Computer Network

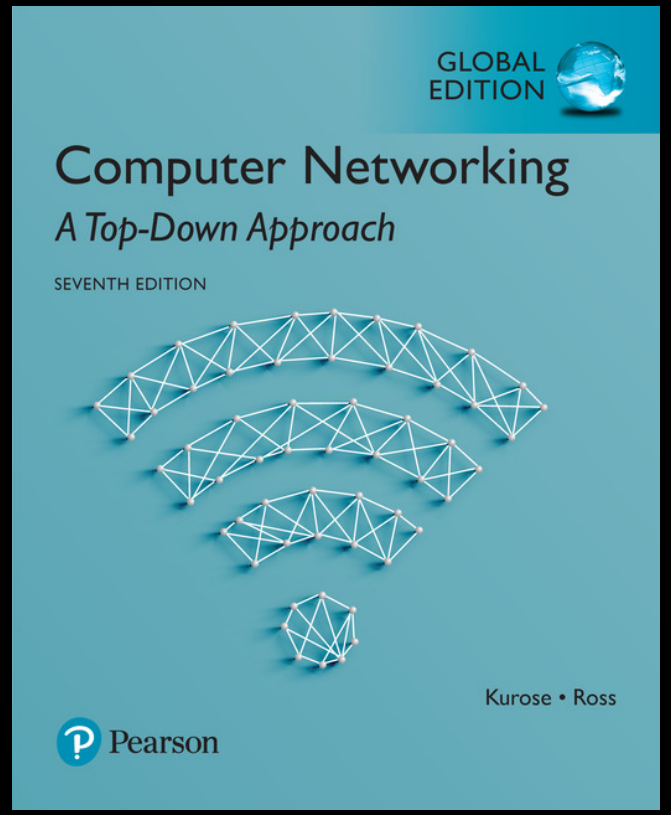
Mobile Network

School of Electric and Computer Engineering

Pusan National University, KOREA

Younghwan Yoo

Textbook



Computer Networking

A Top–Down Approach

7th edition

Jim Kurose, Keith Ross

Pearson

April 2016

Contents

Computer Network introduction

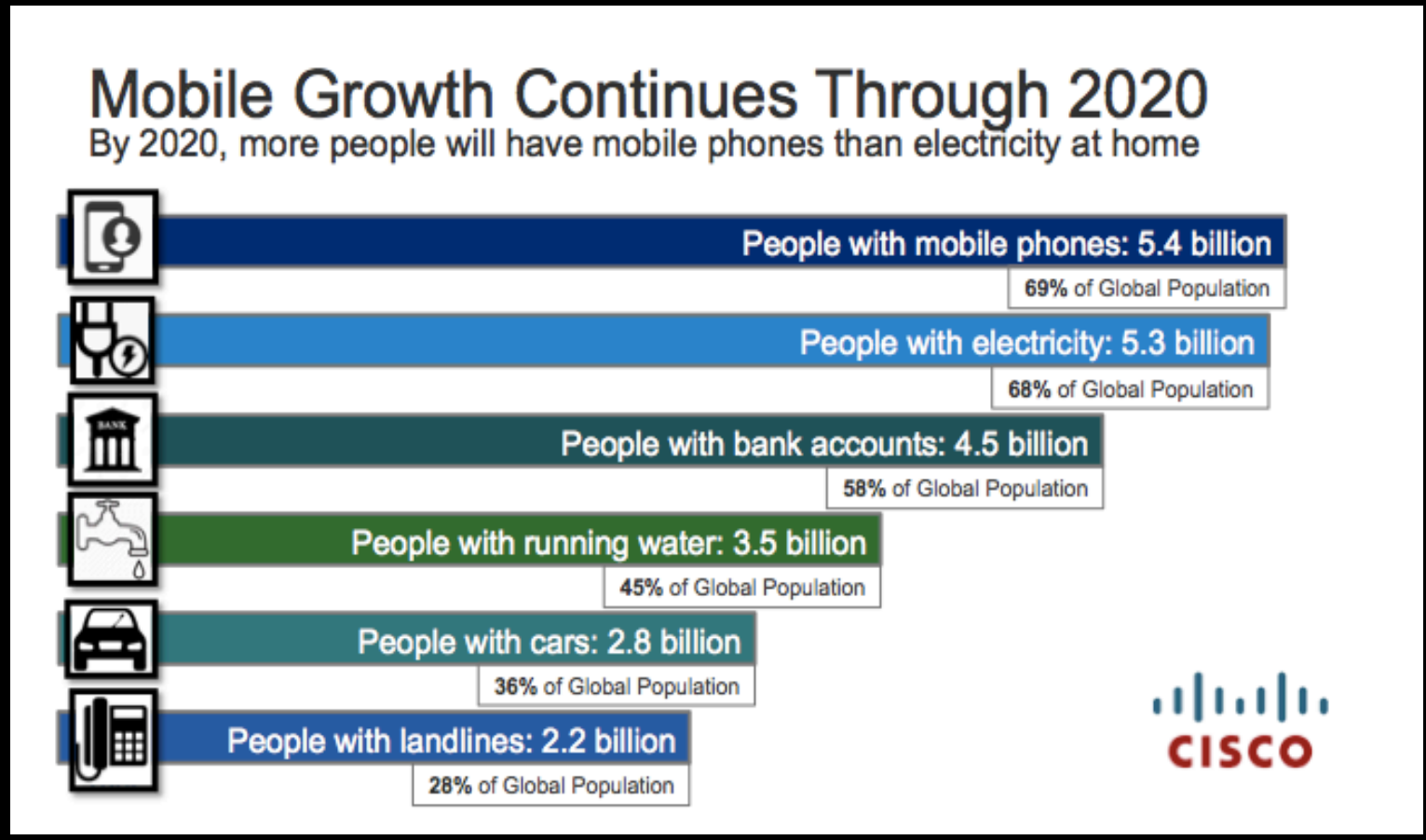
Contents

Computer Network introduction

01. Mobile Network

Background

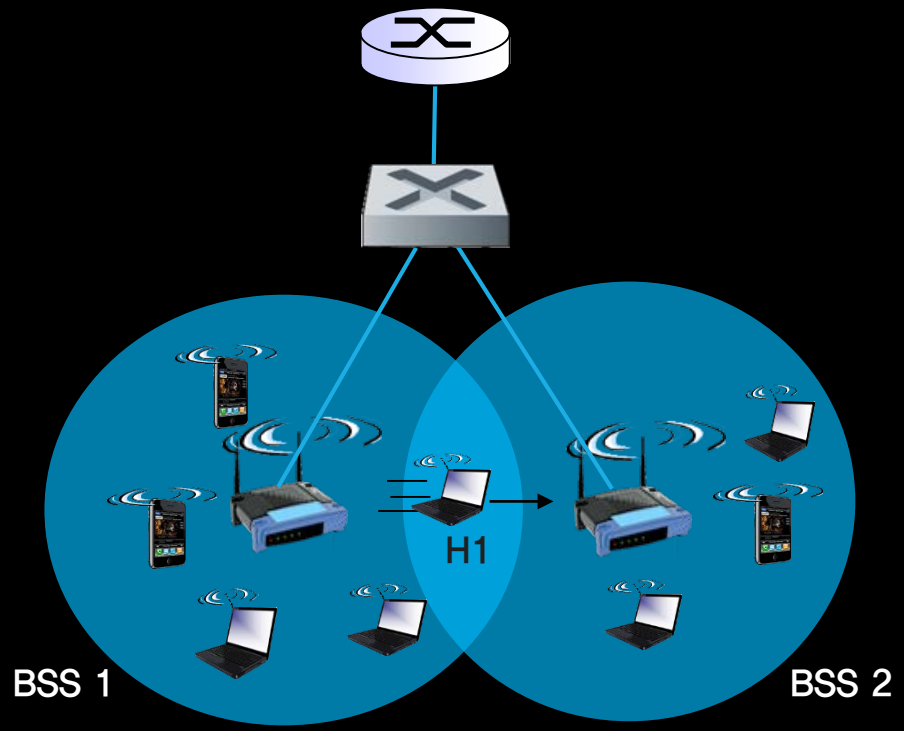
- 5.4 billion mobile subscribers expected through 2020
- 2.5 times larger than people with fixed-wired phones



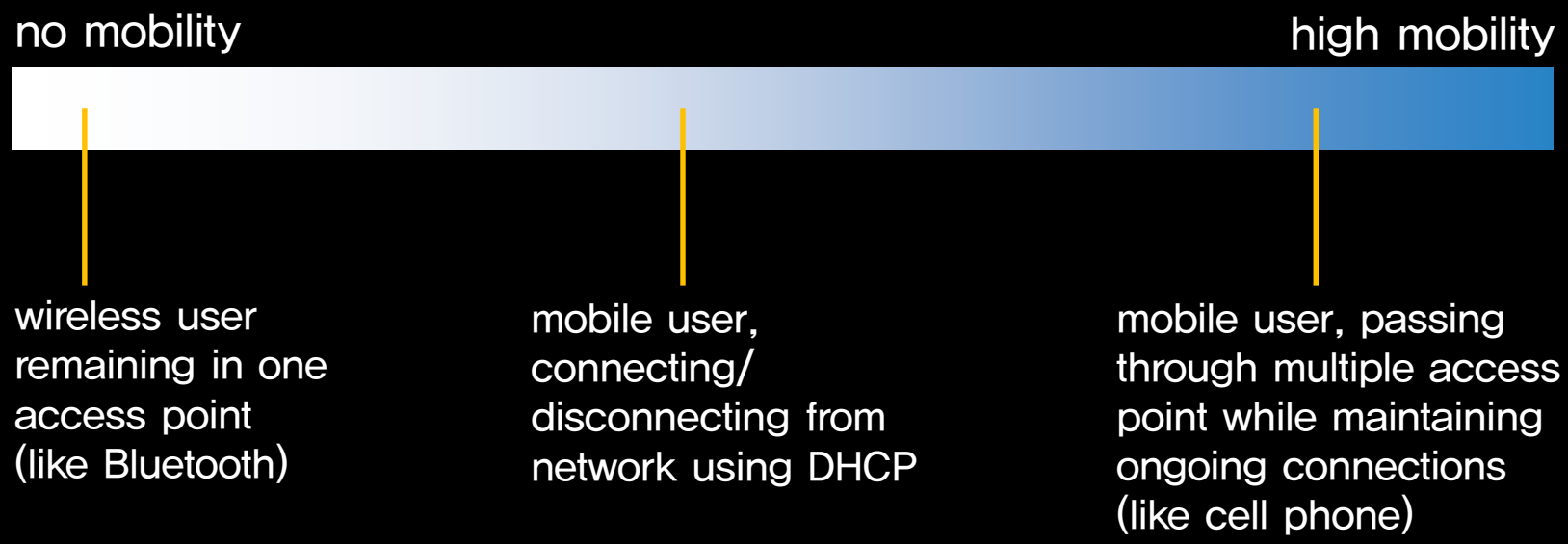
출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiyqazyps3cAhVFTLwKHTPcCulQjRx6BAgBEAU&url=https%3A%2F%2Fnewsroom.cisco.com%2Fpress-release-content%3FarticleId%3D1741352&psig=AOvVaw3506co-BPEBH6PvJNGXCMJ&ust=1533262653993794

Background

- Two important (but different) challenges
  - wireless: communication over wireless link
  - mobility: handling the mobile user who changes point of attachment to network
- If host remains in same IP subnet
  - IP address can remain same
  - switch can know which AP is associated with H1 through the self–learning mechanism
    - switch will see frame from H1 and "remember" which switch port can be used to reach H1



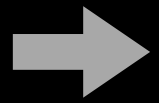
- Spectrum of mobility, from the network perspective:



02. Mobile IP

Approaches to Handle Mobility

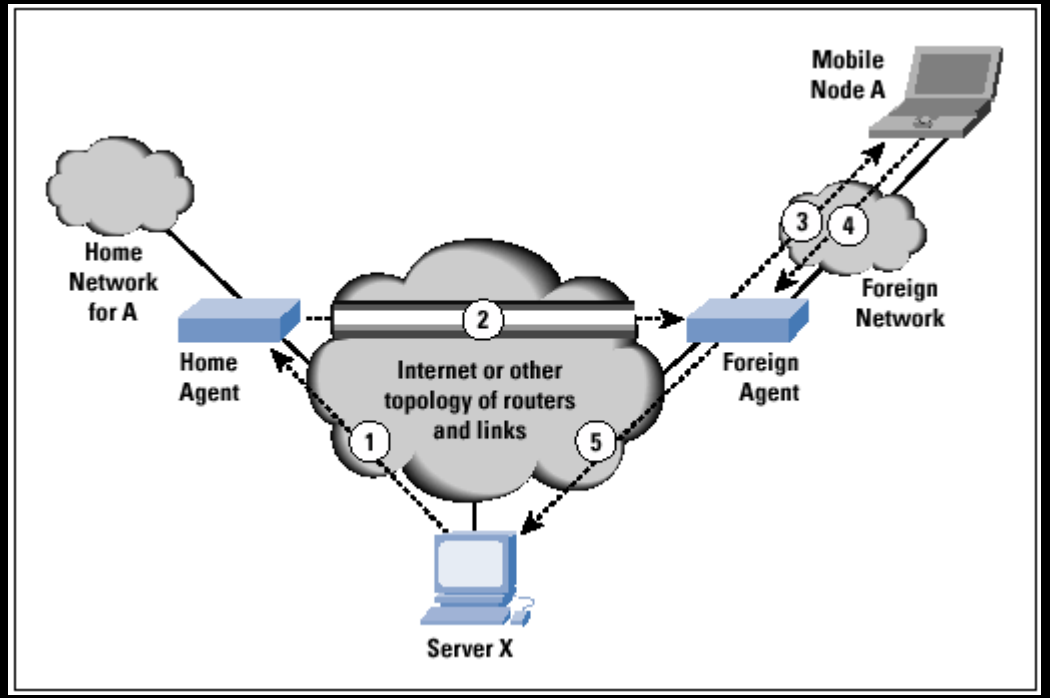
- Let routing handle it: routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange
  - routing tables indicate where each mobile located
  - no changes to end-systems



- Let end-systems handle it:
  - indirect routing: communication from correspondent to mobile goes through original network, then forwarded to current network
  - direct routing: correspondent gets foreign address of mobile, sends directly to mobile

Mobile IP

- RFC 3344
- Three components to standard
  - agent discovery
  - registration with home agent
  - indirect routing of datagrams

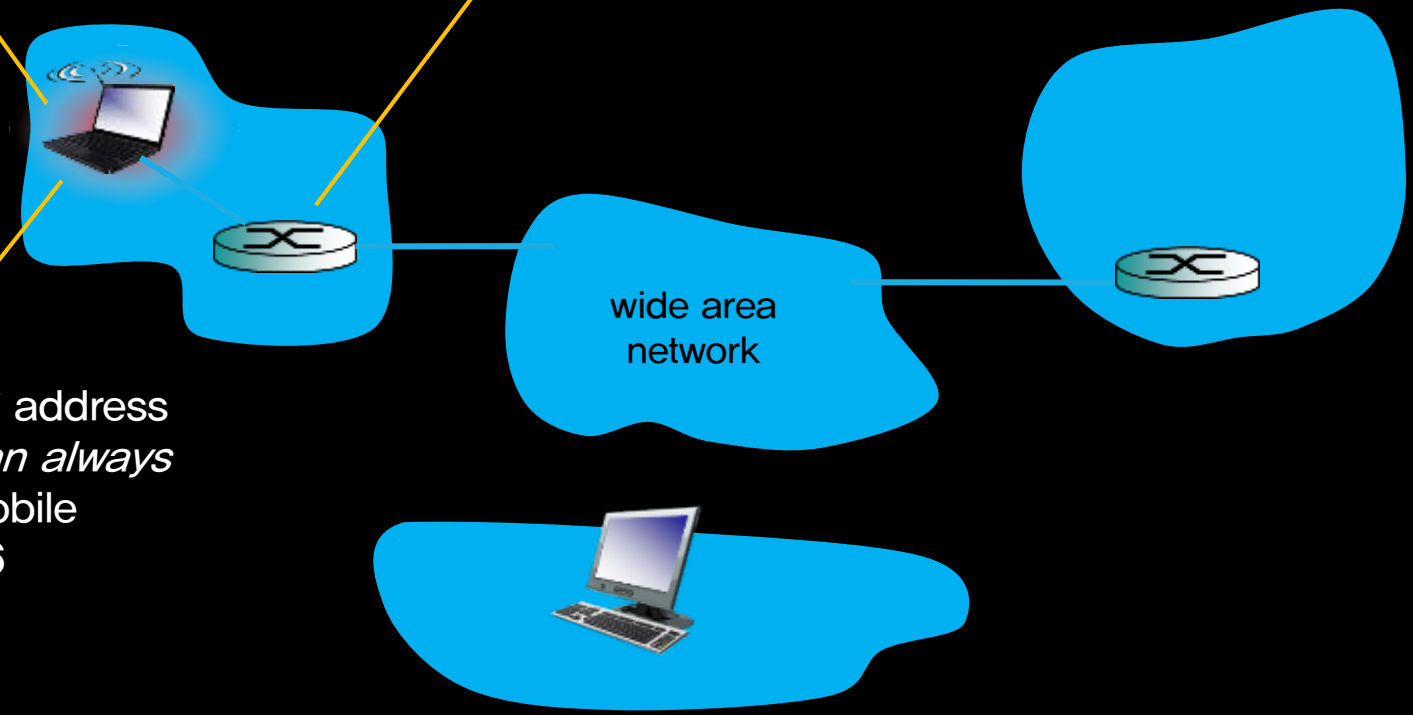


출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwi5kKql89fcAhUSh7wKHbMFAoEQjRx6BAgBEAU&url=https%3A%2F%2Fwww.cisco.com%2Fc%2Fen%2Fus%2Fabout%2Fpress%2Finternet-protocol-journal%2Fback-issues%2Ftable-contents-9%2Fmobile-ip.html&psig=AOvVaw05w4zjSJ3EeGy0HVq4NhtY&ust=1533626829995506

Mobile IP: Terminologies (1/2)

home network: permanent "home" of mobile (e.g., 128.119.40/24)

home agent: *entity that will perform mobility functions on behalf of mobile, when mobile is remote*

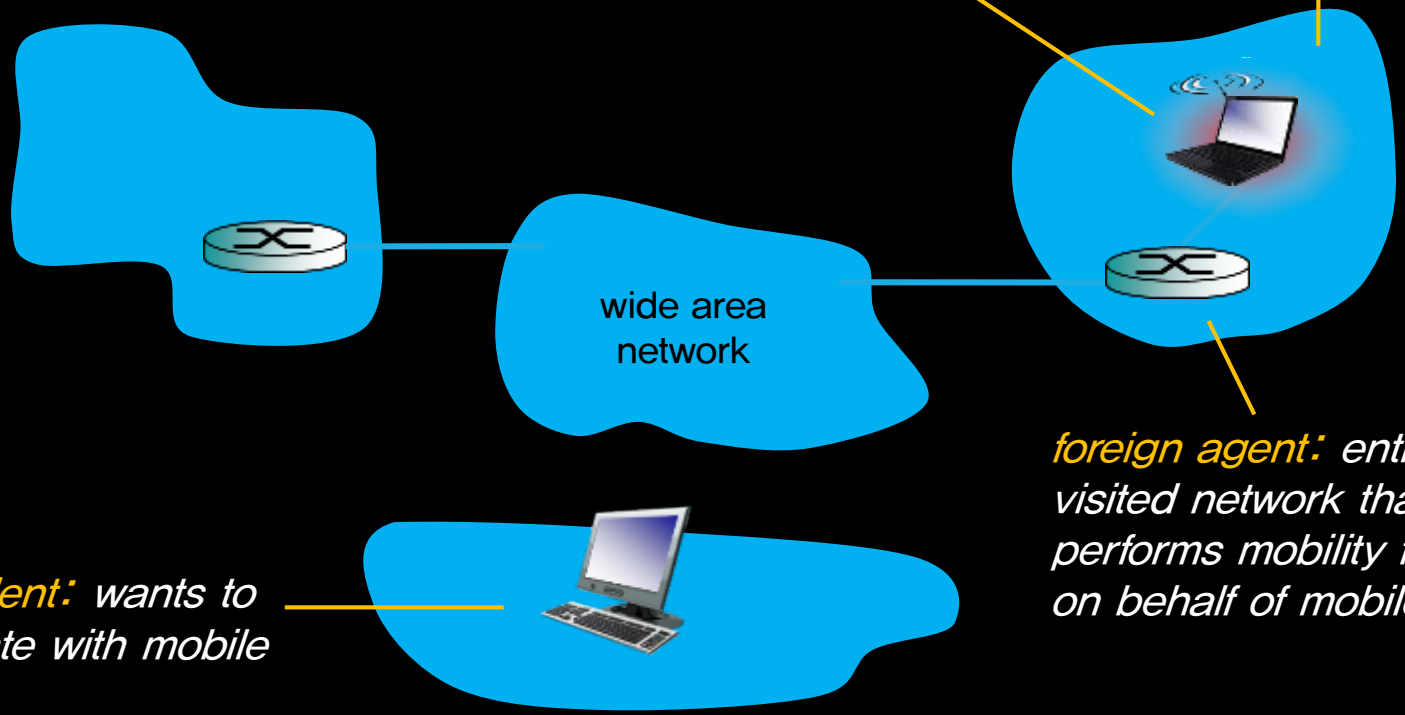


permanent address: address in home network, *can always* be used to reach mobile e.g., 128.119.40.186

Mobile IP: Terminologies (2/2)

permanent address: remains constant (e.g., 128.119.40.186)

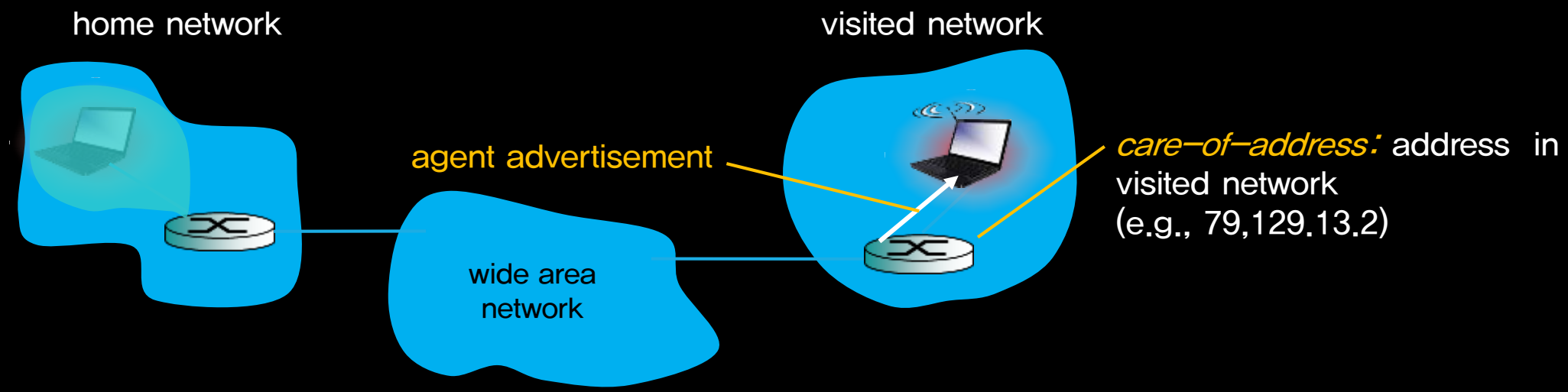
visited network: network in which mobile currently resides (e.g., 79.129.13/24)



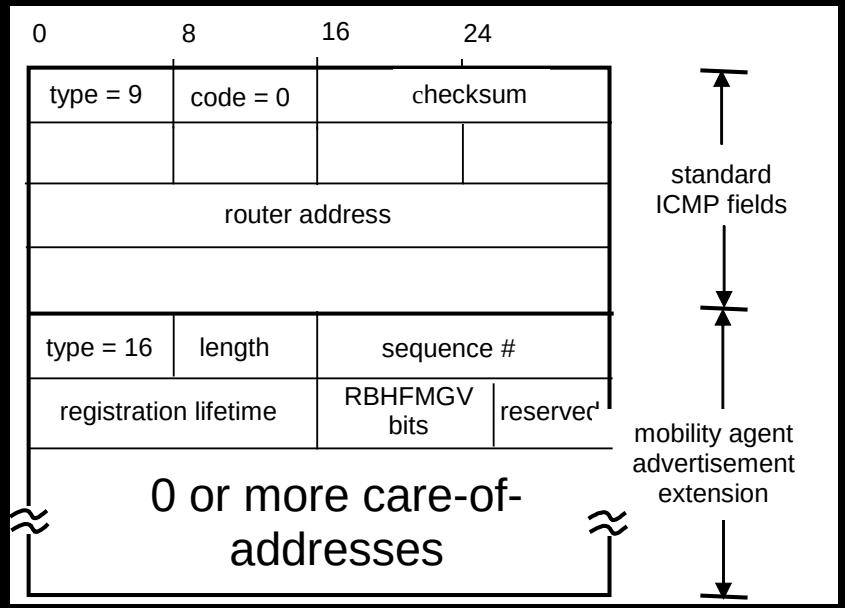
foreign agent: *entity in visited network that performs mobility functions on behalf of mobile*

correspondent: *wants to communicate with mobile*

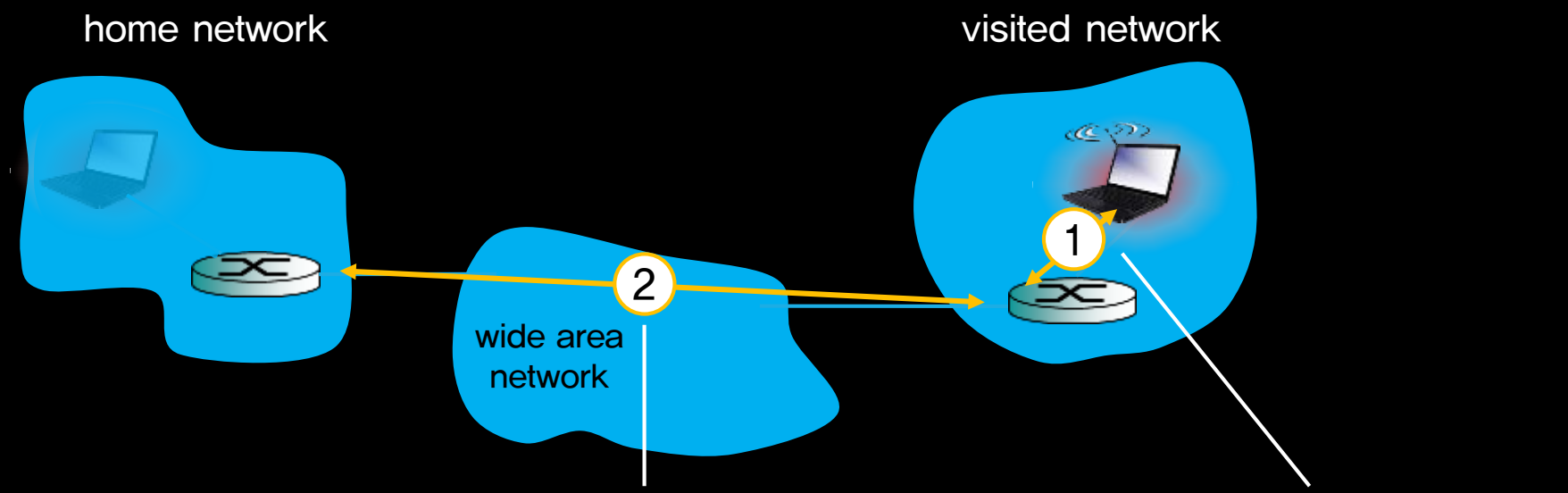
Mobile IP: Agent Discovery



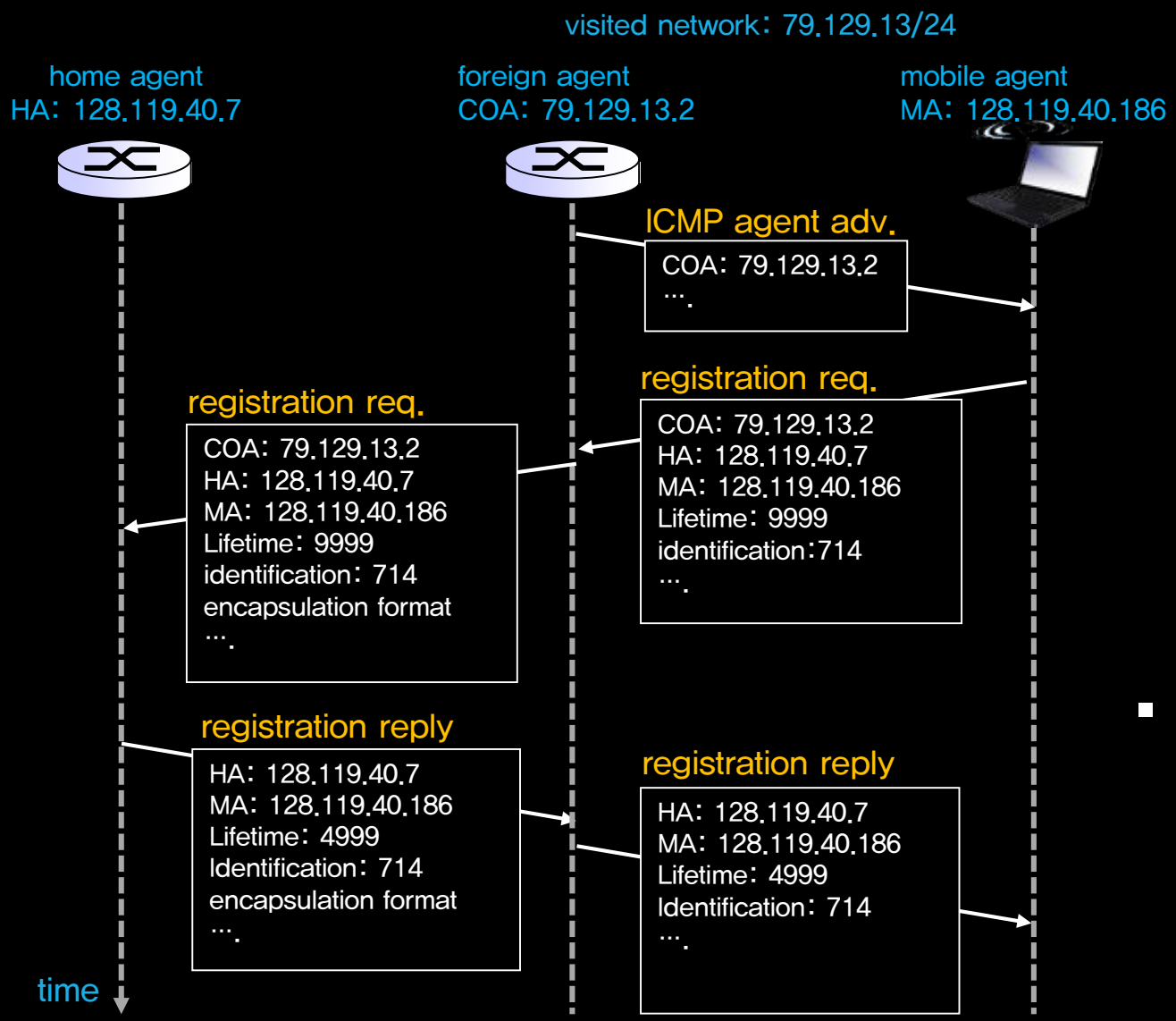
- Agent advertisement: foreign/home agents advertise service by broadcasting ICMP messages (typefield = 9)



Mobile IP: Registration

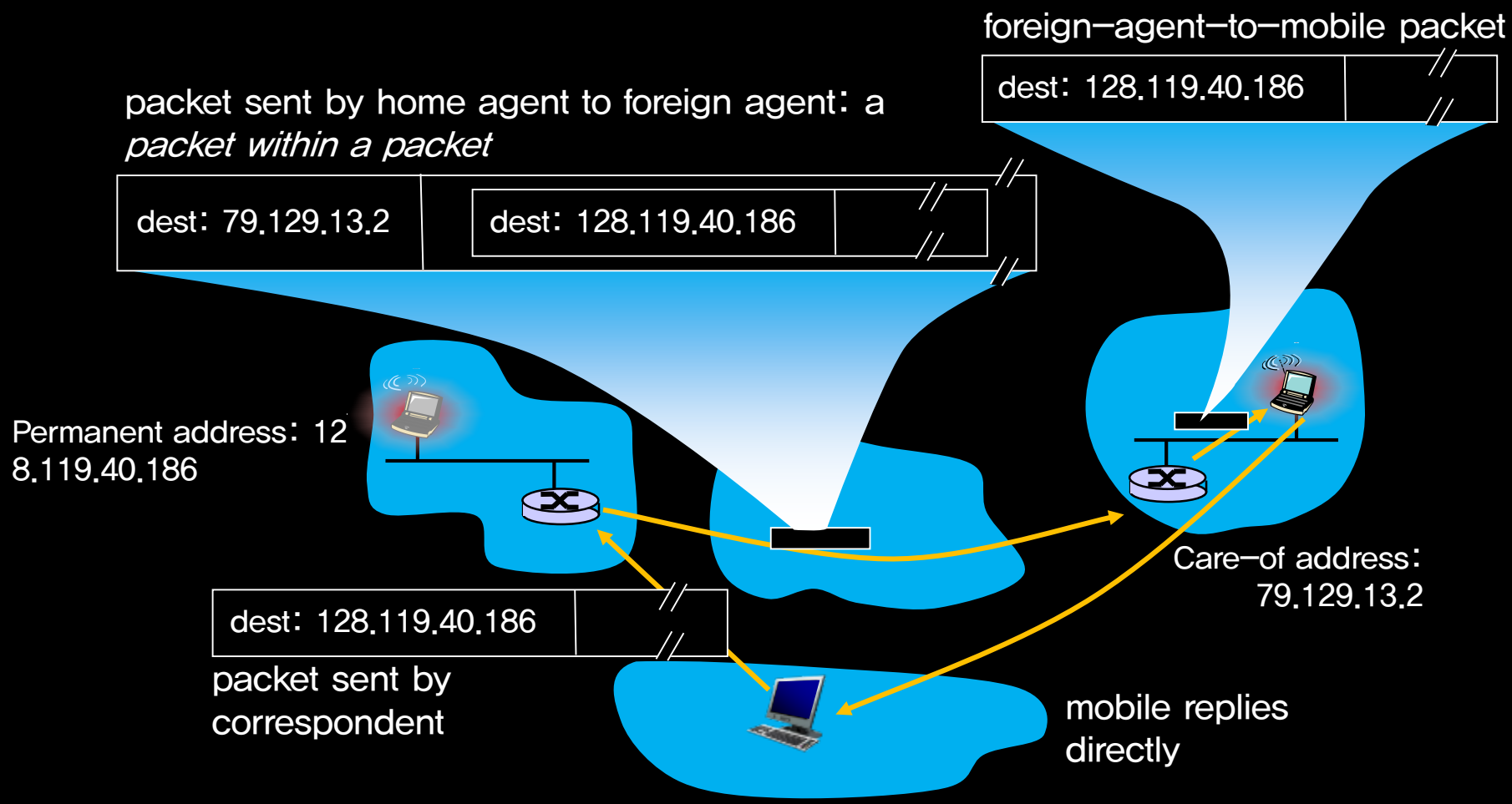


Mobile IP: Registration

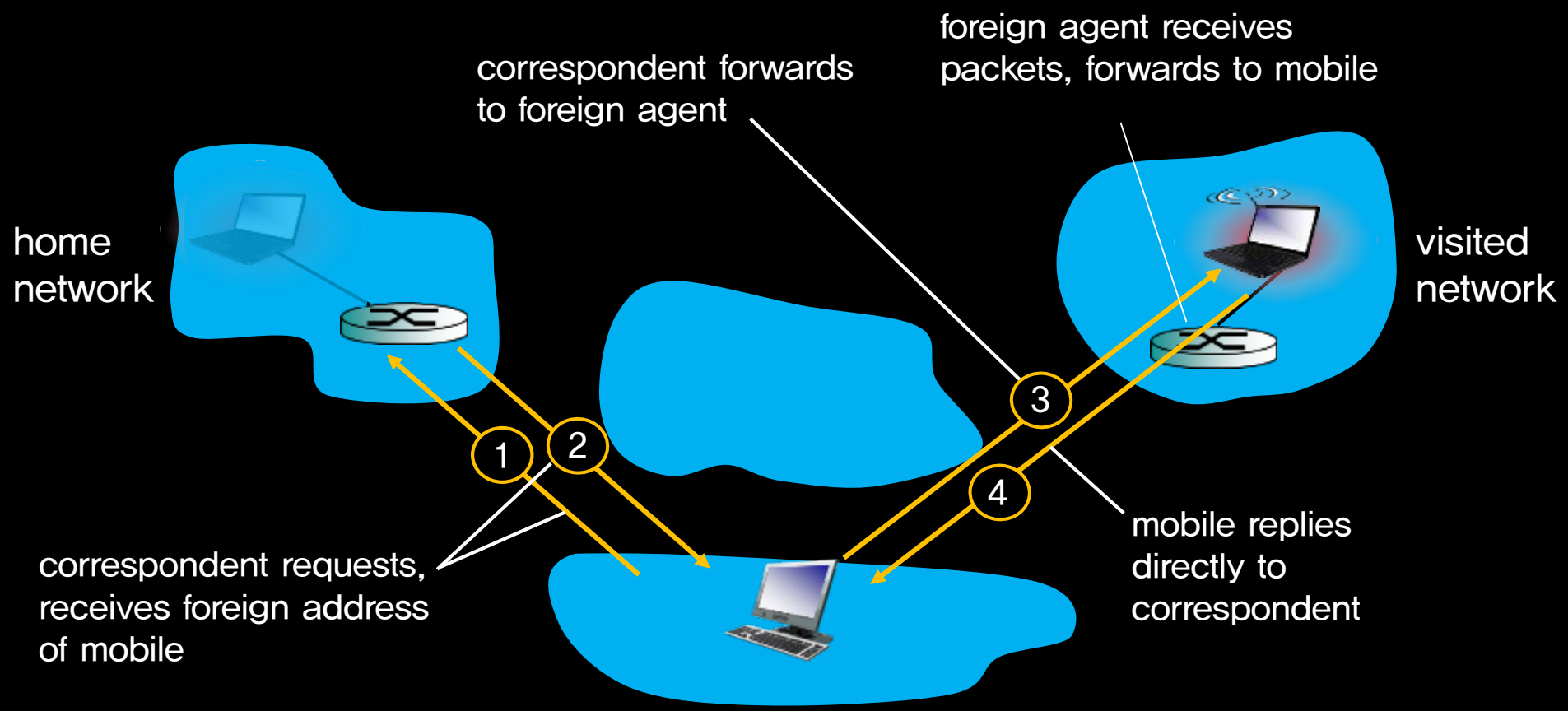


- End result:
  - foreign agent knows about mobile
  - home agent knows location of mobile

Mobile IP: Indirect Routing



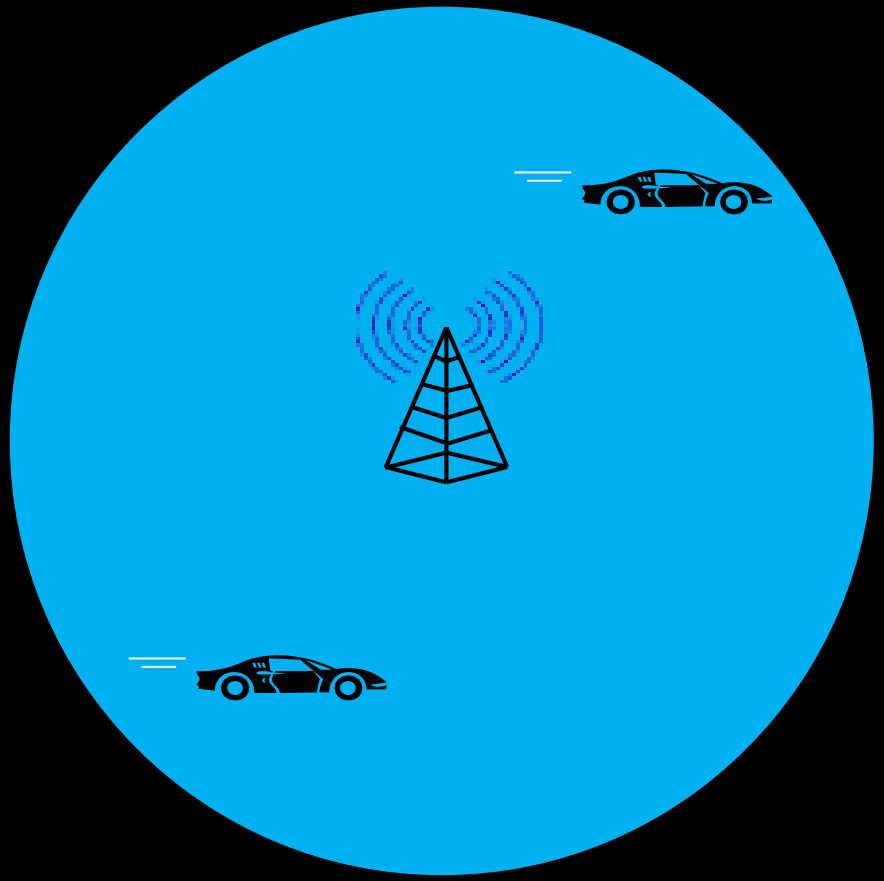
Mobility via Direct Routing



- overcome triangle routing problem
- non–transparent to correspondent: correspondent must get care–of–address from home agent

03. Cellular Network Principles

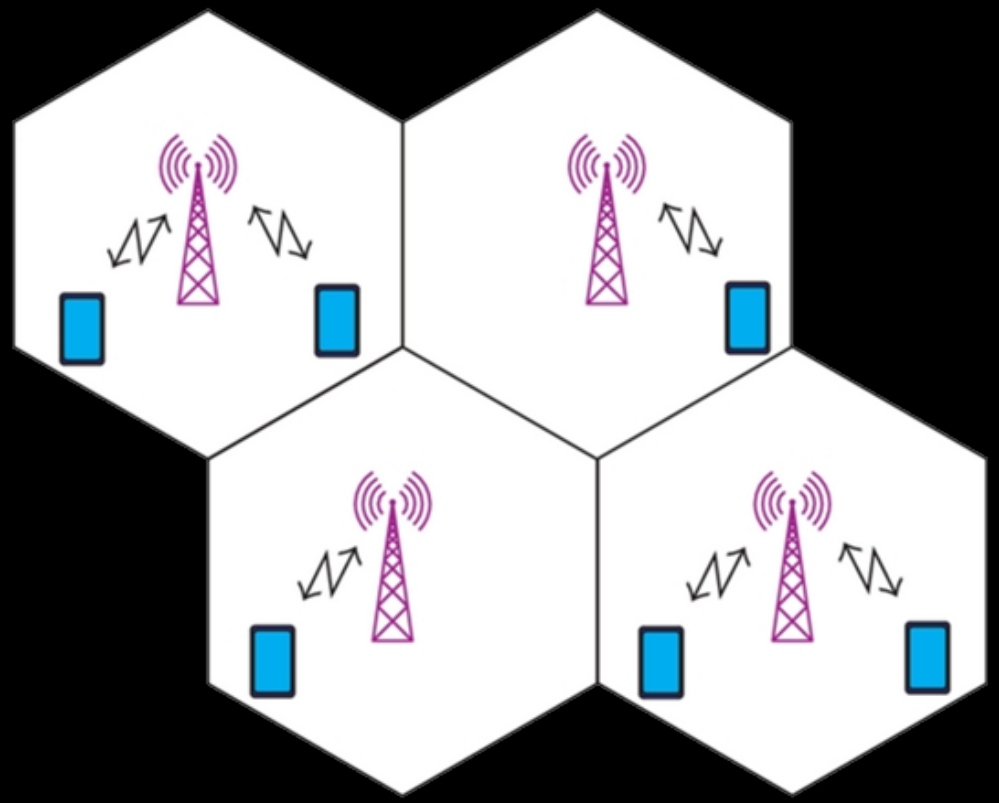
Cellular Network Topology



- Prior to cellular radio
  - mobile service provided by high powered transceivers whose effective range is about 80 km
  - typically 25 channels available

Only 25 users can be serviced at the same time within the area of which radius is 80 km

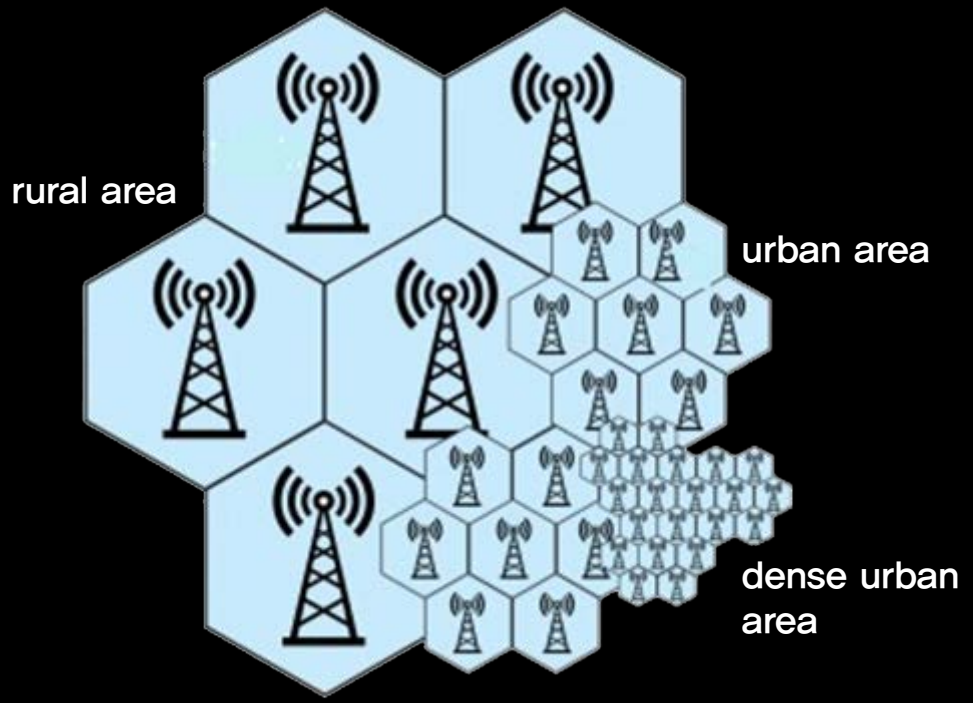
Cellular Network Topology



출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiDgdmKhNjcAhXEVbwKHSe-DegQjRx6BAgBEAU&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FConventional-cellular-network-with-fixed-infrastructure-a-and-mobile-ad-hoc-network_fig4_277930076&psig=AOvVaw1XIVKsPZdd1uQqBKuDBgSZ&ust=1533631196056726

- Cell: area covered by one base station
- Goal of cell
  - to increase the available capacity for mobile service
- In theory, 25 users can be serviced per cell thanks to frequency reuse
  - precise control on signal strength is needed not to interfere neighbor cells

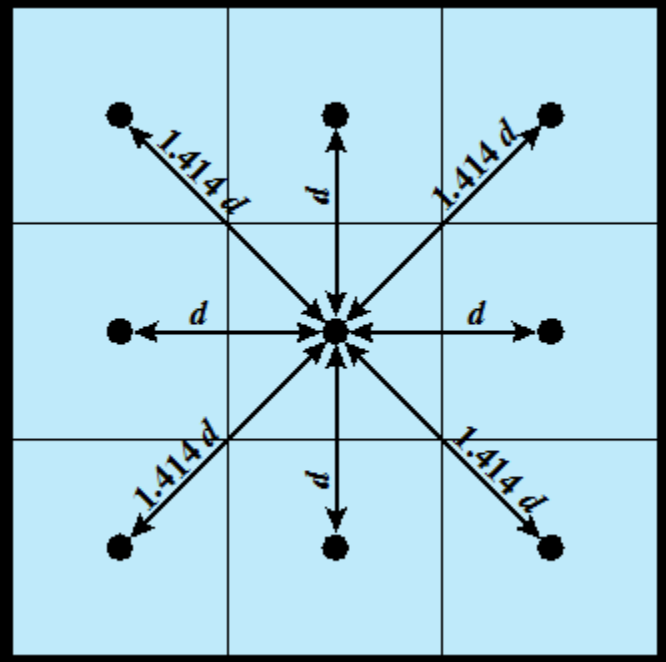
Cell Size



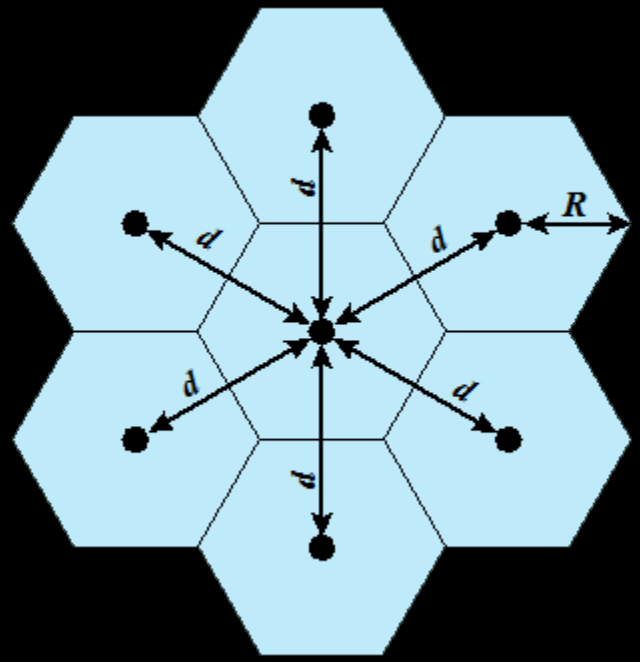
출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiJntnng9jcAhXlV7wKHZAsCEcQjRx6BAgBEAU&url=https%3A%2F%2Fwww.tnuda.org.il%2Fen%2Fphysics-radiation%2Fradio-frequency-rf-radiation%2Fcellular-communication-network-technologies&psig=AOvVaw1XlVKsPZdd1uQqBKuDBgSZ&ust=1533631196056726

- Cell size can be determined according to the trade-off relation between deployment cost and frequency reusability

Cellular Geometry



(a) Square pattern



(b) Hexagonal pattern

출처 – William Stallings, "Data and Computer Communications," 10th Edition, Pearson Education

- In the hexagonal pattern, distances between all pairs of antennas are equivalent

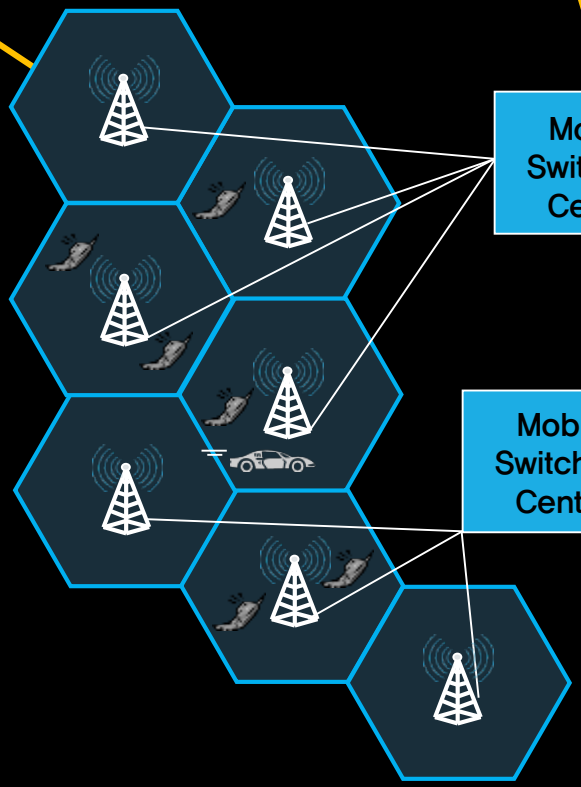
Cellular Network Architecture

MSC

- connects cells to wired tel. net.
- manages call setup (more later!)
- handles mobility (more later!)

cell

- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS



Mobile Switching Center

Mobile Switching Center

Public telephone network

wired network

04. Cellular Network History

Evolution of Cellular Network

1G	2G	3G	4G	5G
1981	1992	2001	2010	2020(?)
2 Kbps	64 Kbps	2 Mbps	100 Mbps	10 Gbps
Basic voice service using analog protocols	Designed primarily for voice using the digital standards (GSM/CDMA)	First mobile broadband utilizing IP protocols (WCDMA / CDMA2000)	True mobile broadband on a unified standard (LTE)	'Tactile Internet' with service-aware devices and fiber-like speeds
				?

출처 – https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjMr-6QldjcAhUW8rwKHU1qAsYQjRx6BAgBEAU&url=https%3A%2F%2Fwww.marketstrategies.com%2Fblog%2F2015%2F03%2Fgimme-5-what-to-expect-from-5g-wireless-networks%2F&psig=AOvVaw11XpqRt9L_8ToWxSeLkUfv&ust=1533635487563417

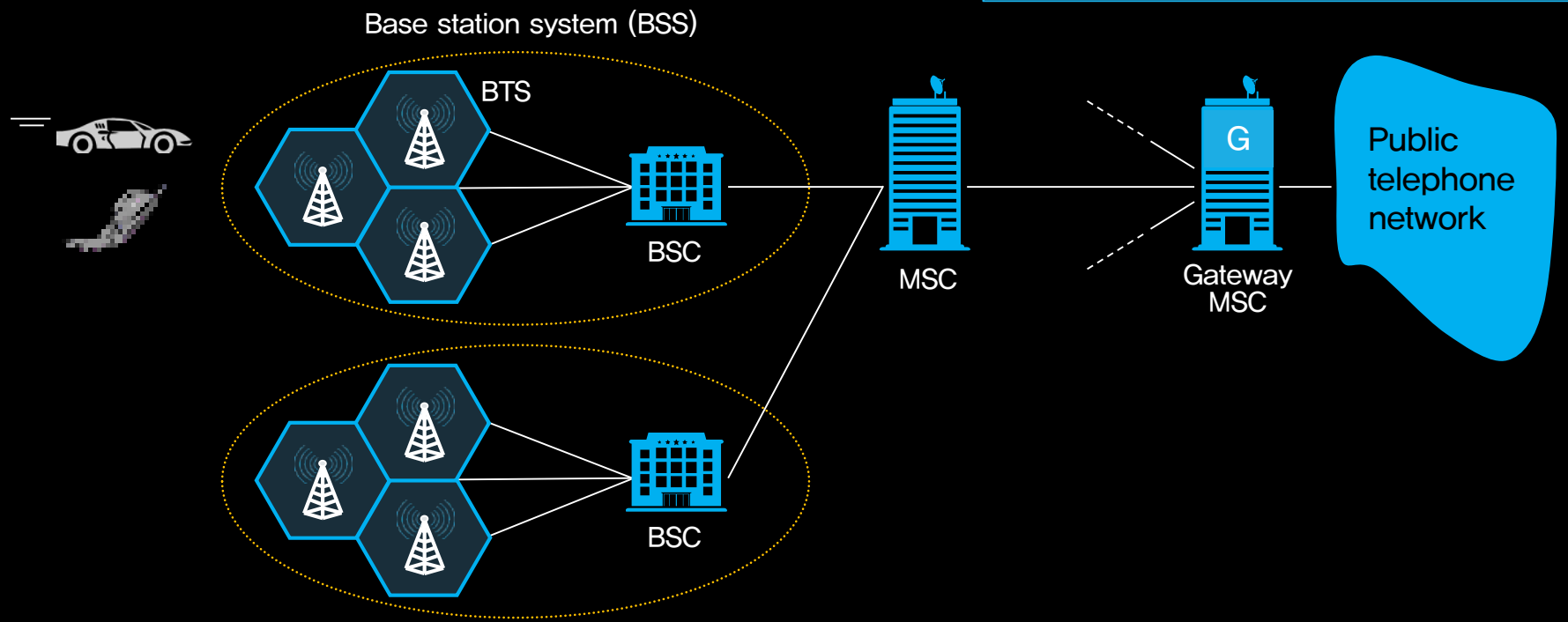
First Generation (1G)

- Focused on voice
- Analog communication
- Speed up to 2.4 Kbps
- Advanced Mobile Phone Service (AMPS) developed by AT&T

출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjl3IrPmdrcAhUlfLwKHVBuCPIQjRx6BAgBEAU&url=http%3A%2F%2Fdrmoazzam.com%2Fdevelopment-of-first-generation-mobile-communication-systems%2F&psig=AOvVaw2jEfkEIr4AE0BUvUOhGtNu&ust=1533705612098491

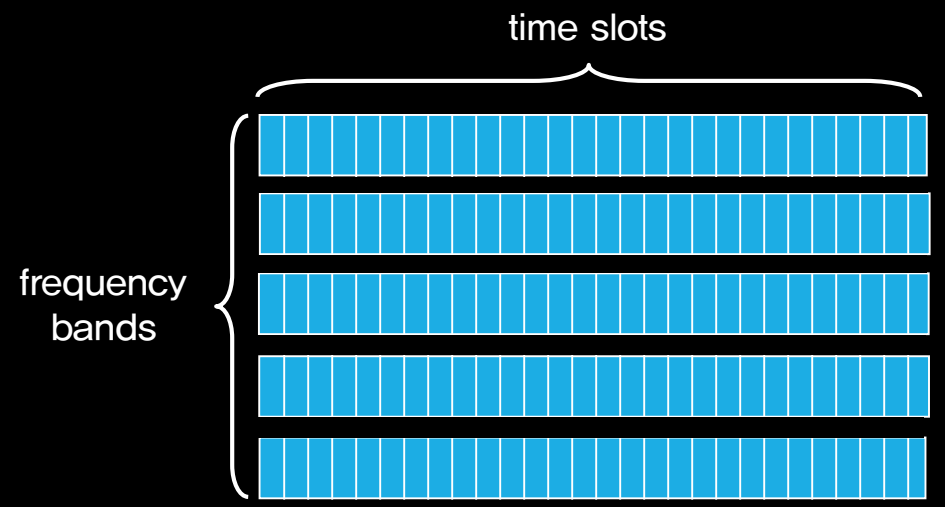
Second Generation (2G)

- Digital standards
  - GSM = FDMA + TDMA
  - CDMA



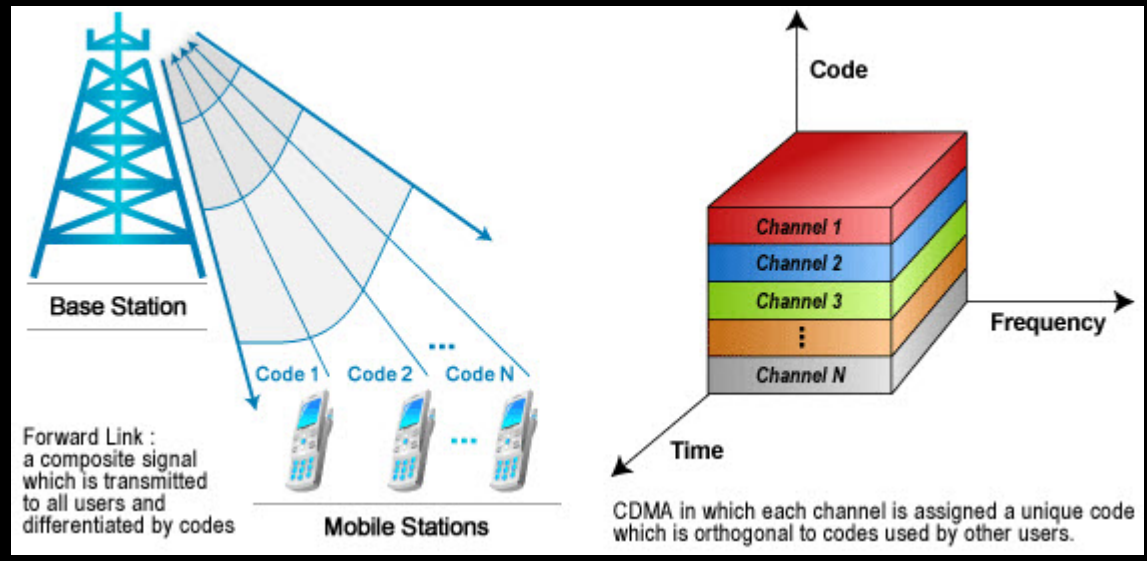
GSM (Global System for Mobile Communications)

- Combined FDMA/TDMA: divide spectrum in frequency channels, divide each channel into time slots



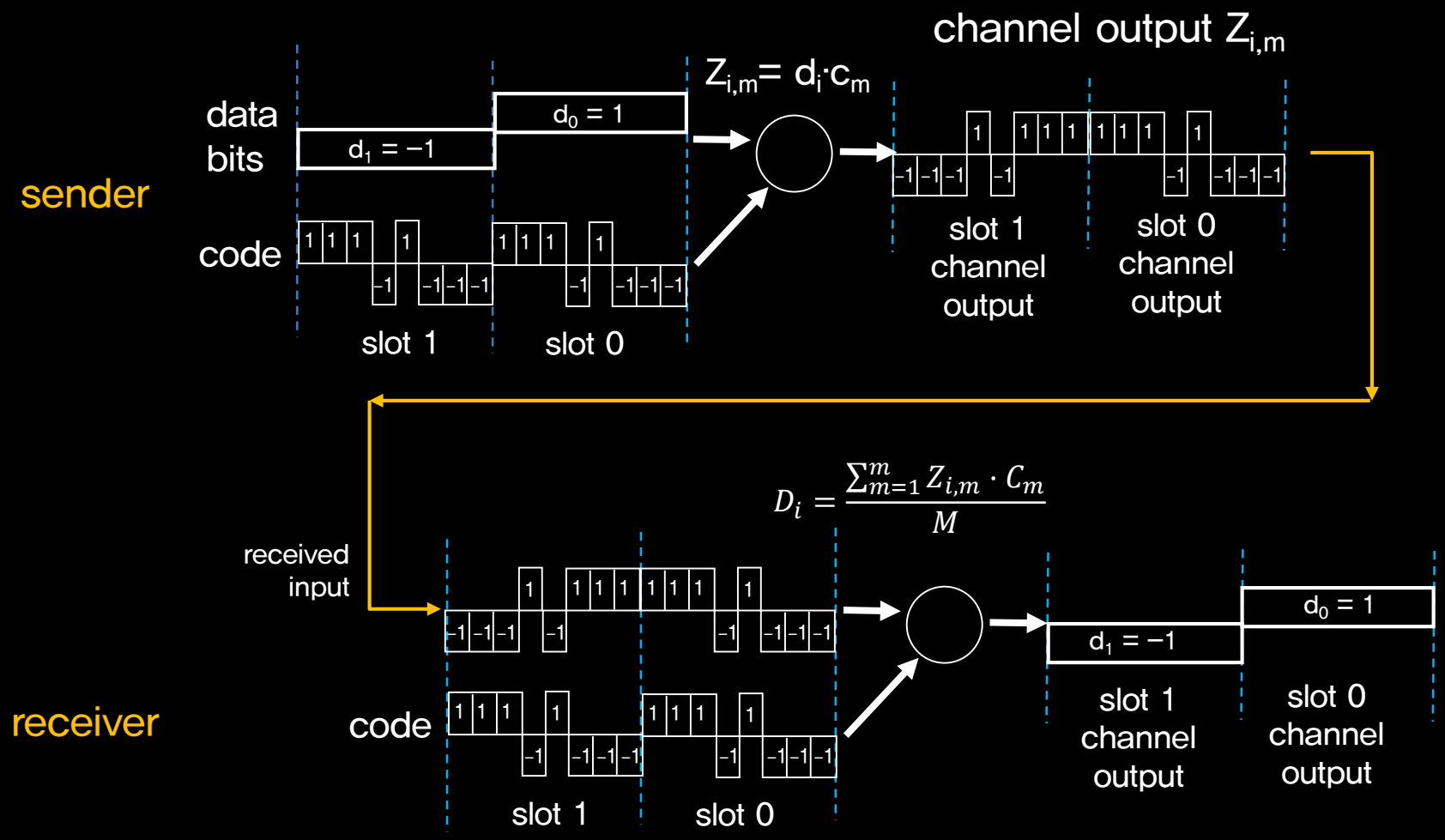
CDMA (Code Division Multiple Access)

- Unique “code” assigned to each user; i.e., code set partitioning
  - all users share same frequency, but each user has own “chipping” sequence (i.e., code) to encode data
- Encoded signal = (original data) X (chipping sequence)
- Decoding: inner-product of encoded signal and chipping sequence

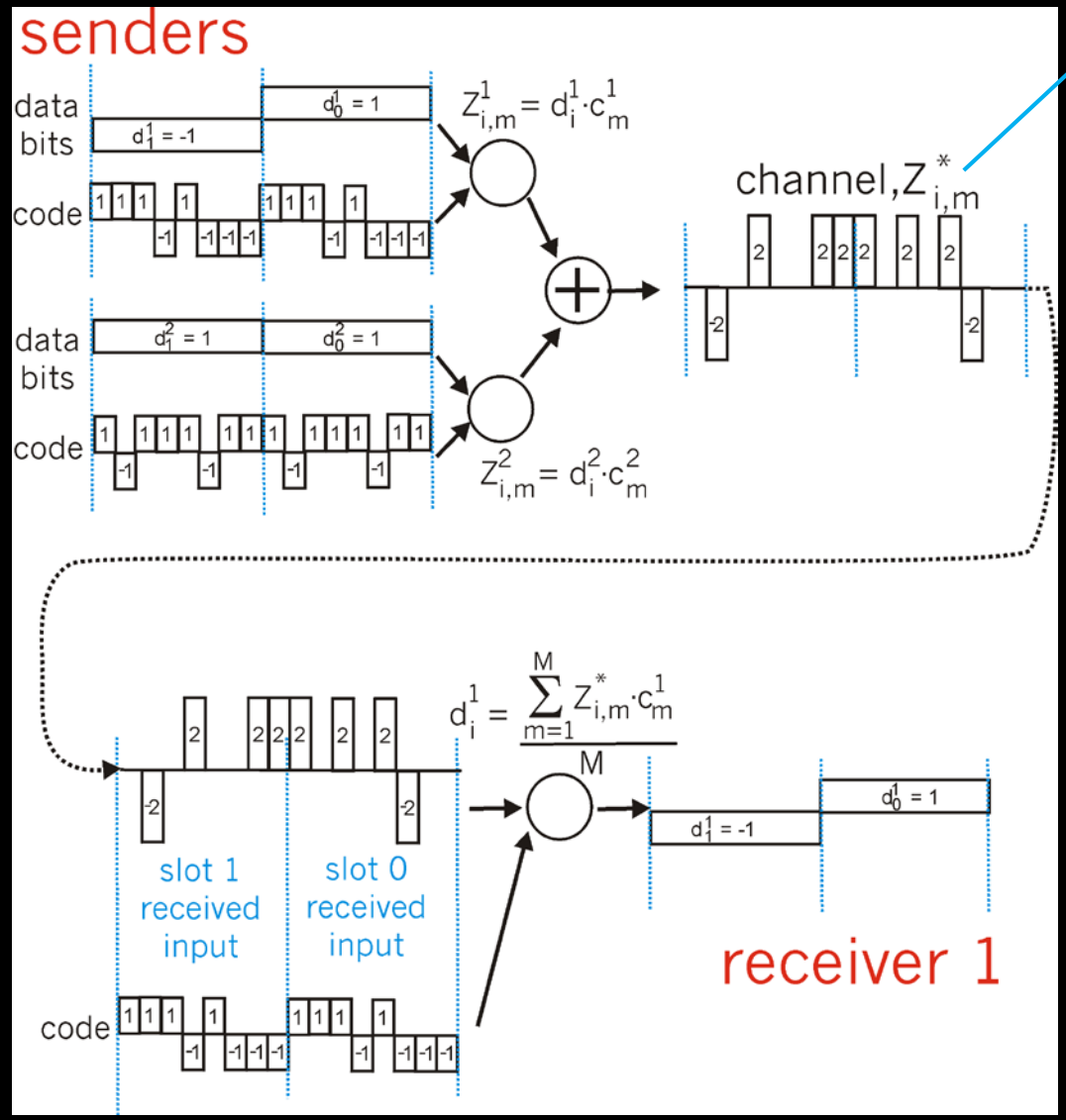


출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjurImOtcbcAhULa94KHd2KDpoQjRx6BAgBEAU&url=https%3A%2F%2Fwww.elprocus.com%2Fcdma-technology-working-applications%2F&psig=AOvVaw2xbSa4_gaotOX16MNQC759&ust=1533025949356844

CDMA Encode/Decode



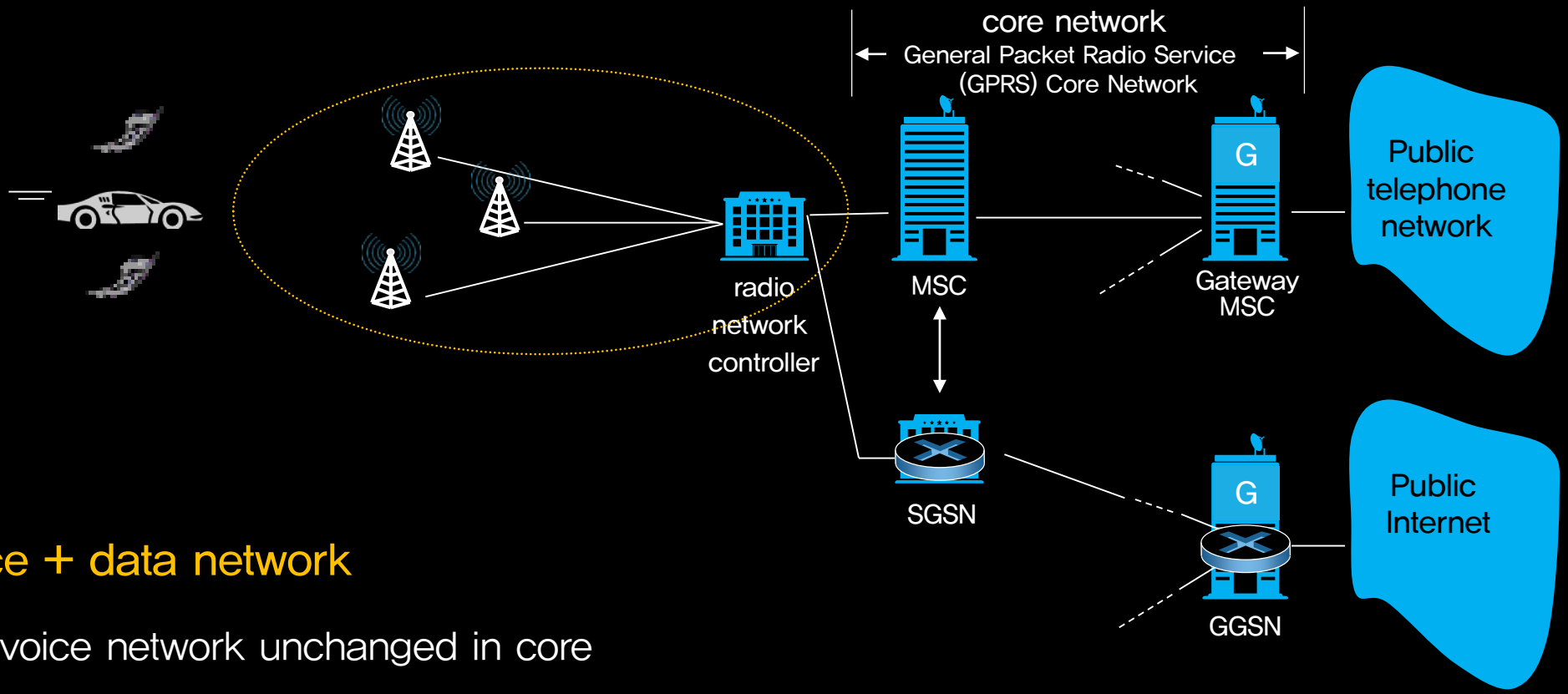
CDMA: Two-Sender Case



channel sums together transmissions by sender 1 and 2

using same code as sender 1, receiver recovers sender 1's original data from summed channel data!

Third Generation (3G)



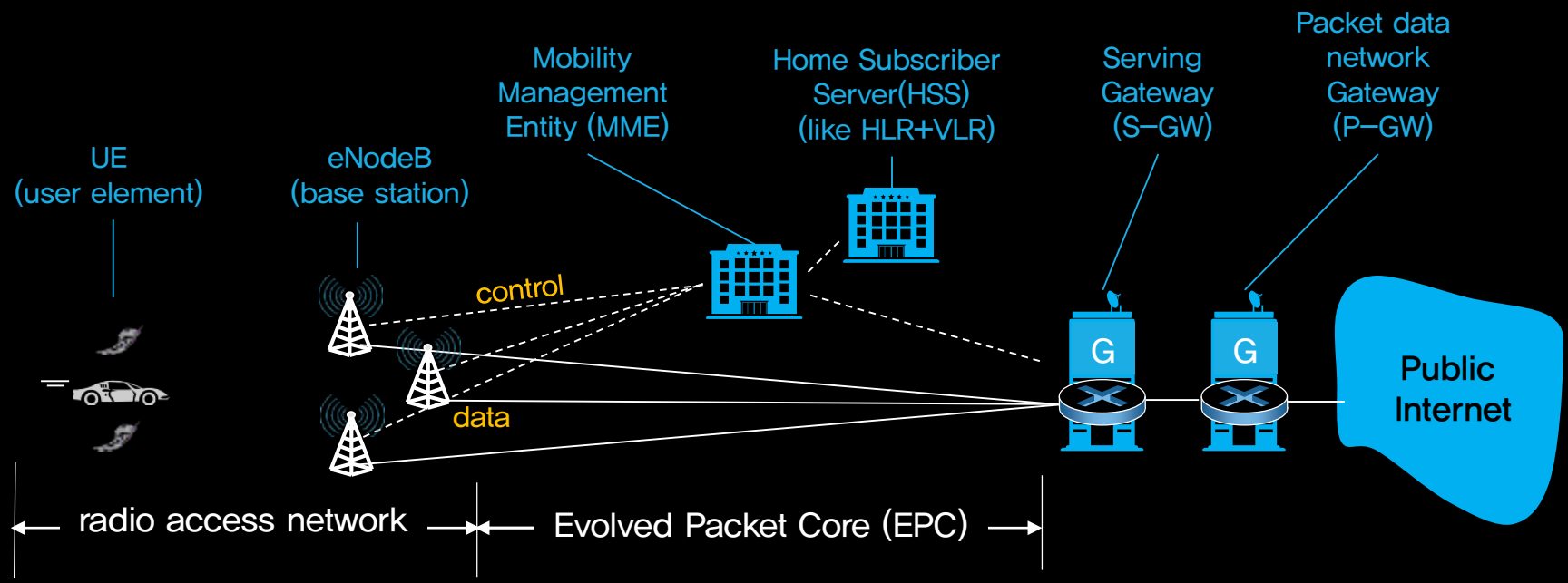
- Voice + data network
  - voice network unchanged in core
  - data network operates in parallel

Serving GPRS Support Node (SGSN)

Gateway GPRS Support Node (GGSN)

Fourth Generation (4G)

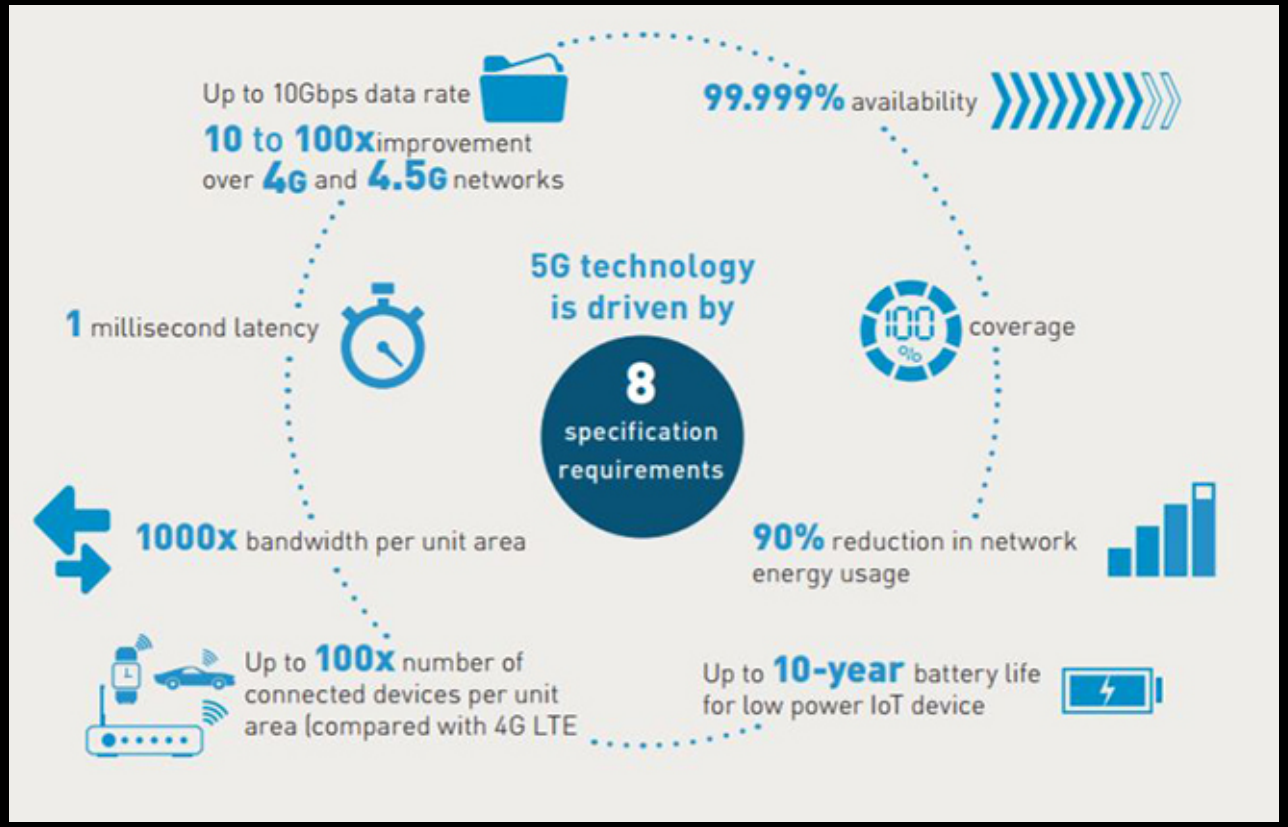
- Base technology candidates: LTE (Long Term Evolution) or WiMAX
- Differences from 3G
  - all IP core: IP packets tunneled (through core IP network) from base station to gateway
  - no separation between voice and data – all traffic carried over IP core to gateway



05. 5G Network

Fifth Generation (5G)

- Requirements for 5G network
  - area traffic capacity
  - peak data rate (10 Gbps)
  - user experienced data rate (100 Mbps)
  - 5th percentile user spectral efficiency
  - transmission latency (〈 1ms)
  - energy efficiency
  - mobility (up to 500 km/h)
  - handover interruption time (〈 10 ms)

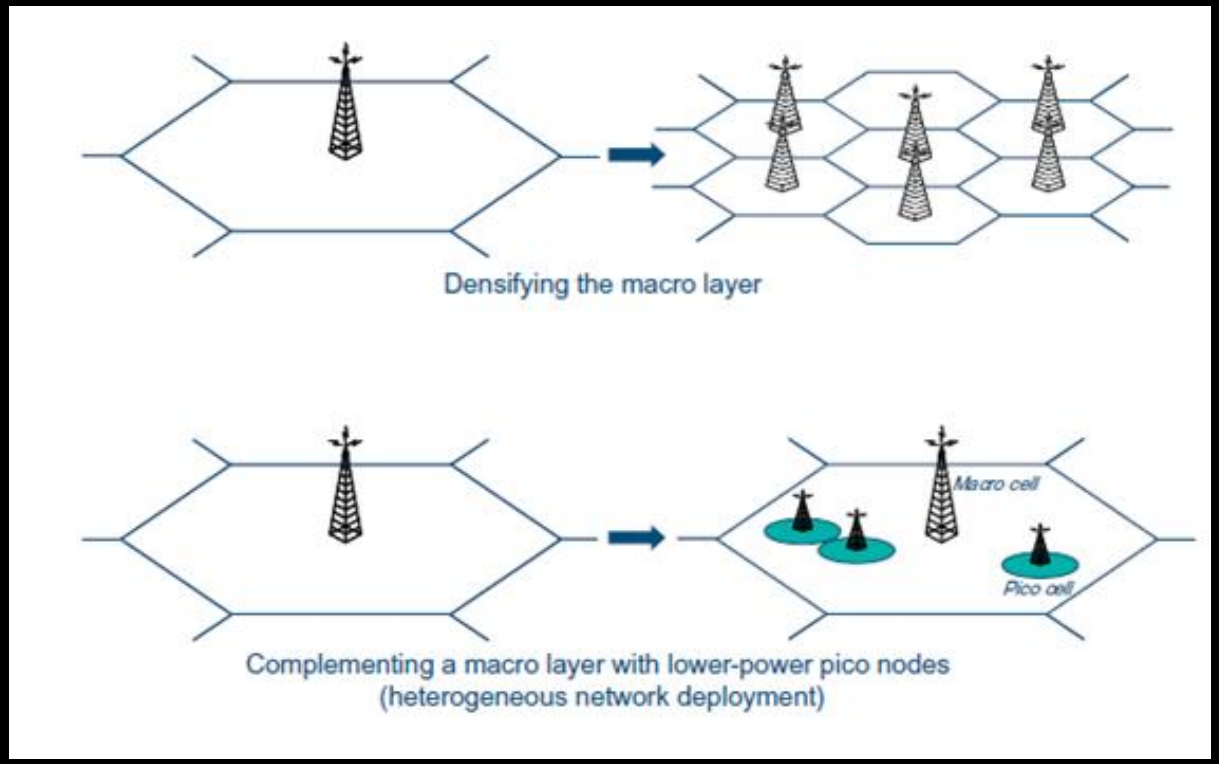


출처 – https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwj2-7f0rdrcAhUBUrwKHXs5BFQQjRx6BAgBEAU&url=https%3A%2F%2Fwww.gemalto.com%2F5g&psig=AOvVaw27Gp3YGlpTxGqjCulaEKQw&ust=1533711208595342

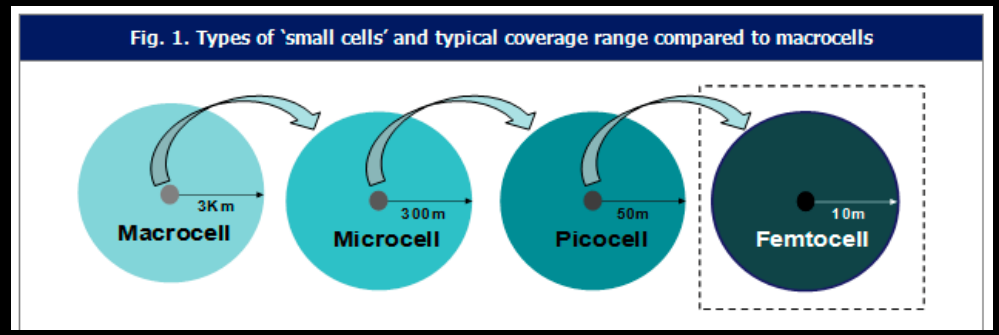
Key Technologies #1: Extremely Dense Cells

Tech. 1: Extremely dense cellular architecture and offloading

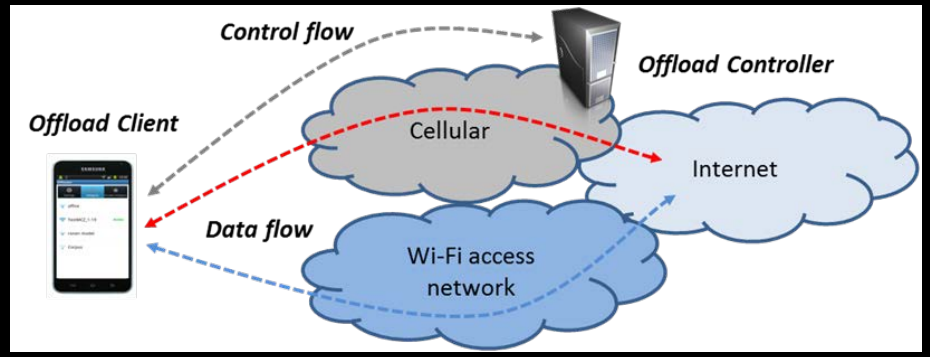
- Extreme densification and offloading to improve the area spectral efficiency. Put differently, more active nodes per unit area and Hz.



출처 – https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwi9-5zxidjcAhUPOrwKHampAvoQjRx6BAgBEAU&url=http%3A%2F%2Ftrends-in-telecoms.blogspot.com%2F2011%2F06%2Flte-network-densification-with.html&psig=AOvVaw1E0kuydPFoyhtAksu3rBsA&ust=1533632799470994



□□ –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjfzpixs9rcAhWlyrwKHTXqBgUQjRx6BAgBEAU&url=http%3A%2F%2Fjson.tv%2Fen%2Fict_telecom_analytics_view%2Ftendencies-and-perspectives-of-market-development-of-picocells-in-russia-and-in-the-world-20140905051232 19&psig=AOvVaw1MpGkDKFLo0ZN-nmMLw1td&ust=1533712753741075



□□ –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwj44sXps9rcAhWBUrwKHcqfCMUQjRx6BAgBEAU&url=http%3A%2F%2Fwww.ctimes.com.tw%2FDispNews%2Ftw%2FWi-Fi-offload%2FWi-Fi-Passpoint%2F1303072349GJ.shtml&psig=AOvVaw1XbfCjoD9TP7ucvDVISV0R&ust=1533712843896454

Key Technologies #2: Extremely High Frequency

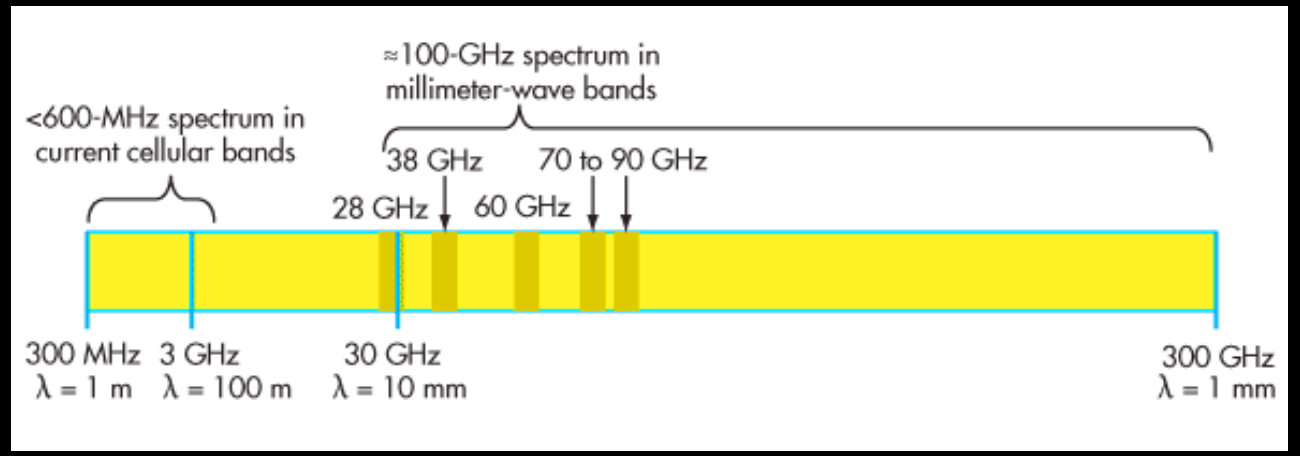
Tech. 2: Extremely higher carrier frequency spectrum

- Increased bandwidth, primarily by moving toward and into mmWave spectrum but also by making better use of WiFi's unlicensed spectrum in the 5–GHz band. Altogether, more Hz.

Beachfront frequency
Crowed

VS

mmWave frequency
Extensive

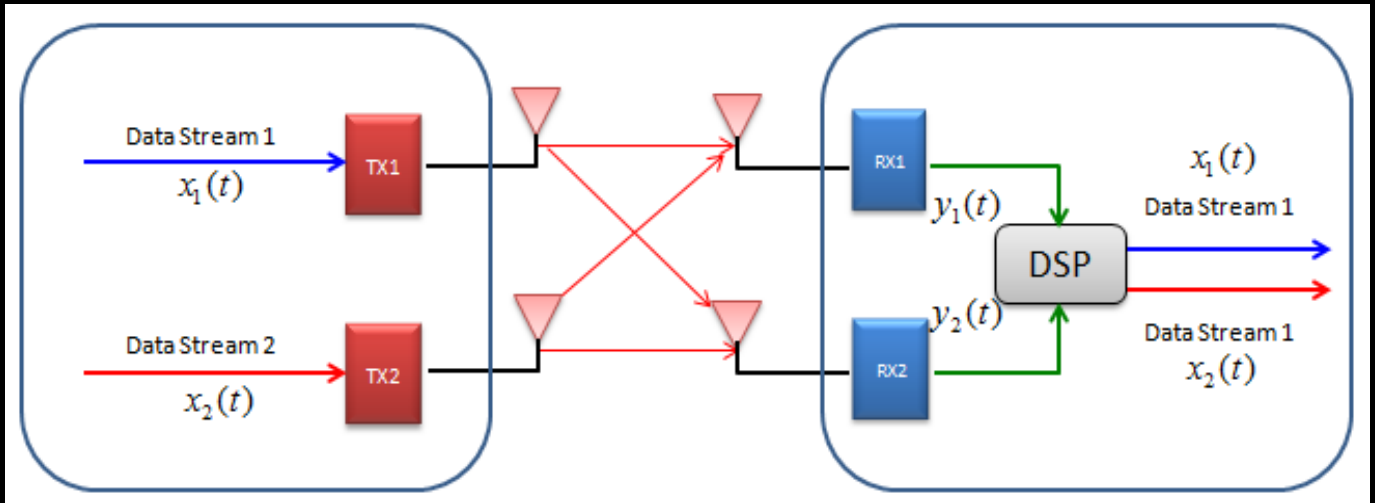


출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwjR17edtdrcAhULvLwKHTPlDwEQjRx6BAgBEAU&url=https%3A%2F%2Fblog.advaoptical.com%2Fis-wireless-the-new-fixed-mmwave-gains-momentum&psig=AOvVaw22bTW74lS8JC1clSfLVO-H&ust=1533713186980337

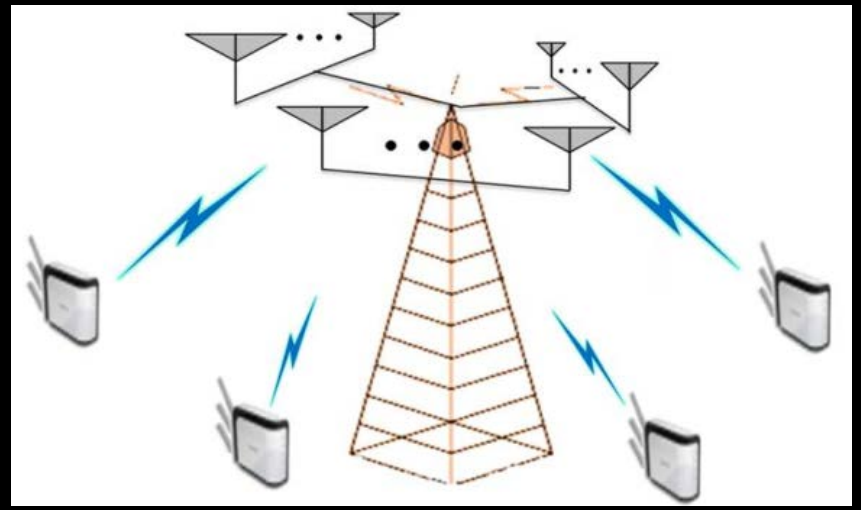
Key Technologies #3: Massive MIMO Antenna

Tech. 3: Large number of antennas

- Increased spectral efficiency, primarily through advances in MIMO, to support more bits/s/Hz per node



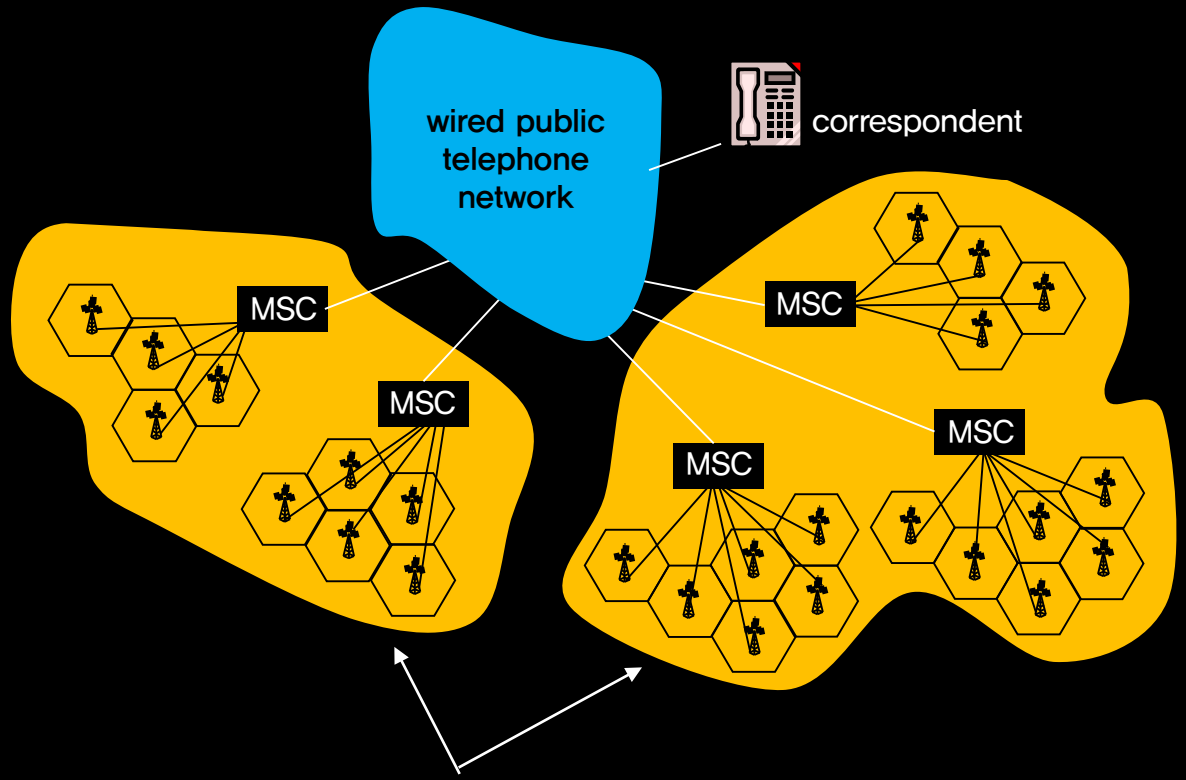
□ □ –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwixrlerttrcAhXDErwKHXztBKQQjRx6BAgBEAU&url=http%3A%2F%2Fwww.sharetechnote.com%2Fhtml%2FBasicProcedure_LTE_MIMO.html&psig=AOvVaw1G5UnVsqnqMth_HGbZzc4U&ust=1533713412042236



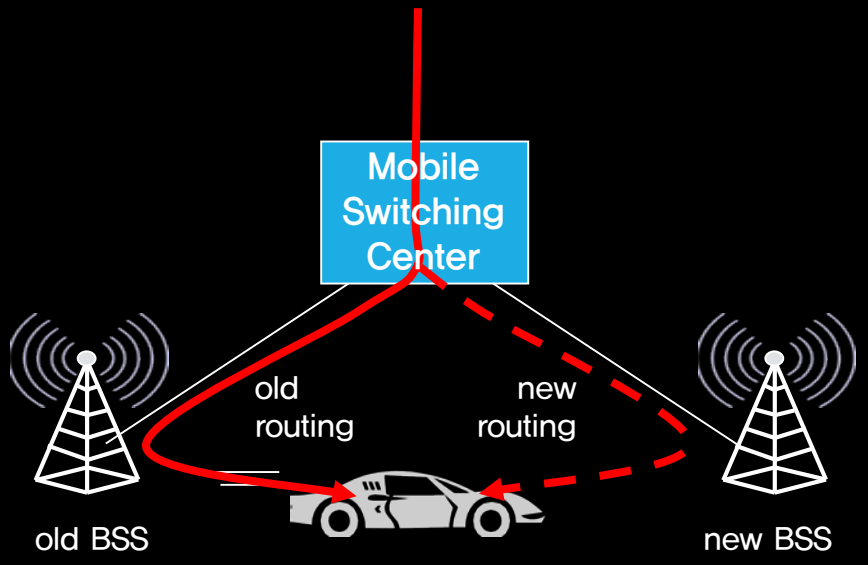
출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwilp-DttdrcAhVlvLwKHVdsCqMQjRx6BAgBEAU&url=http%3A%2F%2Faclab.yonsei.ac.kr%2Fmenu4_4.html&psig=AOvVaw1G5UnVsqnqMth_HGbZzc4U&ust=1533713412042236

06. Handoff in Cellular Network

Components of Cellular Network

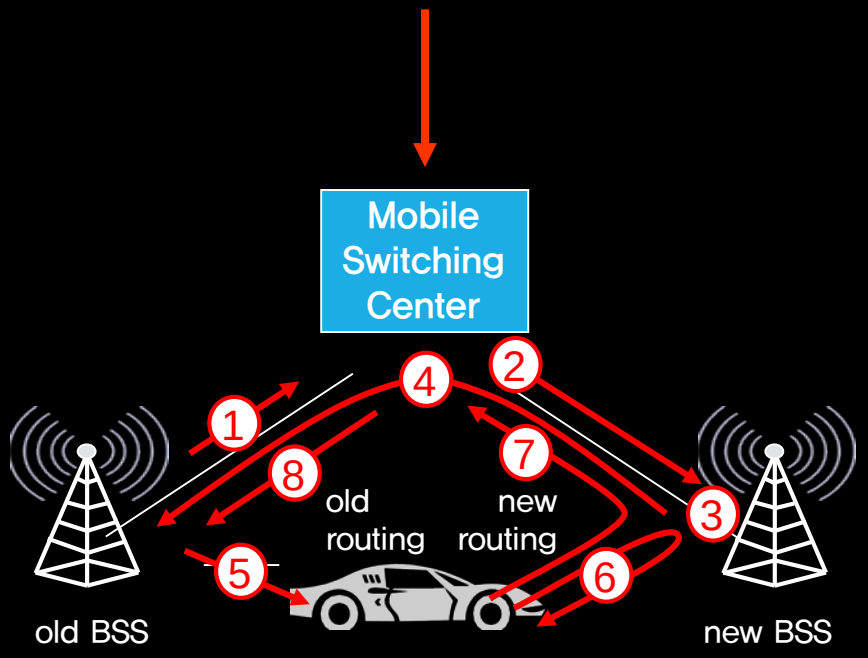


GSM: Handoff with Common MSC



- Handoff goal: route call via new base station (without interruption)
- Reasons for handoff:
  - stronger signal to/from new BSS (continuing connectivity, less battery drain)
  - load balance: free up channel in current BSS
- Handoff initiated by old BSS

GSM: Handoff with Common MSC



① Old BSS informs MSC of impending handoff, provides list of 1+ new BSSs

② MSC sets up path (allocates resources) to new BSS

③ New BSS allocates radio channel for use by mobile

④ New BSS signals MSC, old BSS: ready

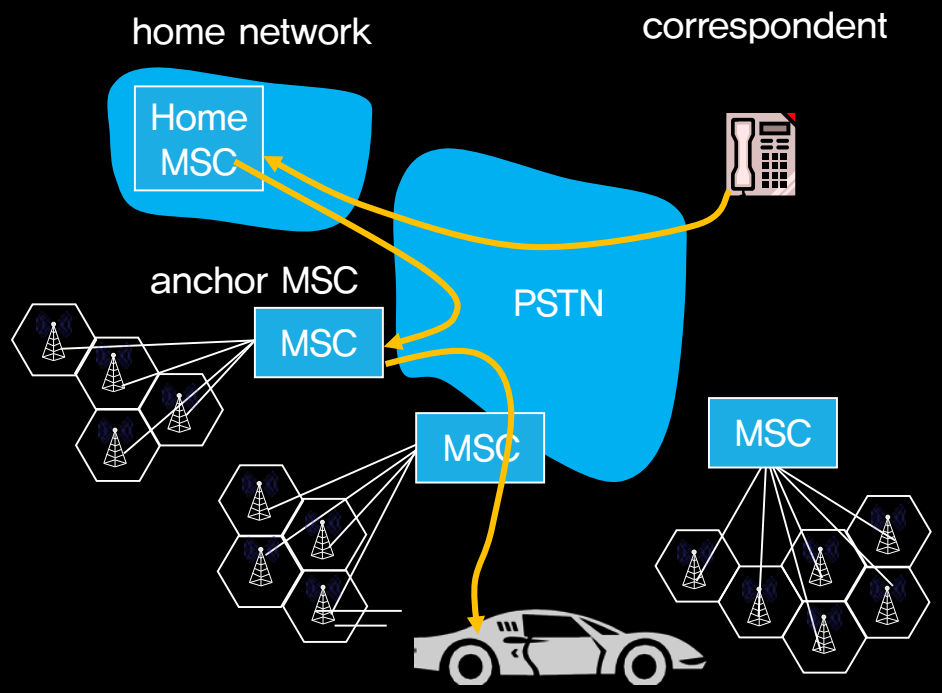
⑤ Old BSS tells mobile: perform handoff to new BSS

⑥ Mobile, new BSS signal to activate new channel

⑦ Mobile signals via new BSS to MSC: handoff complete. MSC reroutes call

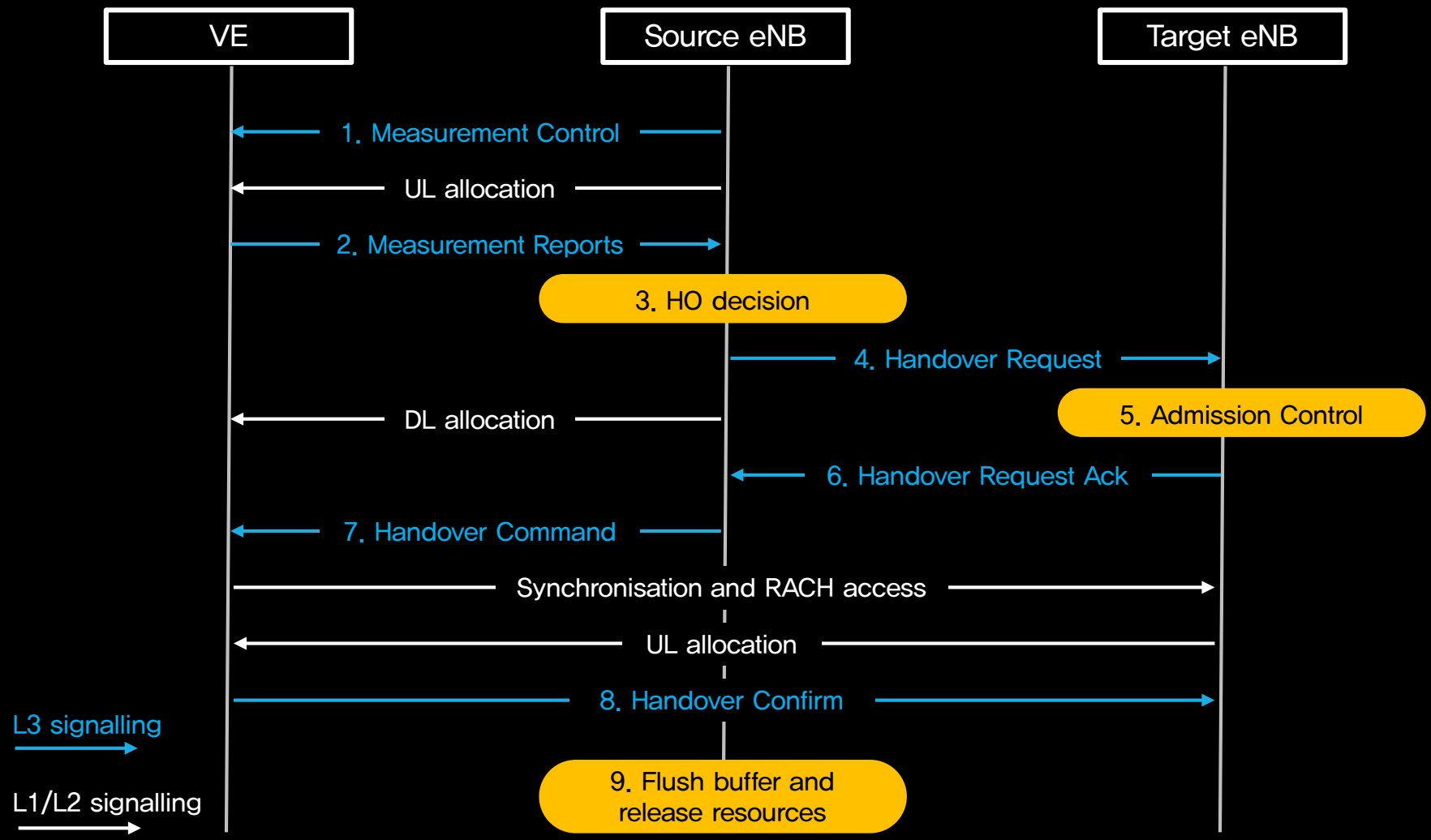
⑧ MSC–old–BSS resources released

GSM: Handoff between MSCs



- Anchor MSC: first MSC visited during call
  - call remains routed through anchor MSC
- New MSCs add on to end of MSC chain as mobile moves to new MSC

Handoff in LTE



출처 –
https://www.google.co.kr/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwiT5qad3NrcAhUH8LwKHa30C80QjRx6BAgBEAU&url=https%3A%2F%2Fwww.semanticscholar.org%2Fpaper%2FHandover-within-3GPP-LTE%253A-Design-Principles-and-Dimou-Wang%2F9d6ccb3e52894240b904585d8fd3a9e34295e831&psig=AOvVaw2B4adwHXHt6vlFyZ3tyWmE&ust=1533722834417981

Summary

Summary (1/2)

01

Mobile Network

- mobile service growth
- mobility vs. wireless

02

Mobile IP

- home agent, foreign agent
- agent advertisement, registration, indirect routing

03

Cellular Network Principles

- increase network capacity by dividing area into cells
- frequency reusability

04

Cellular Network History

- CDMA (Code Division Multiple Access)
- 4G LTE: all IP core

Summary (2/2)

05 **5G Network**

- 10 Gbps PDR, 100 Mbps data rate per user, 1 ms latency
- ultra dense cell, mmWave, massive MIMO

06 **Handoff in Cellular Network**

- maintaining the connection of UEs moving across cells
- handoff in GSM and LTE