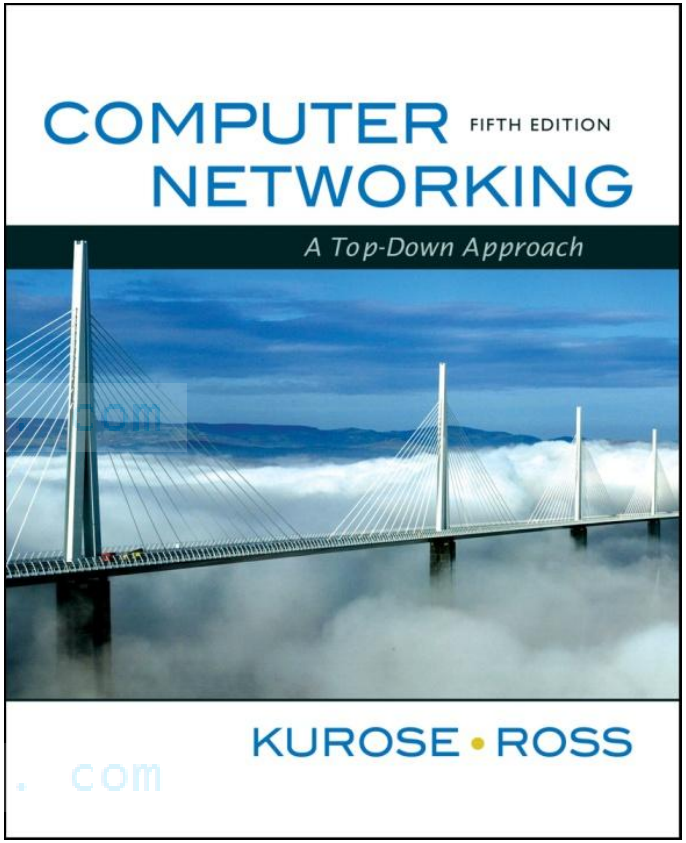
Computer Networks 1 (Mạng Máy Tính 1)

Lectured by: Dr. Phạm Trần Vũ

Chapter 8
Network Security

Computer Networking: A Top Down Approach ,
5th edition.
Jim Kurose, Keith Ross
Addison-Wesley, April 2009.



Chapter 8: Network Security

Chapter goals:

- understand principles of network security:
  - cryptography and its *many* uses beyond "confidentiality"
  - authentication
  - message integrity
- security in practice:
  - firewalls and intrusion detection systems
  - security in application, transport, network, link layers

Chapter 8 roadmap

8.1 What is network security?
8.2 Principles of cryptography
8.3 Message integrity
8.4 Securing e-mail
8.5 Securing TCP connections: SSL
8.6 Network layer security: IPsec
8.7 Securing wireless LANs
8.8 Operational security: firewalls and IDS

What is network security?

Confidentiality: only sender, intended receiver should "understand" message contents

- sender encrypts message
- receiver decrypts message

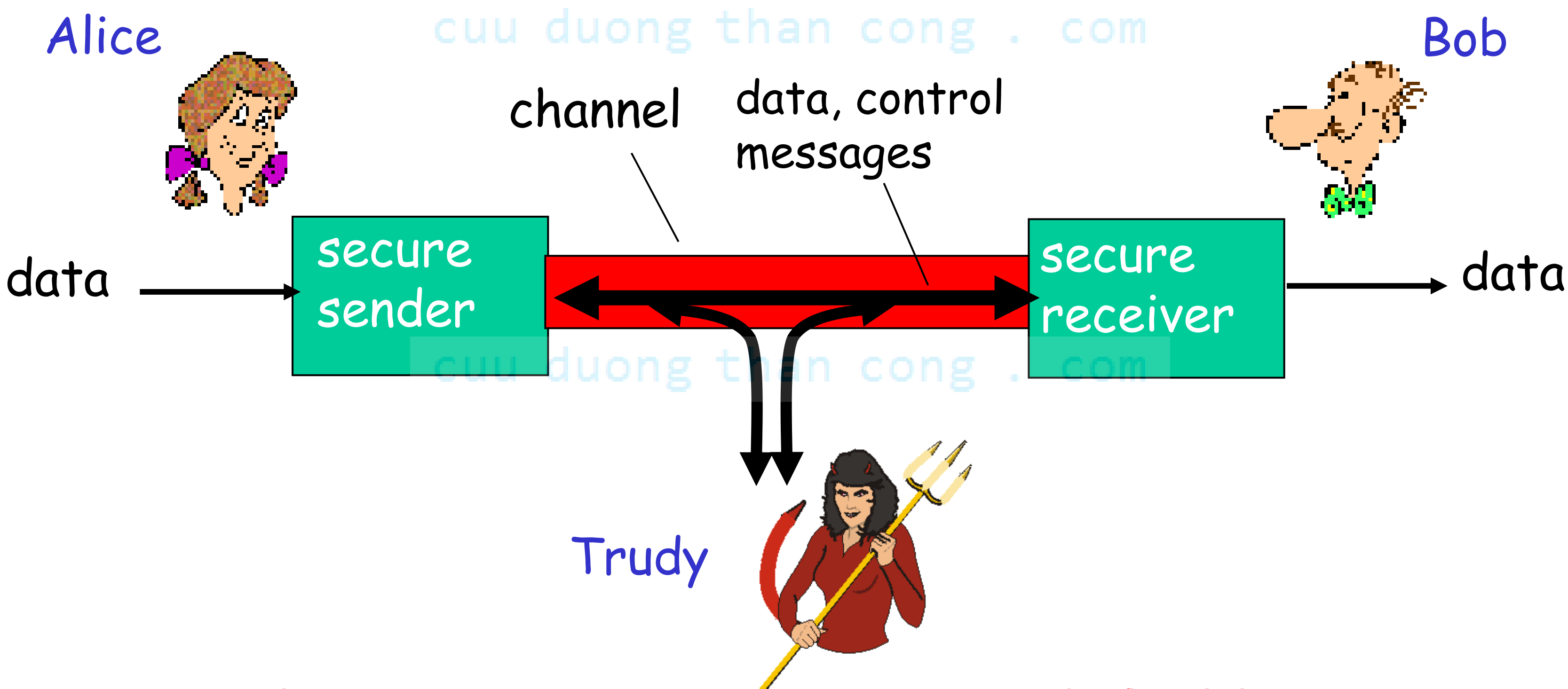
Authentication: sender, receiver want to confirm identity of each other

Message integrity: sender, receiver want to ensure message not altered (in transit, or afterwards) without detection

Access and availability: services must be accessible and available to users

Friends and enemies: Alice, Bob, Trudy

- well-known in network security world
- Bob, Alice (lovers!) want to communicate "securely"
- Trudy (intruder) may intercept, delete, add messages



Who might Bob, Alice be?

- ... well, *real-life* Bobs and Alices!
- Web browser/server for electronic transactions (e.g., on-line purchases)
- on-line banking client/server
- DNS servers
- routers exchanging routing table updates
- other examples?

There are bad guys (and girls) out there!

Q: What can a "bad guy" do?

A: A lot! See section 1.6

- *eavesdrop:* intercept messages
- actively *insert* messages into connection
- *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*: prevent service from being used by others (e.g., by overloading resources)

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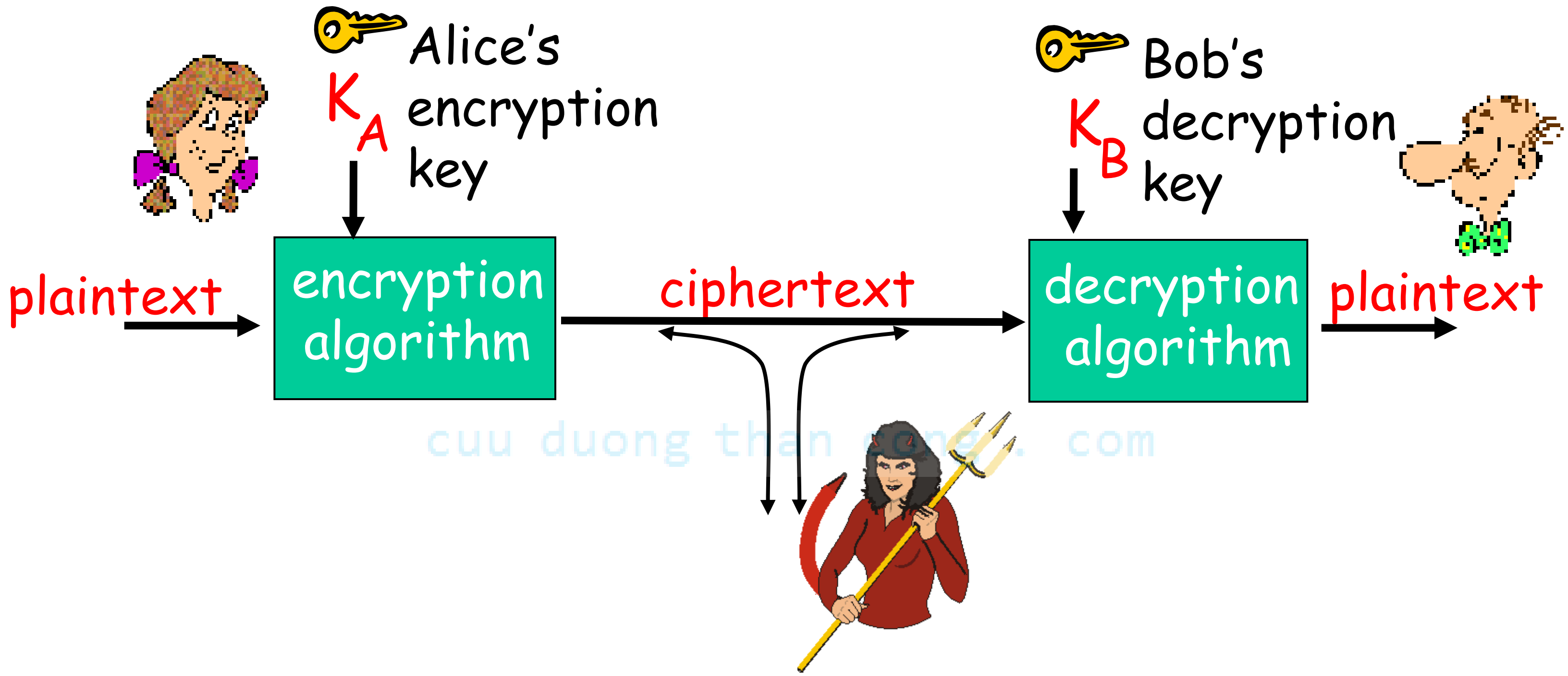
The language of cryptography



m plaintext message

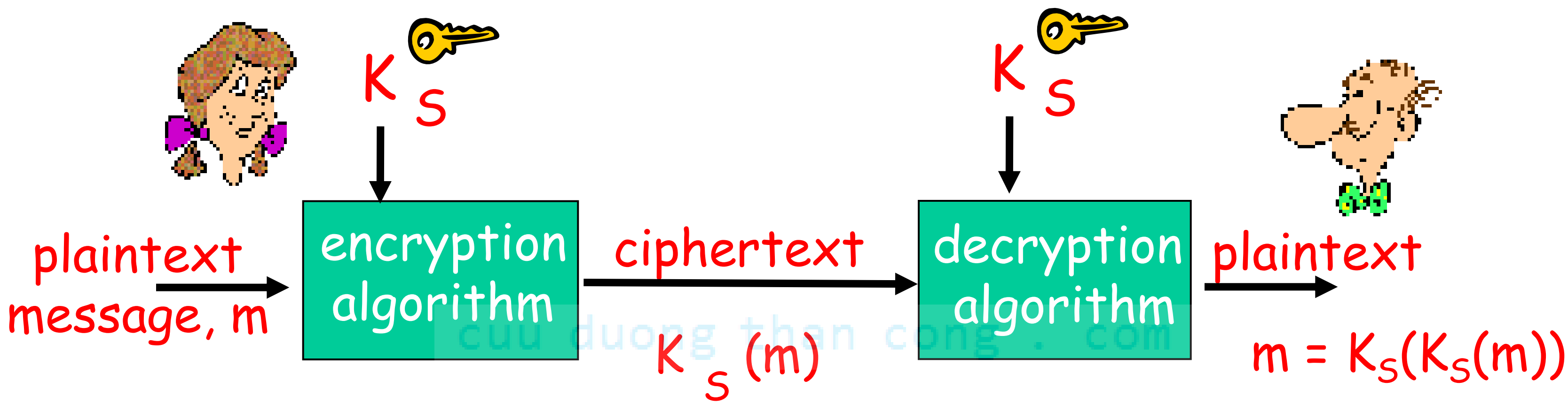
$K_A(m)$ ciphertext, encrypted with key K_A

$m = K_B(K_A(m))$

Types of Cryptography

- Crypto often uses keys:
  - Algorithm is known to everyone
  - Only "keys" are secret
- Public key cryptography
  - Involves the use of two keys
- Symmetric key cryptography
  - Involves the use one key
- Hash functions
  - Involves the use of no keys
  - Nothing secret: How can this be useful?

Symmetric key cryptography



symmetric key crypto: Bob and Alice share same (symmetric) key: K_S

- e.g., key is knowing substitution pattern in mono alphabetic substitution cipher

Q: how do Bob and Alice agree on key value?

Symmetric key crypto: DES

DES: Data Encryption Standard

- US encryption standard [NIST 1993]
- 56-bit symmetric key, 64-bit plaintext input
- Block cipher with cipher block chaining
- How secure is DES?
  - DES Challenge: 56-bit-key-encrypted phrase decrypted (brute force) in less than a day
  - No known good analytic attack
- making DES more secure:
  - 3DES: encrypt 3 times with 3 different keys (actually encrypt, decrypt, encrypt)

AES: Advanced Encryption Standard

- new (Nov. 2001) symmetric-key NIST standard, replacing DES
- processes data in 128 bit blocks
- 128, 192, or 256 bit keys
- brute force decryption (try each key) taking 1 sec on DES, takes 149 trillion years for AES

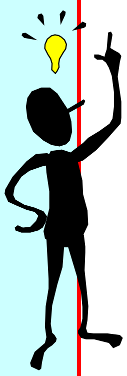
Public Key Cryptography

symmetric key crypto

- requires sender, receiver know shared secret key
- Q: how to agree on key in first place (particularly if never "met")?

public key cryptography

- radically different approach [Diffie-Hellman76, RSA78]
- sender, receiver do *not* share secret key
- *public* encryption key known to *all*
- *private* decryption key known only to receiver



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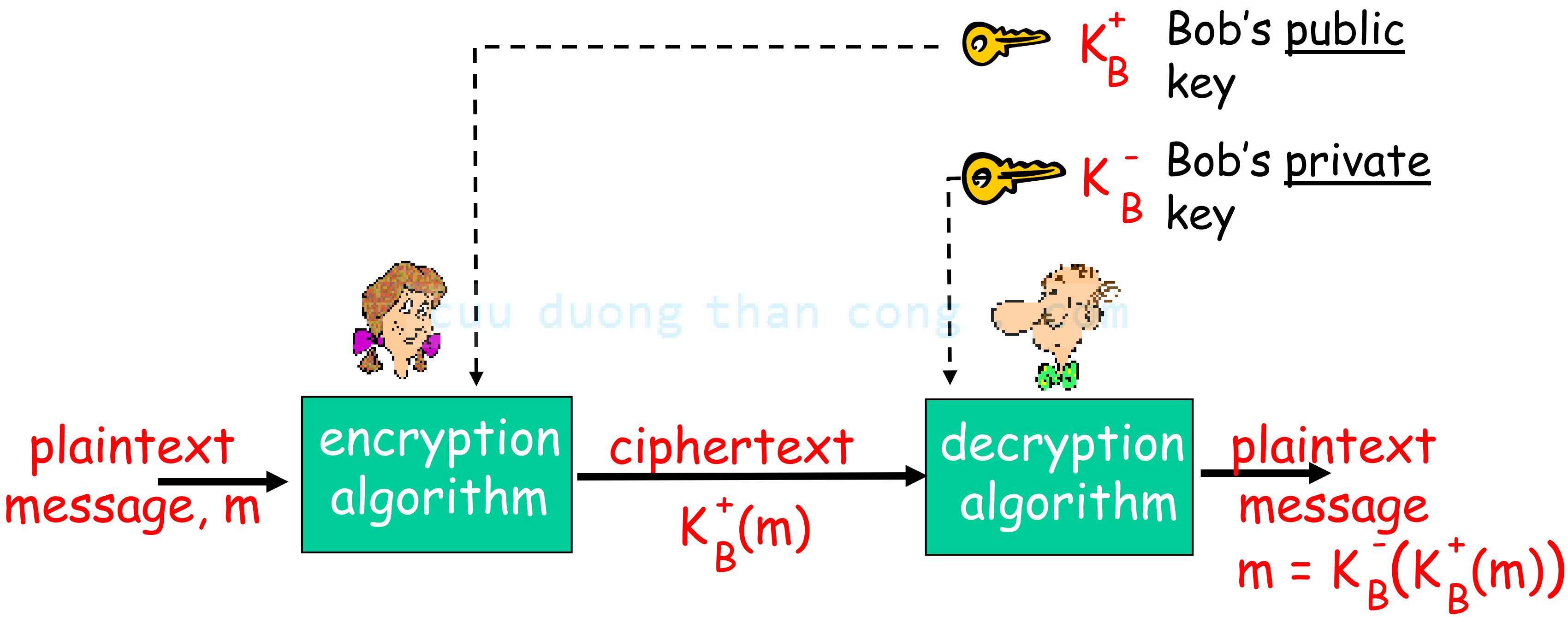
Public key cryptography



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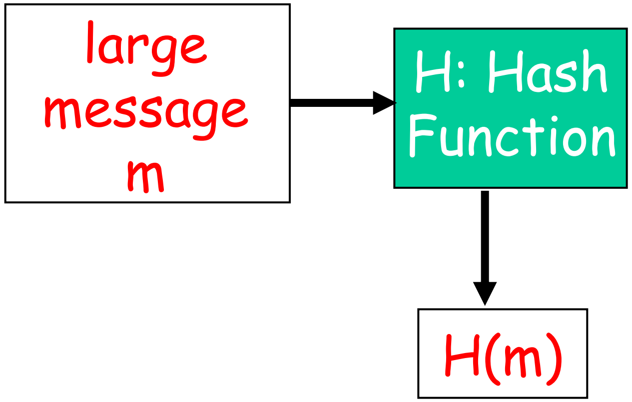
Message Integrity

- Allows communicating parties to verify that received messages are authentic.
  - Content of message has not been altered
  - Source of message is who/what you think it is
  - Message has not been replayed
  - Sequence of messages is maintained
- Let's first talk about message digests

Message Digests

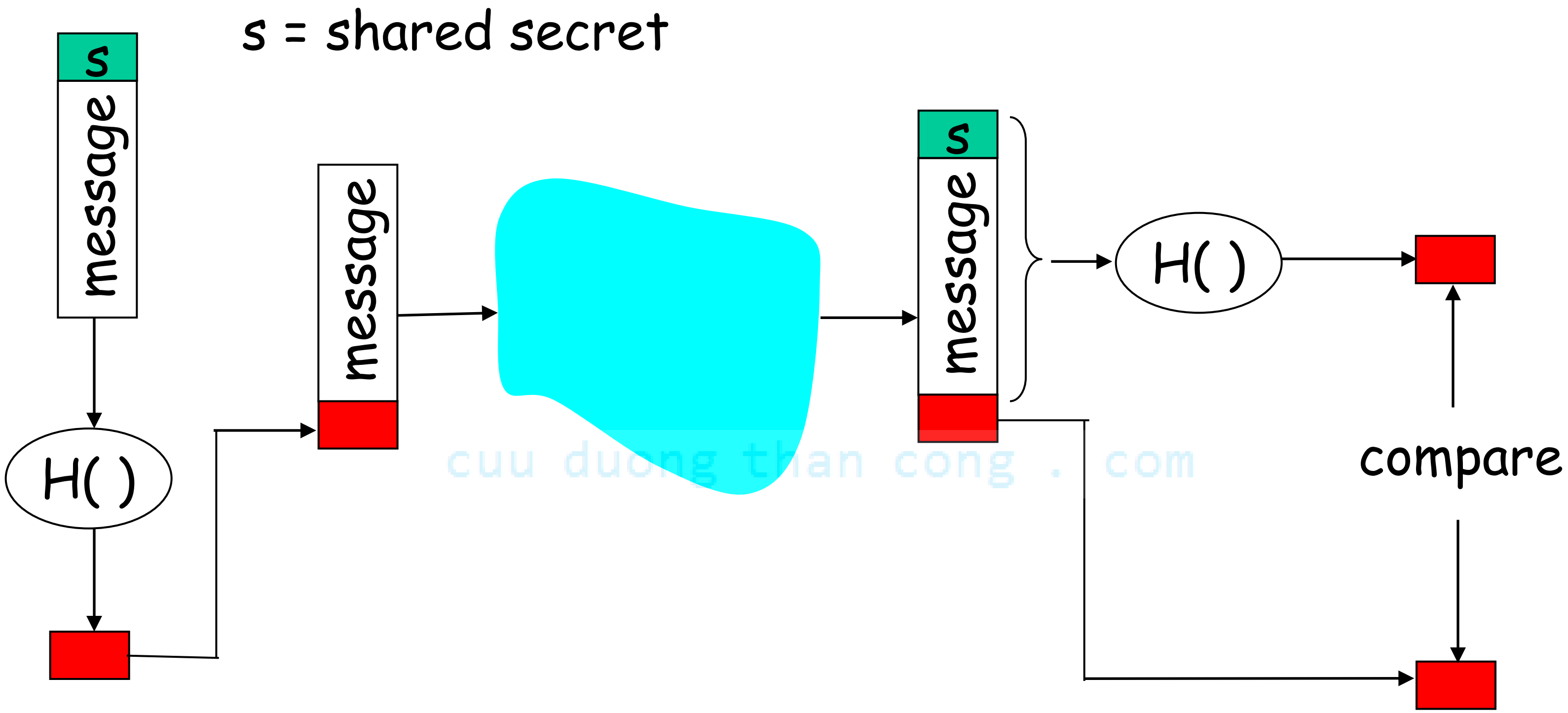


- Function H( ) that takes as input an arbitrary length message and outputs a fixed-length string: "message signature"
- Note that H( ) is a many-to-1 function
- H( ) is often called a "hash function"
- Desirable properties:
  - Easy to calculate
  - Irreversibility: Can't determine m from H(m)
  - Collision resistance: Computationally difficult to produce m and m' such that H(m) = H(m')
  - Seemingly random output

Hash Function Algorithms

- MD5 hash function widely used (RFC 1321)
  - computes 128-bit message digest in 4-step process.
- SHA-1 is also used.
  - US standard [NIST, FIPS PUB 180-1]
  - 160-bit message digest

Message Authentication Code (MAC)

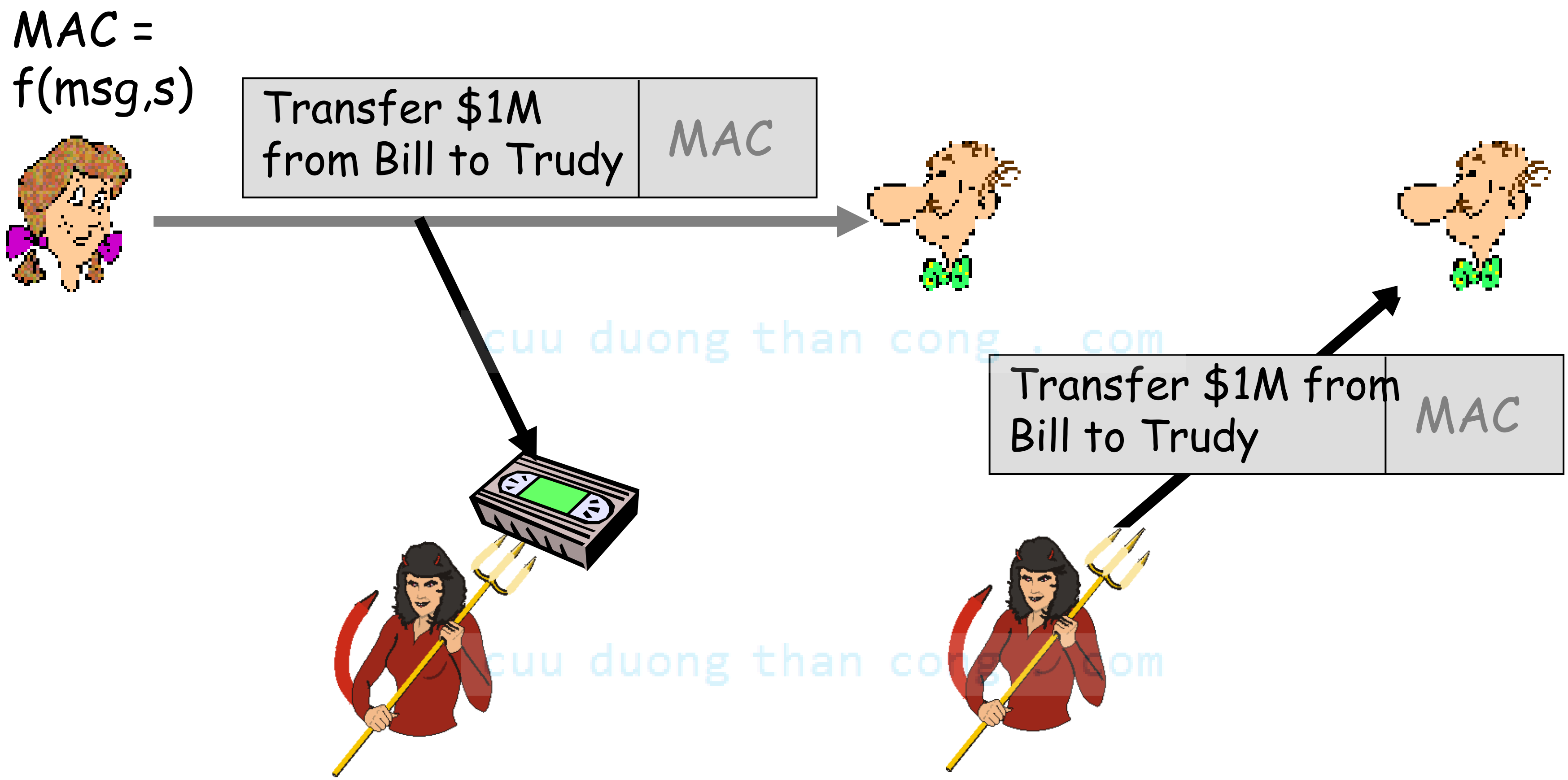


- ***Authenticates sender***
- ***Verifies message integrity***
- No encryption !
- Also called "keyed hash"
- Notation: $MD_m = H(s||m)$; send $m||MD_m$

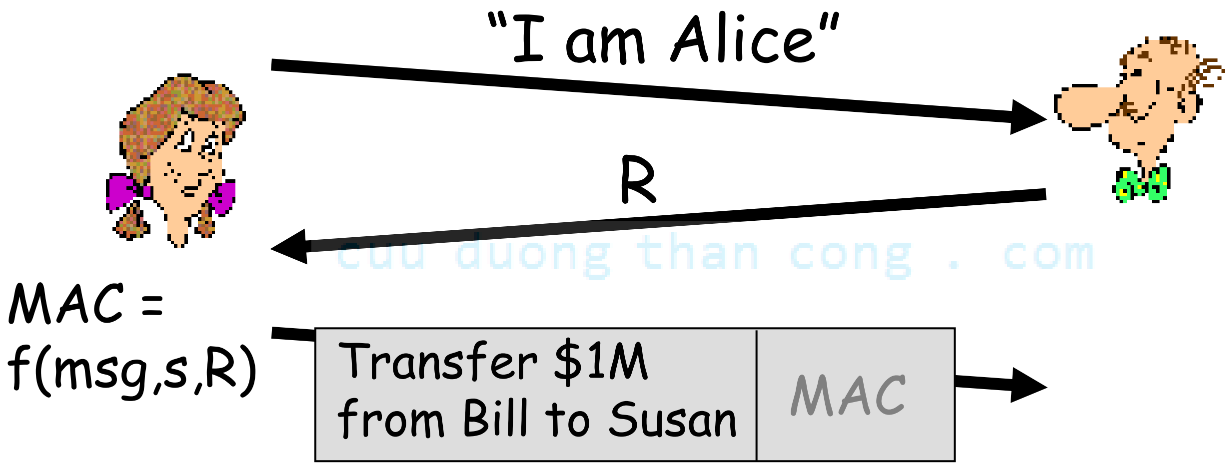
End-point authentication

- Want to be sure of the originator of the message - *end-point authentication*.
- Assuming Alice and Bob have a shared secret, will MAC provide end-point authentication.
  - We do know that Alice created the message.
  - But did she send it?

Playback attack



Defending against playback attack: nonce



Digital Signatures

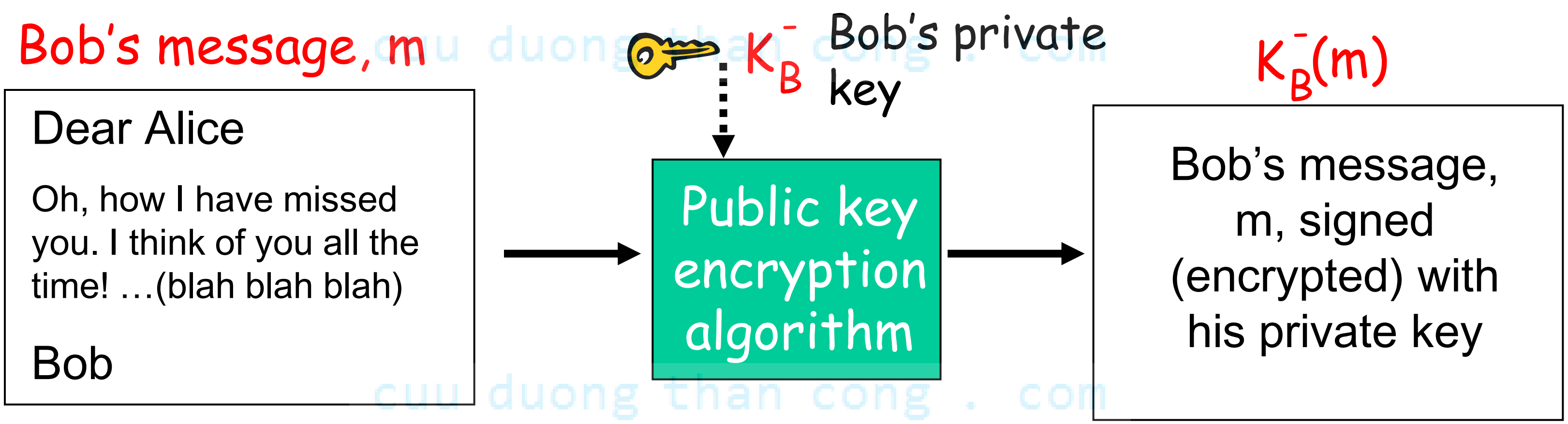
Cryptographic technique analogous to hand-written signatures.

- sender (Bob) digitally signs document, establishing he is document owner/creator.
- Goal is similar to that of a MAC, except now use public-key cryptography
- verifiable, nonforgeable: recipient (Alice) can prove to someone that Bob, and no one else (including Alice), must have signed document

Digital Signatures

Simple digital signature for message m:

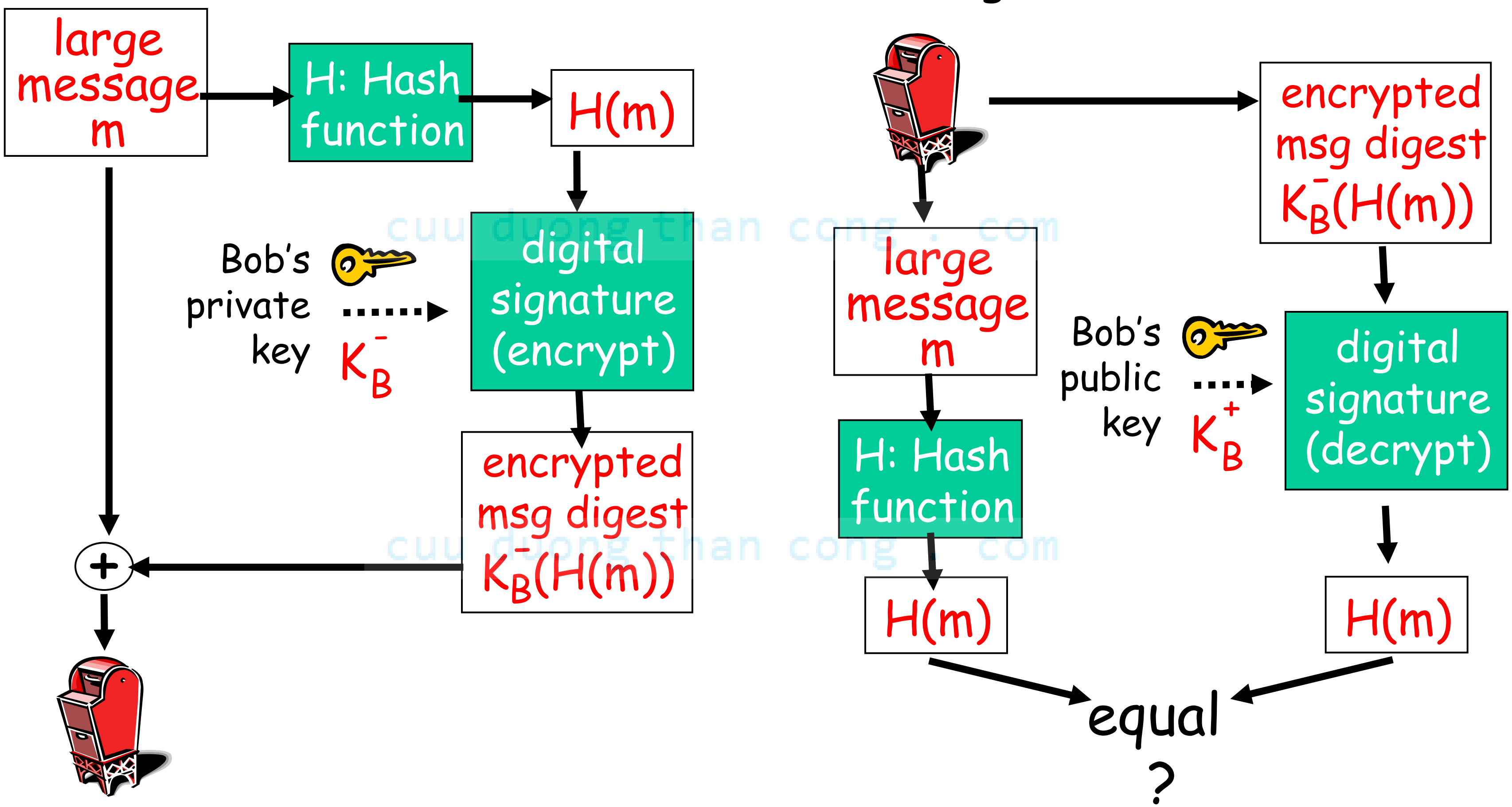
- Bob signs m by encrypting with his private key K_B^-, creating "signed" message, $K_B^-(m)$



Digital signature = signed message digest

Bob sends digitally signed message:

Alice verifies signature and integrity of digitally signed message:



Digital Signatures (more)

- Suppose Alice receives msg m, digital signature $K_B^-(m)$
- Alice verifies m signed by Bob by applying Bob's public key K_B^+ to $K_B^-(m)$ then checks $K_B^+(K_B^-(m)) = m$.
- If $K_B^+(K_B^-(m)) = m$, whoever signed m must have used Bob's private key.

Alice thus verifies that:

- ✓ Bob signed m.
- ✓ No one else signed m.
- ✓ Bob signed m and not m'.

Non-repudiation:

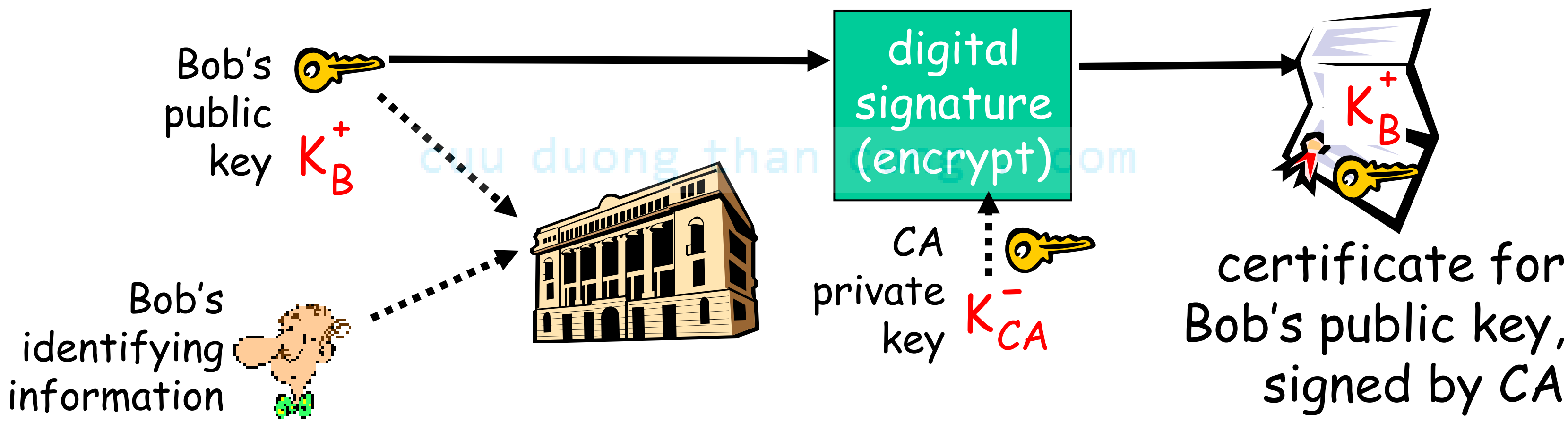
- ✓ Alice can take m, and signature $K_B^-(m)$ to court and prove that Bob signed m.

Public-key certification

- Motivation: Trudy plays pizza prank on Bob
  - Trudy creates e-mail order:
    Dear Pizza Store, Please deliver to me four pepperoni pizzas. Thank you, Bob
  - Trudy signs order with her private key
  - Trudy sends order to Pizza Store
  - Trudy sends to Pizza Store her public key, but says it's Bob's public key.
  - Pizza Store verifies signature; then delivers four pizzas to Bob.
  - Bob doesn't even like Pepperoni

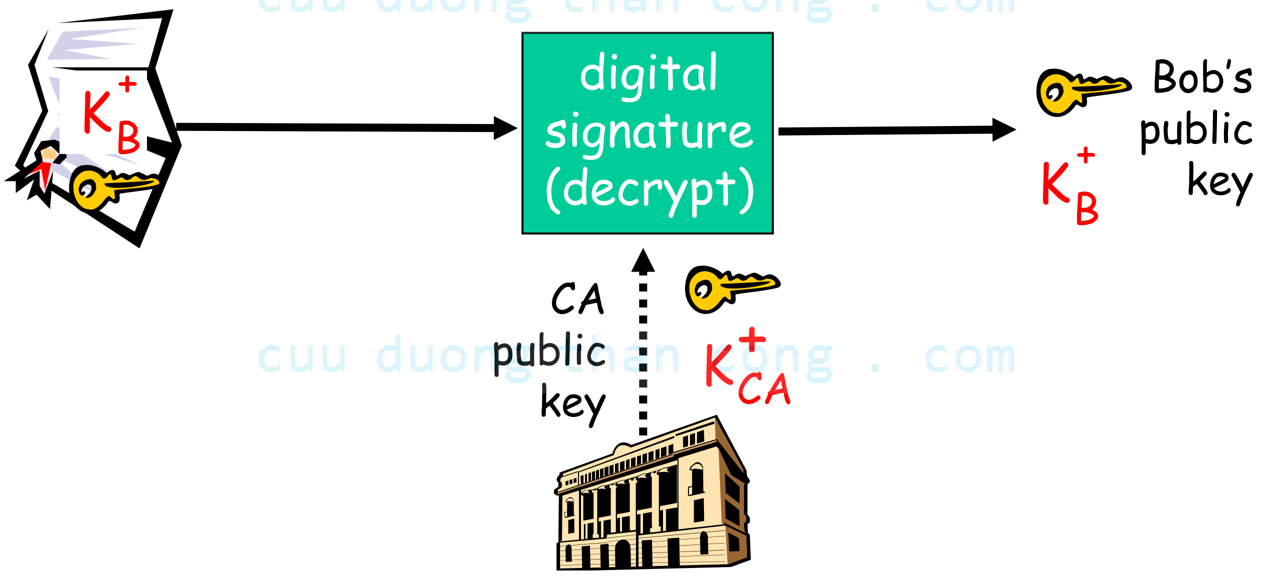
Certification Authorities

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



Certification Authorities

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



Certificates: summary

- Primary standard X.509 (RFC 2459)
- Certificate contains:
  - Issuer name
  - Entity name, address, domain name, etc.
  - Entity's public key
  - Digital signature (signed with issuer's private key)
- Public-Key Infrastructure (PKI)
  - Certificates and certification authorities
  - Often considered "heavy"

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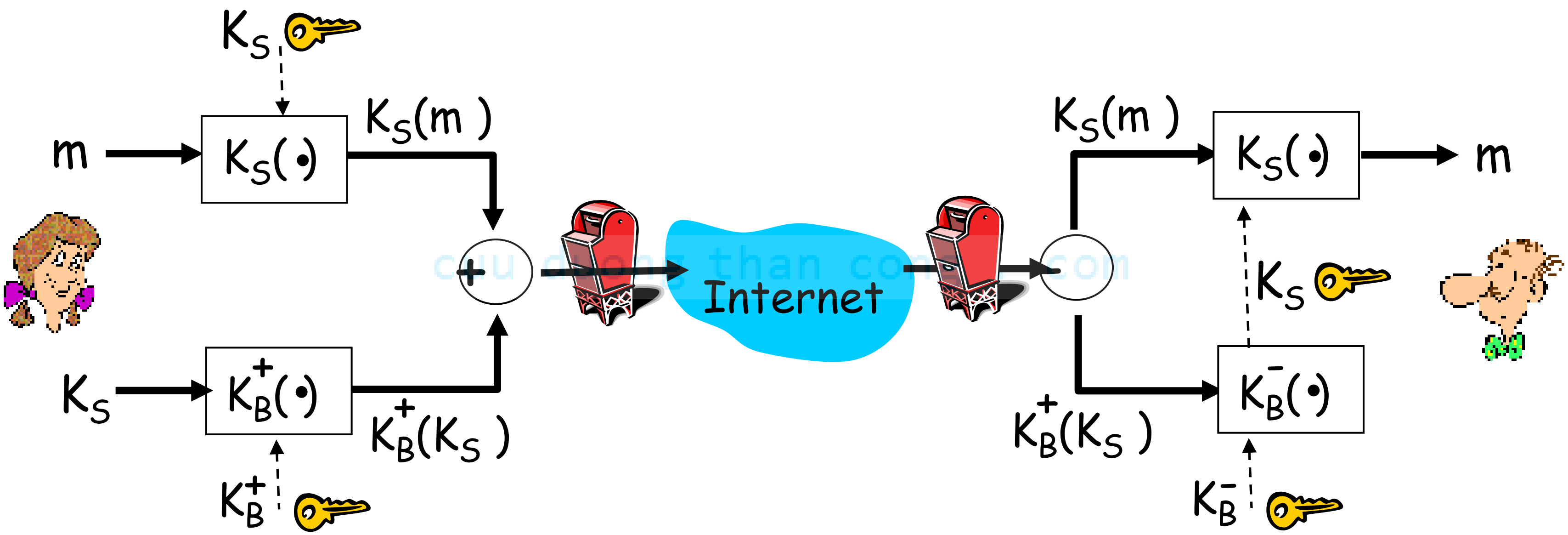
Secure e-mail

- Alice wants to send confidential e-mail, m, to Bob.



Alice:
- generates random *symmetric* private key, K_S.
- encrypts message with K_S (for efficiency)
- also encrypts K_S with Bob's public key.
- sends both $K_S(m)$ and $K_B(K_S)$ to Bob.

Secure e-mail

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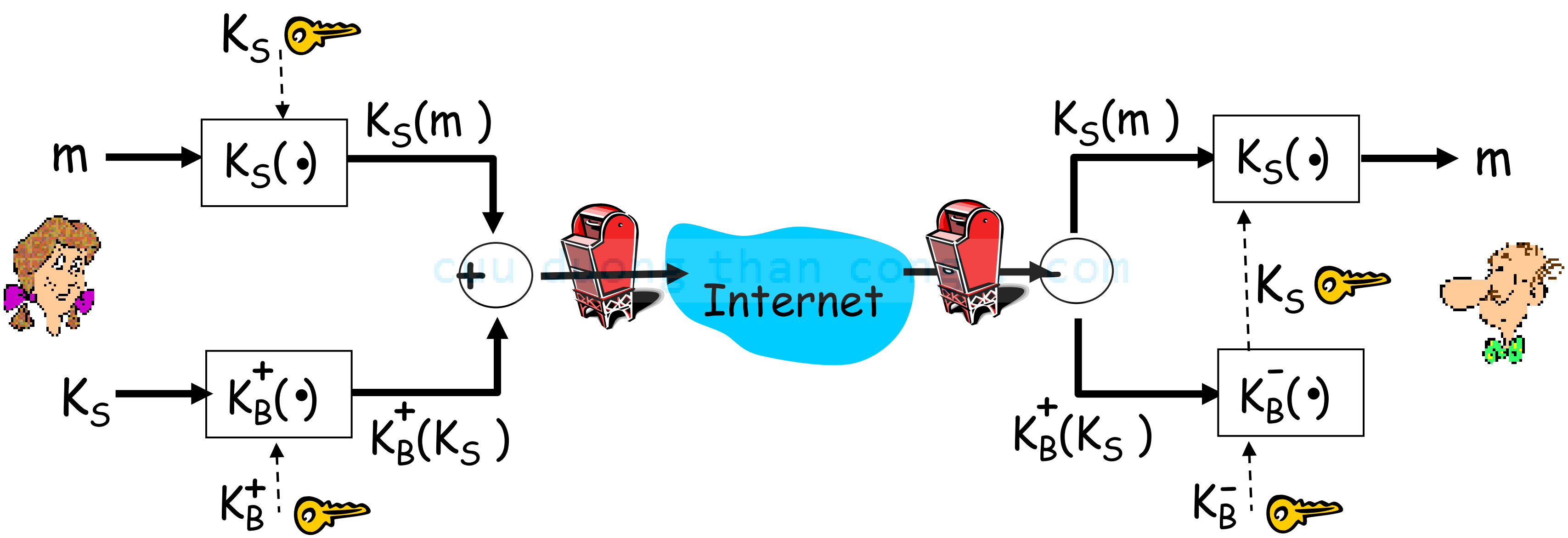
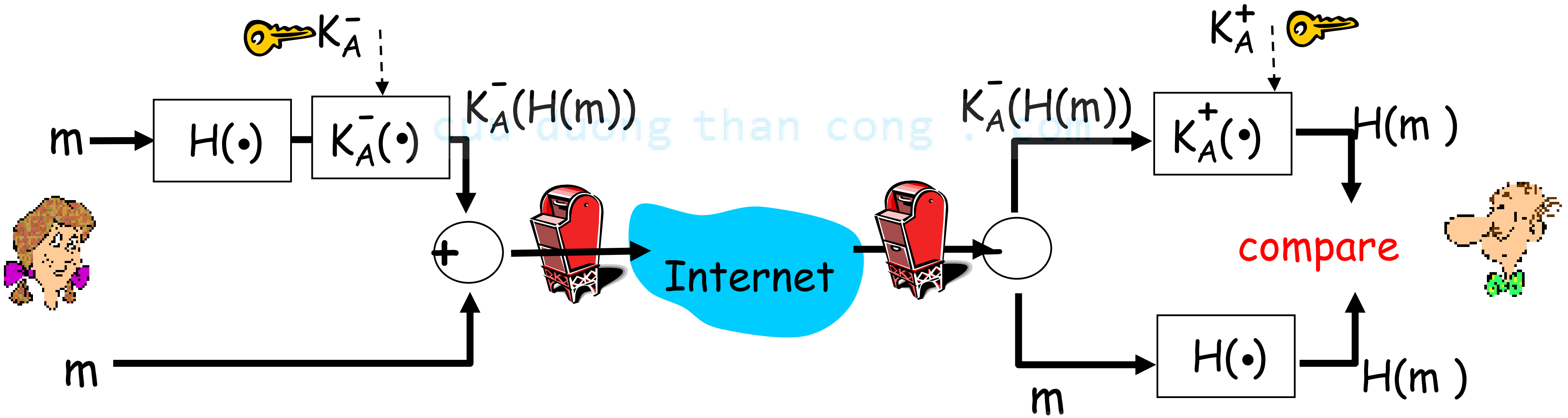


Bob:

- uses his private key to decrypt and recover K_S
- uses K_S to decrypt $K_S(m)$ to recover m

Secure e-mail (continued)

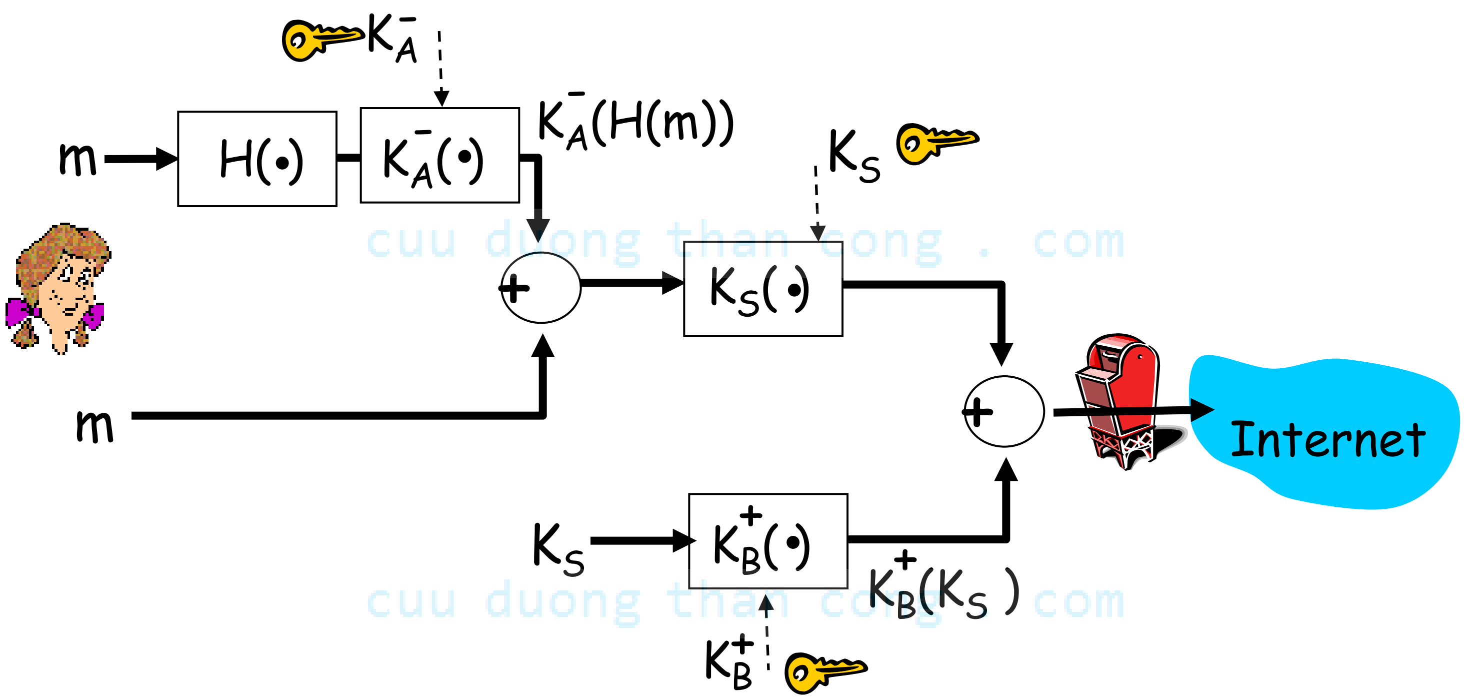
- Alice wants to provide sender authentication message integrity.



- Alice digitally signs message.
- sends both message (in the clear) and digital signature.

Secure e-mail (continued)

- Alice wants to provide secrecy, sender authentication, message integrity.



Alice uses three keys: her private key, Bob's public key, newly created symmetric key

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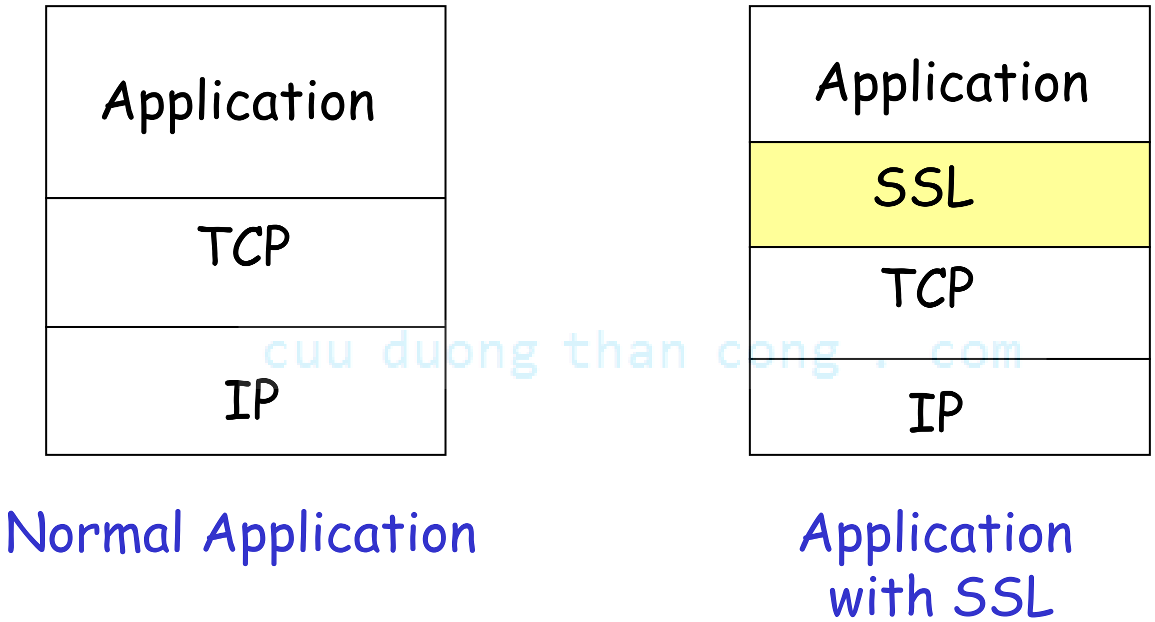
SSL: Secure Sockets Layer

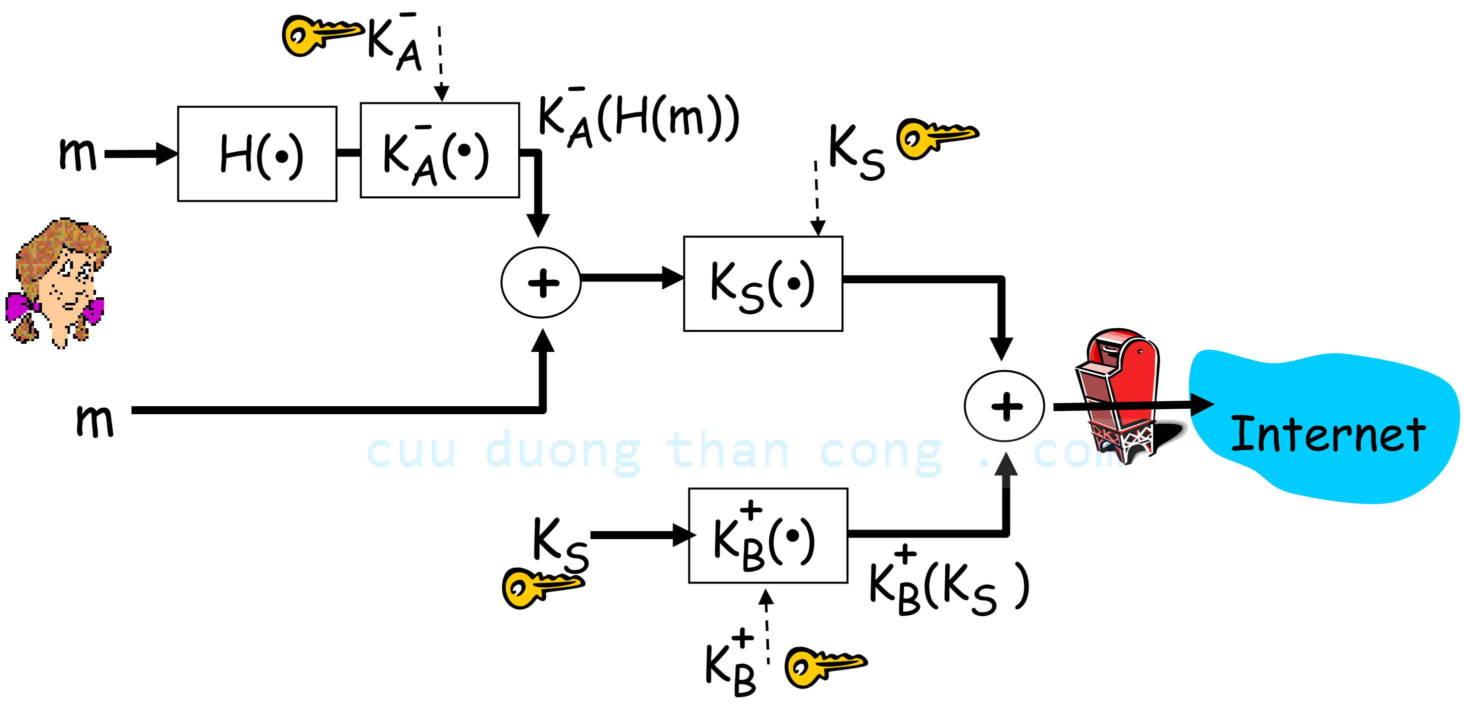
- Widely deployed security protocol
  - Supported by almost all browsers and web servers
  - https
  - Tens of billions $ spent per year over SSL
- Originally designed by Netscape in 1993
- Number of variations:
  - TLS: transport layer security, RFC 2246
- Provides
  - Confidentiality
  - Integrity
  - Authentication
- Original goals:
  - Had Web e-commerce transactions in mind
  - Encryption (especially credit-card numbers)
  - Web-server authentication
  - Optional client authentication
  - Minimum hassle in doing business with new merchant
- Available to all TCP applications
  - Secure socket interface

SSL and TCP/IP



- SSL provides application programming interface (API) to applications
- C and Java SSL libraries/classes readily available

Could do something like PGP:



- But want to send byte streams & interactive data
- Want a set of secret keys for the entire connection
- Want certificate exchange part of protocol: handshake phase

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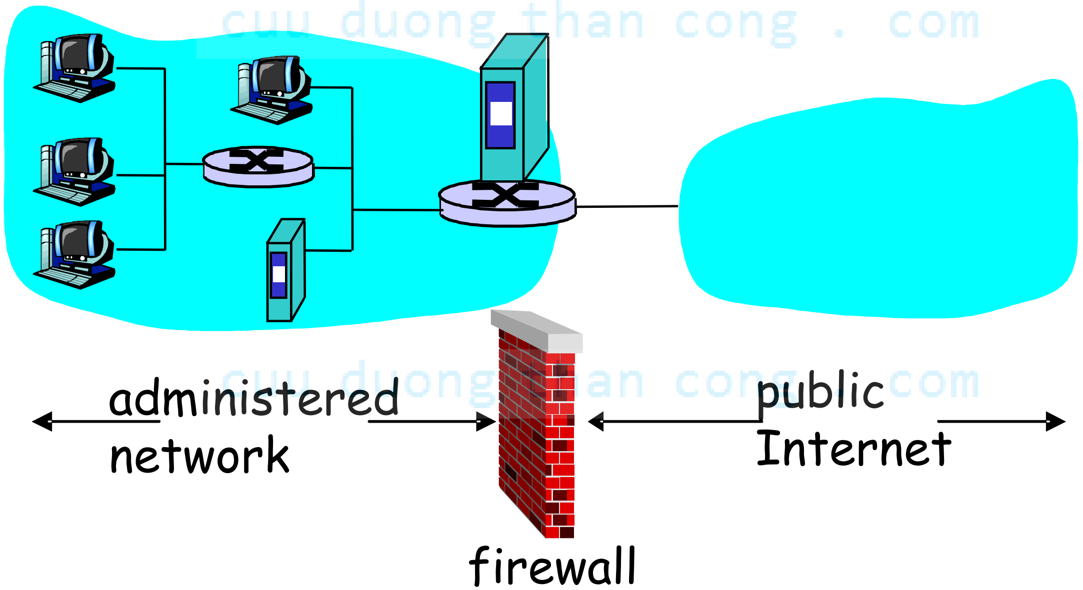
Firewalls

firewall

isolates organization's internal net from larger Internet, allowing some packets to pass, blocking others.



Firewalls: Why

prevent denial of service attacks:

- SYN flooding: attacker establishes many bogus TCP connections, no resources left for "real" connections

prevent illegal modification/access of internal data.

- e.g., attacker replaces CIA's homepage with something else

allow only authorized access to inside network (set of authenticated users/hosts)

three types of firewalls:

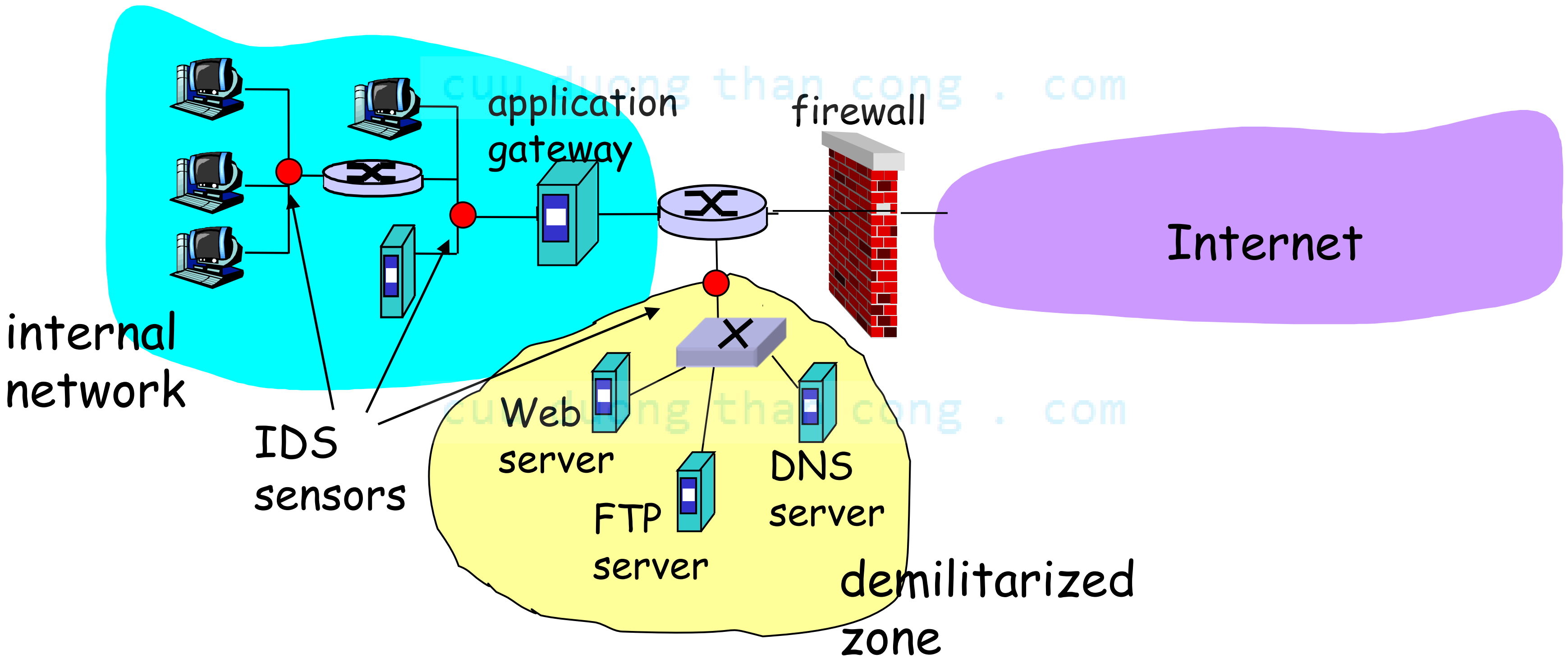
- stateless packet filters
- stateful packet filters
- application gateways

Intrusion detection systems

- packet filtering:
  - operates on TCP/IP headers only
  - no correlation check among sessions
- *IDS: intrusion detection system*
  - *deep packet inspection:* look at packet contents (e.g., check character strings in packet against database of known virus, attack strings)
  - examine correlation among multiple packets
    - port scanning
    - network mapping
    - DoS attack

Intrusion detection systems

- multiple IDSs: different types of checking at different locations



Network Security (summary)

Basic techniques......

- cryptography (symmetric and public)
- message integrity
- end-point authentication

.... used in many different security scenarios

- secure email
- secure transport (SSL)
- IP sec
- 802.11

Operational Security: firewalls and IDS