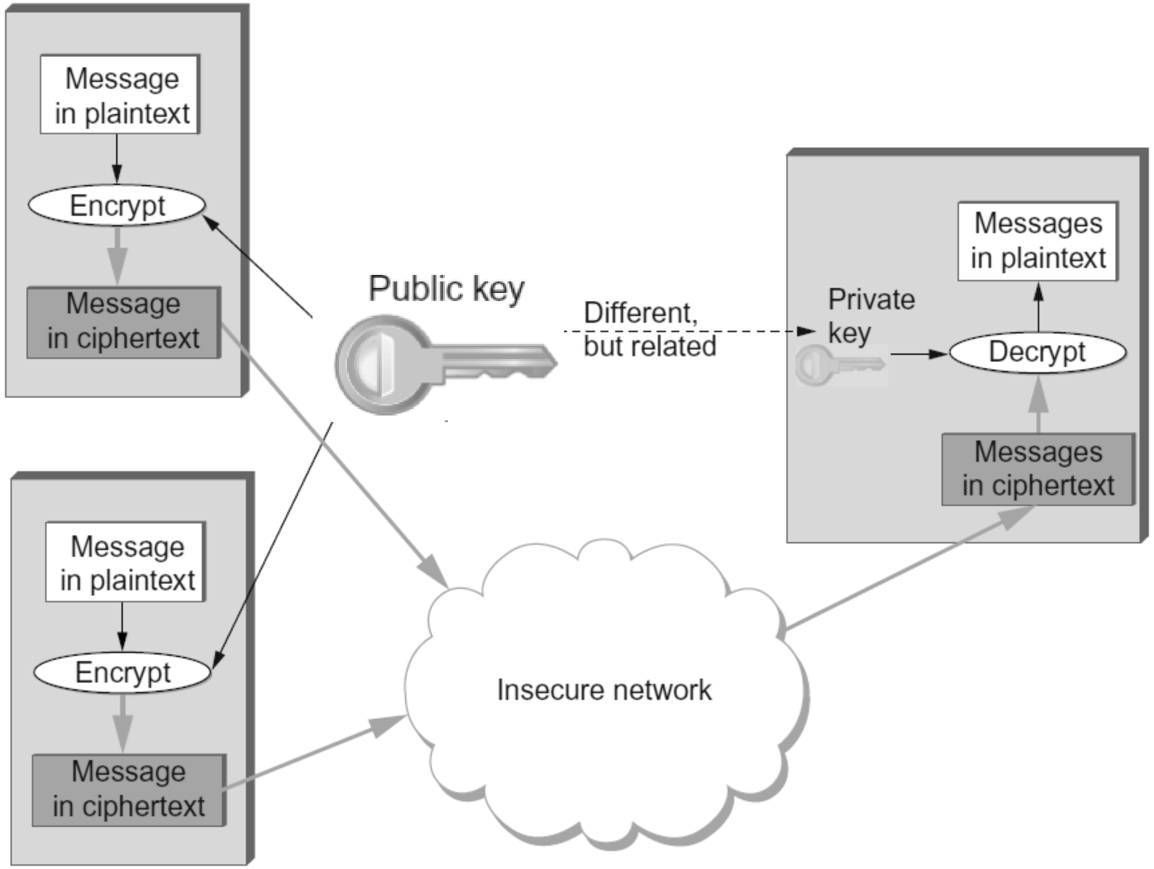
Public-Key Cipher

- If the message is encrypted with the public key
  - The message can only be decrypted with the paired private key

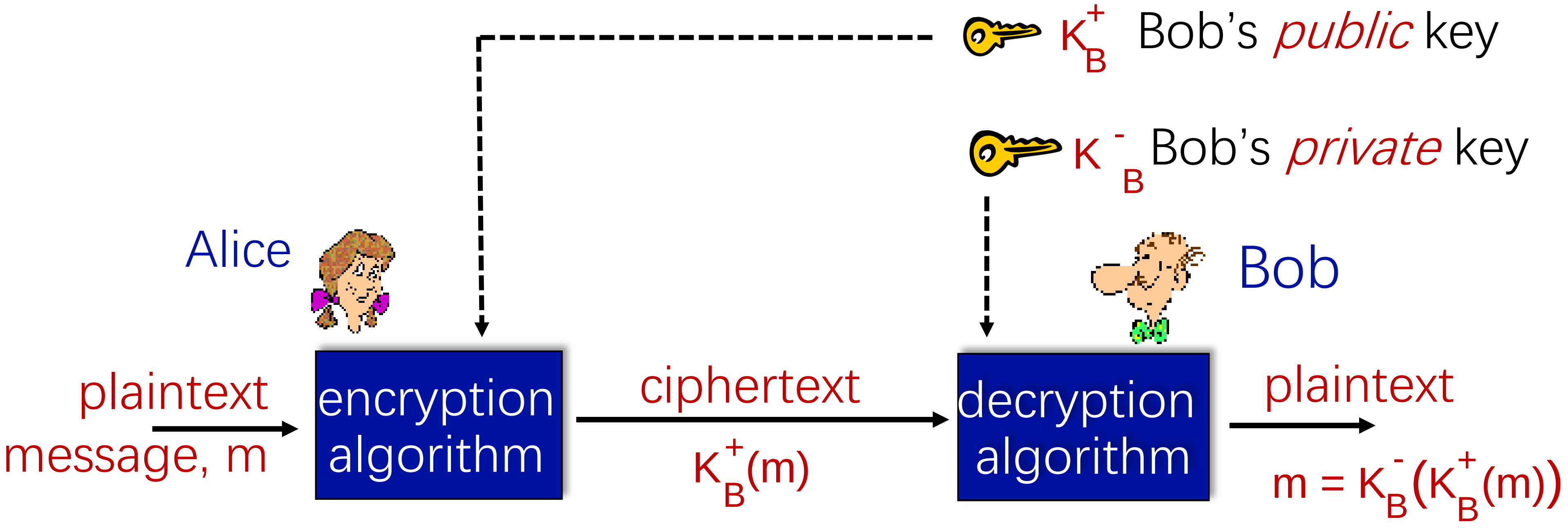


Public-Key Cipher

- For key sharing: the public key can be released to everyone !



Public-Key Cipher



Public-Key Cipher

Requirements:

1. need $K_B^+(.)$ and $K_B^-(.)$ such that

$$K_B^-(K_B^+(m)) = m$$

2. given public key K_B^+, it should be impossible to compute private key K_B^-

Public-Key Cipher

- Example:
  - RSA (Rivest, Shamir, Adelson algorithm)
  - Elliptic Curve Cryptography

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➢Authentication

- To confirm identity of each other

- Timeliness
    - To identify delayed messages

Guarantee	Primitive
Confidentiality	Encryption
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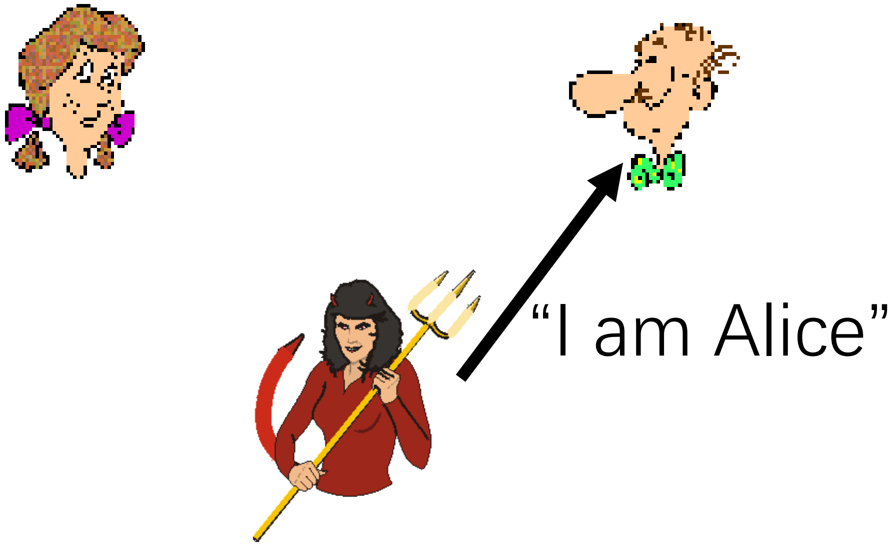
Authentication

Goal: Bob wants Alice to “prove” her identity to him

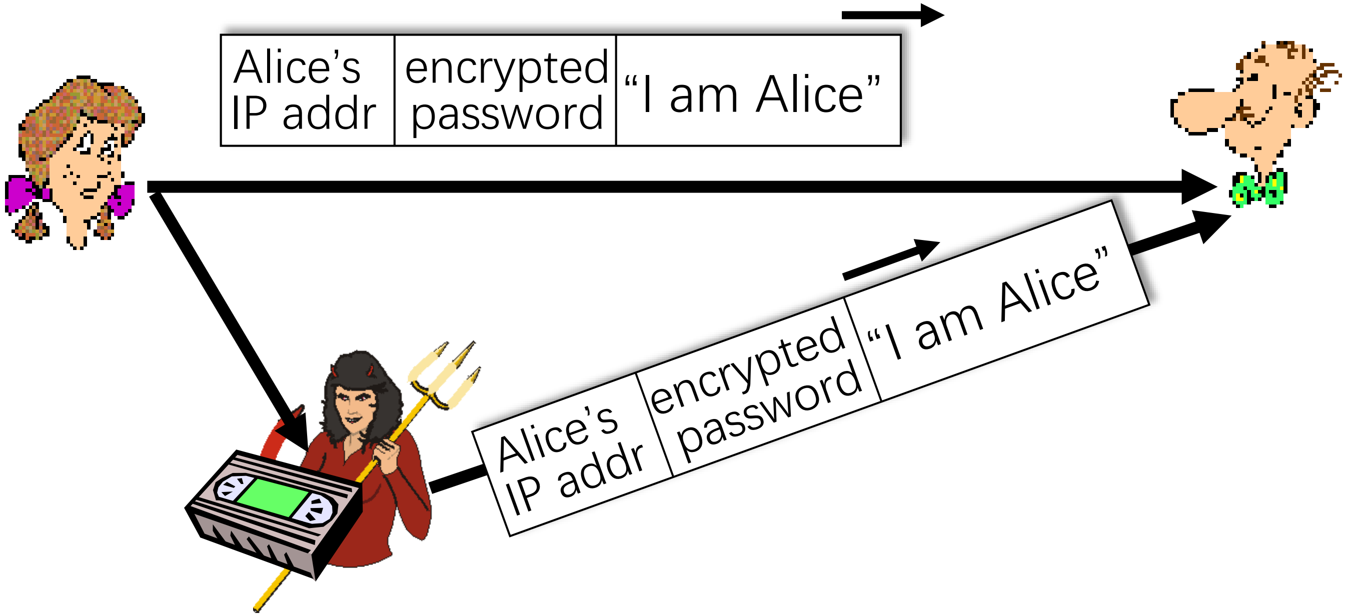
“I am Alice”



“I am Alice”

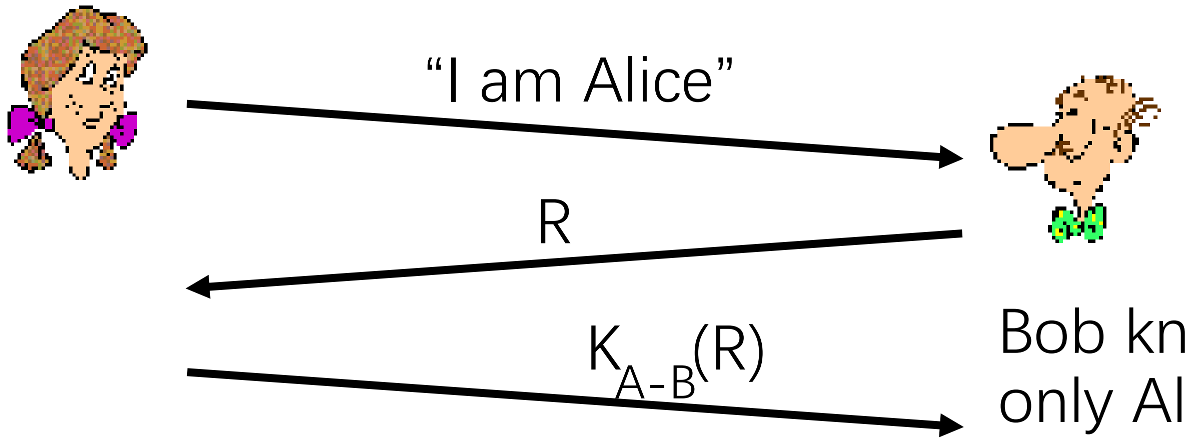
Authentication

- Solution v1
  - Alice says “I am Alice” and sends her encrypted secret password to “prove” it.
  - Problem: replay



Authentication

- Solution v2
  - + challenge with a nonce
  - Need symmetric key



"I am Alice"

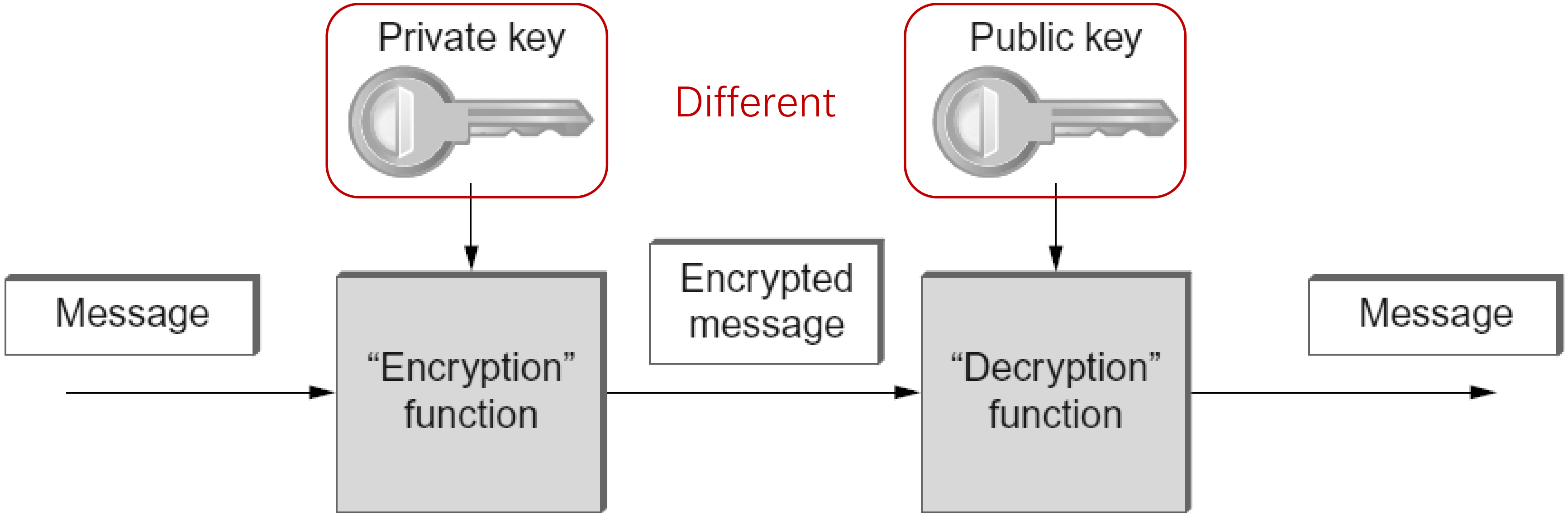
R

$K_{A-B}(R)$

Bob know Alice is live, and only Alice knows key to encrypt nonce, so it must be Alice!

Public-Key Cipher

- If the message is encrypted with the private key
  - The message can only be decrypted with the paired public key



Authentication

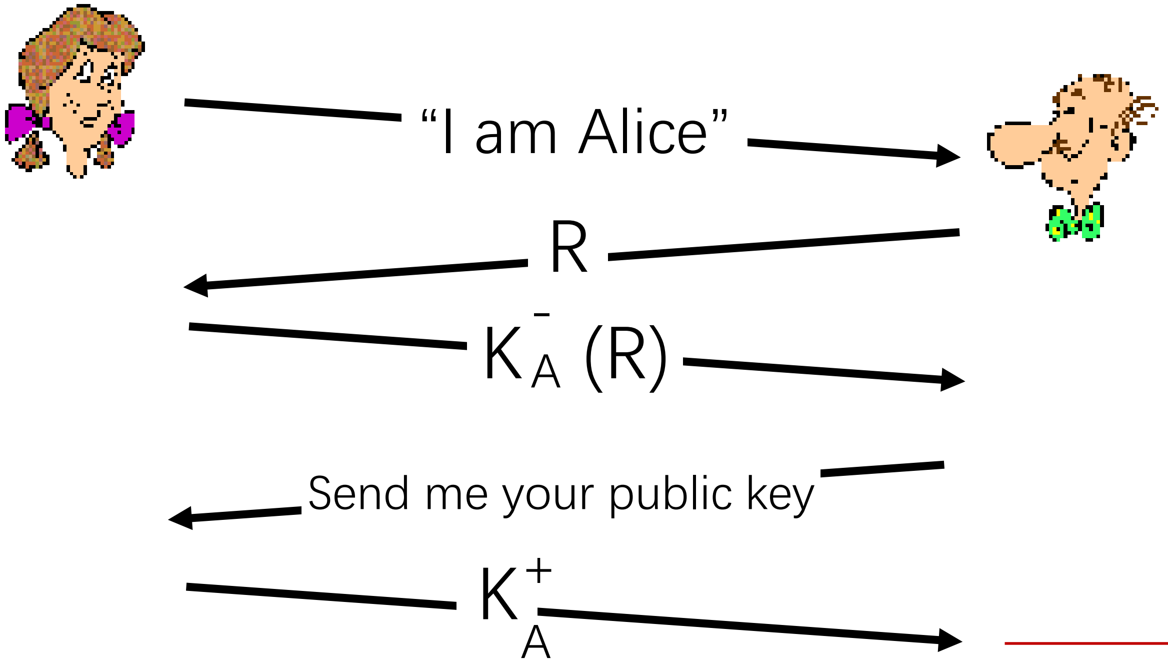
- Solution v3
  - Change to public cypher
  - Fact:

$$\underbrace{K_B^-(K_B^+(m))}_{\substack{\text{use public key}\\ \text{first, followed}\\ \text{by private key}}} = m = \underbrace{K_B^+(K_B^-(m))}_{\substack{\text{use private key}\\ \text{first, followed}\\ \text{by public key}}}$$

result is the same!

Authentication

- Solution v3
  - Change to public cypher



"I am Alice"

R

$K_A^-(R)$

Send me your public key

K_A^+

Bob computes

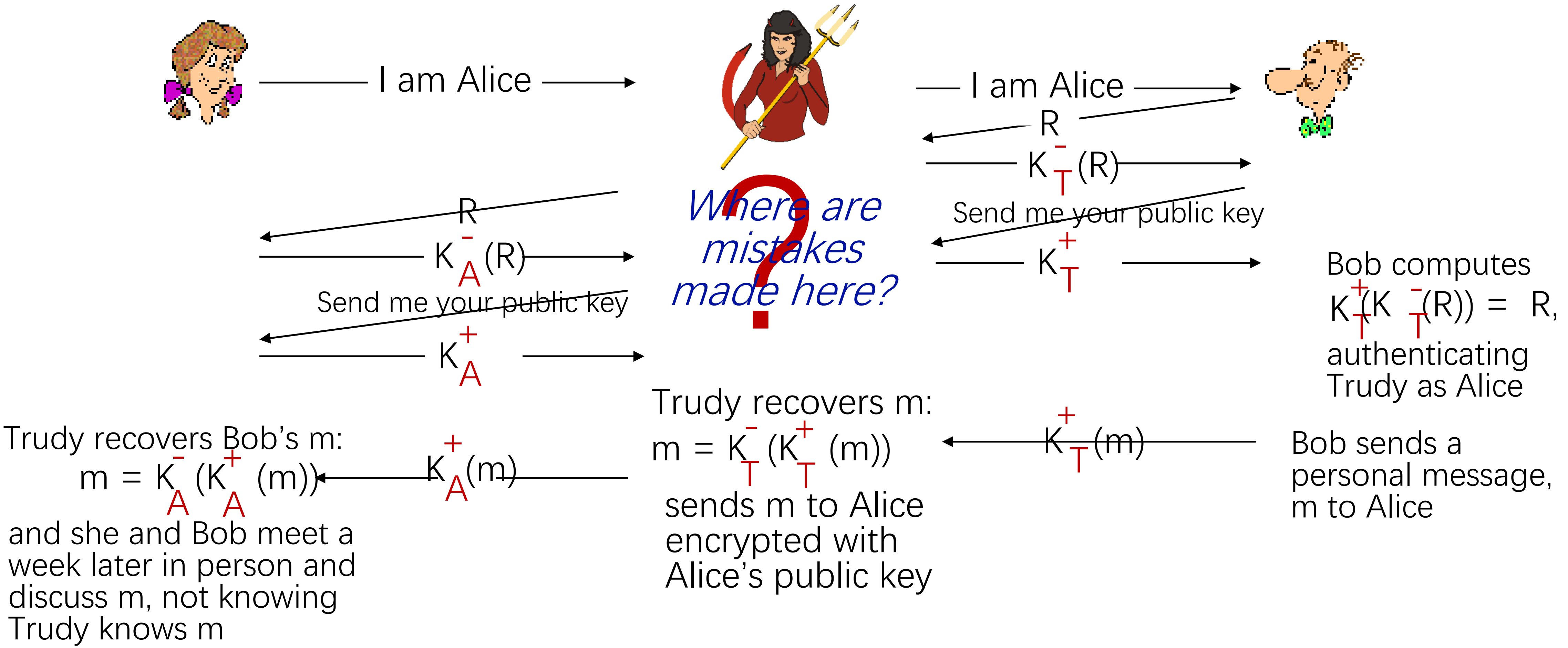
$K_A^+(K_A^-(R)) = R$

and knows only Alice could have the private key, that encrypted R such that

$K_A^+(K_A^-(R)) = R$

Authentication

- Solution v3
  - Still has a flaw: man in the middle !



I am Alice

R

$K_A^-(R)$

Send me your public key

K_A^+

I am Alice

R

$K_T^-(R)$

Send me your public key

K_T^+

Where are mistakes made here?

Bob computes $K_T^+(K_T^-(R)) = R$, authenticating Trudy as Alice

Bob sends a personal message, m to Alice

$K_T^+(m)$

Trudy recovers m: $m = K_T^-(K_T^+(m))$

sends m to Alice encrypted with Alice's public key

$K_A^+(m)$

Trudy recovers Bob's m: $m = K_A^-(K_A^+(m))$

and she and Bob meet a week later in person and discuss m, not knowing Trudy knows m

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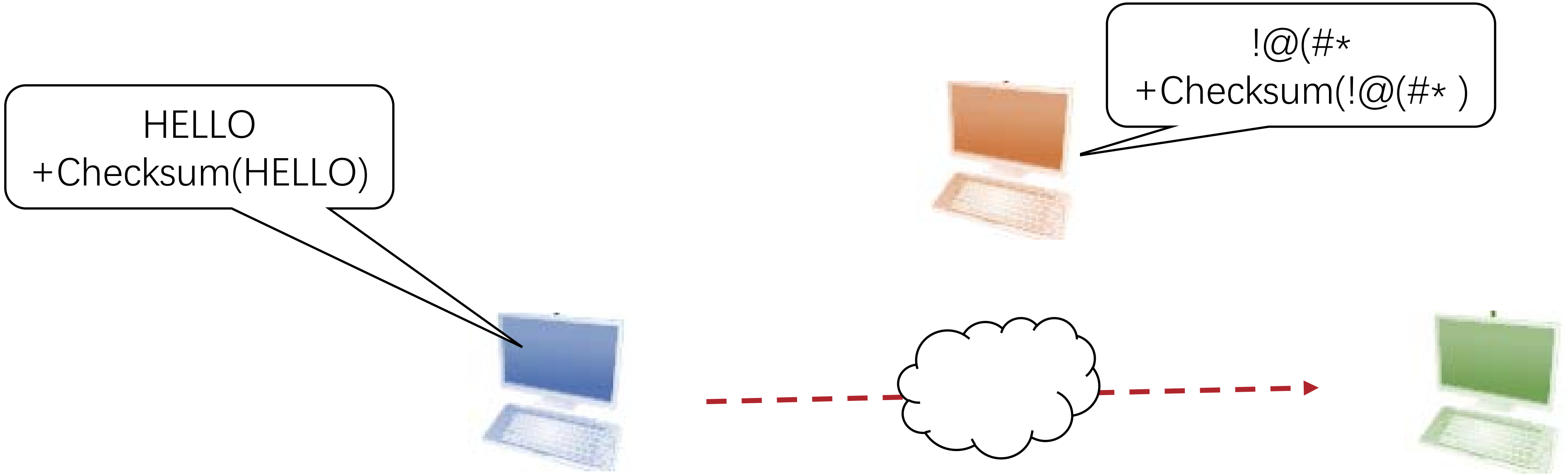
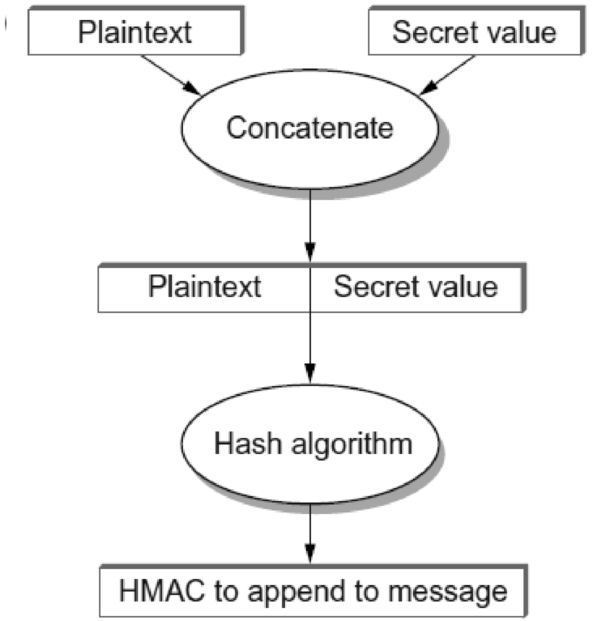
Data Integrity: Checksum

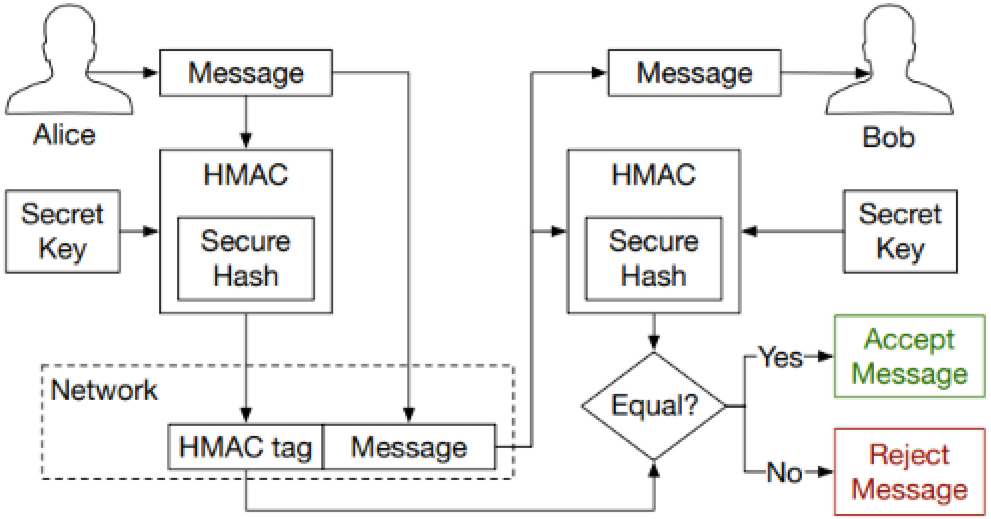
- Checksum can be replicated



Cryptographic Hash

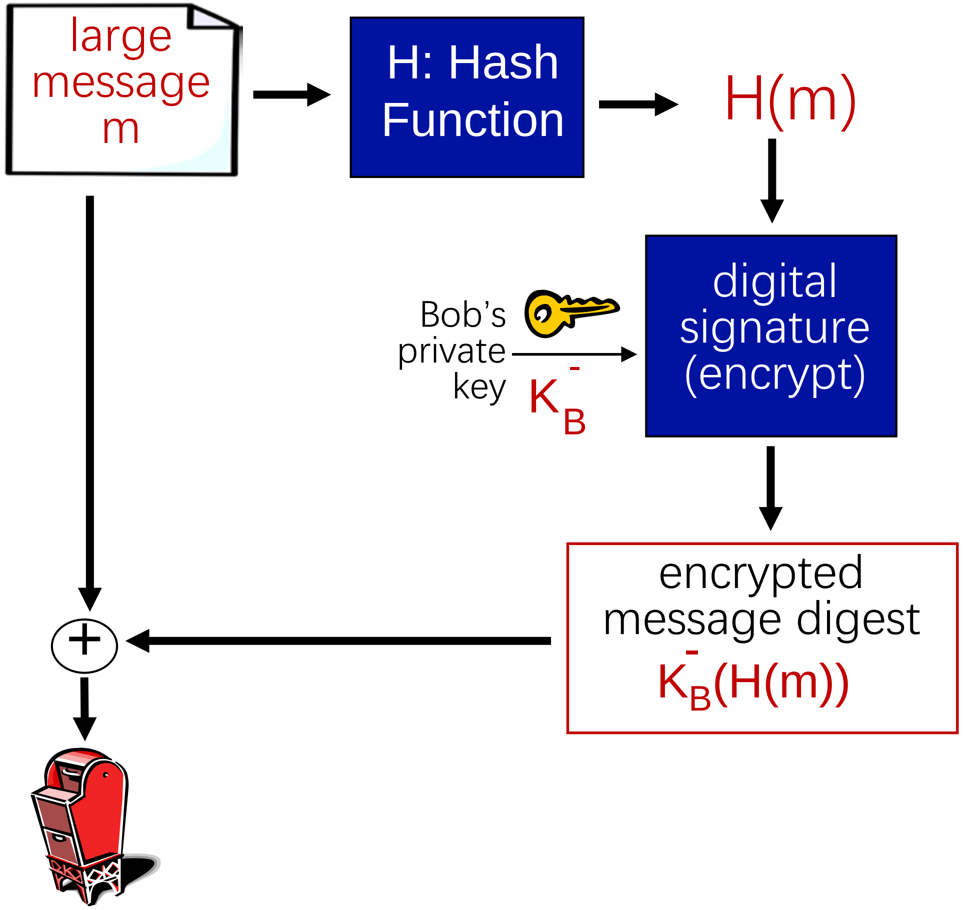
- Cryptographic Hash
  - Example
    - MD5
    - SHA
- HMAC
  - Hash Massage Authentication Code
  - Use Cryptographic Hash Function to generate integrity and authentication check for the message.
- Digital Signature
  - Fixed-length, easy- to-compute digital "fingerprint"
  - Apply hash function H to *m*, get fixed size message digest, *H(m)*
  - use private key to sign the hash



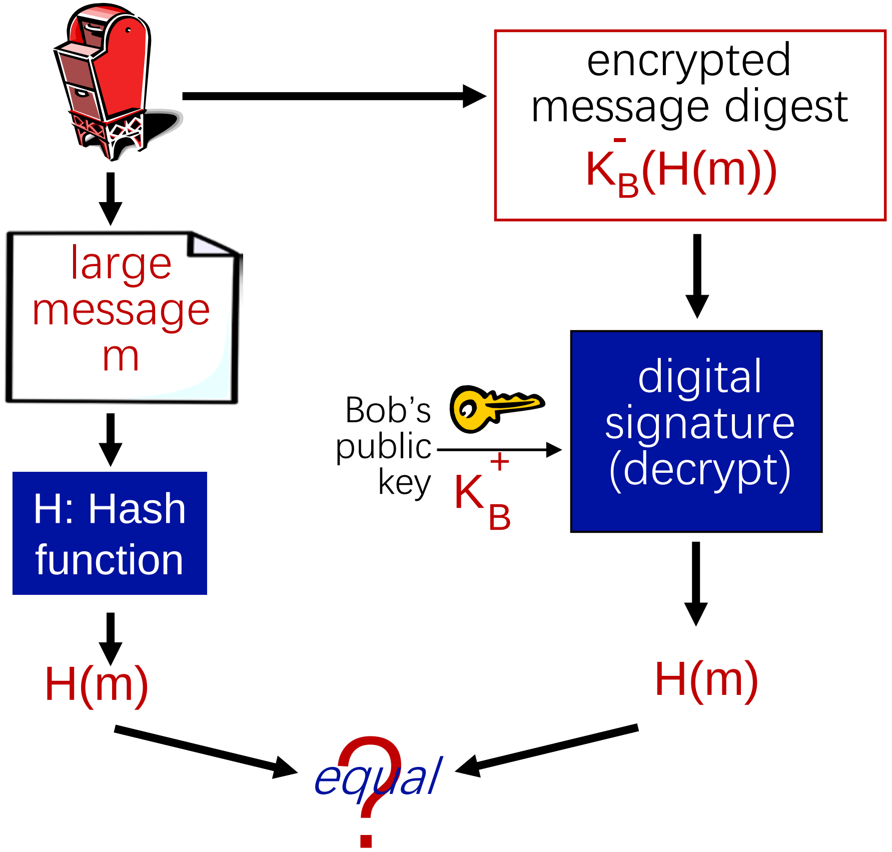


Digital Signature

Bob sends digitally signed message:

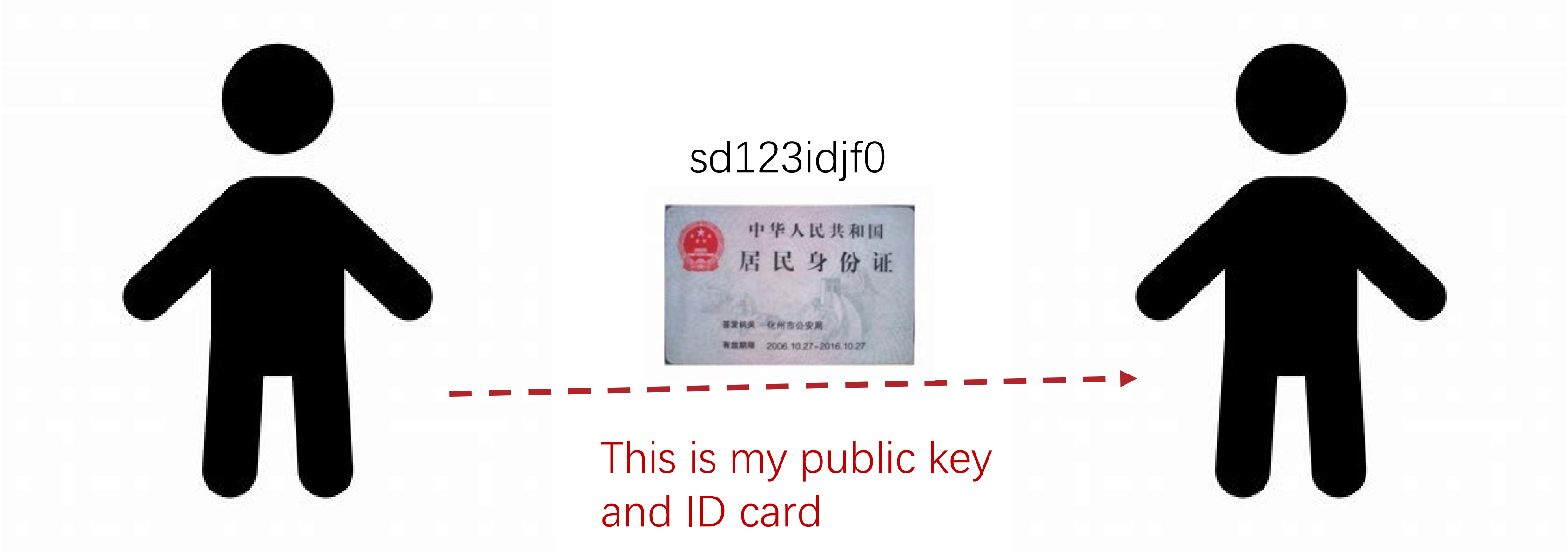


Alice verifies signature, integrity of digitally signed message:



Key Predistribution

- Distribute through Offline Channel
  - Not scalable

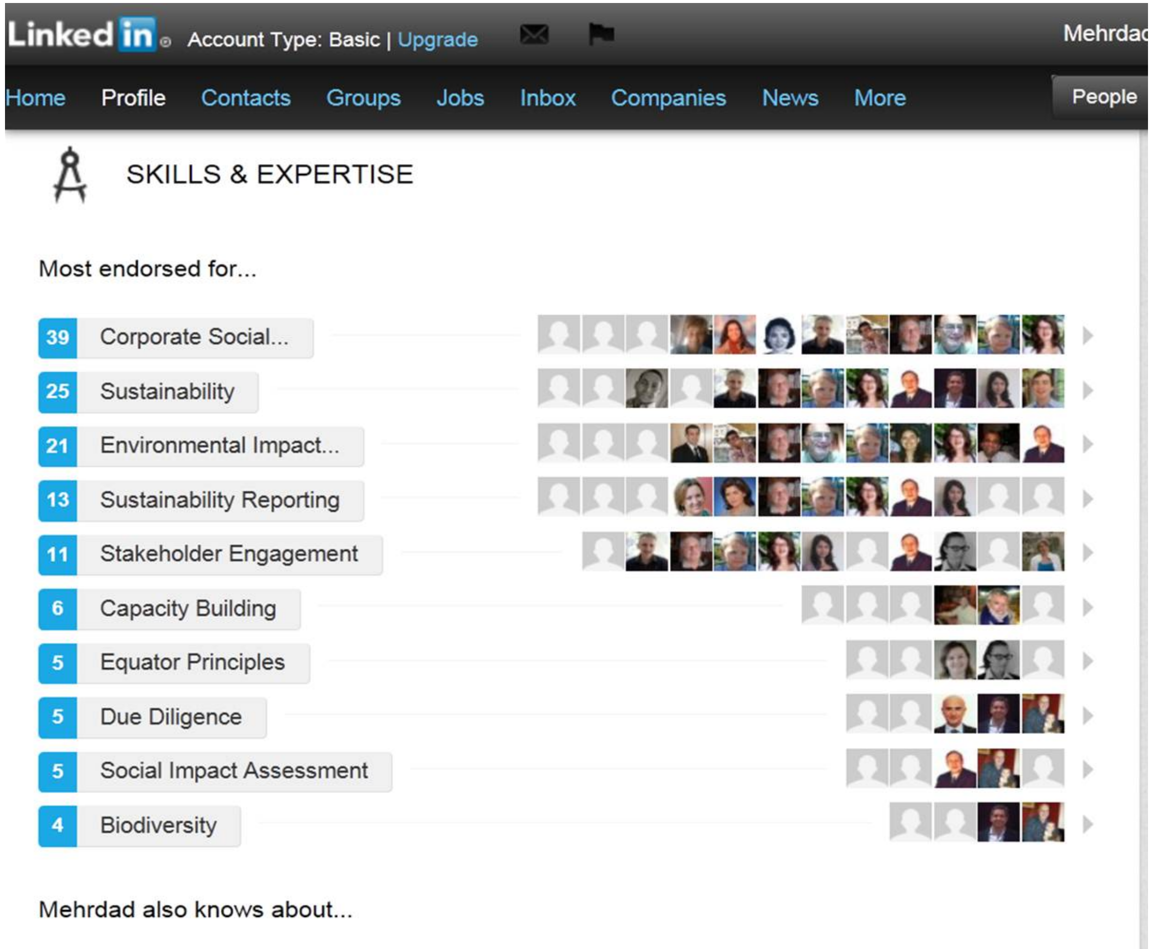


sd123idjf0

This is my public key
and ID card

Public-Key Predistribution

- Endorsement



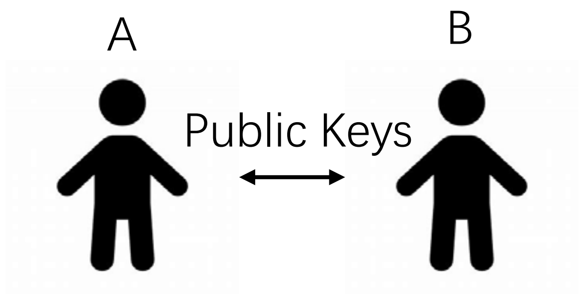
SKILLS & EXPERTISE

Most endorsed for...

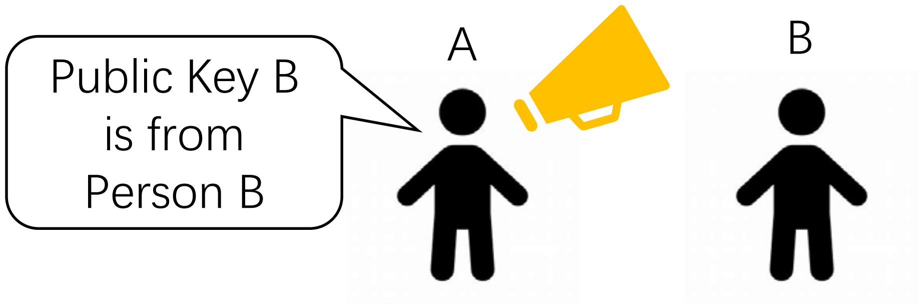
39	Corporate Social...
25	Sustainability
21	Environmental Impact...
13	Sustainability Reporting
11	Stakeholder Engagement
6	Capacity Building
5	Equator Principles
5	Due Diligence
5	Social Impact Assessment
4	Biodiversity

Mehrdad also knows about...

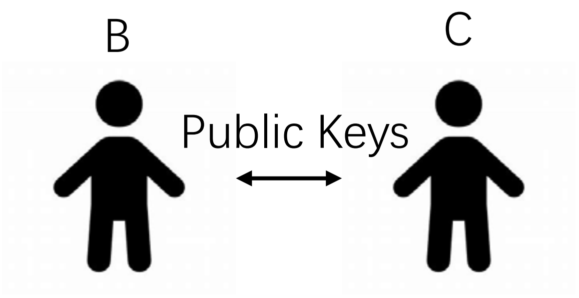
Public-Key Predistribution



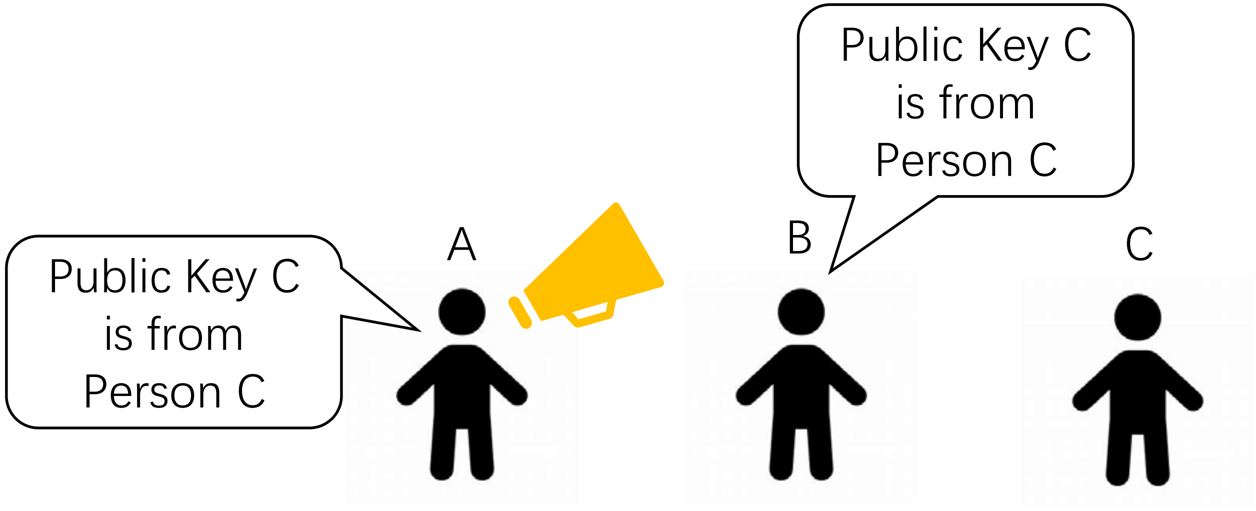
Step 1. Verify Each Other Offline;
Exchange Public Keys



Step 2. Certifies Public Keys



Step 3. Verify Each Other Offline;
Exchange Public Keys



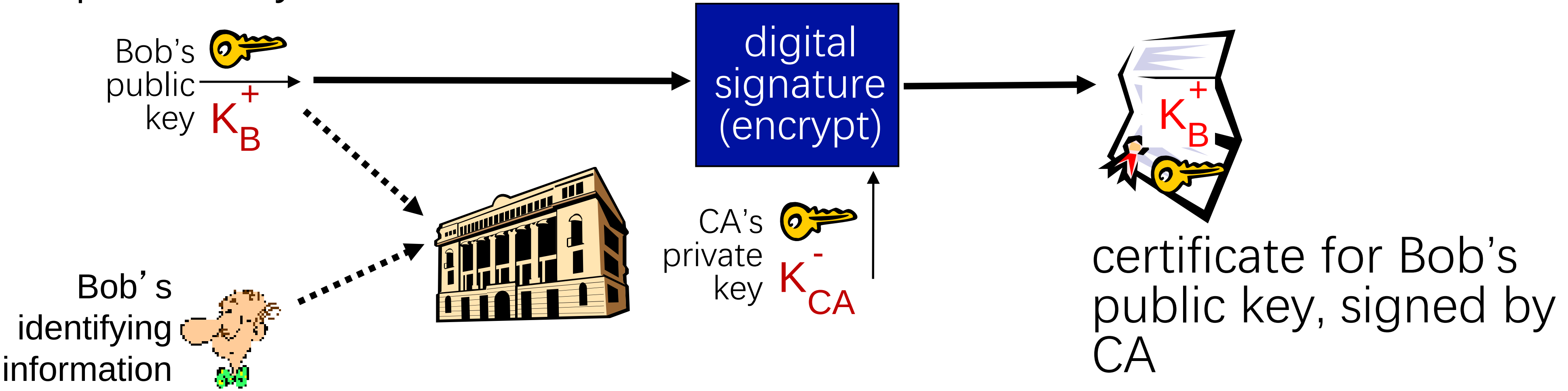
Step 4. Certifies Public Keys from Others

Public-Key Predistribution

- Certificate Authority (CA)
  - Preinstall trusted public keys
- Web of Trust
  - Collect public keys from known people

Public-Key Certification Authorities (CA)

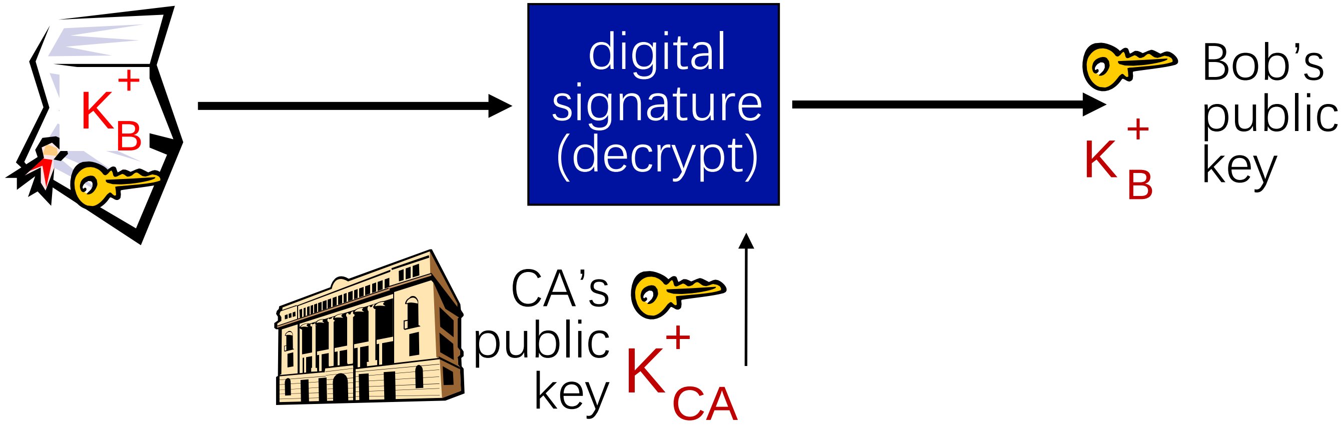
- Certification authority (CA): binds public key to particular entity E
- Entity (person, website, router) registers its public key, provides "proof of identity" to CA
  - CA creates certificate binding identity E to E's public key
  - Certificate containing E's public key digitally signed by CA: CA says "this is E's public key"


Bob's public key K_B^+
digital signature (encrypt)
CA's private key K_{CA}^-
K_B^+
Bob's identifying information

certificate for Bob's public key, signed by CA

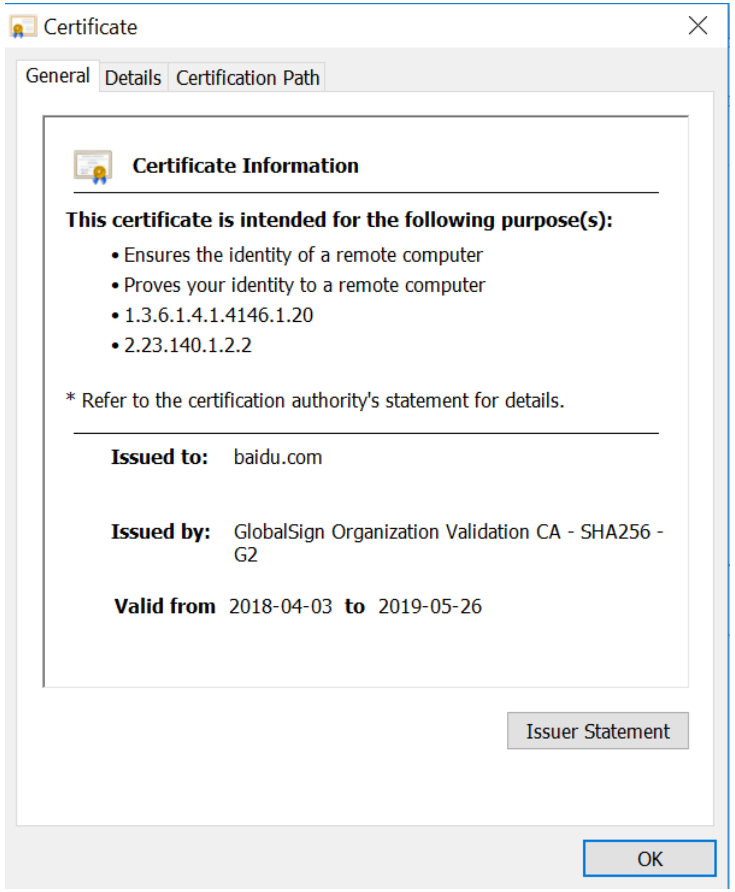
Public-Key Certification Authorities (CA)

- When Alice wants Bob’s public key:
  - gets Bob’s certificate (from Bob or elsewhere)
  - apply CA’s public key to Bob’s certificate, get Bob’s public key



Public-Key Predistribution

- Certificate



This certificate is intended for the following purpose(s):

- Ensures the identity of a remote computer
- Proves your identity to a remote computer
- 1.3.6.1.4.1.4146.1.20
- 2.23.140.1.2.2

* Refer to the certification authority's statement for details.

Issued to: baidu.com

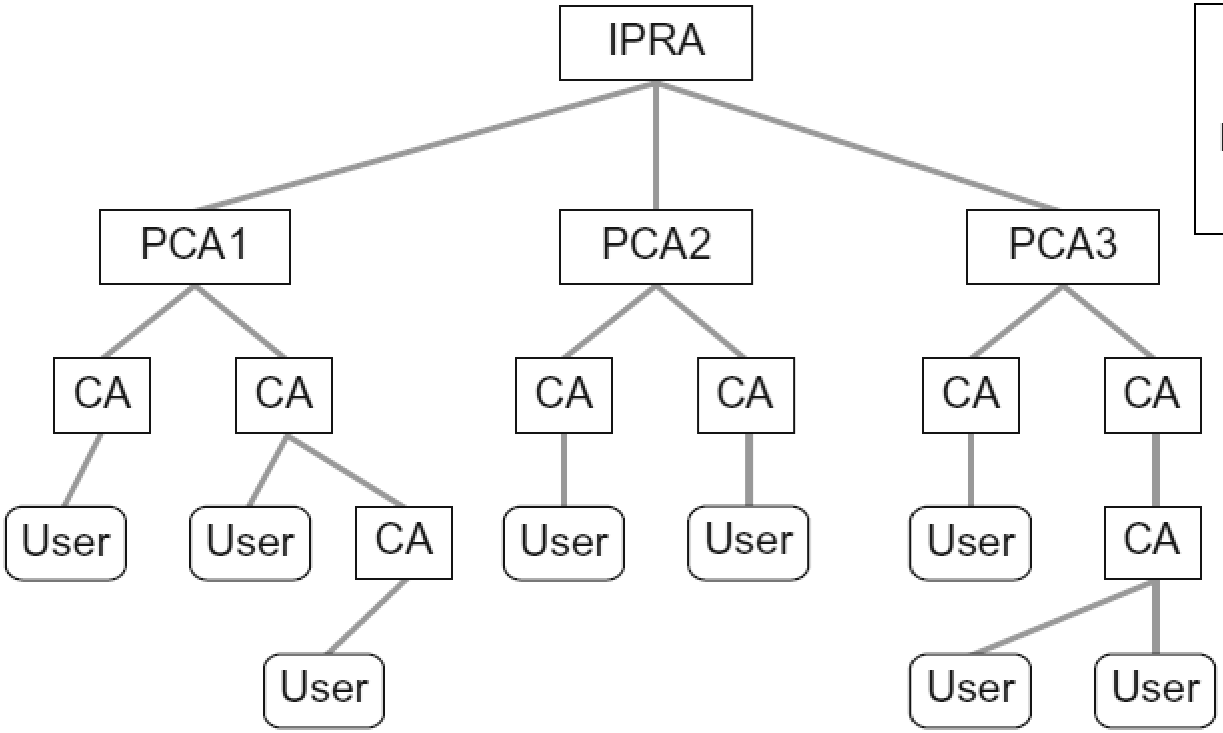
Issued by: GlobalSign Organization Validation CA - SHA256 - G2

Valid from 2018-04-03 **to** 2019-05-26

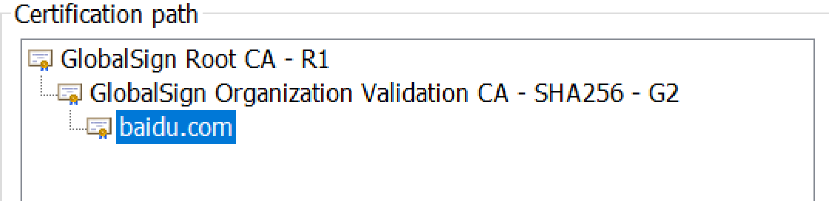
- Contains
  - The identity of the entity being certified
  - The public key of the entity being certified
  - The identity of the signer
  - The digital signature of the signer
  - A digital signature algorithm identifier (which cryptographic hash and which cipher)

Public-Key Predistribution

- Certificate Authority (CA)

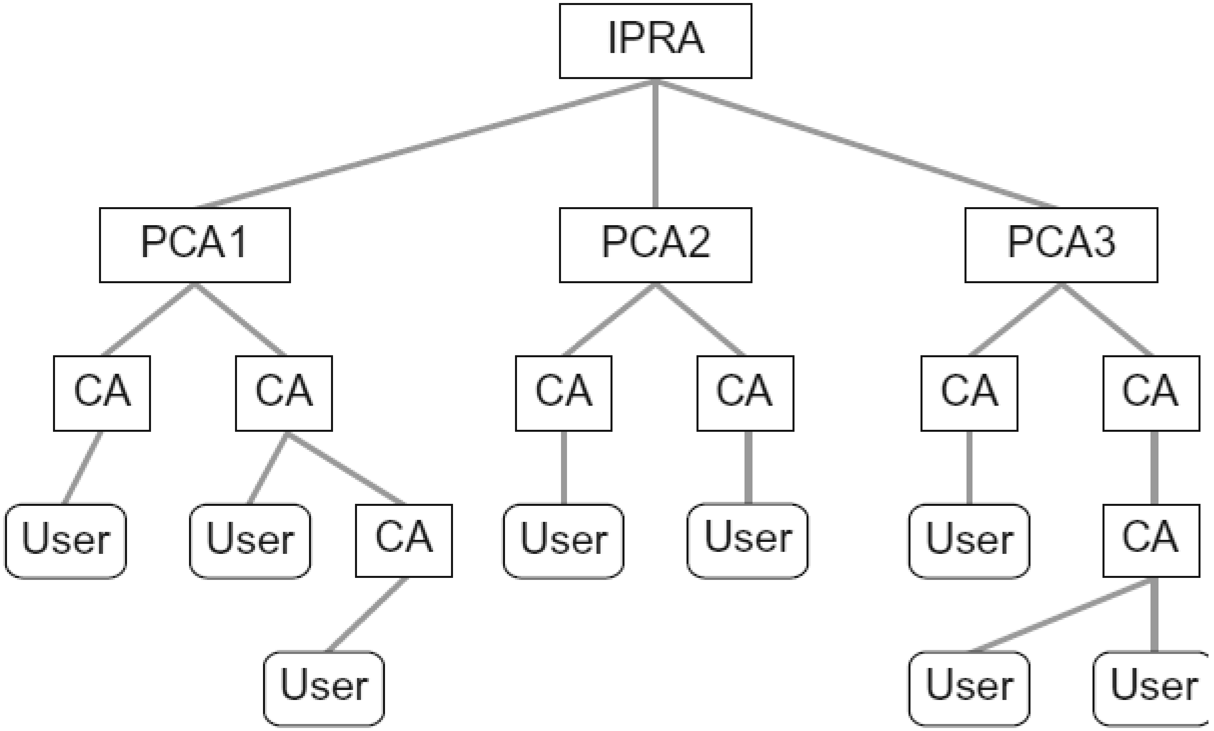


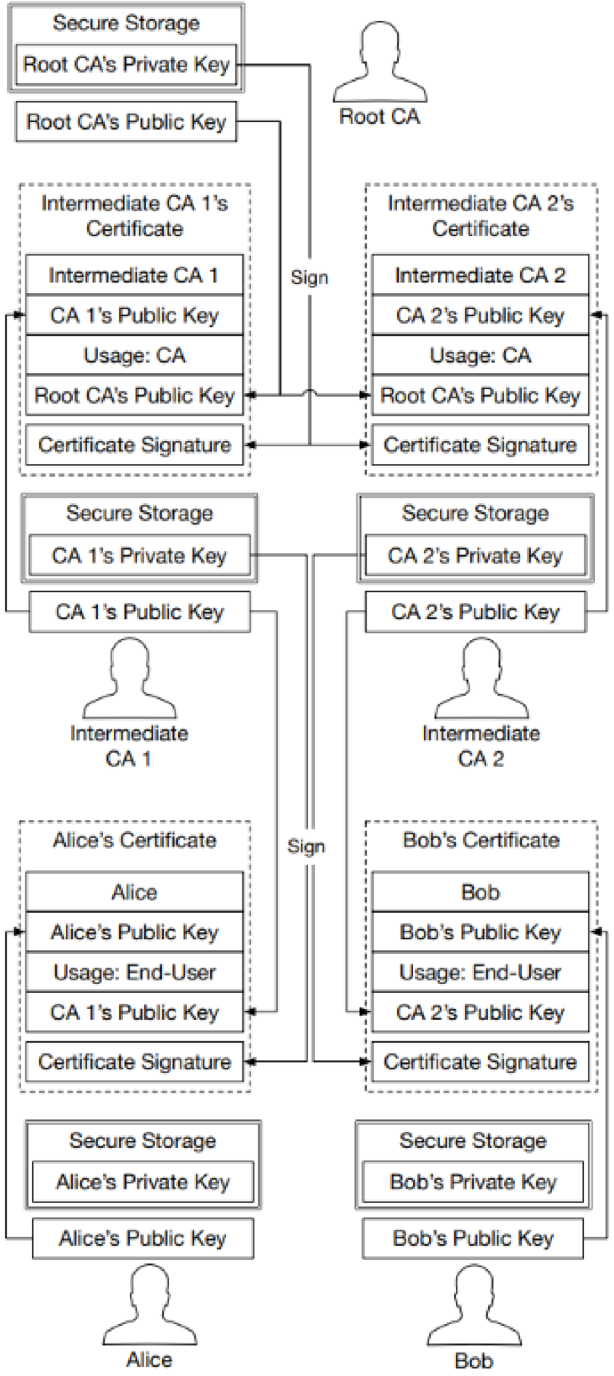
IPRA = Internet Policy Registration Authority (root)
PCA*n* = Policy certification authority
CA = Certification authority


Certification path

- GlobalSign Root CA - R1
  - GlobalSign Organization Validation CA - SHA256 - G2
    - baidu.com

Public-Key Predistribution





Demo

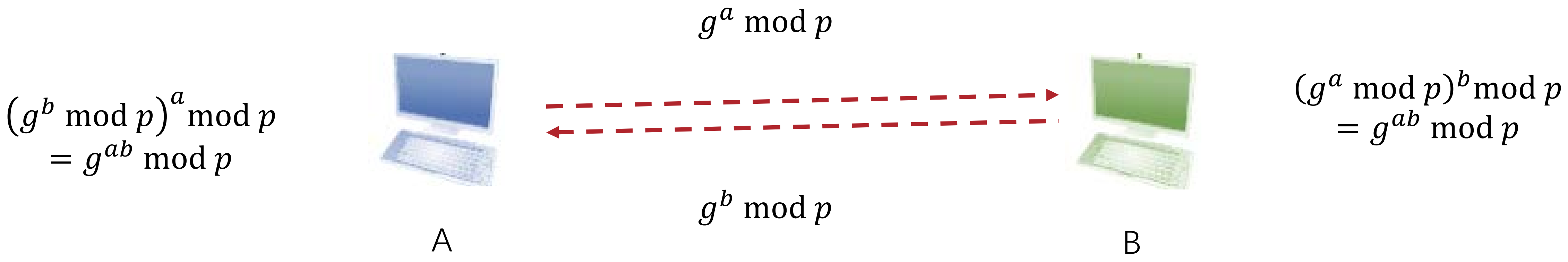
- Certificate Authority (CA)
  - certmgr.msc
  - https://www.sinorailca.com/

Symmetric-Key Predistribution

- Through Trust Server
- Through Public-Key Predistribution

Diffie-Hellman Key Exchange

- Generate shared key without key predistribution
  - a is the secret of A
  - b is the secret of B
  - g and p are public known
  - g^ab mod p is the shared key



$g^a \bmod p$

$(g^b \bmod p)^a \bmod p$
$= g^{ab} \bmod p$

$(g^a \bmod p)^b \bmod p$
$= g^{ab} \bmod p$

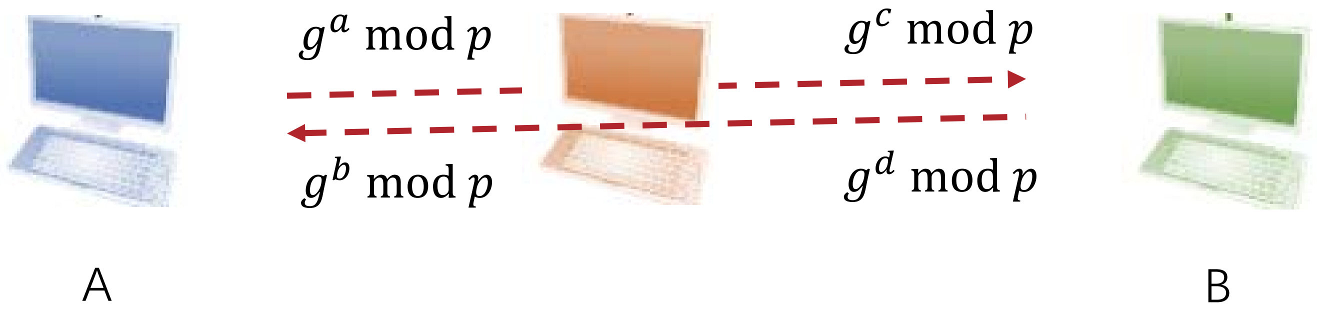
$g^b \bmod p$

A

B

Diffie-Hellman Key Exchange

- Man in the middle attack
  - A cannot authenticate he is talking with B
- Diffie-Hellman Key Exchange is not secure without authentication



Reference

- Textbook 8.1, 8.2, 8.3
- Some slides are adapted from http://www-net.cs.umass.edu/kurose_ross/ppt.htm by Kurose Ross