Link Layer and LANs:
Data Center Networks & Wireless Networks

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

NetS&P
Research Lab @ KAIST

KAIST

Link layer, LANs: roadmap

- introduction
- error detection, correction
- multiple access protocols
- LANs
  - addressing, ARP
  - Ethernet
  - switches
  - VLANs
- link virtualization: MPLS
- data center networking

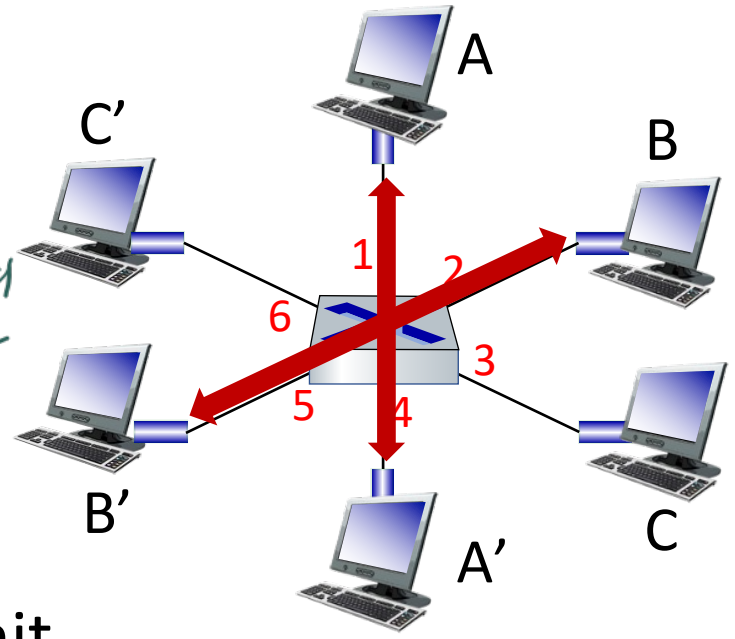
- a day in the life of a web request

Ethernet switch

- Switch is a link-layer device: takes an *active* role
  - store, forward Ethernet frames
  - examine incoming frame's MAC address, *selectively* forward frame to one-or-more outgoing links when frame is to be forwarded on segment, uses CSMA/CD to access segment
- transparent: hosts *unaware* of presence of switches
- plug-and-play, self-learning
  - switches do not need to be configured

Switch: multiple simultaneous transmissions

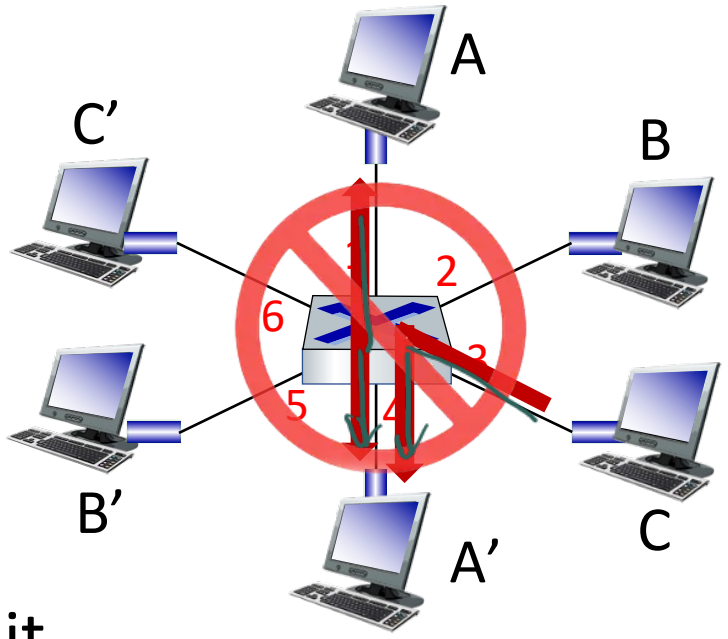
- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, so:
  - no collisions; full duplex
  - each link is its own collision domain
- switching: A-to-A' and B-to-B' can transmit simultaneously, without collisions



switch with six interfaces (1,2,3,4,5,6)

Switch: multiple simultaneous transmissions

- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, so:
  - no collisions; full duplex
  - each link is its own collision domain
- switching: A-to-A' and B-to-B' can transmit simultaneously, without collisions
  - but A-to-A' and C to A' can *not* happen simultaneously → 같은 경로 공유하는 경우에는 동시 전달 불가



switch with six interfaces (1,2,3,4,5,6)

Switch forwarding table

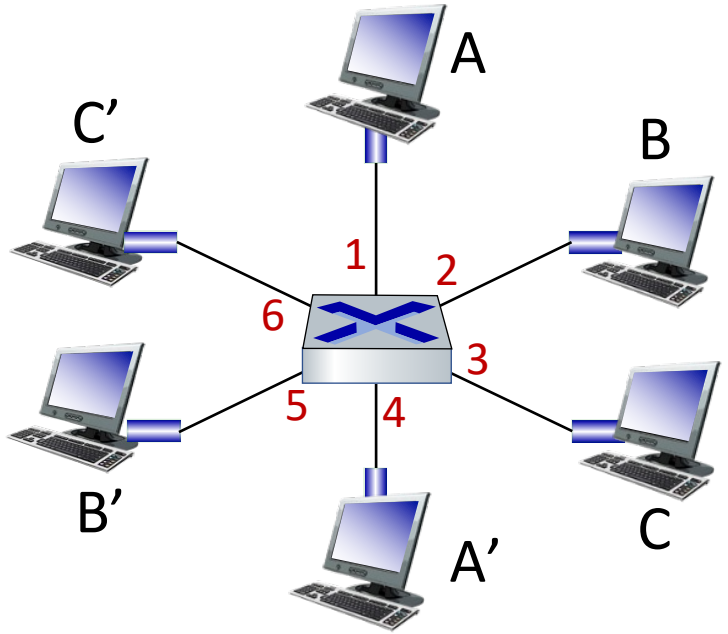
Q: how does switch know A' reachable via interface 4, B' reachable via interface 5?

A: each switch has a switch table, each entry:

- (MAC address of host, interface to reach host, time stamp)
- looks like a routing table!

Q: how are entries created, maintained in switch table?

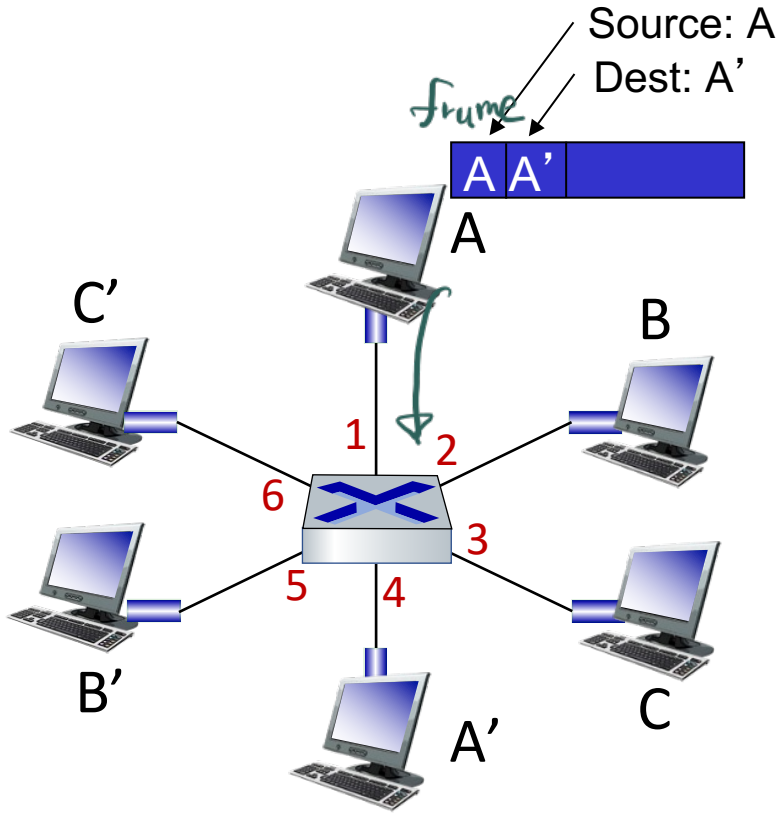
- something like a routing protocol?



Switch: self-learning

- switch *learns* which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment
  - records sender/location pair in switch table

frame을 받을 때마다 switch table update를 하는 것임



MAC addr	interface	TTL
A	*1* port number	*60*

Switch table (initially empty)

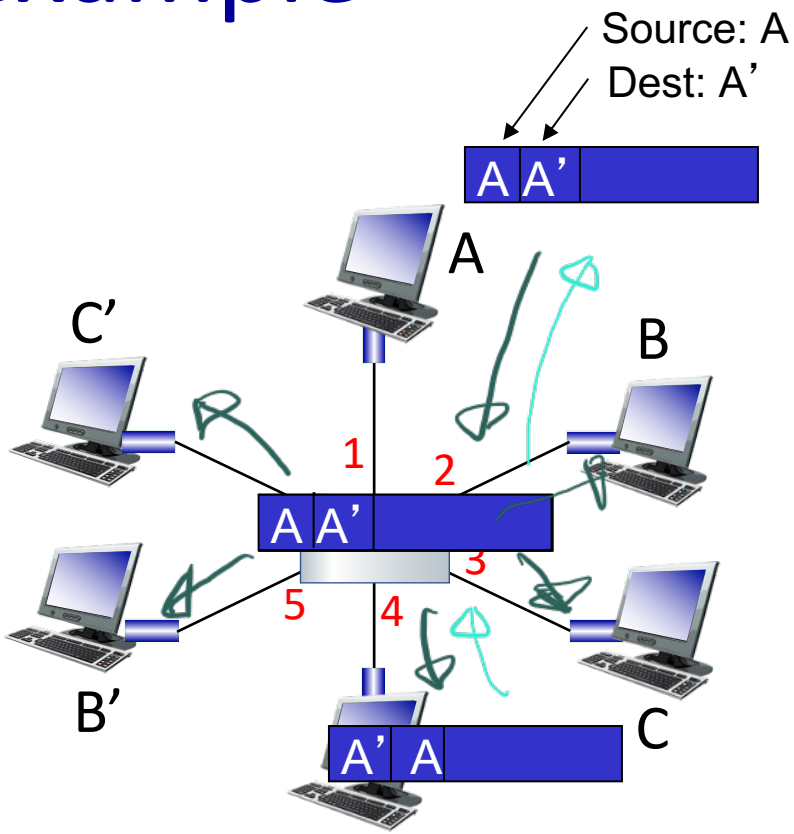
Switch: frame filtering/forwarding

when frame received at switch:

1. record incoming link, MAC address of sending host
2. index switch table using MAC destination address
3. if entry found for destination
   then {
   if destination on segment from which frame arrived
      then drop frame
       else forward frame on interface indicated by entry
    }
   else flood /* forward on all interfaces except arriving interface */

Self-learning, forwarding: example

- frame destination, A', location unknown: flood
- destination A location known: selectively send on just one link

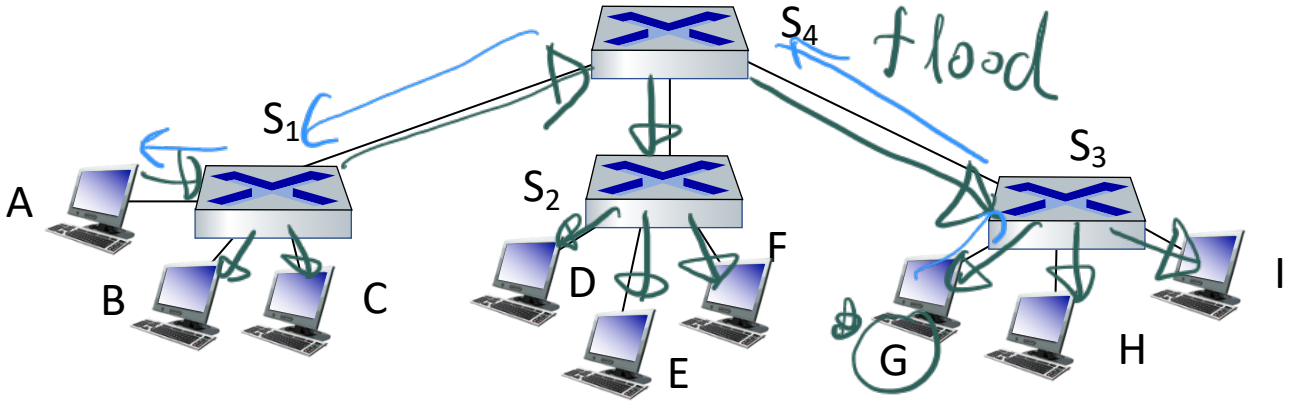


MAC addr	interface	TTL
A	*1*	*60*
A'	*4*	*60*

switch table (initially empty)

Interconnecting switches

self-learning switches can be connected together:

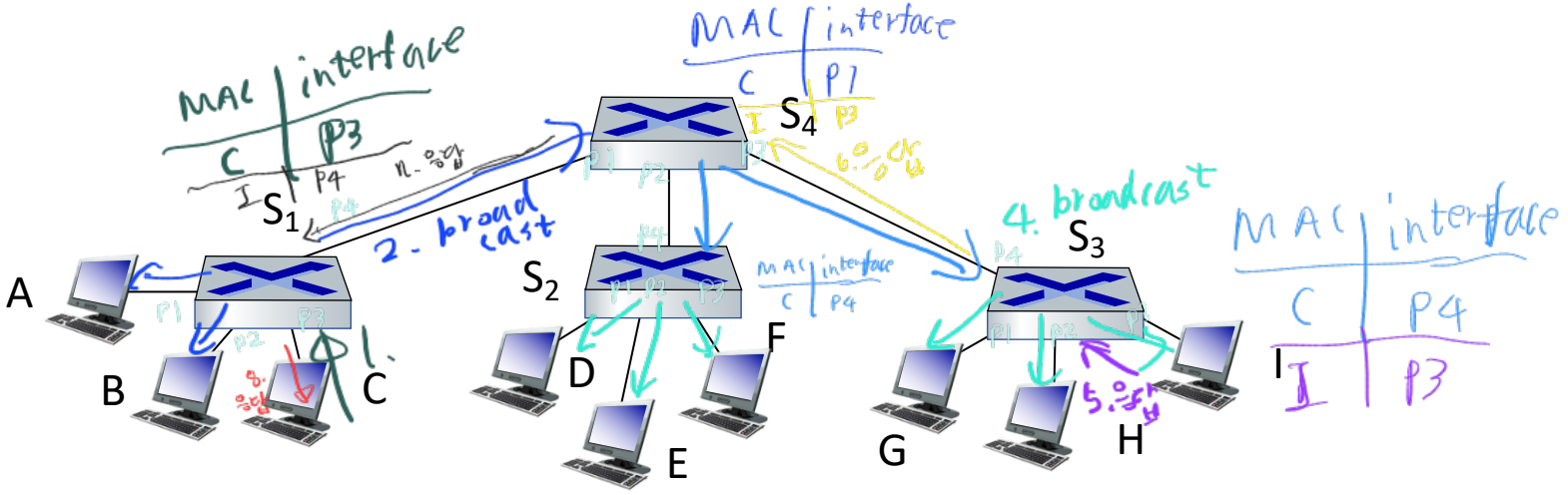


Q: sending from A to G - how does S_1 know to forward frame destined to G via S_4 and S_3?

- *A:* self learning! (works exactly the same as in single-switch case!)

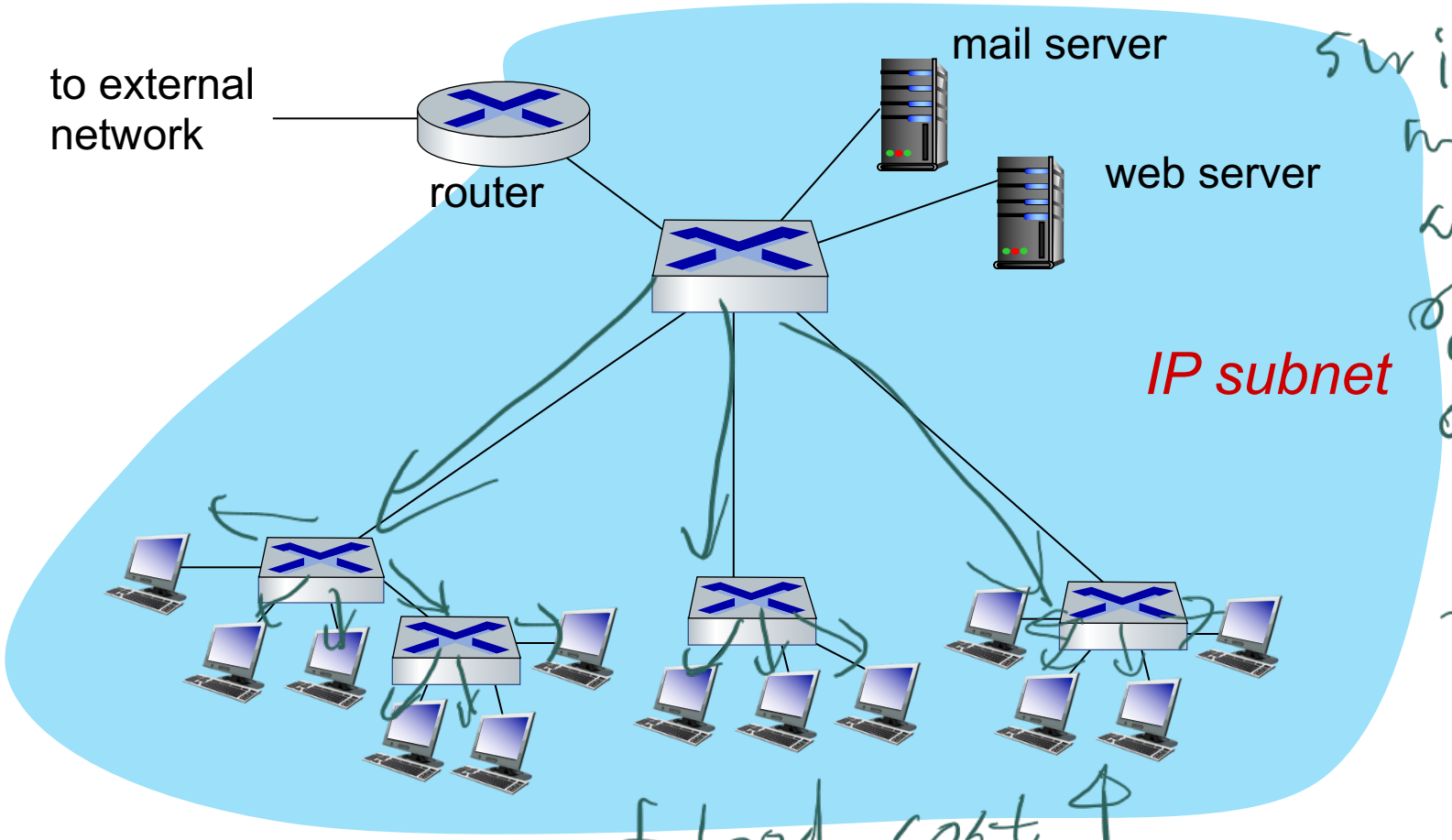
Self-learning multi-switch example

Suppose C sends frame to I, I responds to C



Q: show switch tables and packet forwarding in S_1, S_2, S_3, S_4

Small institutional network



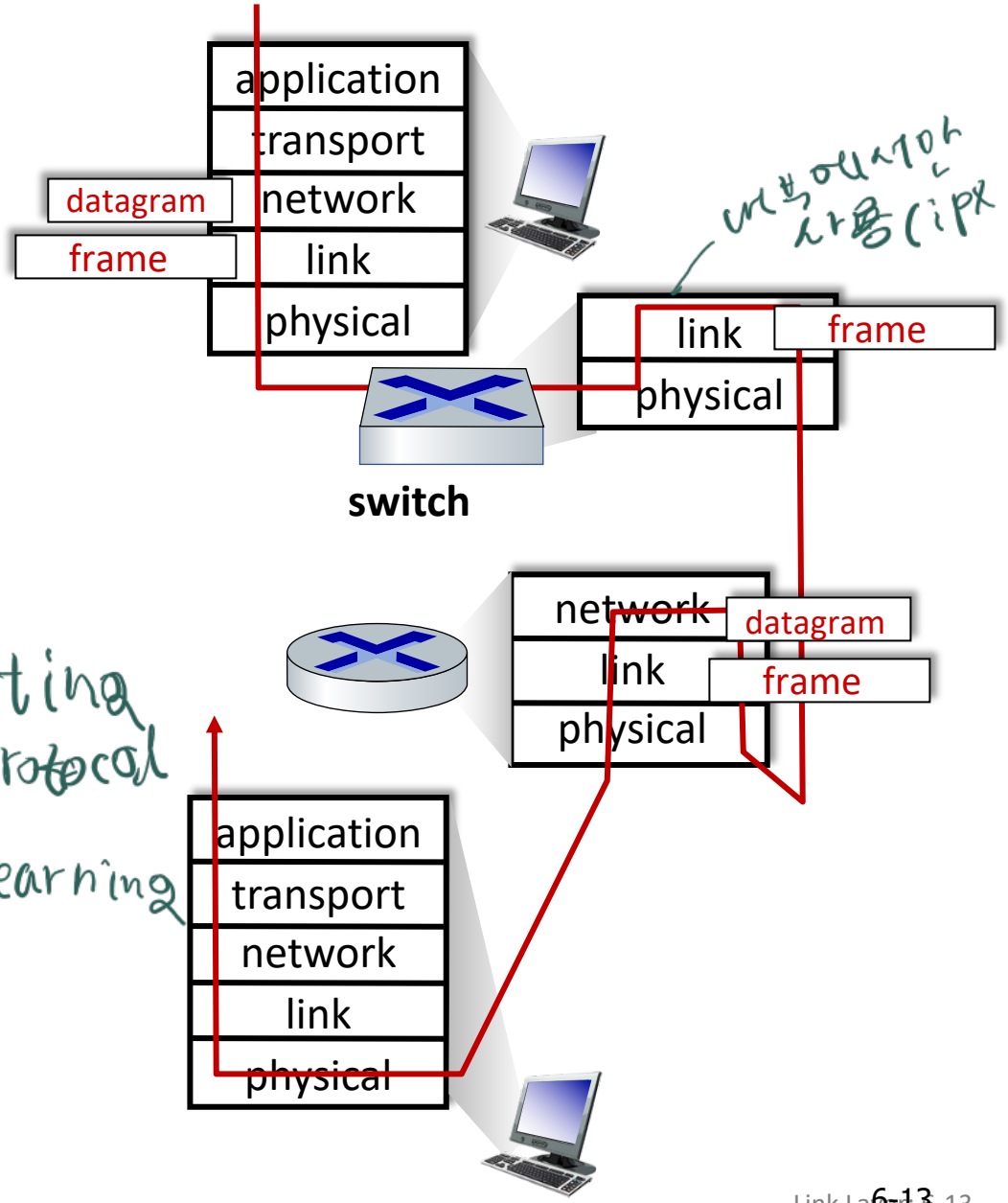
Switches vs. routers

both are store-and-forward:

- *routers*: network-layer devices (examine network-layer headers)
- *switches:* link-layer devices (examine link-layer headers)

both have forwarding tables:

- *routers:* compute tables using routing algorithms, IP addresses
- *switches:* learn forwarding table using flooding, learning, MAC addresses



Link layer, LANs: roadmap

- introduction
- error detection, correction
- multiple access protocols
- LANs
  - addressing, ARP
  - Ethernet
  - switches
  - VLANs —> skip (wiki 참고)
- link virtualization: MPLS
- data center networking

- a day in the life of a web request

Datacenter networks

10's to 100's of thousands of hosts, often closely coupled, in close proximity:

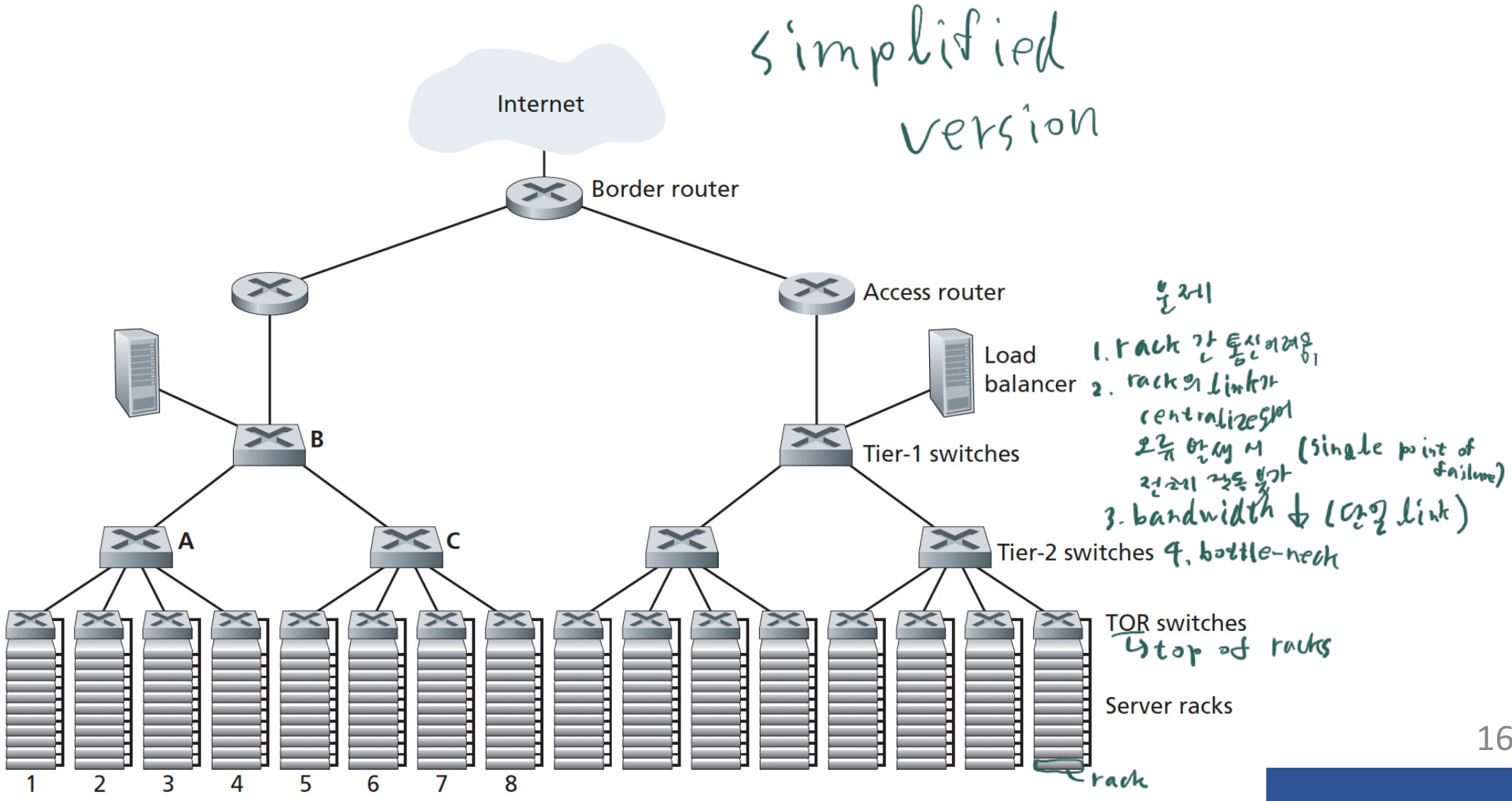
- e-business (e.g. Amazon)
- content-servers (e.g., YouTube, Akamai, Apple, Microsoft)
- search engines, data mining (e.g., Google)

challenges:

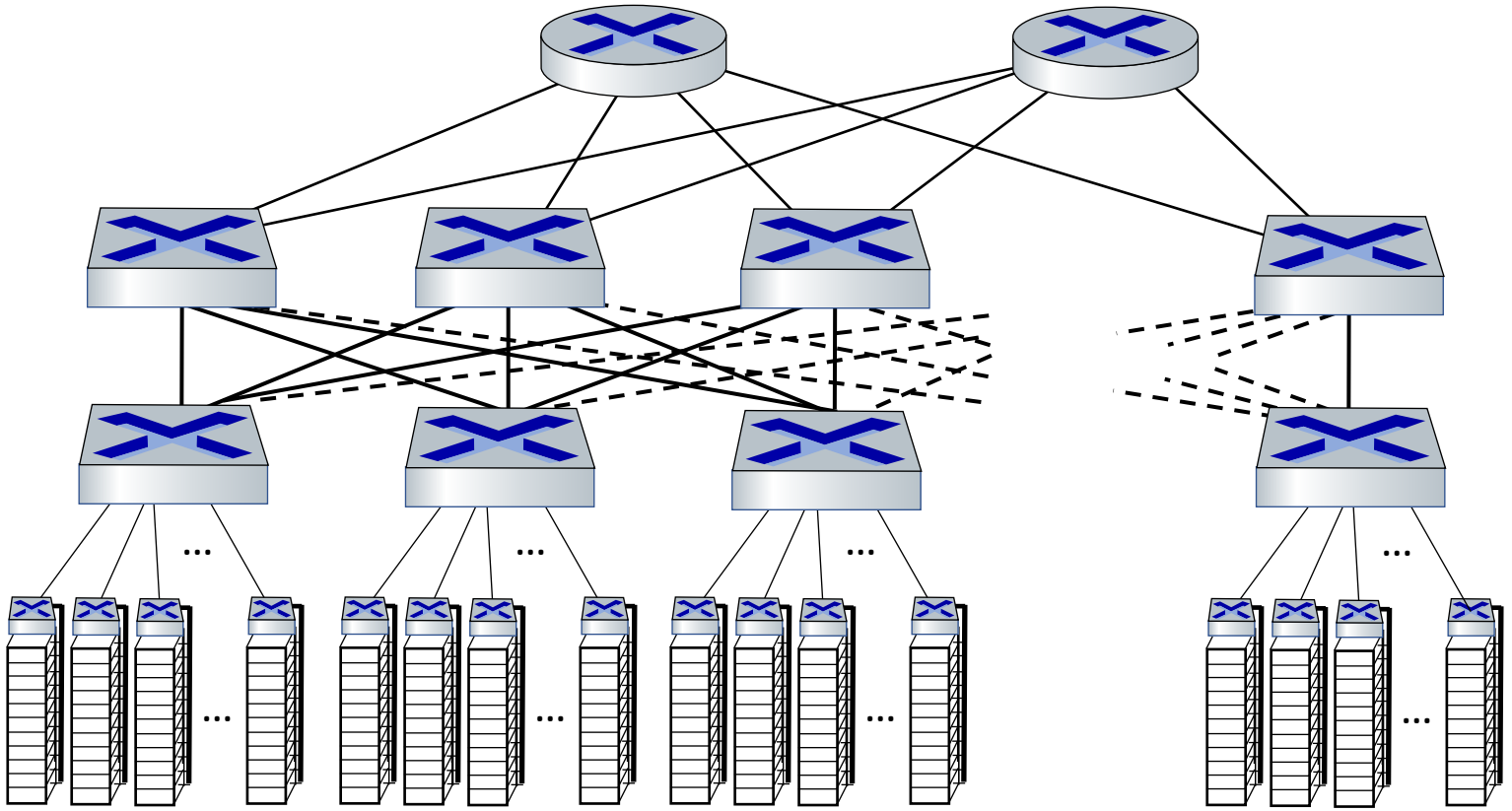
- multiple applications, each serving massive numbers of clients
- reliability
- managing/balancing load, avoiding processing, networking, data bottlenecks

Inside a 40-ft Microsoft container, Chicago data center

Scalable datacenter networks



Datacenter networks: network elements



Border routers

- connections outside datacenter

Tier-1 switches

- connecting to ~16 T-2s below

Tier-2 switches

- connecting to ~16 TORs below

Top of Rack (TOR) switch

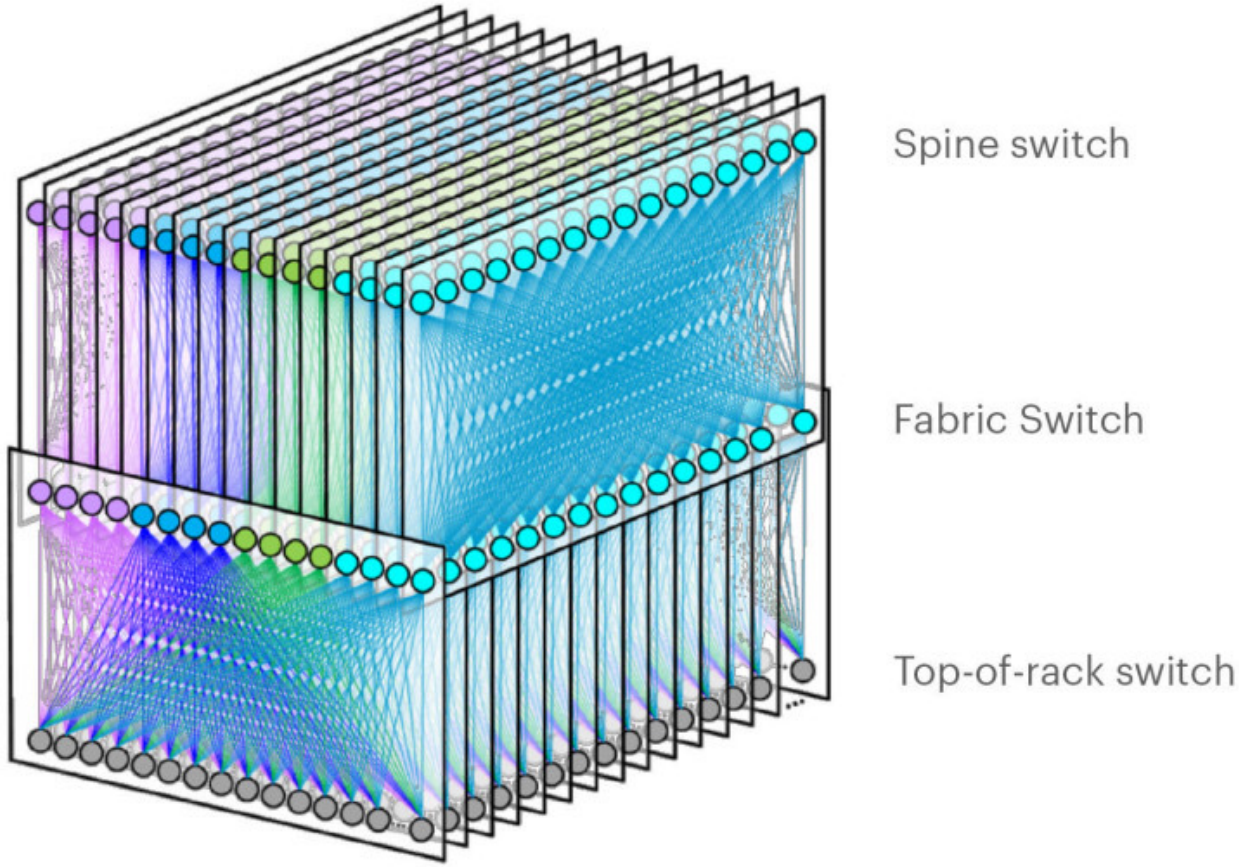
- one per rack
- 40-100Gbps Ethernet to blades

Server racks

- 20- 40 server blades: hosts

Datacenter networks: network elements

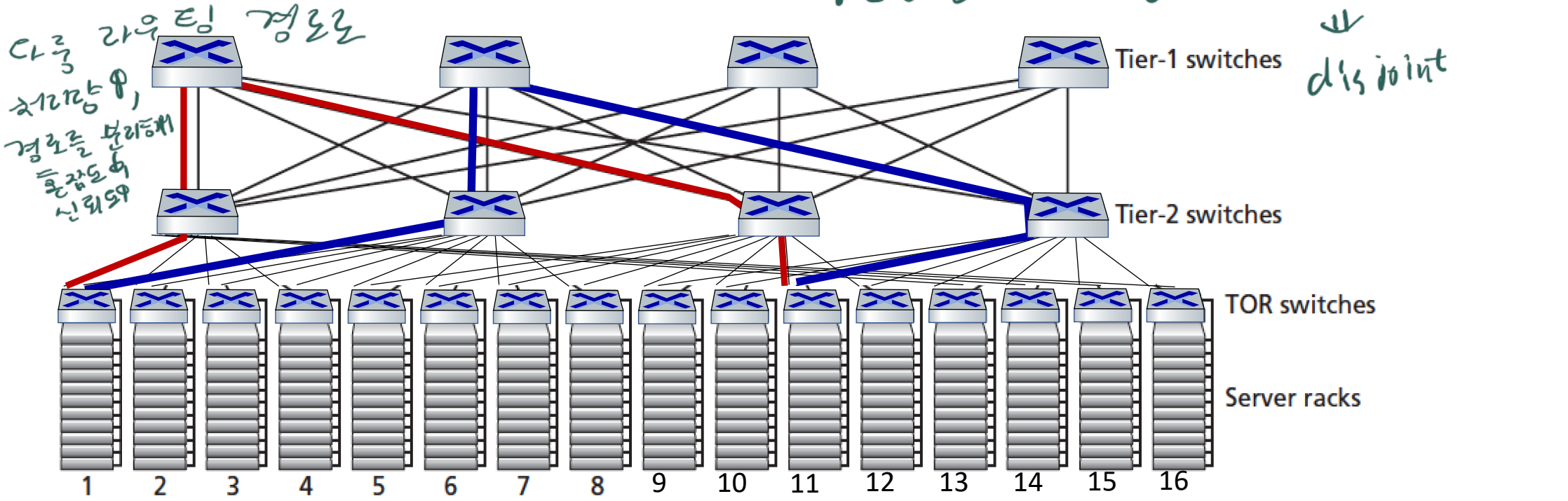
Facebook F16 data center network topology:



https://engineering.fb.com/data-center-engineering/f16-minipack/ (posted 3/2019)

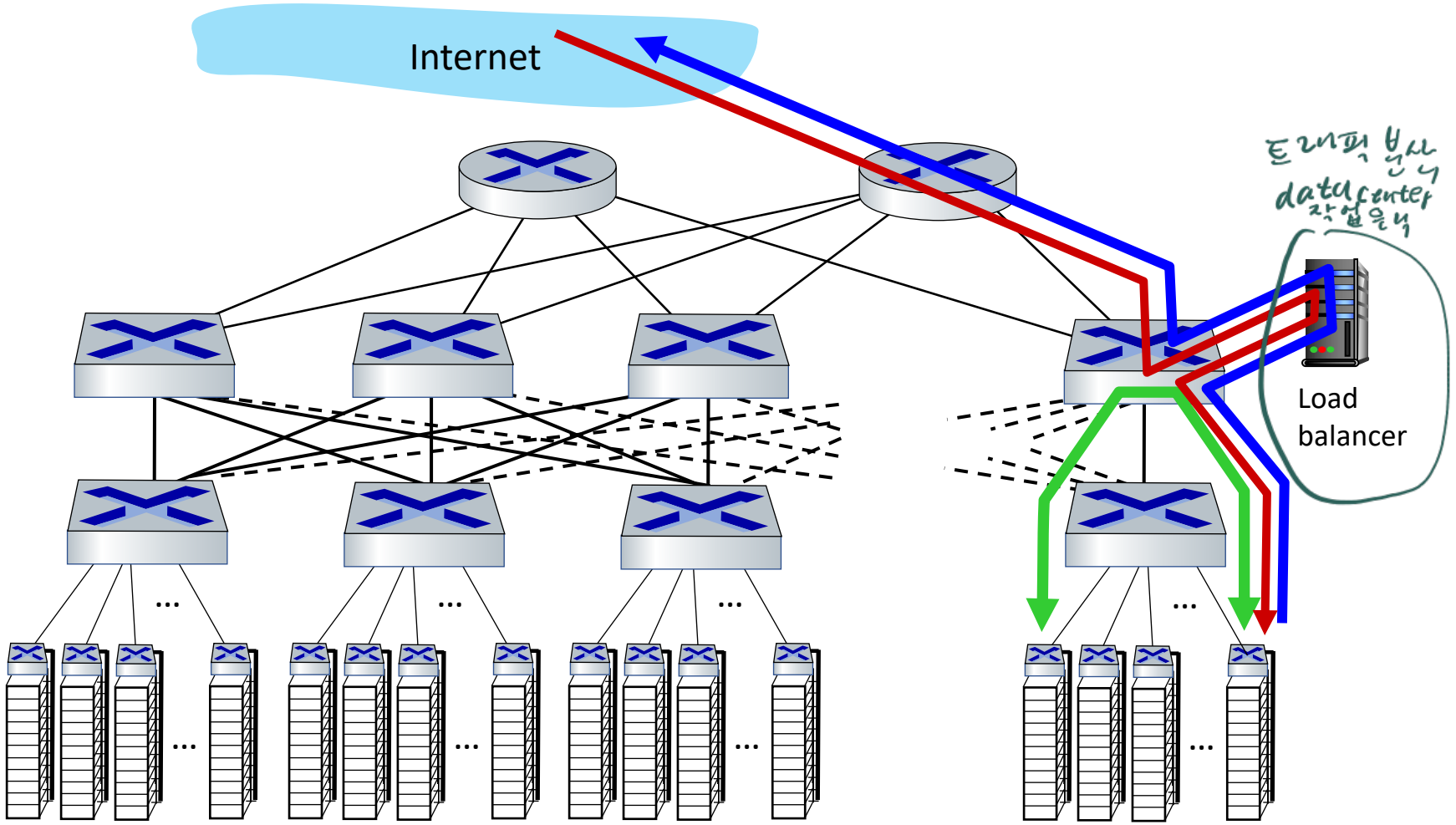
Datacenter networks: multipath

- rich interconnection among switches, racks:
  - increased throughput between racks (multiple routing paths possible)
  - increased reliability via redundancy



two disjoint paths highlighted between racks 1 and 11

Datacenter networks: application-layer routing



load balancer: application-layer routing

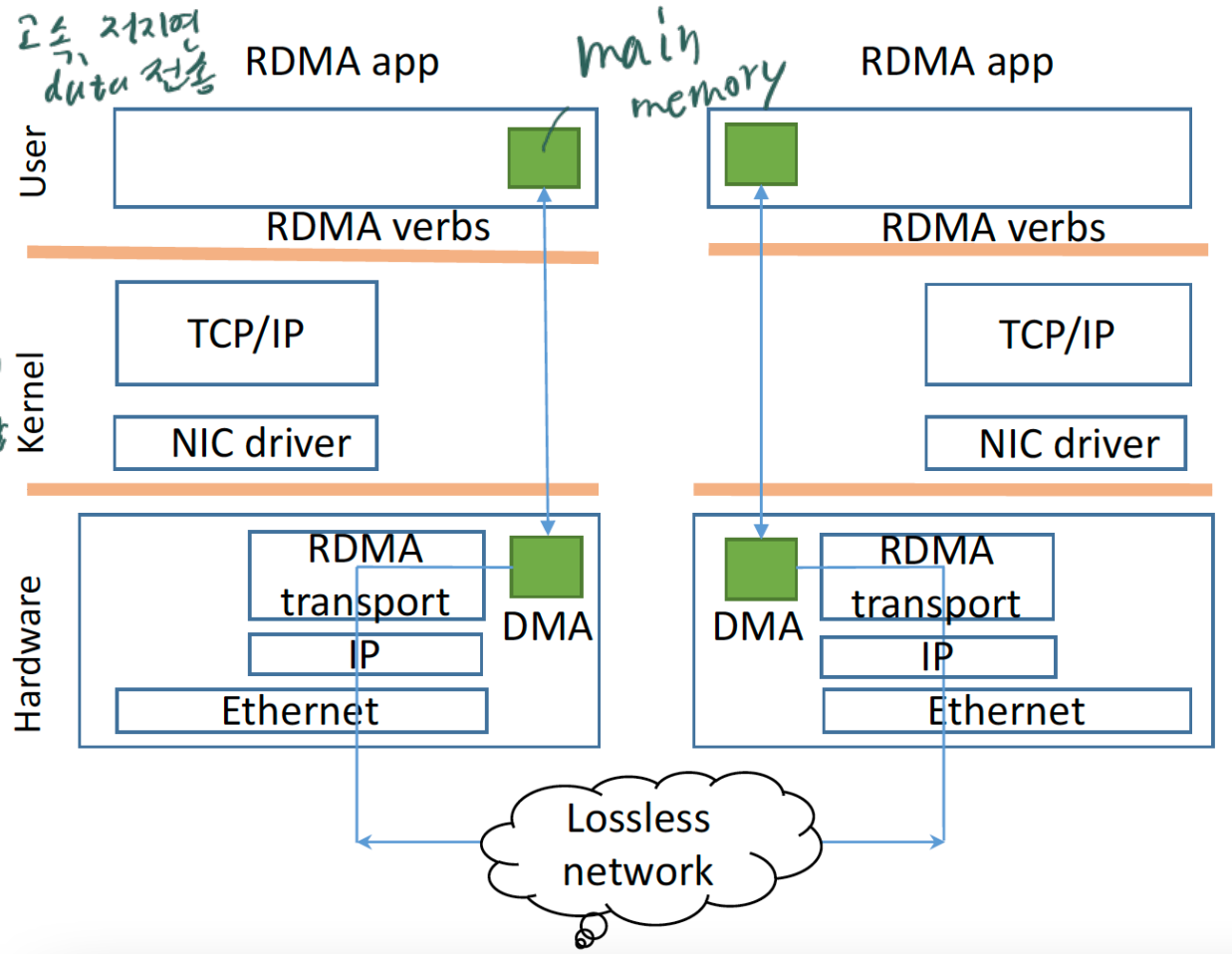
- receives external client requests
- directs workload within data center
- returns results to external client (hiding data center internals from client)

Datacenter networks: protocol innovations

- **link layer:**
  - RoCE: remote DMA (RDMA) over Converged Ethernet
- **transport layer:**
  - ECN (explicit congestion notification) used in transport-layer congestion control (DCTCP, DCQCN)
  - experimentation with hop-by-hop (backpressure) congestion control
- **routing, management:**
  - SDN widely used within/among organizations' datacenters
  - place related services, data as close as possible (e.g., in same rack or nearby rack) to minimize tier-2, tier-1 communication

Datacenter networks: examples

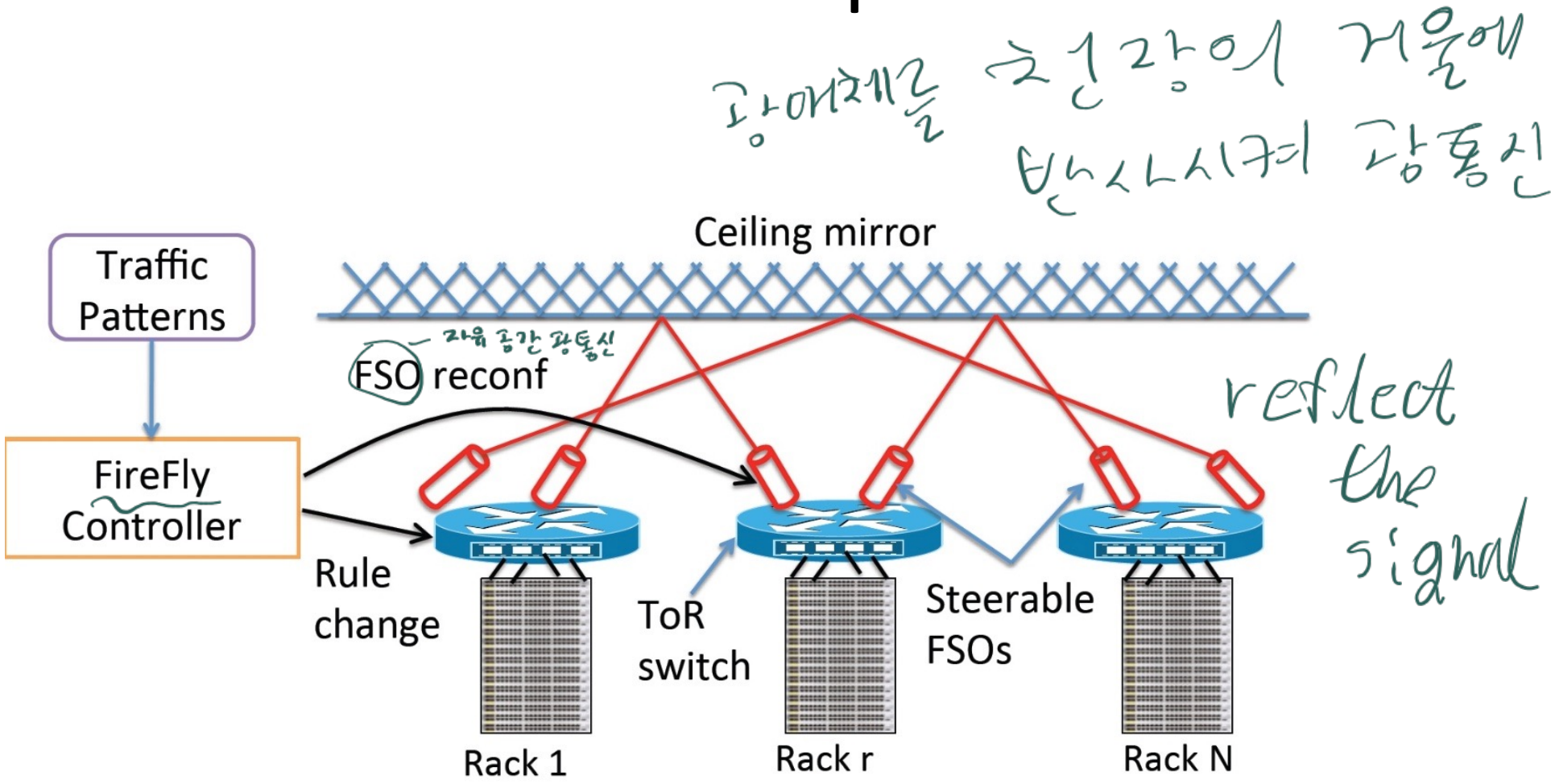
- RoCEv2: RDMA over Commodity Ethernet
  - RoCEv2 for Ethernet based data centers
  - RoCEv2 encapsulates packets in UDP
  - OS kernel is not in data path
  - NIC for network protocol processing and message DMA



Datacenter networks: examples

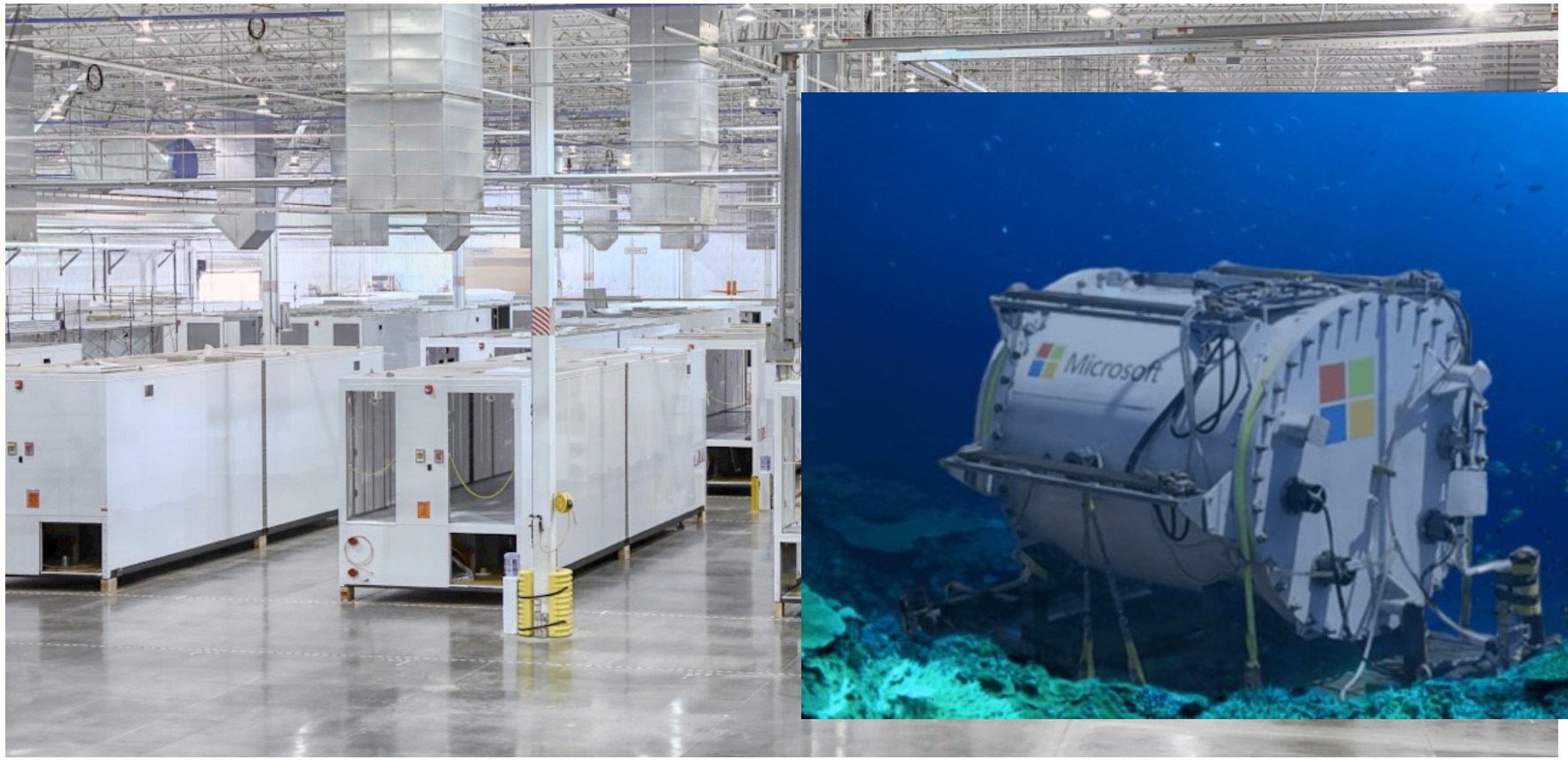
wire - plug 방식을 사용 어려움 ⇒ 무선통신

Datacenter networks: examples



Datacenter networks: examples

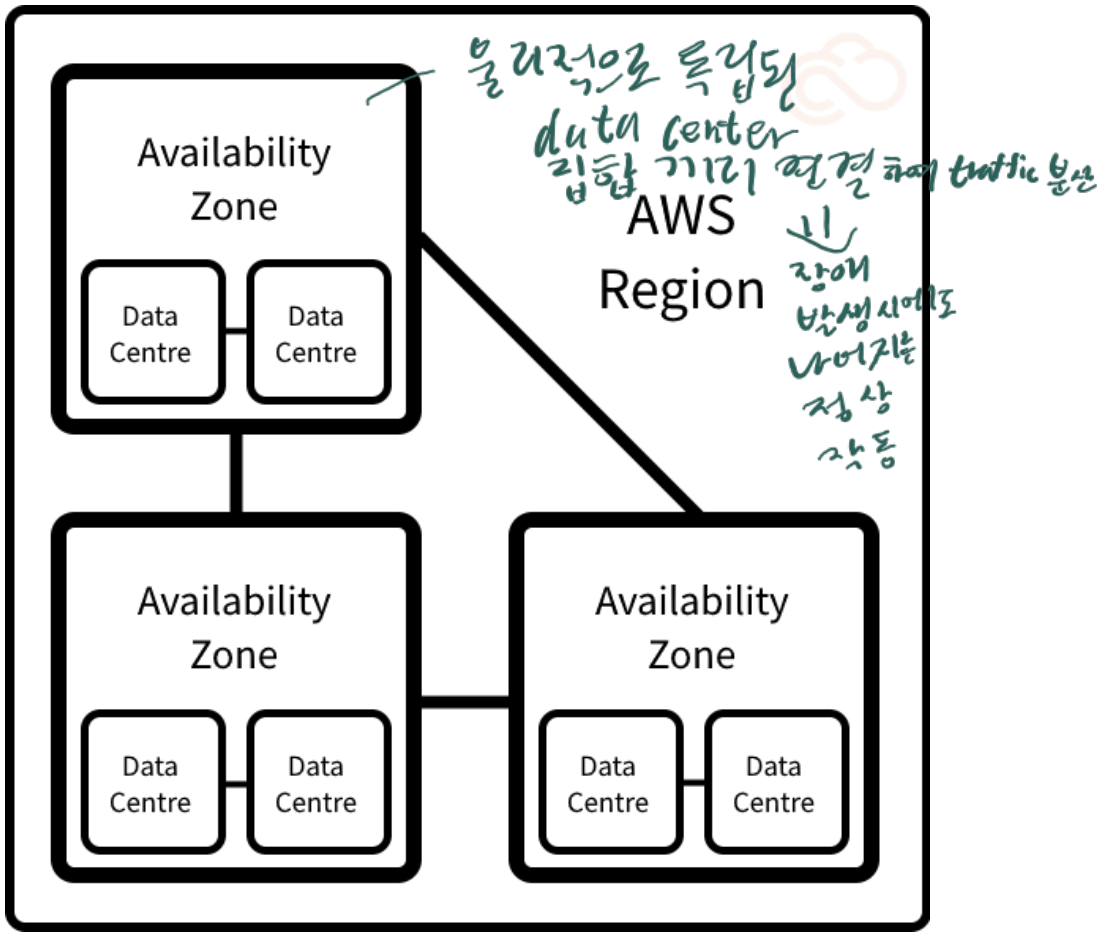
- Modular datacenter



cost-effect cooling
↓
바다에 수장시켜 냉각 cost 절감

Datacenter networks: examples

- Amazon's "availability zones"



Concerns linger as cause of e-government outage remains unclear

By Lee Jung-joo

Published : Nov. 20, 2023 - 17:08

A A

The computer network used by local government offices across South Korea, together with the platform used by residents to interact with the government and issue government documents are back running after a four-day outage, according to the Ministry of Interior and Safety on Monday.

However, local tech experts raised concerns over the risk of another error potentially affecting e-government networks and services, pointing out that the cause of the failure over the weekend remains unclear.

Chapter 7 outline

- Introduction

Wireless

- Wireless Links and network characteristics
- WiFi: 802.11 wireless LANs
- Cellular networks: 4G and 5G

Mobility

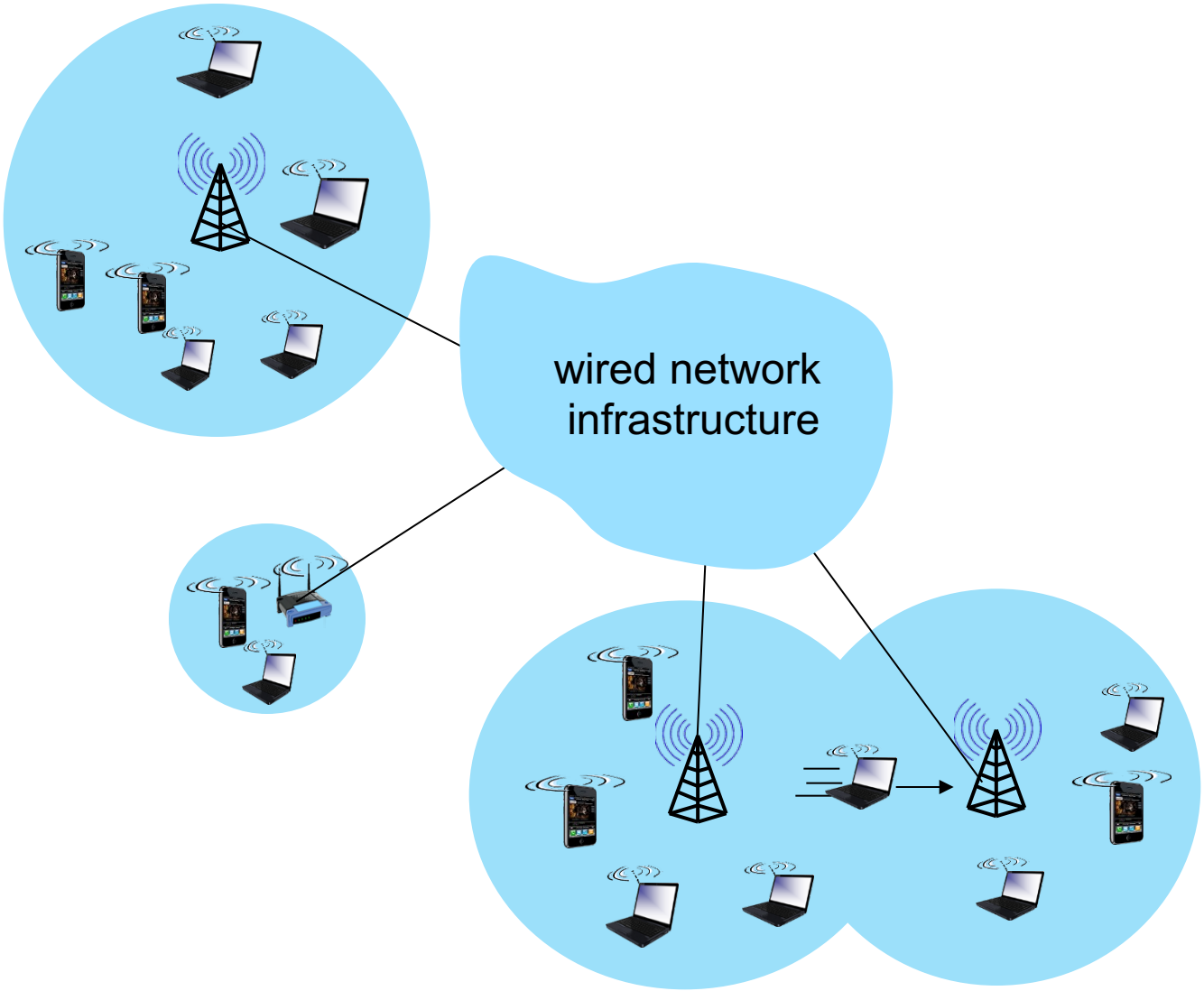
시간 문제로 skip

- Mobility management: principles
- Mobility management: practice
  - 4G/5G networks
  - Mobile IP
- Mobility: impact on higher-layer protocols

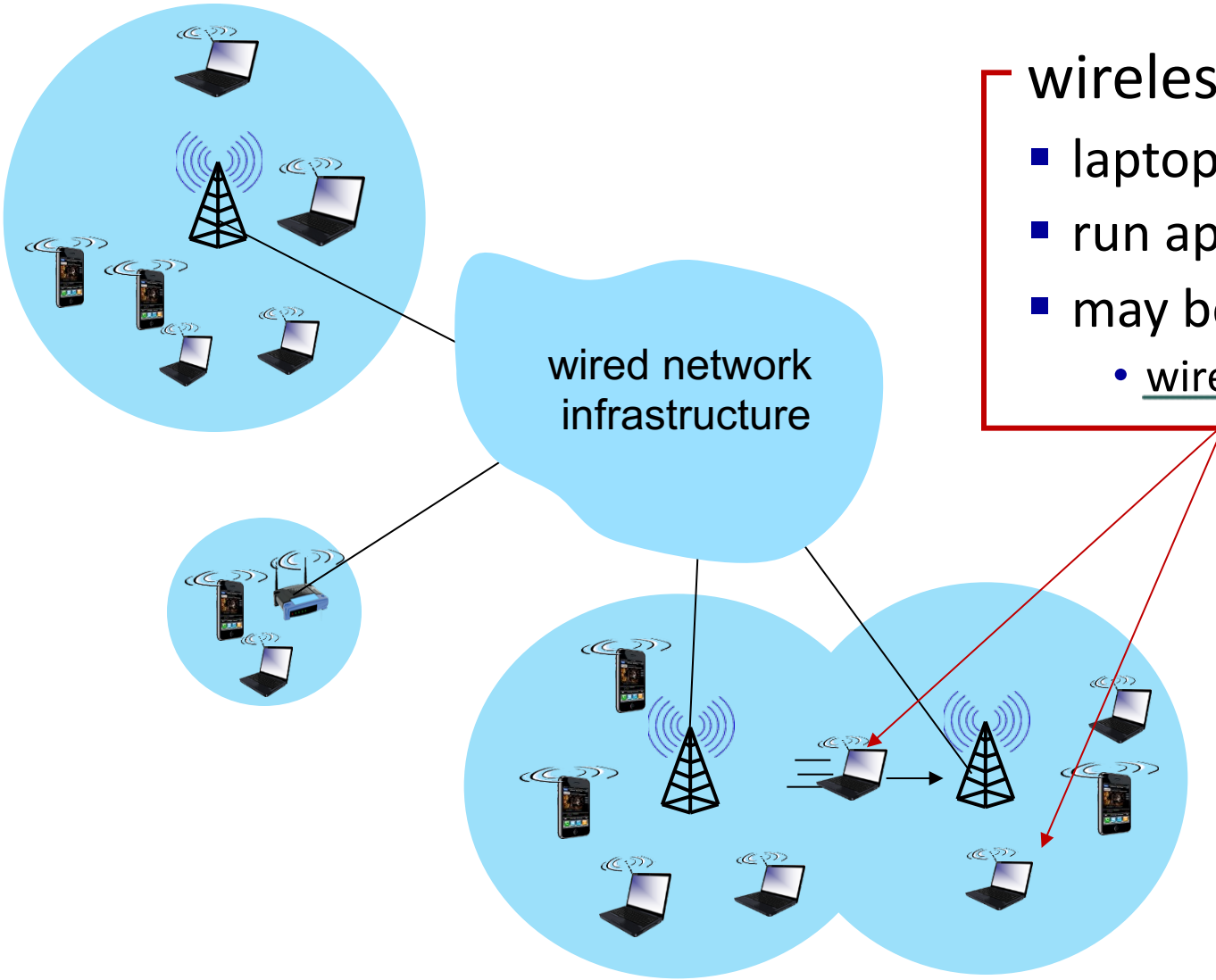
Wireless and Mobile Networks: context

- more wireless (mobile) phone subscribers than fixed (wired) phone subscribers (10-to-1 in 2019)!
- more mobile-broadband-connected devices than fixed-broadband-connected devices devices (5-1 in 2019)!
  - 4G/5G cellular networks now embracing Internet protocol stack, including SDN
- two important (but different) challenges
  - wireless: communication over wireless link
  - mobility: handling the mobile user who changes point of attachment to network

Elements of a wireless network



Elements of a wireless network



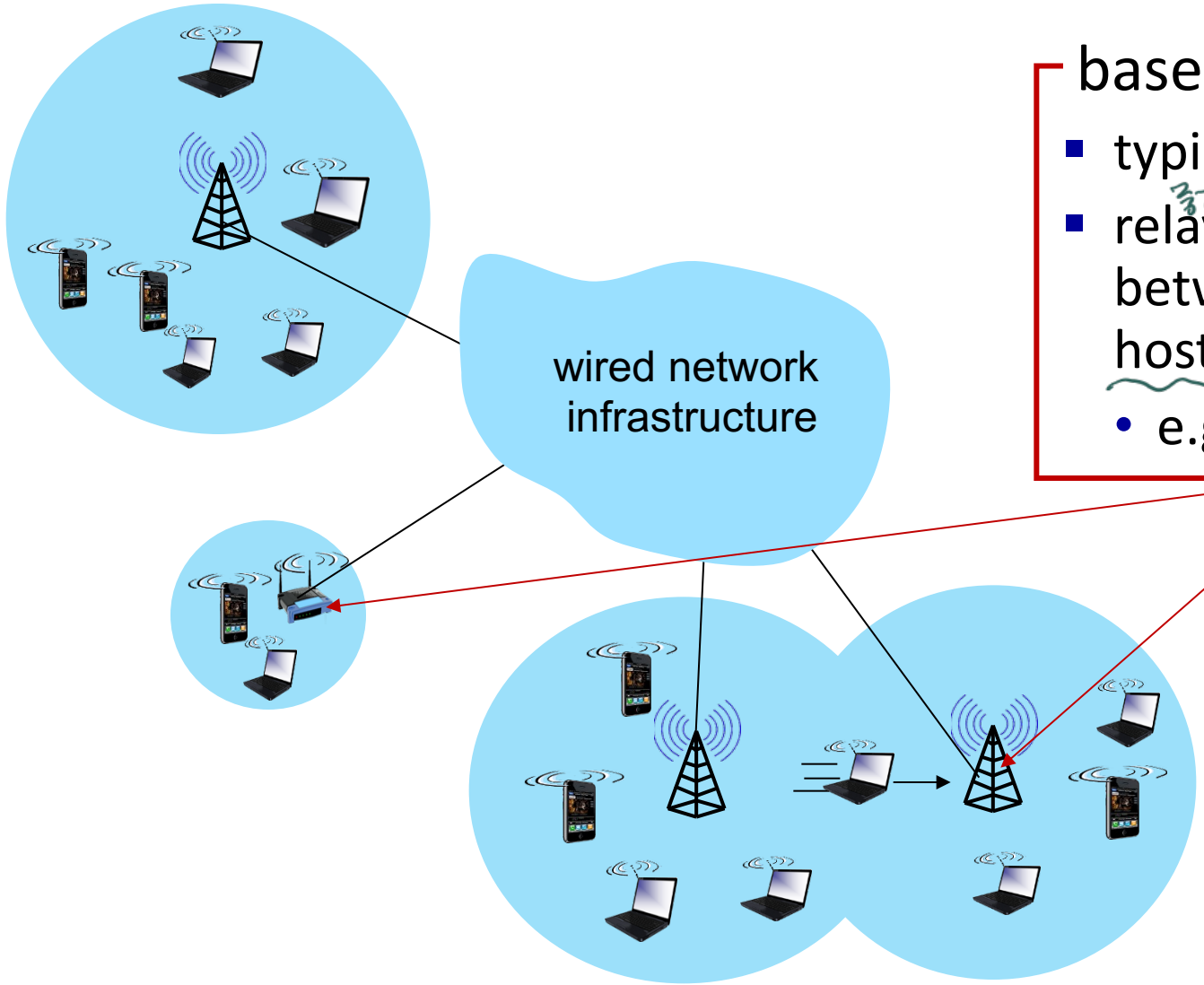
wireless hosts

- laptop, smartphone, IoT

- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility!

application이 구동되는 host

Elements of a wireless network

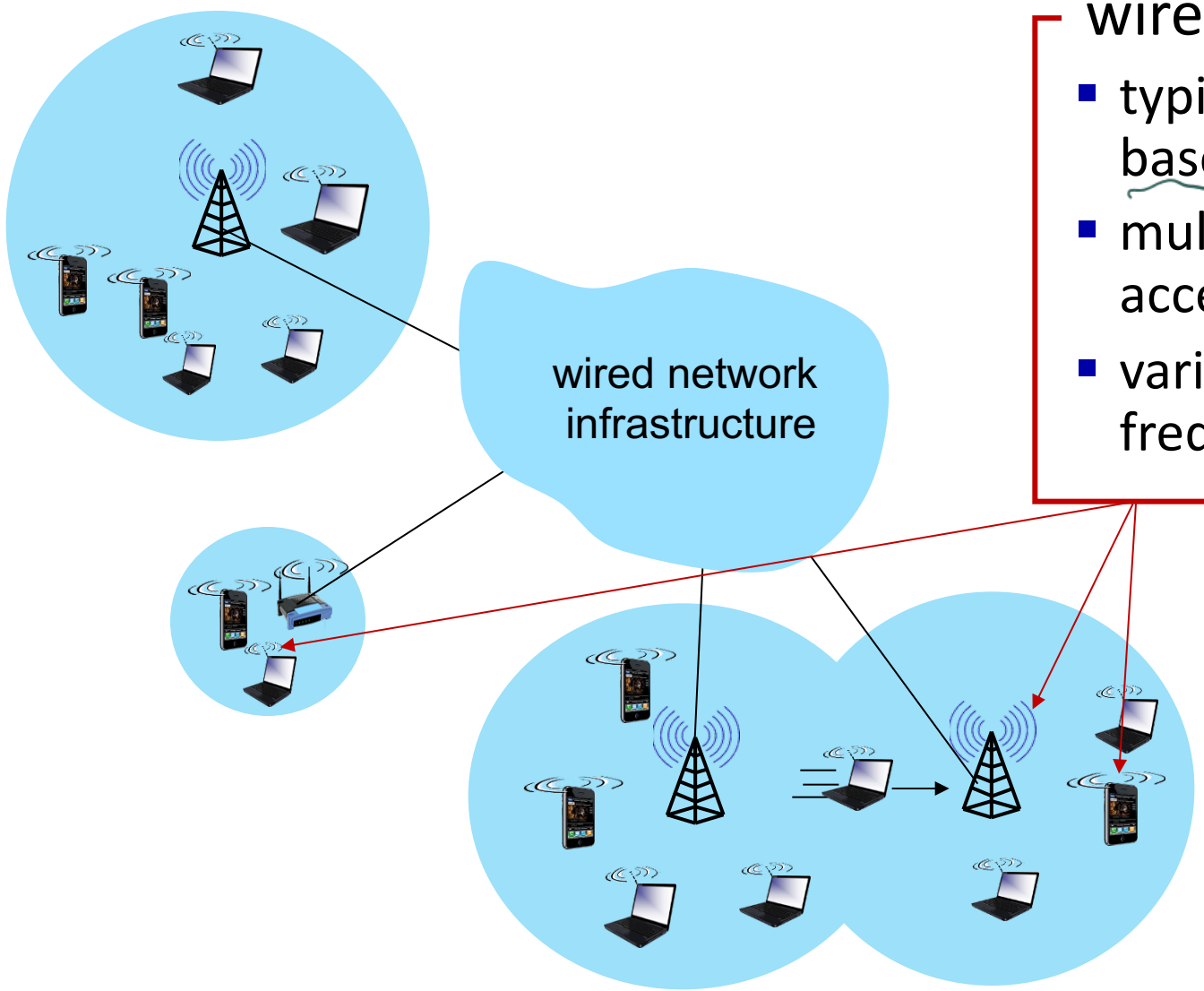


base station

- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its "area"
  - e.g., cell towers, 802.11 access points

유선 네트워크와
무선 host들 릴레

Elements of a wireless network

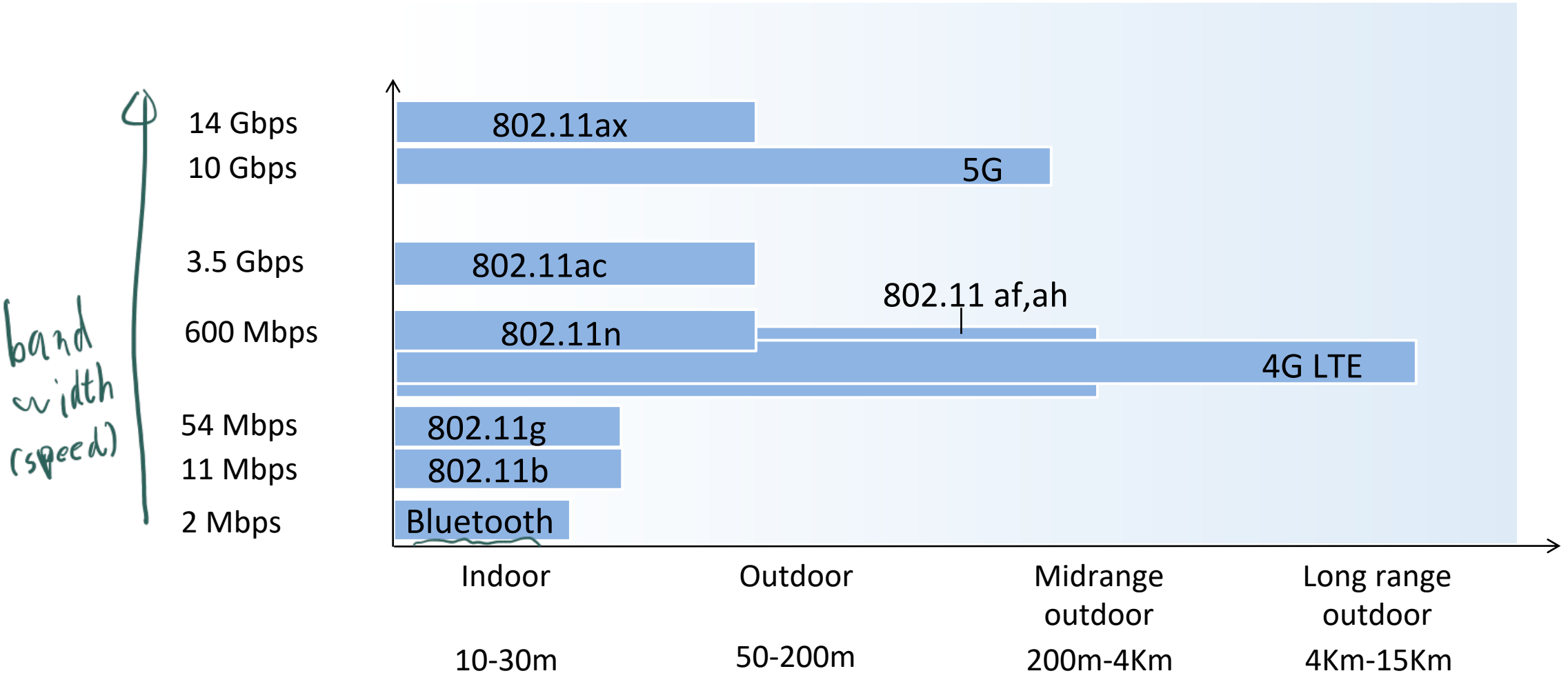


wireless link

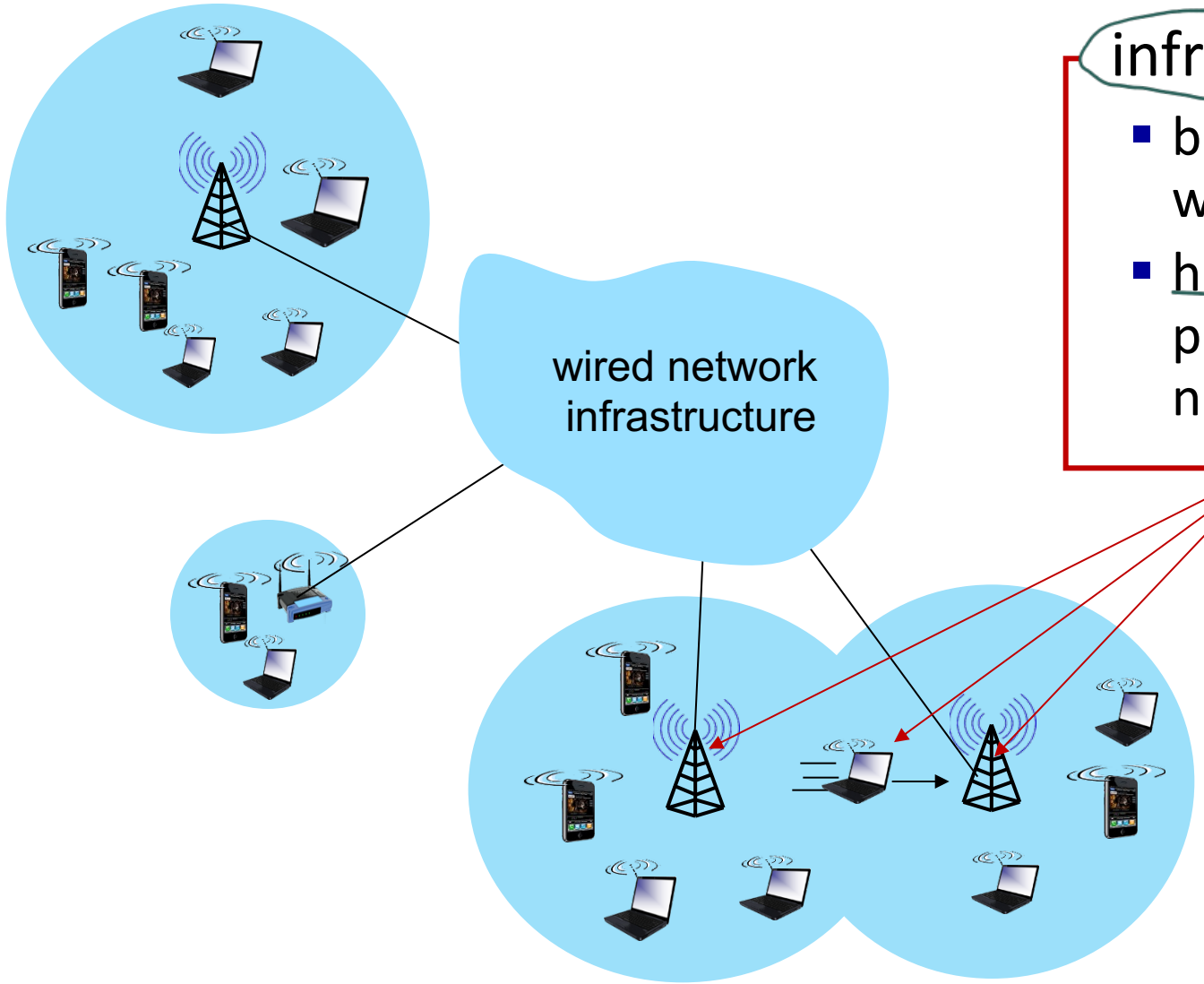
- typically used to connect mobile(s) to base station, also used as backbone link
- multiple access protocol coordinates link access
- various transmission rates and distances, frequency bands

access protocol에 의해 mobile과 base station을 연결

Characteristics of selected wireless links



Elements of a wireless network



base station ~ mobile 연결 방식

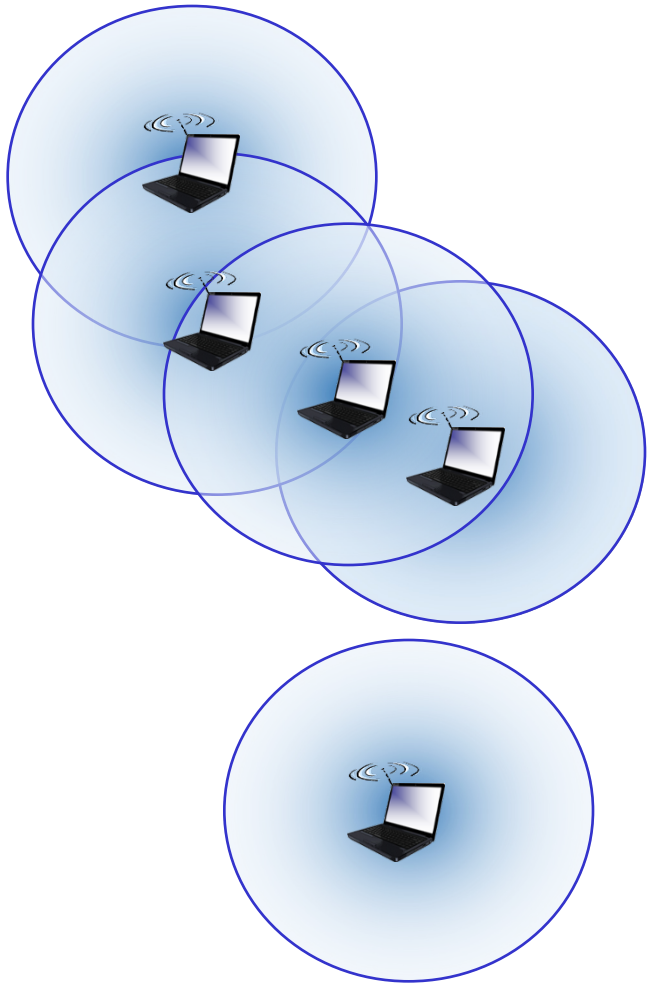
infrastructure mode

- base station connects mobiles into wired network 중계
- handoff: mobile changes base station providing connection into wired network

↳ 모바일 장치 이동 시 새로운 base station 연결

Elements of a wireless network

base station을 사용하지 않는 방식
⇓
모든 장치가 네트워크 노드로서 직접 연결



ad hoc mode

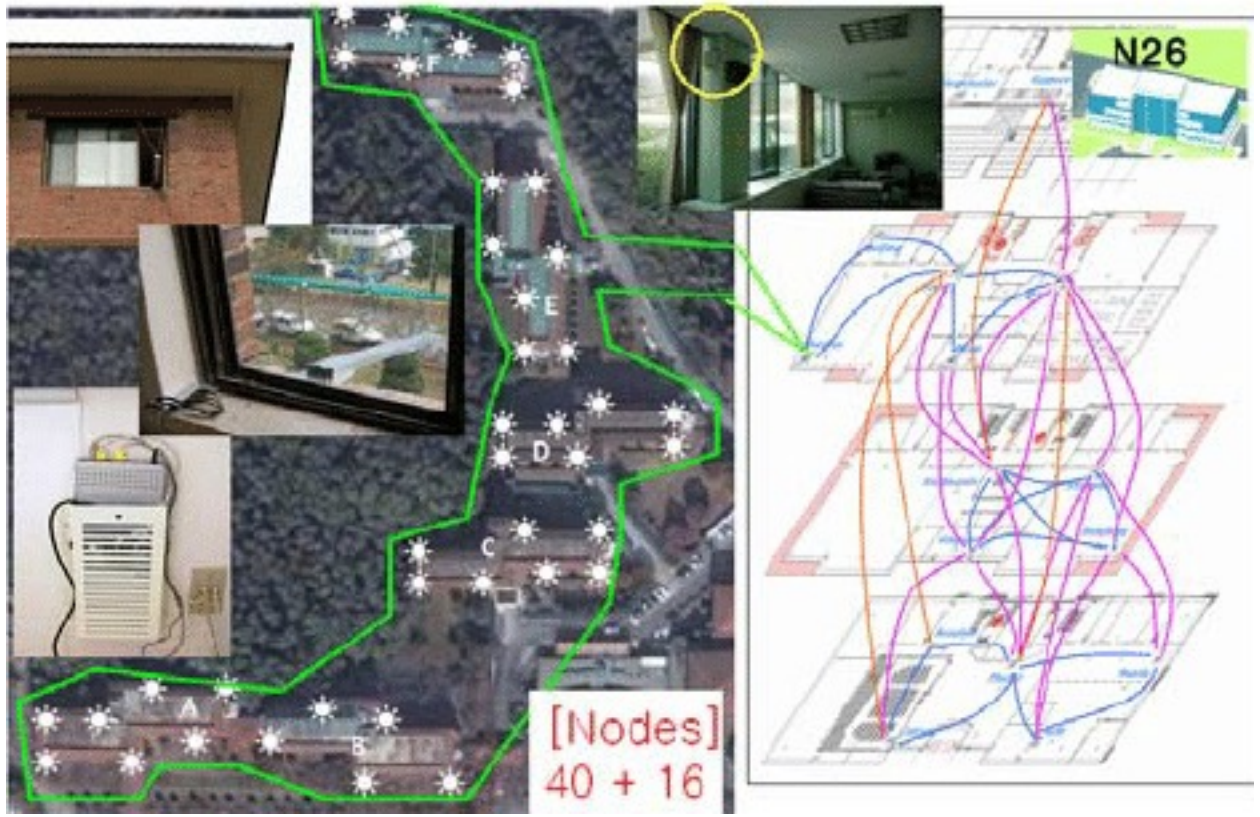
- no base stations
- nodes can only transmit to other nodes within link coverage → link coverage 내의 node와만 통신가능
- nodes organize themselves into a network: route among themselves node끼리 network을 이루어 routing

Wireless network taxonomy

	single hop	multiple hops
infrastructure (e.g., APs)	host connects to base station (WiFi, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: *mesh net*
no infrastructure	no base station, no connection to larger Internet (Bluetooth, ad hoc nets)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

Wireless mesh network @KAIST

↳ 무선통신 router가 노드가 되어 network 구성



여러 노드가 wireless node들을 거쳐 internet과 연결

high frequency

[Jinsung Lee et al. 2009]

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Mobility

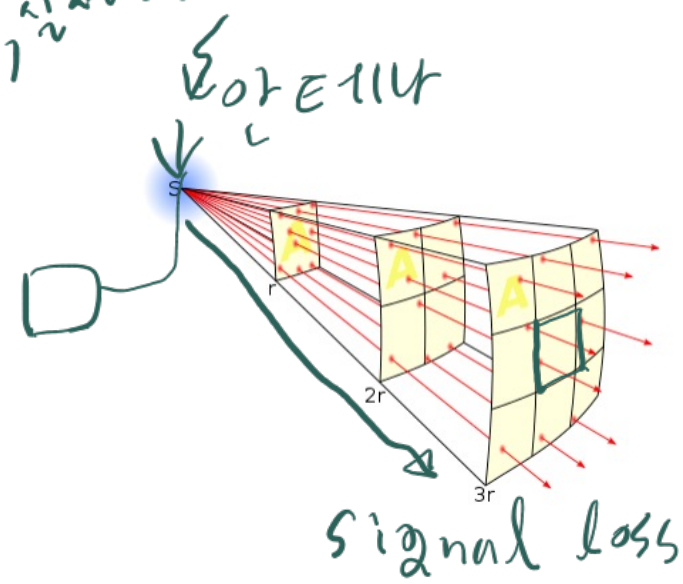
- Mobility management: principles
- Mobility management: practice
  - 4G/5G networks
  - Mobile IP
- Mobility: impact on higher-layer protocols

Wireless link characteristics: fading (attenuation)

Wireless radio signal attenuates (loses power) as it propagates (free space "path loss")

Free space path loss ~ $(fd)^2$

f: frequency
d: distance

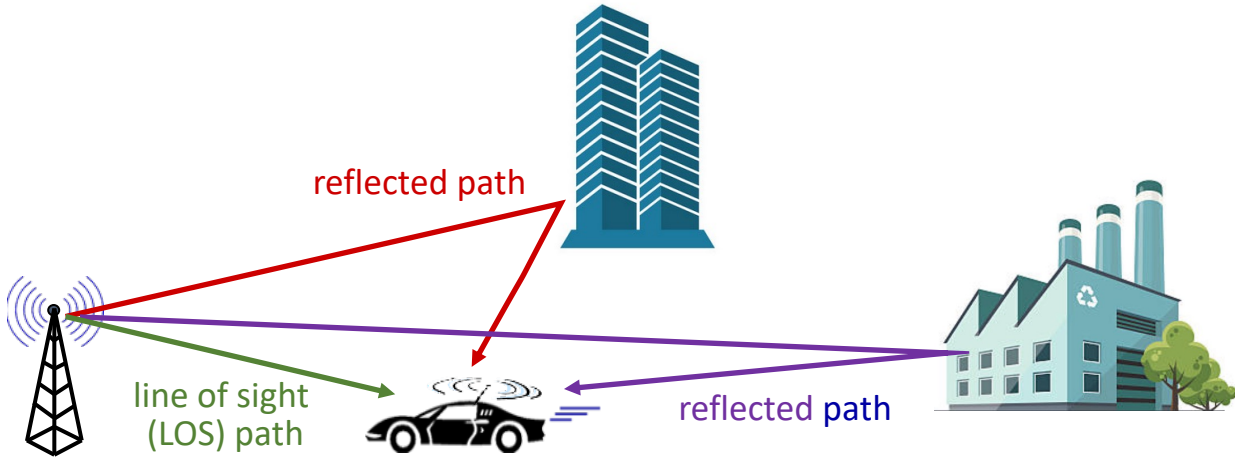


signal loss

higher frequency or longer distance → larger free space path loss

Wireless link characteristics: multipath

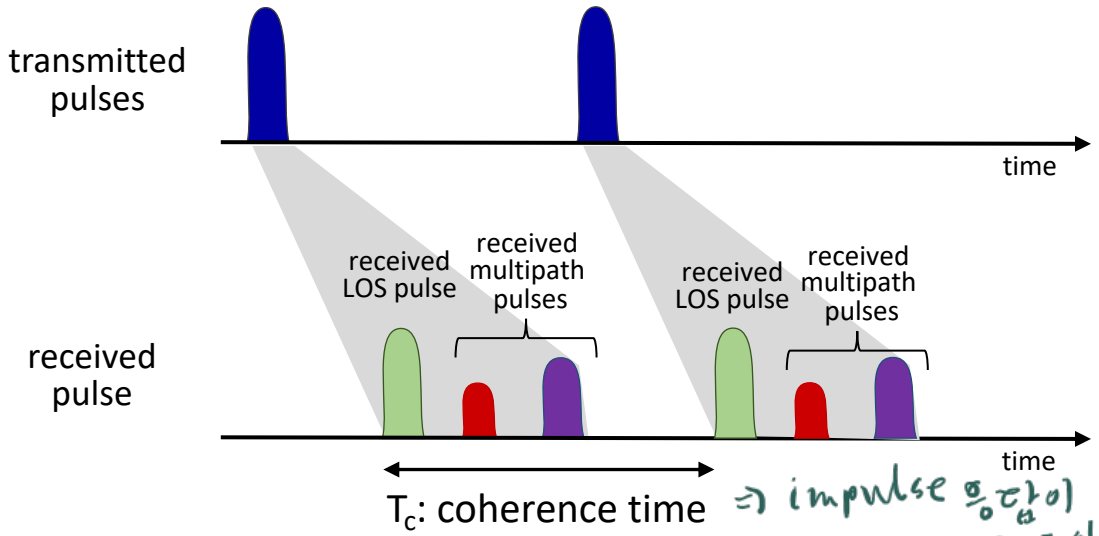
multipath propagation: radio signal reflects off objects ground, built environment, arriving at destination at slightly different times



반사로 인해 약간씩
다른 시간에 도착

Wireless link characteristics: multipath

multipath propagation: radio signal reflects off objects ground, built environment, arriving at destination at slightly different times

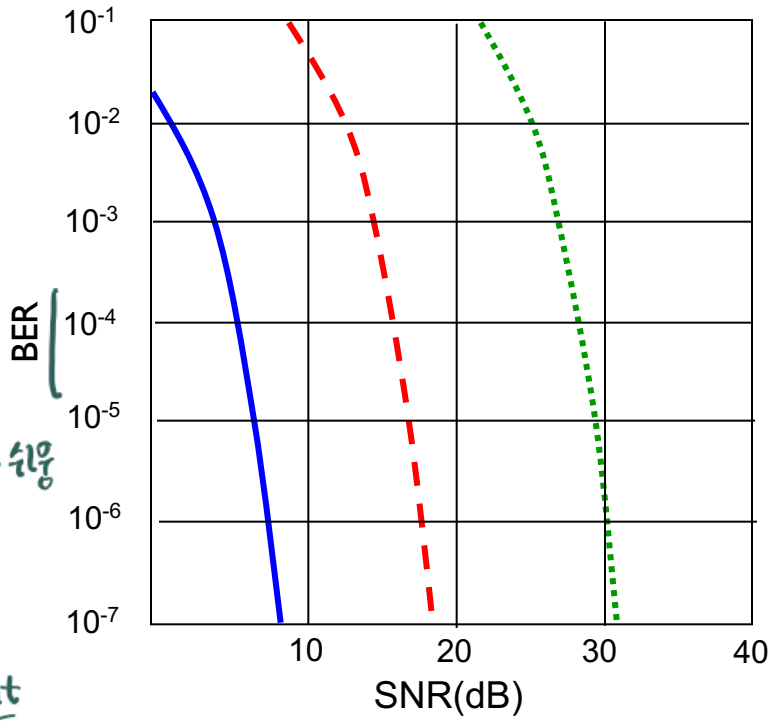


Coherence time:

- amount of time bit is present in channel to be received
- influences maximum possible transmission rate, since coherence times can not overlap
- inversely proportional to
  - frequency
  - receiver velocity

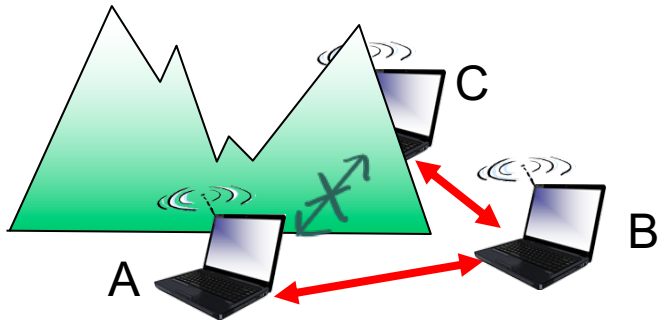
Wireless link characteristics: noise

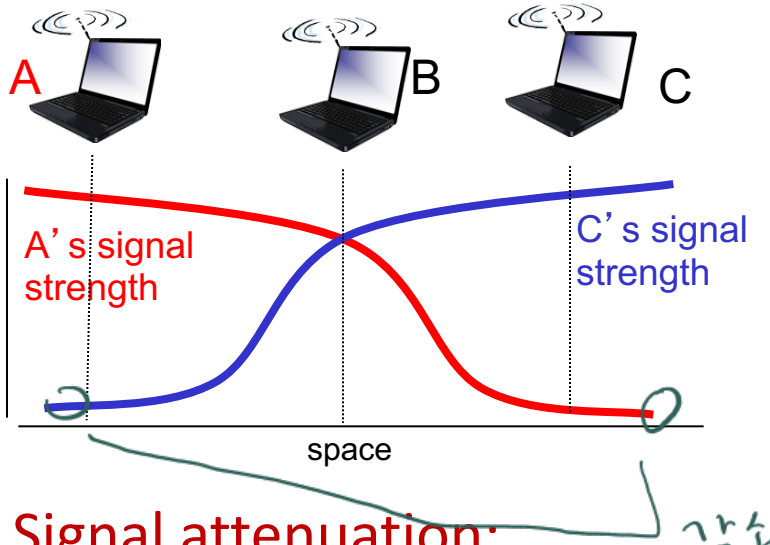
- interference from other sources on wireless network frequencies: motors, appliances
- SNR: signal-to-noise ratio
  - larger SNR – easier to extract signal from noise (a "good thing")
- SNR versus BER tradeoff
  - *given physical layer:* increase power -> increase SNR->decrease BER
  - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)



Wireless link characteristics (3)

Multiple wireless senders, receivers create additional problems (beyond multiple access):





A-C 안 겹치는가

⇒ B에서 A와 C의 신호끼리 간섭해서 오작동 하는가

강도로 인해 signal 약한가

Hidden terminal problem

- B, A hear each other
- B, C hear each other
- A, C can not hear each other means A, C unaware of their interference at B

Signal attenuation:

- B, A hear each other
- B, C hear each other
- A, C can not hear each other interfering at B

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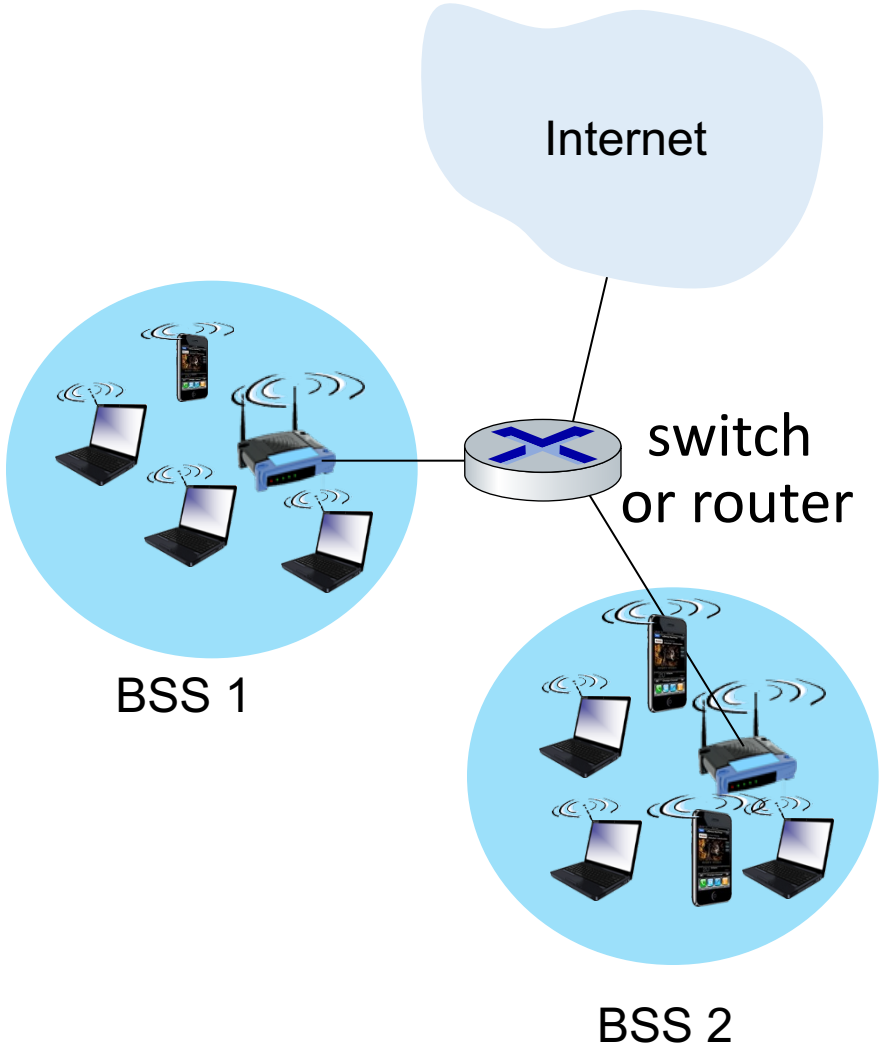
IEEE 802.11 Wireless LAN

IEEE 802.11 standard	Year	Max data rate	Range	Frequency
802.11b	1999	11 Mbps	30 m	2.4 Ghz
802.11g	2003	54 Mbps	30m	2.4 Ghz
802.11n (WiFi 4)	2009	600	70m	2.4, 5 Ghz
802.11ac (WiFi 5)	2013	3.47Gpbs	70m	5 Ghz
802.11ax (WiFi 6)	2020 (exp.)	14 Gbps	70m	2.4, 5 Ghz
802.11af	2014	35 – 560 Mbps	1 Km	unused TV bands (54-790 MHz)
802.11ah	2017	347Mbps	1 Km	900 Mhz

- all use CSMA/CA for multiple access, and have base-station and ad-hoc network versions

802.11 LAN architecture

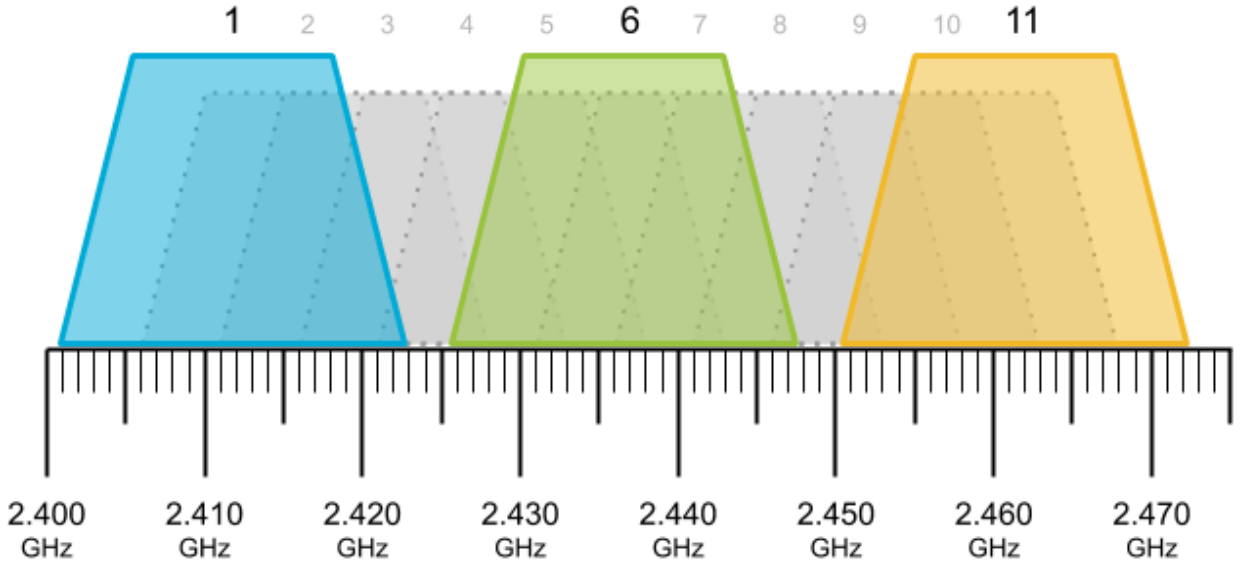


- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka “cell”) in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

802.11: Channels

- spectrum divided into channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!

Example: 2.4 GHz

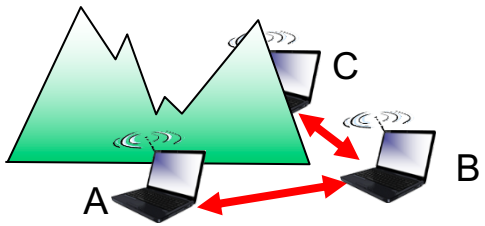


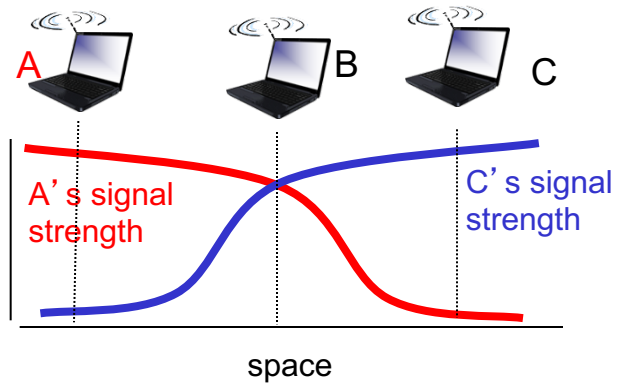
802.11: Association

- arriving host: must associate with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID) and MAC address
  - selects AP to associate with
  - then may perform authentication [Chapter 8]
  - then typically run DHCP to get IP address in AP's subnet

IEEE 802.11: multiple access

- avoid collisions: 2^+ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with detected ongoing transmission by another node
- 802.11: *no* collision detection!
  - difficult to sense collisions: high transmitting signal, weak received signal due to fading
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/CollisionAvoidance





IEEE 802.11 MAC Protocol: CSMA/CA

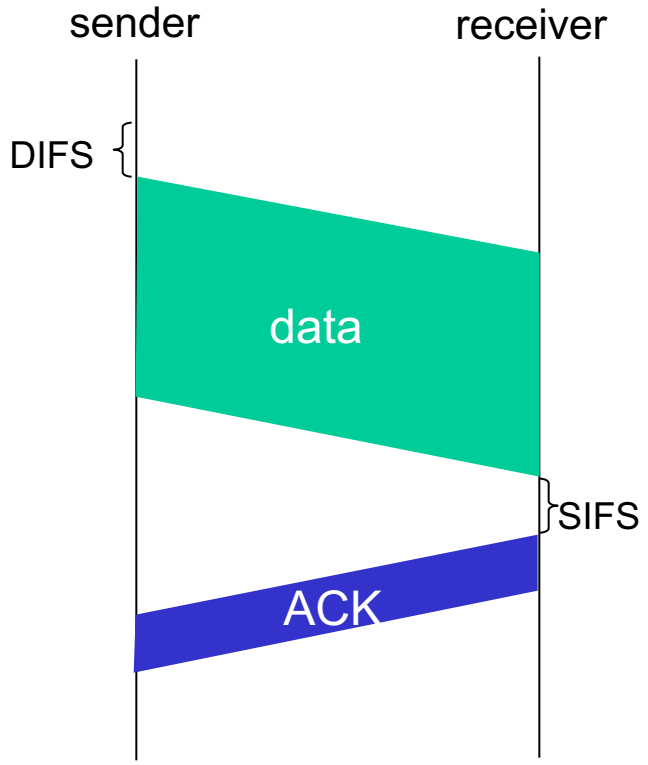
802.11 sender

1 if sense channel idle for **DIFS** then
transmit entire frame (no CD)

2 if sense channel busy then
start random backoff time
timer counts down while channel idle
transmit when timer expires
if no ACK, increase random backoff interval, repeat 2

802.11 receiver

if frame received OK
return ACK after **SIFS** (ACK needed due to hidden terminal problem)

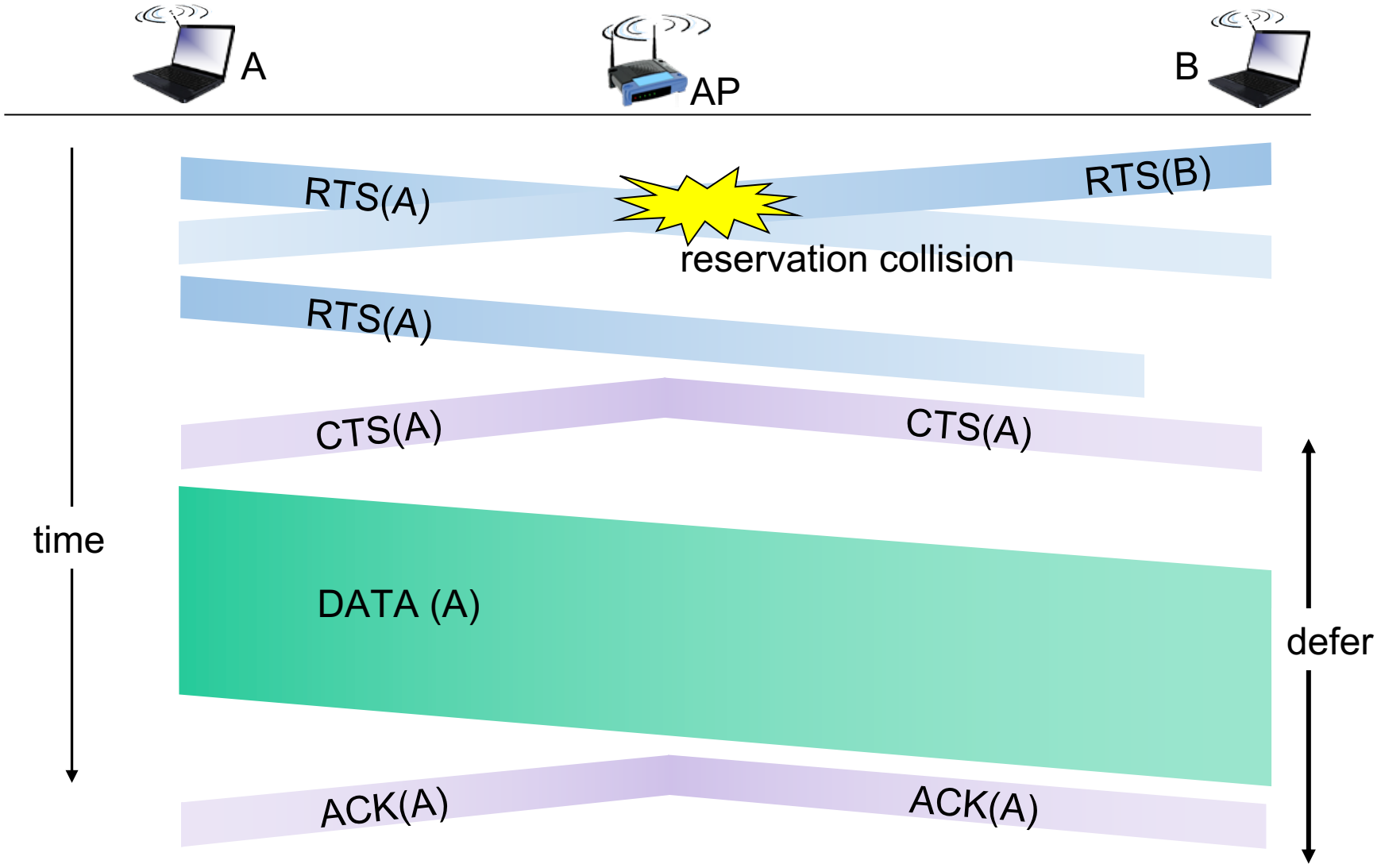


Avoiding collisions (more)

idea: sender "reserves" channel use for data frames using small reservation packets

- sender first transmits *small* request-to-send (RTS) packet to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

Collision Avoidance: RTS-CTS exchange



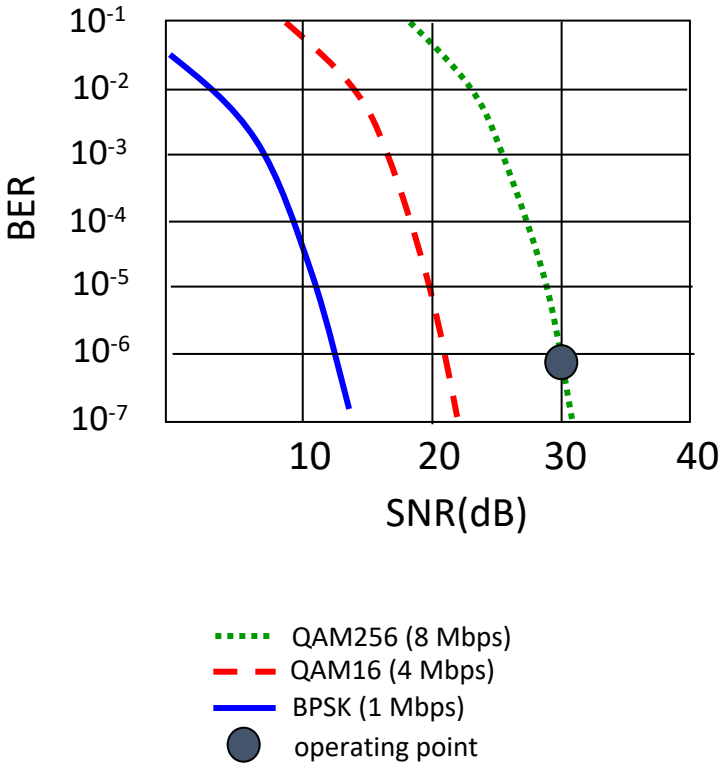
802.11: advanced capabilities

Rate adaptation

- base station, mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies

  1. SNR decreases, BER increase as node moves away from base station

  2. When BER becomes too high, switch to lower transmission rate but with lower BER



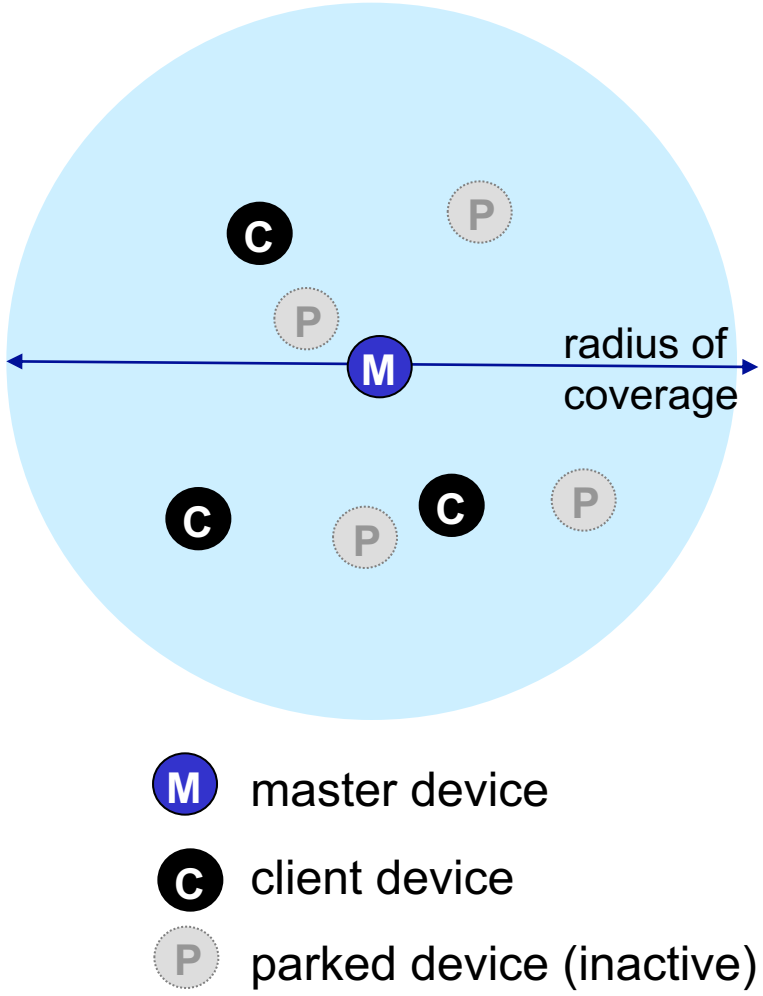
802.11: advanced capabilities

power management

- node-to-AP: “I am going to sleep until next beacon frame”
  - AP knows not to transmit frames to this node
  - node wakes up before next beacon frame
- beacon frame: contains list of mobiles with AP-to-mobile frames waiting to be sent
  - node will stay awake if AP-to-mobile frames to be sent; otherwise sleep again until next beacon frame

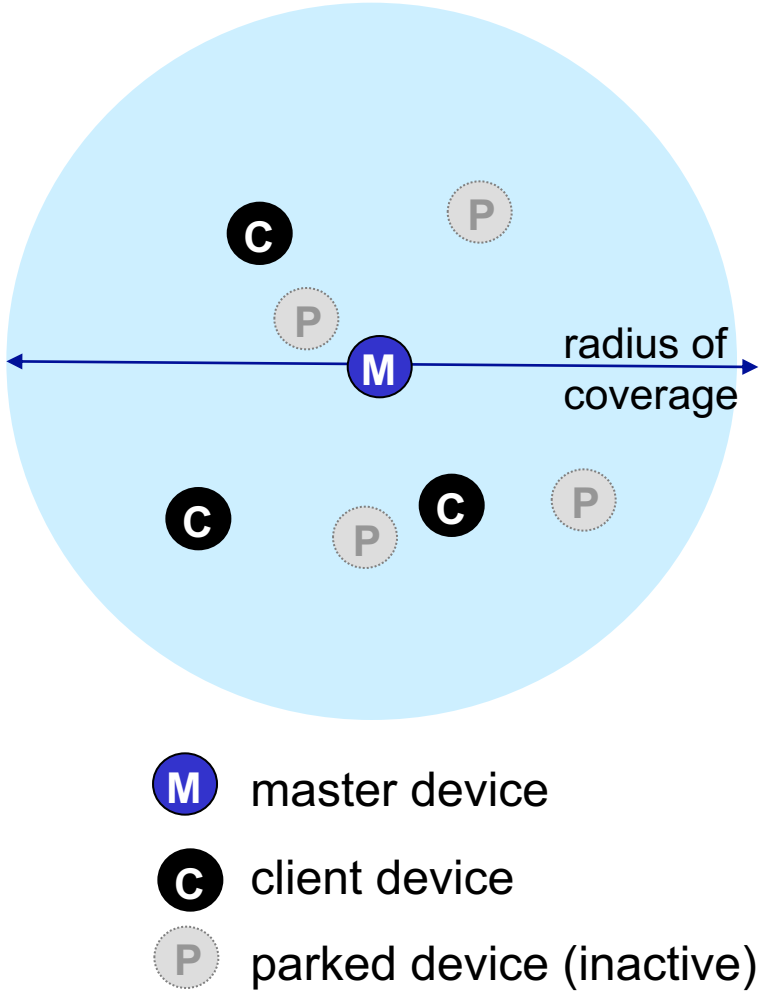
Personal area networks: Bluetooth

- less than 10 m diameter
- replacement for cables (mouse, keyboard, headphones)
- ad hoc: no infrastructure
- 2.4-2.5 GHz ISM radio band, up to 3 Mbps
- master controller / clients devices:
  - master polls clients, grants requests for client transmissions



Personal area networks: Bluetooth

- TDM, 625 μsec sec. slot
- FDM: sender uses 79 frequency channels in known, pseudo-random order slot-to-slot (spread spectrum)
  - other devices/equipment not in piconet only interfere in some slots
- parked mode: clients can "go to sleep" (park) and later wakeup (to preserve battery)
- bootstrapping: nodes self-assemble (plug and play) into piconet



Chapter 7 outline

- Introduction

Wireless

- Wireless links and network characteristics
- WiFi: 802.11 wireless LANs
- Cellular networks: 4G and 5G

Mobility

- Mobility management: principles
- Mobility management: practice
  - 4G/5G networks
  - Mobile IP
- Mobility: impact on higher-layer protocols

4G/5G cellular networks

- *the* solution for wide-area mobile Internet
- widespread deployment/use:
  - more mobile-broadband-connected devices than fixed-broadband-connected devices devices (5-1 in 2019)!
  - 4G availability: 97% of time in Korea (90% in US)
- transmission rates up to 100's Mbps
- technical standards: 3rd Generation Partnership Project (3GPP)
  - wwww.3gpp.org
  - 4G: Long-Term Evolution (LTE)standard

4G/5G cellular networks

similarities to wired Internet

- edge/core distinction, but both below to same carrier
- global cellular network: a network of networks
- widespread use of protocols we've studied: HTTP, DNS, TCP, UDP, IP, NAT, separation of data/control planes, SDN, Ethernet, tunneling
- interconnected to wired Internet

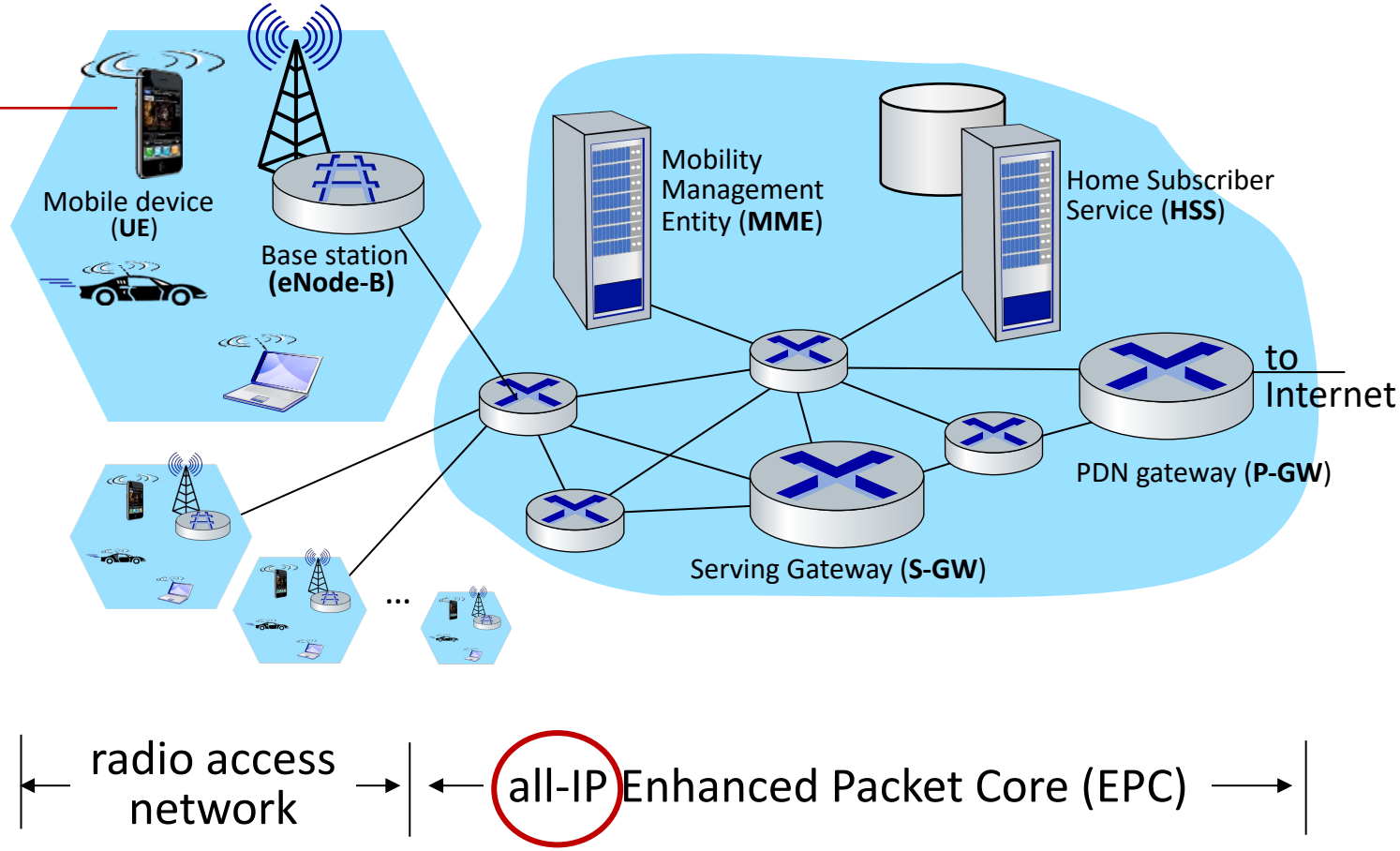
differences from wired Internet

- different wireless link layer
- mobility as a 1st class service
- user "identity" (via SIM card)
- business model: users subscribe to a cellular provider
  - strong notion of "home network" versus roaming on visited nets
  - global access, with authentication infrastructure, and inter-carrier settlements

Elements of 4G LTE architecture

Mobile device:

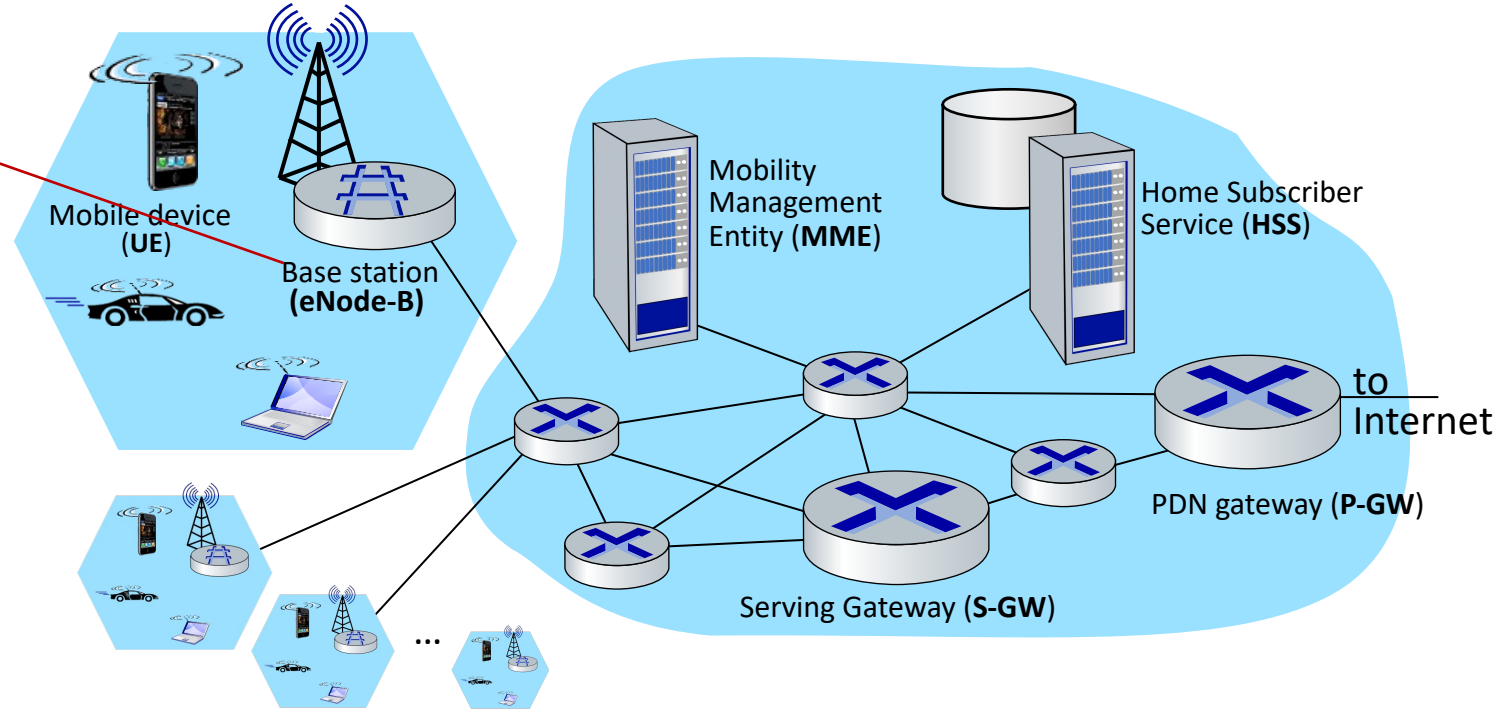
- smartphone, tablet, laptop, IoT, ... with 4G LTE radio
- 64-bit International Mobile Subscriber Identity (IMSI), stored on SIM (Subscriber Identity Module) card
- LTE jargon: User Equipment (UE)



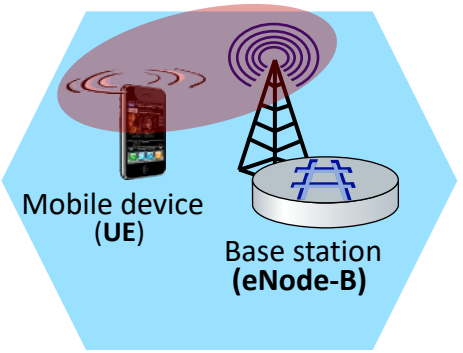
Elements of 4G LTE architecture

Base station:

- at “edge” of carrier’s network
- manages wireless radio resources, mobile devices in its coverage area (“cell”)
- coordinates device authentication with other elements
- similar to WiFi AP but:
  - active role in user mobility
  - coordinates with nearly base stations to optimize radio use
- LTE jargon: eNode-B



Radio Access Network: 4G radio



- connects device (UE) to a base station (eNode-B)
  - multiple devices connected to each base station
- many different possible frequencies bands, multiple channels in each band
  - popular bands: 600, 700, 850, 1500, 1700, 1900, 2100, 2600, 3500 MHz
  - separate upstream and downstream channels
- sharing 4G radio channel among users:
  - OFDM: Orthogonal Frequency Division Multiplexing
  - combination of FDM, TDM
- 100's Mbps possible per user/device

Spectrum

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

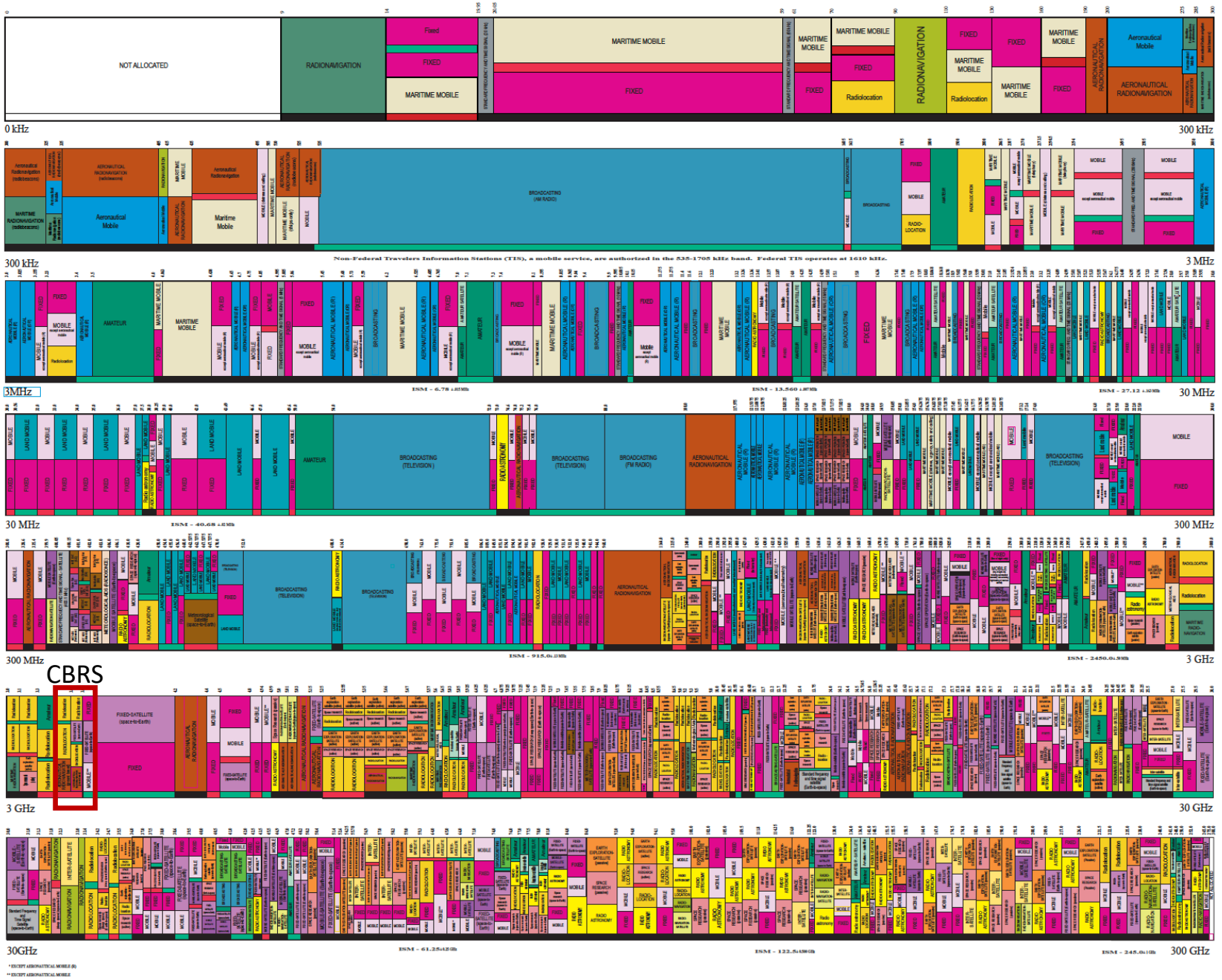
ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC and NTIA. As such, it may not completely reflect all aspects, i.e. footnotes and recent changes made to the Table of Frequency Allocations. Therefore, for complete information, users should consult the Table to determine the current status of U.S. allocations.

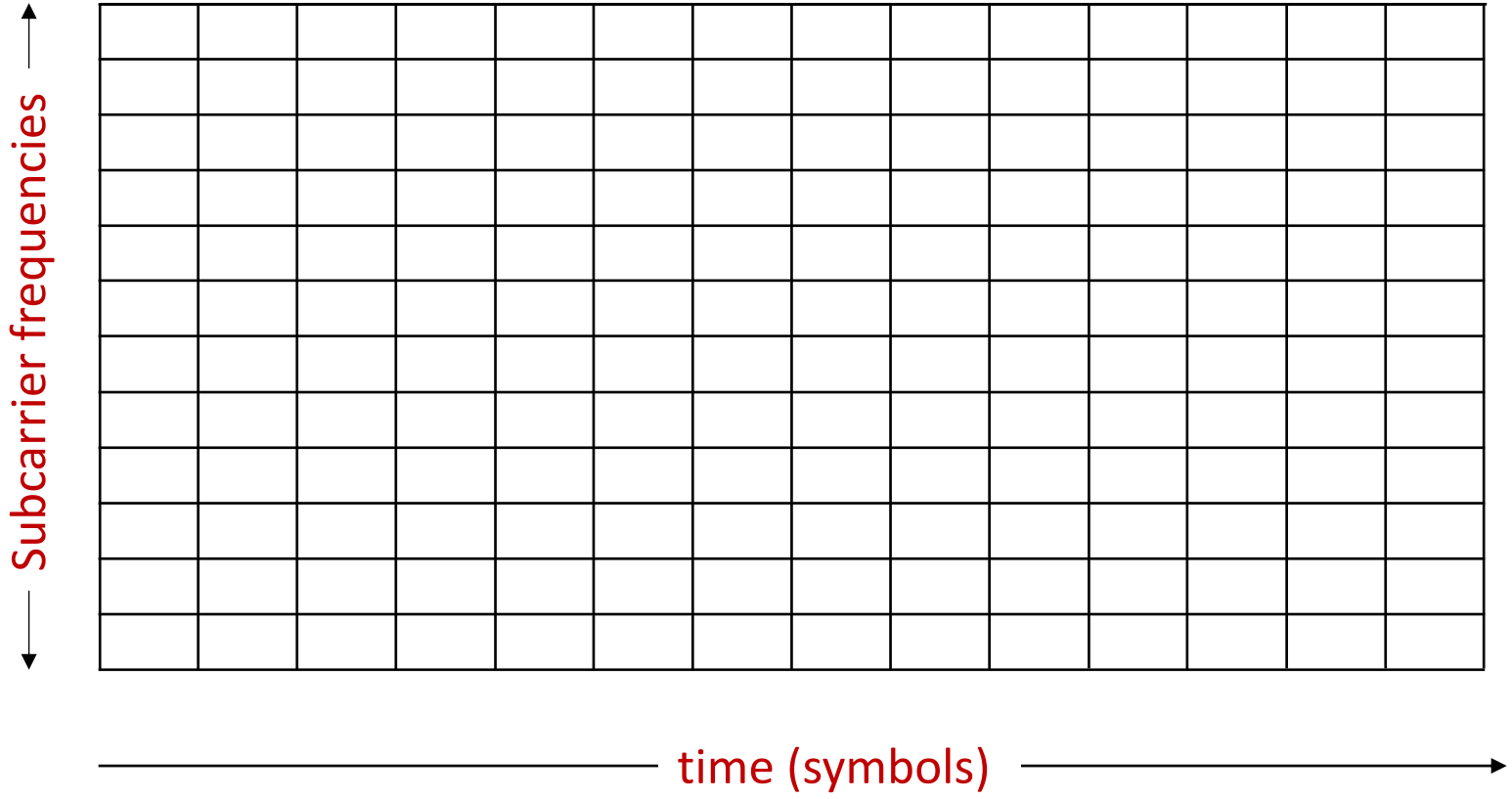
U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management

JANUARY 2016



PLEASE NOTE: THE SPACING ALLOTTED THE SERVICES IN THE SPECTRUM SEGMENTS SHOWN IS NOT PROPORTIONAL TO THE ACTUAL AMOUNT OF SPECTRUM OCCUPIED.

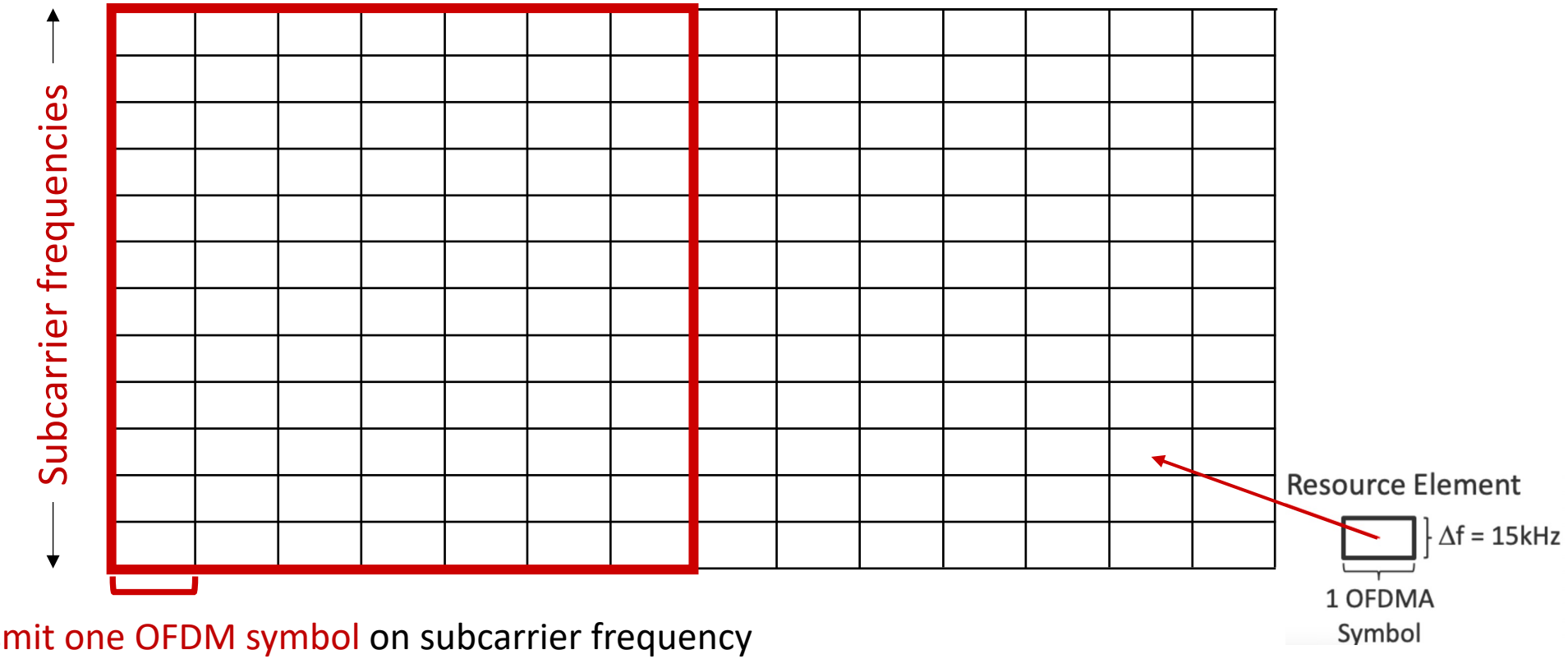
OFDMA: time division (LTE)



OFDMA: time division (LTE)

Physical Resource Block (PRB): blocks of 7x12=84 resource elements

- unit of transmission scheduling



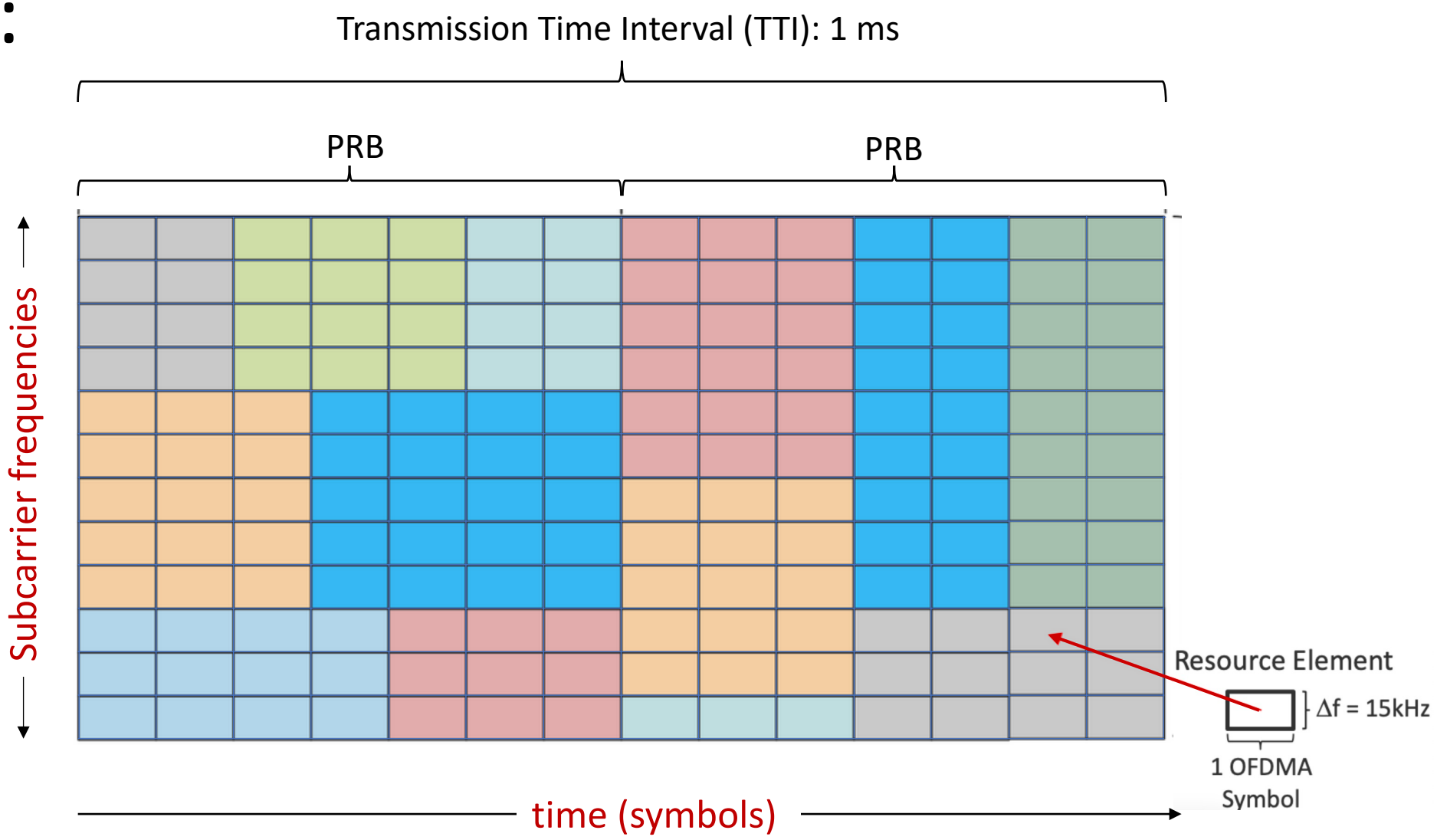
time to transmit one OFDM symbol on subcarrier frequency

OFDMA:

Transmission scheduling example:

- Send to 7 UEs in 7 blocks of REs in one PRB

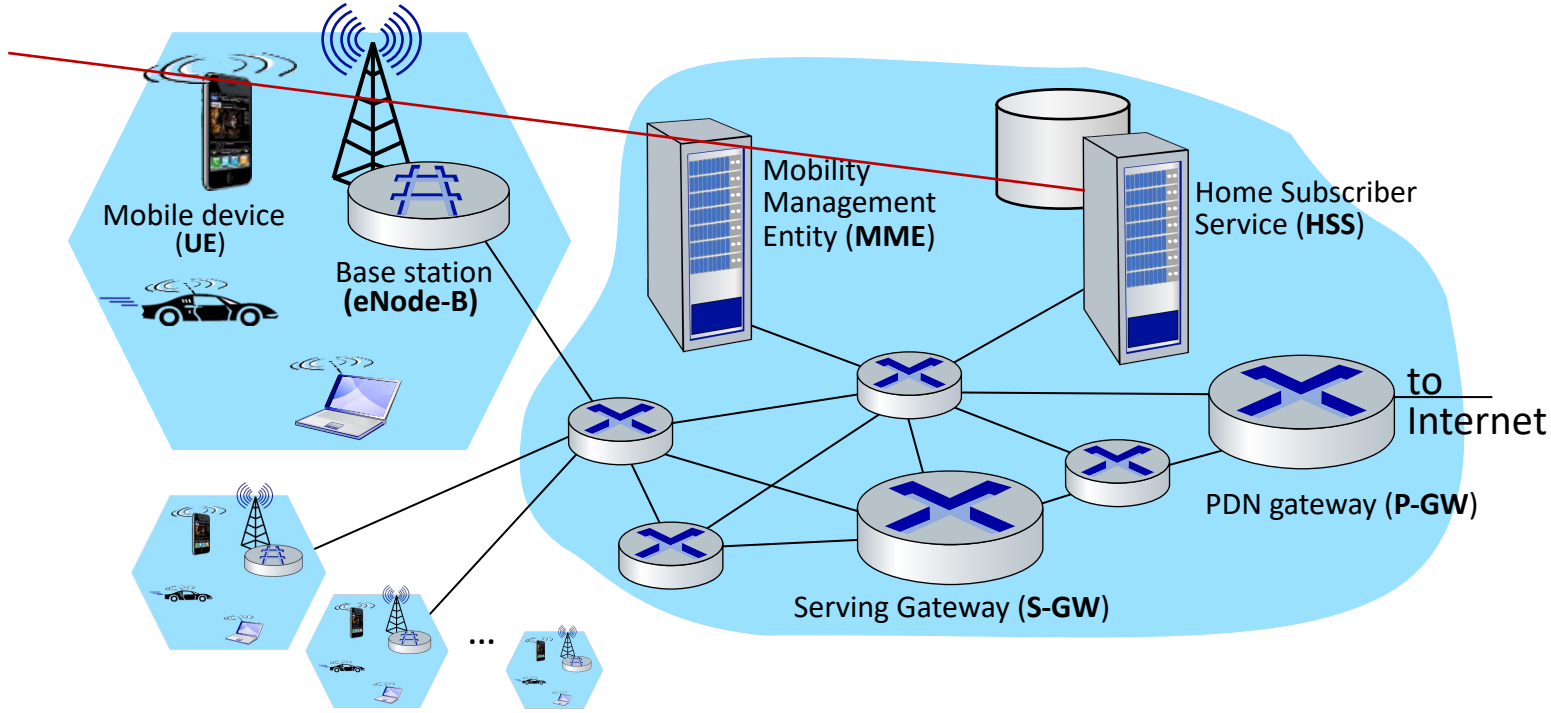
UE_1
UE_2
UE_3
UE_4
UE_5
UE_6
UE_7



Elements of 4G LTE architecture

Home Subscriber Service

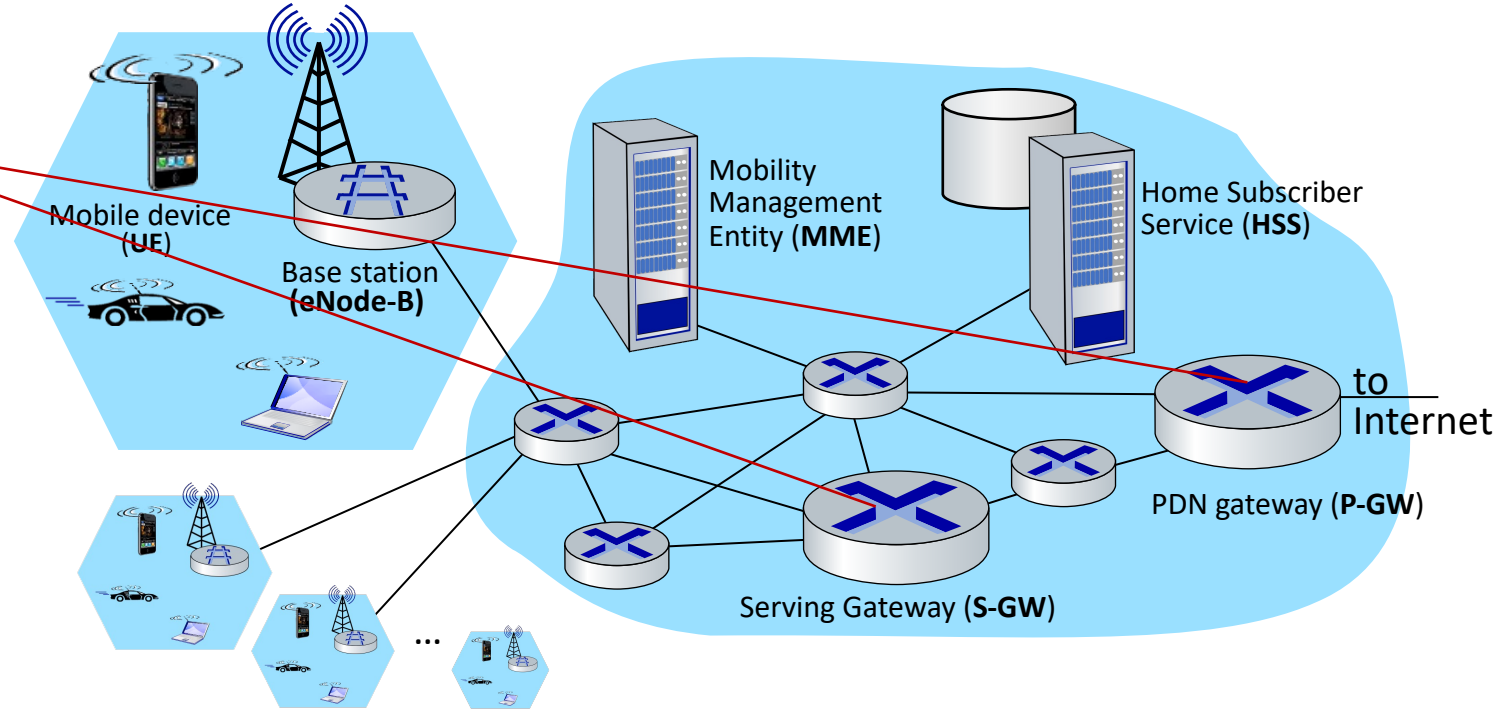
- stores info about mobile devices for which the HSS's network is their "home network"
- works with MME in device authentication



Elements of 4G LTE architecture

Serving Gateway (S-GW),
PDN Gateway (P-GW)

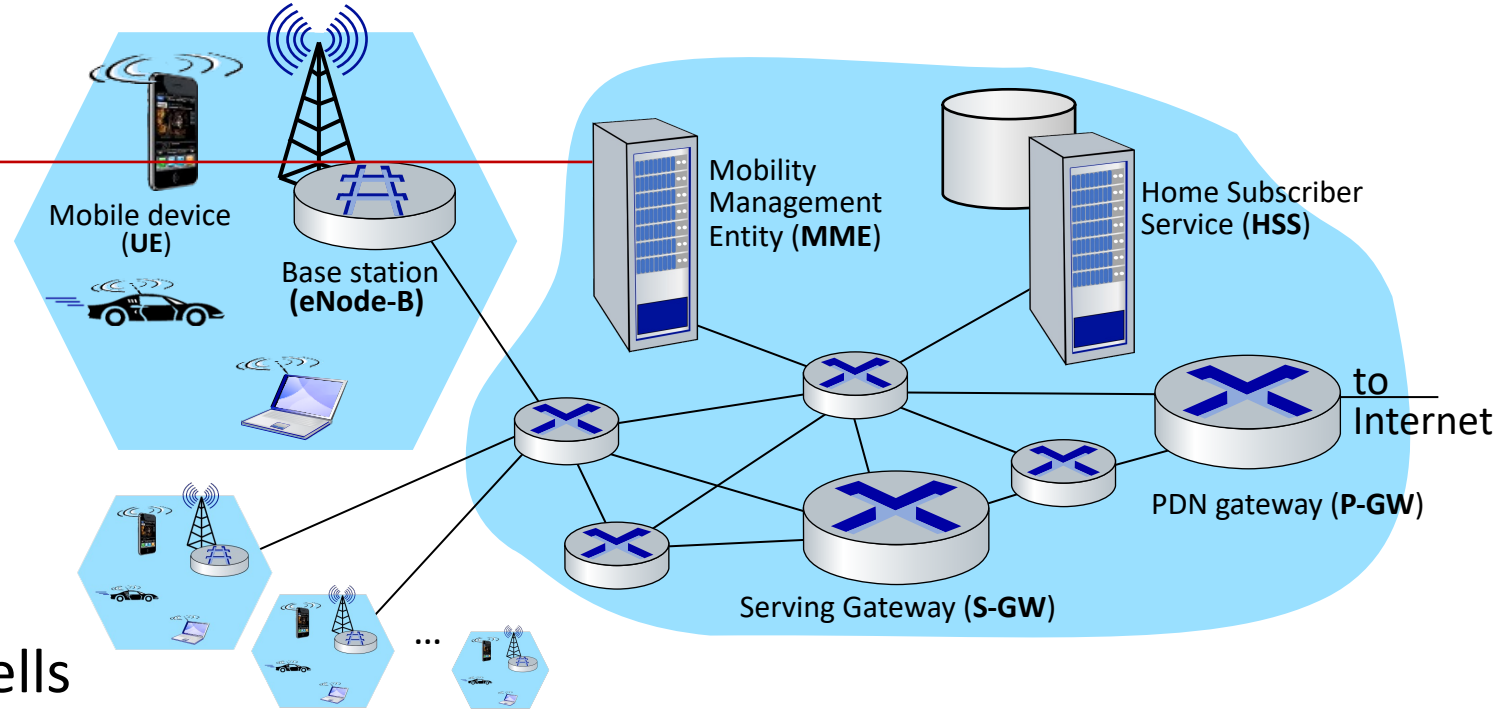
- lie on data path from mobile to/from Internet
- P-GW
  - gateway to mobile cellular network
  - Looks like nay other internet gateway router
  - provides NAT services
- other routers:
  - extensive use of tunneling



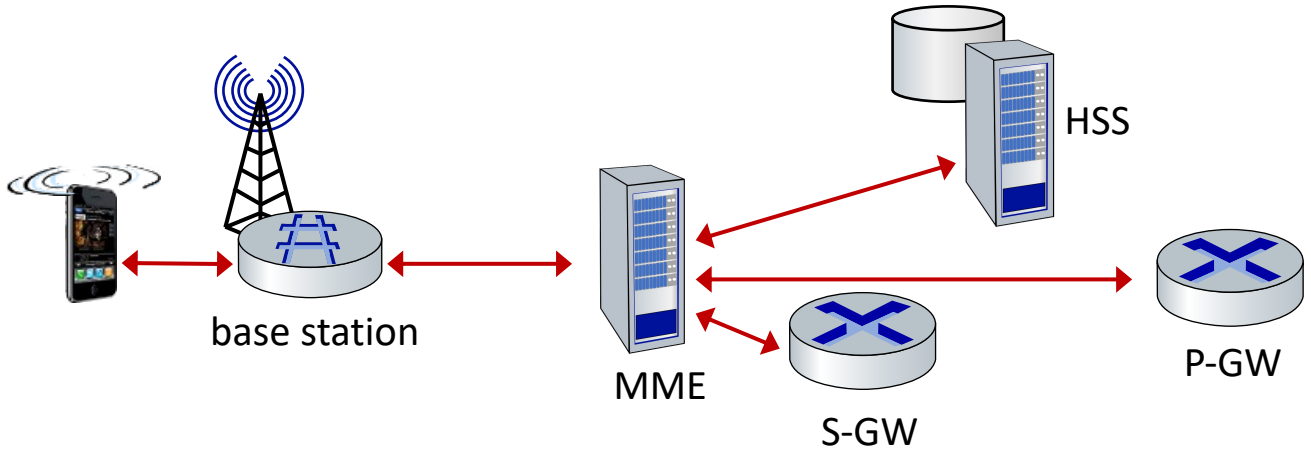
Elements of 4G LTE architecture

Mobility Management Entity

- device authentication (device-to-network, network-to-device) coordinated with mobile home network HSS
- mobile device management:
  - device handover between cells
  - tracking/paging device location
- path (tunneling) setup from mobile device to P-GW

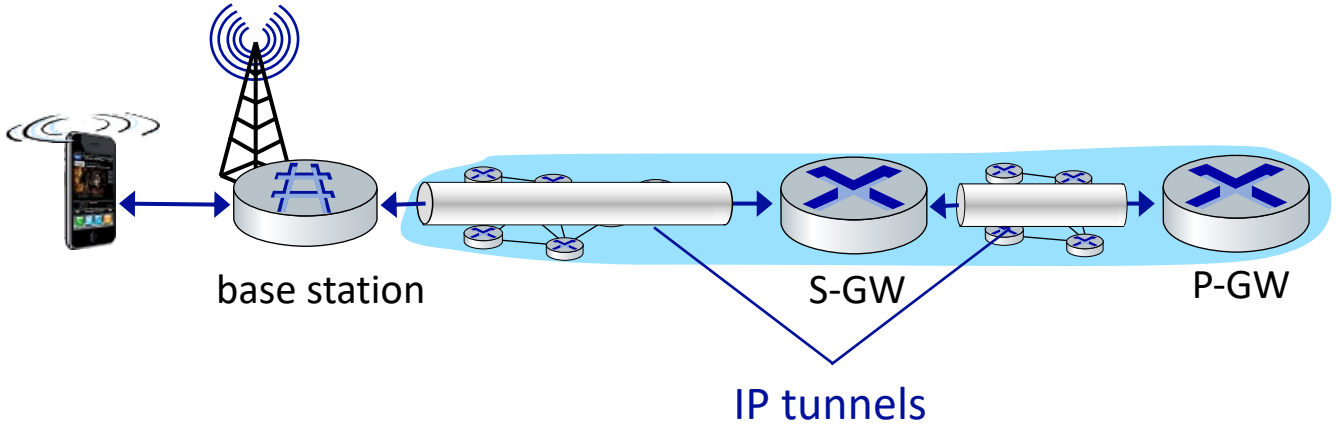


LTE: data plane control plane separation



control plane

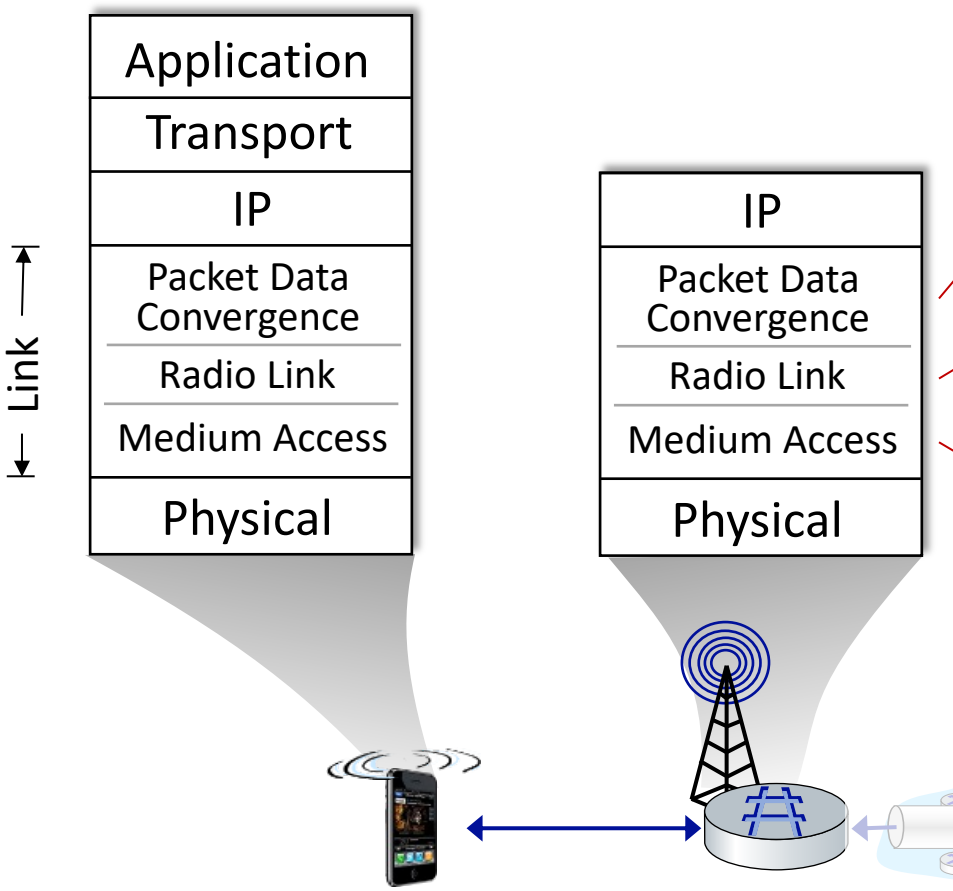
- new protocols for mobility management , security, authentication (later)



data plane

- new protocols at link, physical layers
- extensive use of tunneling to facilitate mobility

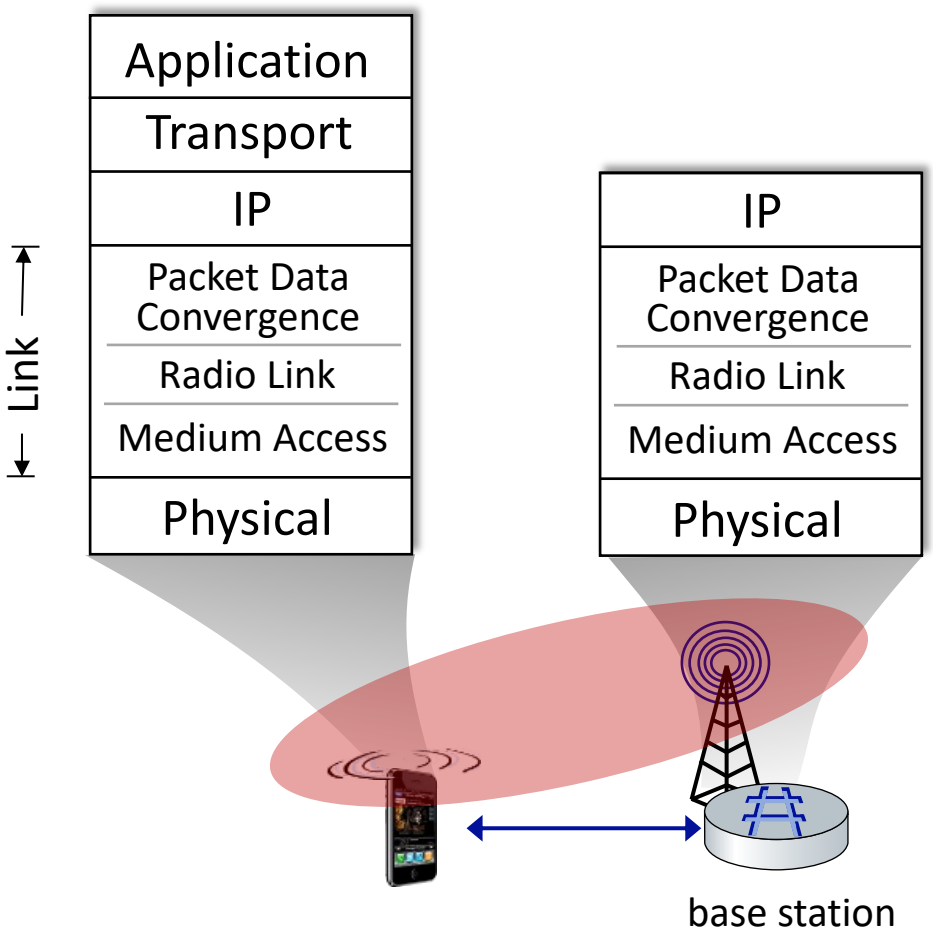
LTE data plane protocol stack: first hop



LTE link layer protocols:

- Packet Data Convergence: header compression, encryption
- Radio Link Control (RLC) Protocol: fragmentation/reassembly, reliable data transfer
- Medium Access: requesting, use of radio transmission slots

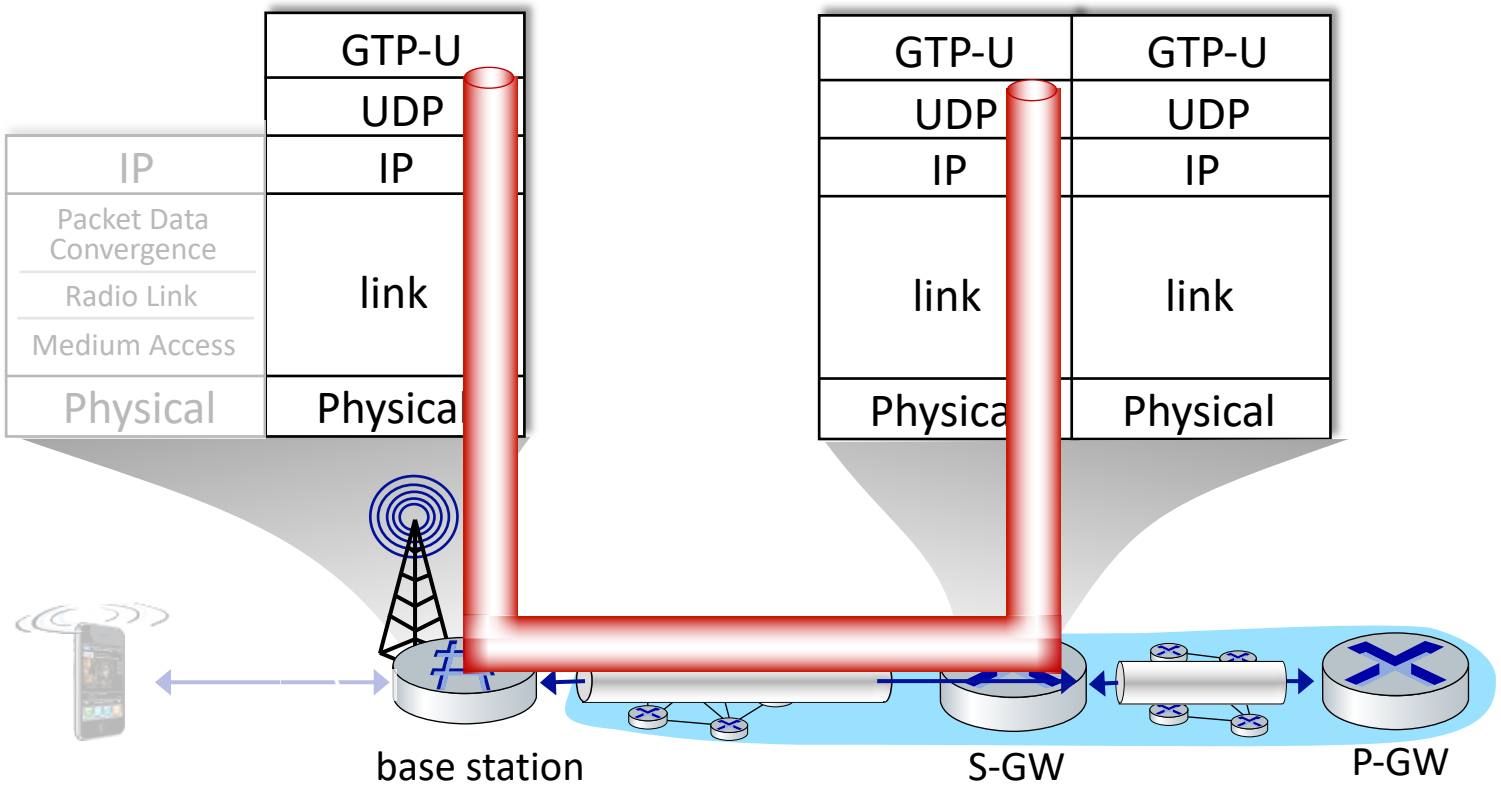
LTE data plane protocol stack: first hop



LTE radio access network:

- downstream channel: FDM, TDM within frequency channel (OFDM - orthogonal frequency division multiplexing)
  - "orthogonal": minimal interference between channels
  - upstream: FDM, TDM similar to OFDM
- each active mobile device allocated two or more 0.5 ms time slots over 12 frequencies
  - scheduling algorithm not standardized – up to operator
  - 100's Mbps per device possible

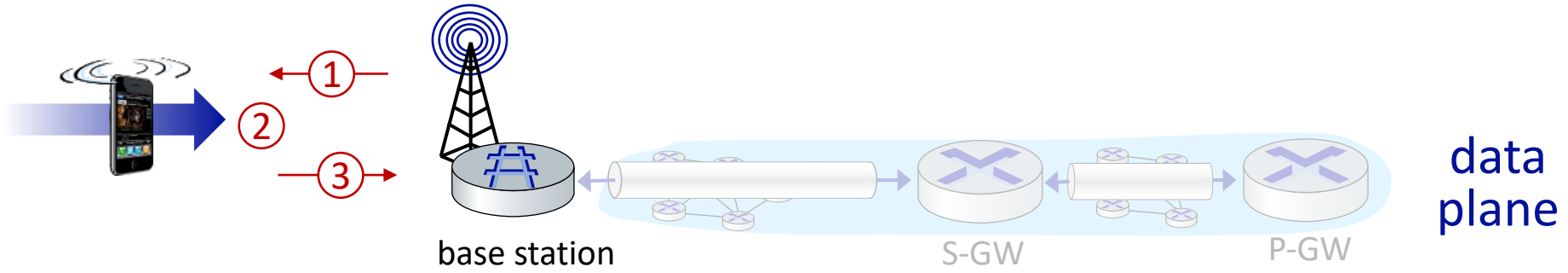
LTE data plane protocol stack: packet core



tunneling:

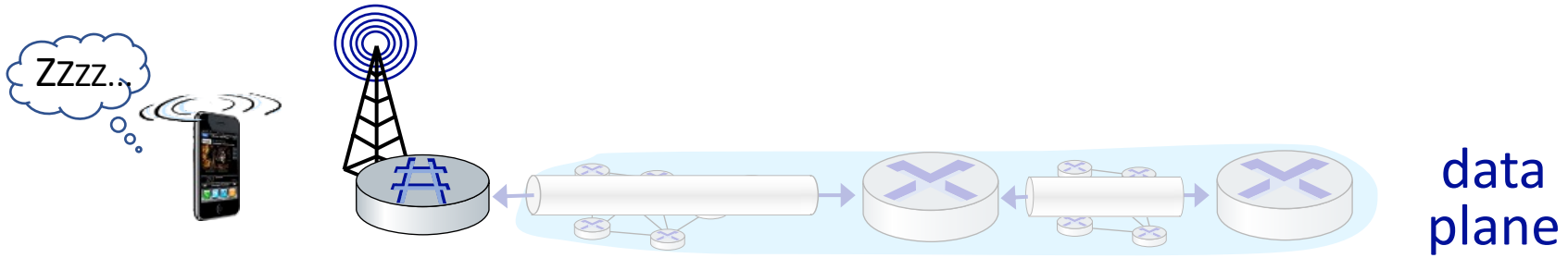
- mobile datagram encapsulated using GPRS Tunneling Protocol (GTP), sent inside UDP datagram to S-GW
- S-GW re-tunnels datagrams to P-GW
- supporting mobility: only tunneling endpoints change when mobile user moves

LTE data plane: associating with a BS



1. BS broadcasts primary synch signal every 5 ms on all frequencies
   - BSs from multiple carriers may be broadcasting synch signals
2. mobile finds a primary synch signal, then locates 2nd synch signal on this freq.
   - mobile then finds info broadcast by BS: channel bandwidth, configurations; BS's cellular carrier info
   - mobile may get info from multiple base stations, multiple cellular networks
3. mobile selects which BS to associate with (*e.g.,* preference for home carrier)
4. more steps still needed to authenticate, establish state, set up data plane

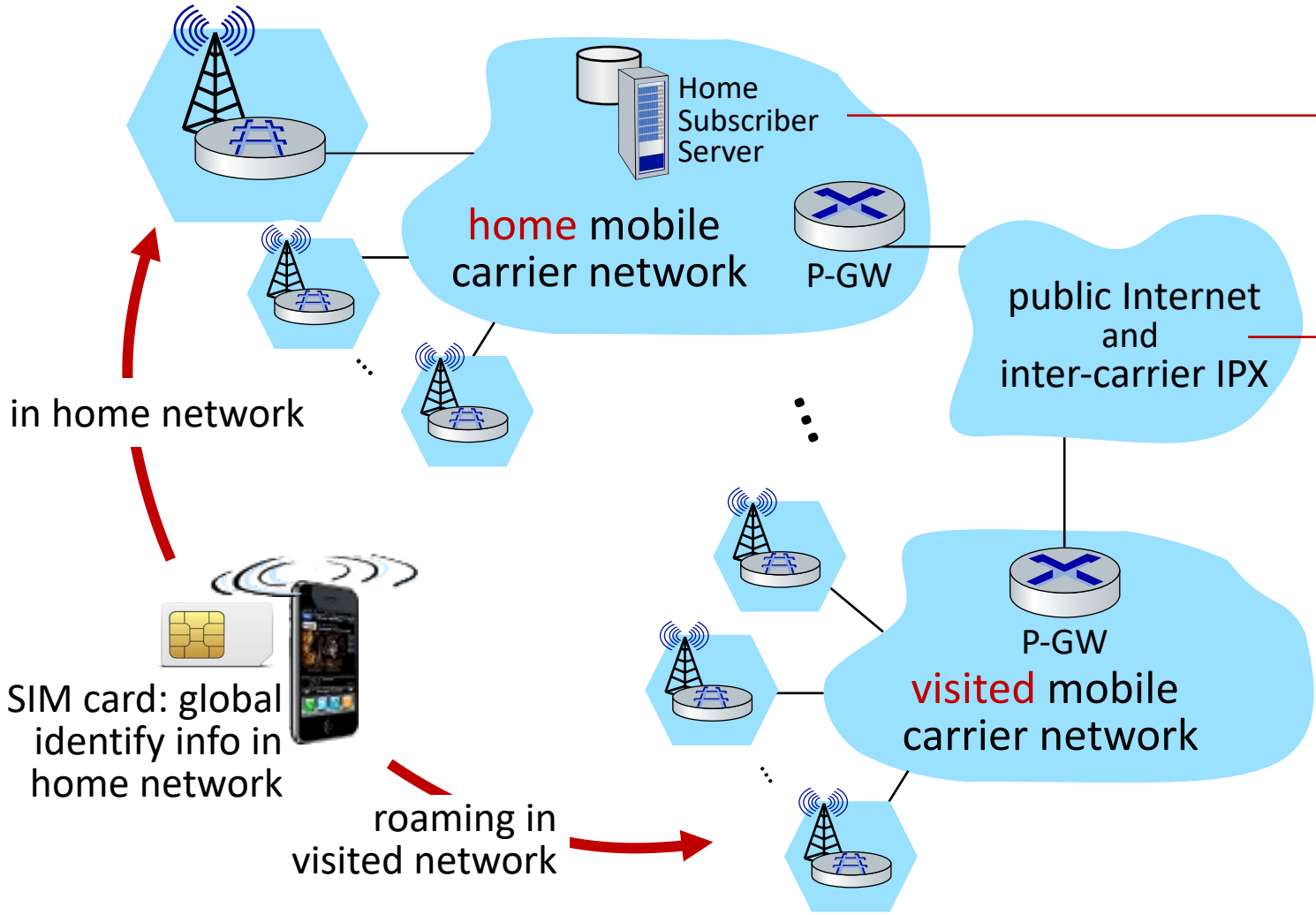
LTE mobiles: sleep modes



as in WiFi, Bluetooth: LTE mobile may put radio to "sleep" to conserve battery:

- light sleep: after 100's msec of inactivity
  - wake up periodically (100's msec) to check for downstream transmissions
- deep sleep: after 5-10 secs of inactivity
  - mobile may change cells while deep sleeping – need to re-establish association

Global cellular network: a network of IP networks



home network HSS:

- identify & services info, while in home network and roaming

all IP:

- carriers interconnect with each other, and public internet at exchange points
- legacy 2G, 3G: not all IP, handled otherwise

On to 5G!

- goal: 10x increase in peak bitrate, 10x decrease in latency, 100x increase in traffic capacity over 4G
- 5G NR (new radio):
  - two frequency bands: FR1 (450 MHz–6 GHz) and FR2 (24 GHz–52 GHz): millimeter wave frequencies
  - not backwards-compatible with 4G
  - MIMO: multiple directional antennae
- millimeter wave frequencies: much higher data rates, but over shorter distances
  - pico-cells: cells diameters: 10-100 m
  - massive, dense deployment of new base stations required

On beyond 5G?

- “6G” not obviously next: “NextG” and “Beyond 5G” heard more often than “6G”
- 5G on an evolutionary path (like the Internet)
  - agility: cloud technologies (SDN) mean new features can be introduced rapidly, deployed continuously
  - customization: change can be introduced bottom-up (e.g., by enterprises and edge cloud partners with Private 5G)
    - No need to wait for standardization
    - No need to reach agreement (among all incumbent stakeholders)

Chapter 7 summary

Wireless

- Wireless Links and network characteristics
- WiFi: 802.11 wireless LANs
- Cellular networks: 4G and 5G

Mobility

- Mobility management: principles
- Mobility management: practice
  - 4G/5G networks
  - Mobile IP
- Mobility: impact on higher-layer protocols

Next…

- ***No class on Nov 28 (Thu)*** *due to* ***University Admission Interviews***

- *Next week…*
- *Chapter 8.1 What Is Network Security?*
- *Chapter 8.2 Principles of Cryptography*
- *Chapter 8.3 Message Integrity and Digital Signatures*