Introduction

Reference

1 Wireless and Mobile Network Architectures，Yi-Bing Lin and Imrich Chlamtac，Wiley Computer Publishing。

Outline

- Introduction
- PCS Architecture
- Cellular Telephony
- Cordless Telephony and Low-Tier PCS
- Summary

Introduction

Personal Communications Services

- Personal Communications Services (PCS) refers to a wide variety of wireless access and personal mobility services.
- PCS systems can connected to Public Switched Telephone Network (PSTN).
- Goal of PCS： enabling communications with a person at anytime, at any place and in any terminal form.

Examples of Wireless Communications Systems (1/4)

- High-tier digital cellular systems
- For vehicular and pedestrian services
  - Global System for Mobile Communication (GSM), Digital Communication System-1800 (DCS1800)
  - IS-136 TDMA based Digital Advanced Mobile Phone Service (DAMPS)
  - Personal Digital Cellular (PDC)
  - IS-95 CDMA-based cdmaOne System

Examples of Wireless Communications Systems (2/4)

- Low-tier telecommunication systems
- For residential, business, and public cordless access applications
  - Cordless Telephone 2 (CT2)
  - Digital European Cordless Telephone (DECT)
  - Personal Access Communications Systems (PACS)
  - Personal Handy Phone System (PHS)

Examples of Wireless Communications Systems (3/4)

- Wideband wireless systems
- To accommodate Internet and multimedia services.
  - cdma2000 (evolved from cdmaOne)
  - W-CDMA (proposed by Europe)
  - TD-SCDMA (proposed by China/Europe)

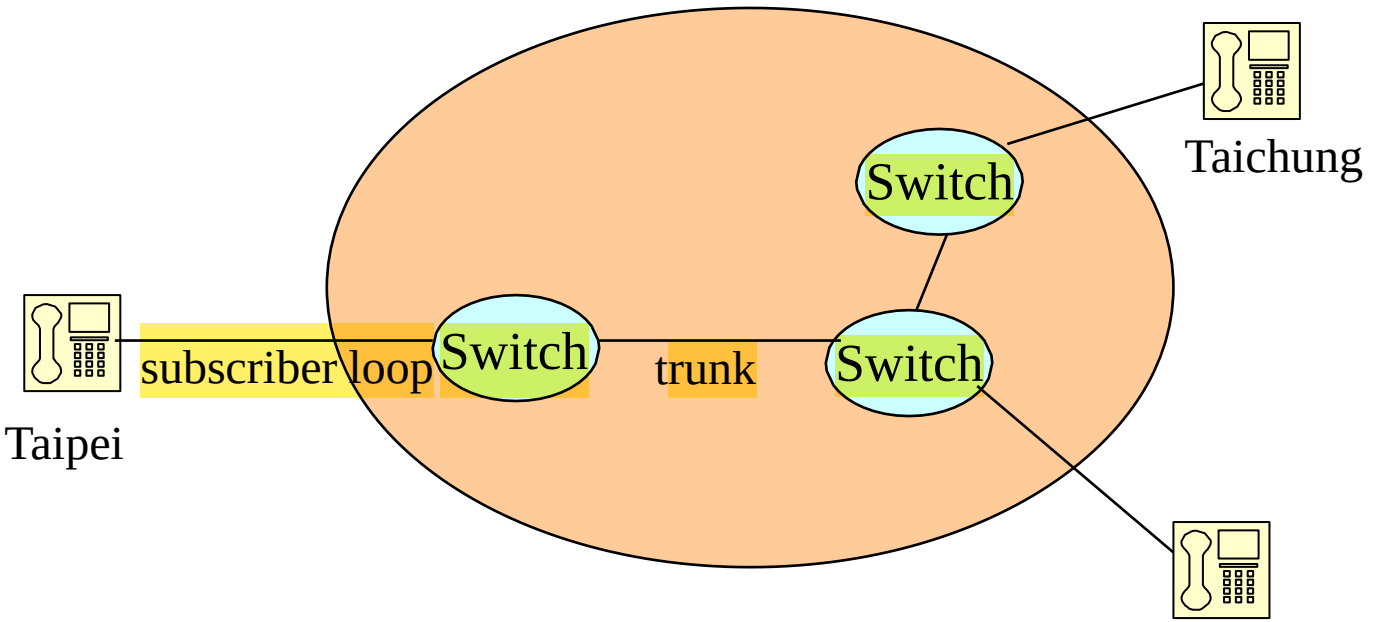
Examples of Wireless Communications Systems (4/4)

- PCS umbrella
  - Paging systems
  - Trunking Radio
  - Mobile-satellite system
  - Unlicensed industrial, scientific, and medical （ISM）band technologies, as well as wireless local area networks（WLANs）

PCS Architecture

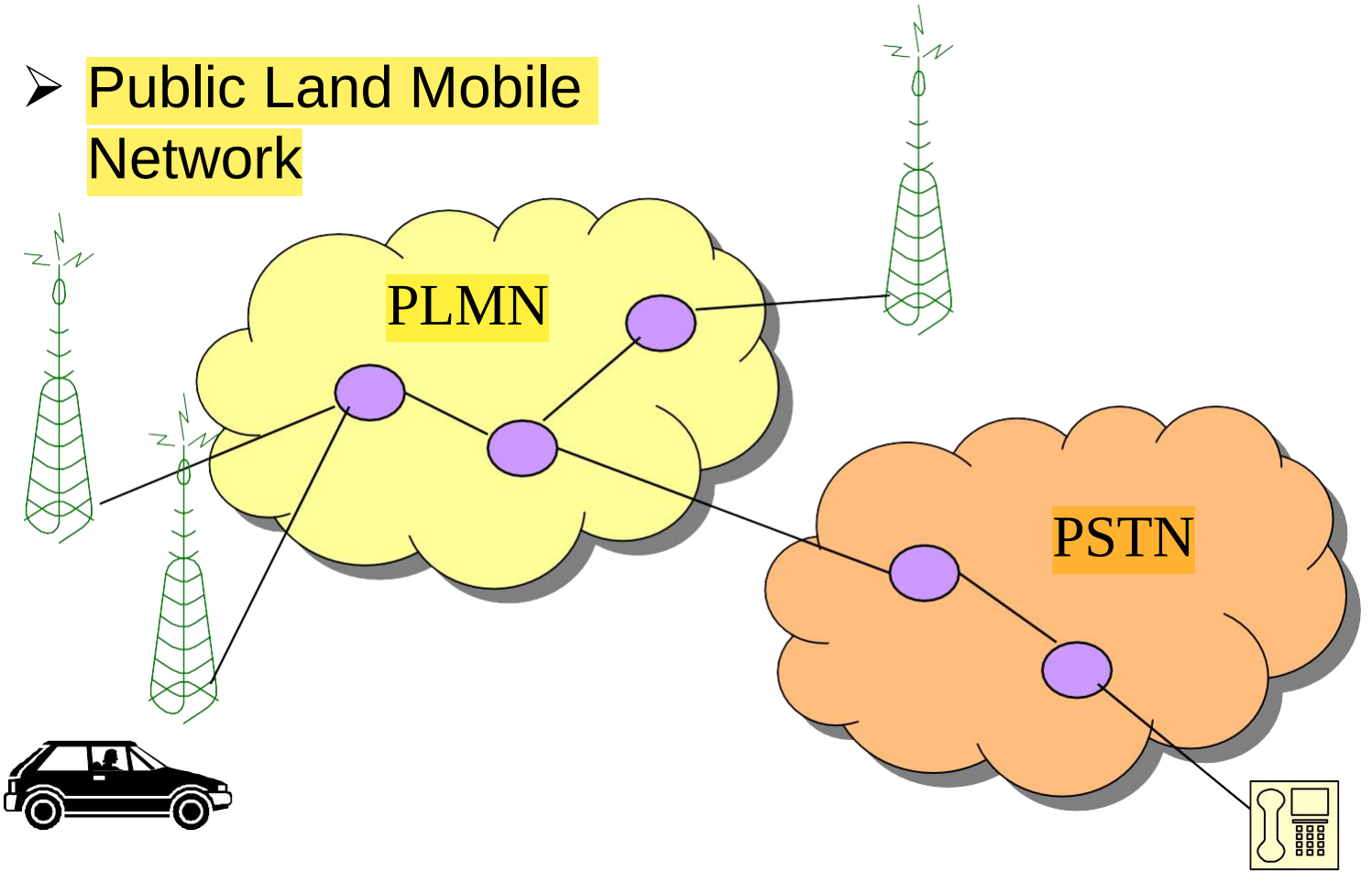
PSTN

- Public Switched Telephone Network

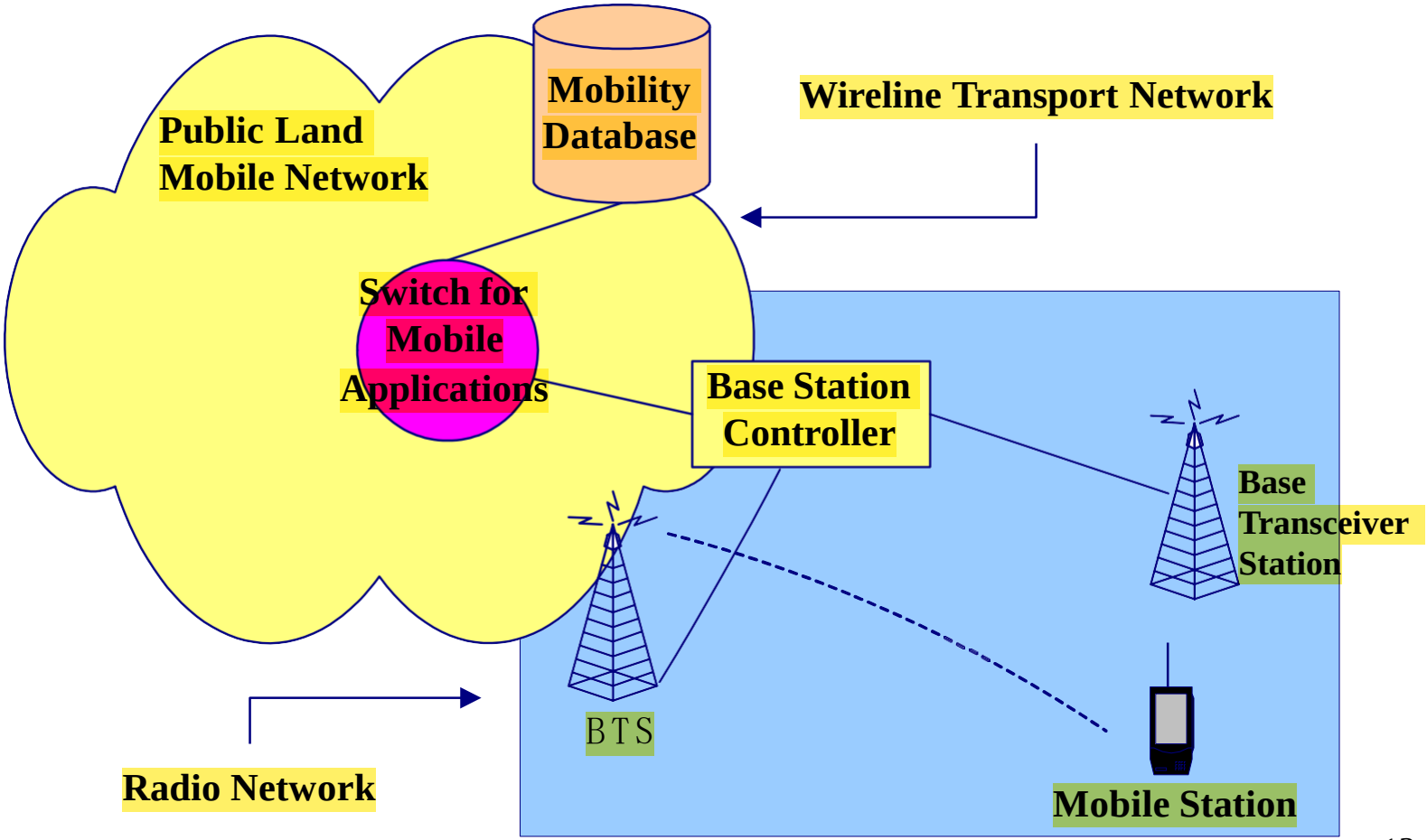


PLMN

- Public Land Mobile Network



The Basic PCS Architecture



PCS Architecture

- Each PCS technology has similar architectures which consists two parts：
  - Radio Network
    - ✓MS (Mobile Station)
    - ✓BS (Base Station) System
  - Wireline Transport Network
    - ✓MSC (Mobile Switching Center)
    - ✓The Mobility Database connected to MSC is used to track the locations of mobile station.

Mobile Station (MS)

- Handset, mobile phone, subscriber unit, portable
- Multi-mode handset

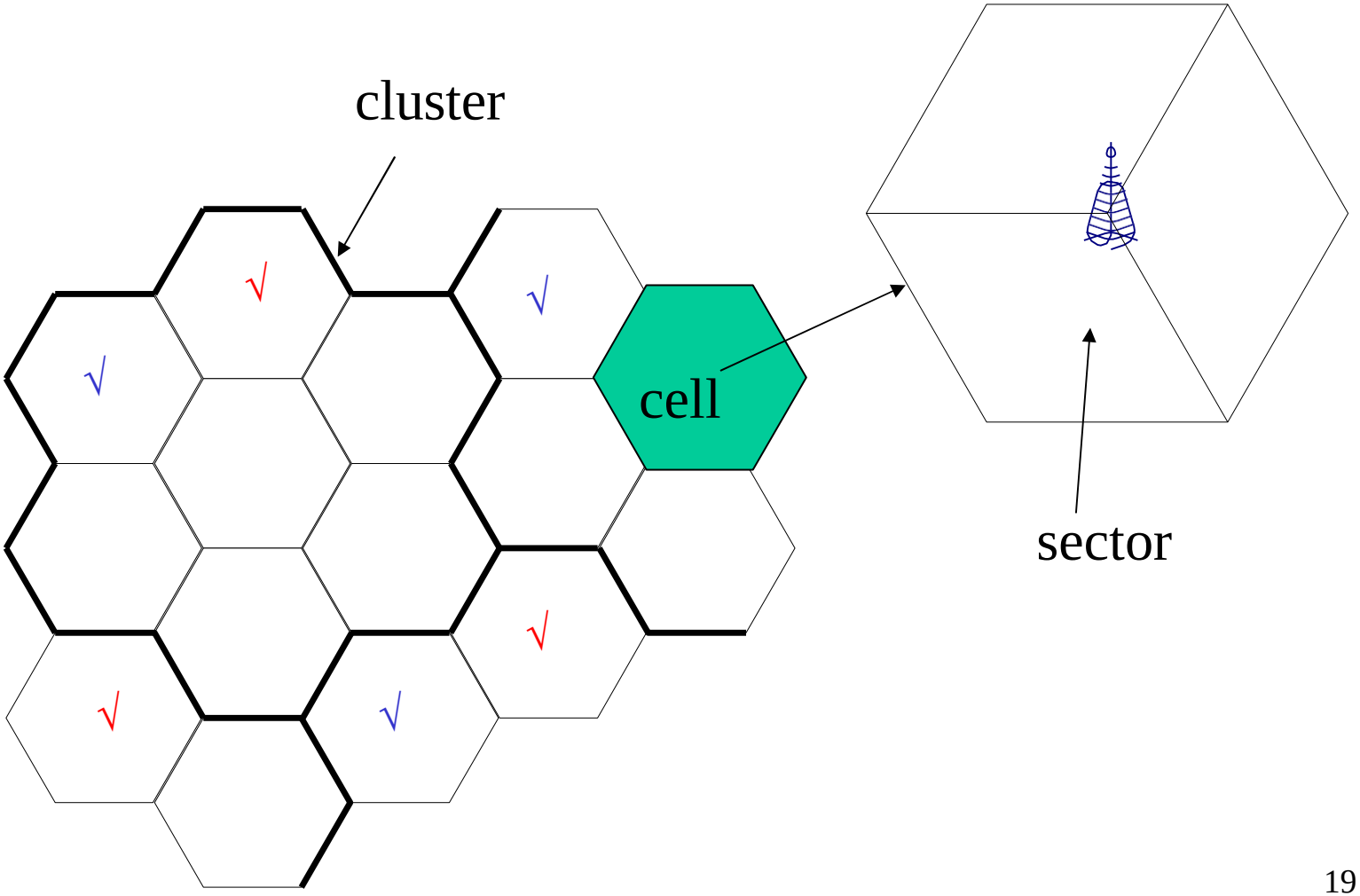
Base Station (BS)

- The radio coverage of a BS is called a Cell.
- The BS system is partitioned into
  - a controller
  - radio transmitters/receivers
- The BSs usually reach the wireless core network via land links or dedicated microwave links.

GSM Antenna

GSM Base Station

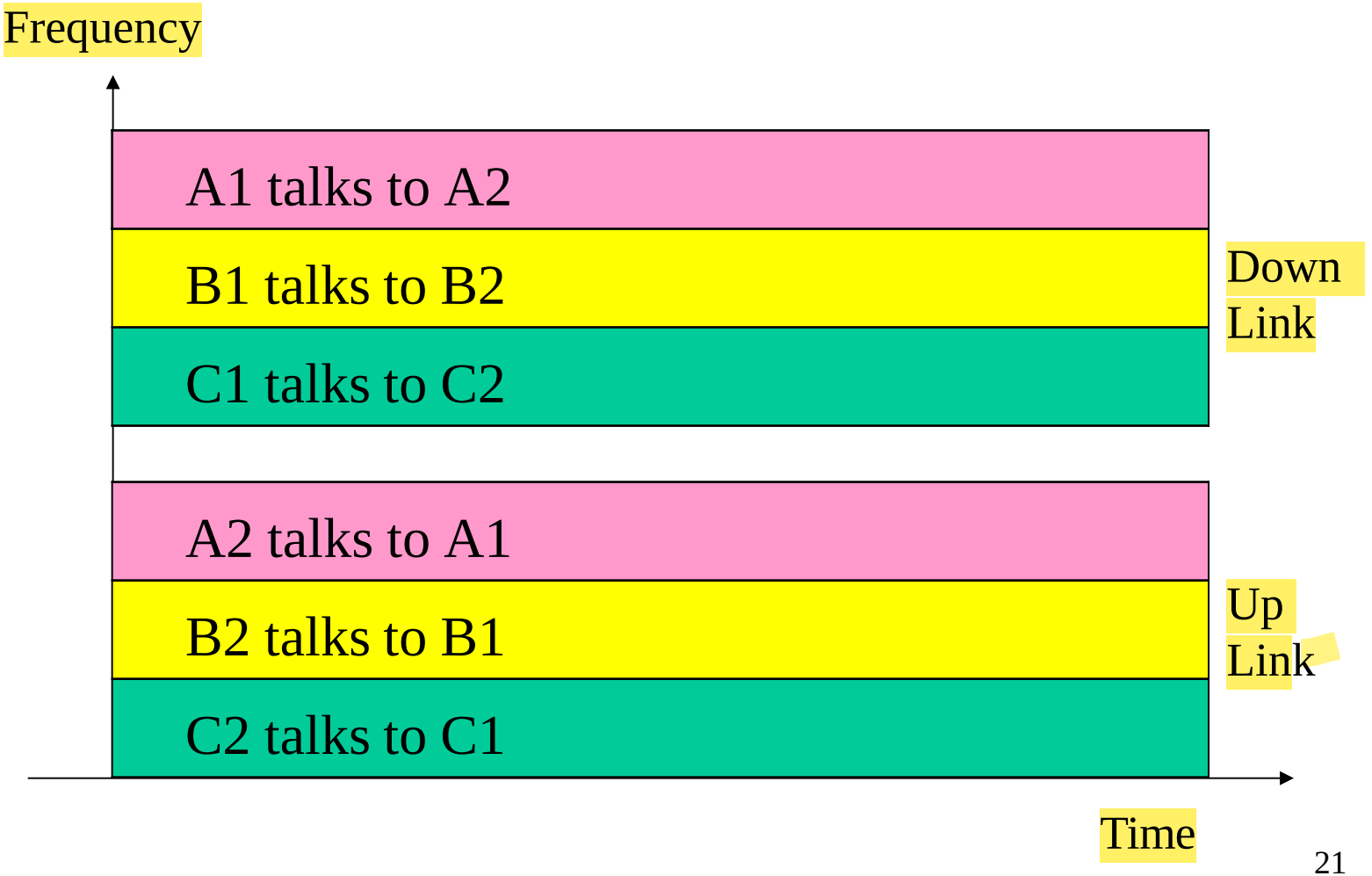
Cellular Concept



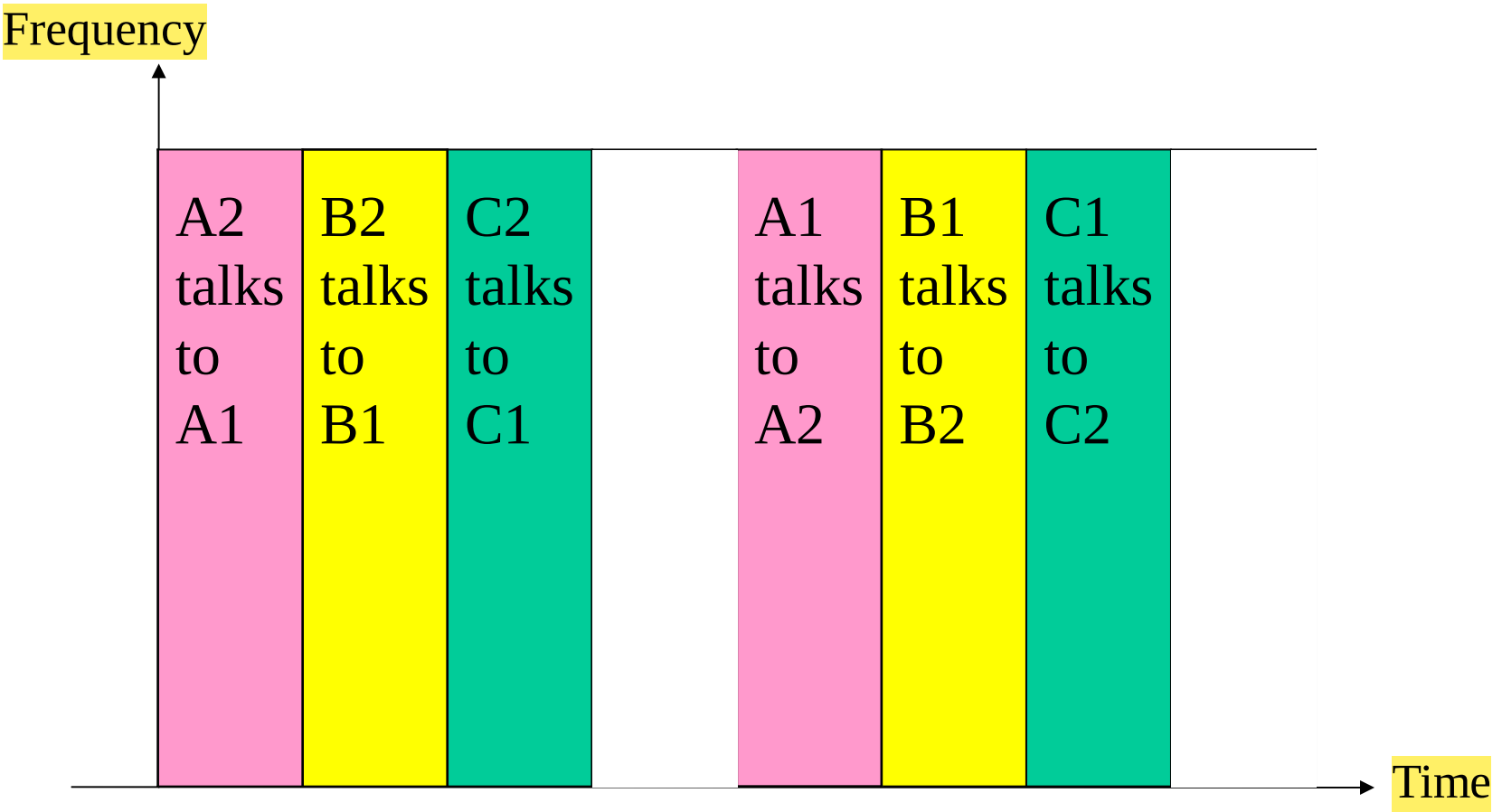
Duplex Technologies

- Down-link: BS to handset
- Up-link: handset to BS
- Two duplex Technologies:
  - FDD（Frequency Division Duplex）
  - TDD（Time Division Duplex）

FDD


Frequency
A1 talks to A2
B1 talks to B2
C1 talks to C2
Down Link
A2 talks to A1
B2 talks to B1
C2 talks to C1
Up Link
Time

TDD

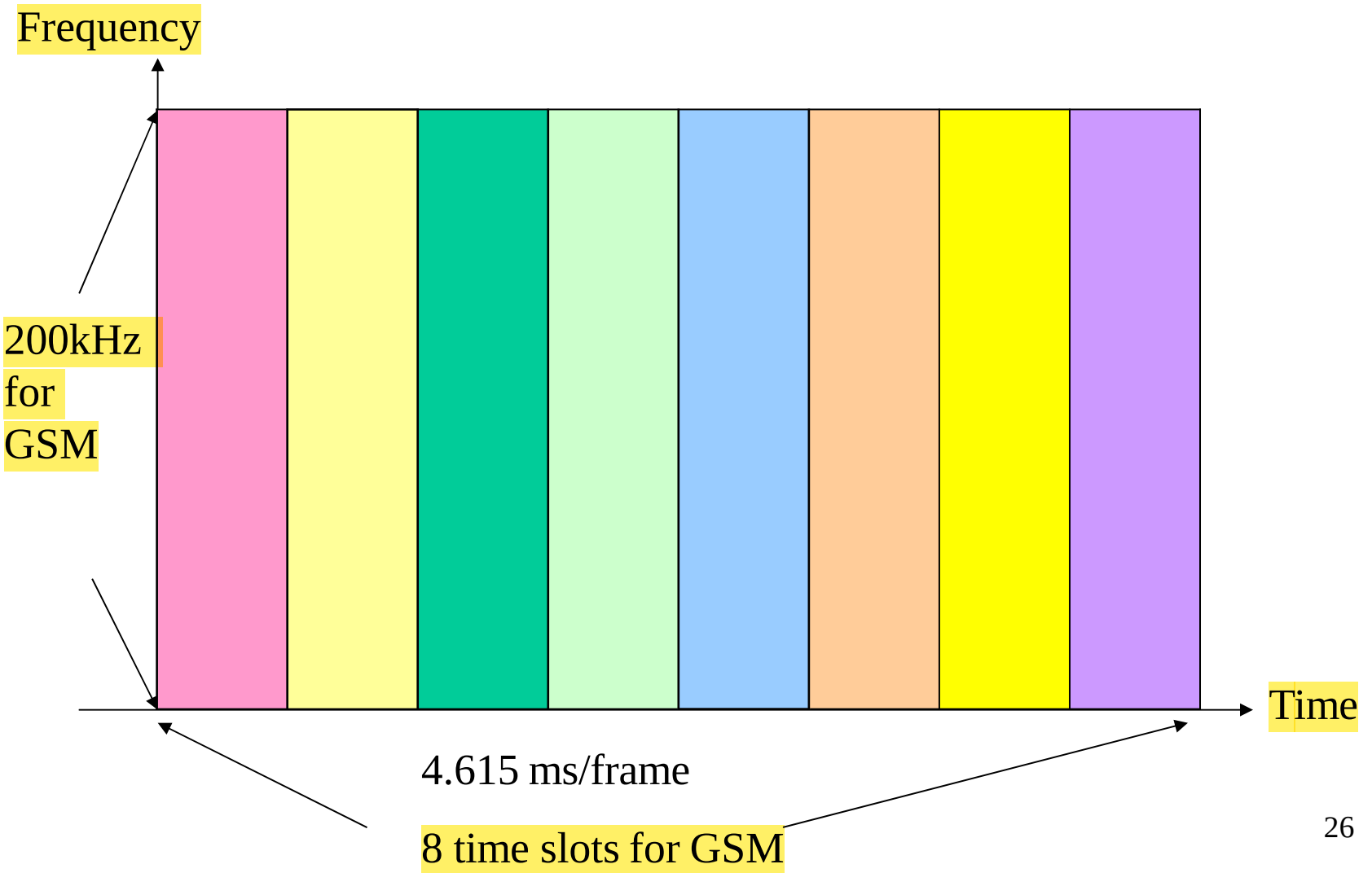

Frequency
A2 talks to A1
B2 talks to B1
C2 talks to C1
A1 talks to A2
B1 talks to B2
C1 talks to C2
Time

Multiple Access Technology

- FDMA（Frequency Division Multiple Access）
- TDMA（Time Division Multiple Access）
- CDMA（Code Division Multiple Access）

FDMA

TDMA


Frequency
200kHz
for
GSM
Time
4.615 ms/frame
8 time slots for GSM

Cellular Telephony

1G Cellular Telephony

- Advanced Mobile Phone Service (AMPS)
- Total Access Communication System (TACS)
- NMT (Nordic Mobile Telephone) 450/900
- NTT (Nippon Telephone & Telegraph) , JTACS (1988), NTACS (1993)
- C450

Advanced Mobile Phone Service (AMPS) (1/2)

- Analog FM radio for voice transmission
- FSK modulation for signal channels
- FDMA
- FDD
- Total 50 MHz=824-849 MHz(down-link) + 869-894 MHz(up-link)
  - 832 full-duplex channels using 1664 discrete frequencies
- 30kMHz spacing

Advanced Mobile Phone Service (AMPS) (2/2)

- Frequency reuse scheme for radio communication
  - 12-cell cluster using omni-directional antennas
  - 7-cell cluster using three sectors per BS
  - 4-cell cluster, 6-sector design in Motorola AMPS system. There are about 50 channels per cell.
- EIA/TIA IS-41 standard for roaming management.

2G Cellular Telephony

- Global System for Mobile Communications (GSM)
- EIA/TIA IS-136 Digital Cellular System
- EIA/TIA IS-95 Digital Cellular System
- Japanese Digital Cellular (JDC) in Japan

Global System for Mobile Communications (GSM) (1/2)

- "Digital" cellular system
  - Group Special Mobile of Conference Europeenne des Posts et Telecommunications (CEPT) and European des Postes et Telecommunications (ETSI)
- TDMA/FDD
- 935-960 MHz for Downlink
- 890-915 MHz for Uplink
- 200 kHz for RF channel spacing
- Speech coding rate 13 Kbps

Global System for Mobile Communication (GSM) (2/2)

- Frequency carrier is divided into 8 time slots
  - Every pair of radio transceiver-receiver supports 8 voice channels.
- GSM Mobile Application Part (MAP) for roaming management
- Digital switch can provide many applications:
  - Example: point-to-point short messaging, group addressing, call waiting, multiparty services

Comparison of Cellular Systems

System	AMPS	GSM DCS1800	IS-136	IS-95	JDC
Region	美	歐,台灣	美	美,韓,中國	日
Duplex	FDD	FDD	FDD	FDD	FDD
MAC	FDMA	FDMA TDMA	FDMA TDMA	FDMA CDMA	FDMA TDMA
Downlink (MHz)	870-890	935-960 1805-1880	869-894	869-894	810-826
Uplink (MHz)	825-845	890-915 1710-1785	824-849	824-849	940-956
Carrier	30kHz	200kHz	30kHz	1.25MHz	25kHz
Channels	1	8	6	32	3
Speech rate	10 kps	13 kps	7.95kps	8 kps	11.2 kps
Channel bit rate		270.833 kps	48.6 kps	1228.8 kps	42 kps

Cellular Characteristics

- The characteristics of the cellular system:
  - Support high mobility
  - Large coverage area
  - High transmission power of BS and handset
  - High signal process power (for handset)
  - Low voice quality
  - High network complexity
- Microcell is developed for:
  - Low transmission power
  - Low base station cost
  - Increase capacity

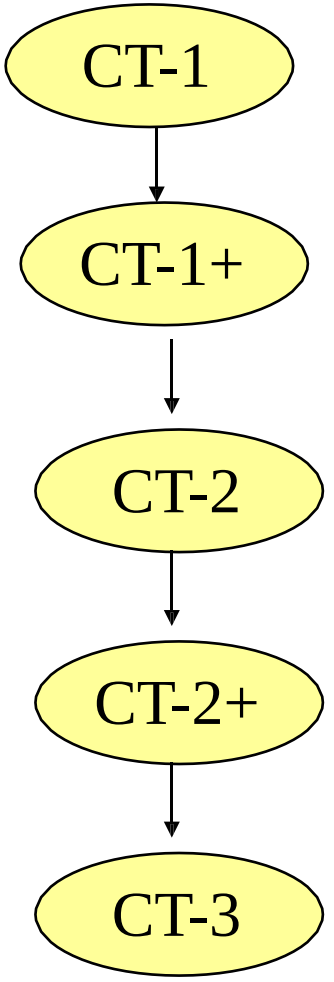
Low-Tier PCS
(2nd Generation)

Examples of Low-Tier PCS

- Cordless Telephone, Second Generation (CT2)
- Digital European Cordless Telephone (DECT)
- Personal Handy Phone System (PHS)
- Personal Access Communications System (PACS)

Cordless Telephone, Second Generation (CT2) (1/2)

- Developed in Europe since 1989.
- 40 FDMA channels
- 32-Kbps speech coding rate
- TDD
- The maximum transmit power of a CT2 handset is 10 mW



Cordless Telephone, Second Generation (CT2) (2/2)

- No handoff in CT2
- No call delivery in CT2
- In CT2+, both handoff and call delivery are OK.

Digital European Cordless Telephone (DECT) (1/2)

- Published in 1992
- TDMA/TDD
- 12 voice channels per frequency carrier
- Sleep mode is employed in DECT to conserve the power of handsets.
- 32 Kbps speech coding rate

Digital European Cordless Telephone (DECT) (2/2)

- DECT is typically implemented as a wireless-PBX connected to the PSTN.
- Dynamic channel allocation
- Time slot transfer
- Seamless handoff
- Dual mode: DECT + GSM

Personal Handy Phone System (PHS) (1/2)

- Developed by Research and Development Center (RCR), Japan 1993
- Telecommunication services for homes, offices, and outdoor environment
- TDMA/TDD
- 4 multiplexed channels/frequency carrier
- 1895-1906.1 MHz = 300 KHz ×37 channels (home/office)
- 1906.1-1918.1 MHz = 300 KHz ×40 channels (public system)

Personal Handy Phone System (PHS) (2/2)

- BS: 500 mW; handset < 10mW
- 32 Kbps speech coding rate
- Dynamic channel allocation.
- Dedicated control channels
- Sleep Mode
- J100: 7 hours talk time, 700 hours standby time, 64kbps wireless data
- Dual mode: PHS + GSM

Personal Access Communications System (PACS)

- Developed at Telcordia, U.S.A.
- PACS is designed for wireless local loop and PCS.
- TDMA
- 8 voice channels/frequency carrier
- Both TDD and FDD are accommodated.
- The highly effective and reliable mobile-controlled handoff (MCHO) completes in less than 20 msec.

Comparison of PCS Systems

System	CT-2	DECT	PHS	PACS
Region	歐,台灣	歐	日本	美
Duplex	TDD	TDD	TDD	FDD
MAC	FDMA	FDMA TDMA	FDMA TDMA	FDMA TDMA
Frequency (MHz)	864-868	1880-1900	1895-1918	1930-1990(down) 1850-1910(uplink)
Carrier	100kHz	1728kHz	300kHz	300MHz
Channels	1	24	8	8
Speech rate	32kps	32kps	32kps	32kps
Channel bit rate	72kps	1152kps	384kps	384kps

Low-tier PCS Characteristics

- The characteristics of the low-tier system:
  - Low transmission power
  - Long talk time
  - Small coverage area
  - Large no. of base station
  - Low transmission delay
  - High voice quality
  - Low mobility
  - Low network complexity
  - Low cost

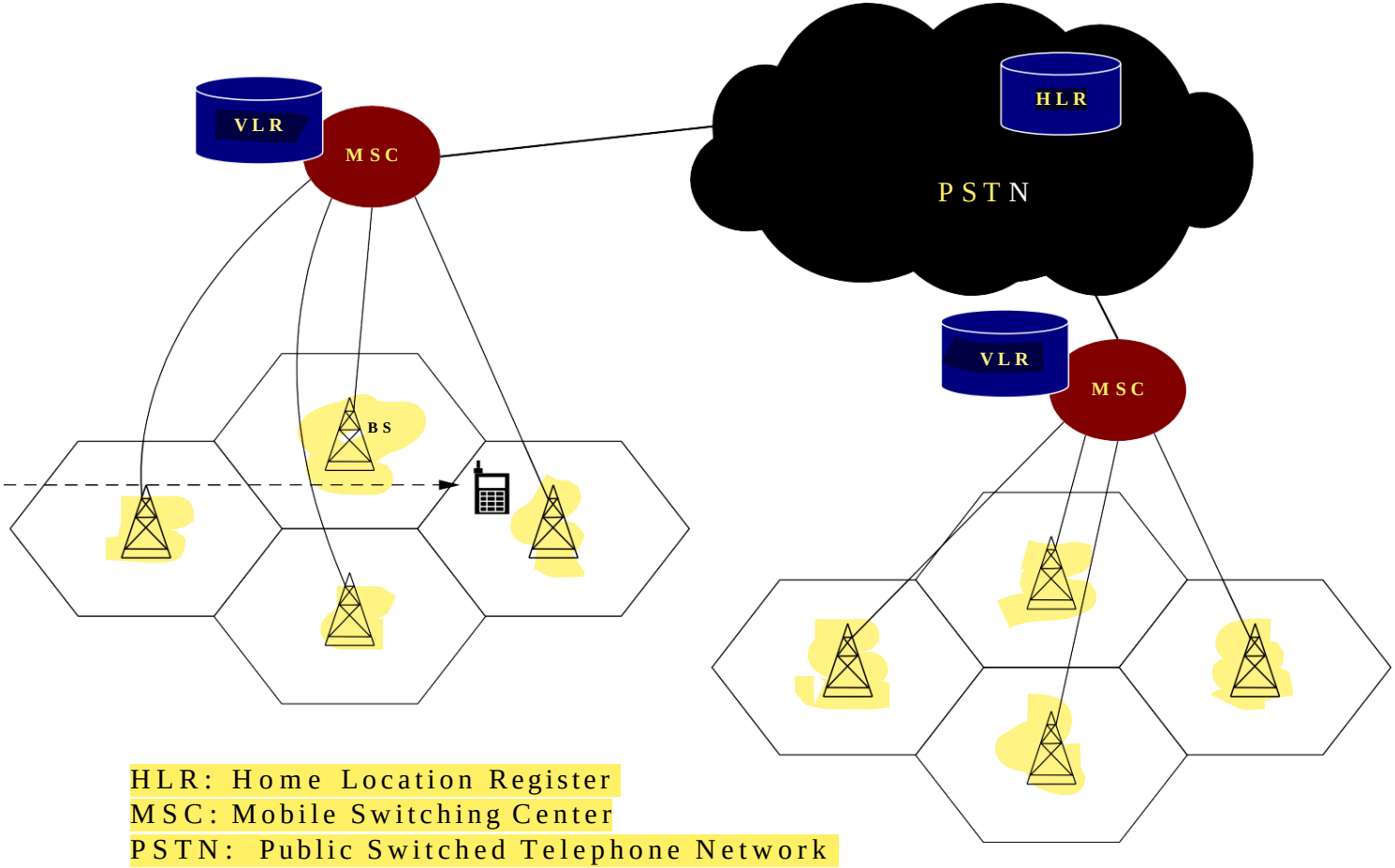
Summary

- PCS Architecture
- Cellular Telephony
- Cordless Telephony and Low-Tier PCS

Outlines

- Introduction
- Handoff
- Roaming Management

A Common PCS Network Architecture



HLR: Home Location Register
MSC: Mobile Switching Center
PSTN: Public Switched Telephone Network
VLR: Visitor Location Register

Introduction

- In the PCS system, the mobile service area is covered by a set of BSs which are responsible for relaying the calls to/from the MSs.
- The BSs are connected to MSCs by land links.
- MSC interfaces the MSs (via BSs) with the PSTN.
- Two types of databases are used for roaming management.
  - Home Location Register (HLR)
  - Visitor Location Register (VLR)
- Examples of the protocols to support mobility management
  - EIA/TIA Interim Standard 41 (IS-41 or ANSI-41)
  - GSM Mobile Application Part (MAP)

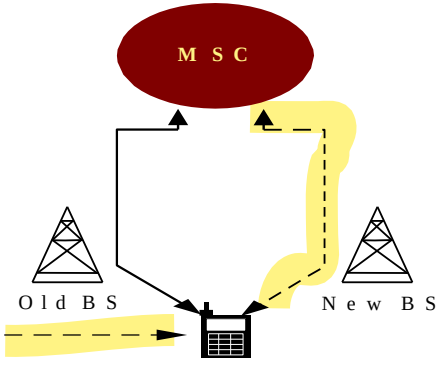
Two Aspects of Mobility in a PCS network

- Handoff (link transfer, or handover).
  - When a mobile user is engaged in conversation, the MS is connected to a BS via a radio link.
  - If the mobile user moves to the coverage area of another BS, the radio link to the old BS is disconnected, and a radio link to the new BS should be established to continue the conversation.
- Roaming.
  - When a mobile user moves from one PCS system (e.g., the system in Taipei) to another (e.g., the system in Tainan), the system should be informed of the current location of the user.

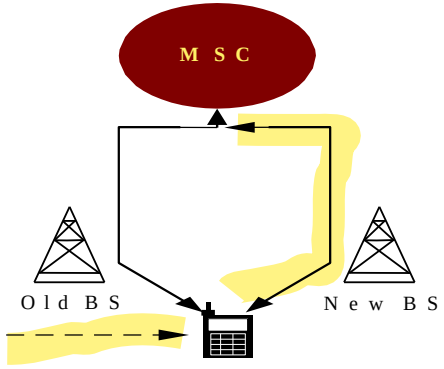
Three Strategies for Handoff Detection

- Mobile-Controlled Handoff (MCHO).
  - MCHO is used in DECT and PACS.
  - Part I. The MS continuously monitors the signals of the surrounding BSs.
  - Part II. The MS initiates the handoff process when some handoff criteria are met.
- Network-Controlled Handoff (NCHO).
  - NCHO is used in CT-2 plus and AMPS.
  - Part I. The surrounding BSs measure the signal from the MS.
  - Part II. The network initiates the handoff process when some handoff criteria are met.
- Mobile-Assisted Handoff (MAHO).
  - MAHO is used in GSM and IS-95.
  - Part I. The network asks the MS to measure the signal from the surrounding BSs.
  - Part II. The network the handoff decision based on the reports from the MS.

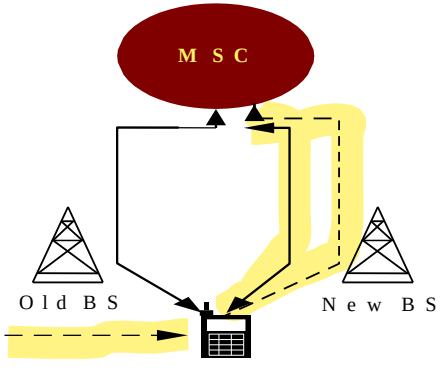
Inter-BS link transfer



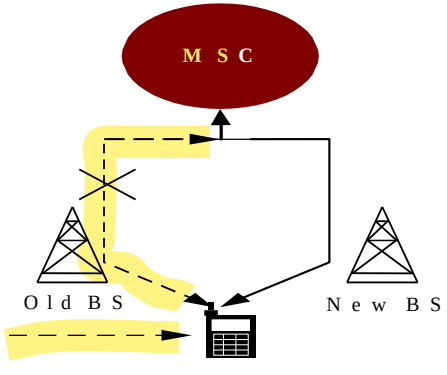
(a) Step 1



(b) Step 2



(c) Step 3



(d) Step 4

Inter-BS Handoff (1/3)

- The new and old BSs are connected to the same MSC. Assume that MCHO is adopted here.
- **Step 1.** The MS momentarily suspends conversation and initiates the handoff procedure by signaling on an idle channel in the new BS. Then it resumes the conversation on the old BS.
- Step 2.
- **Step 2.** Upon receipt of the signal, the MSC transfers the encryption information to the selected idle channel of the new BS and sets up the new conversation path to the MS through that channel. The switch bridges the new path with the old path and informs the MS to transfer from the old channel to the new channel.

Inter-BS Handoff (2/3)

- **Step 3.** After the MS has been transferred to the new BS, it signals the network, and resumes conversation using the new channel.
- **Step 4.** Upon receipt of the handoff completion signal, the network removes the bridge from the path and releases resources associated with the old channel

Inter-BS Handoff

- For NCHO, all handoff signaling messages are exchanged between the MS and the old BS through the failing link. Thus, the whole process must be completed as quickly as possible.
- If the new BS does not have an idle channel, the handoff call may be dropped (forced to terminate).
- Forced termination of an ongoing call is considered less desirable than blocking a new call attempt.

ISSUE 1: Channel Assignment Schemes for Handoff Calls (1/3)

- Nonprioritized Scheme.
  - The networks handle a handoff in the same manner as a new call attempt.
- Reserved Channel Scheme.
  - Similar to the nonprioritized scheme, except that some channels in each BS are reserved for handoff calls.

Channel Assignment Schemes for Handoff Calls (2/3)

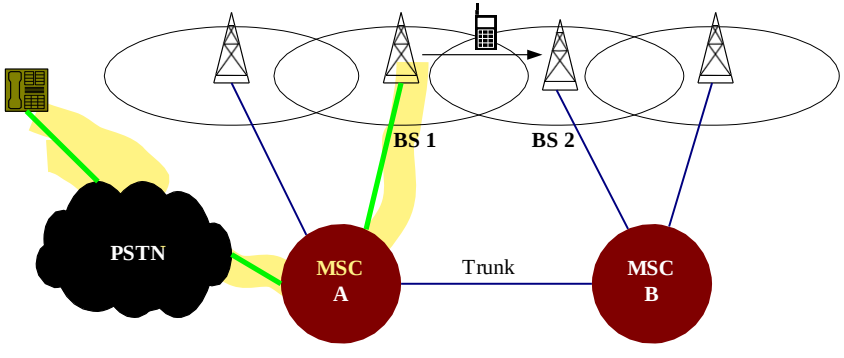
- Queuing Priority Scheme.
  - There is a considerable area where a call can be handled by either BS, which is called the *handoff area*.
  - If no new channel is available in the new BS during handoff, the new BS buffers the handoff request in a *waiting queue*.
  - The MS continues to use the channel with the old BS until either a channel in the new BS becomes available.

Channel Assignment Schemes for Handoff Calls (3/3)

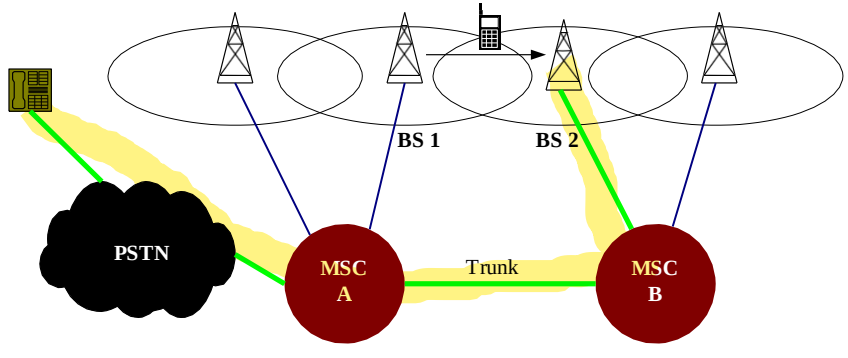
- Subrating Scheme.
  - The new BS creates a new channel for a handoff call by sharing resources with an exiting call if no free channel is available.
  - Subrating means an occupied full-rate channel is temporarily divided into two channels at half the original rate.
  - One half-rate channel is to serve the exiting call, and the other half-rate channel is to serve the handoff request.
  - When occupied channels are released, the subrated channels are immediately switched back to full rate channels.

Intersystem Handoff (1/3)

- In intersystem handoff, the new and old BSs are connected to two different MSCs.
- Assume that NCHO is adopted (as in IS-41 procedure).



(a) Before the Handoff



(b) After the Handoff

Intersystem Handoff (2/3)

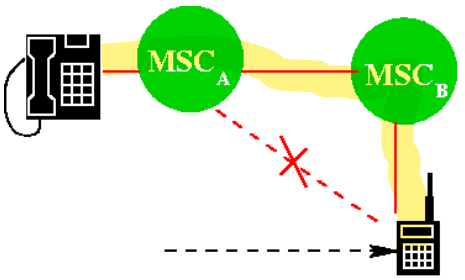
- **Step 1.**
  - Part I. MSC A requests MSC B to perform handoff measurements on the call in progress.
  - Part II. MSC then selects a candidate BS "BS 2", and interrogates BS 2 for signal quality parameters.
  - Part III. MSC B returns the signal quality parameters, along with other relevant information, to MSC A.
- **Step 2.**
  - Part I. MSC A checks if the MS has made too many handoffs recently (e.g., to avoid that MS is moving within overlapped area) or if intersystem trunks are not available.
  - Part II. If so, MSC A exits the procedure.
  - Part III. Otherwise, MSC A asks MSC B to set up a voice channel.

Intersystem Handoff (3/3)

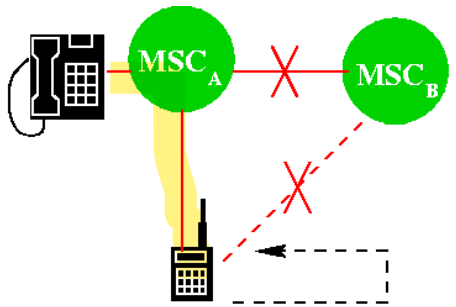
- **Step 3.**
  - Part I. MSC A sends the MS a handoff order.
  - Part II. The MS synchronizes to BS 2.
  - Part III. After the MS is connected to BS 2, MSC B informs MSC A that the handoff is successful.
  - Part IV. MSC A then connects the call path (trunk) to MSC B.
- MSC A is referred to as the *anchor MSC*, and is always in the call path before and after the handoff.

ISSUE 2: Anchor Approach (1/2)

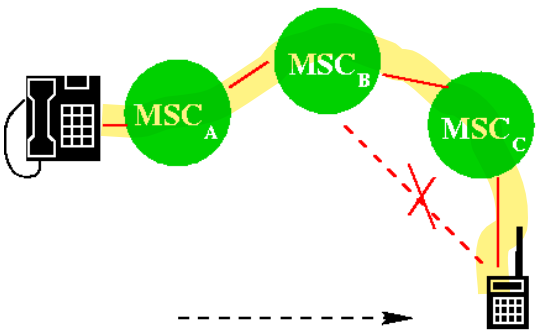
- The Anchor Approach is used in all existing mobile phone networks because the re-establishment of a new call path (without involving MSC A) between MS and the new MSC would require extra trunk release/setup operations in PSTN.



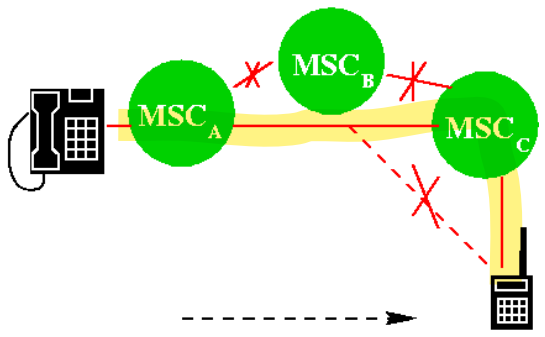
(a) Handoff forward



(b) Handoff Backward



(c) Handoff to the Third



(d) Path Minimization

Anchor Approach (2/2)

- If the MS moves back to MSC A again, the connection between MSC A and MSC B is removed.
- If the MS moves to the third MSC C, then MSC B will be in the call path.
- **Path Minimization.** When the MS moves to the third MSC, the second MSC may be removed from the call path. The link between MSC A and MSC B is disconnected, and MSC C is connected MSC A directly.

Roaming Management

- Two basic operations in roaming management are
  - Registration (or Location Update): the process whereby an MS informs the system of its current location
  - Location Tracking: the process during which the system locates the MS (this process is required when the network attempts to deliver a call to the mobile user)
- The roaming management schemes proposed in IS-41 and GSM MAP are two-level strategies
- They use a two-tier system of home and visited databases that are
  - Home Location Register (HLR), and
  - Visited Location Register (VLR).

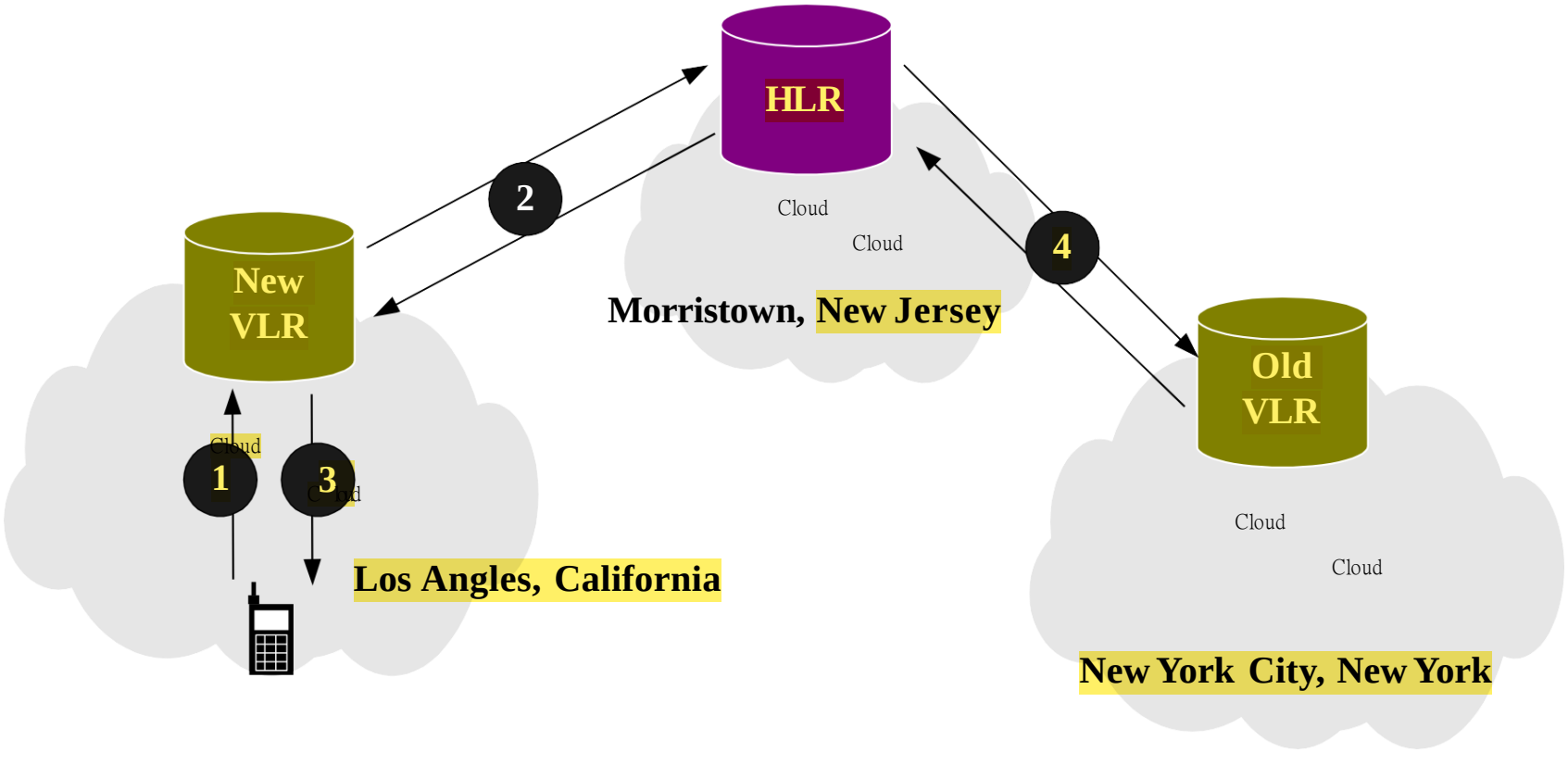
Home Location Register (HLR)

- When a user subscribes to the services of a PCS network, a record is created in the system's database,
- which is referred as to the home system of the mobile user.
- HLR is a network database that stores and manages all subscriptions of a specific operator.
- The information contained in HLR includes
  - *MS Identity,*
  - *directory number,*
  - *profile information,*
  - *current location,*
  - *validation period.*

Visitor Location Register (VLR)

- When the mobile user visits a PCS network other than the home system, a temporary record for the mobile user is created in the visitor location register (VLR) of the visited system.
- The VLR temporarily stores subscription information for the visiting subscribers.
- Thus, the MSC (corresponding with the VLR) can provide service to the mobile user.
- The VLR is the “other” location register used to retrieve information for handling calls to/from a visiting mobile user.

MS Registration Process (1/3)



MS Registration Process (2/3)

- **Step 1.**
  - Suppose that the home system of a mobile user is in Morristown. When the mobile user moves from one visited system (e.g., New York City) to another (e.g., Los Angeles), it must register in the VLR of the new visited system.
- **Step 2.**
  - Part I. The new VLR informs the mobile user's HLR of the person's current location-the address of the new VLR.
  - Part II. The The HLR sends an acknowledgement, which includes the MS's profile, to the new VLR.

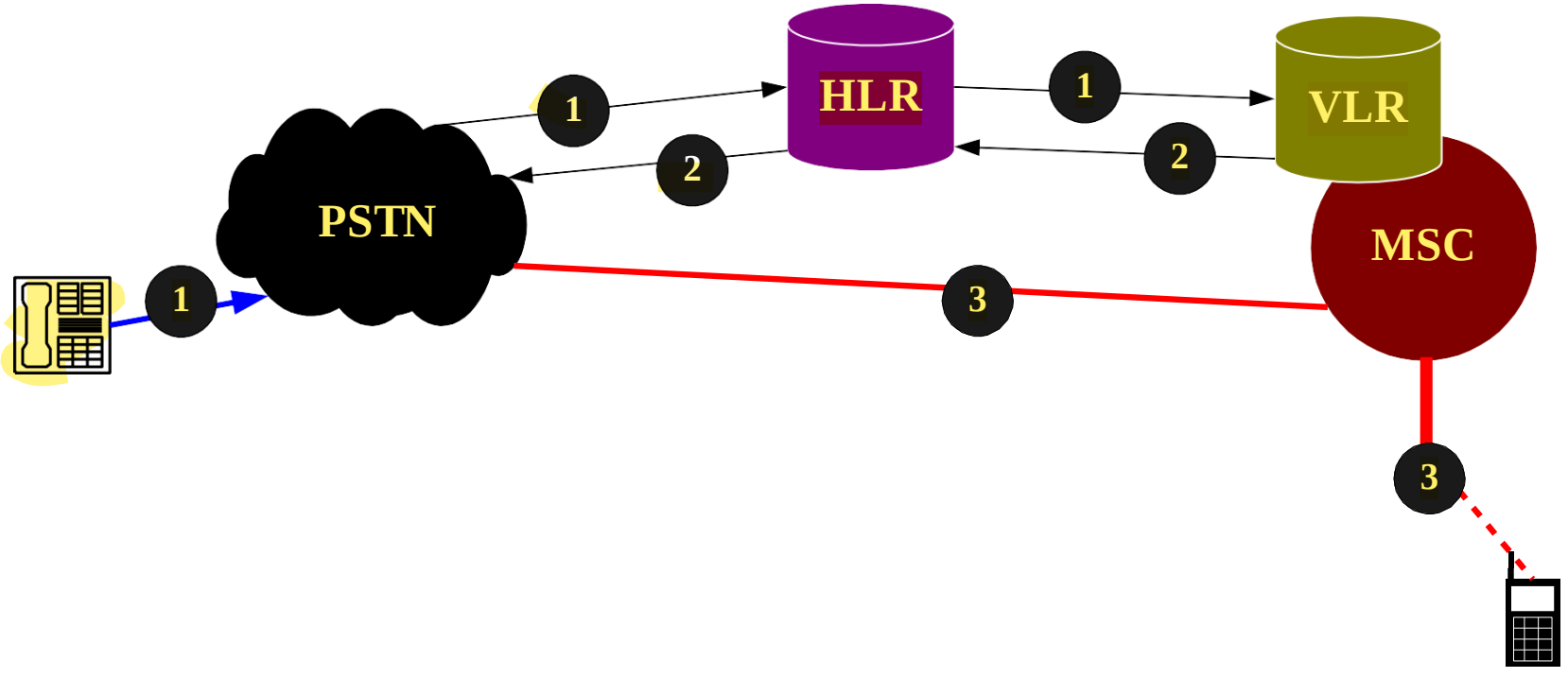
MS Registration Process (3/3)

- **Step 3.**
  - The new VLR informs the MS of the successful registration.
- **Step 4.**
  - After Step 2, the HLR also sends a deregistration message to cancel the obsolete location record of the MS in the old VLR.
  - The old VLR acknowledges the deregistration.

Call Origination Procedure

- To originate a call, the MS executes the following steps.
  - Step 1. MS contacts the MSC in the visited PCS network.
  - Step 2. The call request is forwarded to the VLR for approval.
  - Step 3. If the call is accepted, the MSC sets up the call to the called party following the standard PSTN call setup procedure.

Call Delivery (Call Termination/Location Tracking) (1/3)



Call Delivery (Call Termination/Location Tracking) (2/3)

- **Step 1.**
  - Part I. If a wireline phone attempts to call a mobile subscriber, the call is forwarded to a switch, called the originating switch in the PSTN.
  - Part II. The originating switch queries the HLR to find the current VLR of the MS.
  - Part III. The HLR queries the VLR in the which the MS resides to get a routable address.
  - Note that if the originating switch is not capable of querying the HLR (i.e., it is not equipped to support mobility), the call is routed through the PSTN to the subscriber's Gateway MSC, which queries the HLR to determine the current VLR serving the MS.

- **Step 2.** The VLR returns the routable address to the originating switch through HLR.
- **Step 3.** Based on the routable address, a trunk (voice circuit) is set up from the originating switch to the MS through the visited MSC.