Network Security: Authentication, TLS, Firewall, etc.

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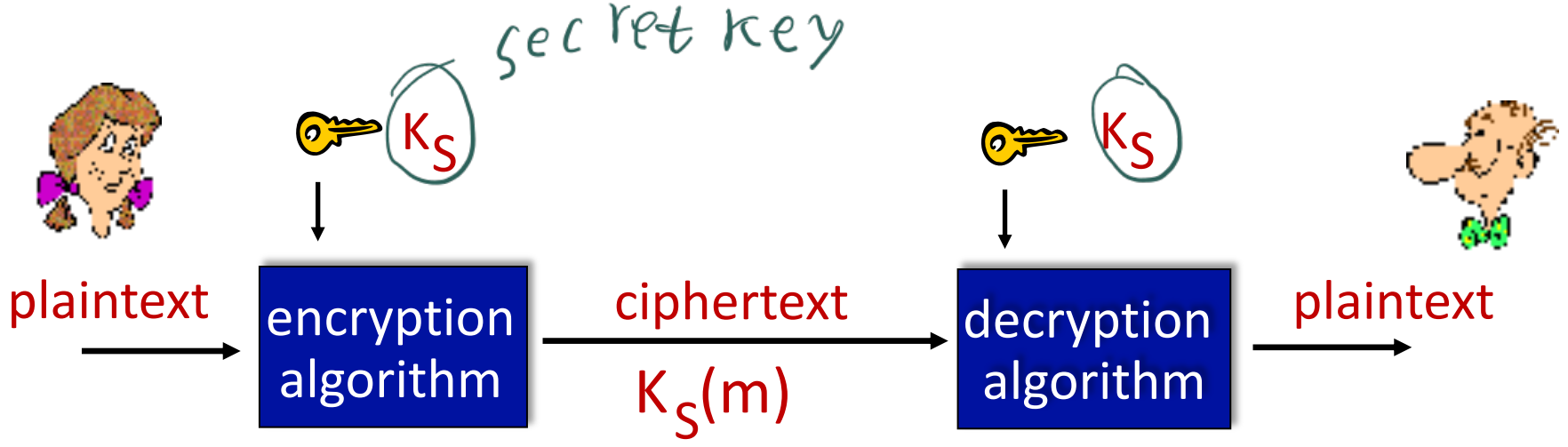
Min Suk Kang
Associate Professor
School of Computing/Graduate School of Information Security

Confidentiality

hiding something from others

Symmetric key cryptography → 암호화/복호화 키동일

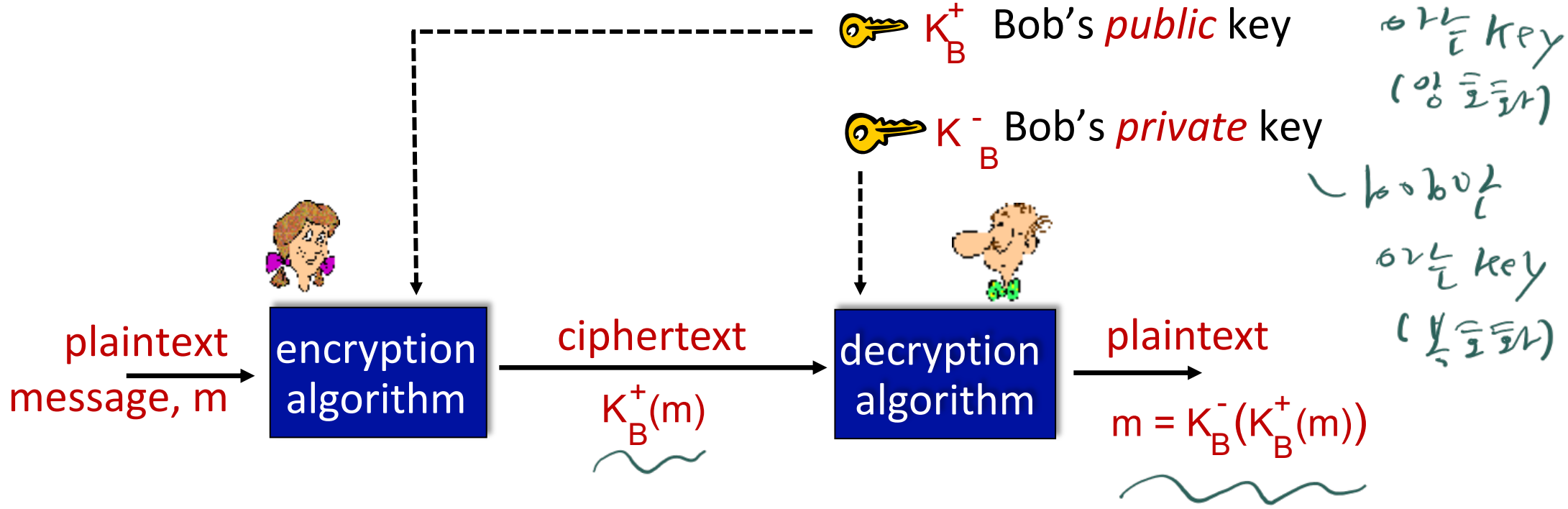


symmetric key crypto: Bob and Alice share same (symmetric) key: K

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

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

Public Key Cryptography



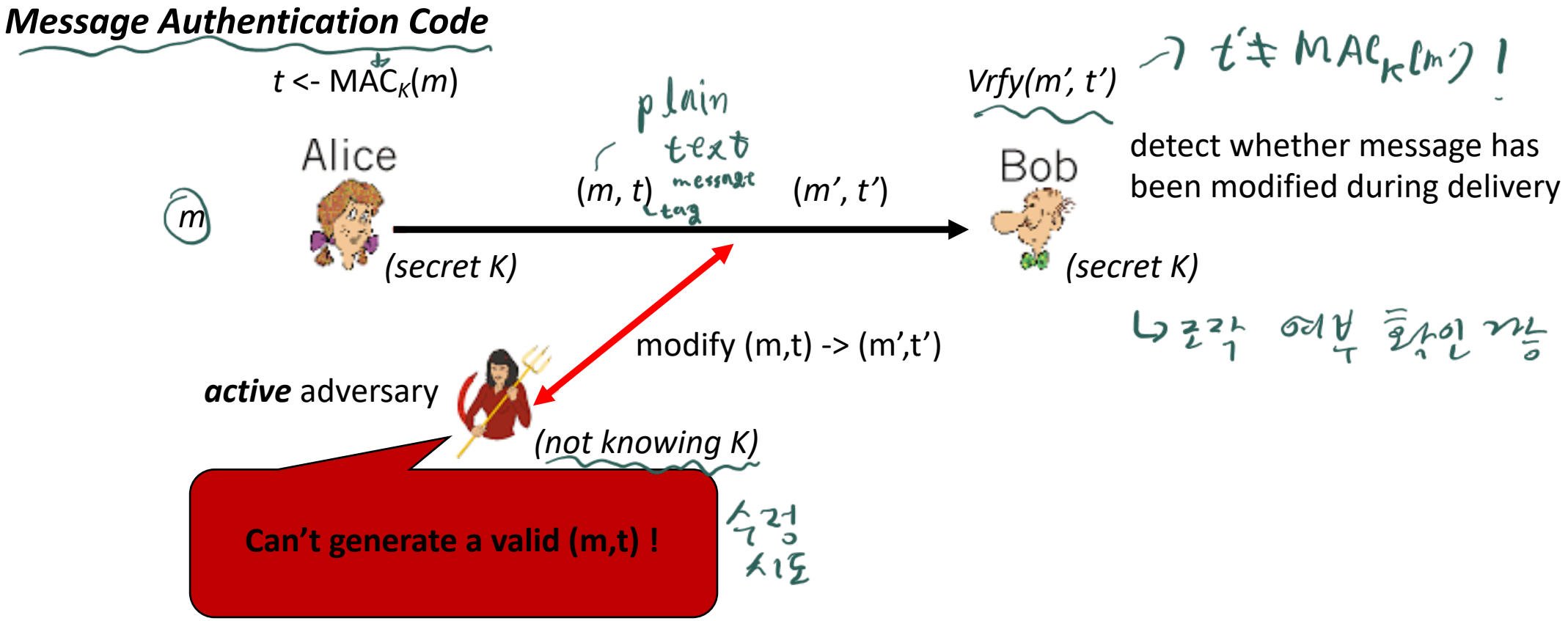
Wow - public key cryptography revolutionized 2000-year-old (previously only symmetric key) cryptography!

- similar ideas emerged at roughly same time, independently in US and UK (classified)

Integrity

protect information from modification

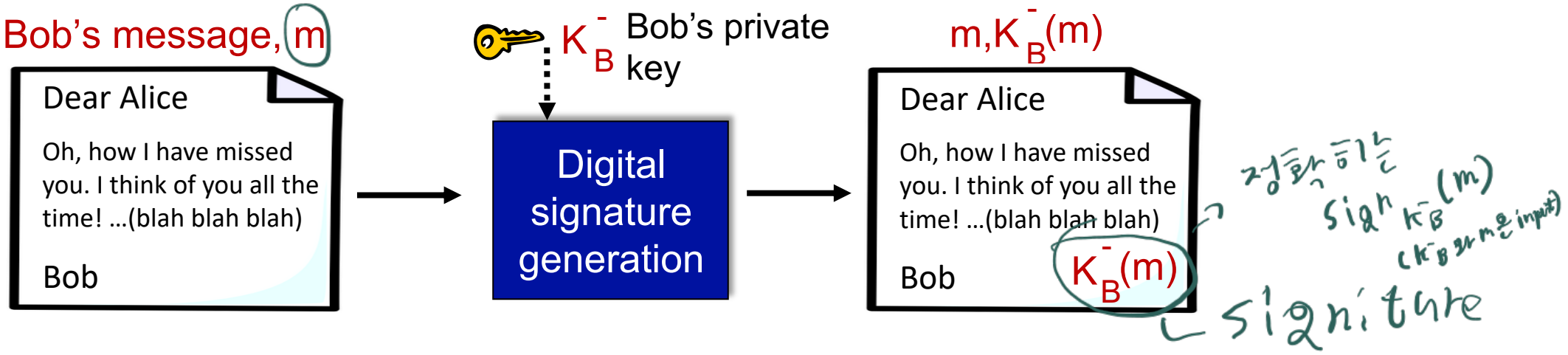
Message integrity (in symmetric key setting)



Digital signatures

cryptographic technique analogous to hand-written signatures:

- sender (Bob) digitally signs document: he is document owner/creator.
- *verifiable, nonforgeable:* recipient (Alice) can prove to someone that Bob, and no one else (including Alice), must have signed document
- simple digital signature for message m:
  - Bob signs m with his private key K_B, creating "signed" message, $K_B^-(m)$



Digital signatures

- suppose Alice receives msg m, with signature: m, $K_B^-(m)$
- 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:

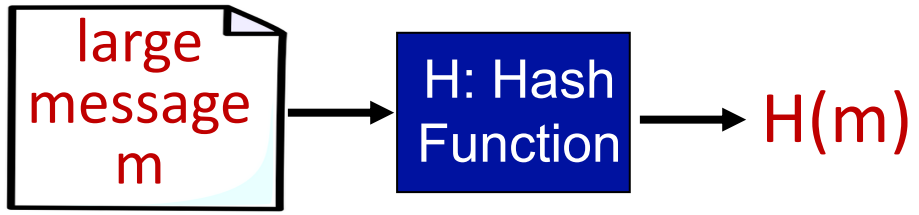
- ✓ Alice can take m, and signature $K_B^-(m)$ to court and prove that Bob signed m

Message digests

computationally expensive to public-key-encrypt long messages

goal: fixed-length, easy- to-compute digital "fingerprint"

- apply hash function H to *m*, get fixed size message digest, *H(m)*

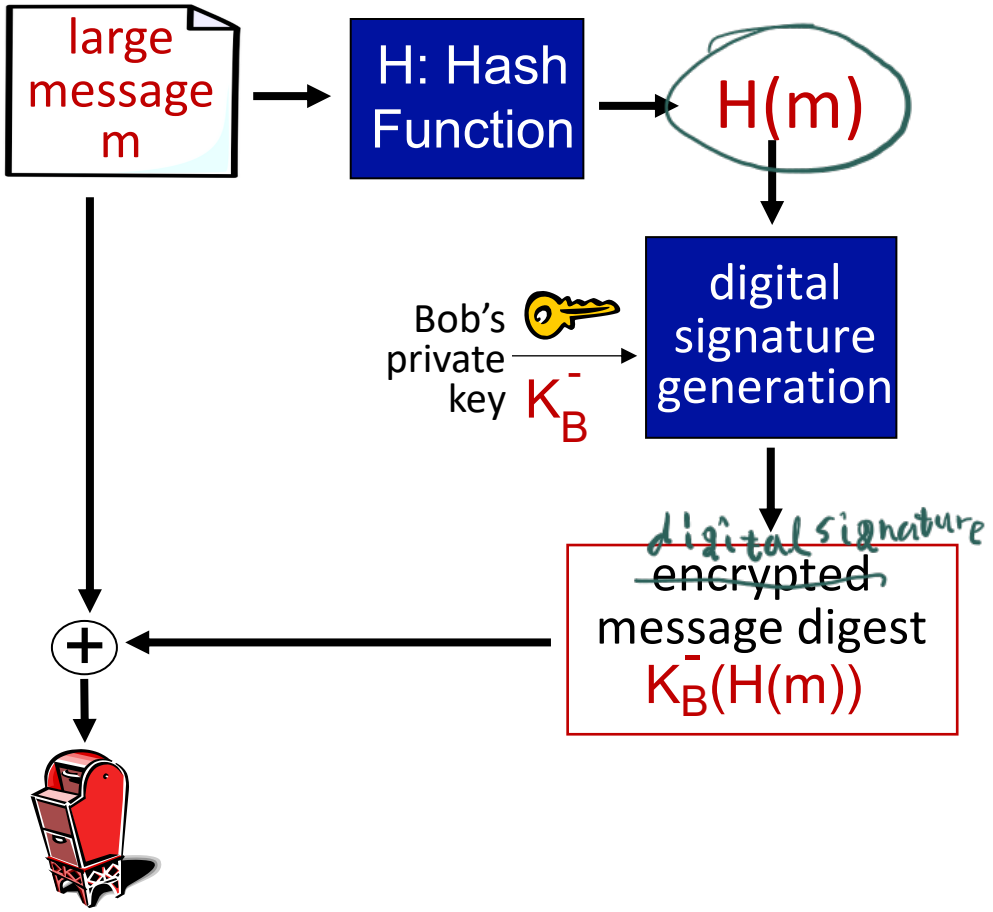


"Cryptographic" (or secure) hash function properties:

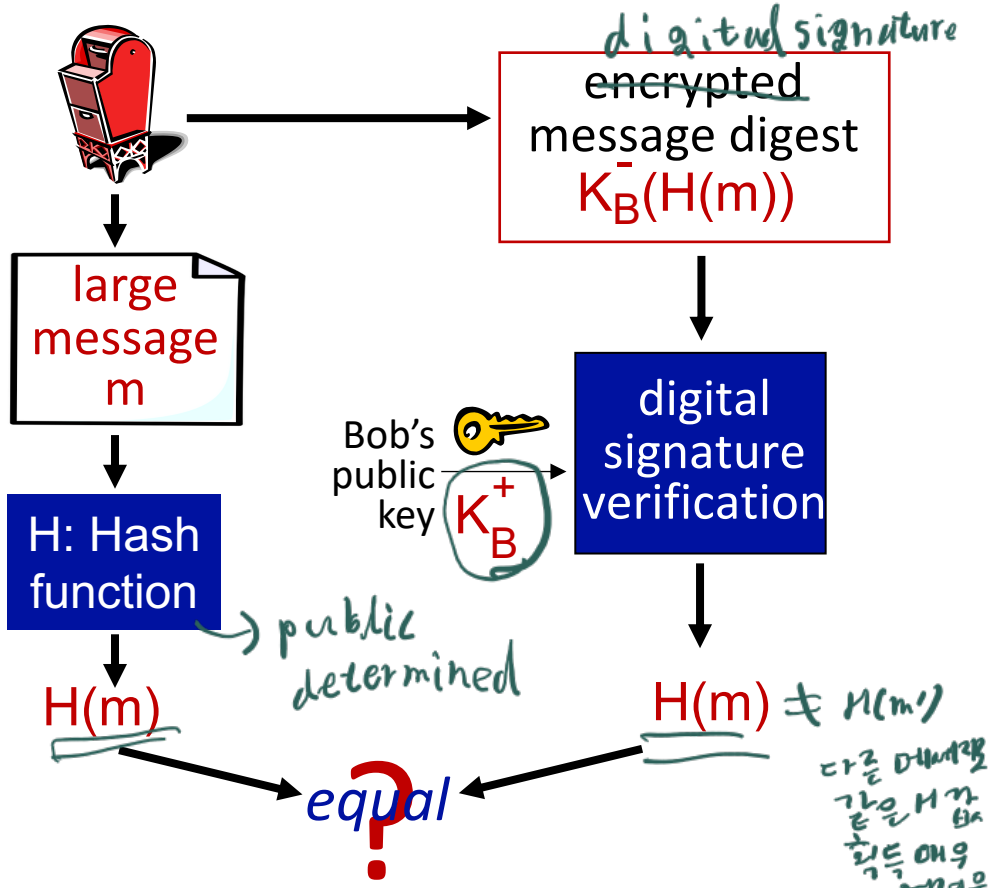
- produces fixed-size msg digest (fingerprint)
- given message *x*, computationally infeasible to find *x'=/=x* such that *H(x)=H(x')*
- given message digest *y*, computationally infeasible to find *x* such that *y = H(x)*

Digital signature = signed message digest

Bob sends digitally signed message:



Alice verifies signature, integrity of digitally signed message:



Hash function algorithms

- MD5 hash function widely used (RFC 1321)
  - computes 128-bit message digest in 4-step process.
  - arbitrary 128-bit string x, appears difficult to construct msg m whose MD5 hash is equal to x
- But now SHA-1, SHA-2, SHA-3 are used in newer systems
  - US standard [NIST, FIPS PUB 180-1]
  - 160-bit, 256-bit, … message digest

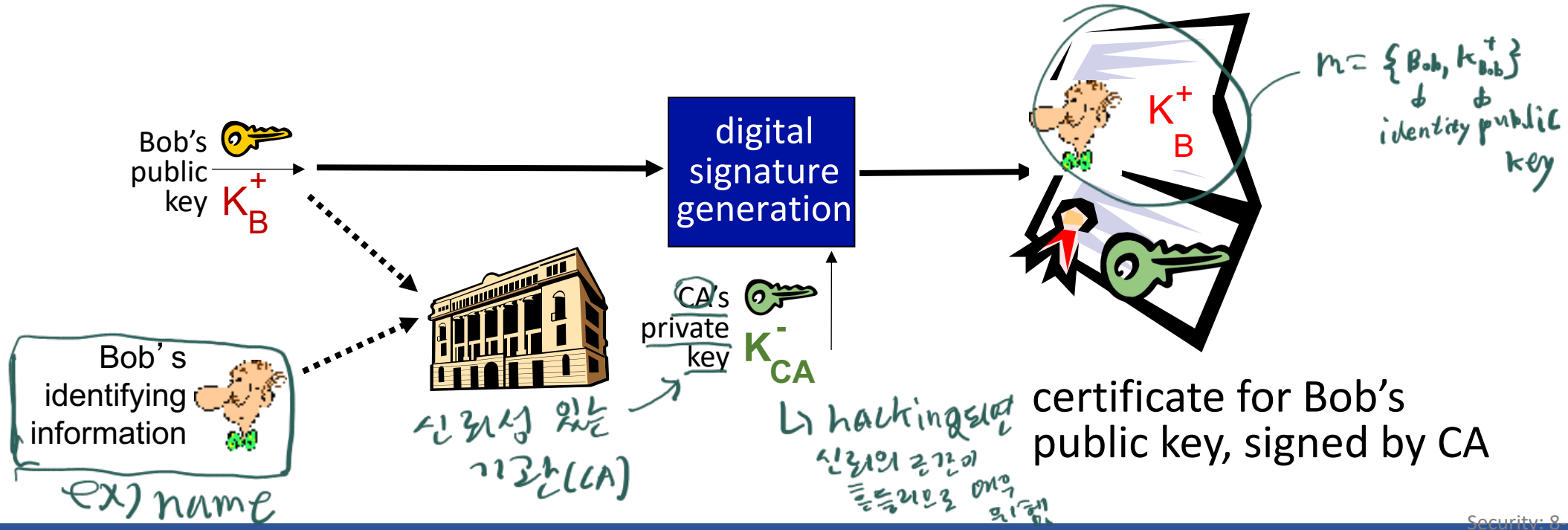
Need for certified public keys

- 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 pepperoni pizzas to Bob
  - Bob doesn't even like pepperoni

Public key Certification Authorities (CA)

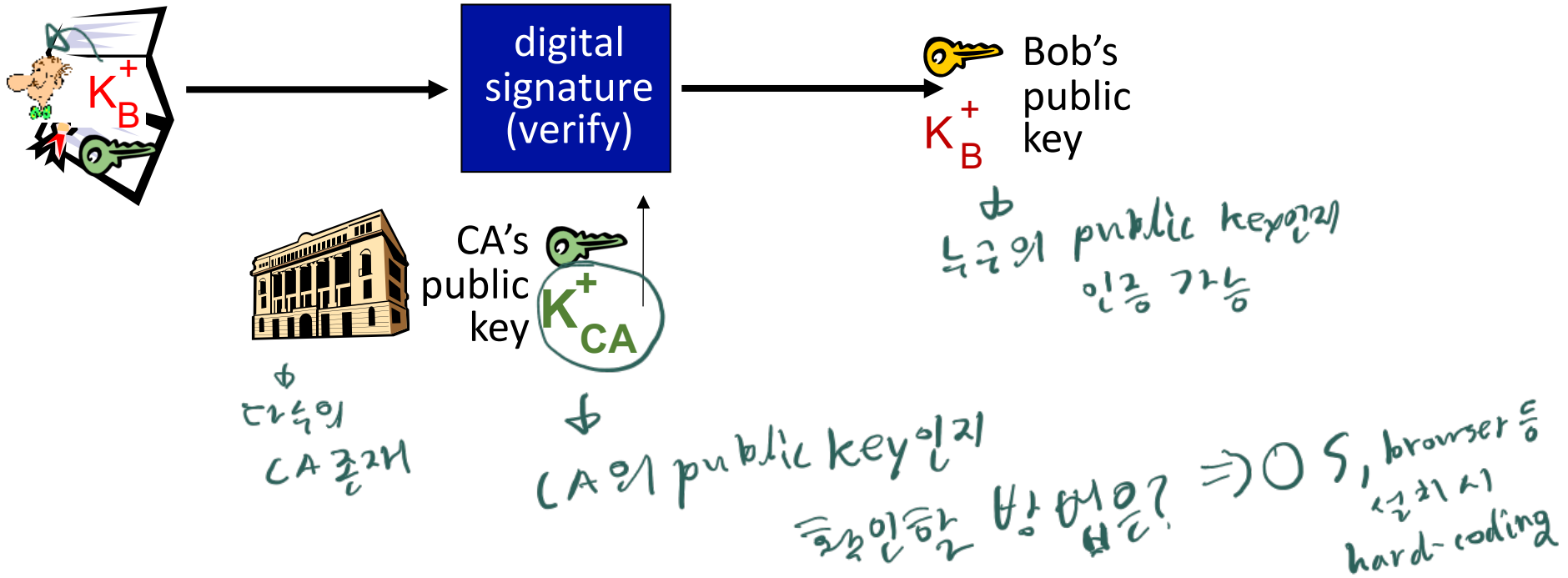
third-party → public key를 누구 것인지 인증해주는 서버

- certification authority (CA): binds public key to particular entity, Bob
- entity (person, website, router) registers its public key
  - CA creates certificate binding identity Bob to Bob's public key (K_B^+)
  - Certificate containing Bob's public key digitally signed by CA: CA says "this is Bob's public key"



Public key Certification Authorities (CA)

- 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



Chapter 8 outline

- What is network security?
- Principles of cryptography
- Authentication, message integrity
- Securing e-mail
- **Securing TCP connections: TLS**
- Network layer security: IPsec
- Security in wireless and mobile networks
- Operational security: firewalls and IDS

Transport-layer security (TLS)

- widely deployed security protocol above the transport layer
  - supported by almost all browsers, web servers: https (port 443)
- provides:
  - confidentiality: via *symmetric encryption* (can hide)
  - integrity: via *cryptographic hashing* (can't change)
  - authentication: via *public key cryptography*

  } *all techniques we have studied!*
- history:
  - early research, implementation: secure network programming, secure sockets
  - secure socket layer (SSL) deprecated [2015]
  - TLS 1.3: RFC 8846 [2018]

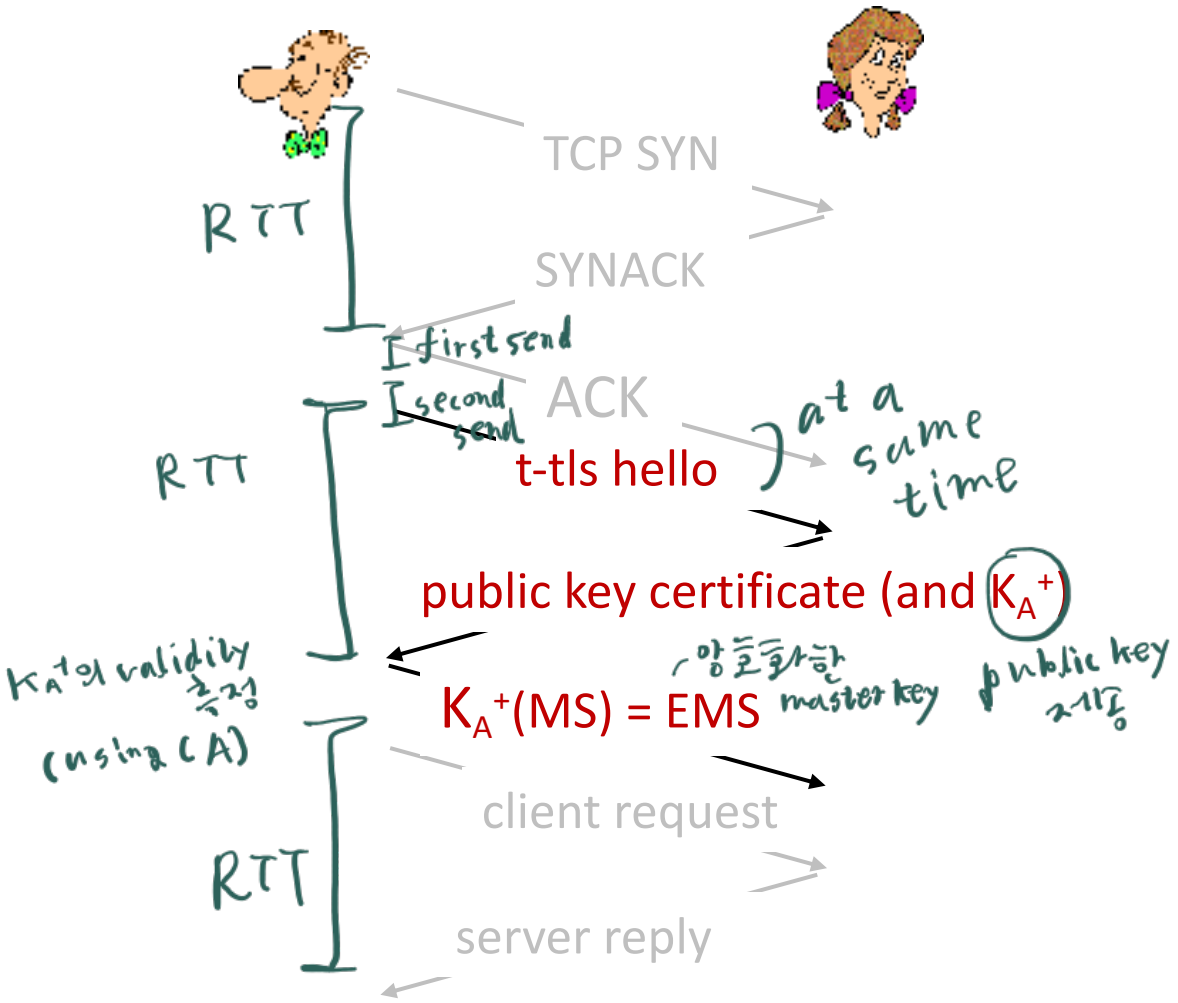
Transport-layer security: what's needed?

- let's *build* a toy TLS protocol, *t-tls,* to see what's needed!
- we've seen the "pieces" already:

  simplified TLS

  - handshake: Alice, Bob use their certificates, private keys to authenticate each other, exchange or create shared secret
  - key derivation: Alice, Bob use shared secret to derive set of keys
  - data transfer: stream data transfer: data as a series of records
    - not just one-time transactions
  - connection closure: special messages to securely close connection

t-tls: initial handshake



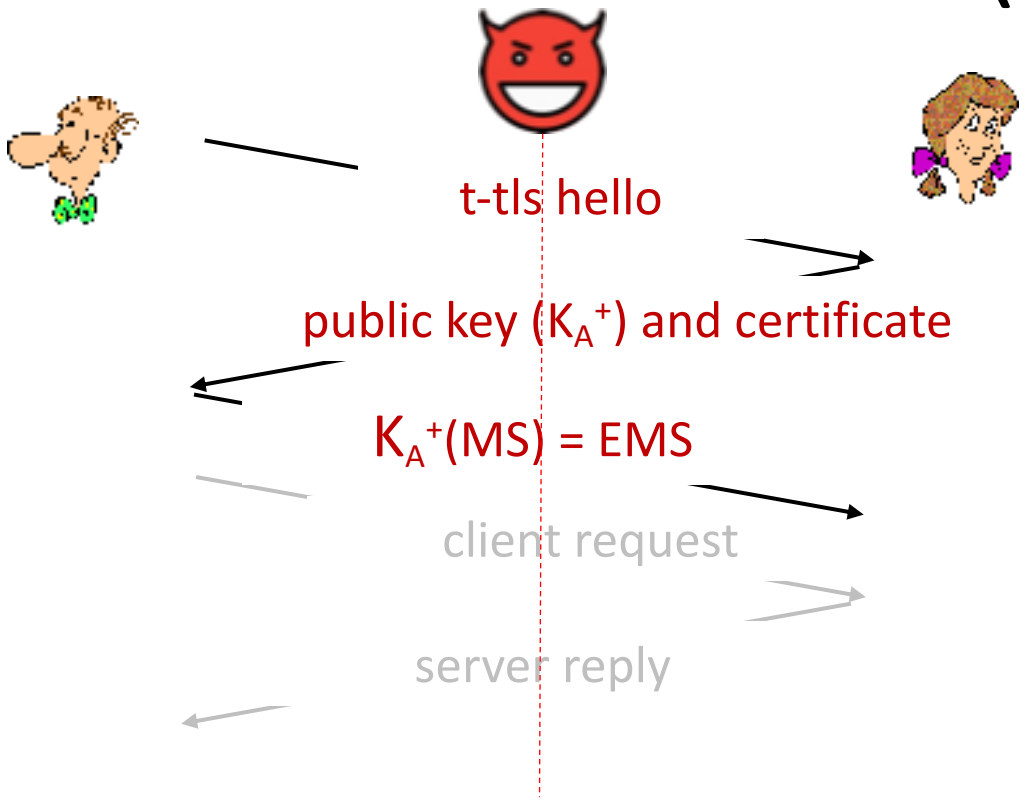
t-tls handshake phase:

- Bob establishes TCP connection with Alice
- Bob verifies that Alice is really Alice
- Bob sends Alice a master secret key (MS), used to generate all other keys for TLS session
- potential issues:
  - 3 RTT before client can start receiving data (including TCP handshake)

t-tls: cryptographic keys

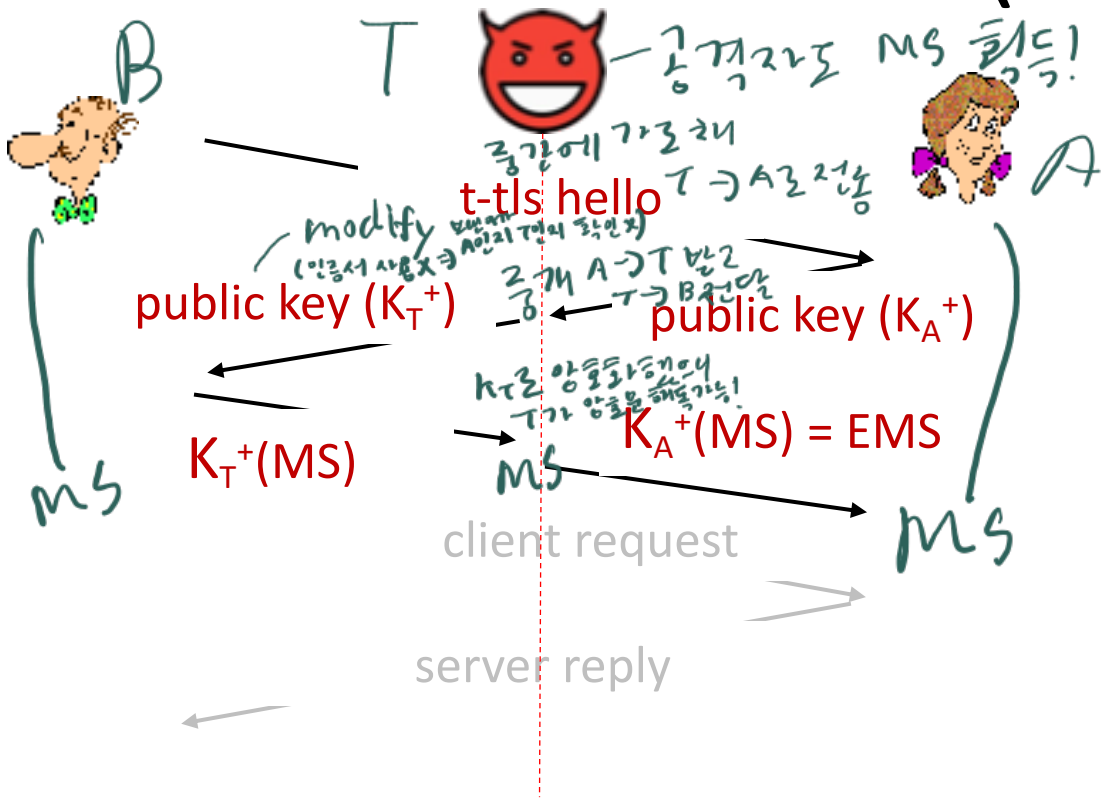
- considered bad to use same key for more than one cryptographic function
  - different keys for message authentication code (MAC) and encryption
- four keys:
  - K_c : encryption key for data sent from client to server
  - M_c : MAC key for data sent from client to server
  - K_s : encryption key for data sent from server to client
  - M_s : MAC key for data sent from server to client
- keys derived from key derivation function (KDF)
  - takes master secret and (possibly) some additional random data to create new keys

Man-in-the-Middle (MITM) Attacks



- Can Mallory obtain encryption and authentication keys?

Man-in-the-Middle (MITM) Attacks



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- *If TLS doesn't use certificate in the first place! (not happening in practice)*

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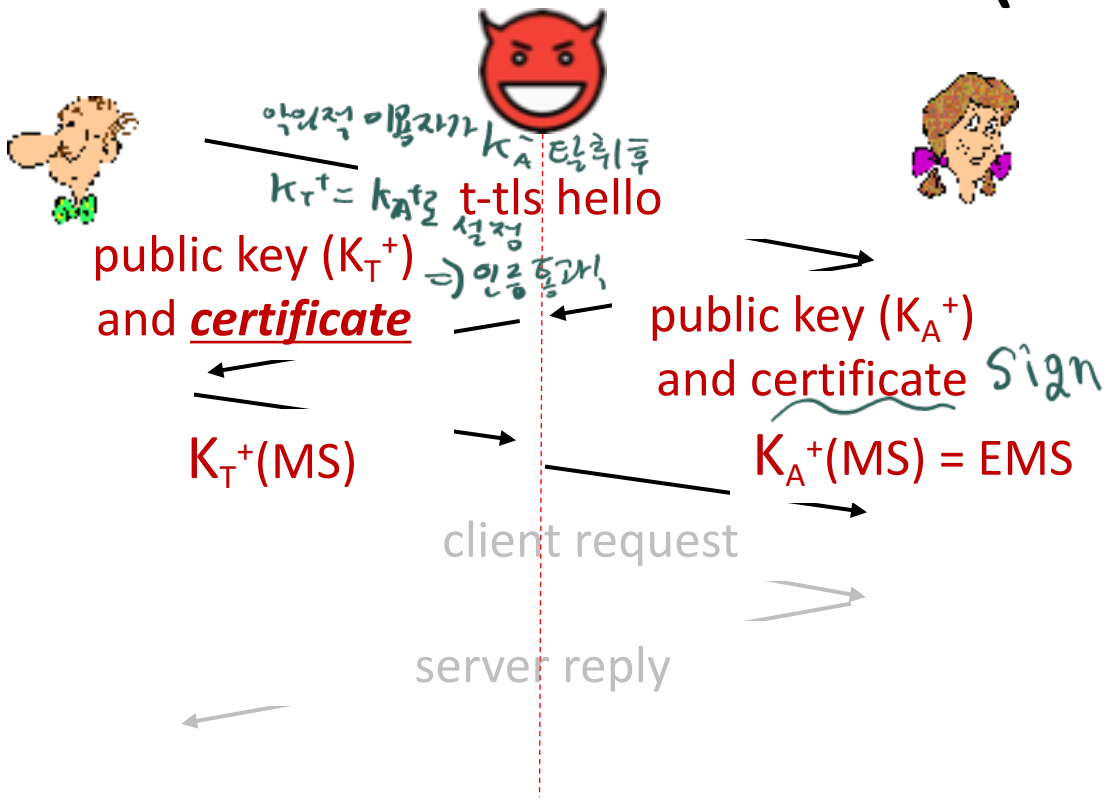
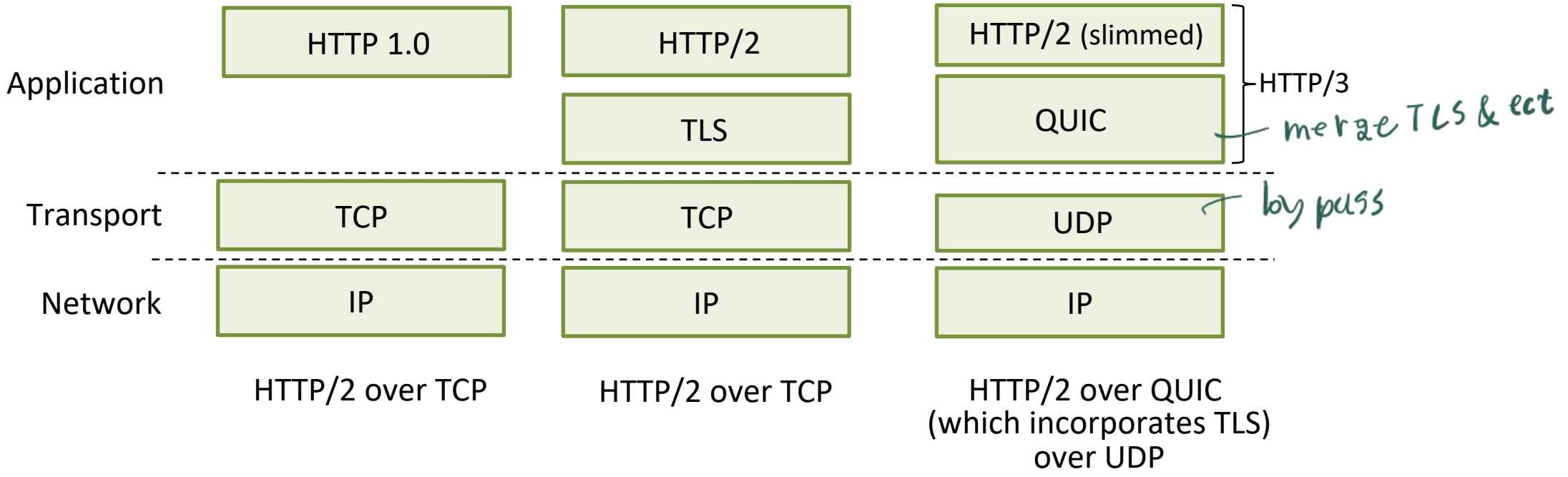


- Can Mallory obtain encryption and authentication keys?
- *If TLS doesn't use certificate in the first place! (not happening in practice)*
- *Or if Mallory compromises Alice's private key or CA's private key*

Transport-layer security (TLS)

- TLS provides an API that *any* application can use
- an HTTP view of TLS:



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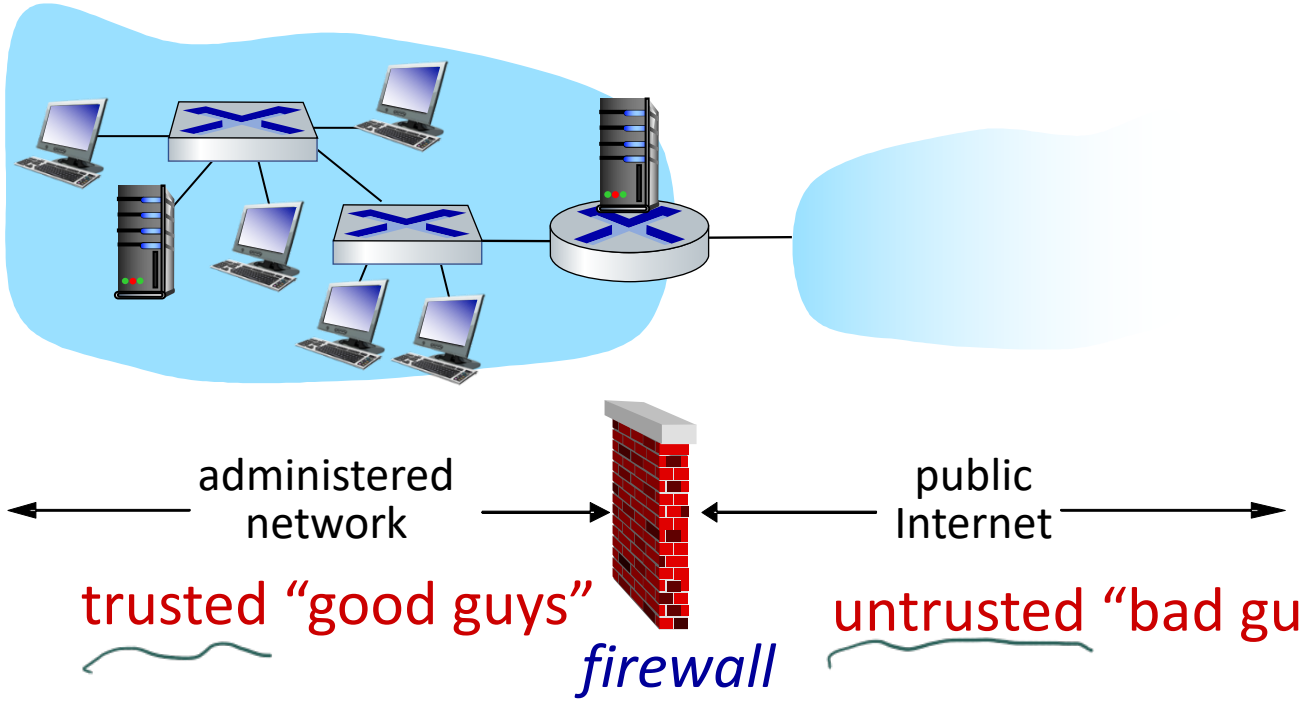
Firewalls

firewall

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

external system



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

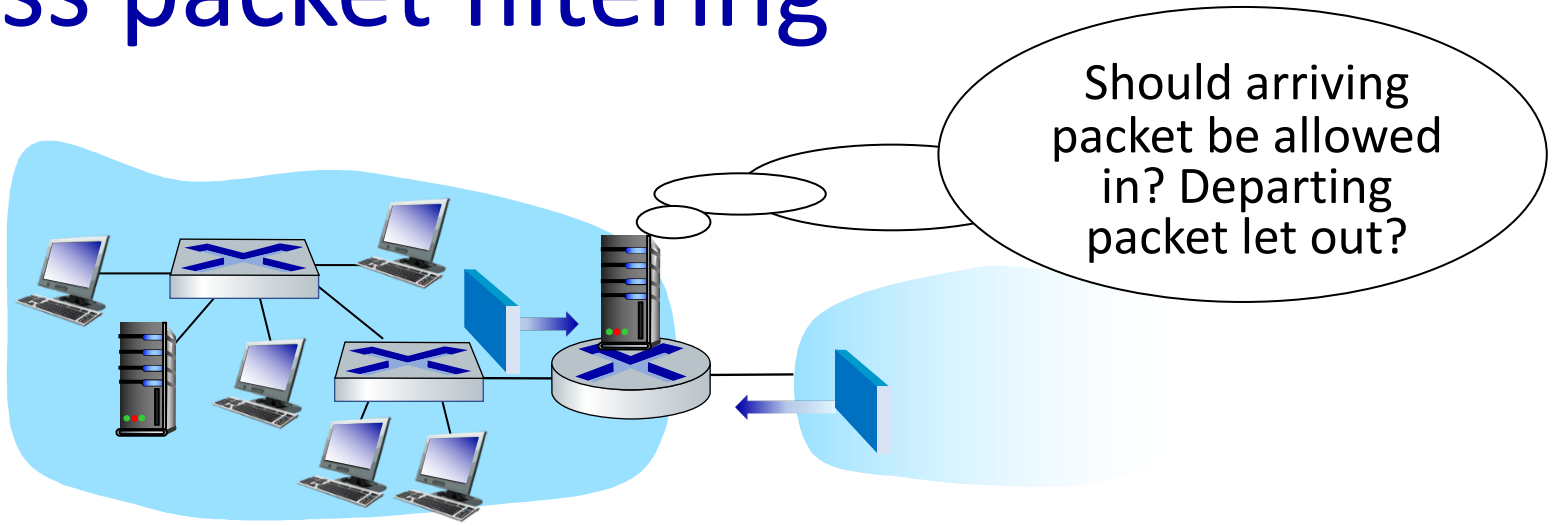
allow only authorized access to inside network

- set of authenticated users/hosts

three types of firewalls:

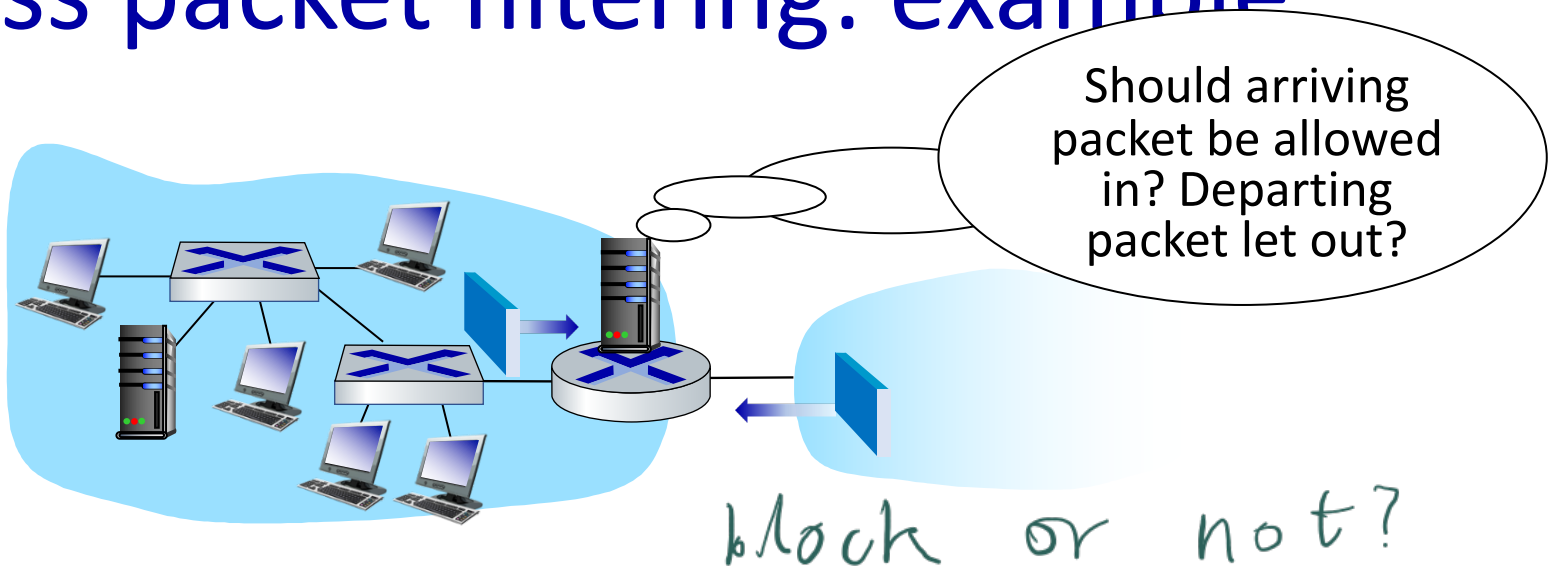
- stateless packet filters
- stateful packet filters
- application gateways

Stateless packet filtering



- internal network connected to Internet via router firewall
- filters packet-by-packet, → pass or drop decision to forward/drop packet based on:
  - source IP address, destination IP address
  - TCP/UDP source, destination port numbers
  - ICMP message type
  - TCP SYN, ACK bits

Stateless packet filtering: example



- example 1: block incoming and outgoing datagrams with IP protocol field = 17 and with either source or dest port = 23
  - result: all incoming, outgoing UDP flows and telnet connections are blocked
- example 2: block inbound TCP segments with ACK=0
  - result: prevents external clients from making TCP connections with internal clients, but allows internal clients to connect to outside

Stateless packet filtering: more examples

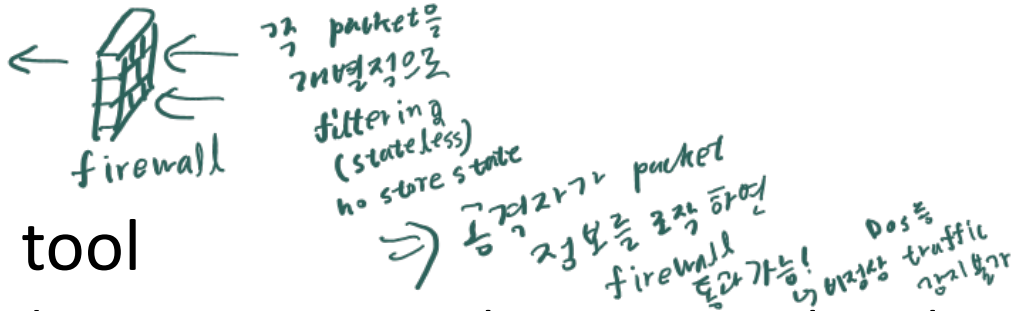
Policy	Firewall Setting
no outside Web access	drop all outgoing packets to any IP address, port 80
no incoming TCP connections, except those for institution's public Web server only.	drop all incoming TCP SYN packets to any IP except 130.207.244.203, port 80
prevent Web-radios from eating up the available bandwidth.	drop all incoming UDP packets - except DNS and router broadcasts.
prevent your network from being used for a smurf DoS attack.	drop all ICMP packets going to a "broadcast" address (e.g. 130.207.255.255)
prevent your network from being tracerouted	drop all outgoing ICMP TTL expired traffic

Access Control Lists

ACL: table of rules, applied top to bottom to incoming packets: (action, condition) pairs: looks like OpenFlow forwarding (Ch. 4)!

action	source address	dest address	protocol	source port	dest port	flag bit
allow	222.22/16	outside of 222.22/16	TCP	> 1023	80	any
allow	outside of 222.22/16	222.22/16	TCP	80	> 1023	ACK
allow	222.22/16	outside of 222.22/16	UDP	> 1023	53	---
allow	outside of 222.22/16	222.22/16	UDP	53	> 1023	----
deny	all	all	all	all	all	all

Stateful packet filtering



- *stateless packet filter:* heavy handed tool
  - admits packets that "make no sense," e.g., dest port = 80, ACK bit set, even though no TCP connection established:

action	source address	dest address	protocol	source port	dest port	flag bit
allow	outside of 222.22/16	222.22/16	TCP	80	> 1023	ACK

- *stateful packet filter:* track status of every TCP connection
  - track connection setup (SYN), teardown (FIN): determine whether incoming, outgoing packets "makes sense"
  - timeout inactive connections at firewall: no longer admit packets

Stateful packet filtering

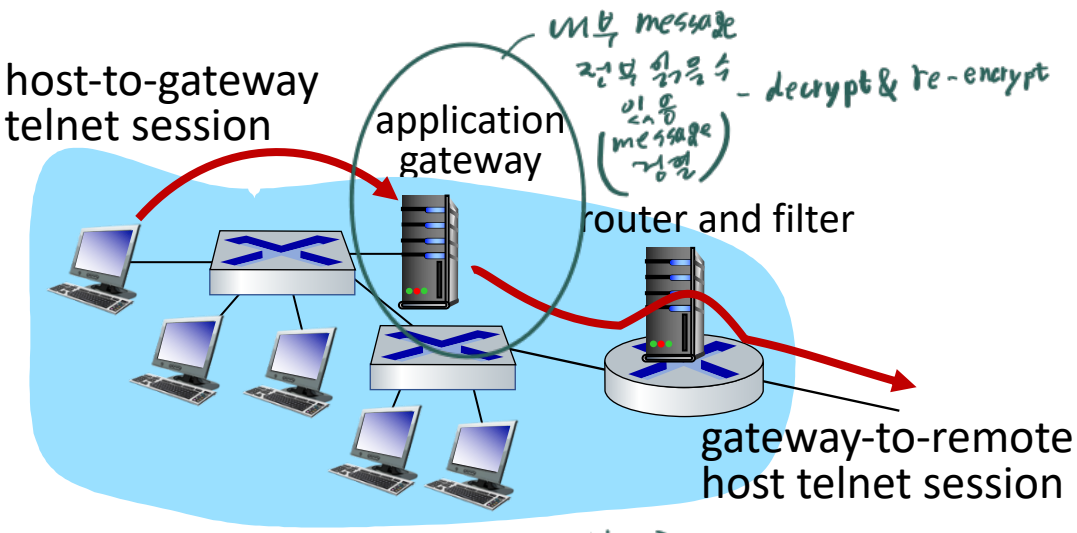
ACL augmented to indicate need to check connection state table before admitting packet

five tupl
1,2. src/dest IP
3,4 - src/dest port
5. protocol (TCP/UDP)

action	source address	dest address	proto	source port	dest port	flag bit	check connection
allow	222.22/16	outside of 222.22/16	TCP	> 1023	80	any	
allow	outside of 222.22/16	222.22/16	TCP	80	> 1023	ACK	X
allow	222.22/16	outside of 222.22/16	UDP	> 1023	53	---	
allow	outside of 222.22/16	222.22/16	UDP	53	> 1023	----	X
deny	all	all	all	all	all	all	

Application gateways

- filter packets on application data as well as on IP/TCP/UDP fields.
- *example:* allow select internal users to telnet outside

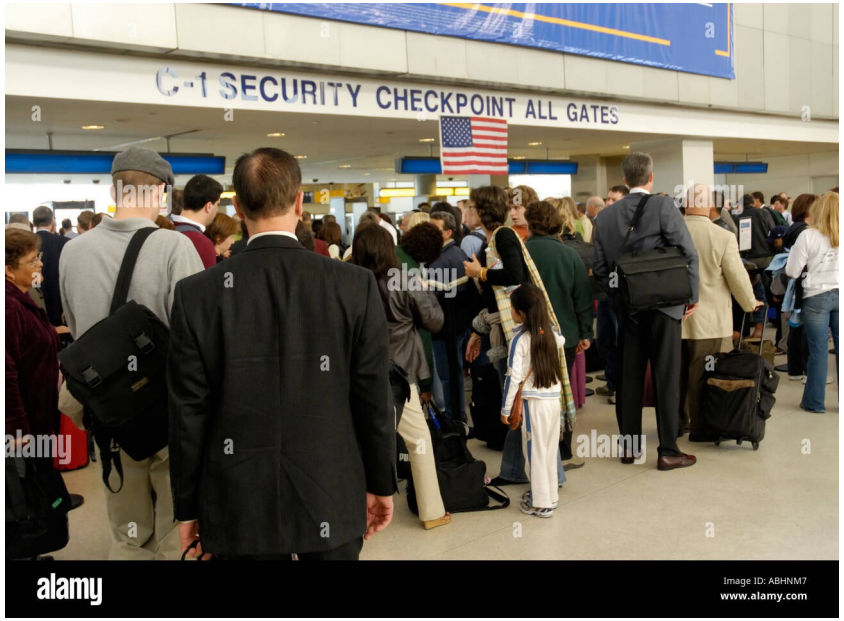


1. require all telnet users to telnet through gateway.
2. for authorized users, gateway sets up telnet connection to dest host
   - gateway relays data between 2 connections
3. router filter blocks all telnet connections not originating from gateway

Limitations of firewalls, gateways

- IP spoofing: router can't know if data "really" comes from claimed source
- if multiple apps need special treatment, each has own app. gateway
- client software must know how to contact gateway
  - e.g., must set IP address of proxy in Web browser

- filters often use all or nothing policy for UDP
- *tradeoff:* degree of communication with outside world, level of security
- many highly protected sites still suffer from attacks


C-1 SECURITY CHECKPOINT ALL GATES
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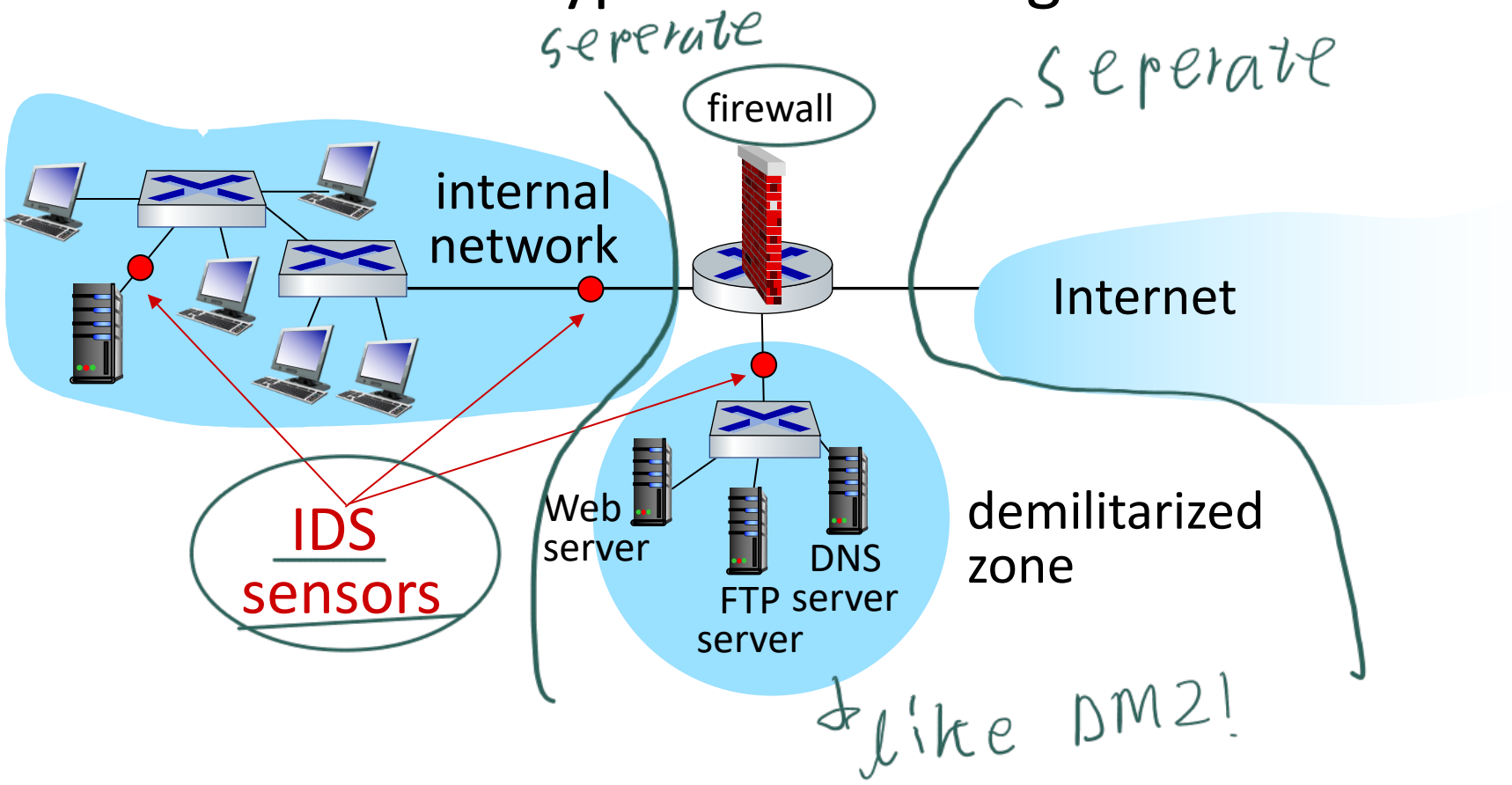
Intrusion detection systems

IDS

- packet filtering:
  - operates on TCP/IP headers only
  - no correlation check among sessions ⇒ 세션 간 상관관계 분석 X
- 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 key)
- message integrity
- end-point authentication

…. used in many different security scenarios

- secure email
- secure transport (TLS)
- IP sec
- 802.11, 4G/5G

operational security: firewalls and IDS

Next…

- Warp-up: Review Session
- (Zoom; one more time)