# Lecture 24 Security
# Authentication, TLS/SSL

COMP 411, Fall 2022

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**Acknowledgements**: materials adapted from Computer Networking: A Top Down Approach 7th edition: ©1996-2016, J.F Kurose and K.W. Ross, All Rights Reserved as well as from slides by Abraham Matta at Boston University, and some material from Computer Networks by Tannenbaum and Wetherall.

# Today

1. Network security
   - authentication
   - message integrity

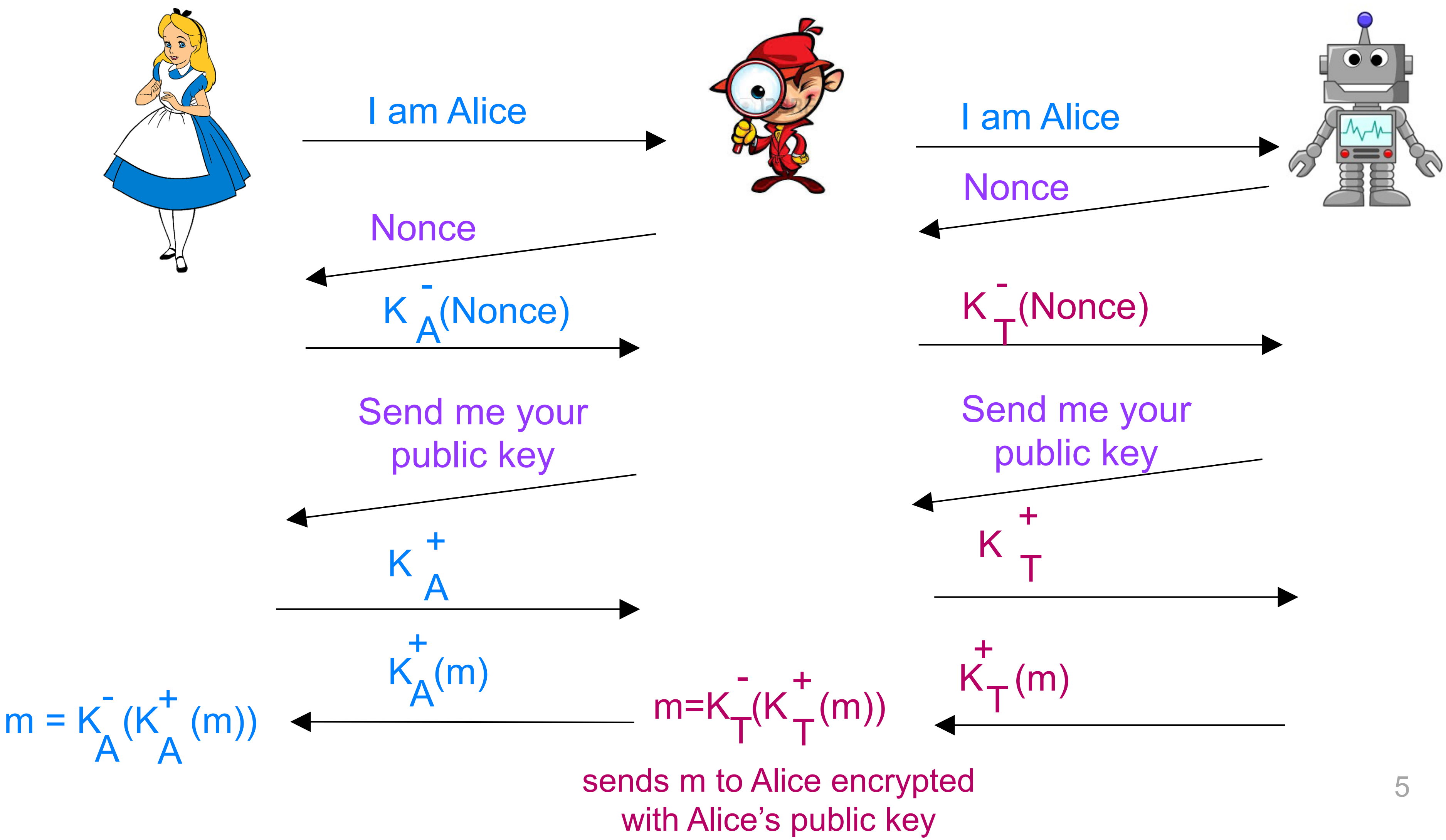
2. Transport layer security
   - overview
   - toy TLS
   - real TLS

## Network Security

# AUTHENTICATION

# Recall: ap5.0 man-in-the-middle attack

Trudy poses as Alice (to Bob) and as Bob (to Alice)



# Distinguishing Alice's vs. Trudy's public key

Use certification authority (CA)

- binds public key to particular entity
  - e.g., Alice, Bob, website, …
- 100s of certification authorities

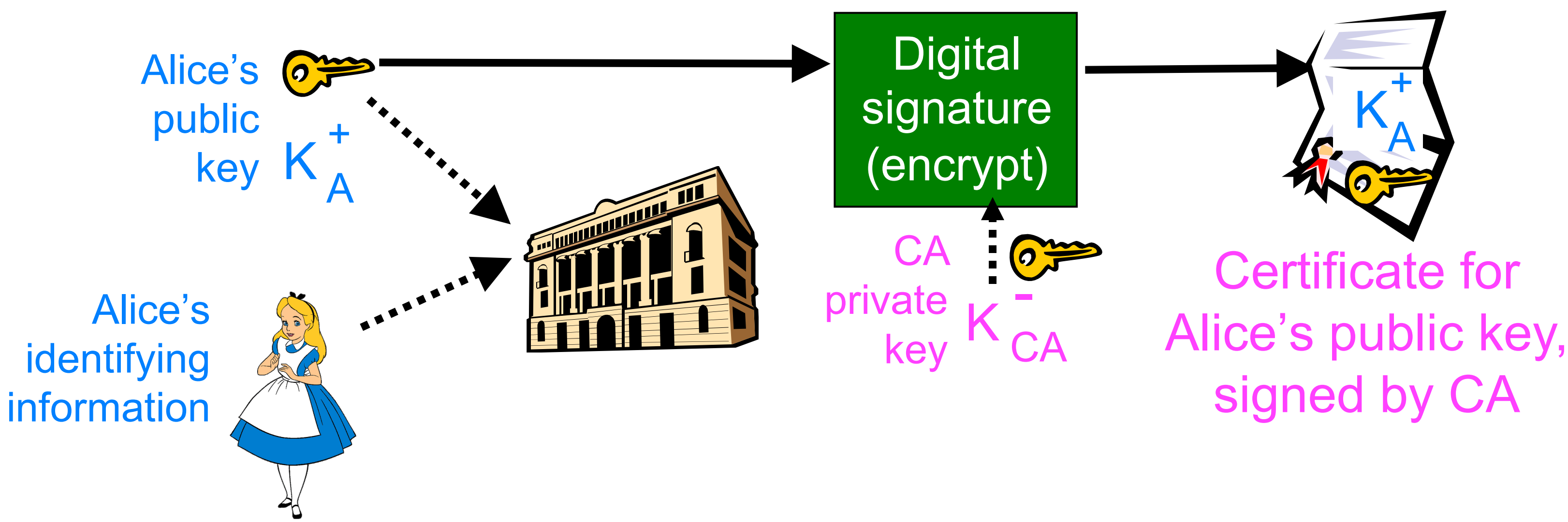
Aside

- CAs are critical but potentially weak link …

# How certification authorities work

## Alice registers her public key with CA

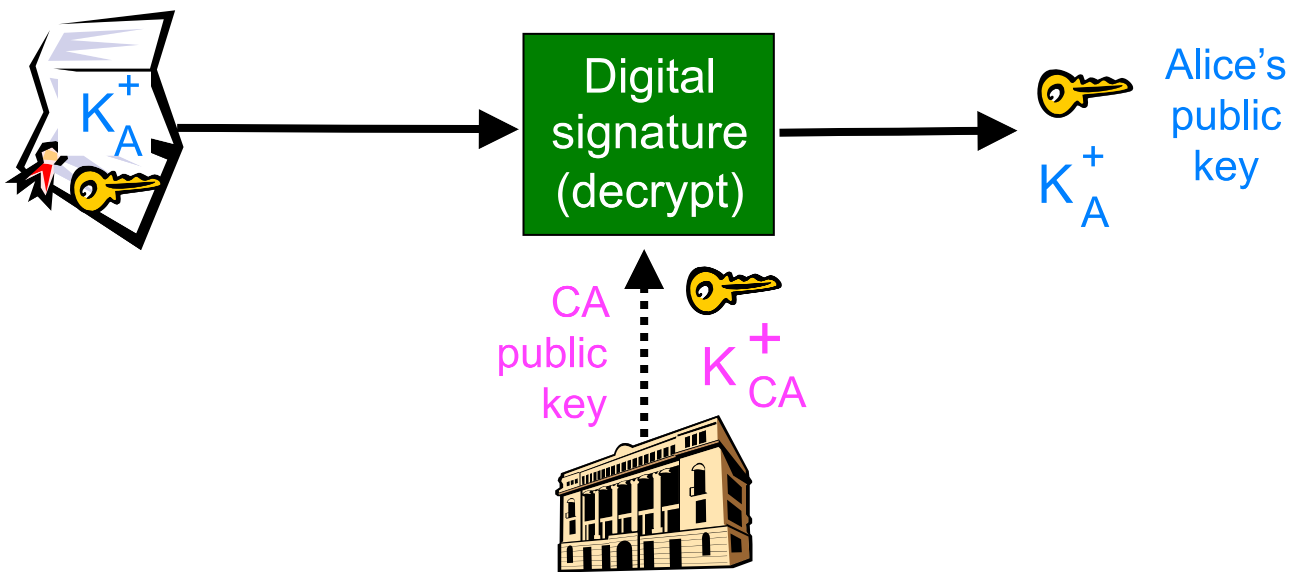
- Alice provides proof of identity to CA
- CA creates certificate binding Alice to its public key
  - certificate digitally signed by CA



# Certification authorities

## When Bob wants Alice's public key

1. gets Alice's certificate from Alice or elsewhere
2. applies CA's public key to Alice's certificate
3. gets Alice's public key



# Example

VeriSign Class 3 Public Primary Certification Authority - G5

↳ Symantec Class 3 EV SSL CA - G3

↳ www.bankofamerica.com

**www.bankofamerica.com**

Issued by: Symantec Class 3 EV SSL CA - G3

Expires: Thursday, July 26, 2018 at 7:59:59 PM Eastern Daylight Time

✔ This certificate is valid

▼ **Details**

| Subject Name | |
|---|---|
| Inc. Country | US |
| Inc. State/Province | Delaware |
| Business Category | Private Organization |
| Serial Number | 2927442 |
| Country | US |
| Postal Code | 60603 |
| State/Province | Illinois |
| Locality | Chicago |
| Street Address | 135 S La Salle St |
| Organization | Bank of America Corporation |
| Organizational Unit | eComm Network Infrastructure |
| Common Name | www.bankofamerica.com |

| Issuer Name | |
|---|---|
| Country | US |
| Organization | Symantec Corporation |
| Organizational Unit | Symantec Trust Network |
| Common Name | Symantec Class 3 EV SSL CA - G3 |

| | |
|---|---|
| Serial Number | 4E 49 91 F1 B7 6A 9D 8D 16 23 5F 38 81 DD F5 E1 |
| Version | 3 |
| Signature Algorithm | SHA-256 with RSA Encryption ( 1.2.840.113549.1.1.11 ) |
| Parameters | none |
| Not Valid Before | Monday, July 24, 2017 at 8:00:00 PM Eastern Daylight Time |
| Not Valid After | Thursday, July 26, 2018 at 7:59:59 PM Eastern Daylight Time |

| Public Key Info | |
|---|---|
| Algorithm | RSA Encryption ( 1.2.840.113549.1.1.1 ) |

## Network Security

# MESSAGE INTEGRITY

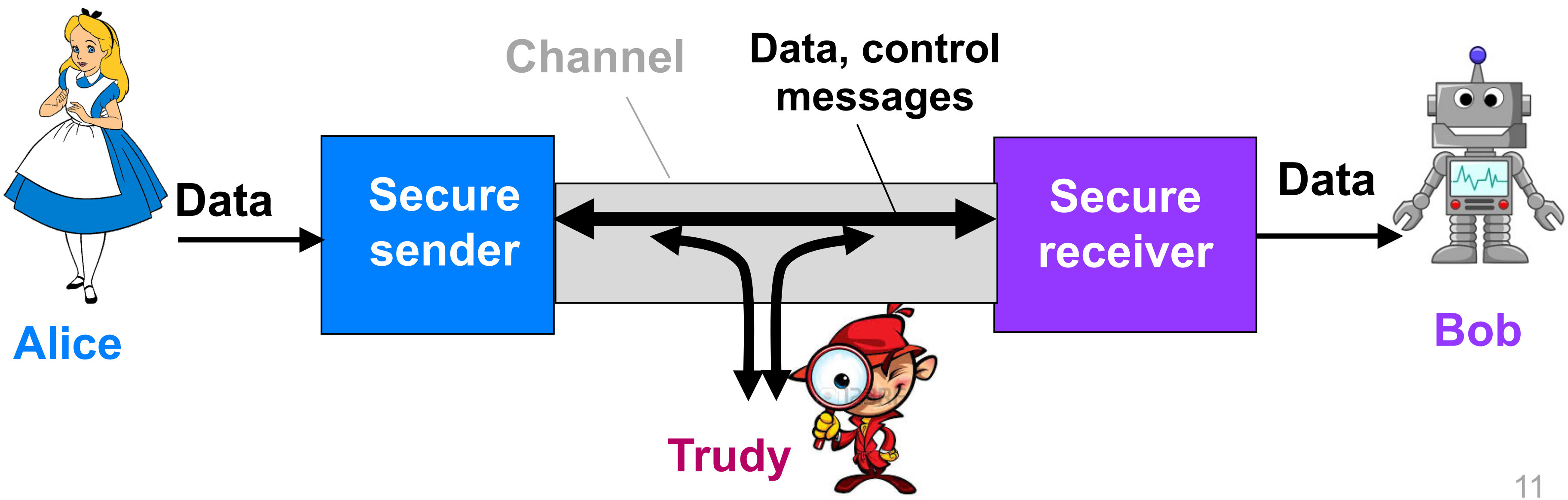
# Message integrity

Alice and Bob must be able to detect whether msg changed

1. verify msg originated from Alice
2. verify msg not tampered with on way to Bob

Solution

– digital signatures: cryptographic technique like hand-written signature



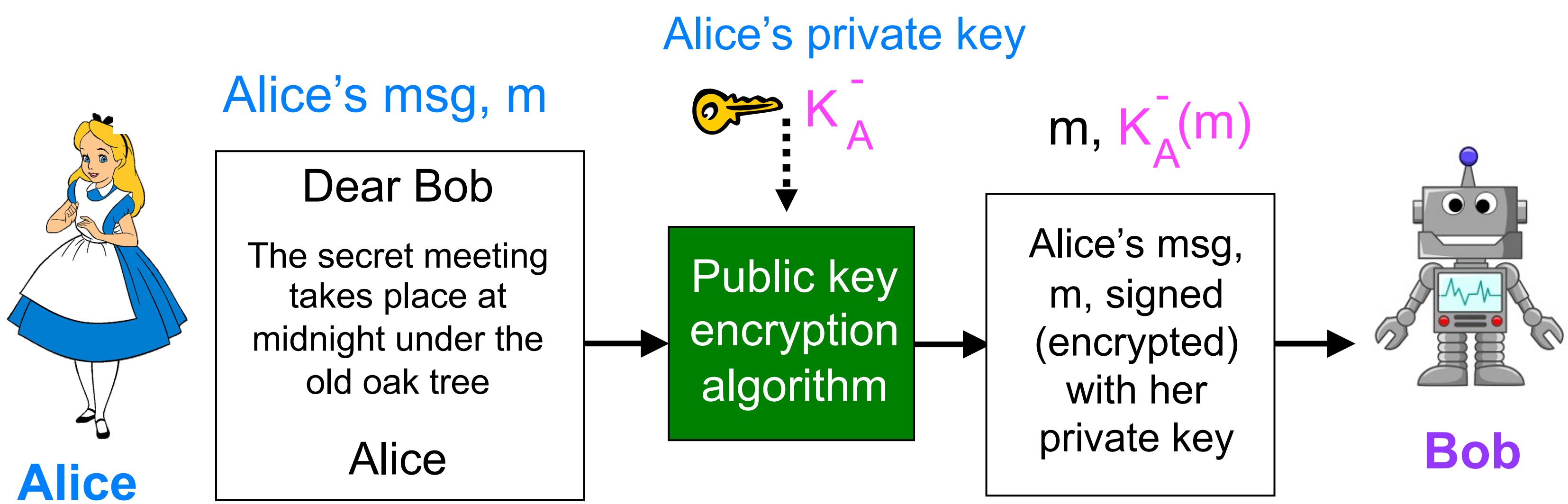
# Simple digital signature for message, m

## Sender (Alice)

- encrypts msg m with her private key $K_A^-$ to create signed message, $K_A^-(m)$
- proves she is owner/creator

## Recipient (Bob)

- applies Alice's public key $K_A^+$ to $K_A^-(m)$
- if $K_A^+(K_A^-(m))$ = m whoever signed m was Alice or has Alice's private key



# Problem for digital signatures

Public key cryptography is expensive

- more expensive the longer the message is
- Why?

Solution

- sign digital ``fingerprint” of msg rather than msg itself

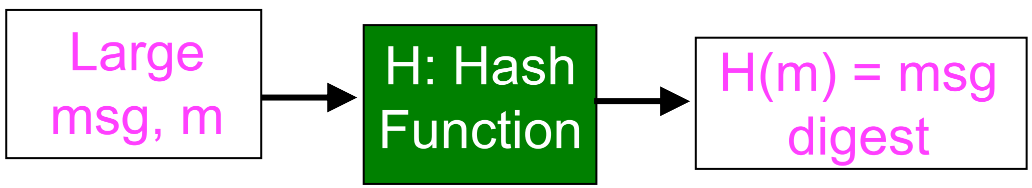
Message digest

# Message digest

## Desired features are what hash function gives

- fixed-length
- easy-to-compute
- 2 msgs unlikely to have same digest

## Apply hash function H to m




## Hash function properties

- many-to-1 function
- produces fixed-size msg digest, H(m)
- given message digest H(m), computationally infeasible to find m' such that H(m) = H(m')

# Some hash function standards

## MD5 hash function (RFC 1321)

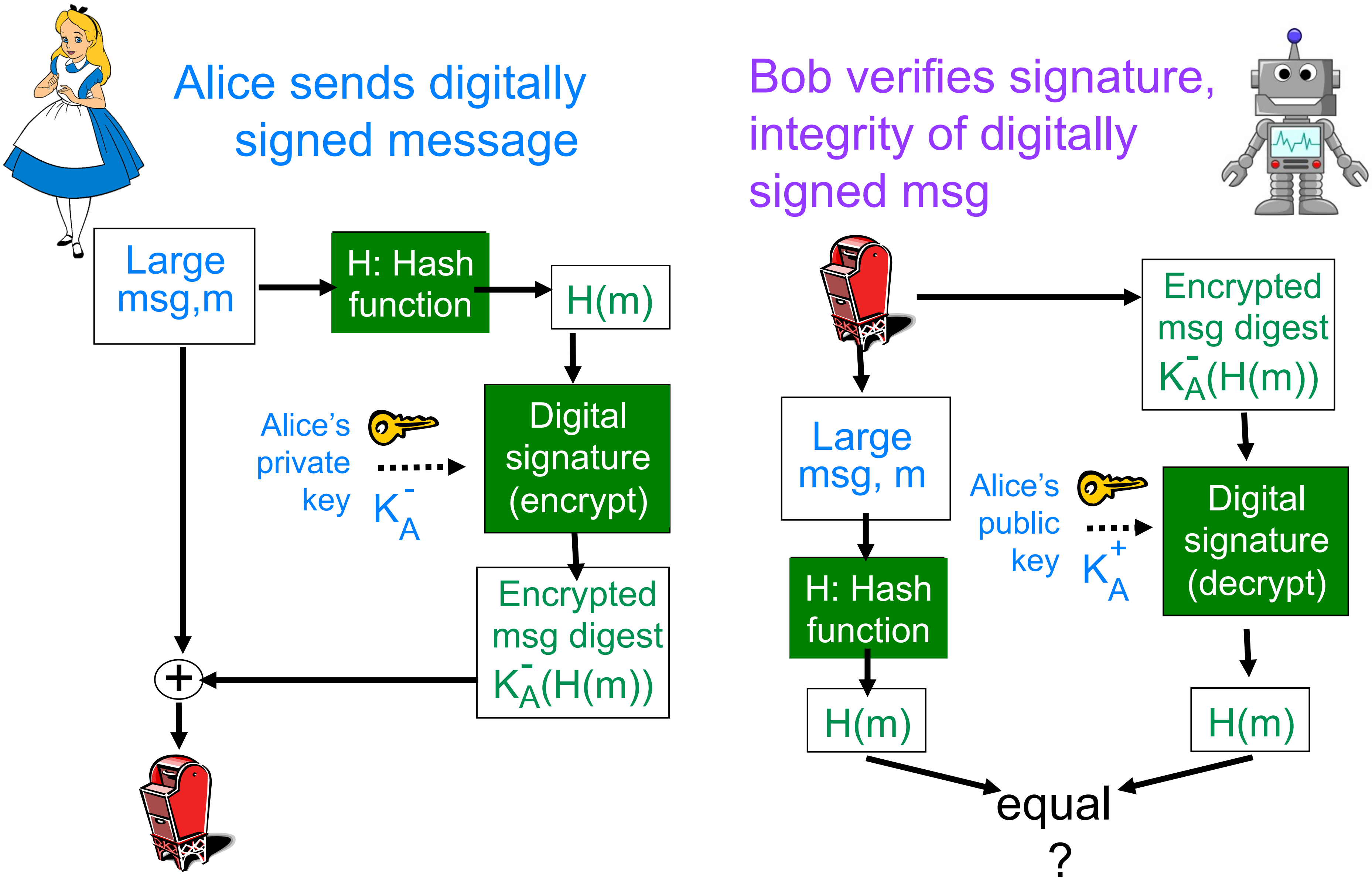
- computes 128-bit message digest in 4-step process.
- "cryptographically broken and unsuitable for further use"
  - CMU Software engineering Institute

## SHA-1

- 160-bit message digest
- many vulnerabilities, browsers will no longer use/accept

## SHA-2, SHA-3

# Use signed message digest as digital signature



## Transport Layer Security

# OVERVIEW

# TLS aka SSL

Secures data at and above transport layer

- provides confidentiality, integrity, authentication
- SSL: Secure Sockets Layer, predecessor to TLS
- TLS: Transport Layer Security

Available to all TCP applications

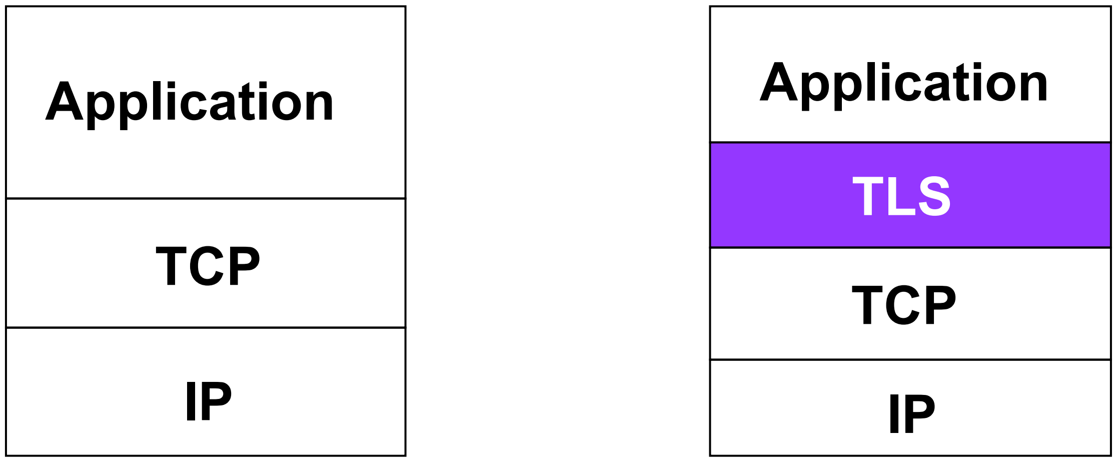
- first setup TCP connection, then run TLS as application

Widely deployed

- supported by almost all browsers, web servers
- billions $/year over SSL
- HTTP + SSL = HTTPS

# Where TLS sits in Internet stack

TLS provides application programming interface to apps




Normal application

Application with TLS

Very likely your operating system using open source library

- https://www.openssl.org/
- https://developer.mozilla.org/en-US/docs/Mozilla/Projects/NSS

# TLS goals

Send byte streams & interactive data

- why?

Want set of secret keys for entire connection

- why?

Want certificate exchange as part of protocol handshake phase

- why?

## Transport Layer Security

# TOY TLS

# A simple secure channel

## Handshake

- Alice and Bob use their certificates, private keys to authenticate each other and exchange shared secret

## Key derivation

- Alice and Bob use shared secret to derive set of keys

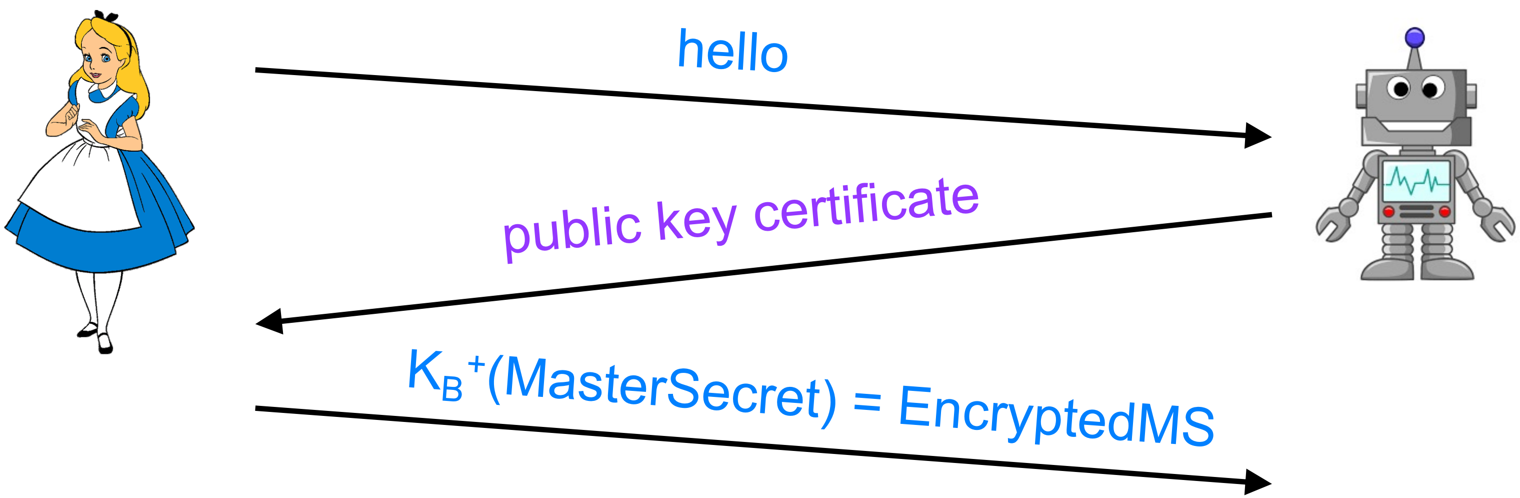
## Data transfer

- data to be transferred is broken up into series of records

## Connection closure

- special messages to securely close connection

# A simple handshake




## Derive keys from master secret

- use key derivation function (KDF)
  - takes master secret and additional random data and creates keys

# Key derivation

Don’t use same key for more than one cryptographic operation

- keys for message authentication code (MAC): like hash
- keys for encryption

Encryption keys

- $K_c$ = encryption key for data sent from client to server
- $K_s$ = encryption key for data sent from server to client

MAC keys

- $M_c$ = MAC key for data sent from client to server
- $M_s$ = MAC key for data sent from server to client

# Data records

Why not encrypt data in constant stream as we write it to TCP?

- where to put MAC?
  - if at end, no message integrity until all data processed
- e.g., instant messaging
  - how can we do integrity check over all bytes sent before displaying?

Solution: break stream in series of records

- each record carries MAC
- receiver can act on each record as it arrives

# More attacks

## What if attacker replays or re-orders records?

- Solution: put sequence # into MAC (no seq # field)
- MAC = MAC($M_x$, sequence || data)

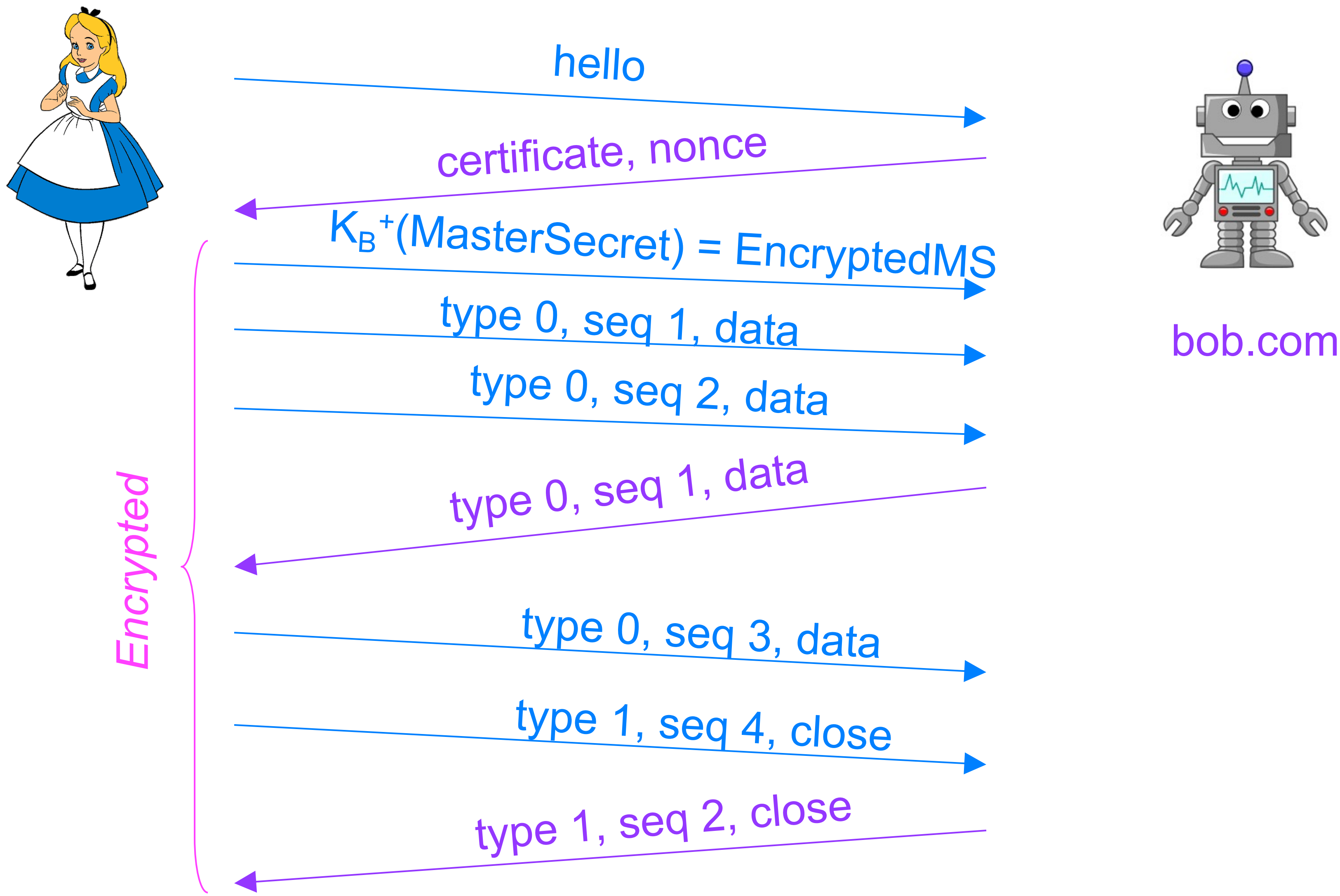
## What if attacker replays all records?

- Solution: use nonce

## What if attacker forges TCP connection close?

- Solution: have record types, with one type for closure
  - type 0 for data
  - type 1 for closure
- MAC = MAC($M_x$, sequence || type || data)

# Summary


hello
certificate, nonce
$K_B^+$(MasterSecret) = EncryptedMS
type 0, seq 1, data
type 0, seq 2, data
type 0, seq 1, data
type 0, seq 3, data
type 1, seq 4, close
type 1, seq 2, close
Encrypted
bob.com