Παρουσιάσεις για το Μάθημα Ασύρματων και Κινητών Τηλεπικοινωνιών του ΔΜΠΣ στο ΕΚΠΑ

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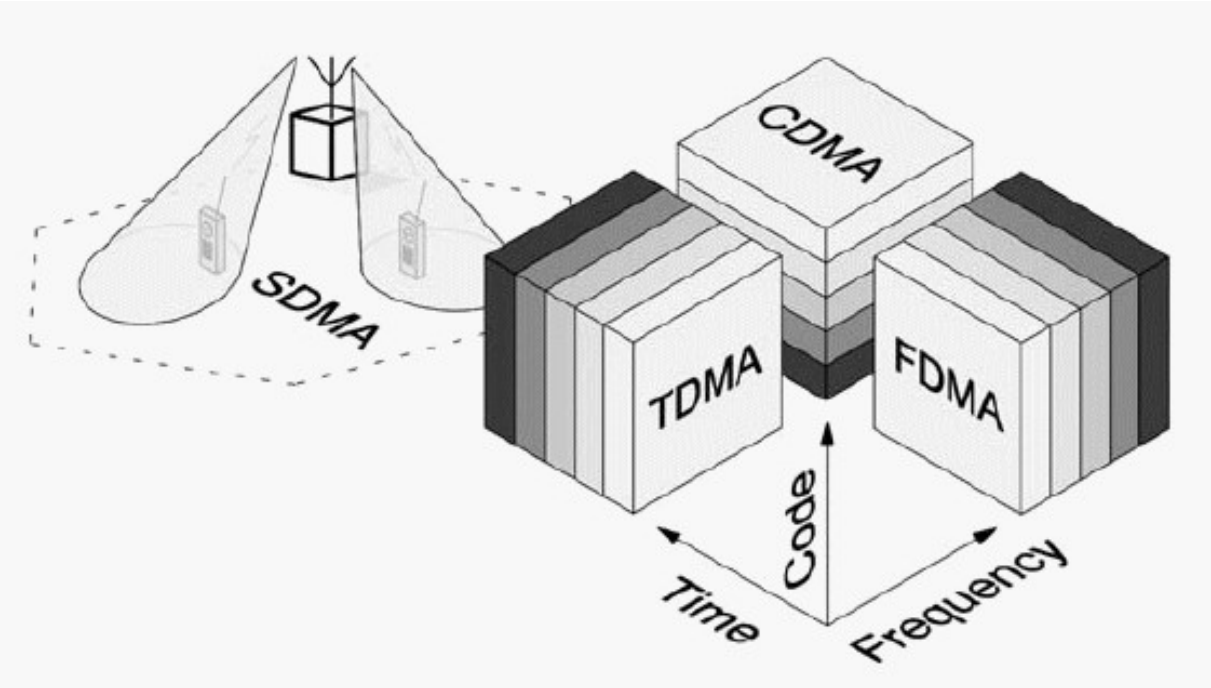
Wireless Access Technologies and Systems

Multiple Access Techniques

- **Multiple access techniques allow many users to use a limited amount of spectrum**
- **Multiple access may be done:**
  - **Either over narrow channels (narrowband), or**
  - **Wide channels (wideband)**
  - **Frequency Division Multiple Access (FDMA)**
  - **Time Division Multiple Access (TDMA)**
  - **Code Division Multiple Access (CDMA)**
  - **Space Division Multiple Access (SDMA)**

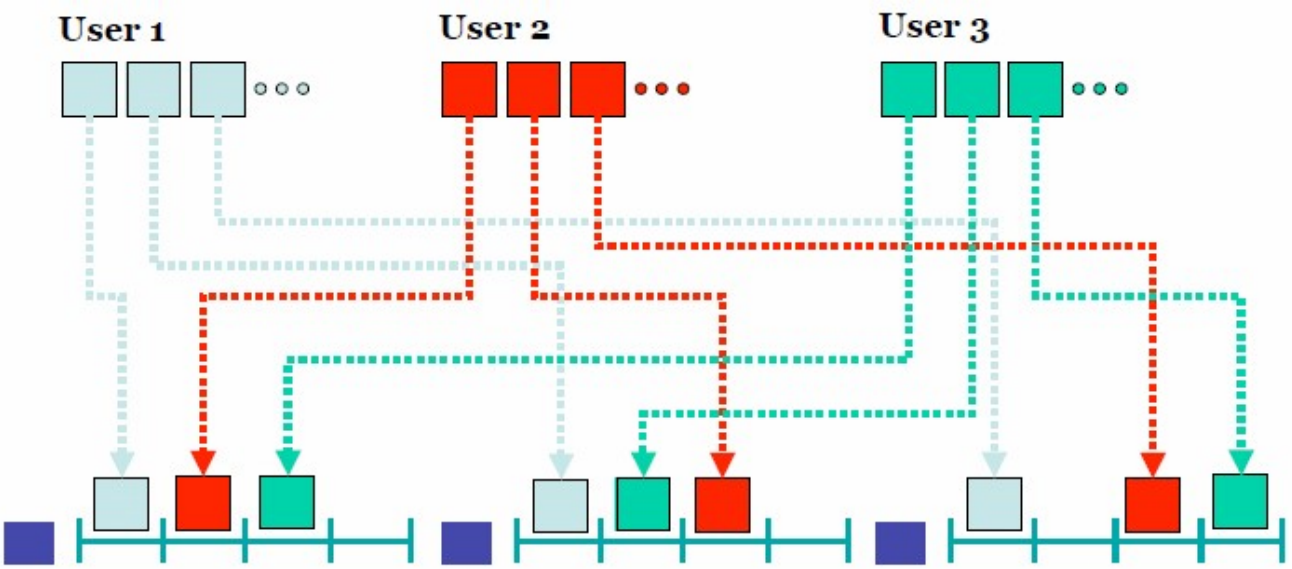


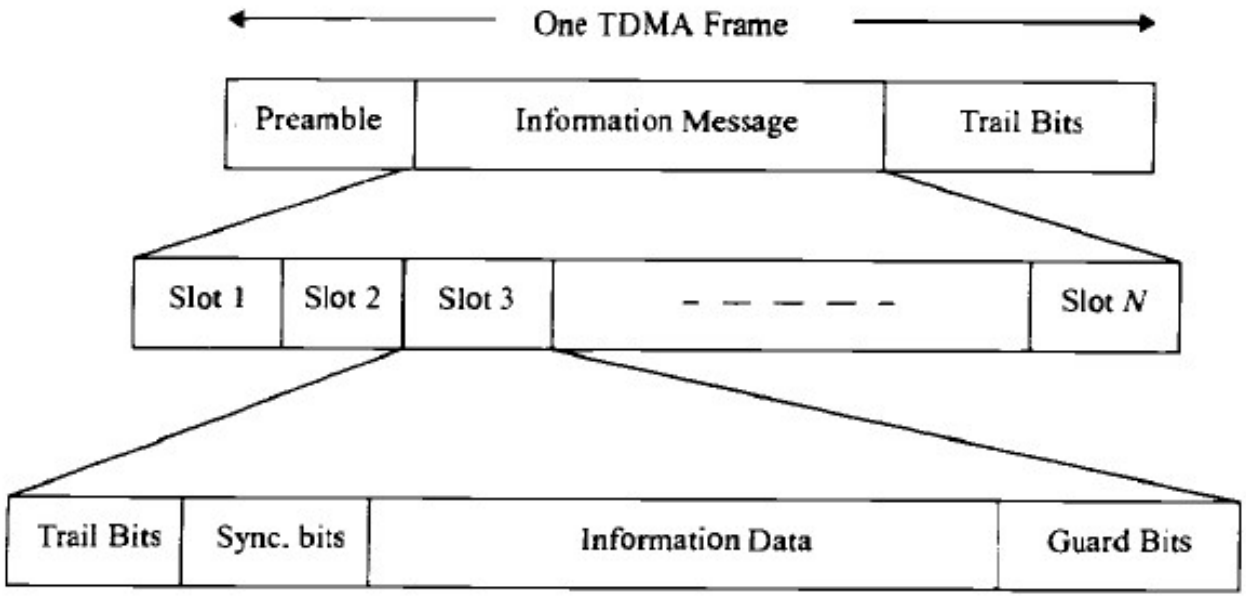
Frequency Division Multiple Access (FDMA)

- **The FDMA channel carries only one phone circuit at a time**
- **If an FDMA channels is not in use, then it sits idle and cannot be used by another user**
- **After channel assignments, BS and MS transmit simultaneously and continuously**
- **The bandwidth of FDMA channels are relatively narrow (~30KHz), as each FDMA channel supports only one circuit per carrier**
- **Relatively low equipment complexity**
- **Fewer bits are needed for overhead purposes, due to continous transmission scheme**
- **Typically higher system cost per cell site, due to single channel per carrier and the need for bandpass filters at the BS**
- **Higher cost of MS & BS, due to simoultaneous transmission / reception (use of duplexers)**
- **Sensitive to adjacent channel interference, so it requires more sophisticated RF filtering**

Time Division Multiple Access (TDMA)

Frame Structure





Time Division Multiple Access (TDMA) – cont'd

- **It shares a single carrier frequency with several users, where each user makes use of non-overlapping time slots**
- **Data transmission for users is not continuous, but occurs in bursts**
  - **The MS may be turned off, when it is not in use, leading to low battery consumption**
- **Handoff process is much simpler; the MS is able to listen to other BS's during idle time slots**
- **Transmission and reception are performed at different time slots, so duplexers are not needed, leading to less costly hardware**
- **Transmission rates are typically higher than those in FDMA, so adaptive equalization schemes are needed**
- **Synchronization is needed throughout the network, to assure proper time slot allocation. In addition, guard slots are needed to separate users**
- **It is possible to allocate different number of time slots per frame to different users. Thus, bandwidth can be supplied on demand to different users by assigning more time slots**

FDMA vs TDMA

Technology	Advantages	Disadvantages
TDMA	✓ Permits flexible bit rates ✓ No Freq. guard band is required between channels or precise narrowband filters ✓ Utilizes all advantages of digital techniques (modulation, interleaving, coding, etc.) ✓ Easier implementation of handoffs	➢ Requires network-wide synchronization mechanism ➢ Requires more complex signal processing techniques
FDMA	✓ Low cost hardware technology ✓ No need for network timing ✓ No restriction regarding the type of modulation employed	➢ Requires frequency guard bands ➢ Requires RF filtering to minimize adjacent channel interference ➢ Max bit rate per channel is fixed and small ➢ Behavior similar to that of analog systems

Multiple Access Technologies Comparison

Approach	SDMA	TDMA	FDMA	CDMA
Idea	Segment space into cells/sectors	Segment sending time into disjoint time-slots, demand driven or fixed patterns	Segment the frequency band into disjoint sub-bands	Spread the spectrum using orthogonal codes
Terminals	Only one terminal can be active in one cell/one sector	All terminals are active for short periods of time on the same frequency	Every terminal has its own frequency, uninterrupted	All terminals can be active at the same place at the same moment, uninterrupted
Signal separation	Cell structure directed antennas	Synchronization in the time domain	Filtering in the frequency domain	Code plus special receivers

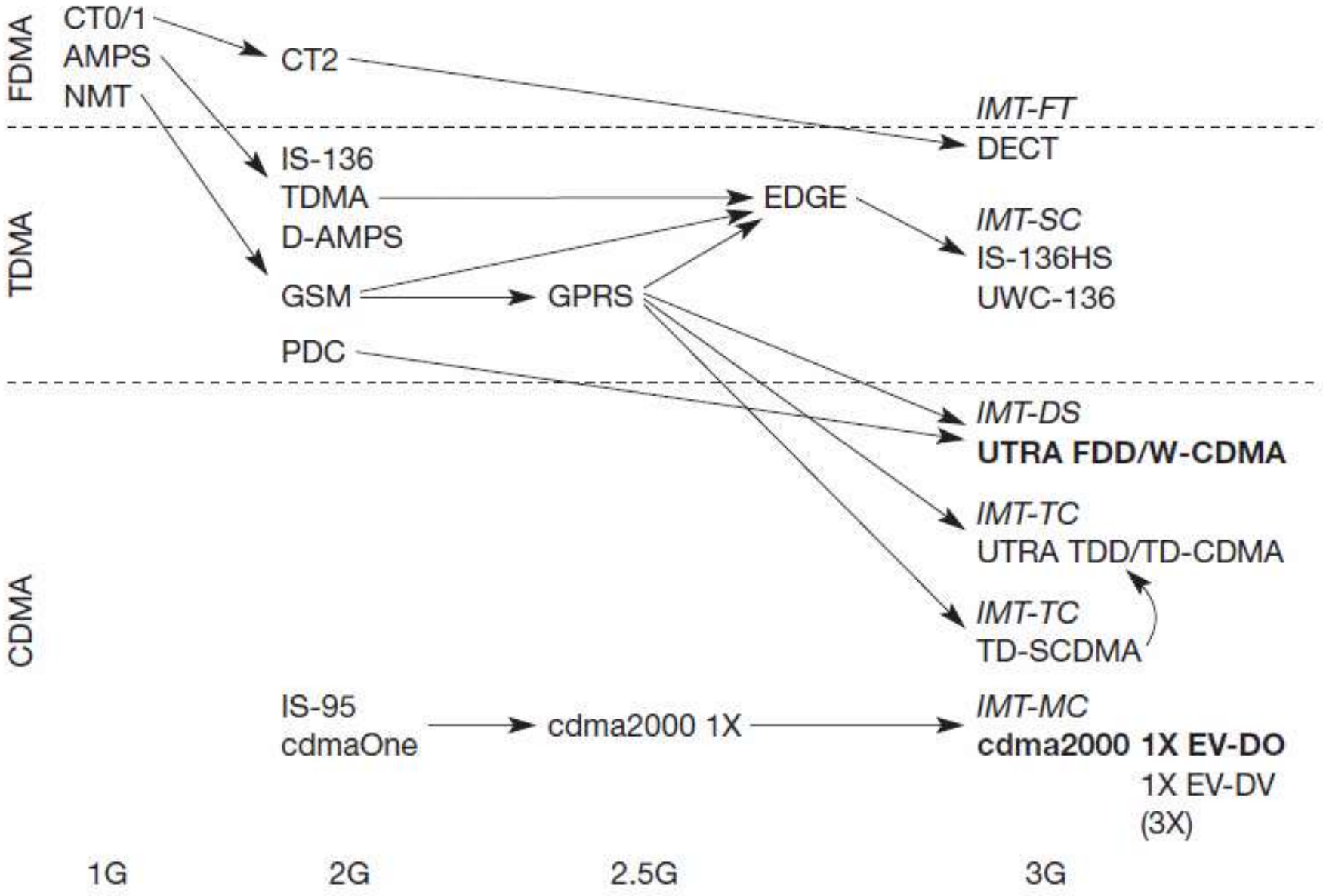
Multiple Access Technologies Comparison

Advantages	Very simple, increases capacity per km^2	Established, fully digital, very flexible	Simple, established, robust	Flexible, less planning needed, soft handover
Disadvantages	Inflexible, antennas typically fixed	Guard space needed (multi-path propagation), synchronization difficult	Inflexible, frequencies are a scarce resource	Complex receivers, needs more complicated power control for senders
Comment	Only in combination with TDMA, FDMA or CDMA useful	Standard in fixed networks, together with FDMA/SDMA used in many mobile networks	Typically combined with TDMA (frequency hopping patterns) and SDMA (frequency reuse)	Used in many 3G systems, higher complexity, lowered expectations; integrated with TDMA/FDMA

The Global System for Mobile Communications

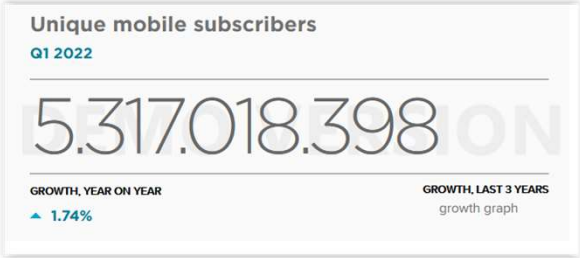
(GSM)

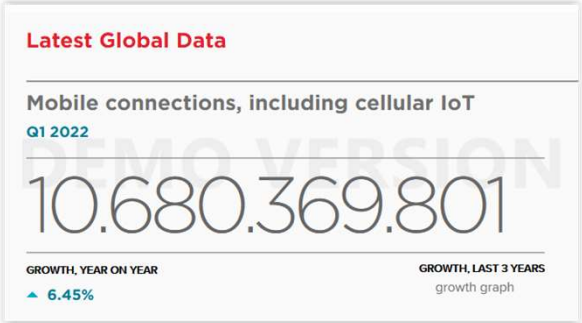
Wireless Systems and Standards



The Global System for Mobile Communications

- **It was developed in Europe (late 1980's) to unify existing 1G mobile communication systems that existed in various countries of Europe**
- **It is the first 2G system that uses digital modulation**
- **It was designed by European Telecommunications Standards Institute (ETSI) to provide a wide-range network coverage through the use of Integrated Services Digital Network (ISDN) standard**
- **By the early 1990's, the standard was adopted by most of the European countries as well as countries in other continents at either 900MHz or 1800MHz (DCS1800) bands and soon, became very popular achieving high penetration rates**





www.gsma.com

"GSM is now in more countries than McDonalds"
(Mike Short, Chairman MoU Association 1995-1996)

GSM Key Design Criteria

- **Good subjective speech quality**
- **Low terminal and service cost**
- **Support for international roaming**
- **Ability to support handheld terminals**
- **Support for range of new services and facilities**
- **Spectral efficiency**
- **ISDN compatibility**

GSM Evolution

Year	Event
1982	Groupe Spécial Mobile established by the CEPT.
1986	Reservation of the 900 MHz spectrum band for GSM agreed in the EC Telecommunications Council.
	Trials of different digital radio transmission schemes and different speech codes in several countries.
1987	Basic parameters of the GSM standard agreed in February.
1988	Completion of first set of detailed GSM specifications for infrastructure.
1989	Groupe Spéciale Mobile (transferred to an ETSI technical committee) defines the GSM standard as the internationally accepted digital cellular telephony standard.
1990	GSM adaptation work started for the DCS1800 band.
1991	First GSM call made by Radiolinja in Finland.
1992	First international roaming agreement signed between Telecom Finland and Vodafone (UK).
	First SMS sent.
1993	Telstra Australia becomes the first non-European operator.
	Worlds first DCS1800 (later GSM1800) network opened in the UK.
1994	GSM Phase 2 data/fax bearer services launched.
	GSM MoU membership surpasses 100 operators.
	GSM subscribers hit one million.

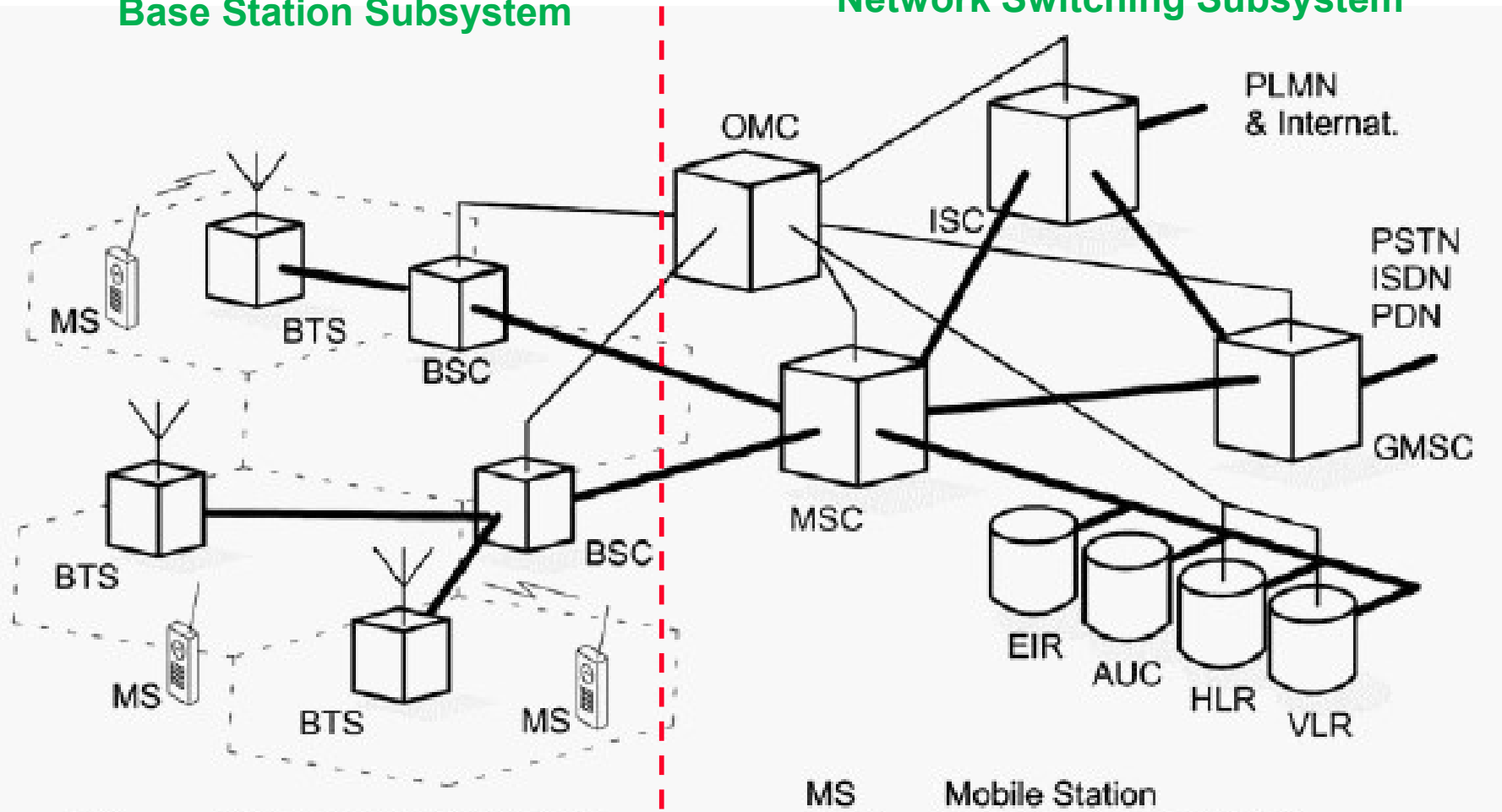
GSM Evolution – cont'd

1994	GSM Phase 2 data/fax bearer services launched.
	GSM MoU membership surpasses 100 operators.
	GSM subscribers hit one million.
1995	117 GSM networks on air.
	The number of GSM subscribers worldwide exceeds 10 million.
	Fax, data and SMS services started, video over GSM demonstrated.
	The first North American PCS 1900 (now GSM 1900) network opened.
1996	First GSM networks in Russia and China go live.
	Number of GSM subscribers hits 50 million.
1997	First tri-band handsets launched.
1998	Number of GSM subscribers worldwide over 100 million.
1999	WAP trials begin in France and Italy.
2000	First commercial GPRS services launched.
	First GPRS handsets enter the market.
	Five billion SMS messages sent in one month.
2001	First 3GSM (W-CDMA) network goes live.
	Number of GSM subscribers exceed 500 million worldwide.
2003	First EDGE networks go live.
	Membership of GSM Association breaks through 200-country barrier.
	Over half a billion handsets produced in a year.
2008	GSM surpasses three billion customer threshold.

GSM Services

- Telephone Services, incl.:
  - emergency calling,
  - fax,
  - videotex,
  - teletex,
- Bearer (Data) Services
  - Packet switched protocols and data rates from 300 bps – 9,6 kbps
- Supplementary ISDN services
  - Call diversion, call waiting
  - Closed user groups
  - Caller ID
  - Short Message Services (SMS)
  - Cell message broadcasting
  - Etc.

GSM System Architecture



The Subscriber Identity Module

- **It stores:**
  - **Subscriber ID number**
  - **Subscriber phone number**
  - **Network ID and country code**
  - **Privacy keys**
  - **Short messages**
  - **Charging information**
  - **Other user-specific information (ex. Phone directory, short list of call numbers, etc.)**
  - **Network-specific information, such as list of frequencies used by the network to broadcast system information**

- **It can be accessed via a PIN code, so it can be moved to any phone**
- **It takes over security functions (ex. Authentication, data encryption, etc.)**

GSM Addressing

- "User" or "Equipment" "identifiers" are used to address specific user or equipment
- User identities are stored in SIM, while equipment identities are stored in the MS
  - International Mobile Subscriber Identity (IMSI)
    - Consists of 15 decimal digits
      - Mobile Country Code (MCC), 3 internationally standardized digits (ex. Code 202 for Greece)
      - Mobile Network Code (MNC), 2 country-wide standardized digits
      - Mobile Subscriber Identification Number (MSIN), 10 digits, identifies each subscriber in his home network, assigned by the home network
  - Mobile Subscriber ISDN Number (MSISDN)
    - It is the "real" telephone number of the mobile user
    - A subscriber may have more than one telephone numbers (ex. for different services)
    - The IMSI may be kept private

GSM Addressing – cont'd

- International Mobile station Equipment Identity (IMEI)
  - Like a Serial number, it identifies mobile terminals
  - Obsolete, stolen or discontinued terminals can be identified
  - Usually, it is requested by network during terminal registration, but it can also be requested periodically
- Mobile Station Roaming Number (MSRN)
  - A temporary location-dependent ISDN number
  - Calls are routed to the MS from the VLR using the MSRN
- Location Area Identifier (LAI)
  - An internationally unique number that identifies each location area (set of local cells)
  - Its structure contains country-dependent and network-dependent parts
- Temporary Mobile Subscriber Identity (TMSI)
  - A temporary identity, given by VLR, with local significance
  - During an out-of-area call, the IMSI is substituted by {TMSI, LAI}

Location Registers (HLR & VLR)

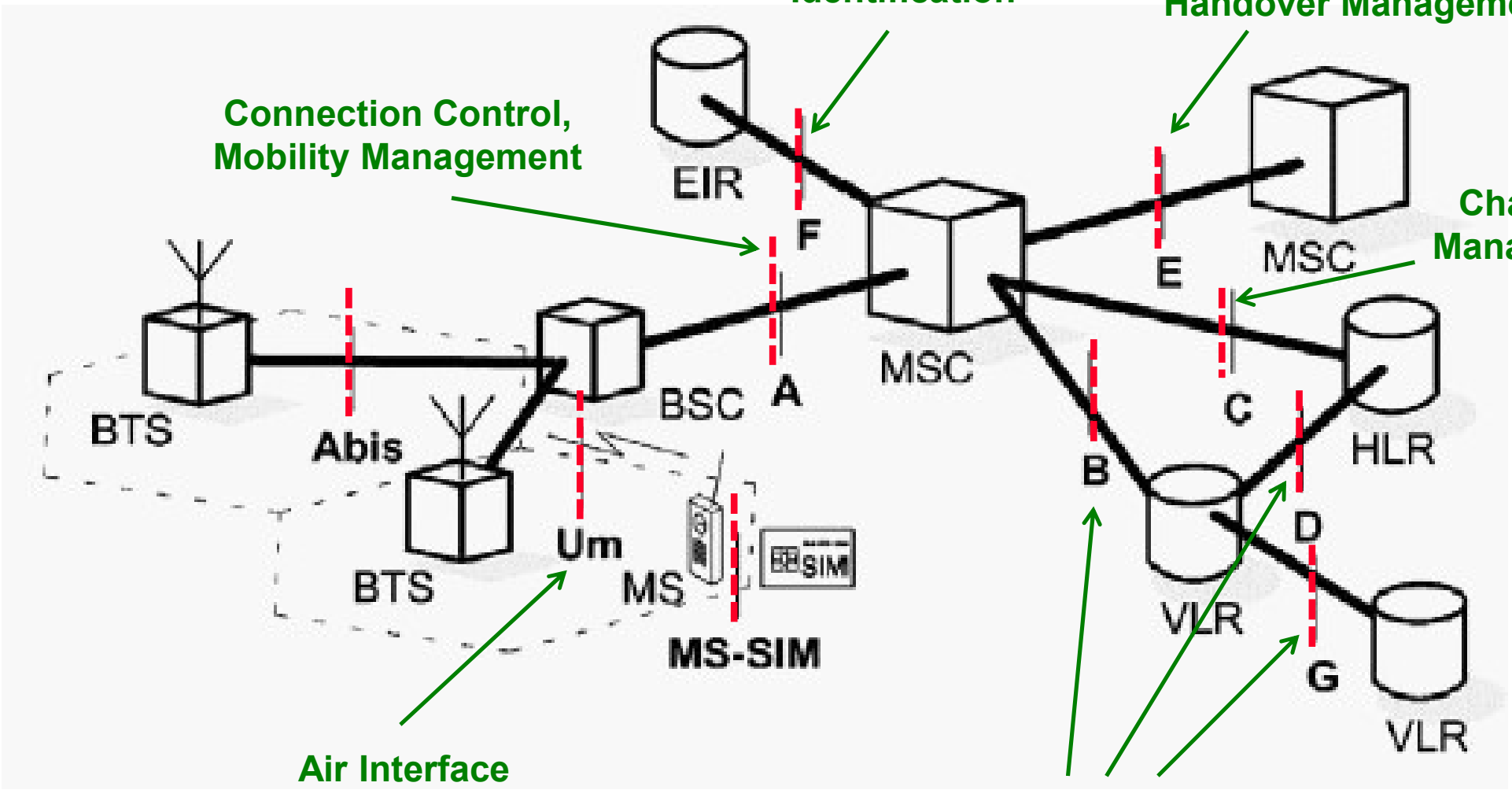
Table 3.1 Mobile subscriber data in the HLR.

Subscriber and subscription data:	– IMSI – MSISDN – Service subscriptions – Service restrictions (e.g., roaming restrictions) – Information on the subscriber's equipment (if available) – Authentication data (subject to implementation)
Tracking and routing information:	– Mobile Station Roaming Number (MSRN) – Current VLR address (if available) – Current MSC address (if available) – Local Mobile Subscriber Identity (LMSI) (if available)

Table 3.2 Mobile subscriber data in the VLR.

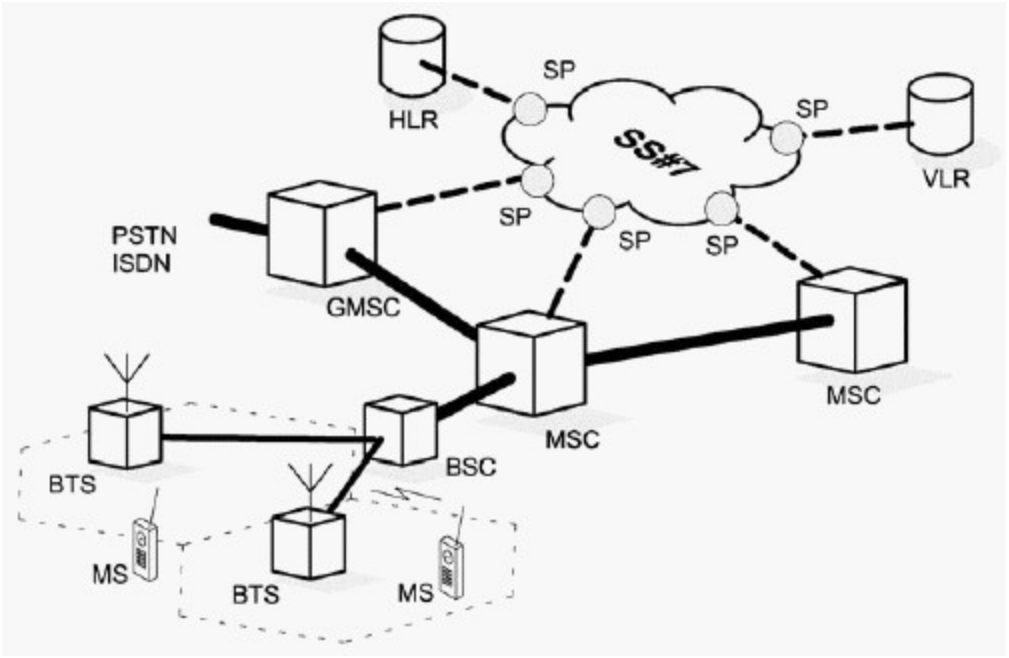
Subscriber and subscription data:	– IMSI – MSISDN – Parameters for supplementary services – Information on the subscriber's equipment (if available) – Authentication data (subject to implementation)
Tracking and routing information:	– MSRN – TMSI – LMSI (if available) – LAI of LA where the MS was registered (used for paging and call setup)

Network Interfaces

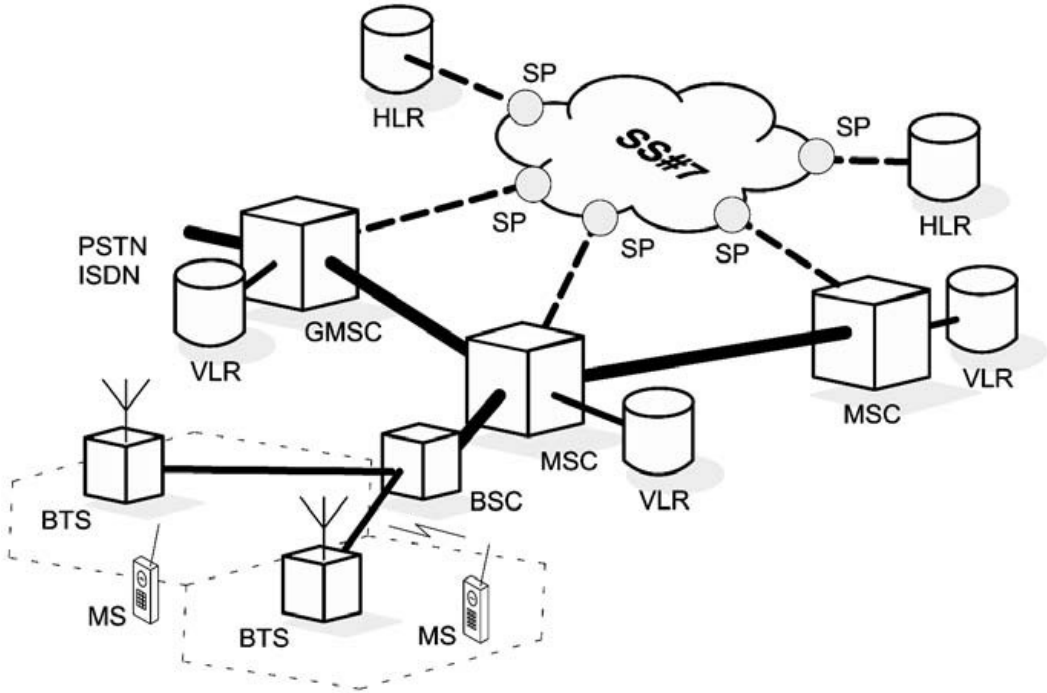


Network Configurations

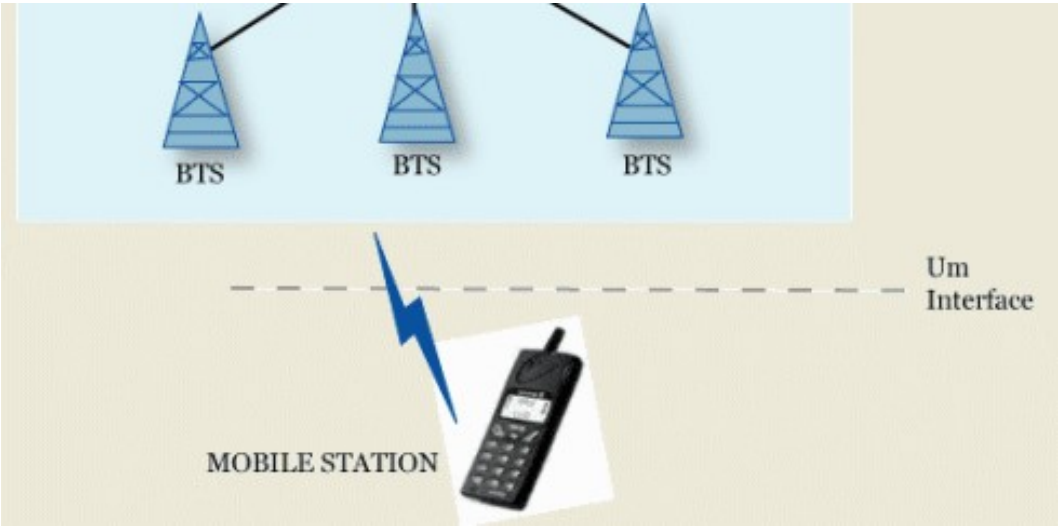
Basic Configuration

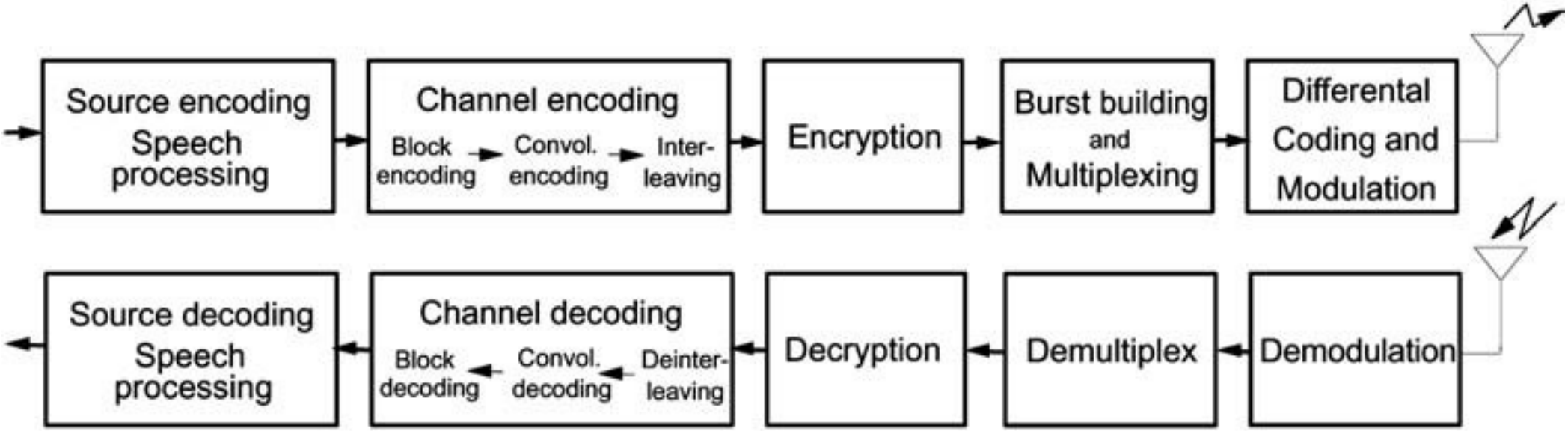


A VLR (or HLR) at every MSC to reduce signaling overhead



GSM Transmission Chain





GSM Radio Subsystem, cont'd

GSM Air Interface Specifications

GSM is a multicarrier TDMA system

Parameter	Specifications
Reverse Channel Frequency	890 - 915 MHz
Forward Channel Frequency	935 - 960 MHz
ARFCN Number	0 to 124 and 975 to 1023
Tx/Rx Frequency Spacing Tx/Rx Time Slot Spacing	45 MHz 3 Time slots
Modulation Data Rate	270.833333 kbps
Frame Period	4.615 ms
Users per Frame (Full Rate)	8
Time slot Period	576.9 μs
Bit Period	3.692 μs
Modulation	0.3 GMSK
ARFCN Channel Spacing	200 kHz
Interleaving (max. delay)	40 ms
Voice Coder Bit Rate	13.4 kbps

Frequency Channels

Different time slot per user per freq. (TDMA)

Good spectral efficiency and Low complexity

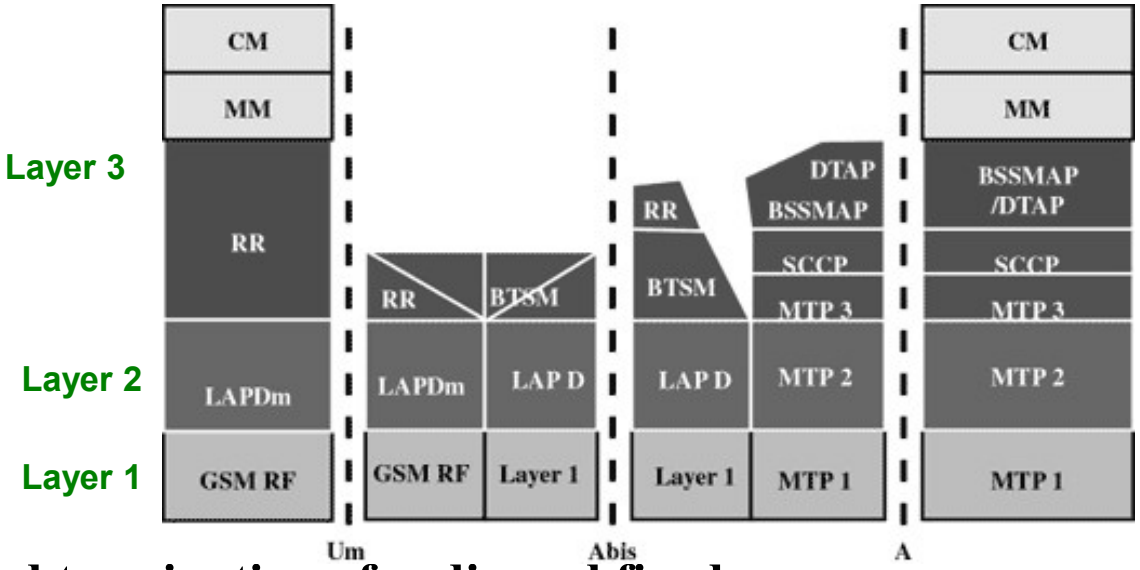
Division of available spectrum in freq. carriers (FDMA)

GSM Radio Subsystem – cont'd

- **Frequency Hopping (FH)**
  - **It is optional**
  - **MS and BS transmit each frame on different frequencies to combat multipath fading**
  - **Good speech quality may be achieved at 9 dB SNR (from 11 dB without FH)**
  - **Freq. hopping algorithm is broadcast on the Broadcast Control Channel (BCCH)**
- **Discontinuous Transmission (DTX)**
  - **It exploits the fact that during an average phone conversation, the persons speak less than 40% of the time**
  - **Tx is turned off during silence period, thus reducing interference and preserving MS battery**
  - **Accuracy of Voice Activity Detection mechanism is thus very important**
- **Power Control**
  - **Adjustment of Tx power (at MS or BTS), to reduce interference**
  - **Five classes of MS, according to peak Tx power (20, 8, 5, 2, 0,8 Watts)**
  - **Power levels get adjusted by +/- 2 dB from peak power up to 13 dBm**

Signaling Protocols

- Functionality includes:
  - Registration
  - Authentication
  - Call routing
  - Location updating
  - Handover implementation

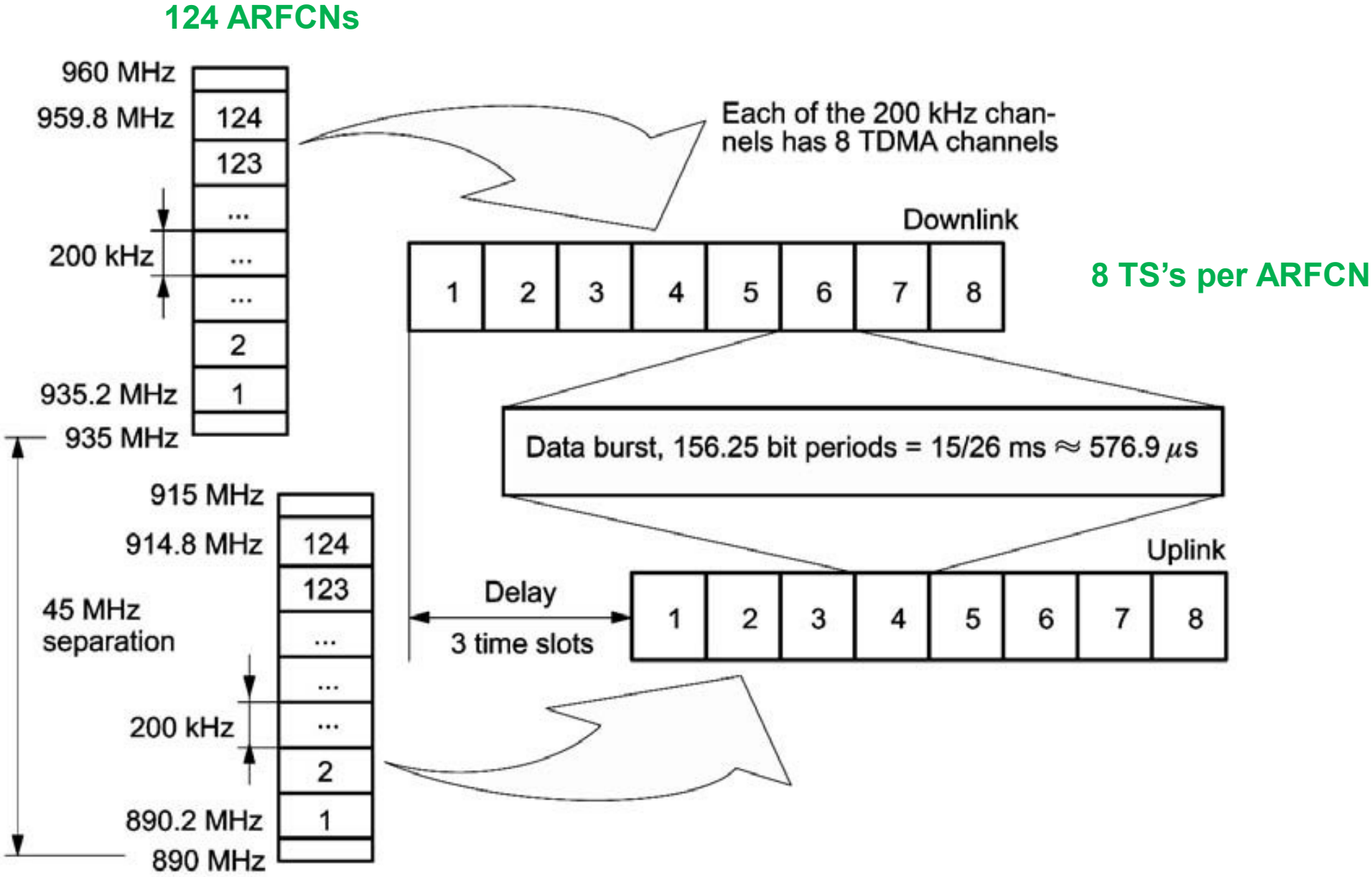


- Radio Resources Management (RR)
  - It controls the setup, maintenance and termination of radio and fixed channels, including handovers
- Mobility Management (MM)
  - Responsible for location updating and registration procedures, as well as
  - security and authentication
- Communication Management (CM)
  - It handles several call control, manages SMS and supplementary services

GSM Channels

- **Physical channels**
  - **The combination of Absolute Radio Frequency Channel Number (ARFCN) and a Time Slot (TS) that is used to transport data**
- **Logical Channels**
  - **A set of "virtual' channels, each one responsible for a specific task**
  - **They are transported through the physical channels via the air interface**
  - **Traffic Channels are responsible for transporting speech / data**
  - **Control Channels are responsible for transporting signaling data**

Physical Channels



GSM Traffic Channels

Full Rate	
Full Rate Speech Channel (TCH/FS)	It carries user speech, digitized at 13 kbps raw data rate. With GSM channel coding the rate increases to 22,8 kbps
Full Rate Data Channel at 9600 bps (TCH/F9.6)	It carries user data, at 9,6 kbps raw data rate. With additional GSM data channel coding the rate increases to 22,8 kbps
Full Rate Data Channel at 4800 bps (TCH/F4.8)	It carries user data, at 4,8 kbps raw data rate. With additional GSM data channel coding the rate increases to 22,8 kbps
Full Rate Data Channel at 2400 bps (TCH/F2.4)	It carries user data, at 2,4 kbps raw data rate. With additional GSM data channel coding the rate increases to 22,8 kbps
Half Rate	
Half Rate Speech Channel (TCH/HS)	It carries user speech, digitized at 6,5 kbps raw data rate. With GSM channel coding the rate increases to 11,4 kbps
Half Rate Data Channel at 4800 bps (TCH/H4.8)	It carries user data, at 4,8 kbps raw data rate. With additional GSM data channel coding the rate increases to 11,4 kbps
Half Rate Data Channel at 2400 bps (TCH/H2.4)	It carries user data, at 2,4 kbps raw data rate. With additional GSM data channel coding the rate increases to 11,4 kbps

GSM Control Channels

Broadcast Channels (BCH)	
Broadcast Control Channel (BCCH)	A forward link channel that is used to broadcast information such as cell and network identity, operating characteristics of the cell, etc. It also broadcasts the list of channels that are currently in use (freq. hopping algorithm, etc.)
Frequency Correction Channel (FCCH)	It allows each MS to sync its internal frequency to the exact freq of the BS
Synchronization Channel (SCH)	It is used to identify the serving BS and synchronize the frames between MS's and BS
Common Control Channels (CCCH)	
Paging Channel (PCH)	It provides paging signals from the BS to all MS's and notifies the MS of an incoming call from PSTN Alternatively, it may be used to provide cell broadcast text messages, as part of SMS feature.
Random Access Channel (RACH)	It is a reverse link channel used by a MS to acknowledge a page from PCH. It is also used by mobiles to request access to the network (call origination)
Access Grant Channel (AGCH)	It is used by the BS to provide forward link communication to the mobile and carries data which instruct the mobile to operate on a particular dedicated control channel. It is also used by BS to respond to a RACH sent by a MS

GSM Control Channels – cont'd

Dedicated Control Channels (DCCH)	
Stand Alone Dedicated Control Channel (SDCCH)	It carries signaling data, following the connection of the MS to the BS, just before a TCH assignment is issued by the BS. An intermediate and temporary channel which accepts a newly completed call from the BCH and holds the traffic while waiting for the BS to allocate a TCH channel.
Slow Associated Control Channel (SACCH)	It carries general information between the MS and BTS. It is always associated with a traffic channel. On the forward link, it sends regular and slow info, such as Tx power adjustment, etc. On the reverse link, it carries info about the strength of the received signal and the quality of the TCH, as well as BCH measurement results from neighboring cells.
Fast Associated Control Channel (FACCH)	It carries urgent messages and contains essentially the same type of information as the SDCCH. A FACCH is assigned when a SDCCH has not been dedicated to a user and there is an urgent message (ex. a handoff request)

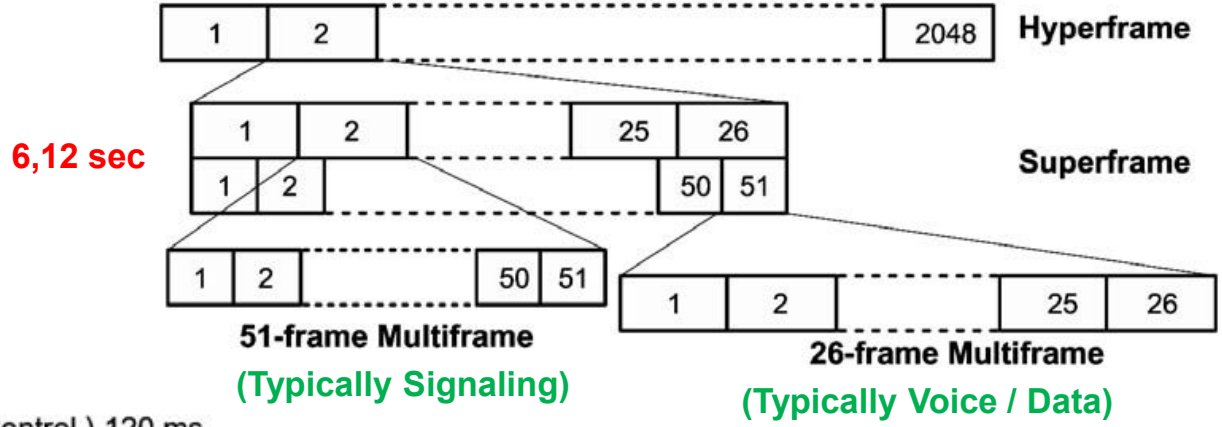
GSM Logical Channels

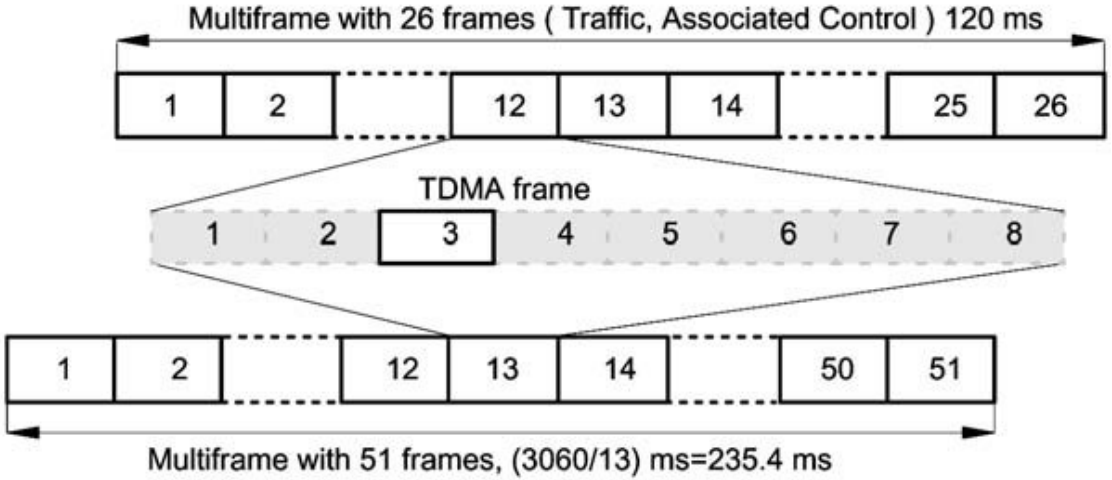
Group		Channel	Function	Direction
Traffic channel	TCH	TCH/F, Bm	Full-rate TCH	MS ↔ BSS
		TCH/H, Lm	Half-rate TCH	MS ↔ BSS
Signaling channels (Dm)	BCH	BCCH	Broadcast control	MS ← BSS
		FCCH	Frequency correction	MS ← BSS
		SCH	Synchronization	MS ← BSS
	CCCH	RACH	Random access	MS → BSS
		AGCH	Access grant	MS ← BSS
		PCH	Paging	MS ← BSS
		NCH	Notification	MS ← BSS
	DCCH	SDCCH	Stand-alone dedicated control	MS ↔ BSS
		SACCH	Slow associated control	MS ↔ BSS
		FACCH	Fast associated control	MS ↔ BSS

Logical – Physical Channel Mapping

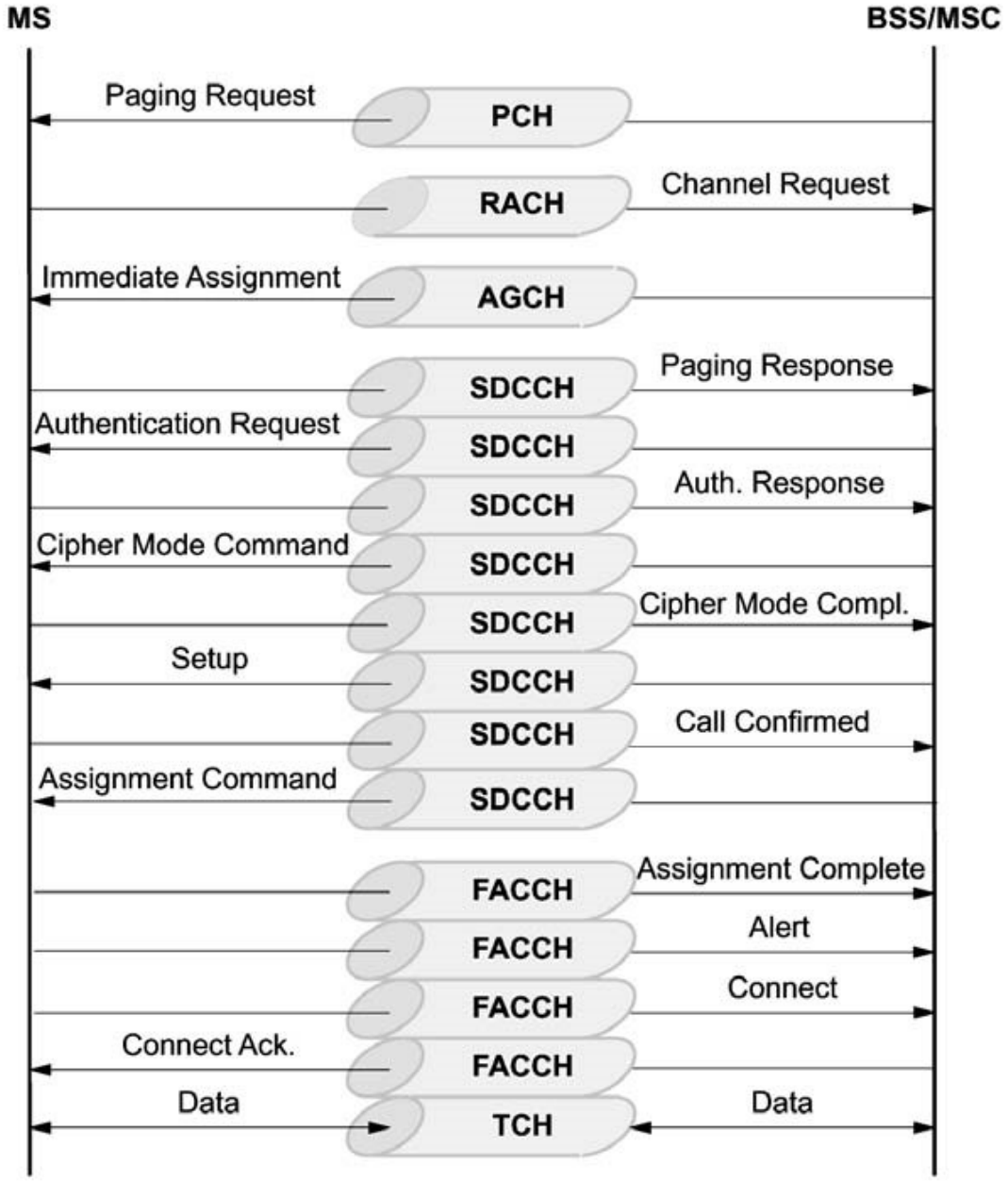
Logical Channels

- are transported in a specific time slot of a physical channel
- are time multiplexed and may occupy a complete or partial physical channel
- Forming complex frame-structures on top of TDMA frames (multiframes, superframes, hyperframes, etc.)





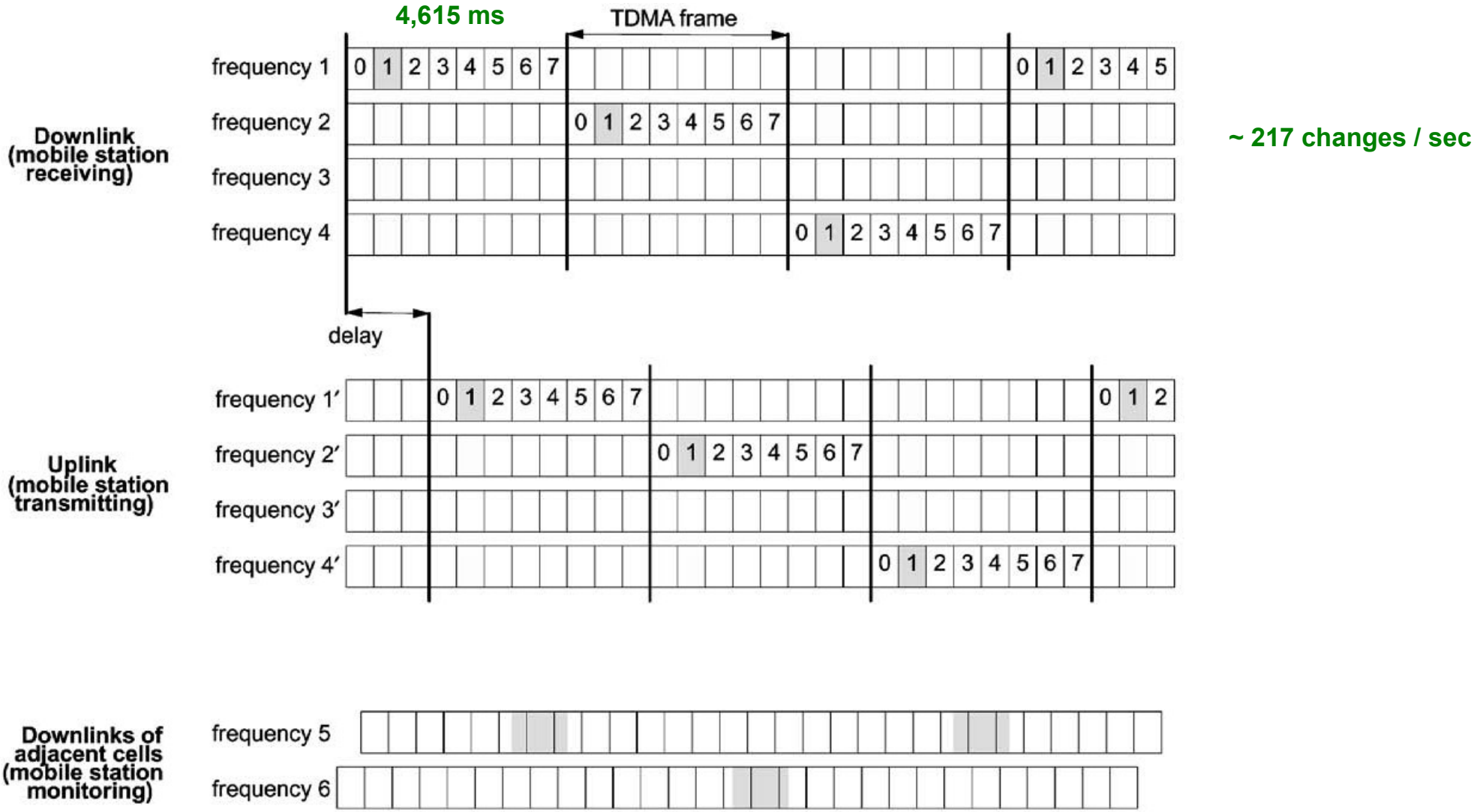
Incoming Call Connection Setup



- MS is called via the PCH and requests a signaling channel on RACH
- It obtains the SDCCH through an "immediate assignment" message on the AGCH
- Then, the following are performed:
  - Authentication
  - Ciphering
  - Start of setup over SDCCH
- An "assignment command" message gives the traffic channel to the MS,
- Which acknowledges its receipt on the FACCH
- The FACCH is also used to continue the connection setup

Frequency Hopping

Full rate traffic channel
With frequency hopping



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