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

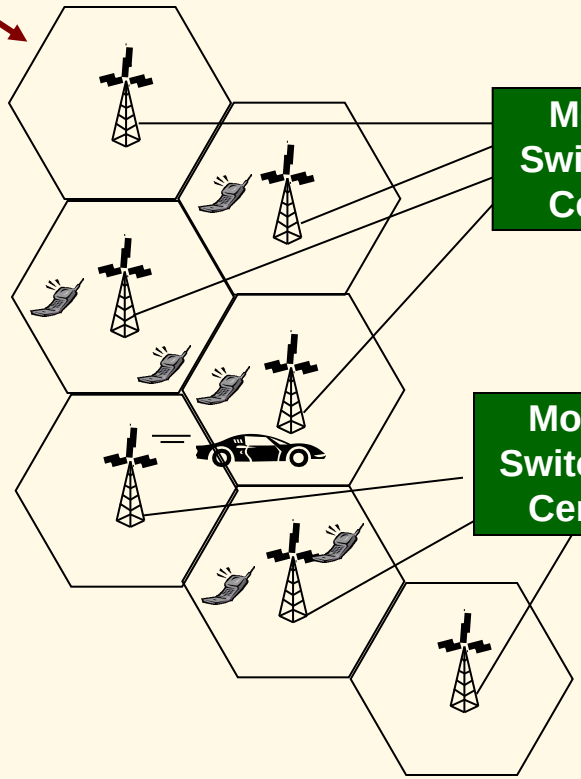
Cellular Network Architecture

MSC

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

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

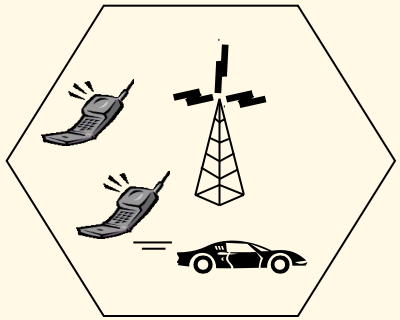
Public telephone network, and Internet

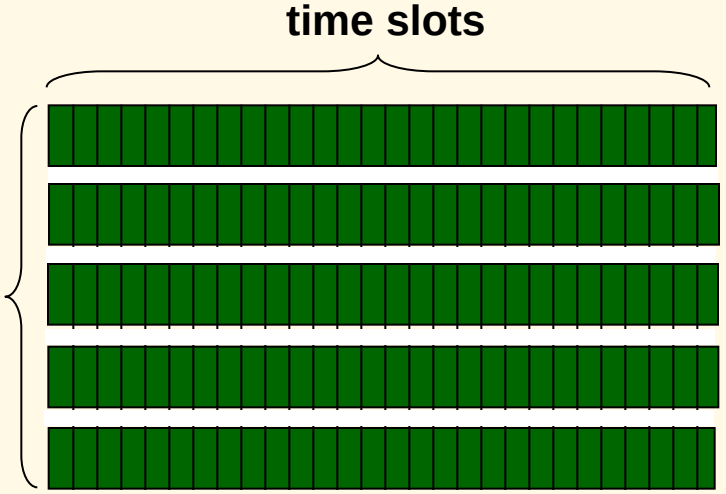
wired network

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.

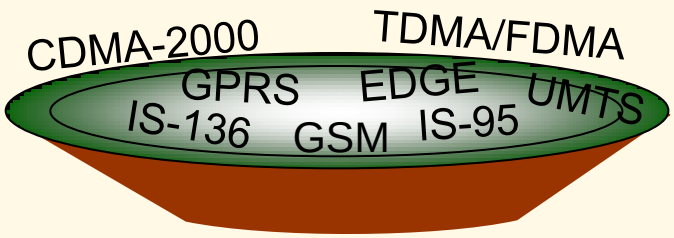




Cellular Standards: Brief Survey

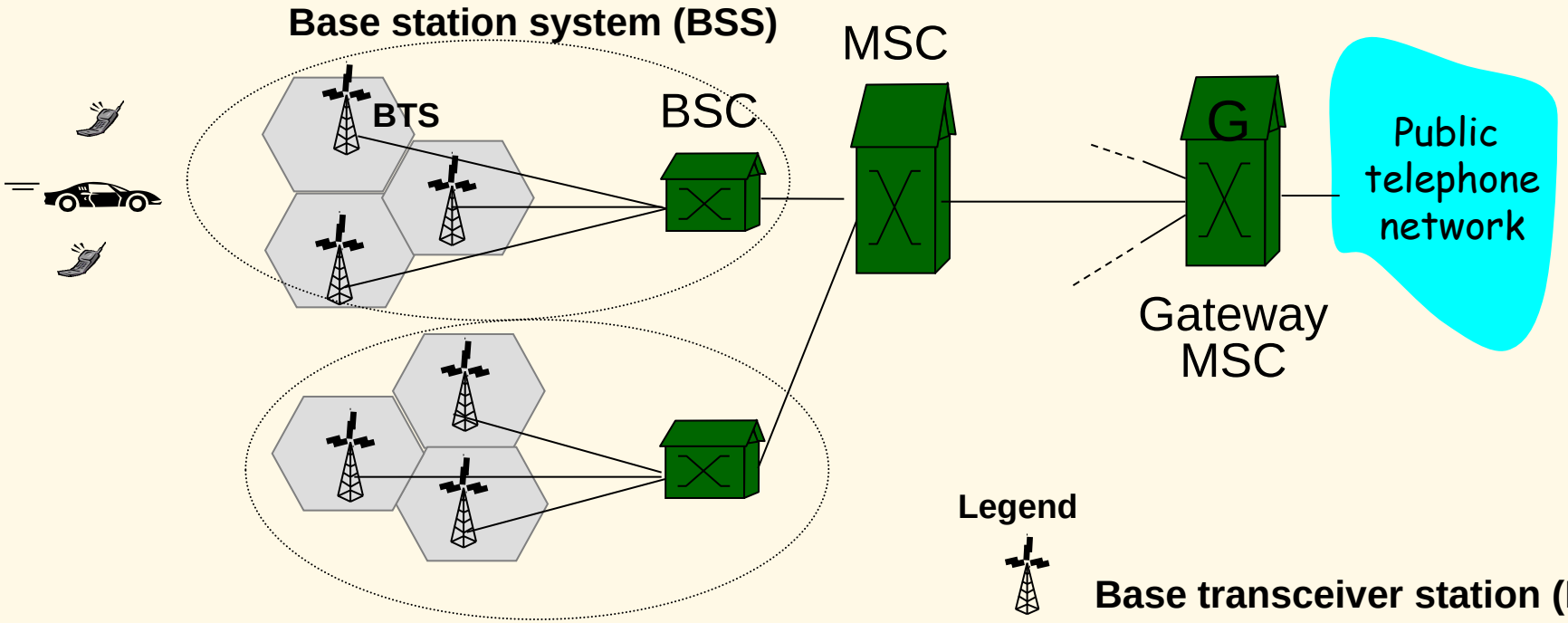
2G Systems: voice channels/digital technology

- 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



2G: Voice Connections to the Telephone Company

Cellular Standards: 2.5G

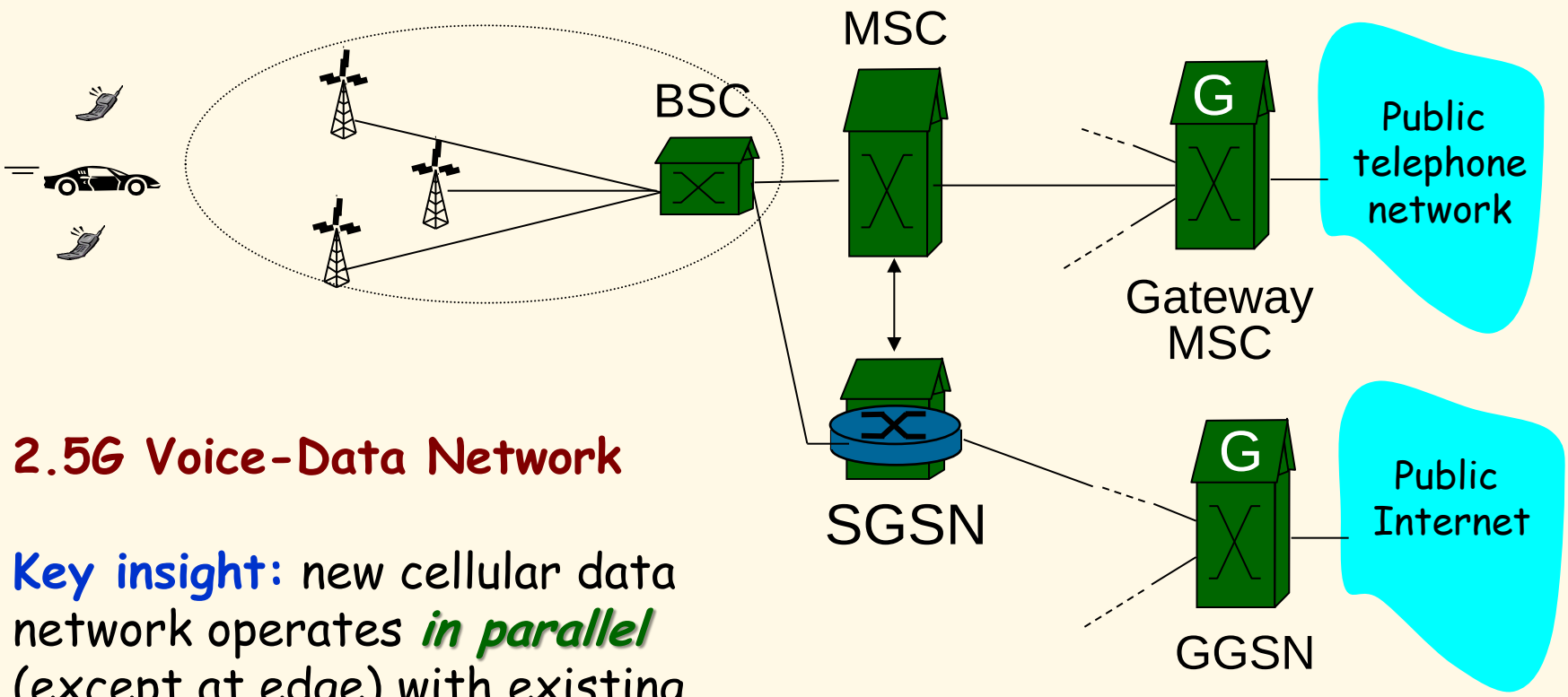
2.5G systems: voice and data channels

{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

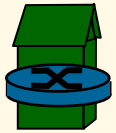


2.5G Voice-Data Network

Key insight: new cellular data network operates ***in parallel*** (except at edge) with existing cellular voice network.

- voice network is unchanged in core.
- data network operates in parallel.

Serving GPRS Support Node (SGSN)



Gateway GPRS Support Node (GGSN)

Cellular Standards: 3G

3G systems: voice/data

Two technologies:

1. **U**niversal **M**obile **T**elecommunications **S**ervice **(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 A – 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.

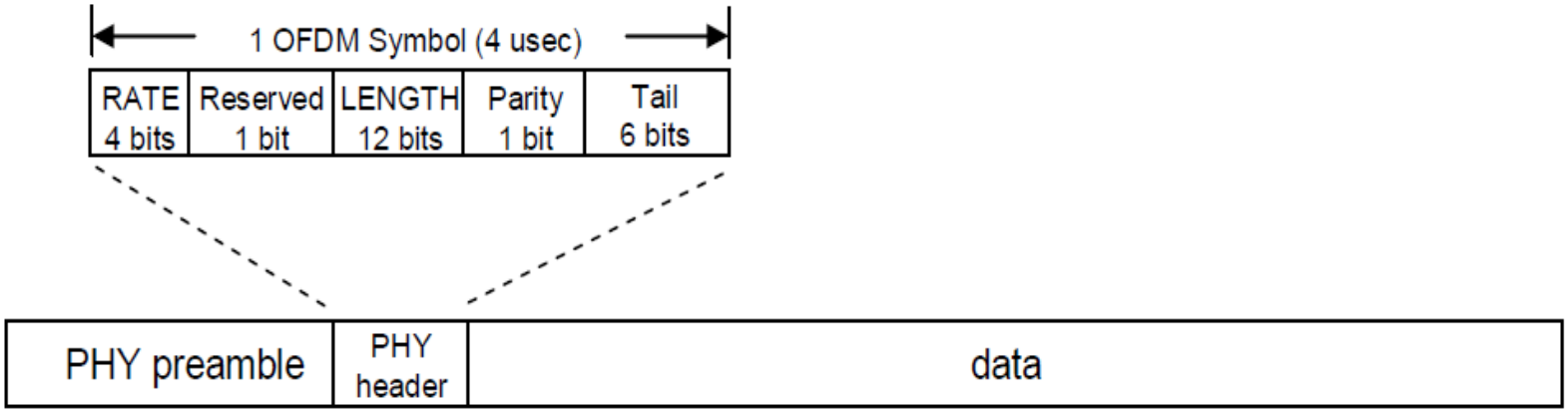
EVDO DRC Table

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)

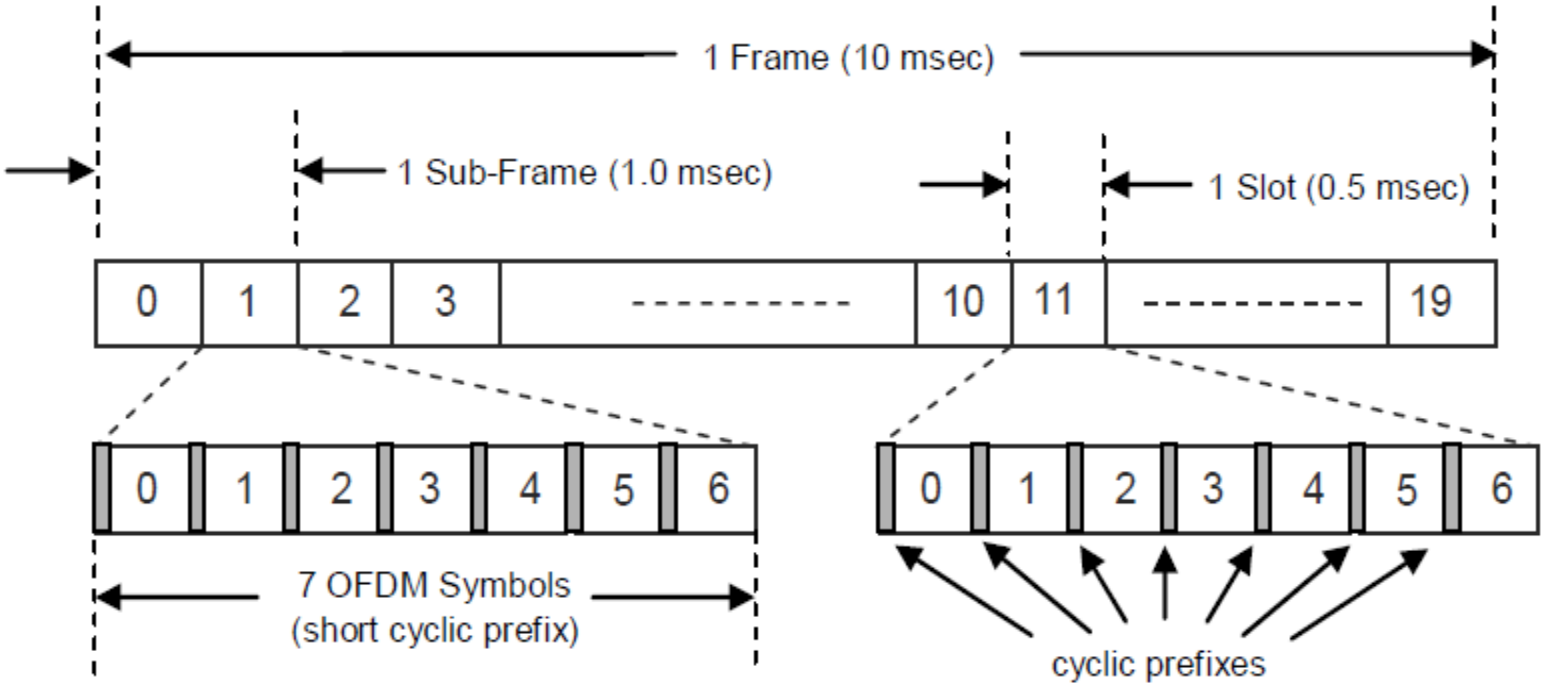
4G LTE == 3GPP LTE

- Uses OFDM on downlink in cellular space. Uplink is SC-FDMA (Singular Carrier).
- 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

Freescale



- Slots consist of 6 or 7 ODFM symbols.

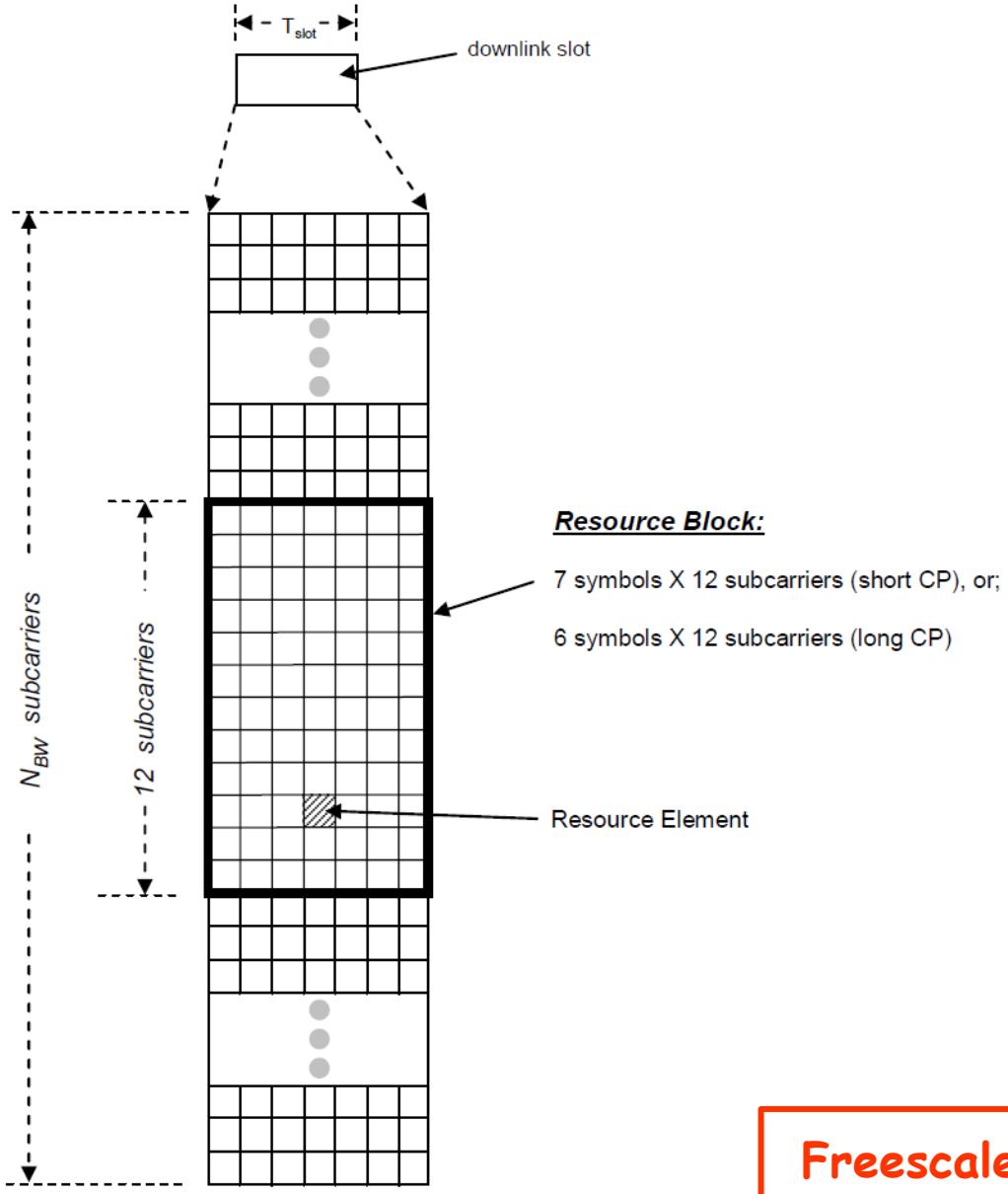
LTE Physical Resource Block (PRB)

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



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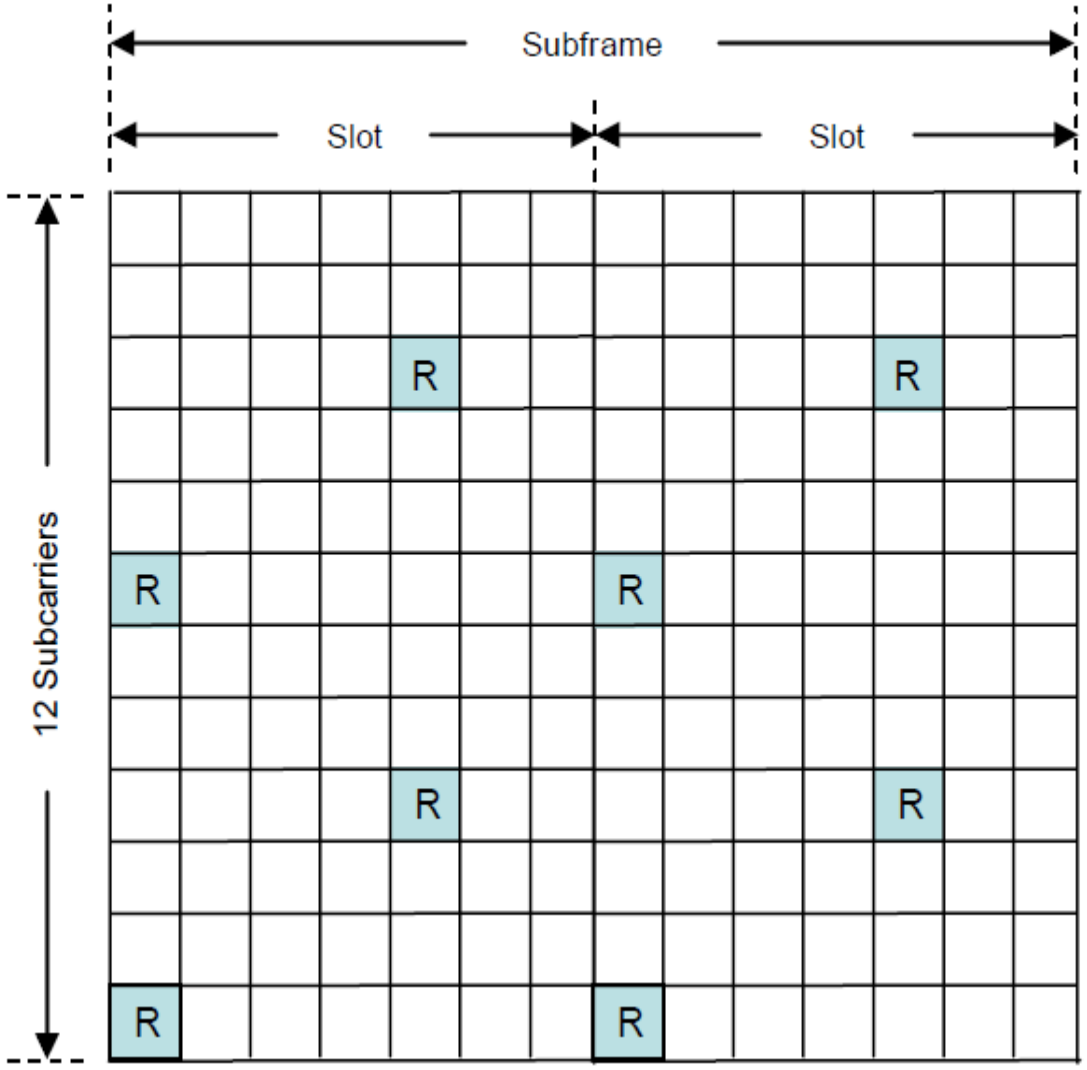
LTE Reference Symbols

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

LTE also employs MIMO.



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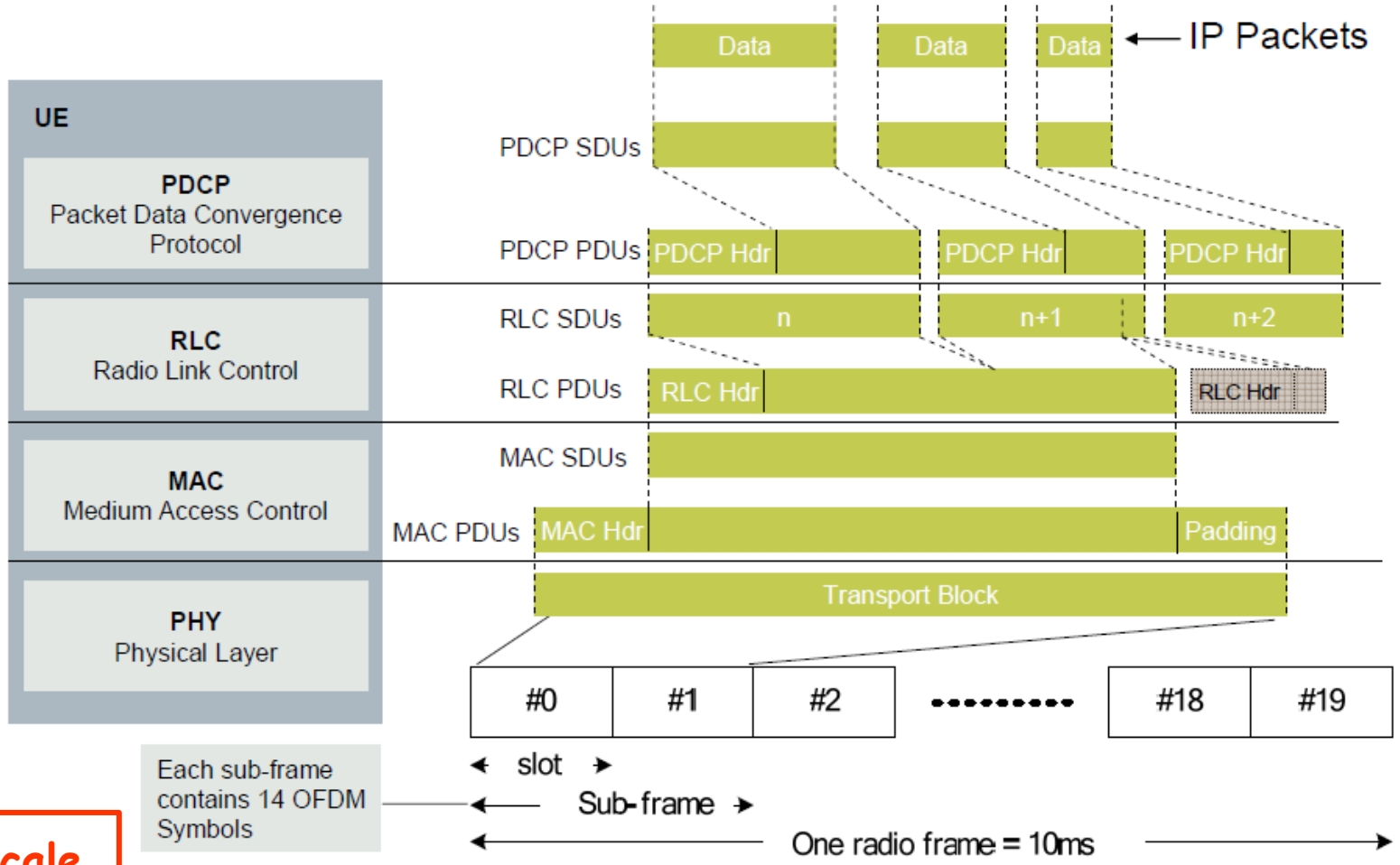
LTE Layer 2

Figure 2.2. Time domain view of the LTE downlink

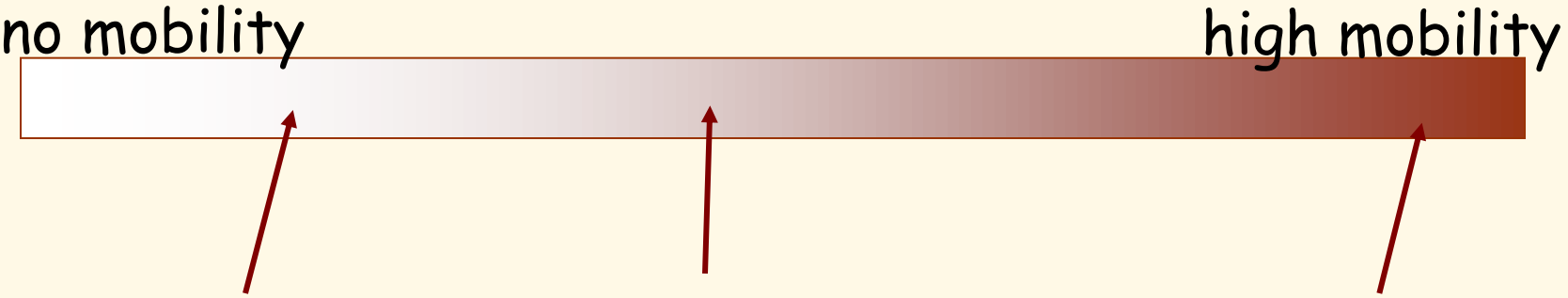


Freescale

Mobile Wireless Networks

What is Mobility?

Spectrum of mobility, from the network layer perspective:



User only moves within the same wireless access network.

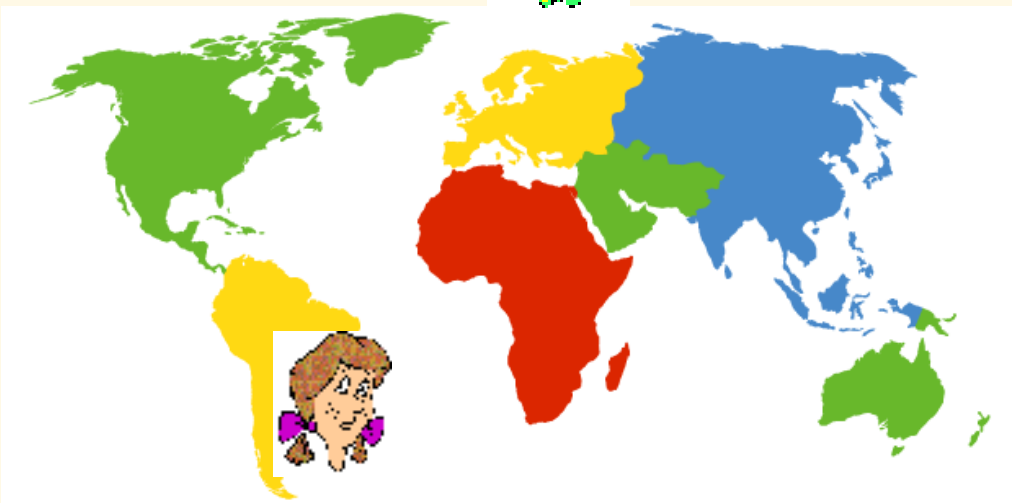
User moves between access networks, disconnecting while between networks.

User passes through multiple access networks while maintaining ongoing connections (like cell phone).

Human Analogy: How to Contact a Mobile Friend ?

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

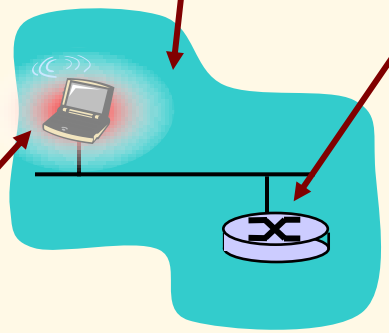
- Search all phone books?
- Call her parents or her friends?
- Expect her to let you know where he/she now lives?

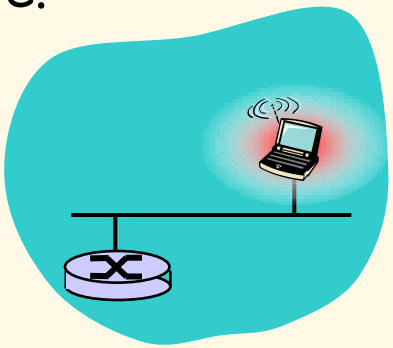


Mobile Network Architecture

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

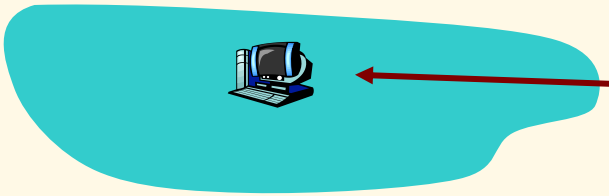
Home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote.





wide area network

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



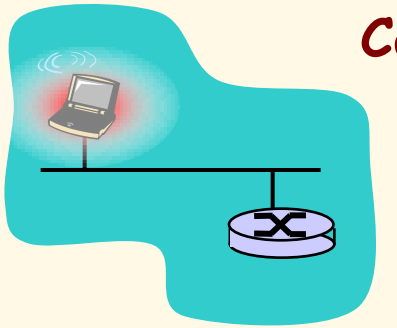
Correspondent: wants to communicate with mobile node.

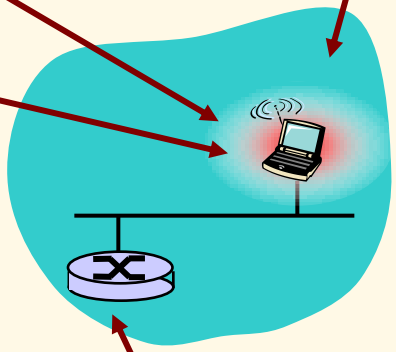
More Mobility Vocabulary

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

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

Care-of-address: address in visited network. (e.g., 79.129.13.2)





wide area network

Foreign agent: entity in visited network that performs mobility functions on behalf of mobile.

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

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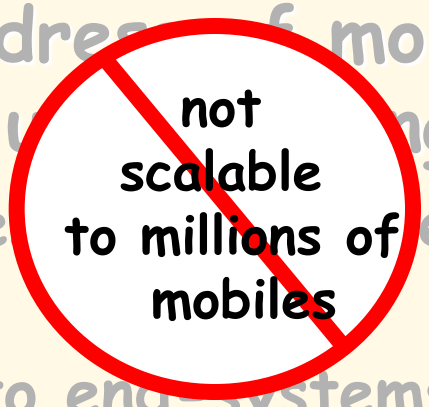

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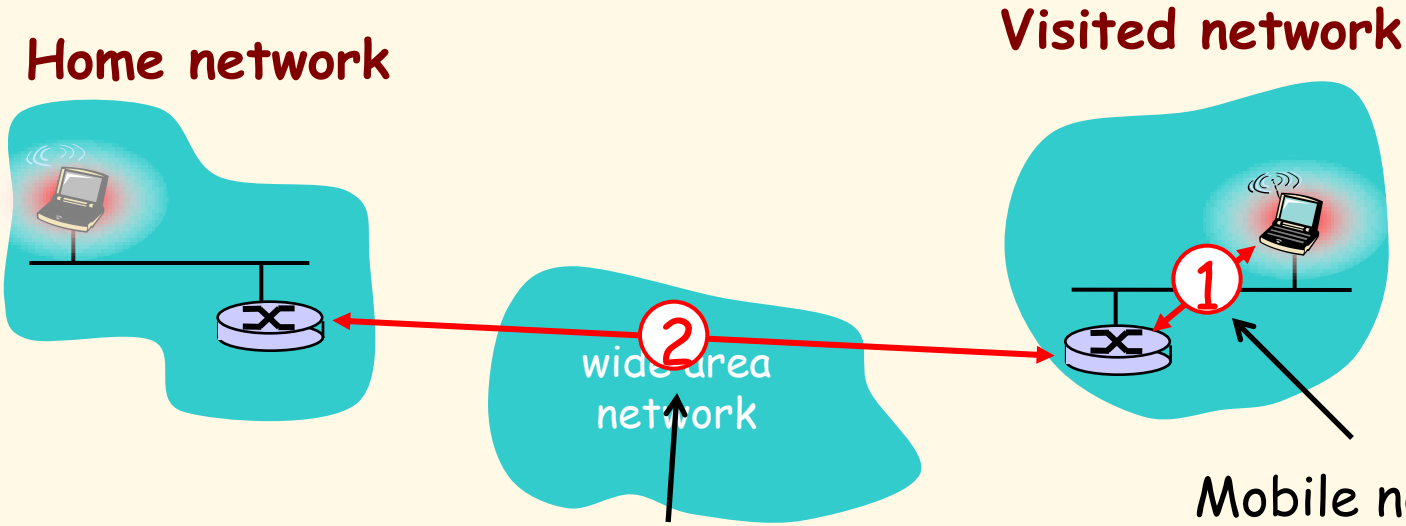
Mobility Registration



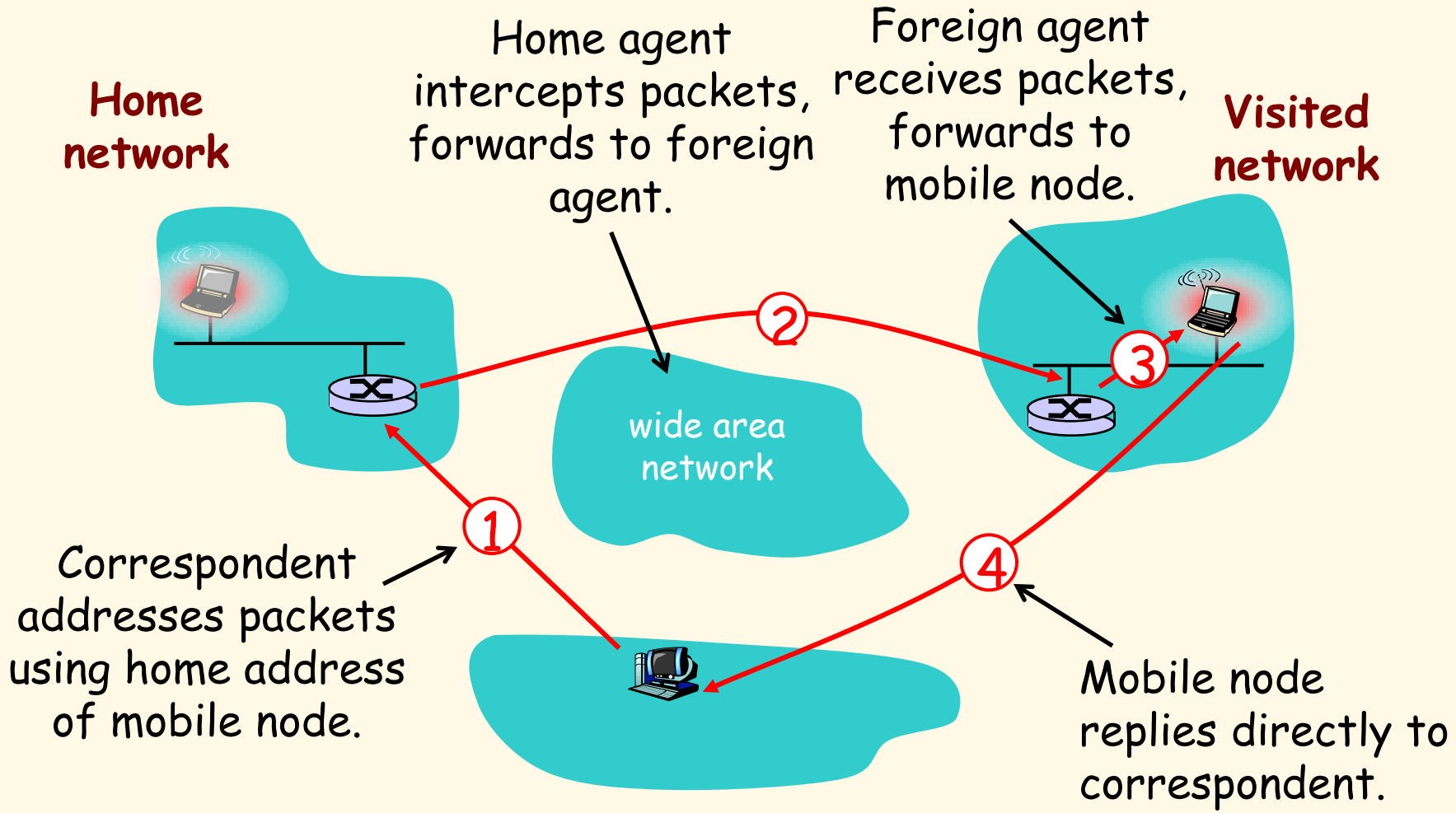
Foreign agent contacts home agent home: "This mobile node is resident in my network".

Mobile node contacts foreign agent upon entering visited network.

End result:

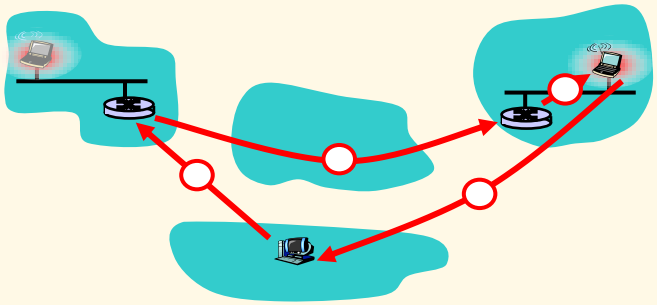
- Foreign agent knows about mobile node.
- Home agent knows location of mobile node.

Mobility via Indirect Routing



Indirect Routing

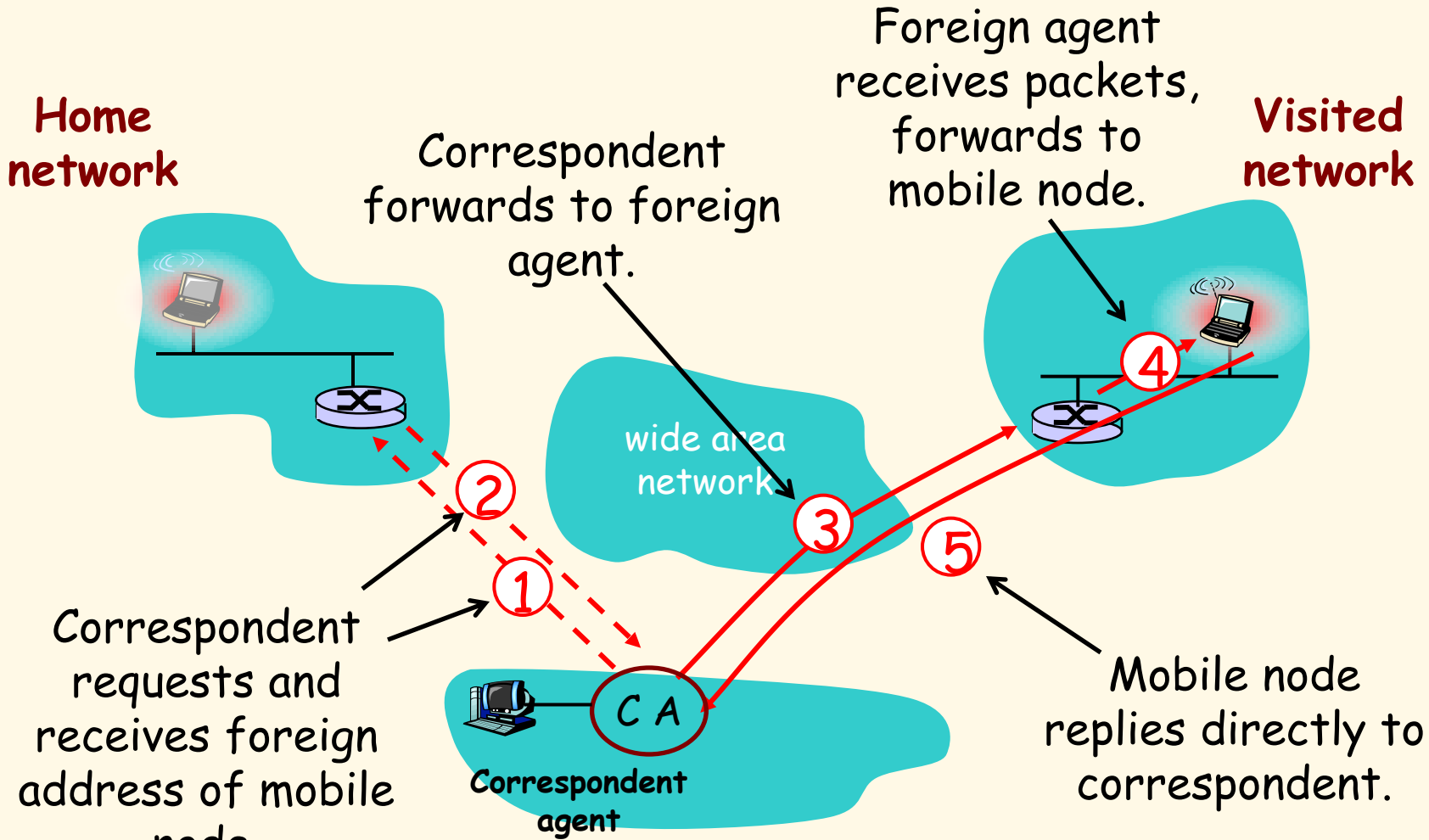
- Mobile uses two addresses:
  - permanent address: used by correspondent (Hence, mobile location is *transparent* to correspondent.)
  - care-of-address: used by home agent to forward datagrams to mobile node via foreign agent.
- Foreign agent functions may be done by mobile node itself (e.g., use DHCP).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



Indirect Routing
Moving between Networks

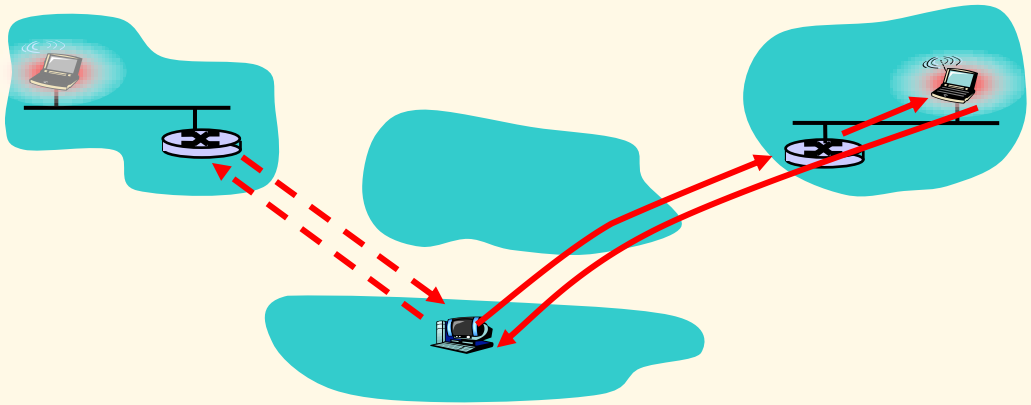
- Suppose the mobile node moves to another network:
  - registers with new foreign agent.
  - new foreign agent registers with home agent.
  - home agent updates COA for mobile node.
  - packets continue to be forwarded to mobile node (but with new care-of-address).
- Mobility involving multiple foreign 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



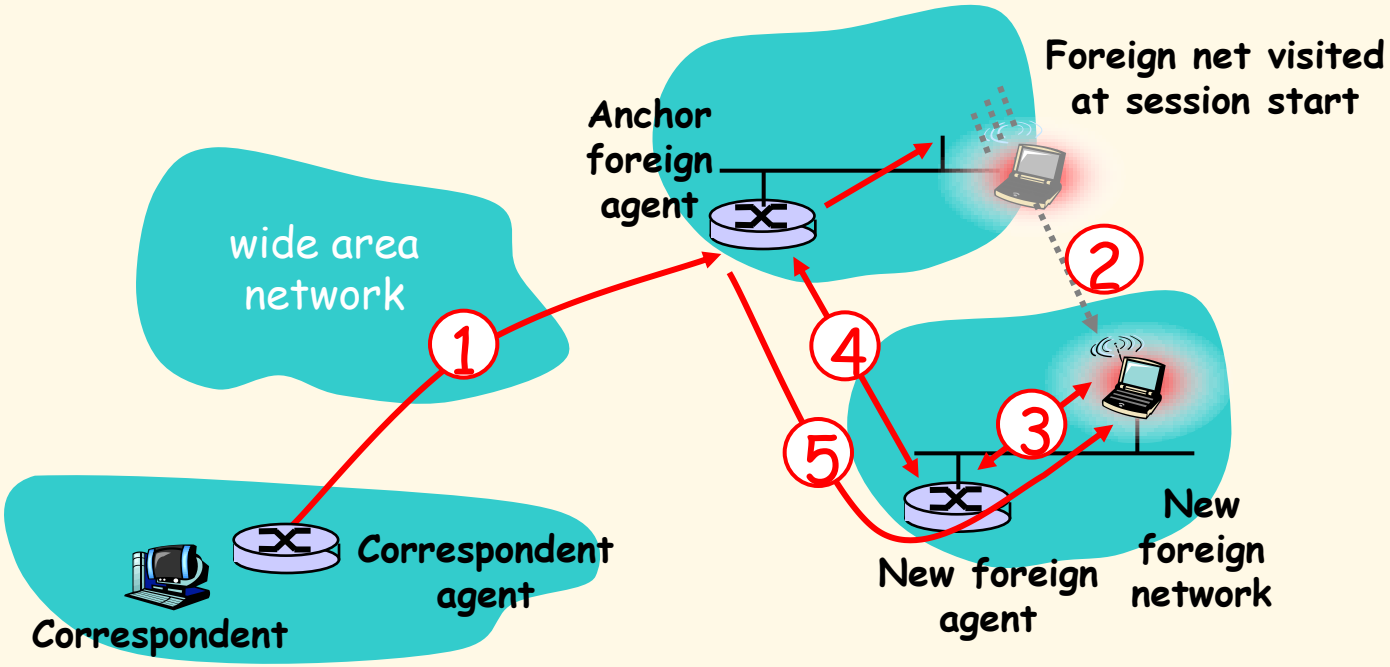
Mobility via Direct Routing

- 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