2nd Generation Cellular Systems: GSM -1

- GSM Architecture
- GSM Structure
- GSM Channel Structure

Review

- **Basic Cellular operation –AMPS**
  - **Mobile Initialisation**
  - **Mobile Originated Call**
  - **Mobile Call Reception**

- **Power Control**

- **Handoff**

- **Cellular Hierarchy**

Differences Between First and Second Generation Systems

- Digital traffic channels – first-generation systems are predominately analog; second-generation systems are all digital
- Encryption – all second generation systems provide encryption to prevent eavesdropping
- Second-generation digital traffic allows error detection and correction, giving clear voice reception
- Channel access – second-generation systems allow channels to be dynamically shared by a number of users

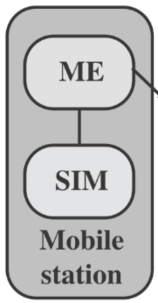
TDMA 2nd Generation Systems

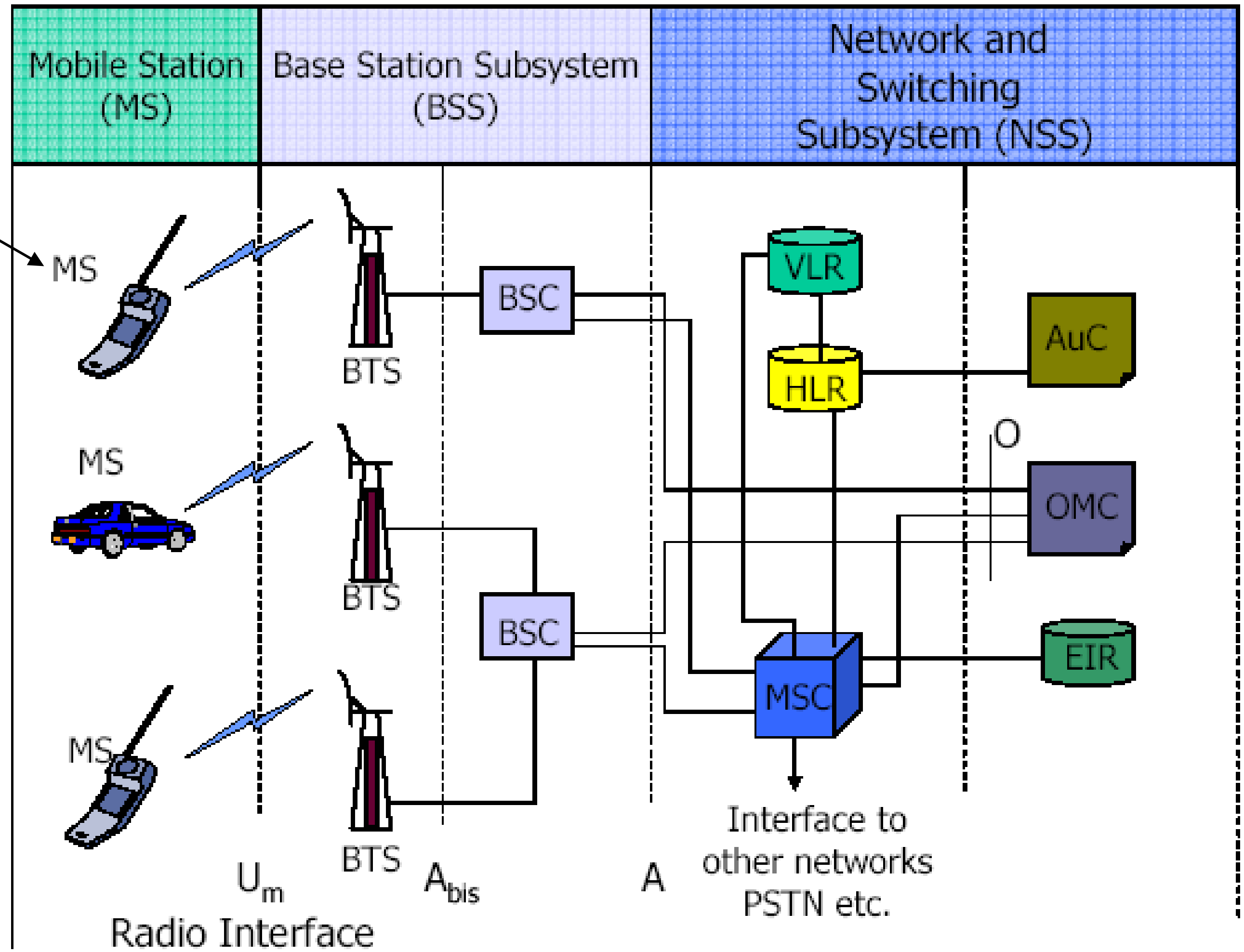
- **USA**
  - **North American TDMA (D-AMPS): (IS-54) IS-136**
    - **Same spectrum of AMPS**
    - **30kHz carriers**
    - **3 users per carrier (deployed) (up to 6 in the standard)**
    - **TDMA/FDD (Frequency Division Duplexing)**
- **Europe**
  - **GSM (Globe System for Mobile Communications)**
    - **200 kHz carriers**
    - **8 users per carrier**
    - **Spectrum: 890Mhz – 960MHz**
    - **TDMA/FDD**
    - **Later GSM-1800 – First known as Digital Cellular System 1800 (DCS-1800)**
- **Japan**
  - **PDC**
    - **Personal Digital Cellular (similar to NA-TDMA)**

GSM

- [Stallings 02] chapter 10
- [PK 02] chapter 7
- Design Considerations
  - Number of logical channels (number of time slots in TDMA frame): 8
  - Maximum cell radius (R): 35 km
  - Frequency:
    - 890-915 MHz uplink
    - 935-960 MHz downlink
  - Maximum vehicle speed (V_m):250 km/hr
  - Maximum coding delay: approx. 20 ms
  - Bandwidth: Not to exceed 200 kHz

GSM Architecture [PK 02]





AuC Authentication Center
EIR Equipment identity register
HLR Home location register
ME Mobile equipment
PSTN Public switched telephone network
SIM Subscriber identity module
VLR Visitor location register

Figure 7.2: A different view of the reference architecture for GSM

The Mobile Station

- Mobile station communicates across Um interface (air interface) with base transceiver station (BTS) in same cell as mobile unit
- Mobile equipment (ME) – physical terminal, such as a telephone or PCS (*personal communication services*)
  - ME includes radio transceiver and digital signal processors
  - IMEI (***International Mobile Equipment Identity***)
    - It is stored in the ME
    - It can be requested by MSC
    - It is used to identify stolen or mal-functioning devices

[Meht 97]

The Mobile Station

- GSM subscriber units are generic until SIM(subscriber identity module) is inserted
  - SIMs roam, not necessarily the subscriber devices
  - MSISDN ***(Mobile Subscriber ISDN Number)***
    - It is the number dialled by a caller
  - IMSI ***(International Mobile Subscriber Identity)***
    - Unique number permanently assigned to a subscriber within the mobile network
  - TMSI ***(Temporary Mobile Subscriber Identity)***
    - A subscriber identity confidentiality procedure is required for the protection of IMSI
    - Each time a MS requests one of the system's location updating procedures, call attempt or the service activation, MSC/VLR allocates to an IMSI a new TMSI and transmits it to MS with the order to use the TMSI for all future communications with the GSM system

Base Station Subsystem (BSS)

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
  - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

Network Subsystem (NS)

- NS provides link between cellular network and public switched telecommunications networks
  - Controls handoffs between cells in different BSSs
  - Authenticates users and validates accounts
  - Enables worldwide roaming of mobile users
- Central element of NS is the mobile switching centre (MSC)
- Home location register (HLR) database
  - stores information about each subscriber that belongs to it
- Visitor location register (VLR) database
  - maintains information about subscribers currently physically in the region

Network Subsystem (NS)

- Authentication centre database (AuC)
  - used for authentication activities, holds encryption keys
- Equipment identity register database (EIR)
  - keeps track of the type of equipment that exists at the mobile station (white, grey and black lists)
- Operational and Maintenance Centre (OMC)
  - It is connected to all equipments in the MSC and BSC
  - Performs the maintenance of the HLR
  - Performs administrative functions, for example, billing

GSM Structure [Meh 97]

- GSM service area
  - It is the total area served by the combination of all countries where a GSM mobile can be serviced (Figure 2.2 (d))
- PLMN (*Public Land Mobile Network*) service area (Figure 2.2 (a))
  - Licensed and operated by a network operator
  - There may be several inside a country
  - On the level of international and national transit exchanges
  - All incoming calls for a GSM/PLMN network are routed to a *Gateway* MSC (*transit exchange*)
- MSC/VLR service area (Figure 2.2 (b))
  - one PLMN may have several MSC/VLR service areas
  - It controls the calls within its jurisdiction

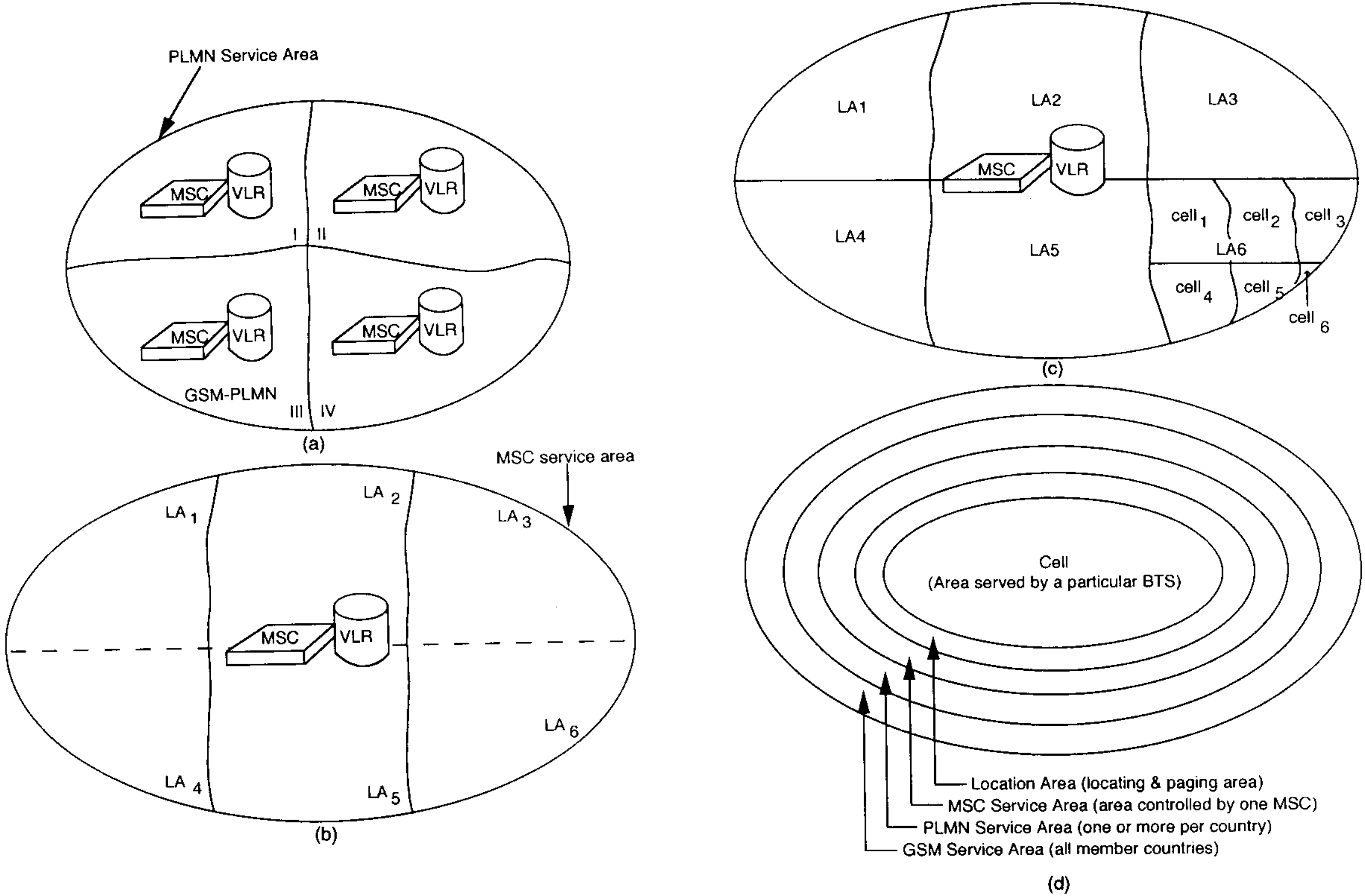


Figure 2.2 (continued).

GSM Structure [Meh 97]

- *Location Areas – LAs* (Figure 2.2 (c))
  - There are several LAs inside a MSC/VLR
  - It is the part of the MSC/VLR in which the MS may freely move without updating location information
  - Within a LA a paging message is broadcasted in order to find the called MS
  - The LA can be identified by the system using the ***Location Area Identity – LAI***
  - A LA is divided into many cells
- cell
  - It is an identity served by one BTS
  - The MS distinguishes between cells using the ***Base Station Identification Code – BSIC*** that is broadcasted by the cell

GSM Structure [Meh 97]

- At the cell boundary, the received power should lead to an acceptable ***bit error rate – BER***
- The cells' coverage overlap (Figure 2.3(a))
  - The cell boundaries are the lines of equal power from two adjacent BTSs, therefore cells sizes vary with adjustments made by BTSs
- The frequency reuse pattern is normally 4 cells per cluster, each cell divided in three sectors (120^{o} antennas), each sector has a BTS
- In low traffic areas, an omni directional antenna can be used
- There are 12 sectors (called GSM cells) in a 4-cell cluster and 124 frequency carriers in the system, if we assume that one operator has the full spectrum, we could have:
  - The reuse pattern shown in figure 2.3(b)
  - The channel assignment shown in table 2.1

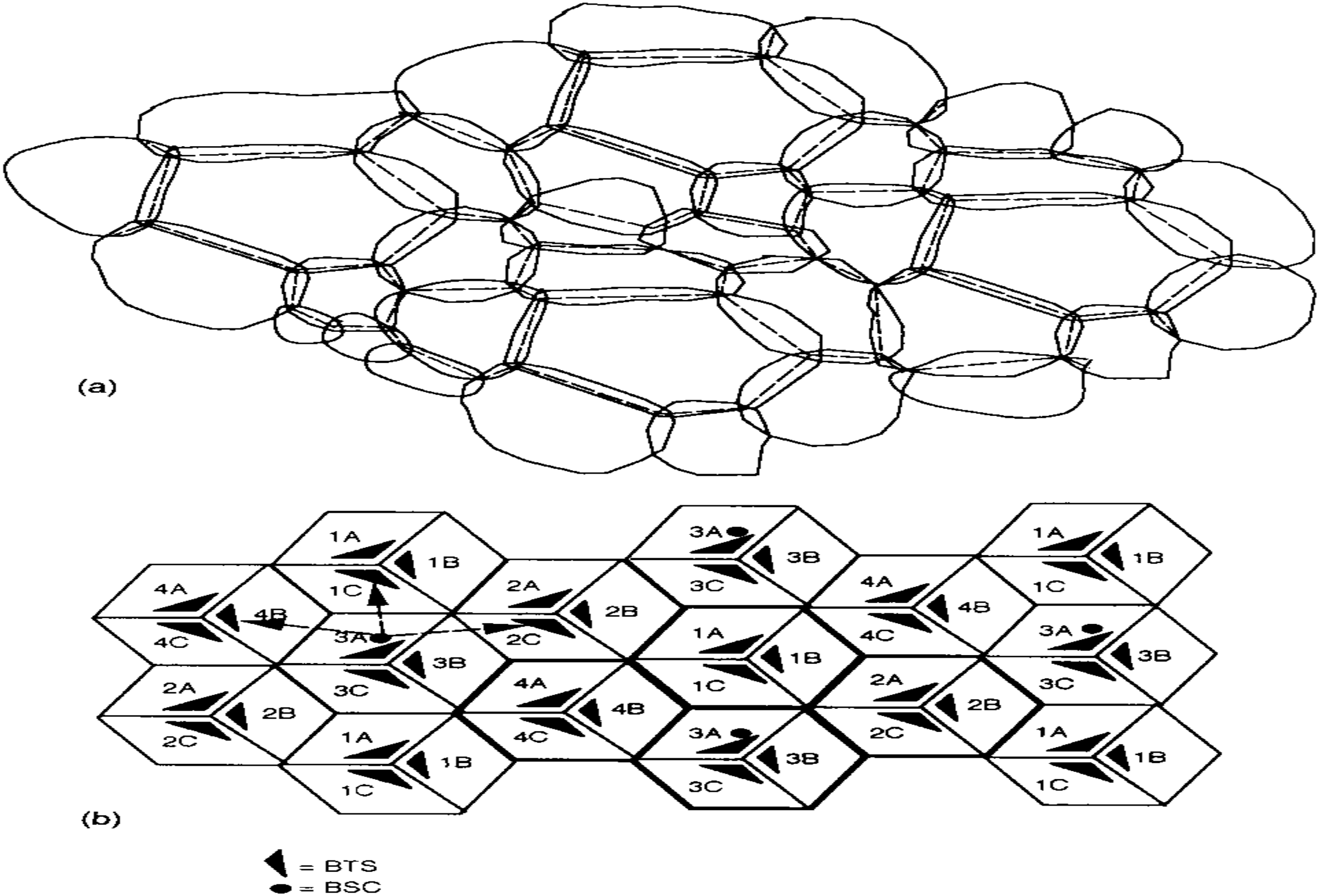


Figure 2.3 (a) MSC/VLR LA with overlapping cell sites and (b) GSM sectored four-cell coverage.

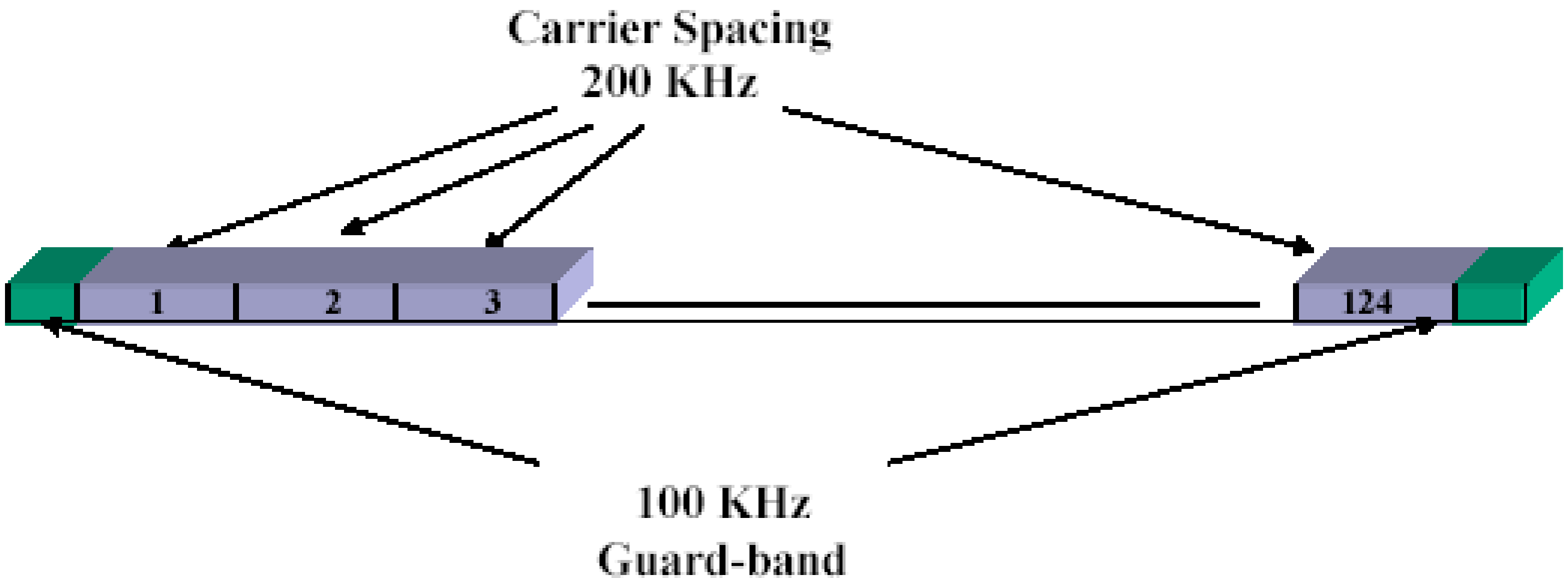
GSM Frequency Assignment [Meh 97]

Table 2.1

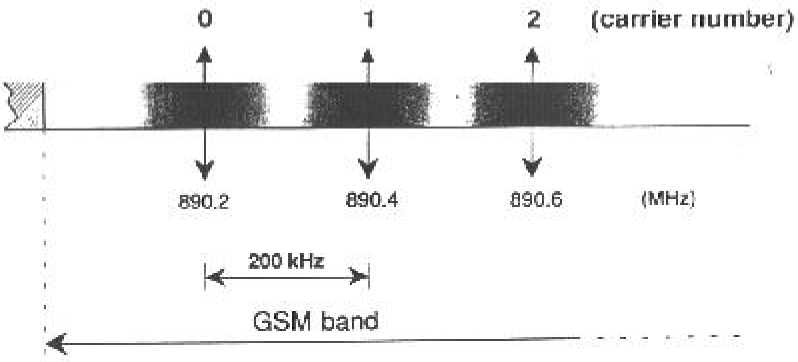
Frequency Assignment for 12 Sectors (four-cell repeat)

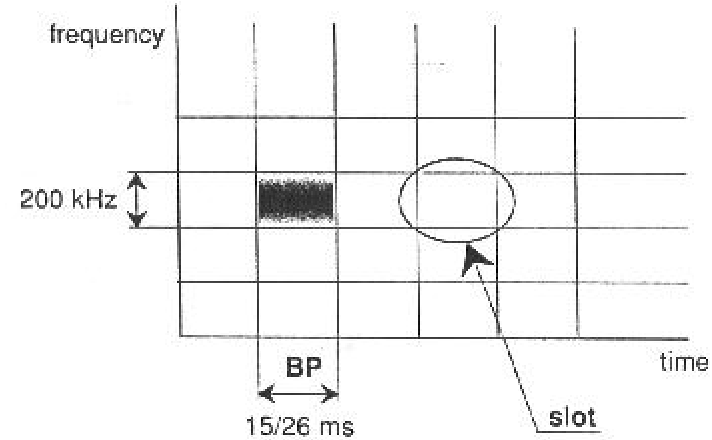
1A	*2A*	*3A*	*4A*	*1B*	*2B*	*3B*	*4B*	*1C*	*2C*	*3C*	*4C*
1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81	82	83	84
85	86	87	88	89	90	91	92	93	94	95	96
97	98	99	100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117	118	119	120
121	122	123	124								

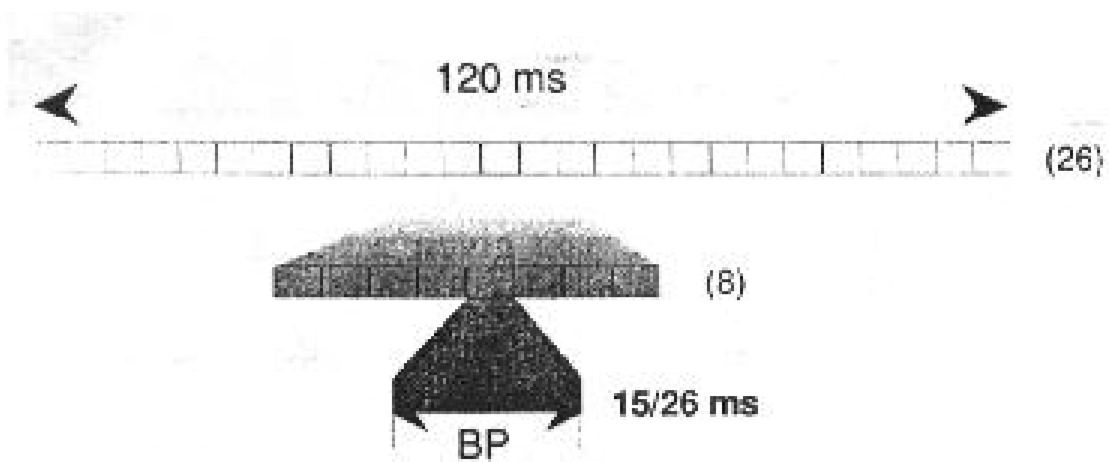
GSM Carrier Structure [PK 02]

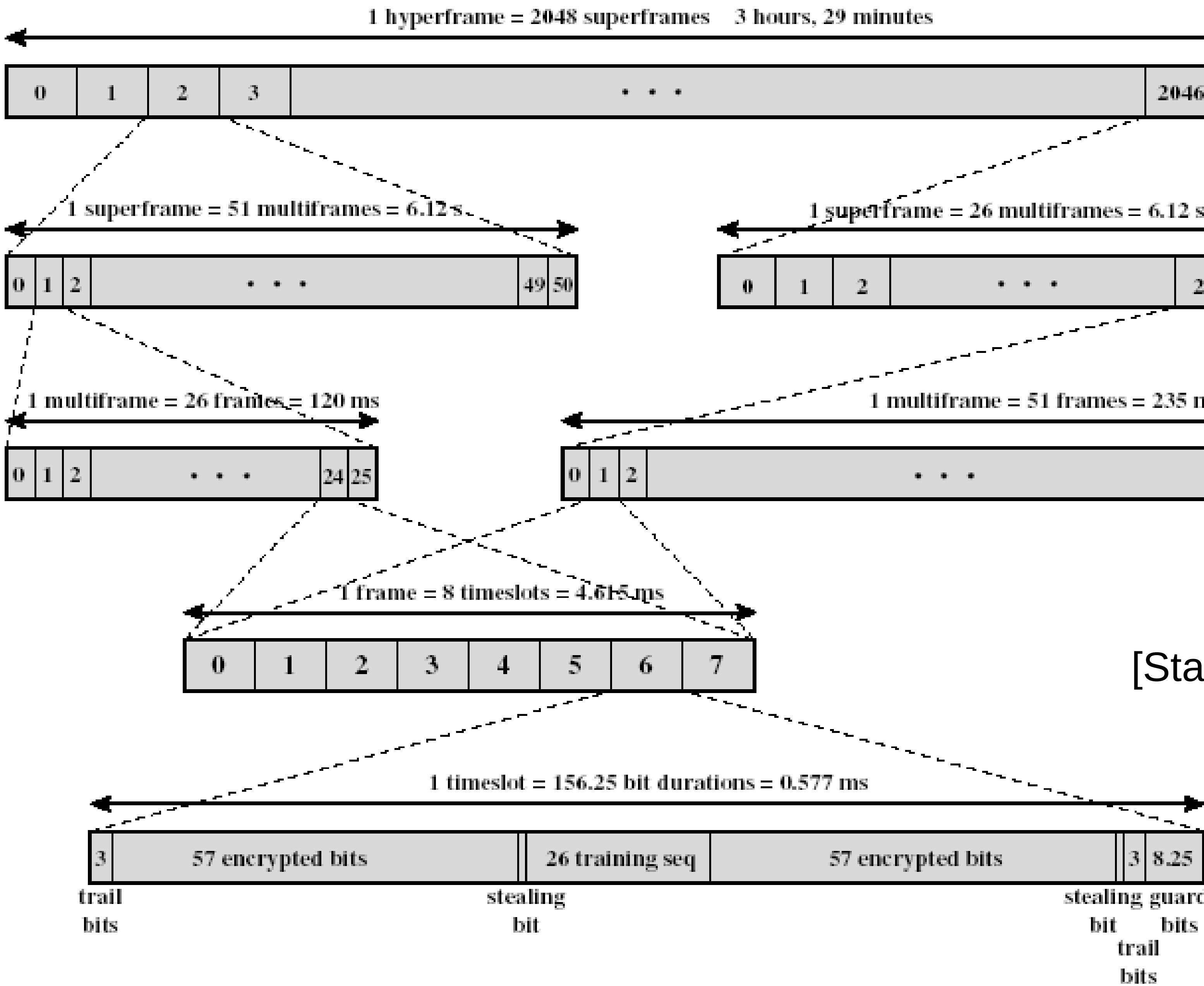


GSM Channel Structure [MP 92]









[Stallings 02]

Figure 10.15 GSM Frame Format

GSM Channel Structure

- GSM uses a complex hierarchy of TDMA frames to define logical channels (Figure 10.15)
- Fundamentally, each 200-kHz frequency band is divided into 8 logical channels defined by the repetitive occurrence of time slots
- At the lowest level is the **time slot**, also called a **burst period**, which has a duration of 15/26 ms, or approximately 0.577 ms
  - With a bit rate of 270.833 kbps, each time slot has a length of 156.25 bits
- The time slot format in figure 10.15 is called ***normal burst*** and carries ***user data traffic***, other bursts formats are used for control signaling
- Capacity in kbps of a full rate traffic channel in GSM
  - Each traffic channel receives one slot per frame and 24 frames per 120ms (26 frames – one for controlling channel and one unused)
  - The resulting data rate is114 (bits/slot) X 24 (slots/multi-frame) /120 ms/multi-frame = 22.8 kbps

Fields inside a Normal Burst

- Trail bits

  3 zero bits providing a gap time for the radio circuitry to cover the uncertainty period to ramp on and off the radiated power and to initiate the convolutional decoding
- Encrypted bits
  - Data is encrypted in blocks by conventional encryption of 114 plaintext bits into 114 ciphertext bits; the encrypted bits are then placed in two 57-bit fields in the time slot
- Stealing bit
  - Used to indicate whether this block contains data or is “stolen” for urgent control signaling
- Training sequence
  - Used to adapt the parameters of the receiver to the current path propagation characteristics and to select the strongest signal in case of multipath propagation
  - The training sequence is a known bit pattern that differs for different adjacent cells
  - In addition, the training sequence is used for multipath equalization, by determining how the known training sequence is modified by multipath fading, the rest of the signal is processed to compensate for these effects
- Guard bits
  - Used to avoid overlapping with other bursts due to different path delays

Class Quizzes

- **What are the components in GSM architecture?**
- **What is cellular structure in GSM?**
- **What is the channel formats in GSM?**

References

- [Meht 97] Asha Mehrotra. GSM System Engineering. Mobile Communications Series. Artech House Publishers.1997.
- [MP 92] Michel Mouly, Marie-Bernadette Pautet. GSM Systems for Mobile Communications, Telecom Publishing, 1992.
- [PK 02] Kaveh Pahlavan and Prashant Krishnamurthy. Principles of Wireless Networks. Prentice Hall Communications Engineering and Emerging Technologies Series. 2002.
- [Stallings 02] William Stallings. Wireless Communications and Networks. *Prentice Hall*. ISBN 0-13-040864-6, 2002.