Cellular and Mobile Wireless Networks

Internet of Things

Fall 2015

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

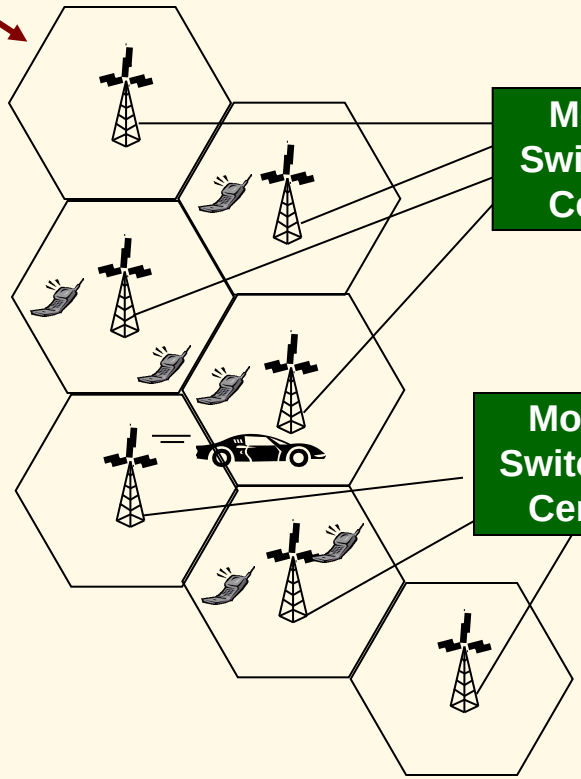
Cellular Network Architecture

MSC

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

cell

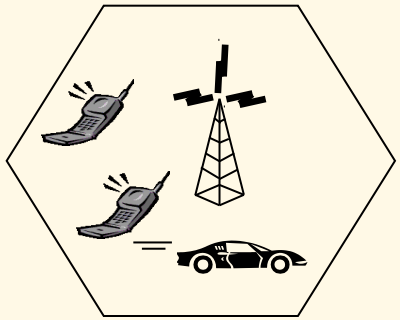
- covers geographical region
- **base station** (BS) analogous to 802.11 AP
- **mobile users** attach to network through BS
- **air-interface**: physical and link layer protocol between mobile and BS

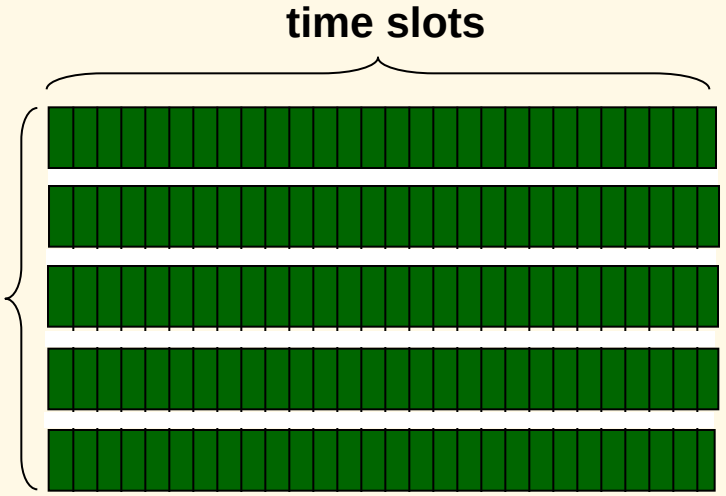


Cellular Networks: The First Hop

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.

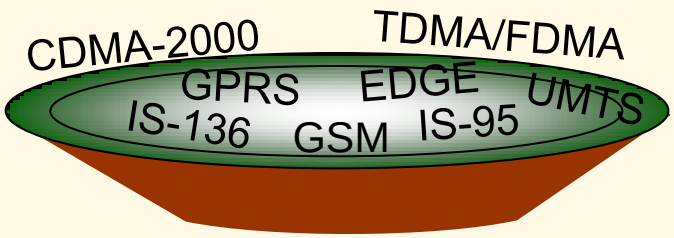




Cellular Standards: Brief Survey

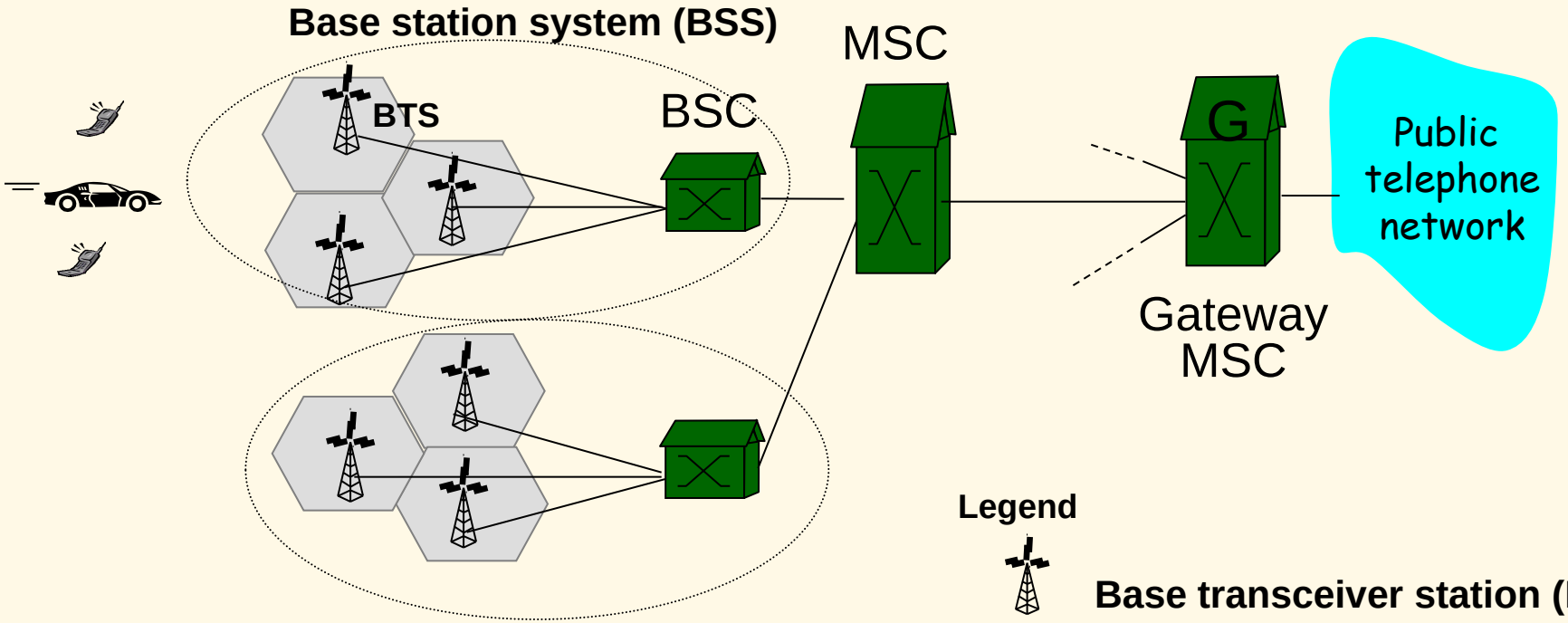
2G Systems: voice channels/digital technology

- 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

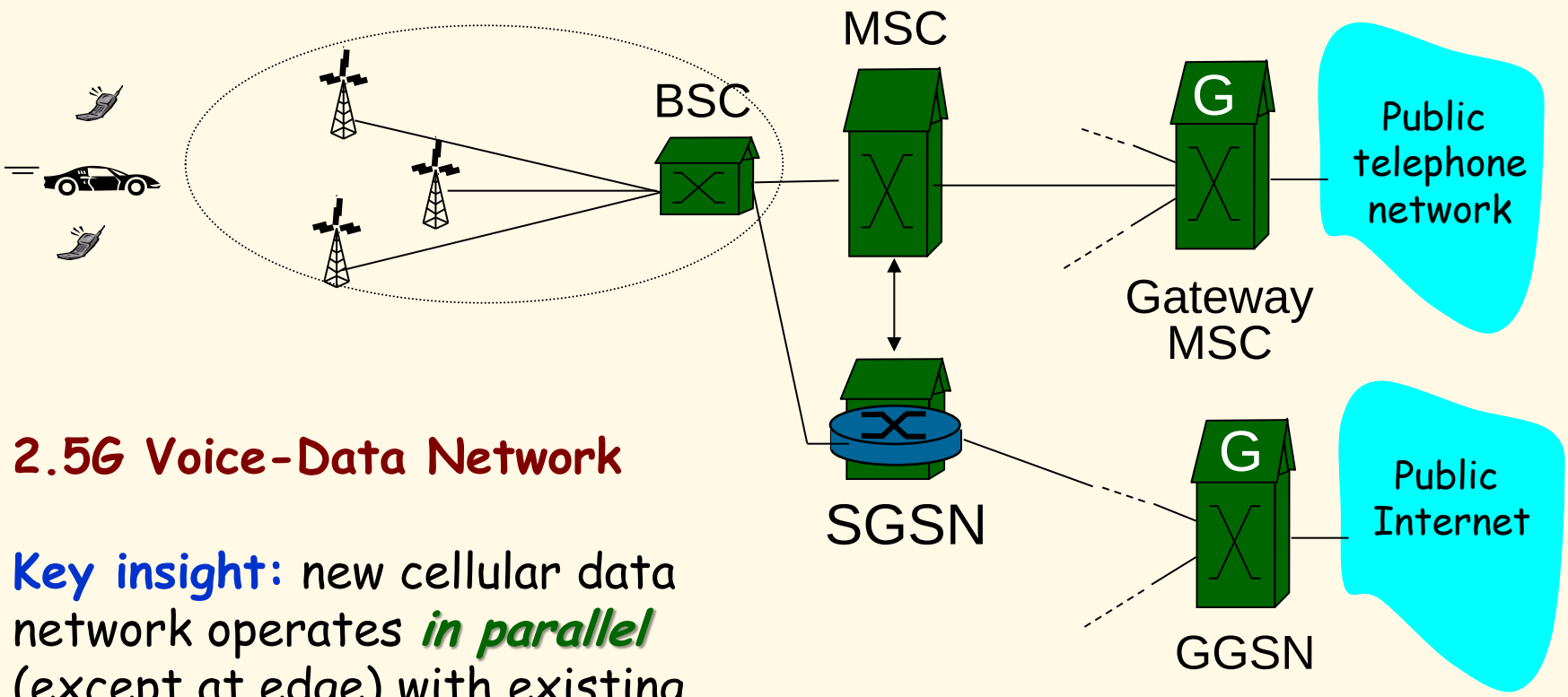
2.5G systems: voice and data channels

{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

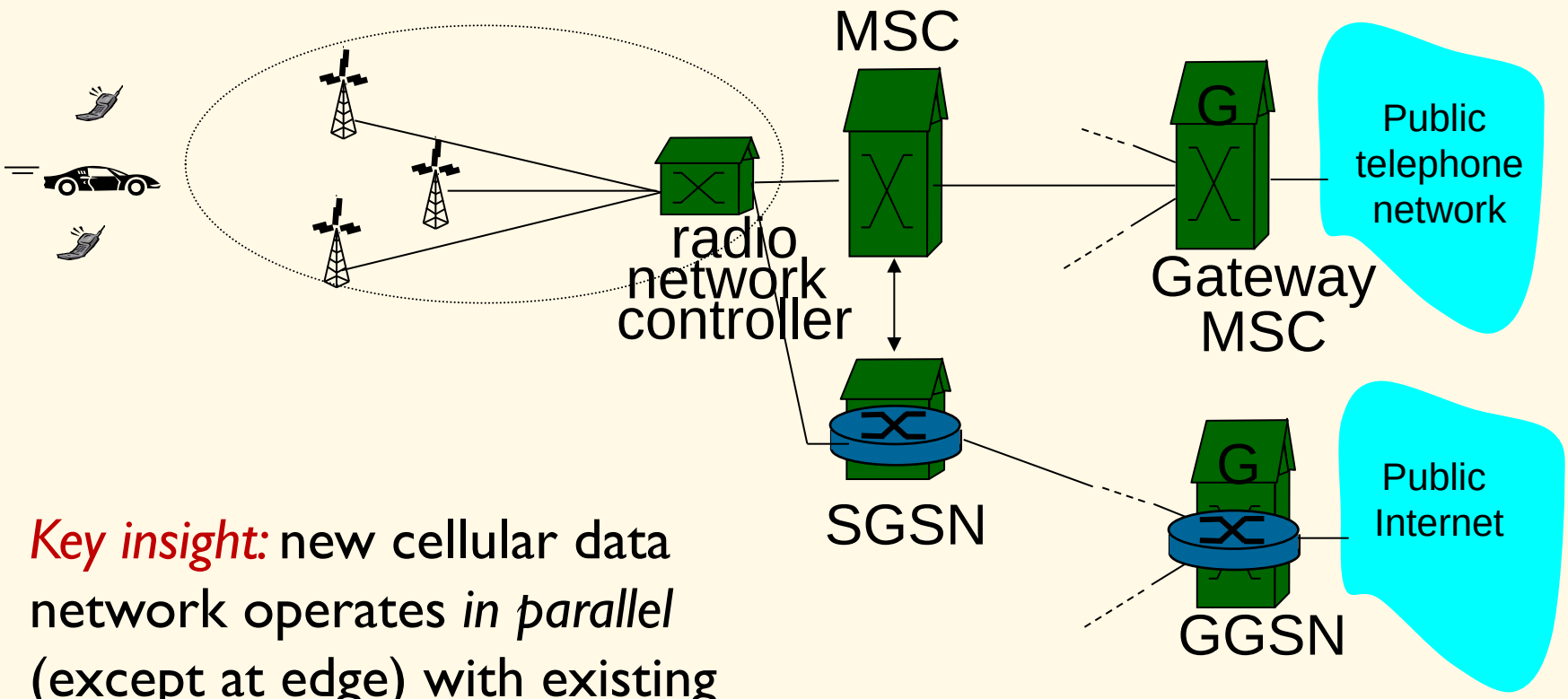


2.5G Voice-Data Network

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.

3G (Voice+Data) Network Architecture



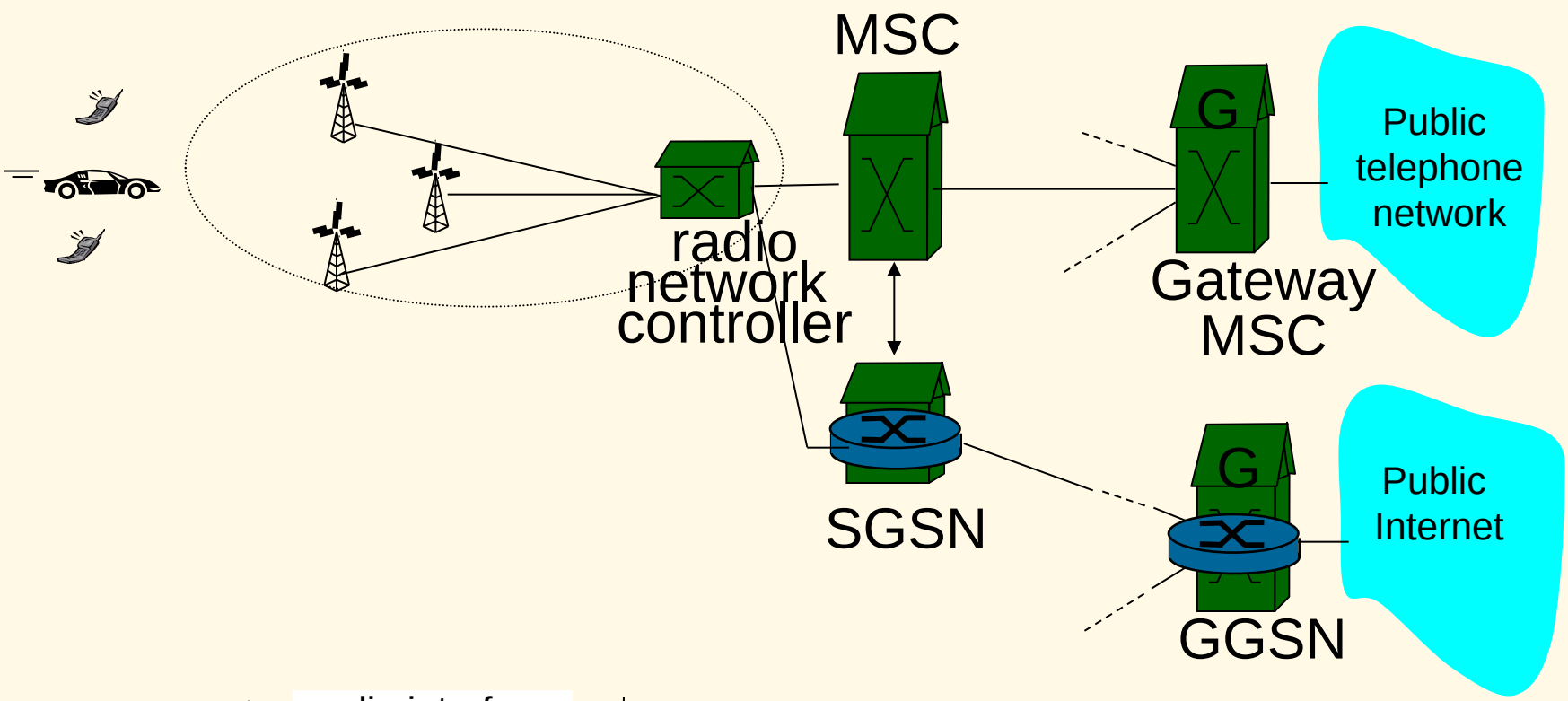
Key insight: new cellular data network operates *in parallel* (except at edge) with existing cellular voice network

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


Serving GPRS Support Node (SGSN)


Gateway GPRS Support Node (GGSN)

3G (Voice+Data) Network Architecture



radio interface
(WCDMA, HSPA)

radio access network
Universal Terrestrial Radio Access Network (UTRAN)

core network
General Packet Radio Service (GPRS) Core Network

public Internet

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 Downlink/Uplink 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.

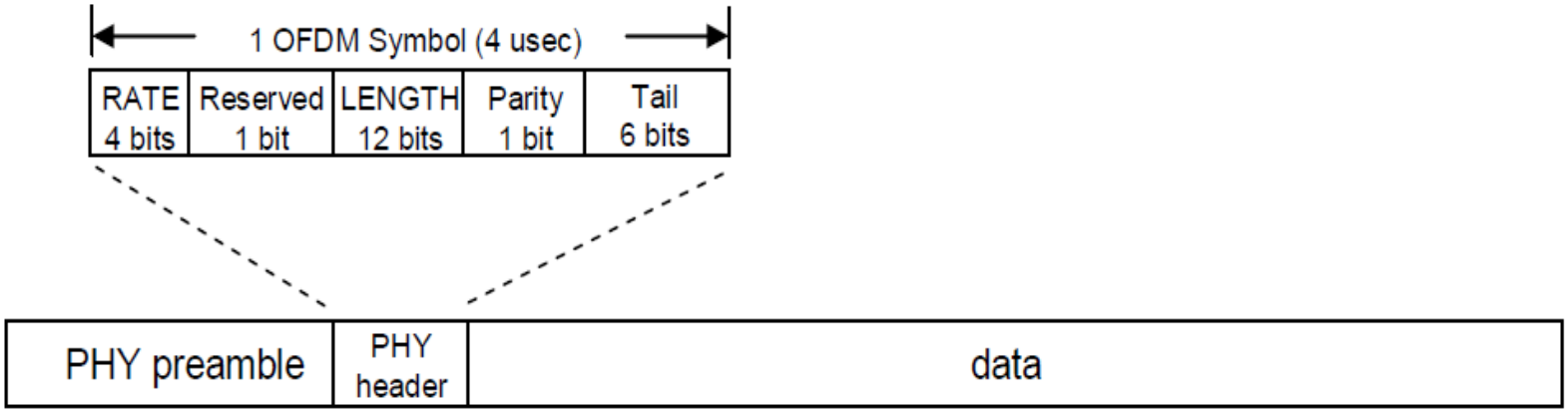
EVDO DRC Table

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)

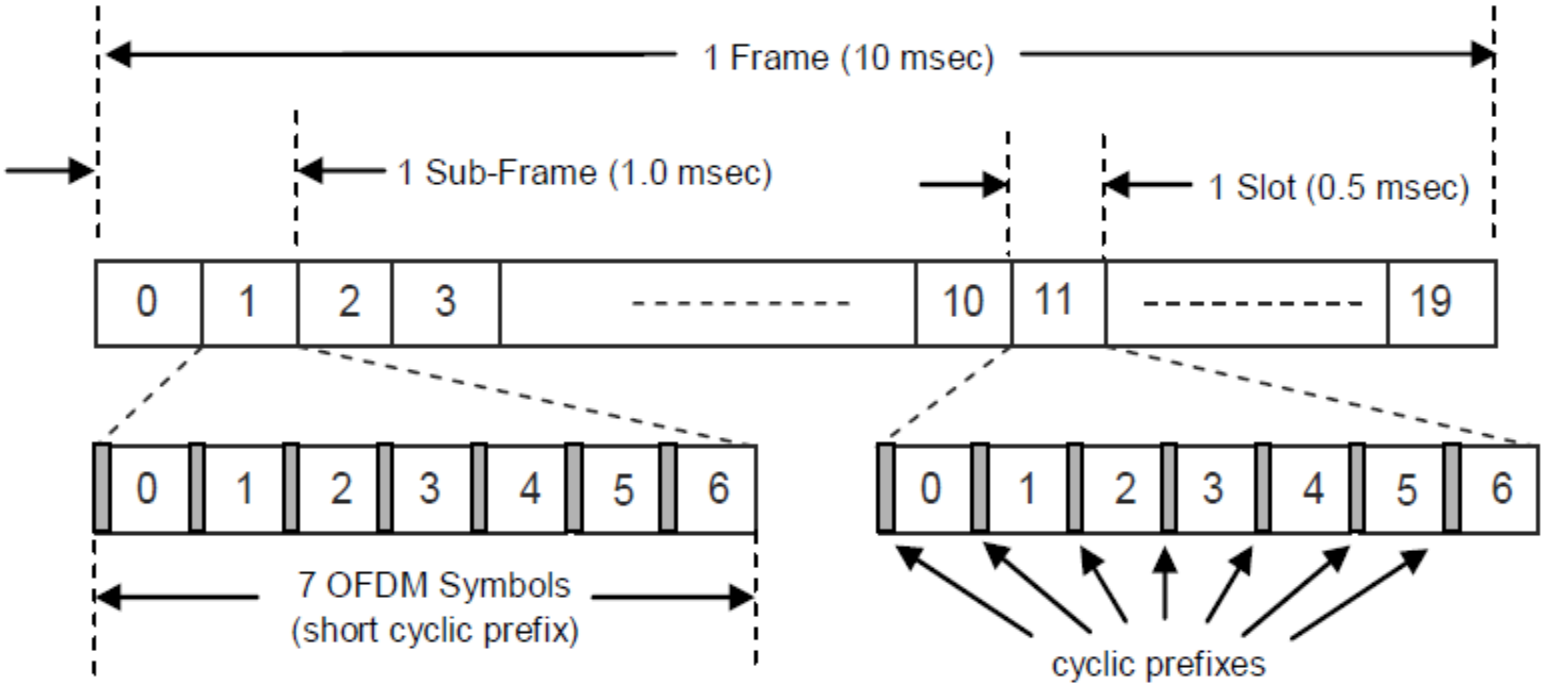
4G LTE == 3GPP LTE

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

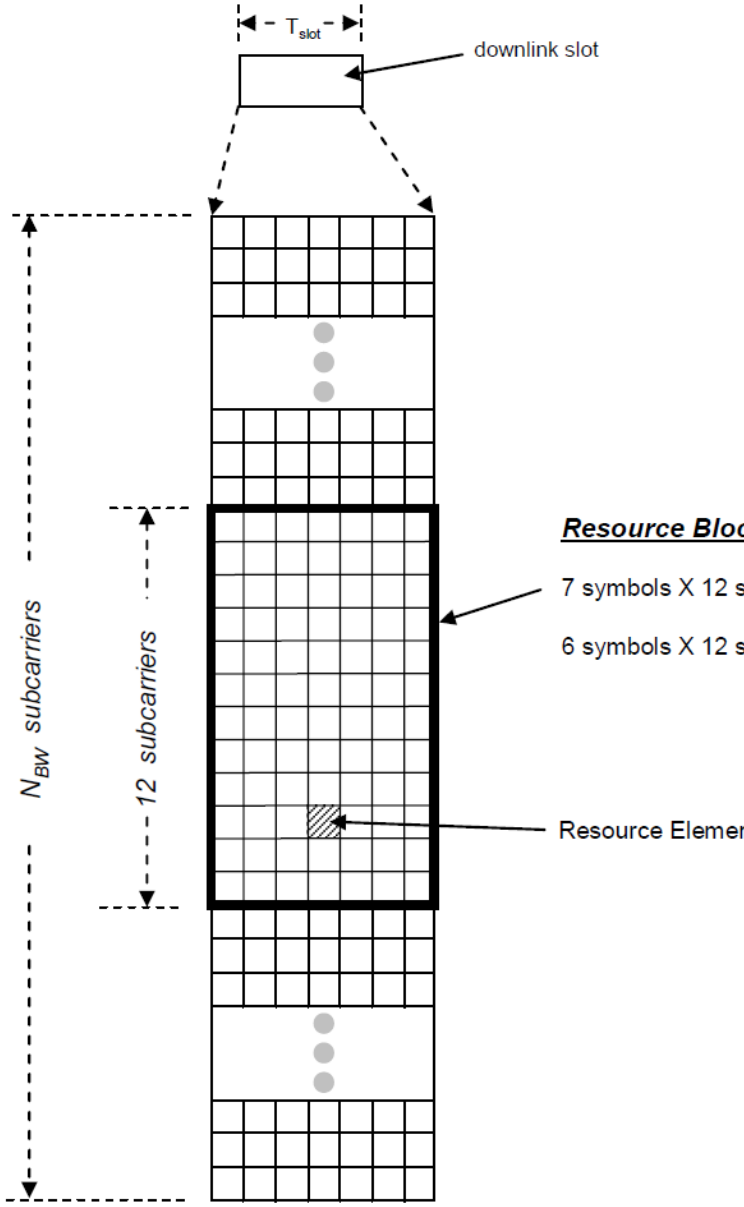
LTE Physical Resource Block (PRB)

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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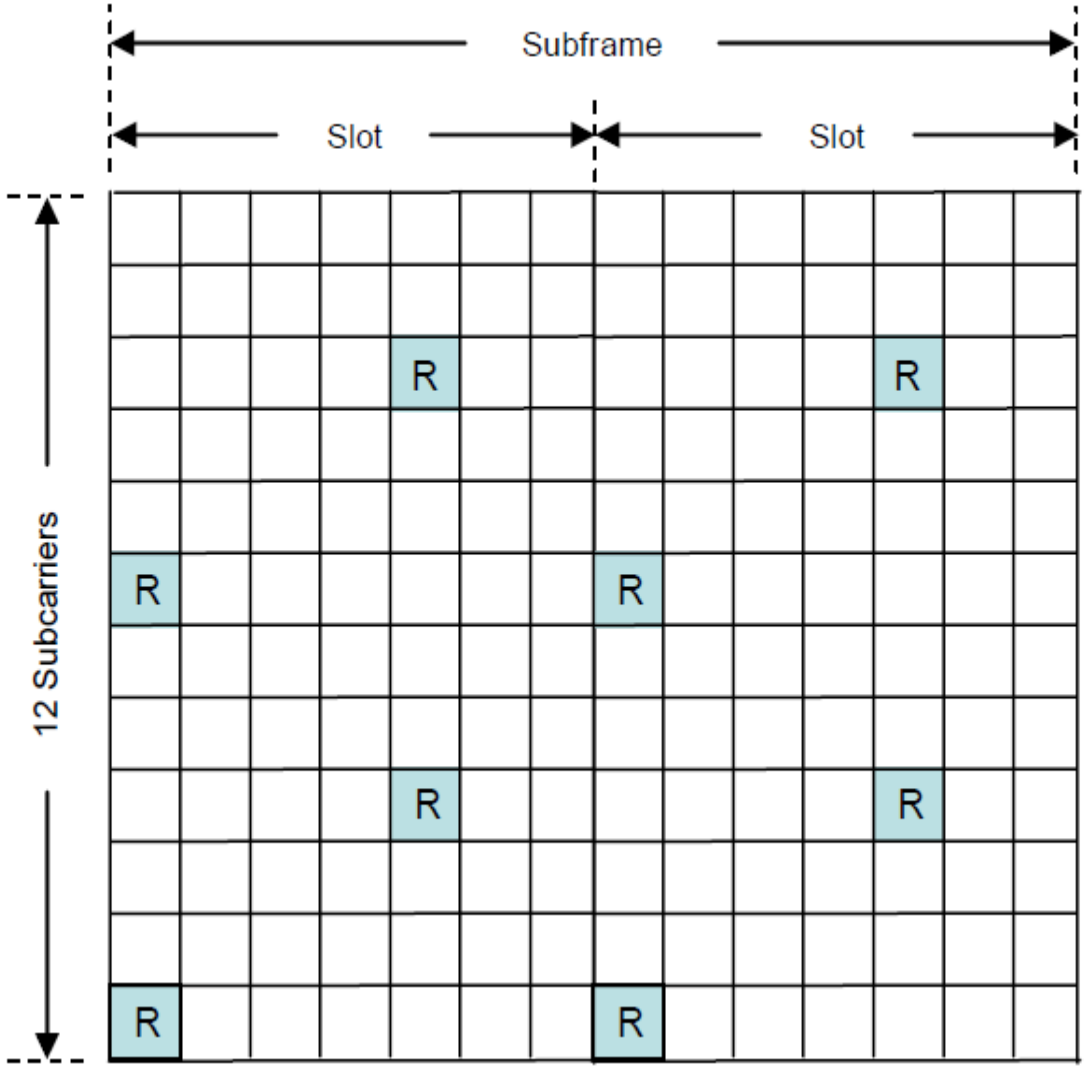
LTE Reference Symbols

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

LTE also employs MIMO.



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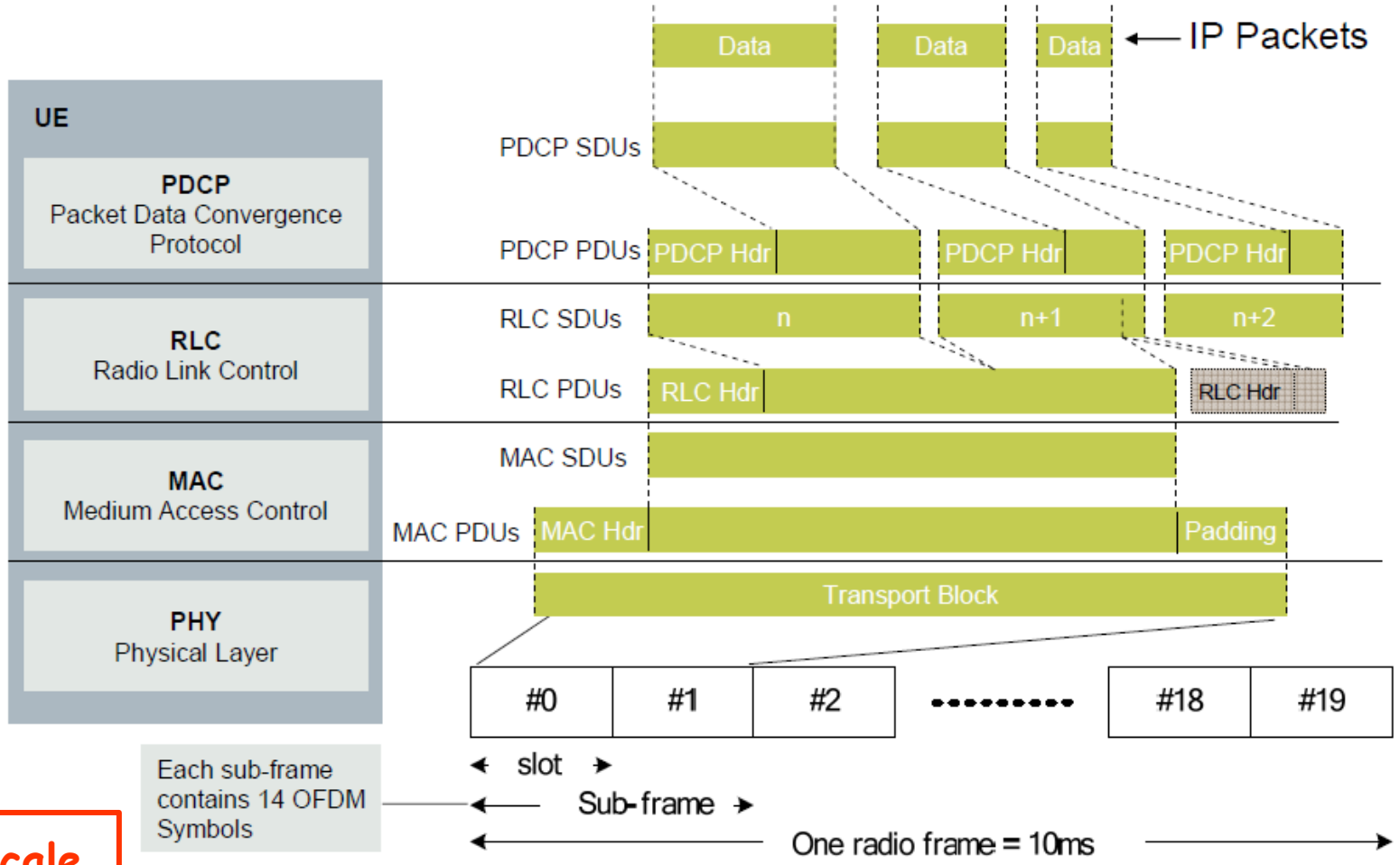
LTE Layer 2

Figure 2.2. Time domain view of the LTE downlink

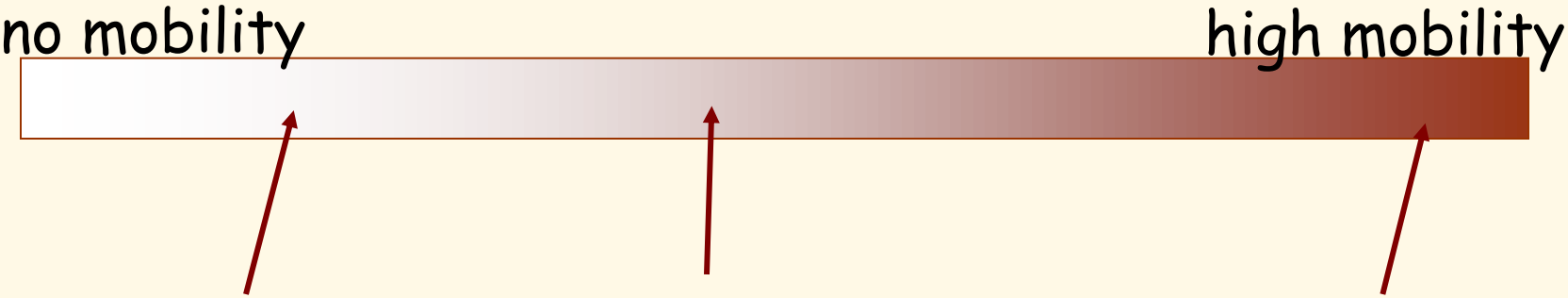


Freescale

Mobile Wireless Networks

What is Mobility?

Spectrum of mobility, from the network layer perspective:



Human Analogy: How to Contact a Mobile Friend ?

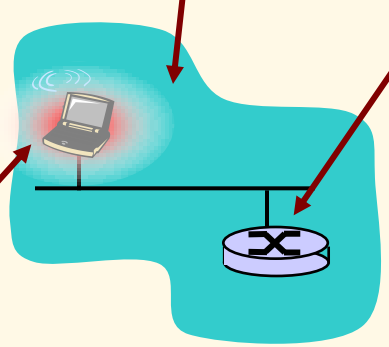
Consider a friend frequently changing residence addresses. How do you find her?

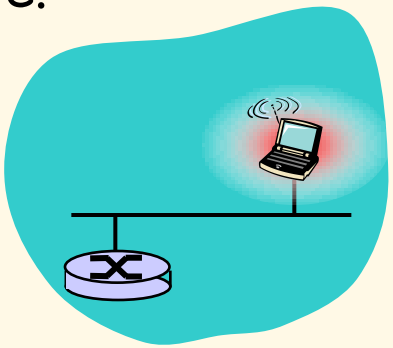
- Search all phone books?
- Call her parents or her friends?
- Expect her to let you know where he/she now lives?

Mobile Network Architecture

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

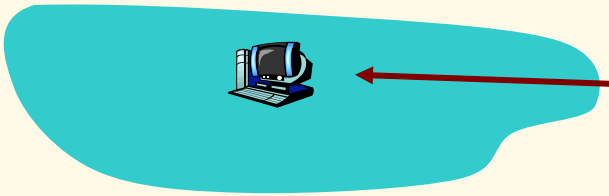
Home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote.





wide area network

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



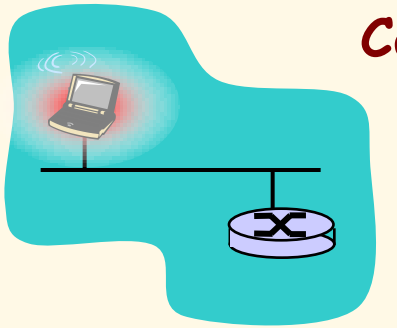
Correspondent: wants to communicate with mobile node.

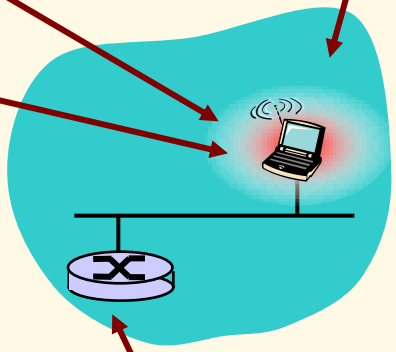
More Mobility Vocabulary

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

Correspondent

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.

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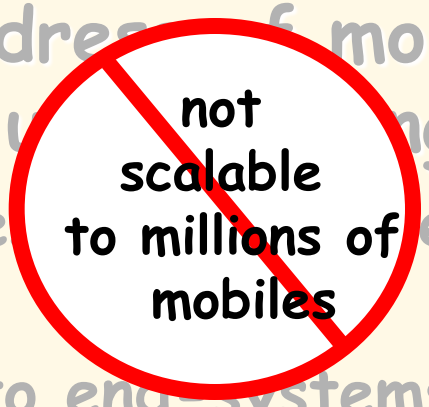

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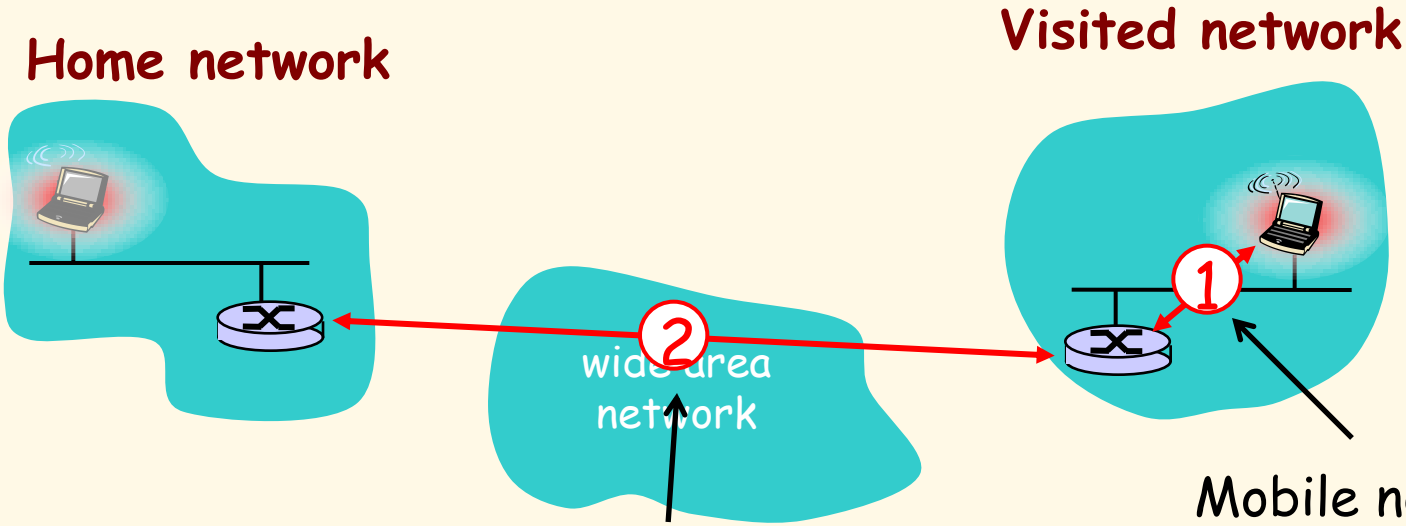
Mobility Registration



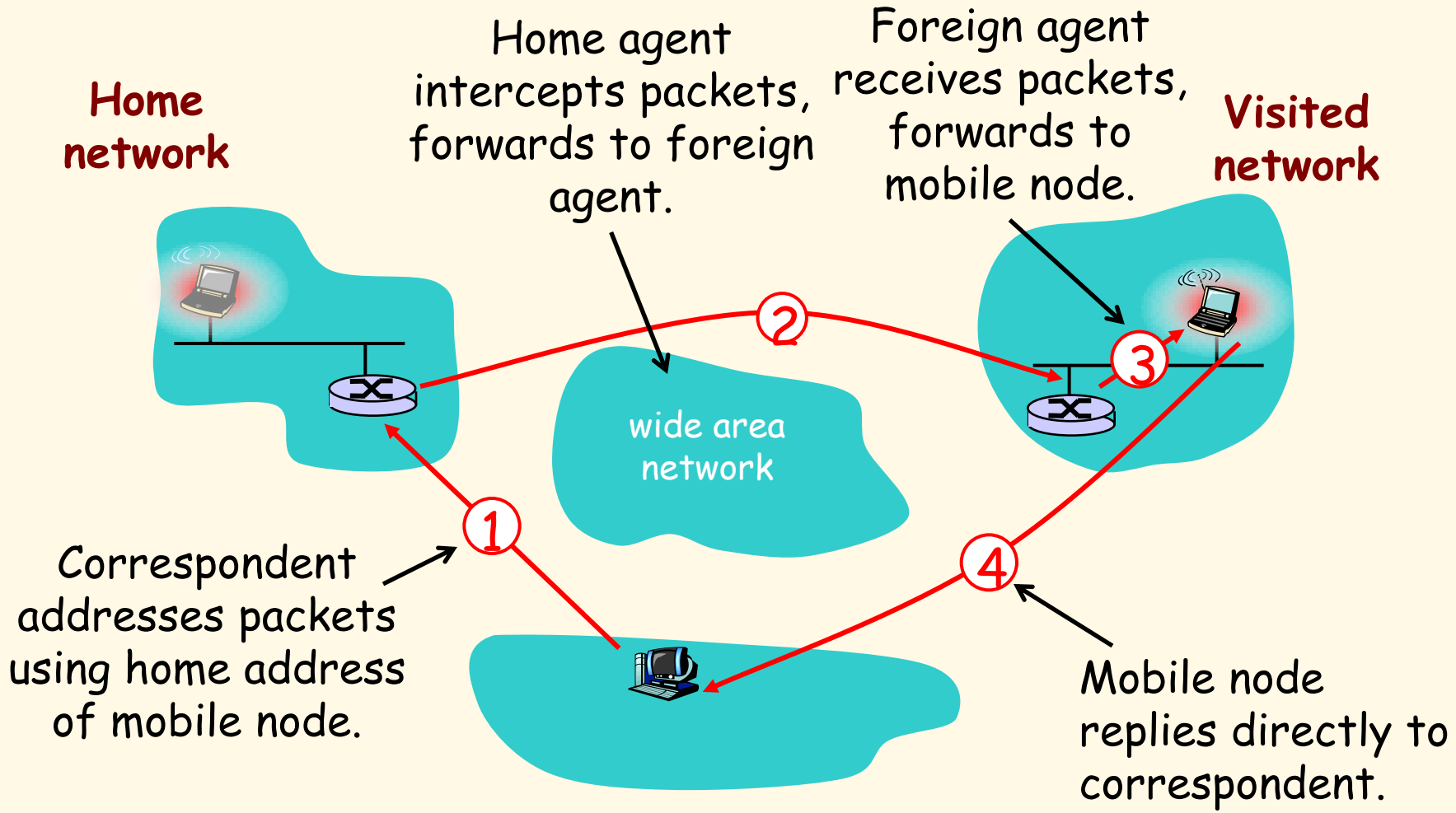
Foreign agent contacts home agent home: "This mobile node is resident in my network".

Mobile node contacts foreign agent upon entering visited network.

End result:

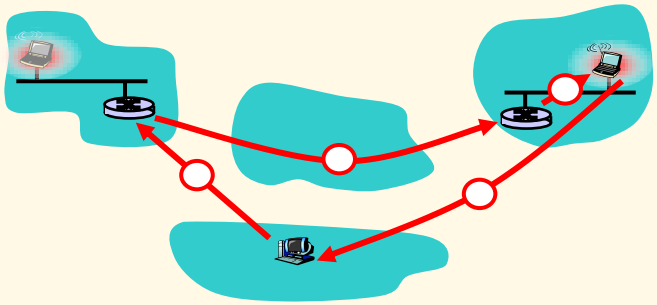
- Foreign agent knows about mobile node.
- Home agent knows location of mobile node.

Mobility via Indirect Routing



Indirect Routing

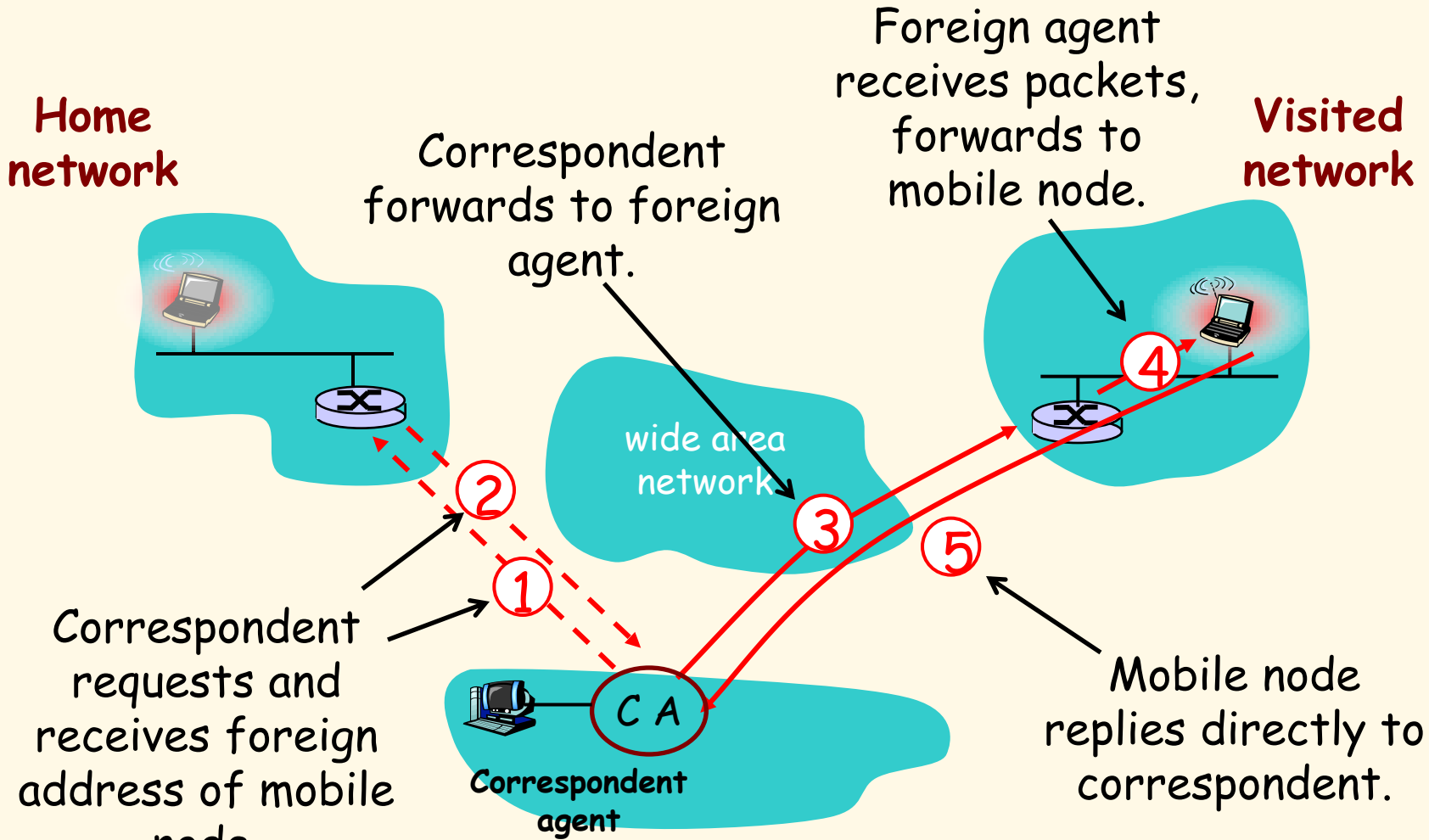
- Mobile uses two addresses:
  - permanent address: used by correspondent (Hence, mobile location is *transparent* to correspondent.)
  - care-of-address: used by home agent to forward datagrams to mobile node via foreign agent.
- Foreign agent functions may be done by mobile node itself (e.g., use DHCP).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



Indirect Routing
Moving between Networks

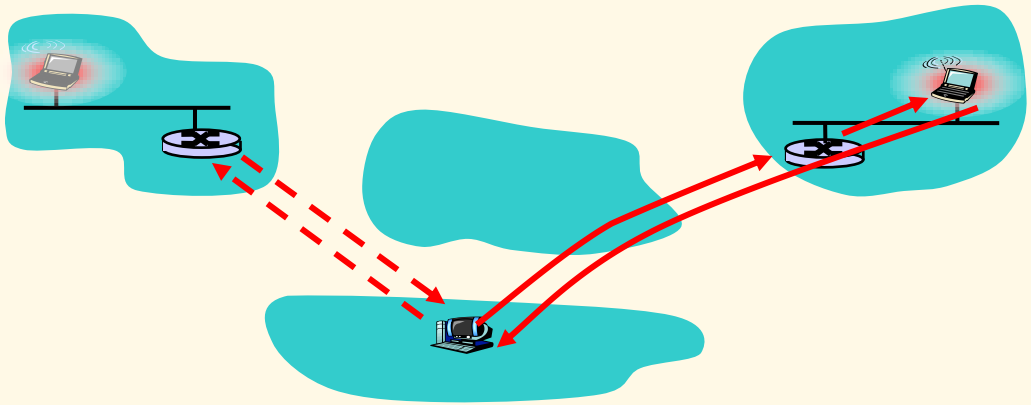
- Suppose the mobile node moves to another network:
  - registers with new foreign agent.
  - new foreign agent registers with home agent.
  - home agent updates COA for mobile node.
  - packets continue to be forwarded to mobile node (but with new care-of-address).
- Mobility involving multiple foreign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



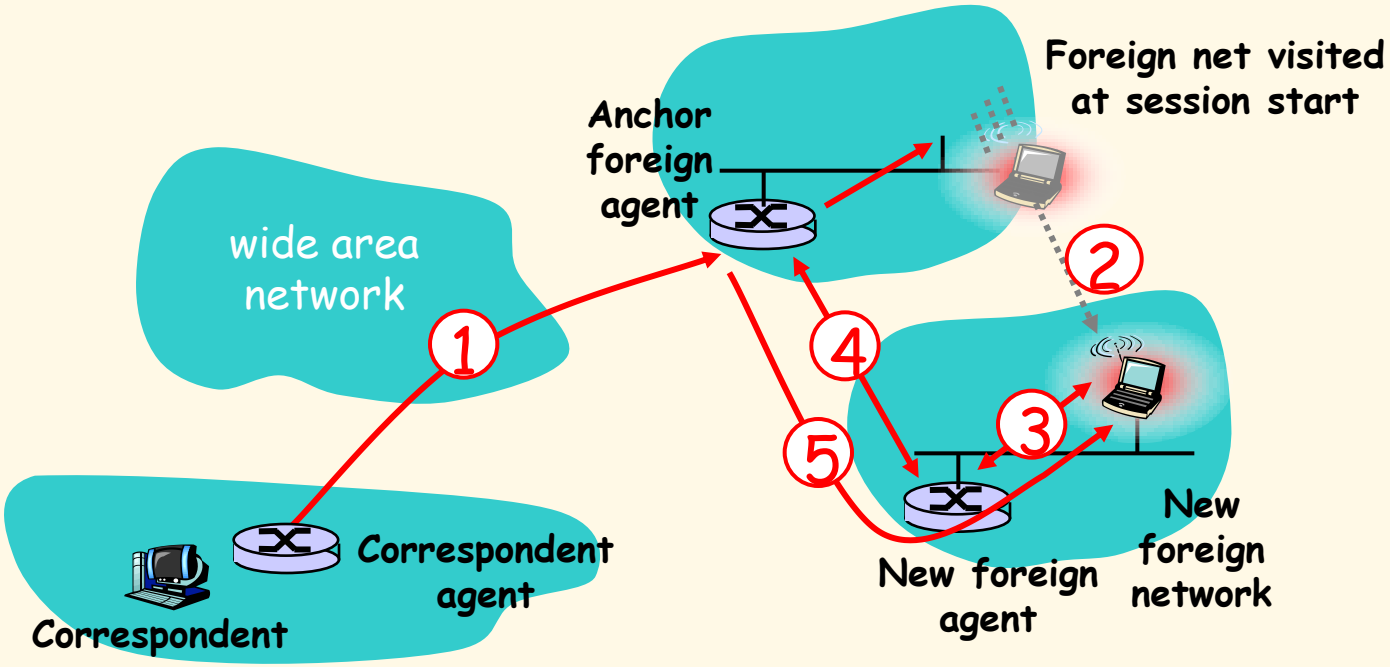
Mobility via Direct Routing

- 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