# Chapter 8
# Security

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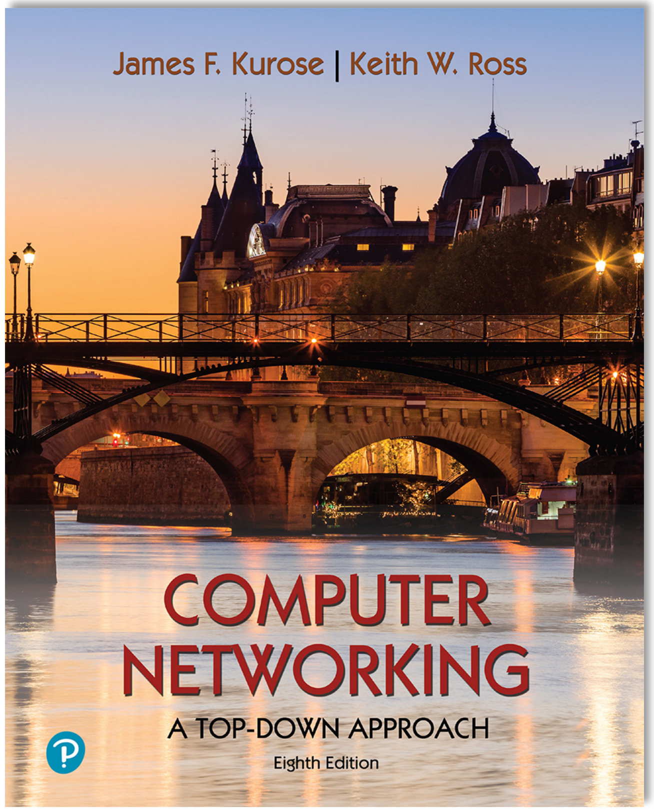
Thanks and enjoy! JFK/KWR



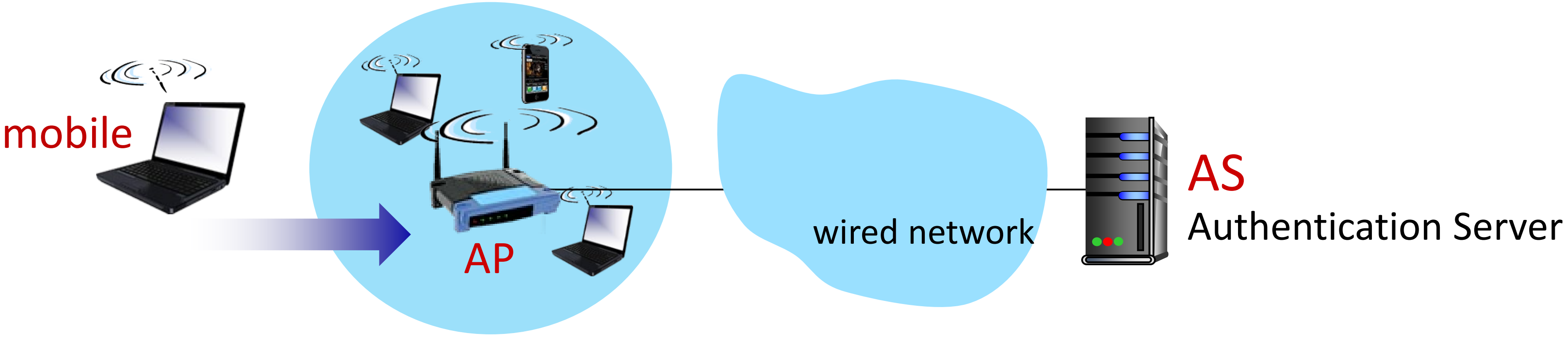



*Computer Networking: A Top-Down Approach*
8th edition
Jim Kurose, Keith Ross
Pearson, 2020

# 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
  - 802.11 (WiFi)
  - 4G/5G
- Operational security: firewalls and IDS

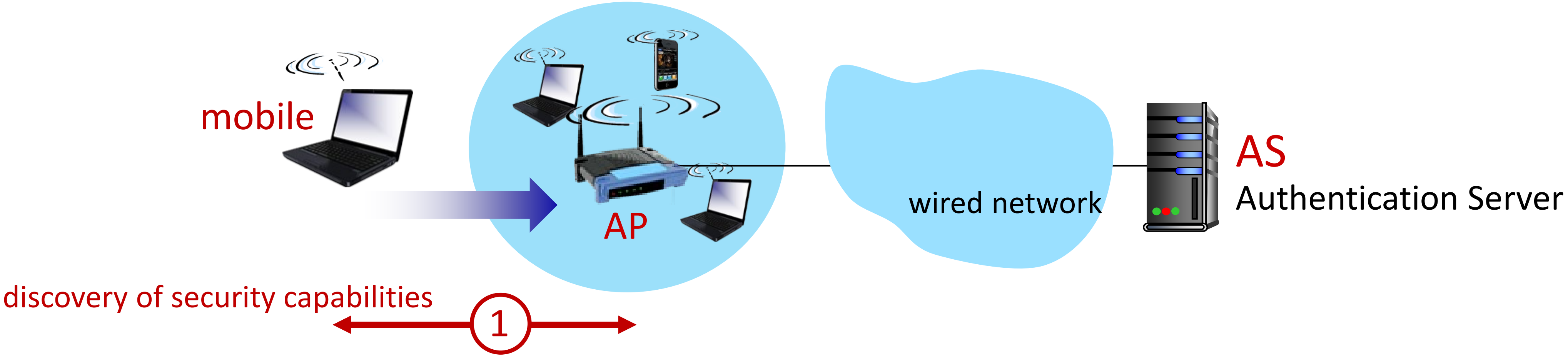
# 802.11: authentication, encryption




Arriving mobile must:

- associate with access point: (establish) communication over wireless link
- authenticate to network

# 802.11: authentication, encryption

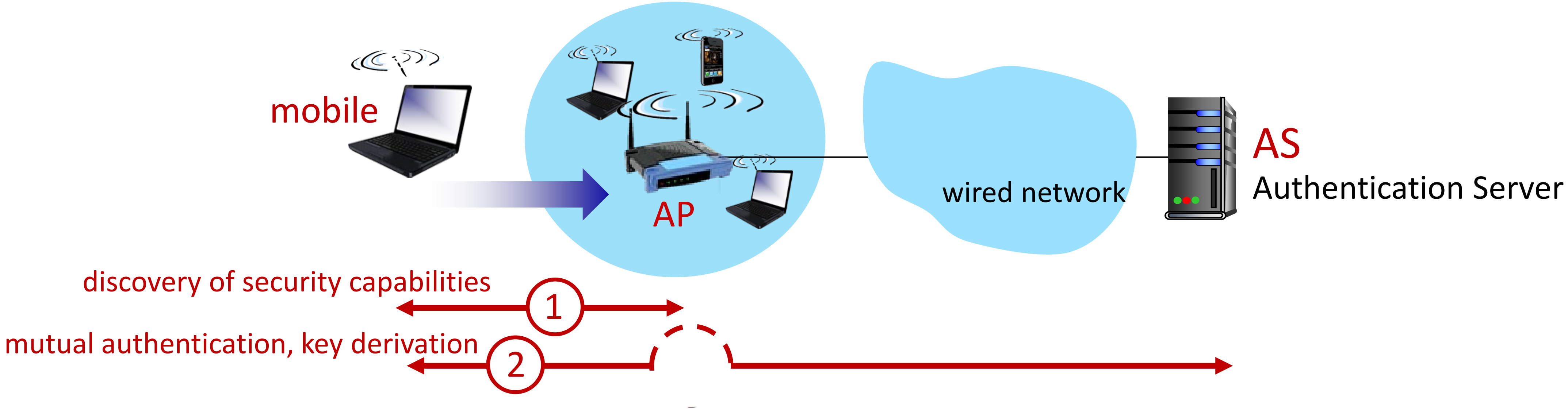



1 discovery of security capabilities:

- AP advertises its presence, forms of authentication and encryption provided
- device requests specific forms authentication, encryption desired

although device, AP already exchanging messages, device not yet authenticated, does not have encryption keys

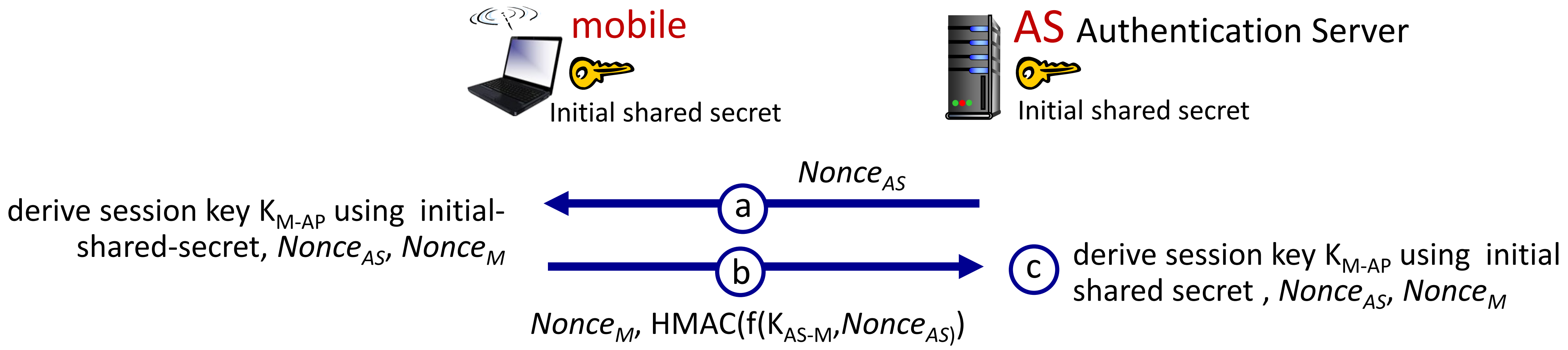
# 802.11: authentication, encryption




(2) mutual authentication and shared symmetric key derivation:

- AS, mobile already have shared common secret (e.g., password)
- AS, mobile use shared secret, nonces (prevent relay attacks), cryptographic hashing (ensure message integrity) to authenticating each other
- AS, mobile derive symmetric session key

# 802.11: WPA3 handshake

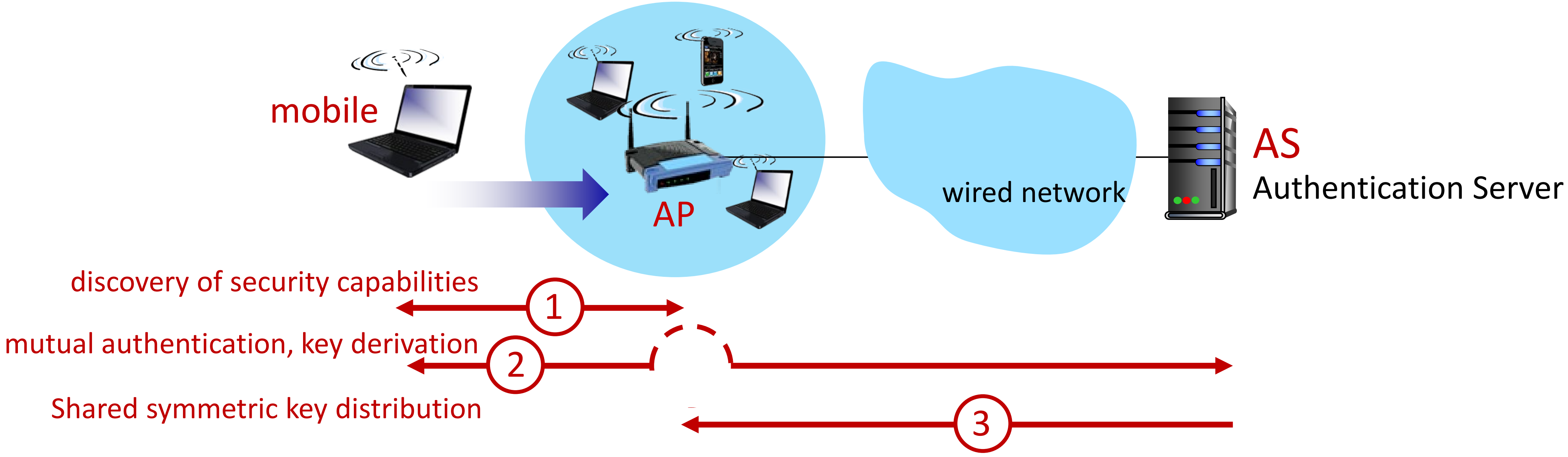



ⓐ AS generates $Nonce_{AS}$, sends to mobile

ⓑ mobile receives $Nonce_{AS}$
- generates $Nonce_M$
- generates symmetric shared session key $K_{M\text{-}AP}$ using $Nonce_{AS}$, $Nonce_M$, and initial shared secret
- sends $Nonce_M$, and HMAC-signed value using $Nonce_{AS}$ and initial shared secret

ⓒ AS derives symmetric shared session key $K_{M\text{-}AP}$

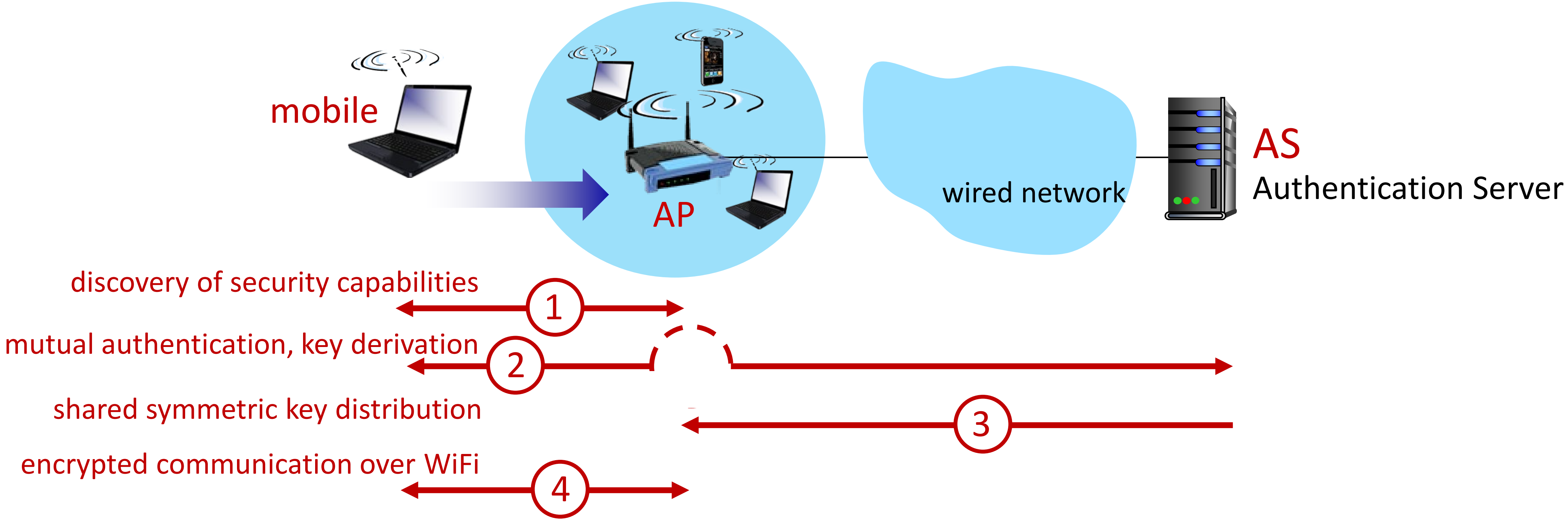
# 802.11: authentication, encryption




3 shared symmetric session key distribution (e.g., for AES encryption)

- same key derived at mobile, AS
- AS informs AP of the shared symmetric session

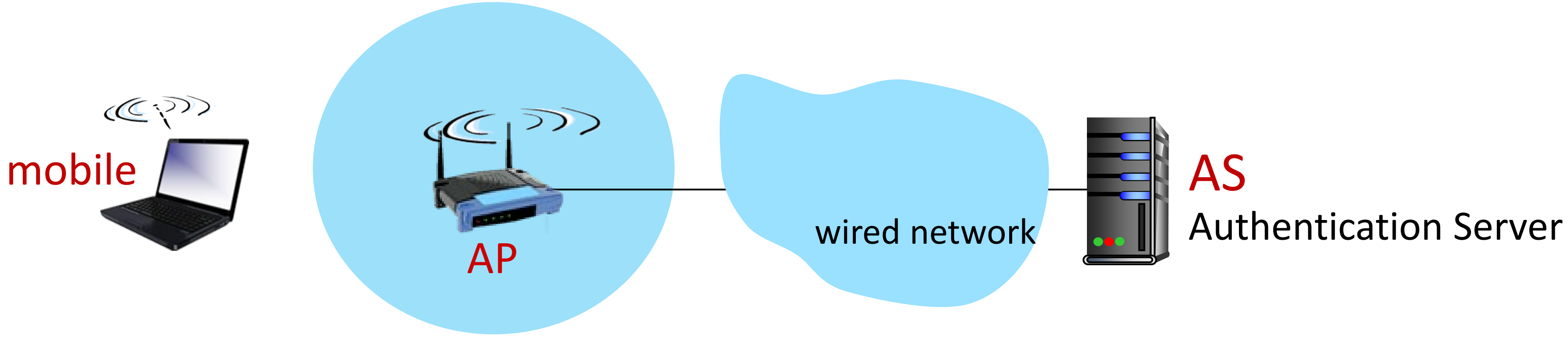
# 802.11: authentication, encryption




4 encrypted communication between mobile and remote host via AP

- same key derived at mobile, AS
- AS informs AP of the shared symmetric session

# 802.11: authentication, encryption




<table>
<tr><td colspan="3">EAP TLS</td></tr>
<tr><td colspan="3">EAP</td></tr>
<tr><td>EAP over LAN (EAPoL)</td><td rowspan="2"></td><td>RADIUS</td></tr>
<tr><td>IEEE 802.11</td><td>UDP/IP</td></tr>
</table>

- Extensible Authentication Protocol (EAP) [RFC 3748] defines end-to-end request/response protocol between mobile device, AS

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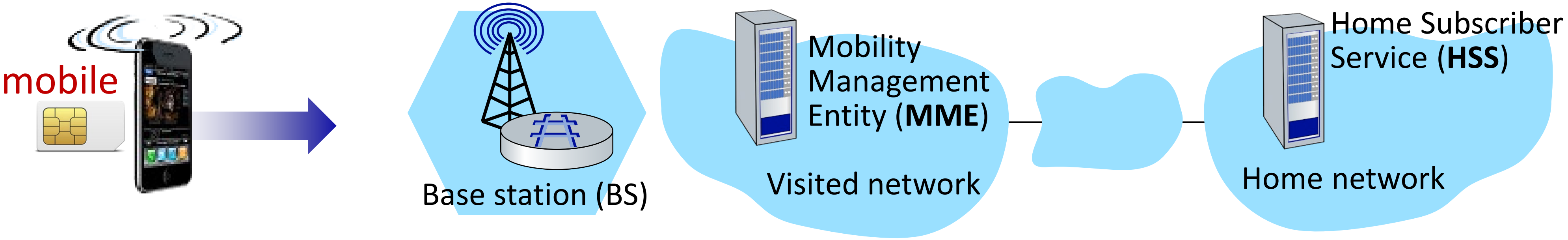
- Operational security: firewalls and IDS

# Authentication, encryption in 4G LTE

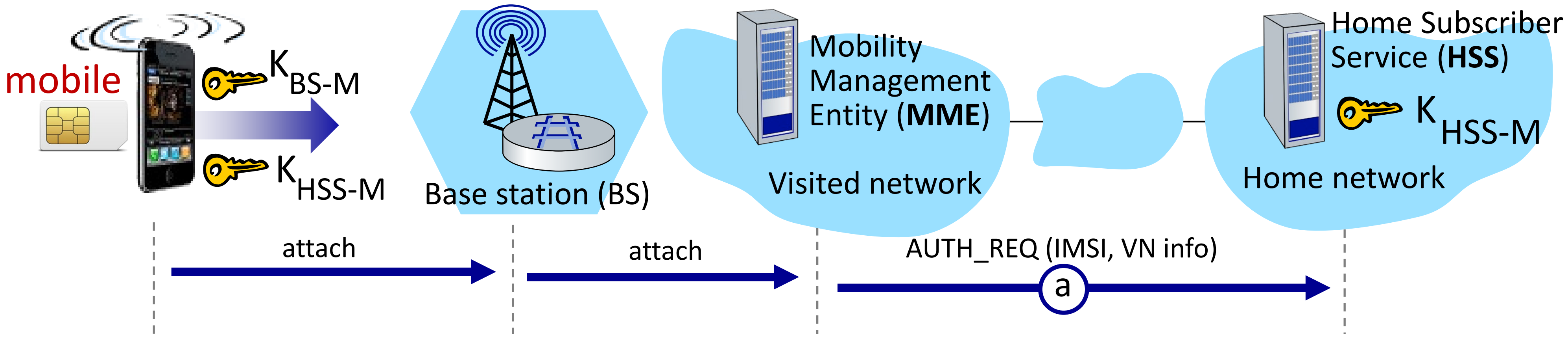



- arriving mobile must:
  - associate with BS: (establish) communication over 4G wireless link
  - authenticate itself to network, and authenticate network
- notable differences from WiFi
  - mobile's SIMcard provides global identity, contains shared keys
  - services in visited network depend on (paid) service subscription in home network

# Authentication, encryption in 4G LTE


- mobile, BS use derived session key $K_{BS-M}$ to encrypt communications over 4G link
- MME in visited network + HHS in home network, together play role of WiFi AS
  - ultimate authenticator is HSS
  - trust and business relationship between visited and home networks

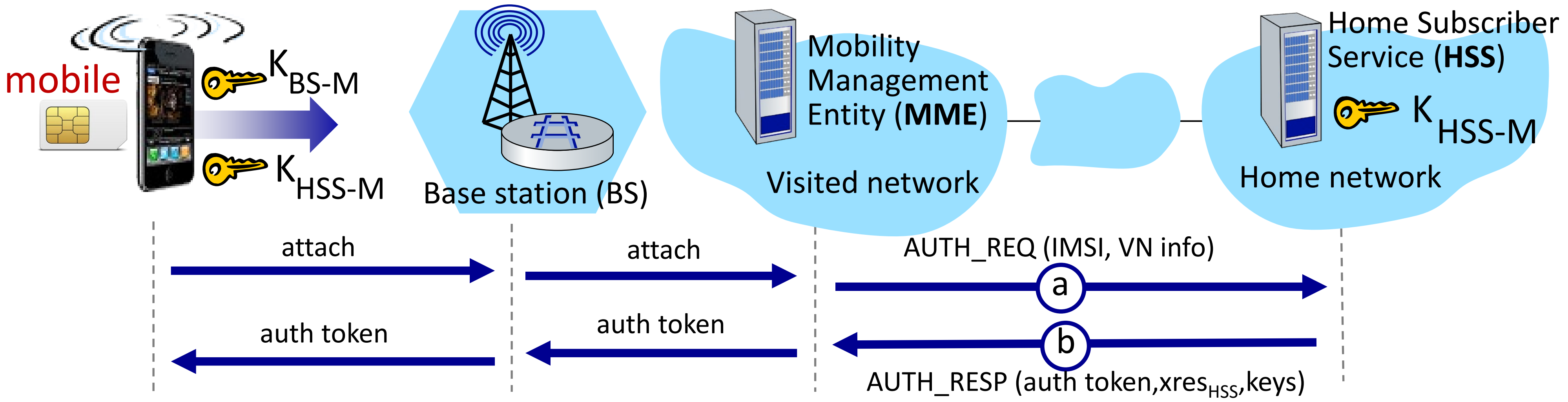
# Authentication, encryption in 4G LTE




ⓐ authentication request to home network HSS

- mobile sends attach message (containing its IMSI, visited network info) relayed from BS to visited MME to home HHS
- IMSI identifies mobile's home network

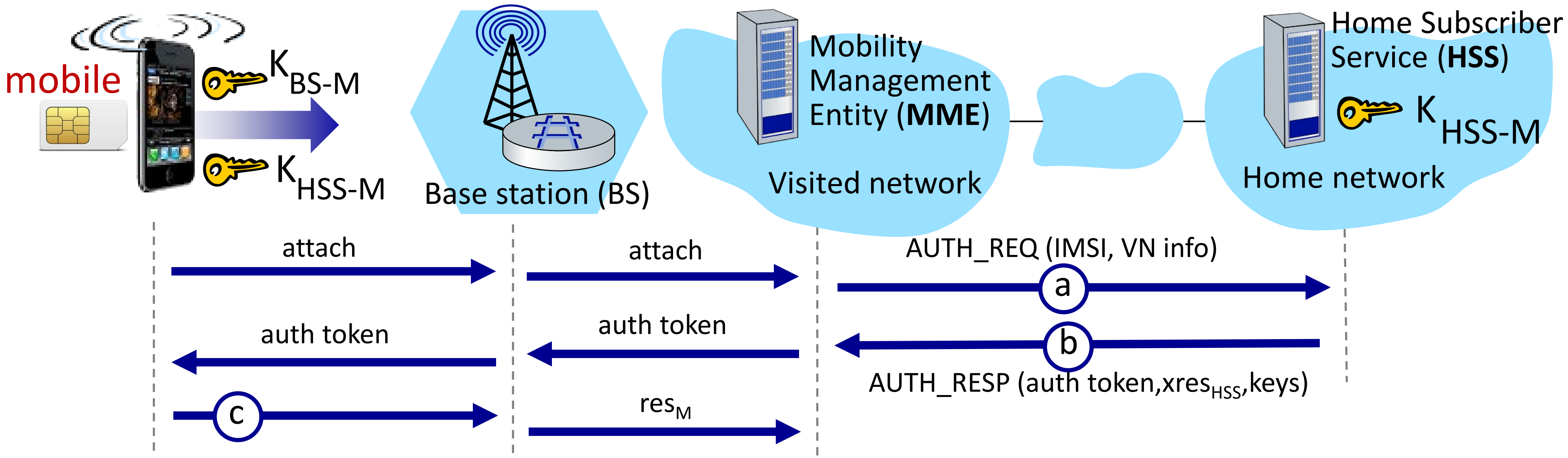
# Authentication, encryption in 4G LTE




ⓑ HSS use shared-in-advance secret key, $K_{HSS-M}$, to derive authentication token, *auth_token*, and expected authentication response token, *xres*$_{HSS}$

- *auth_token* contains info encrypted by HSS using $K_{HSS-M}$ , allowing mobile to know that whoever computed *auth_token* knows shared-in-advance secret
- mobile has authenticated network
- visited HSS keeps *xres*$_{HSS}$ for later use

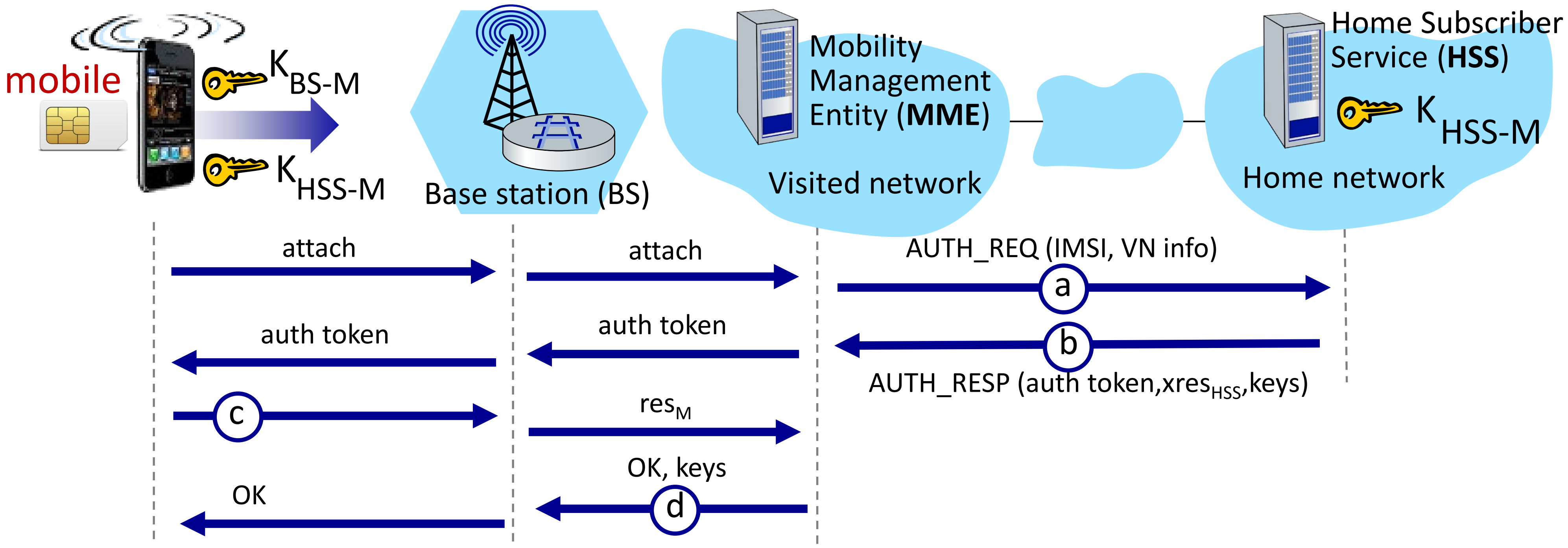
# Authentication, encryption in 4G LTE




ⓒ authentication response from mobile:

- mobile computes $res_M$ using its secret key to make same cryptographic calculation that HSS made to compute $xres_{HSS}$ and sends $res_M$ to MME

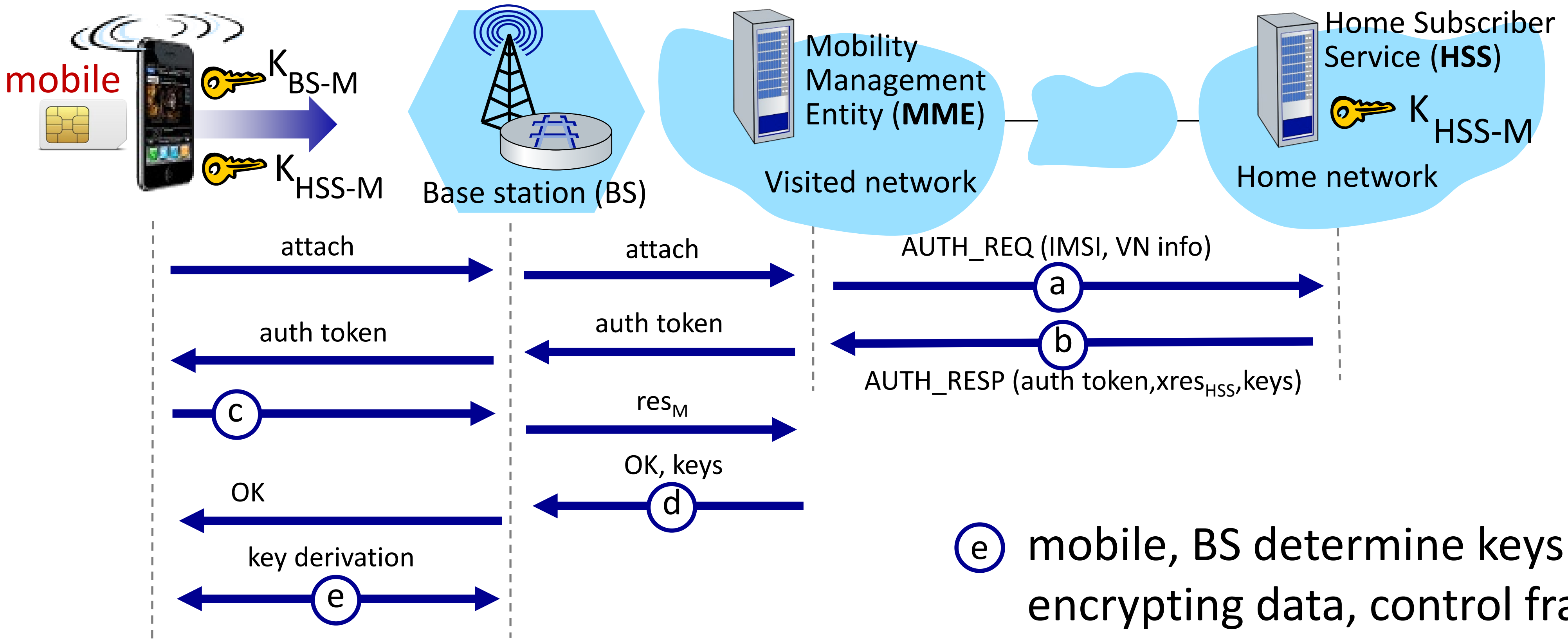
# Authentication, encryption in 4G LTE




d mobile is authenticated by network:

- MMS compares mobile-computed value of $res_M$ with the HSS-computed value of $xres_{HSS}$ . If they match, mobile is authenticated ! (why?)
- MMS informs BS that mobile is authenticated, generates keys for BS

# Authentication, encryption in 4G LTE




(e) mobile, BS determine keys for encrypting data, control frames over 4G wireless channel
- AES can be used

# Authentication, encryption: from 4G to 5G

- 4G: MME in visited network makes authentication decision
- 5G: home network provides authentication decision
  - visited MME plays "middleman" role but can still reject

- 4G: uses shared-in-advance keys
- 5G: keys not shared in advance for IoT

- 4G: device IMSI transmitted in cleartext to BS
- 5G: public key crypto used to encrypt IMSI

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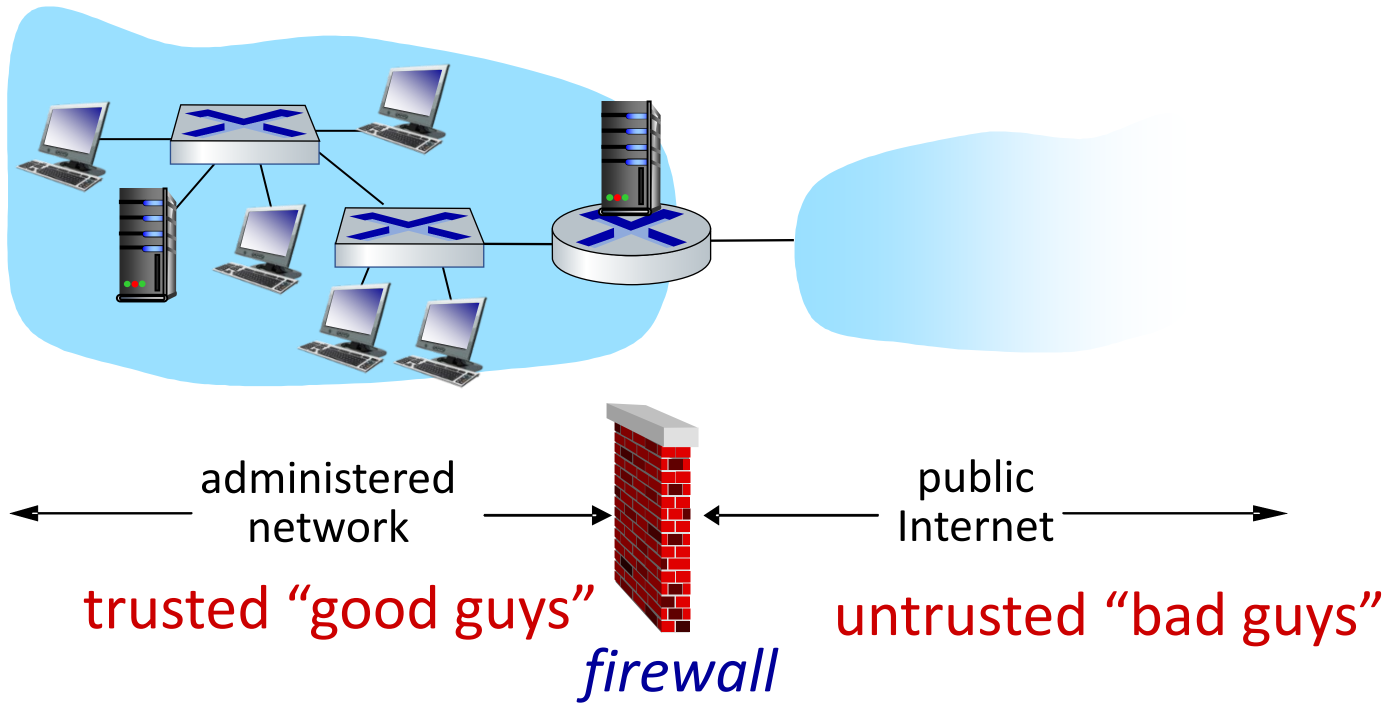
# Firewalls

**firewall**

isolates organization's internal network 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

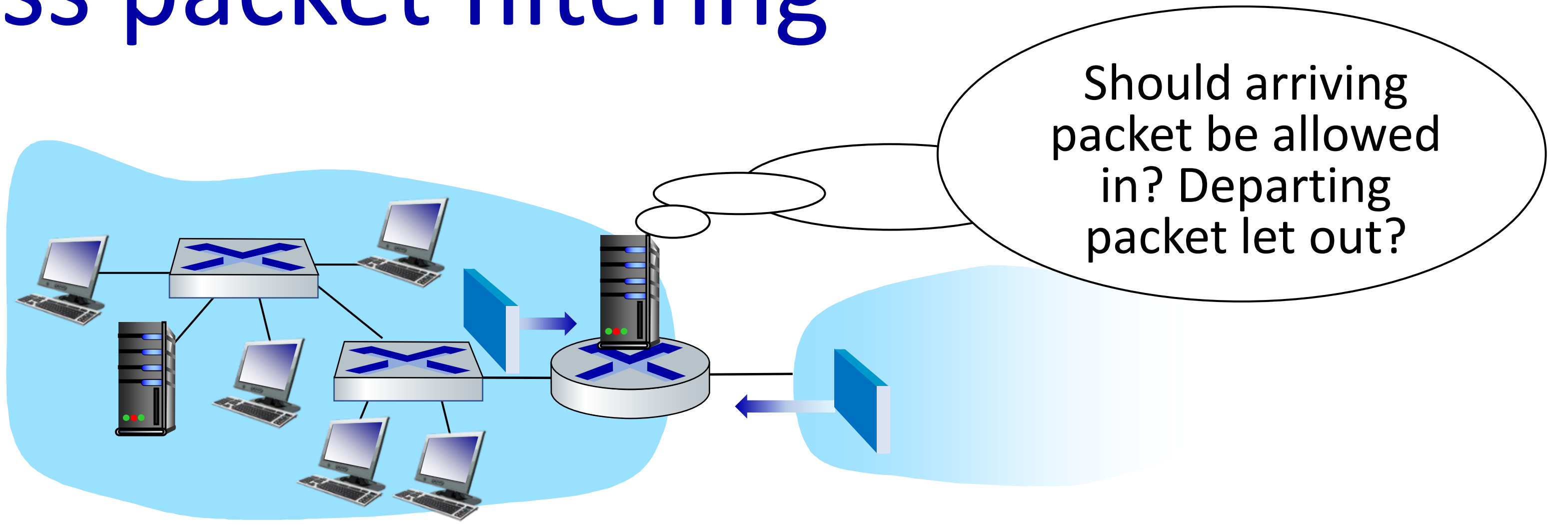
allow only authorized access to inside network

- set of authenticated users/hosts

three types of firewalls:

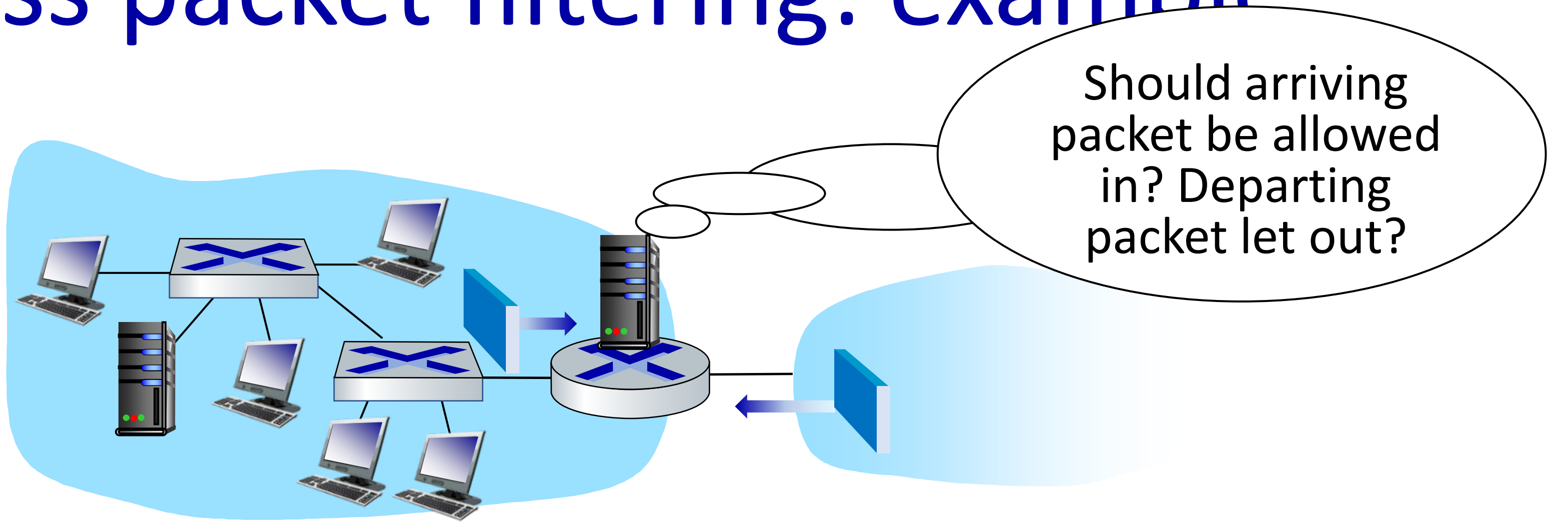
- stateless packet filters
- stateful packet filters
- application gateways

# Stateless packet filtering




- internal network connected to Internet via router firewall
- filters packet-by-packet, 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

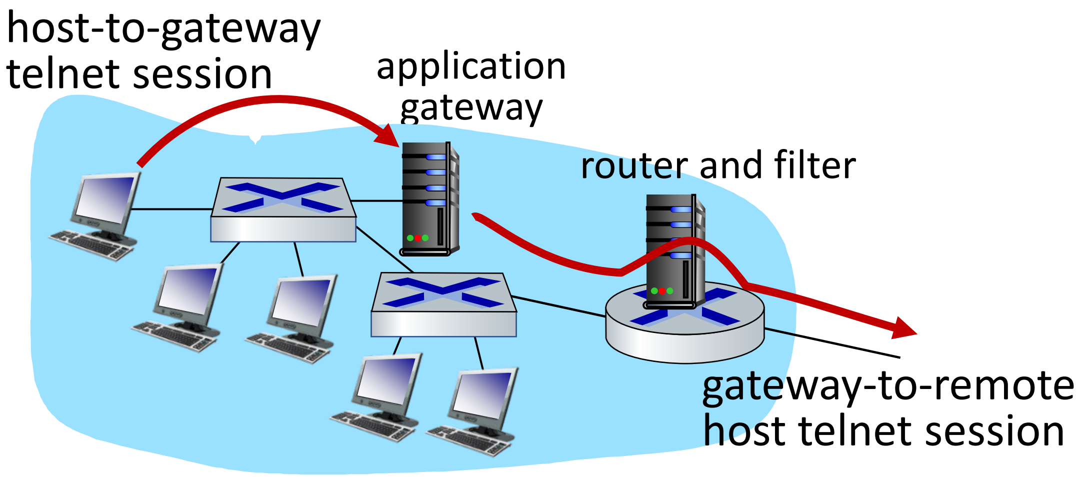
# Stateful packet filtering

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

| 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

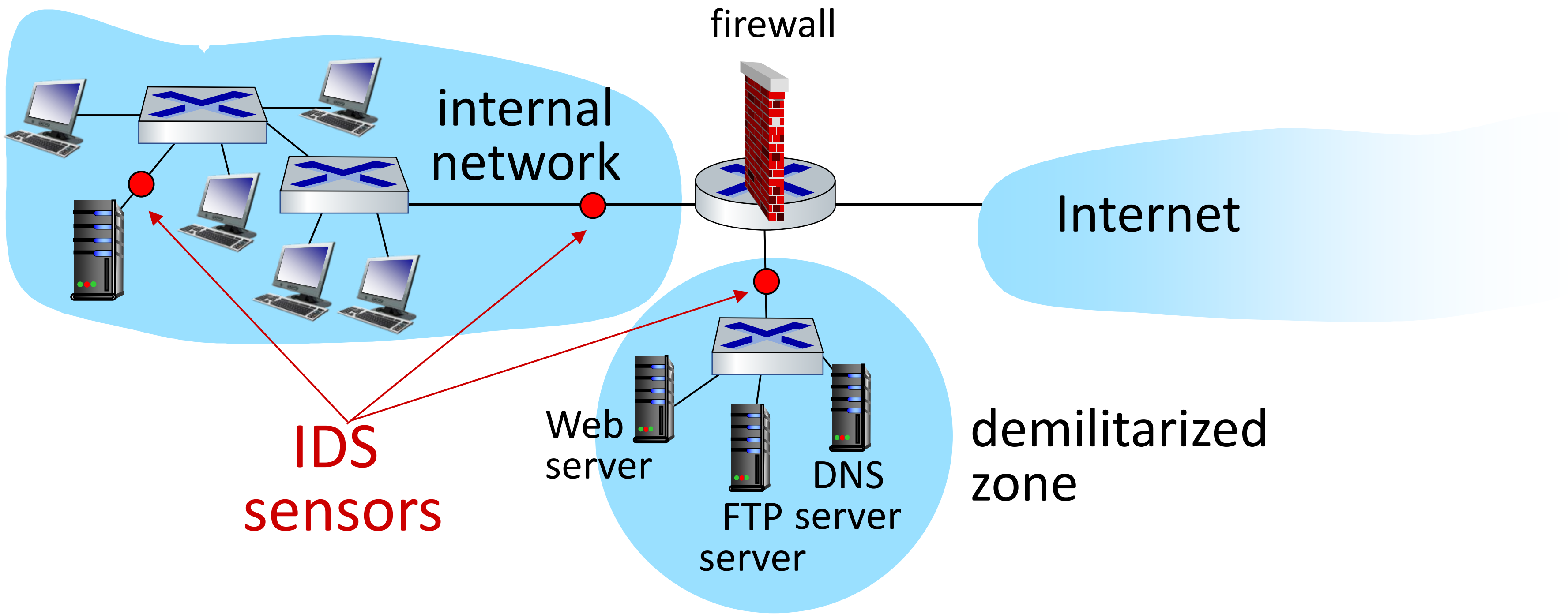
- IP spoofing: router can't know if data "really" comes from claimed source
- if multiple apps need special treatment, each has own app. gateway
- client software must know how to contact gateway
  - e.g., must set IP address of proxy in Web browser
- filters often use all or nothing policy for UDP
- *tradeoff:* degree of communication with outside world, level of security
- many highly protected sites still suffer from attacks

# 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 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