

Cellular and Mobile Wireless Networks



Advanced Computer Networks

Cellular/Mobile Wireless Outline

- Cellular Architecture
- Cellular Standards
 - GSM, 2G, 2.5G, 3G and 4G LTE
- Mobile Definitions
 - Agents, addresses, correspondent
- Mobile Architecture
 - Registering
 - Indirect Routing
 - Direct Routing

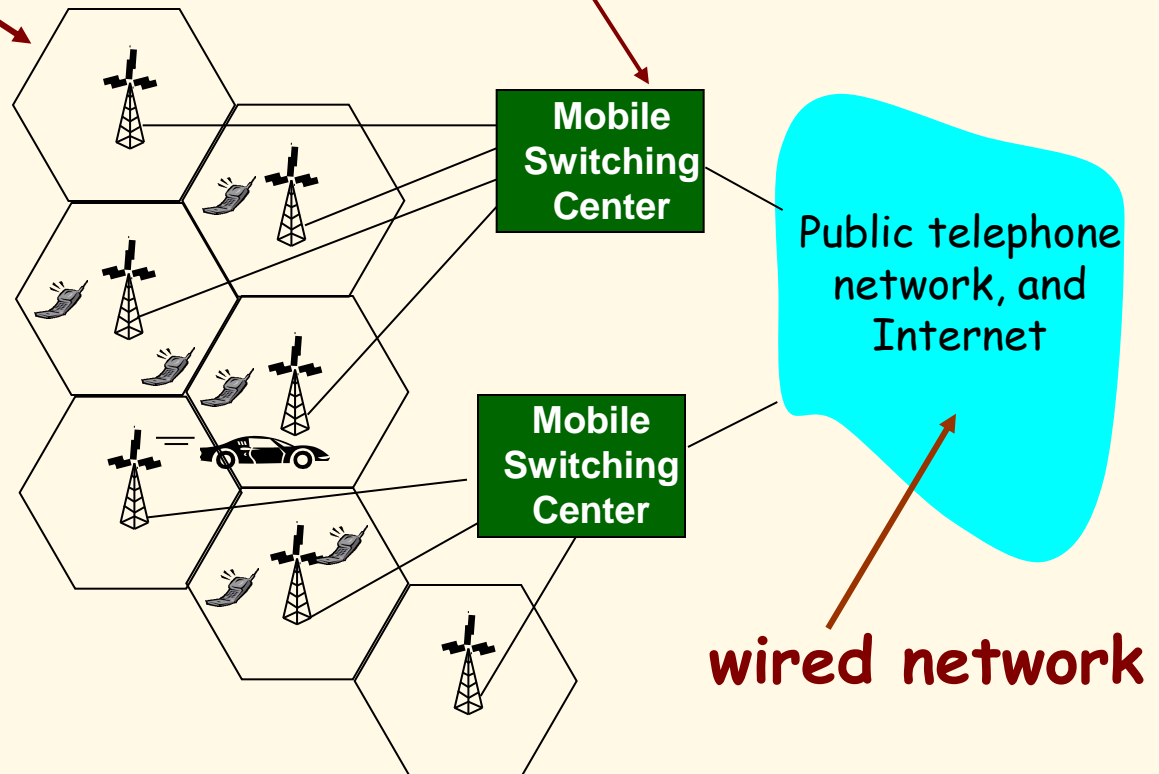
Cellular Network Architecture

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

MSC

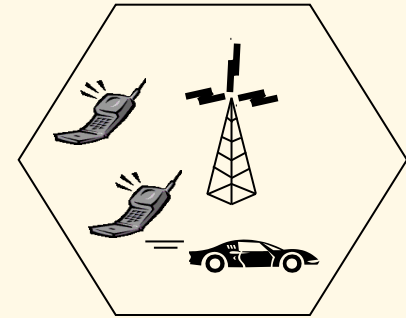
- connects cells to wide area net
- manages call setup
- handles mobility



Cellular Networks: The First Hop

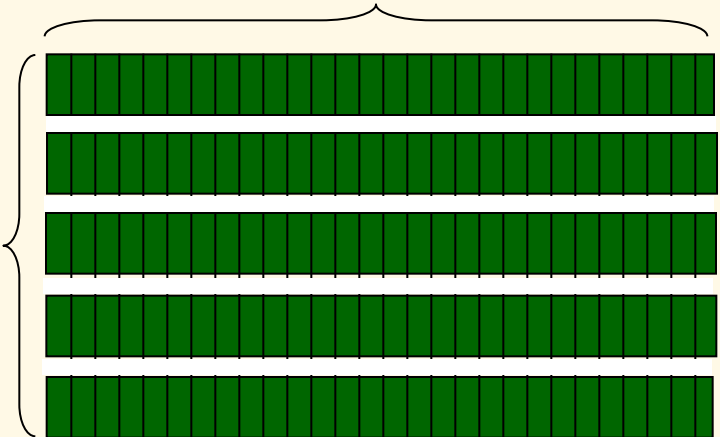
Two techniques for sharing mobile-to-BS radio spectrum:

- **combined FDM/TDM**: divide spectrum in frequency channels, divide each channel into time slots.
- **CDMA**: Code Division Multiple Access
- **Global System for Mobile Communications (GSM)**:
 - 200 kHz frequency bands
 - Each band supports 8 TDM calls.
 - Speech encoded at 12.2 and 13 kbps.



time slots

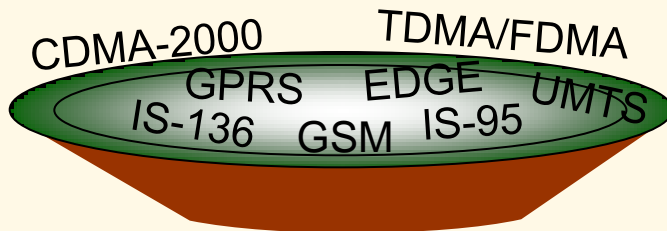
frequency bands



Cellular Standards: Brief Survey

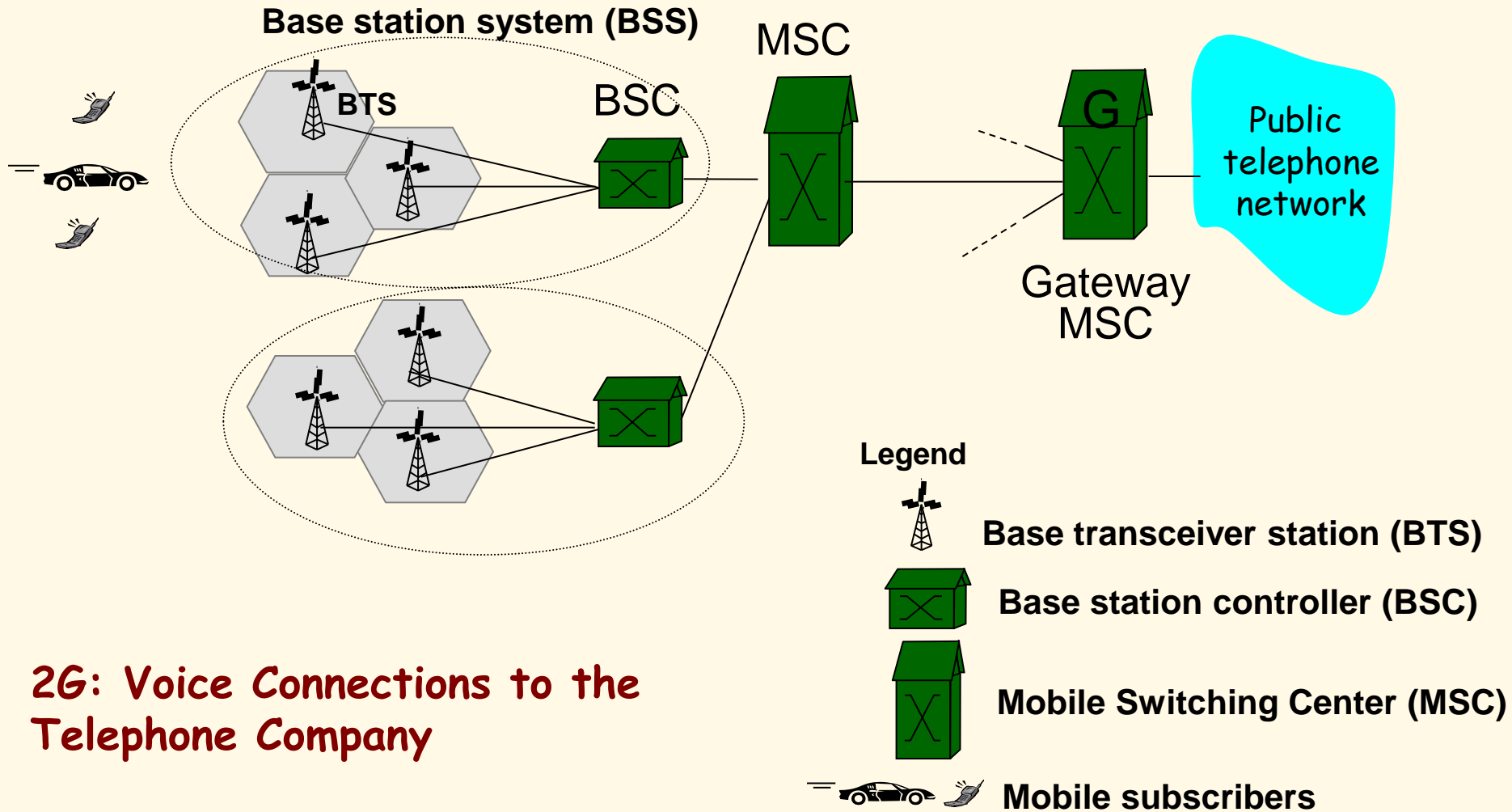
2G Systems: voice channels/digital technology

- IS-136 TDMA: combined FDM/TDM (North America)
- GSM (Global System for Mobile Communications): combined FDM/TDM
 - most widely deployed **
- IS-95 CDMA: Code Division Multiple Access



Don't drown in a bowl
of alphabet soup: use this
for reference only

2G Network Architecture



Cellular Standards: 2.5G

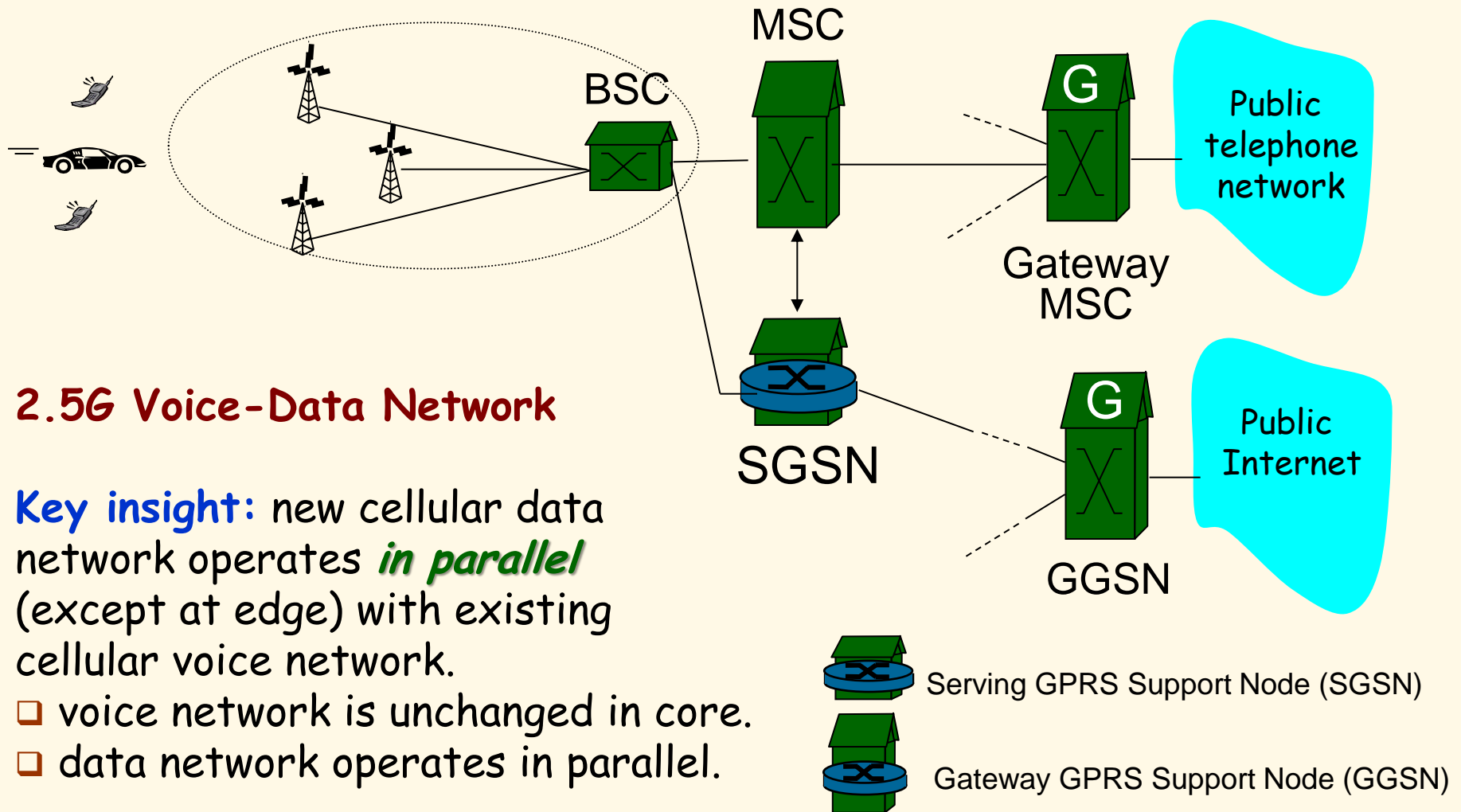
2.5G systems: voice and data channels

{For those who could not wait for 3G service}

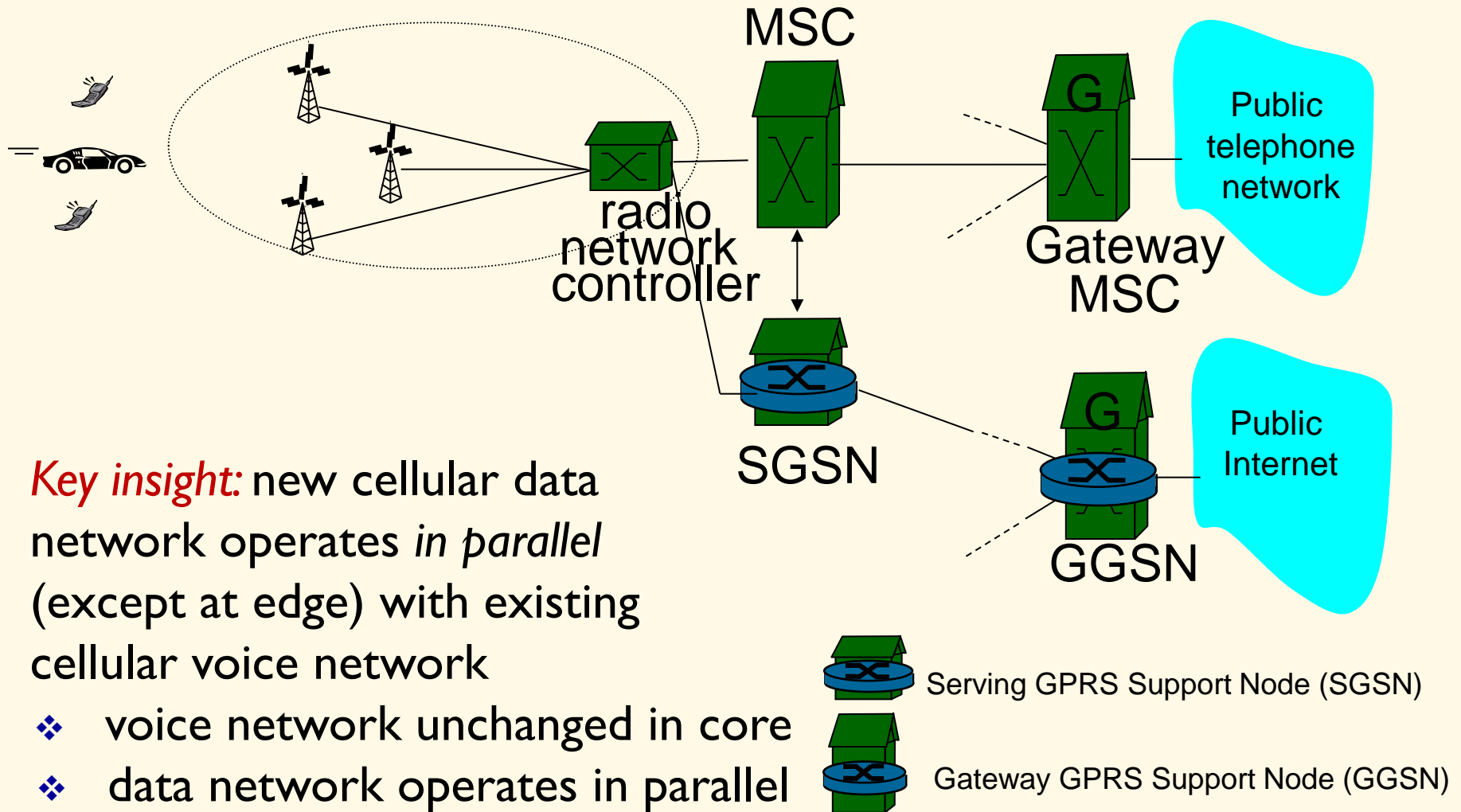
Provide 2G extensions:

- **General Packet Radio Service (GPRS)**
 - evolved from GSM.
 - data sent dynamically on multiple channels (if available).
 - Data rates up to 115 Kbps.
- **Enhanced Data Rates for Global Evolution (EDGE)**
 - also evolved from GSM, using enhanced modulation
 - data rates up to 384 Kbps.
- **CDMA-2000 (phase 1)**
 - data rates up to 144 Kbps.
 - evolved from IS-95.

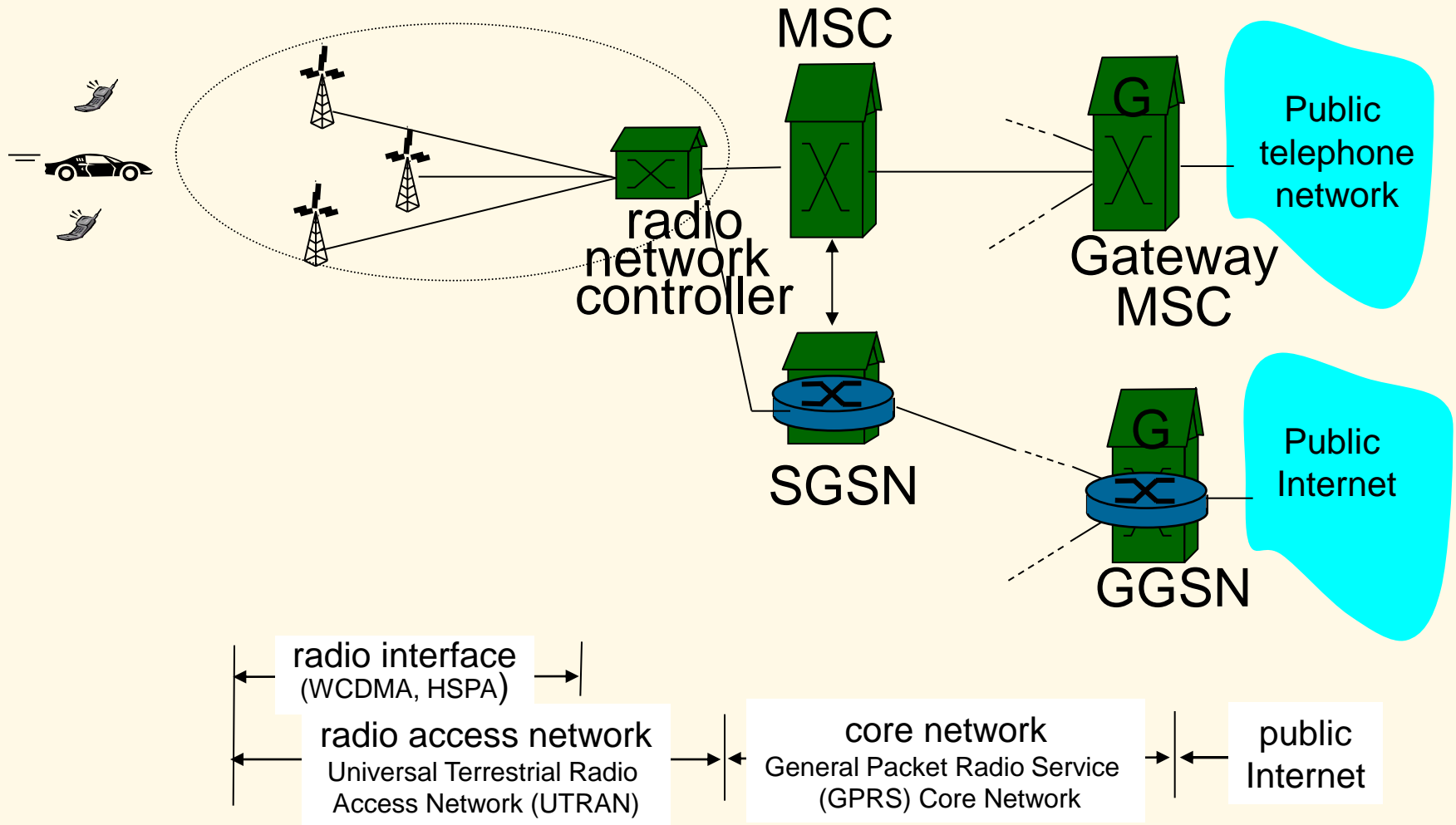
2.5G Network Architecture



3G (Voice+Data) Network Architecture



3G (Voice+Data) Network Architecture



Cellular Standards: 3G

3G systems: voice/data

Two technologies:

1. **Universal Mobile Telecommunications Service (UMTS)**

- Leaves the existing 2.5G system in place.
- data service: High Speed Uplink/Downlink Packet Access (HSDPA/HSUPA) up to 14 Mbps.

Cellular Standards: 3G

2. CDMA-2000: CDMA in TDMA slots

- data service: 1xEVolution Data Optimized (1xEVDO) up to 14 Mbps (Rev B - latest version)
 - DL layer = Several sub-layers
 - Practical capacity 3.1 Mbps
 - 1.67 ms slots 16 slots per frame
 - Wireless AT sends DRC indicator back to BS to dynamically adjust sending rate within the slot
 - Proportional Fair Scheduler
 - Uses 'turbo code' FEC on multiple slots with 'early completion'. **Note – redundancy is on the same channel.**
- **Multipath fading hurts EVDO performance across a single channel.**

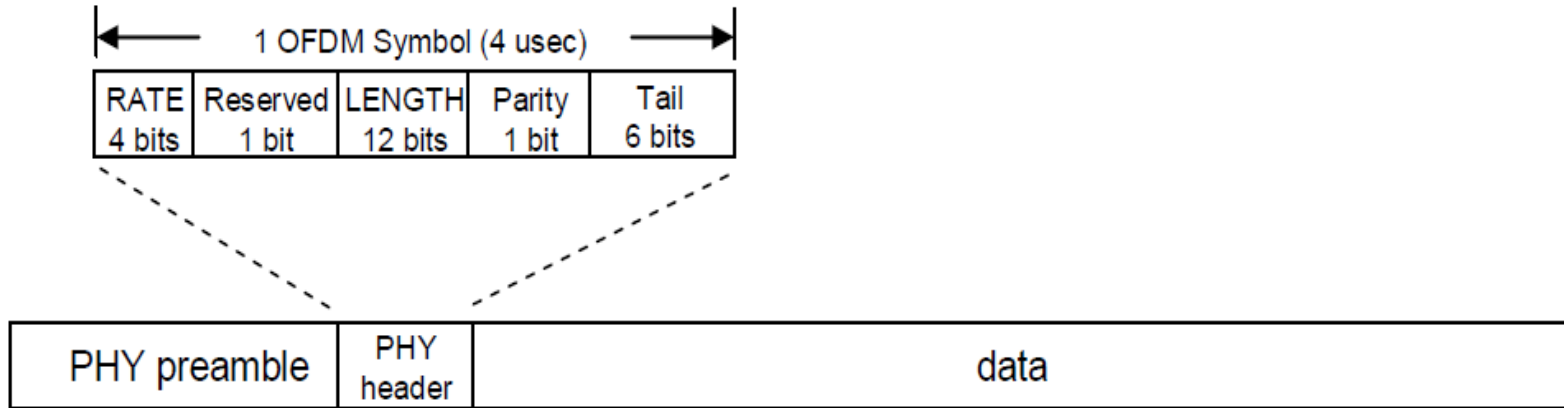
EVDO DRC Table

TABLE I
ADAPTIVE MODULATION AND CODING SCHEMES IN CDMA2000 1X
EV-DO REV. A DOWNLINK

DRC	Data rate (kbps)	Bits	Code Rate	Modulation
1	38.4	1024	1/4	QPSK
2	76.8	1024	1/4	QPSK
3	153.6	1024	1/4	QPSK
4	307.2	1024	1/4	QPSK
5	307.2	2048	1/4	QPSK
6	614.4	1024	1/4	QPSK
7	614.4	2048	1/4	QPSK
8	921.7	3072	3/8	8-PSK
9	1228.8	2048	1/2	QPSK
10	1228.8	4096	1/2	16-QAM
11	1843.2	3072	1/2	8-PSK
12	2457.8	4096	1/2	16-QAM
13	1586.0	5120	1/2	16-QAM
14	3072.0	5120	1/2	16-QAM

OFDM in IEEE802.11a

Figure 2.3.1-1 Conventional Packet Oriented Networks Like IEEE 802.11a Precede Each Data Transmission with a PHY Layer Preamble and Header



- PHY preamble is 20 microsec.
- Real-world efficiency is about 50%
- Randomized CSMA backoff period represents idle time.

Freescale

3GPP LTE (Long Term Evolution)

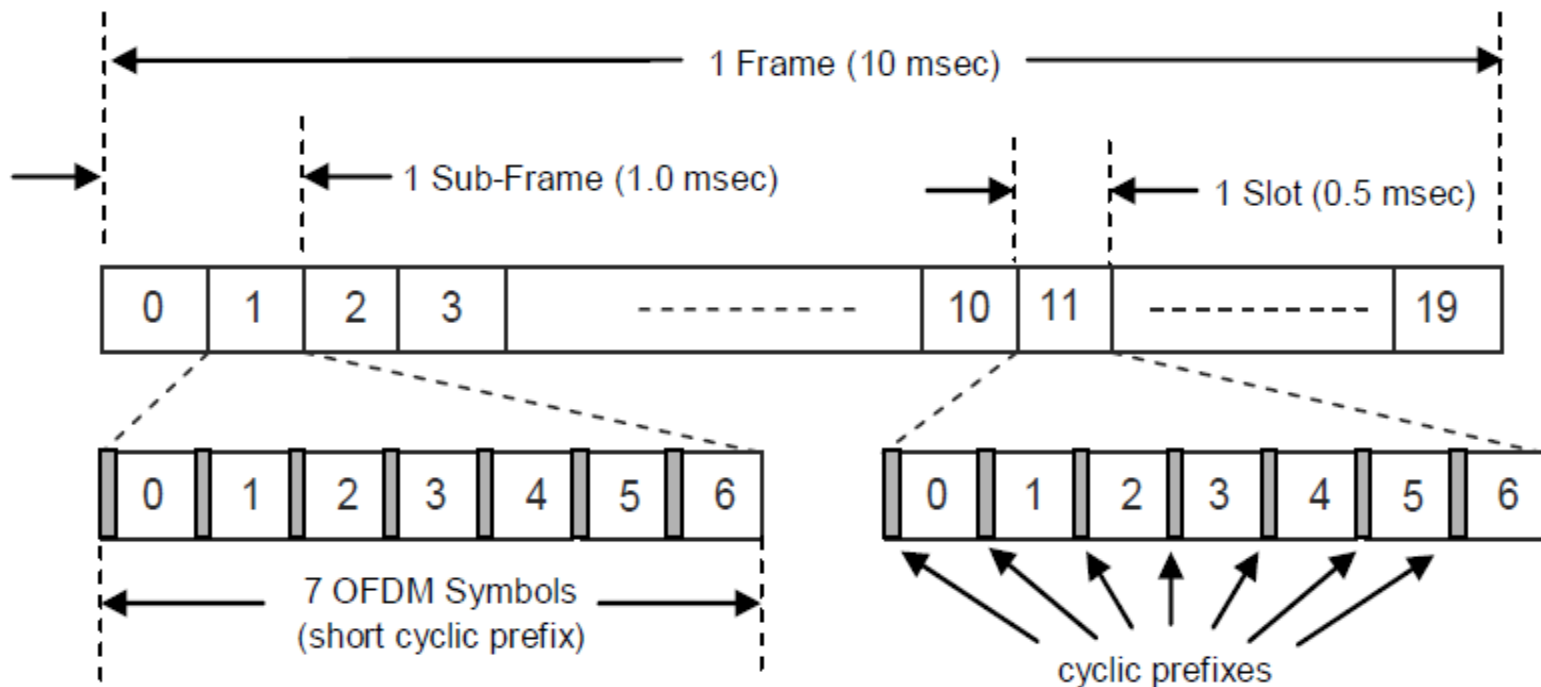
4G LTE == 3GPP LTE

- Uses OFDM on downlink in cellular space. Uplink is **SC**-FDMA (**S**ingular **C**arrier).
- Has a CP (cyclic prefix) to avoid symbol distortion over a 'slot'.
- LTE frames (10 msec) are divided into 10 1msec subframes which in turn are divided into 2 two slots (0.5 msec).

LTE Frame Structure

Figure 2.3.2-1 LTE Generic Frame Structure

Freescall



- Slots consist of 6 or 7 OFDM symbols.

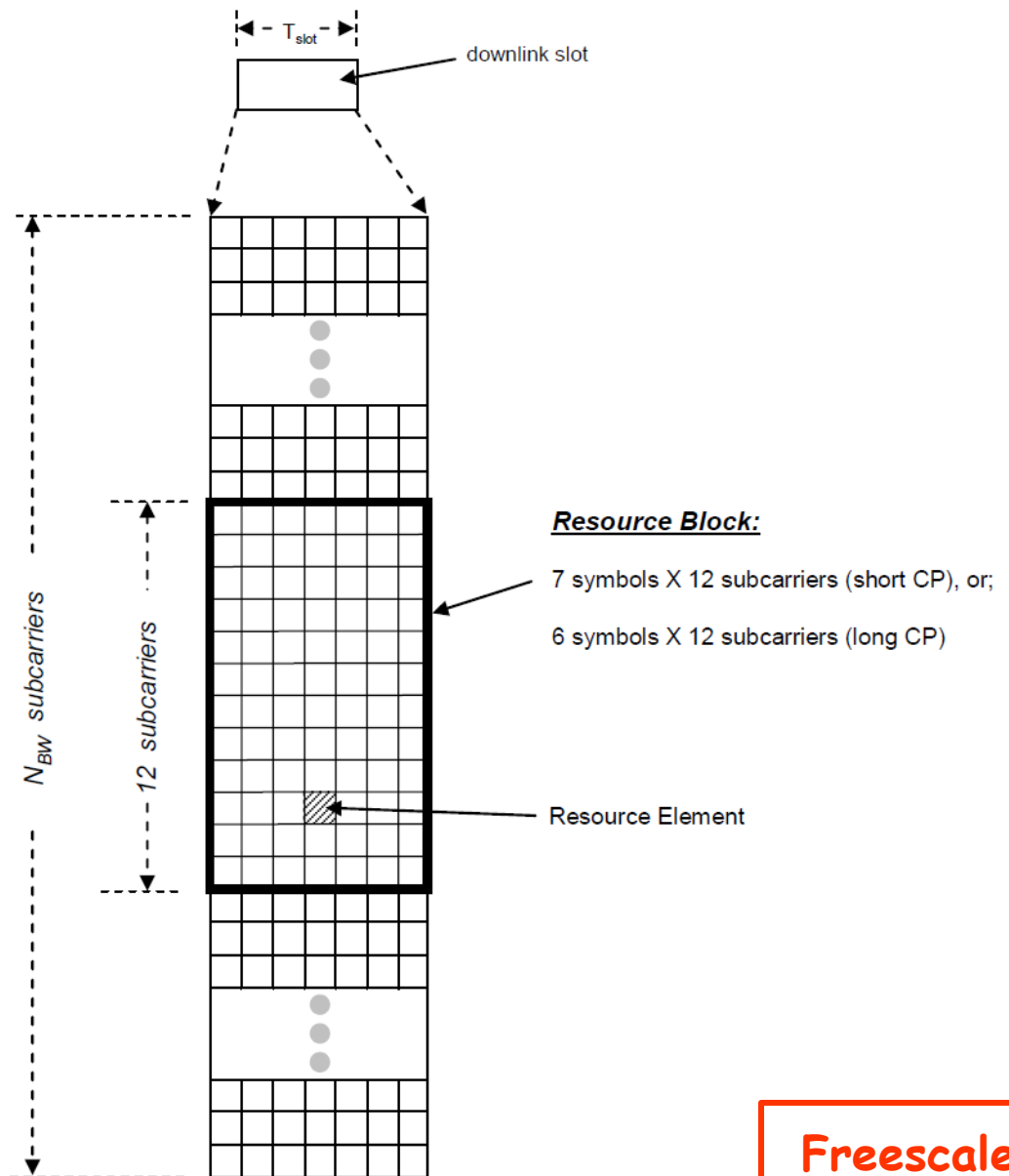
LTE Physical Resource Block (PRB)

OFDMA allocates a PRB (Physical Resource Block) to users.

A PRB consists of 12 consecutive subcarriers (15 kHz bandwidth) for one slot.

PRB is then (6 or 7) symbols x 12 subcarriers.

Figure 2.3.2-2 Downlink Resource Grid



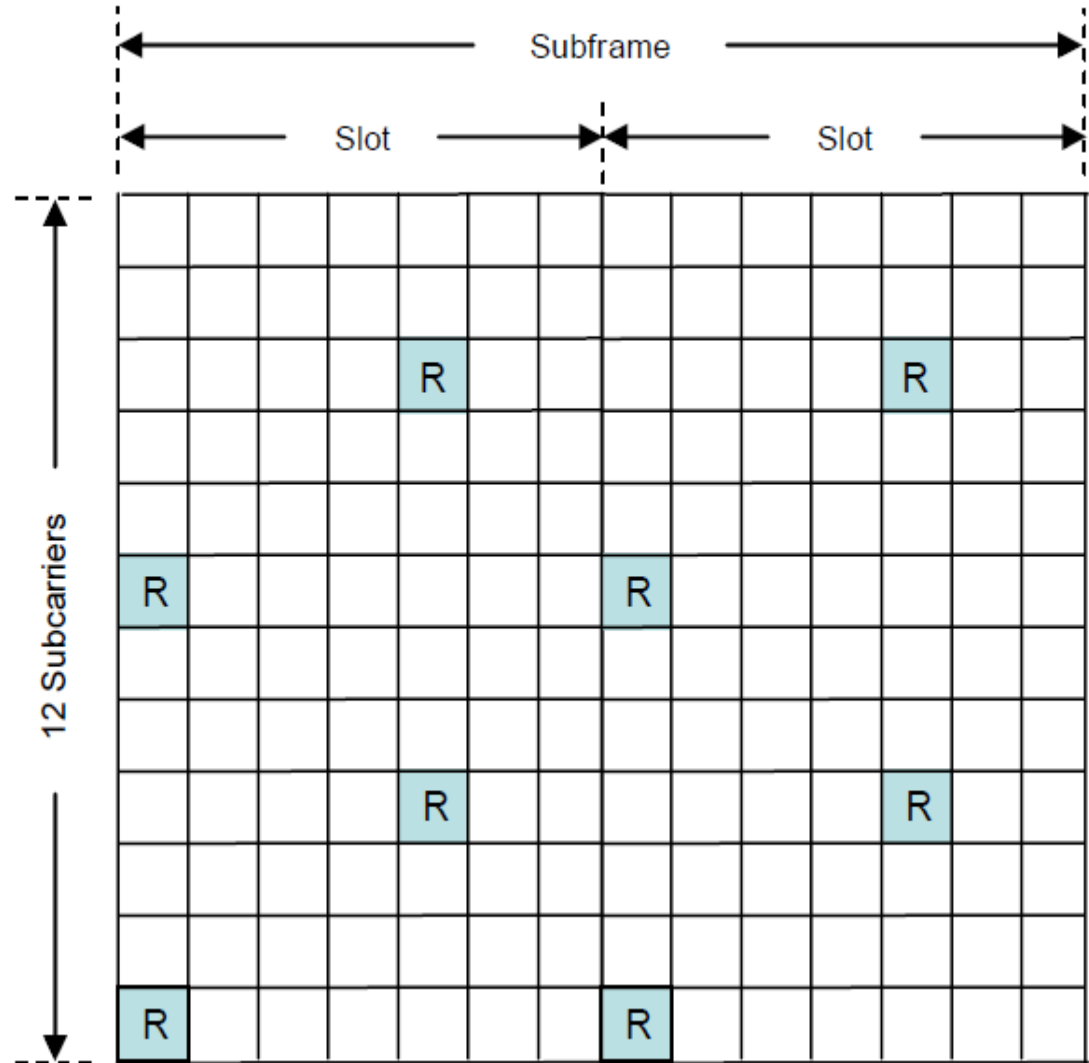
Freescle

LTE Reference Symbols

Instead of PHY preambles (802.11), reference symbols are embedded in the PRB.

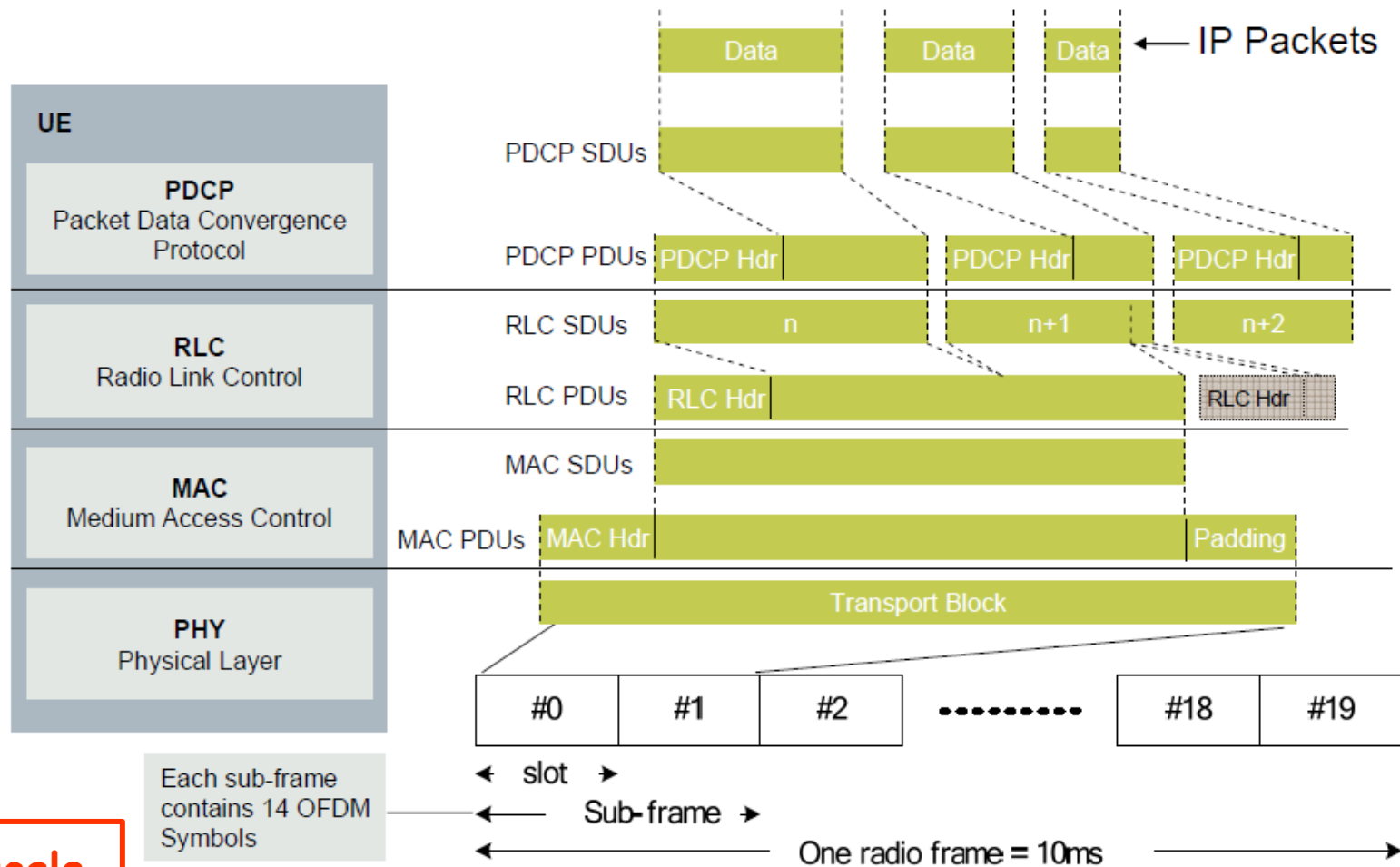
LTE also employs MIMO.

Freescale



LTE Layer 2

Figure 2.2. Time domain view of the LTE downlink



Freescall

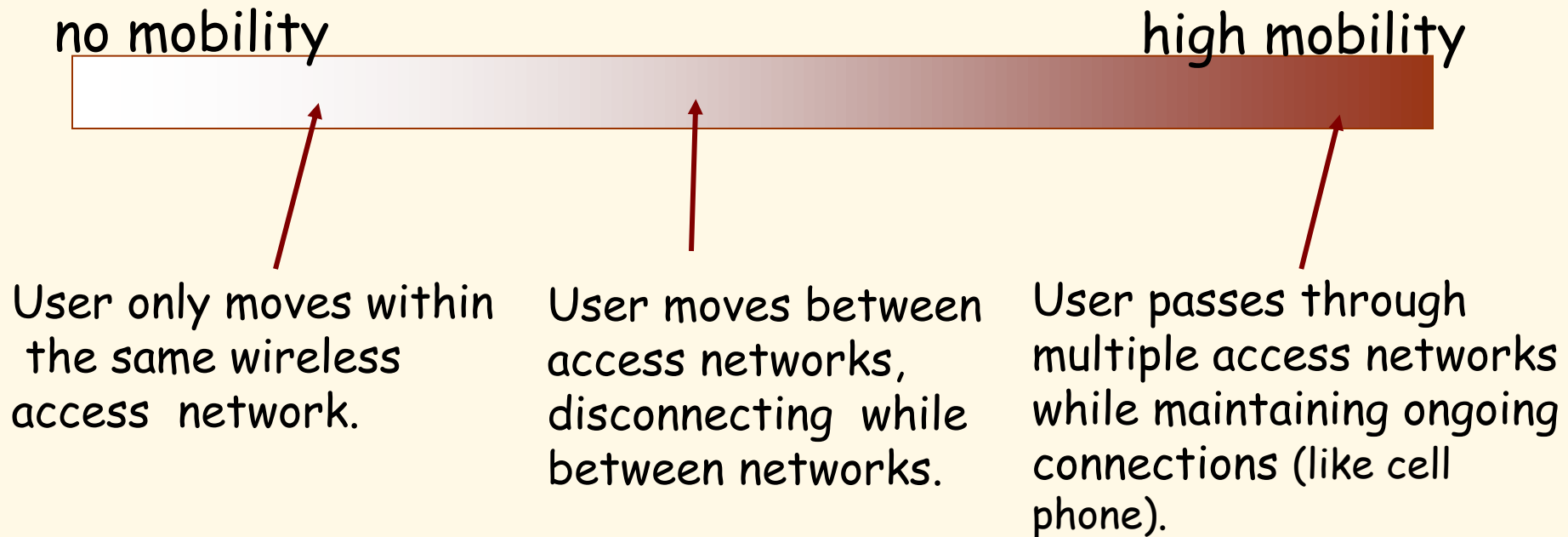
Mobile Wireless Networks



Computer Networks

What is Mobility?

Spectrum of mobility, from the **network layer** perspective:



Human Analogy: How to Contact a Mobile Friend ?

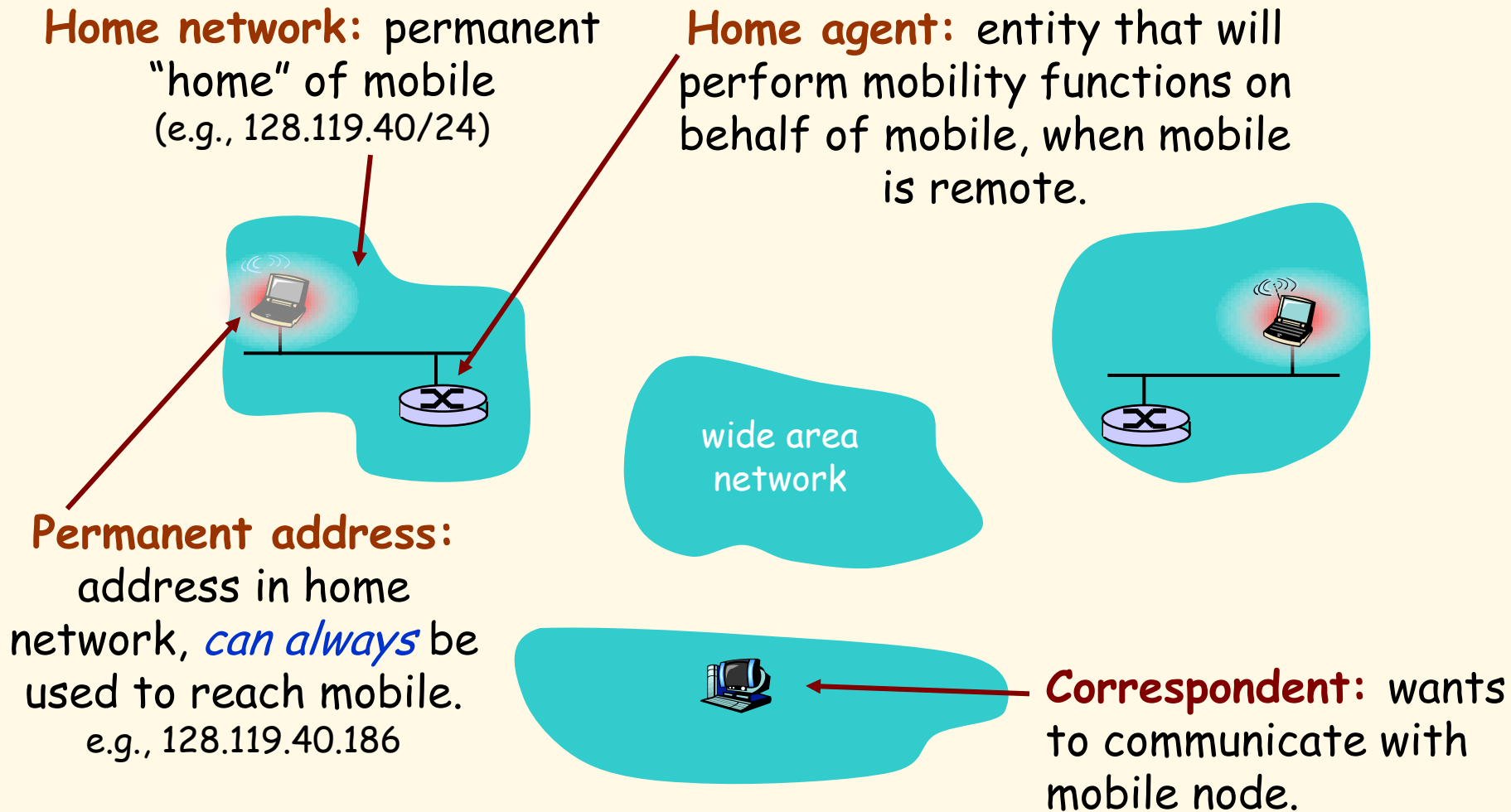
Consider a friend frequently changing residence addresses.
How do you find her?

- Search all phone books?
- Call her parents or her friends?
- Expect her to let you know where he/she now lives?

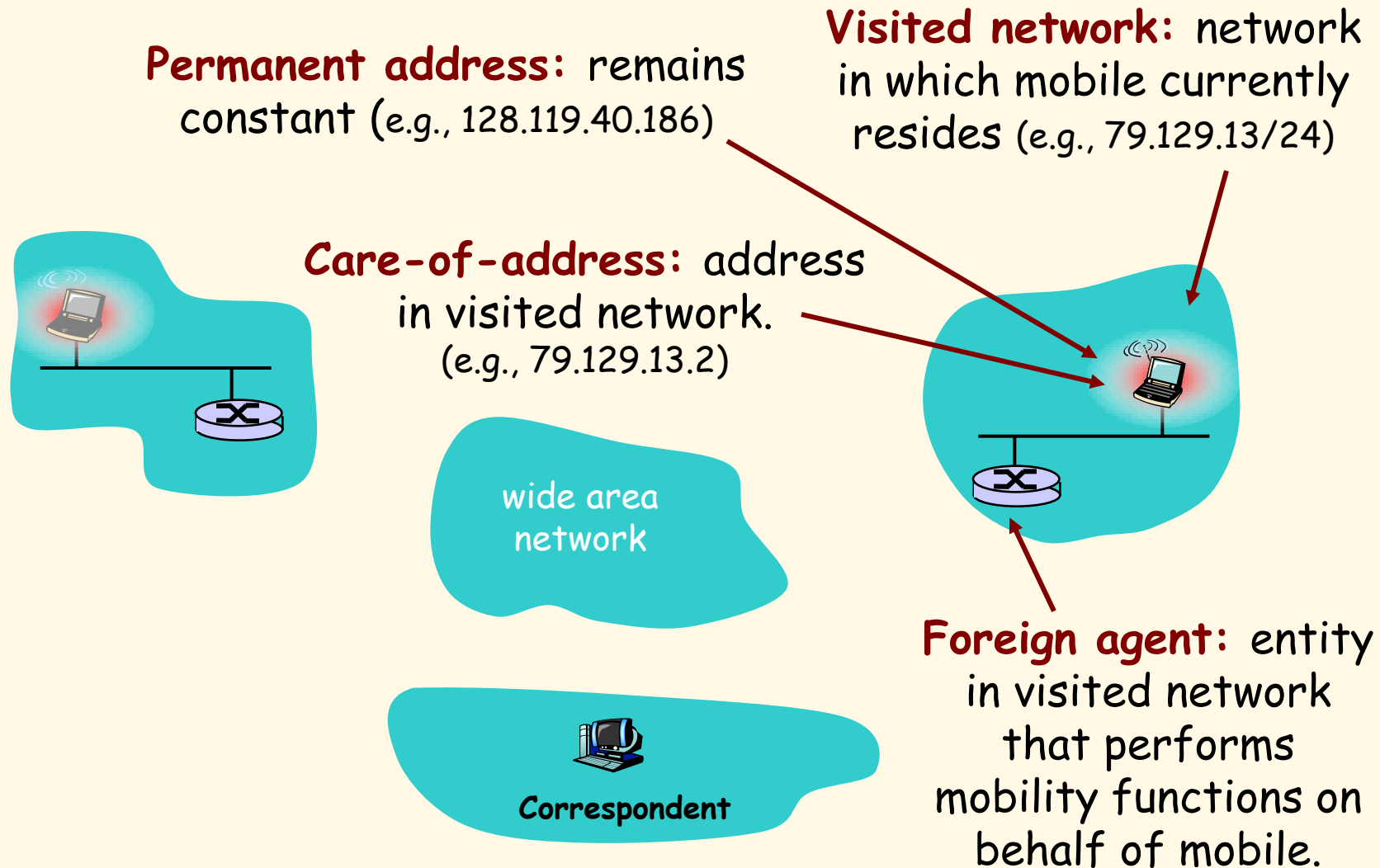
I wonder where Alice moved to?



Mobile Network Architecture



More Mobility Vocabulary



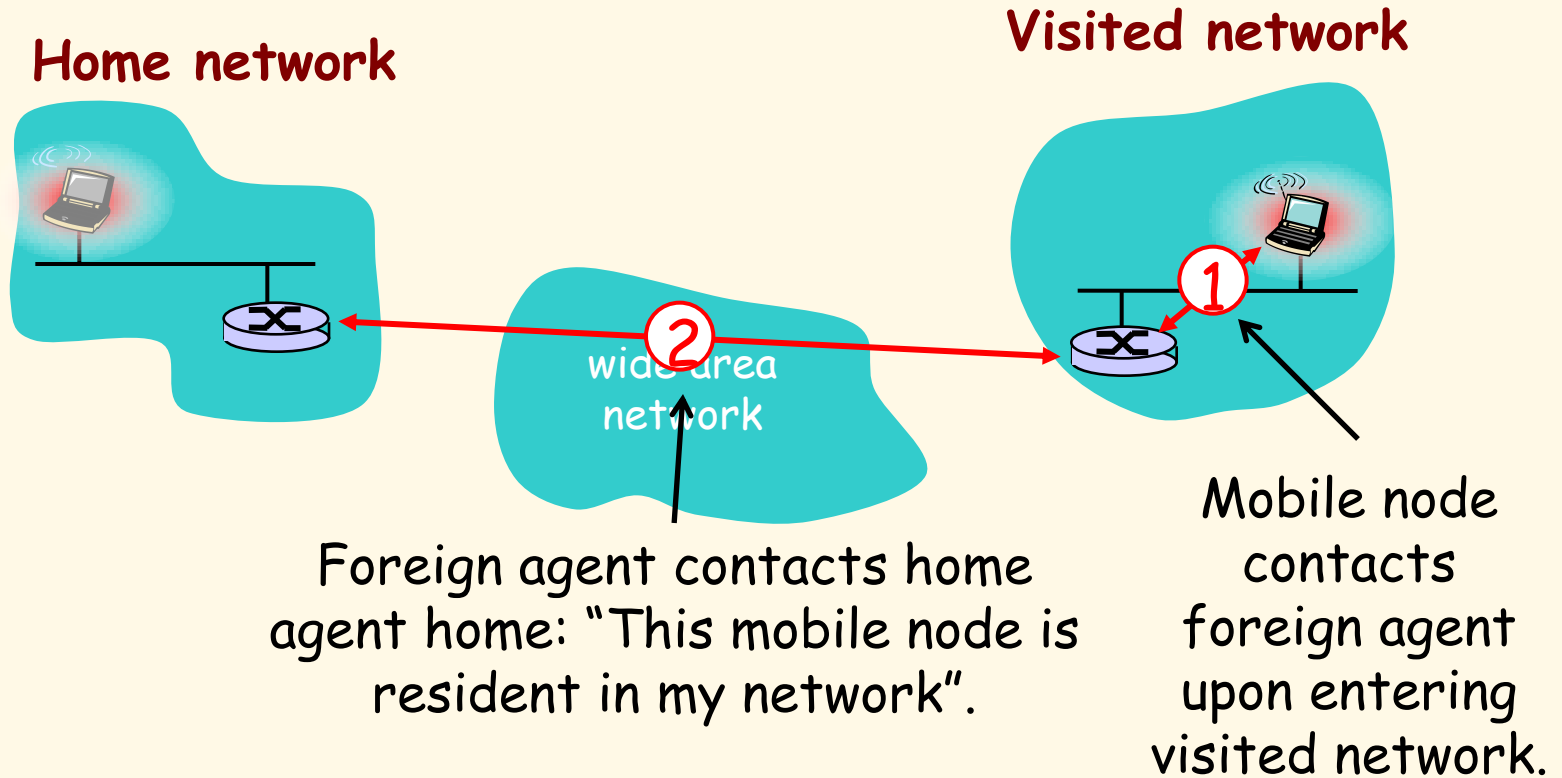
Mobility Approaches

- **Let routing handle it:** Routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.
 - routing tables indicate where each mobile node is located.
 - no changes to end-systems.
- **Let end-systems handle it:**
 - **indirect routing:** communication from correspondent to mobile node goes through home agent, then forwarded to remote network.
 - **direct routing:** correspondent gets foreign address of mobile node, sends directly to mobile node.

Mobility Approaches

- Let routing handle it: Routers advertise permanent address of mobile-nodes-in-residence via routing table exchange.
 - routing table to millions of mobiles
 - no changes to end-systems
- Let end-systems handle it:
 - **indirect routing**: communication from correspondent to mobile node goes through **home agent**, then forwarded to remote network.
 - **direct routing**: correspondent gets foreign address of mobile node, sends directly to mobile node.

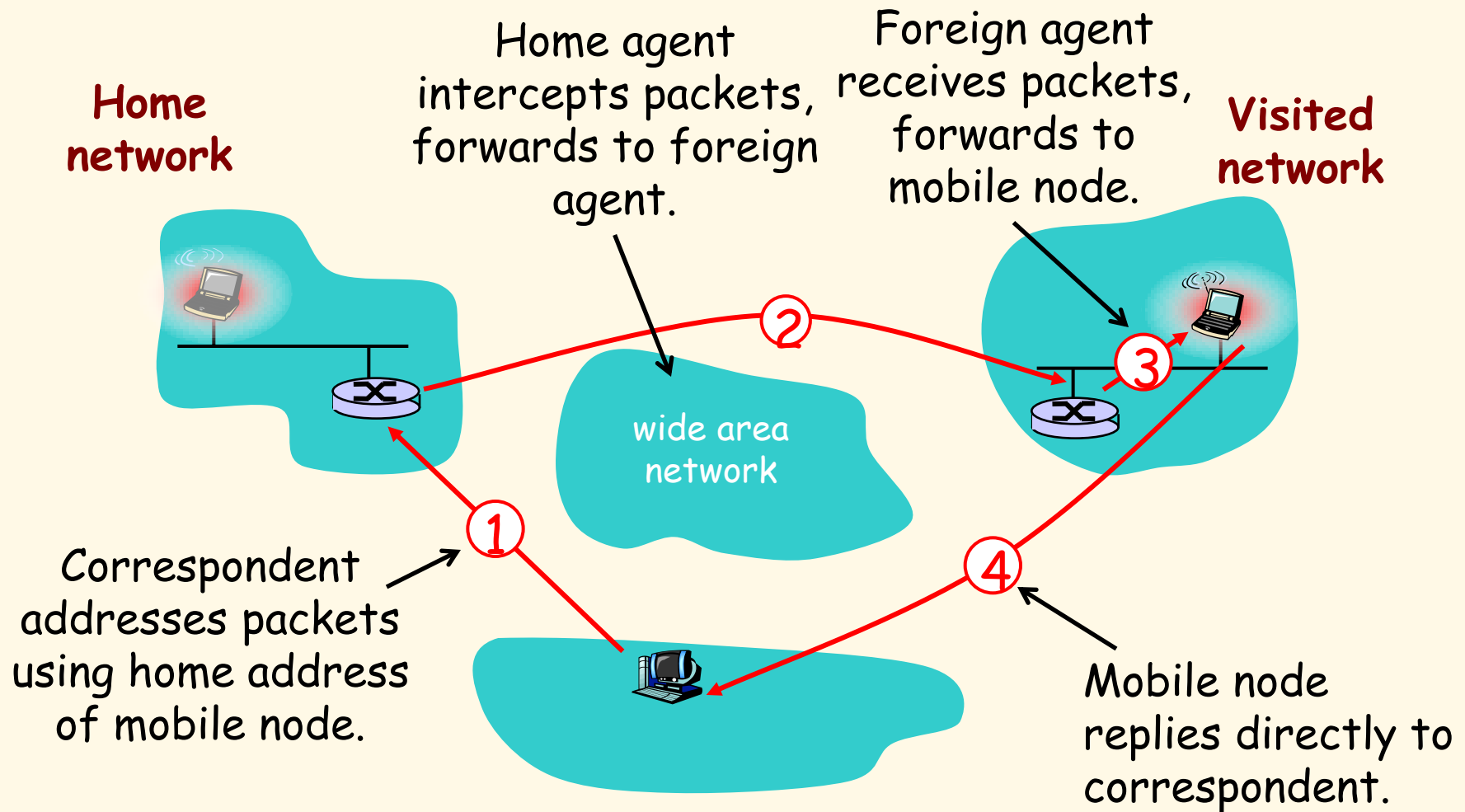
Mobility Registration



End result:

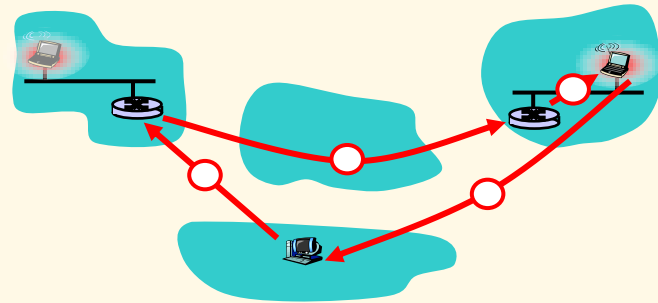
- Foreign agent knows about mobile node.
- Home agent knows location of mobile node.

Mobility via Indirect Routing



Indirect Routing

- Mobile uses two addresses:
 - **permanent address**: used by correspondent (Hence, mobile location is *transparent* to correspondent.)
 - **care-of-address**: used by home agent to forward datagrams to mobile node via foreign agent.
- Foreign agent functions may be done by mobile node itself (e.g., use DHCP).
- **Triangle routing**: correspondent-home-network-mobile
 - inefficient when the correspondent and mobile are in the same network.

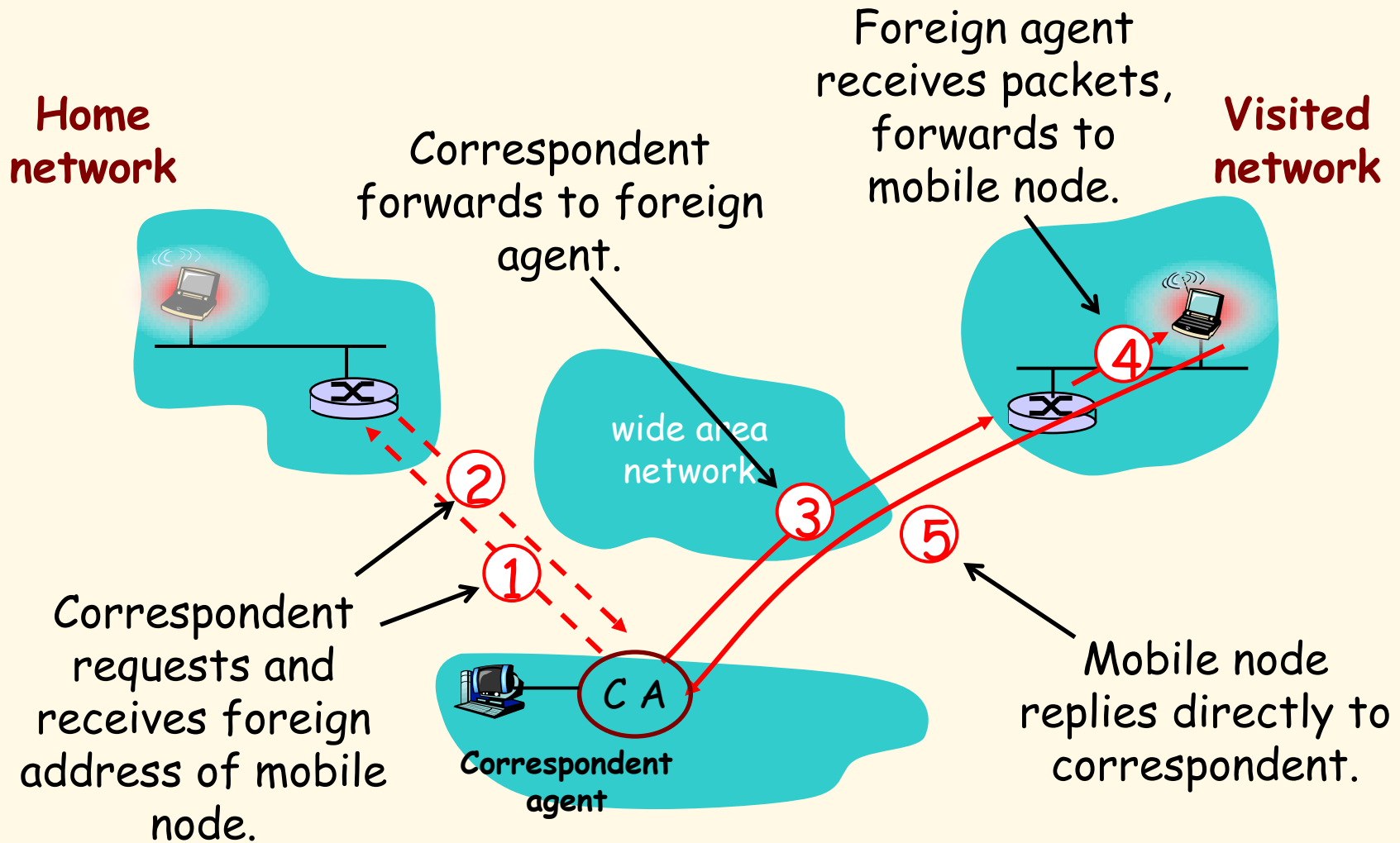


Indirect Routing

Moving between Networks

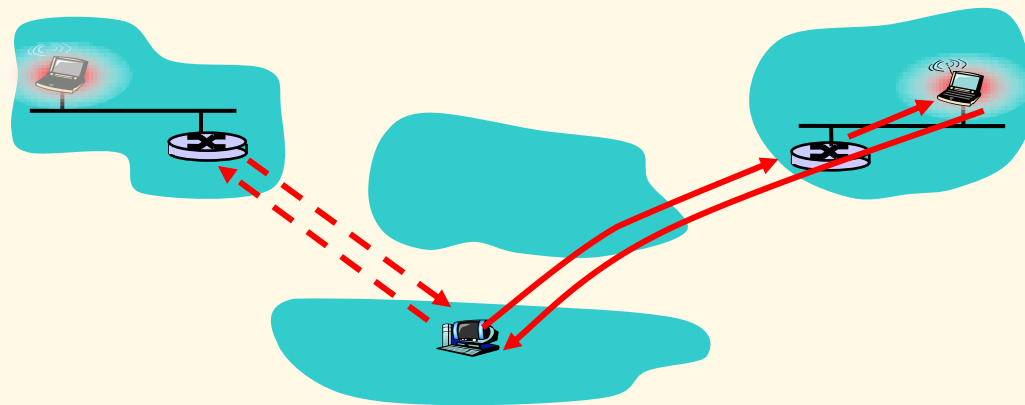
- Suppose the mobile node moves to another network:
 - registers with new foreign agent.
 - new foreign agent registers with home agent.
 - home agent updates COA for mobile node.
 - packets continue to be forwarded to mobile node (but with new care-of-address).
- Mobility involving multiple foreign networks is transparent.
 - On-going connections can be maintained!
 - However, potential for datagram loss when disconnection/reattachment time is not short.

Mobility via Direct Routing



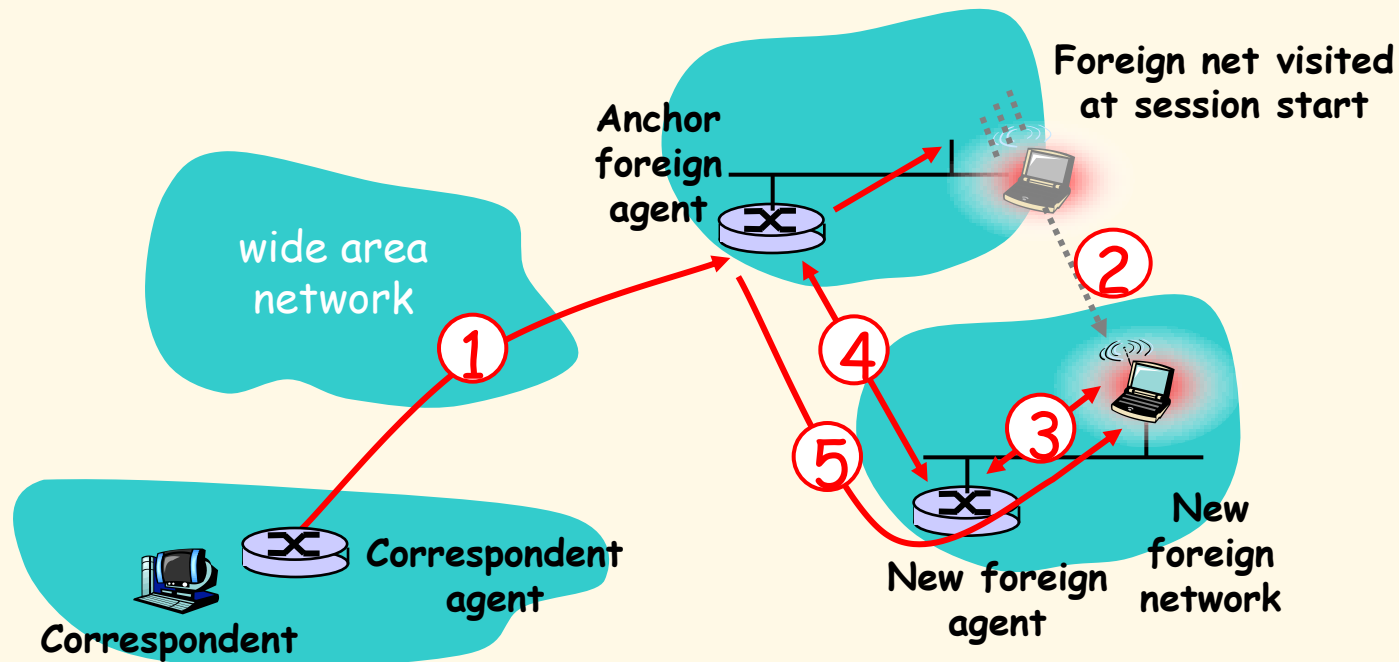
Mobility via Direct Routing

- Overcomes the triangle routing problem.
- **Non-transparent to correspondent:**
Correspondent must get care-of-address from home agent.
- What if mobile node changes visited network?



Accommodating Mobility with Direct Routing

- Anchor foreign agent: FA in first visited network.
- Data always routed first to Anchor FA.
- When mobile node moves: new FA arranges to have data forwarded from old FA (chaining).



Cellular/Mobile Wireless Summary

- Cellular Architecture
 - FDM/TDM, CDMA
- Cellular Standards
 - GSM, 2G,
 - BSS, BTS, BSC, MSC
 - 2.5G
 - GPRS, EDGE, CDMA-2000
 - 3G
 - UTMS, CDMA-2000 (EVDO)
 - 4G LTE
 - OFDM, PRB

Cellular/Mobile Wireless Summary

- **Mobile Definitions**
 - Home and foreign agents, permanent and care-of-addresses, correspondent, home and foreign networks.
- **Mobile Architecture**
 - Move routing to edge, use agents.
 - Registering with agents
 - Indirect Routing
 - Triangular routing
 - Direct Routing
 - Anchor foreign agent