

Mobile Communications

GSM

Manuel P. Ricardo

Faculdade de Engenharia da Universidade do Porto

Acknowledgements

- ◆ These slides are based on the slides developed by
 - » Prof. Jochen Schiller
 - Slides from the book “Mobile Communication: Wireless Telecommunication Systems”
 - <http://www.jochenschiller.de>

 - » Prof. Mário Jorge Leitão
 - <http://www.fe.up.pt/~mleitao/>

- ◆ *What are the main network elements of GSM?*
- ◆ *What are the GSM addresses?*
- ◆ *How is the data transmitted over the air interface?*
- ◆ *What are the main logical channels?*
- ◆ *What is the GSM protocol stack for signalling?*
- ◆ *How is a Mobile Terminated Call processed?*
- ◆ *How is a Mobile Initiated Call processed?*

GSM - Overview

- ◆ Formerly: Groupe Spéciale Mobile (founded 1982)
- ◆ Now: Global System for Mobile Communication
- ◆ Pan-European standard
 - » ETSI, European Telecommunications Standardisation Institute
- ◆ Seamless roaming within Europe possible
- ◆ Many providers all over the world

Services

- ◆ Basic services
 - » voice services, data services, short message service
- ◆ Additional services
 - » emergency number, group 3 fax
- ◆ Supplementary services
 - » identification: forwarding of caller number
 - » suppression of number forwarding
 - » automatic call-back

Basic Services

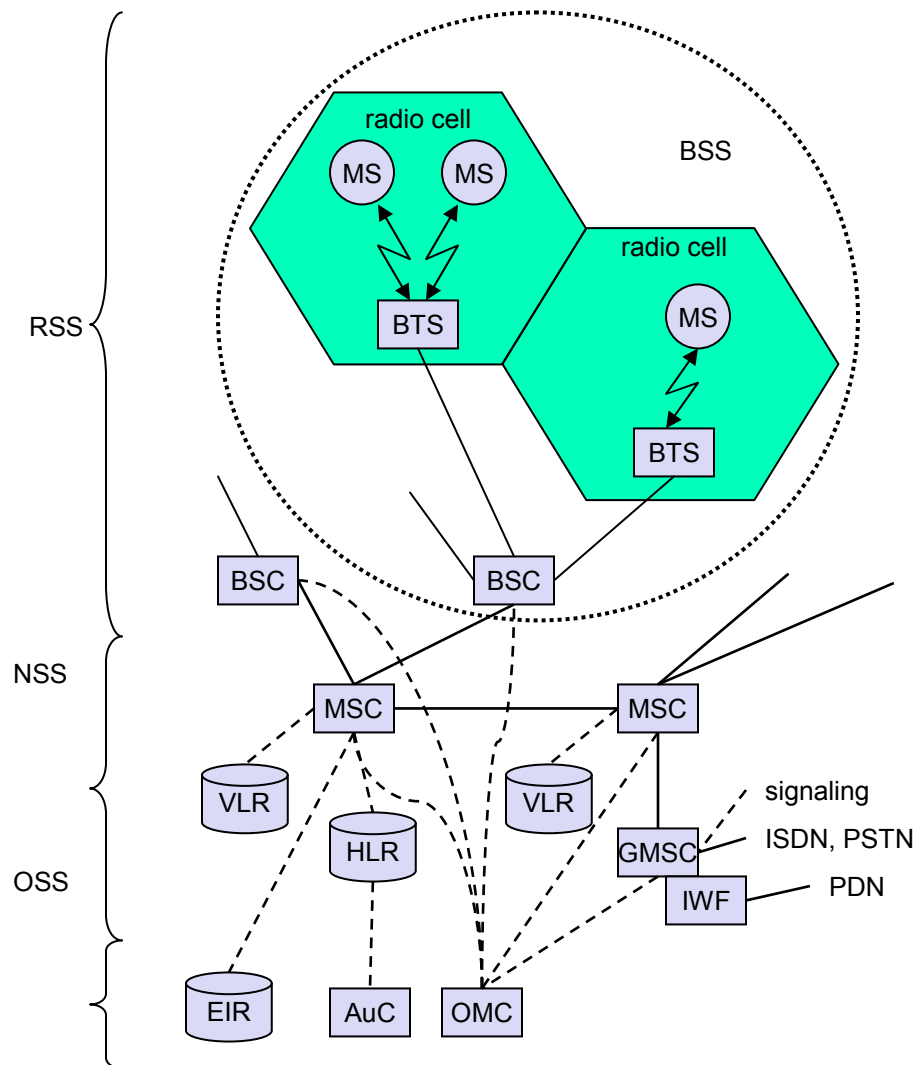
- ◆ Voice services (speech coding with protection)
 - » full rate: 13 / 12.2 kbit/s (original coder / enhanced full rate coder)
 - » half rate: 5.6 kbit/s (enhanced half rate coder)

- ◆ Data services (coding with different levels of protection)
 - » full rate: 9.6 / 4.8 / 2.4 kbit/s
 - » half rate: 4.8 / 2.4 kbit/s

- ◆ Enhanced data services → GPRS (General Packet Radio Service)
 - » various rates (typically up to 53.6 kbit/s)

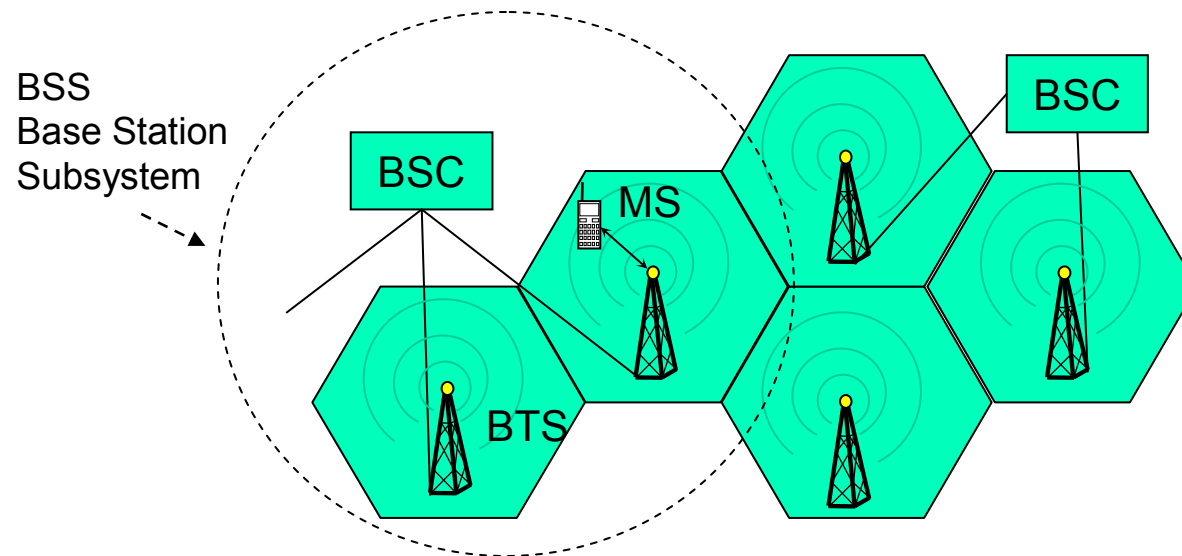
Public Land Mobile Network (PLMN)

GSM 7



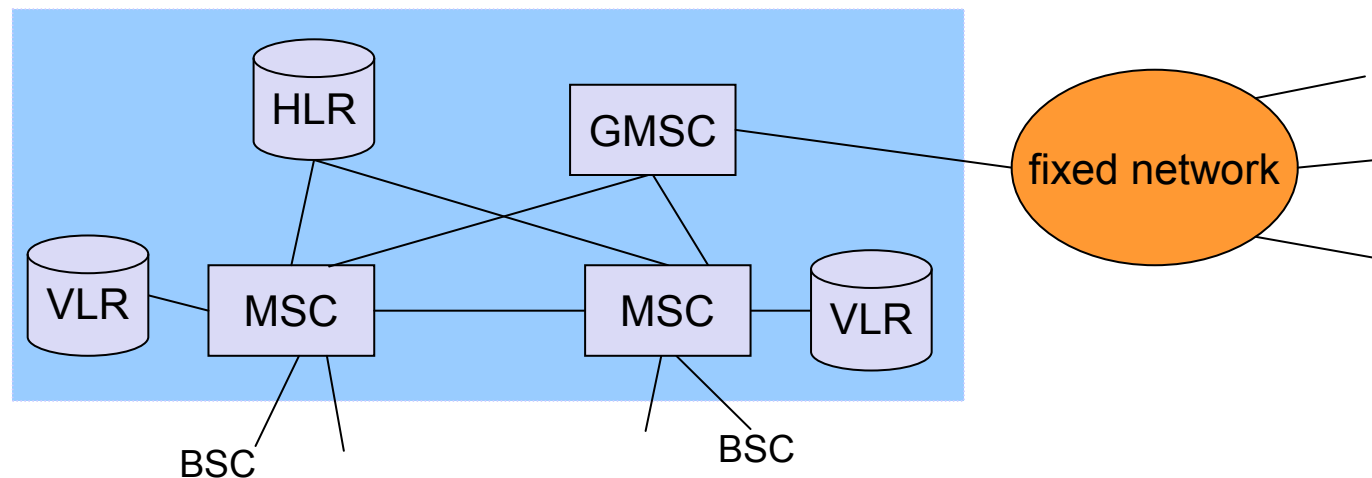
GSM Architecture – Radio Subsystem (RSS)

- » MS - Mobile Station
 - Mobile terminal equipment
- » BTS- Base Transceiver Station
 - Transmitter, receiver and antennas
- » BSC - Base Station Controller
 - Management of several BTS and MS



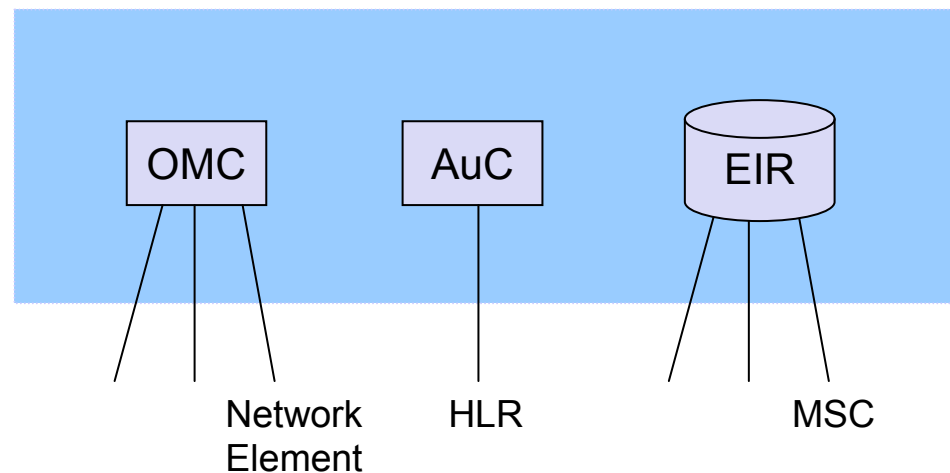
GSM Architecture – Network Subsystem (NSS)

- » Switching, mobility management,
- » Interconnection to other networks, system control
- » MSC - Mobile Switching Centre: Management of connections
- » HLR - Home Location Register: Associated to each PLMN
- » VLR - Visitor Location Register: Associated to each MSC
- » GMSC - Gateway MSC: MSC providing interconnection to other networks

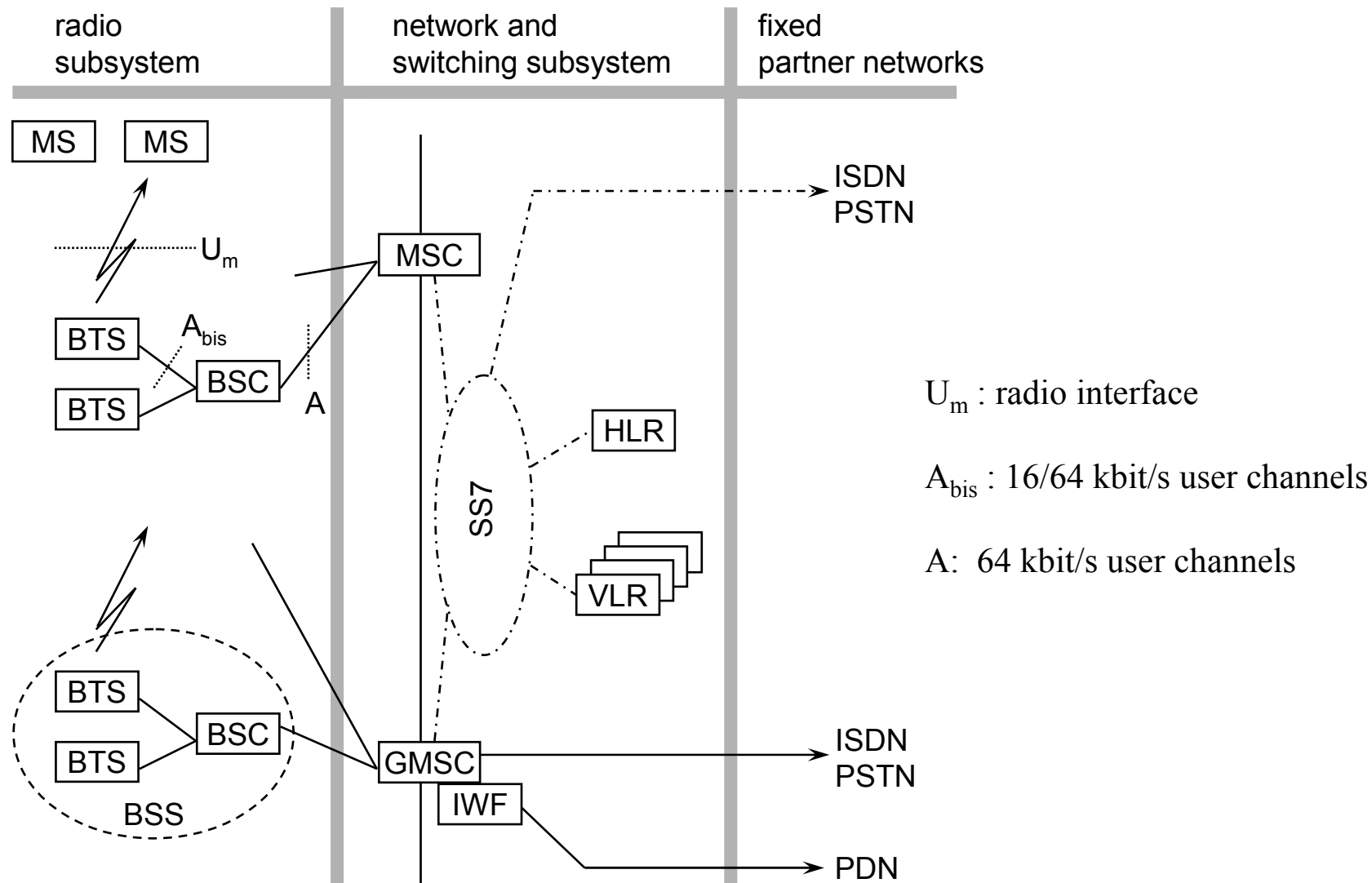


GSM Architecture – Operation Subsystem (OSS)

- » Centralized operation, management and maintenance of GSM subsystems
- » OMC - Operation and Management
 - Control of the radio and network subsystems
- » AuC - Authentication Centre
 - Security functions
- » EIR - Equipment Identity Register
 - Mobile station registration

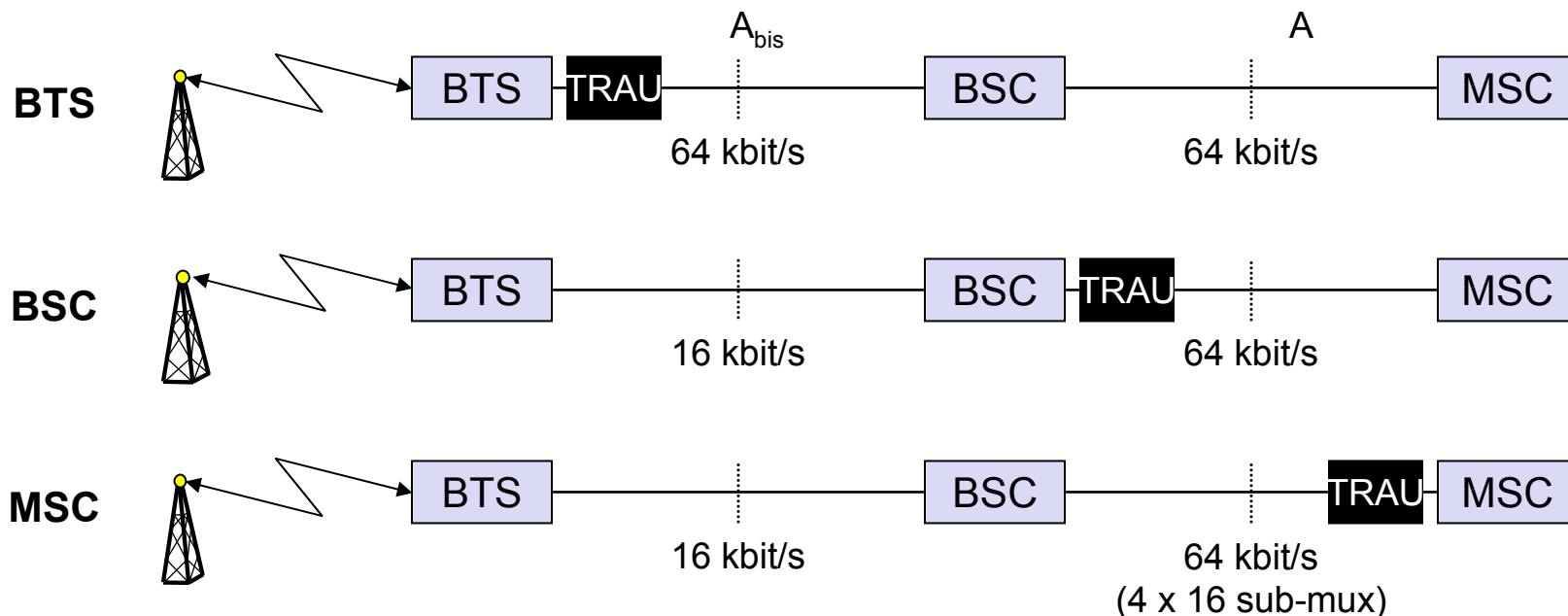


GSM Architecture - Interfaces



Voice Transcoding and Rate Adaptation

- ◆ Need for transcoding and rate adaptation
 - » BTS - 13 kbit/s air-interface (original coder)
 - » MSC - 64 kbit/s ISDN type switching (PCM, A-law)
- ◆ 3 options for Transcoding and Rate Adapter Unit (TRAU)



Mobile Addresses

- ◆ Several mobile numbers are needed
 - » IMSI - International Mobile Subscriber Identity
 - Mobile Country Code (MCC) + Mobile Network Code (MNC) + Mobile Subscriber Identification Number (MSIN)
 - uniquely identifies the user (SIM card)
 - » TMSI - Temporary Mobile Subscriber Identity
 - 32 bits
 - local number allocated by VLR; may be changed periodically
 - hides the IMSI over the air interface; transmitted instead of IMSI
 - » MSRN - Mobile Station Roaming Number
 - Visitor Country Code (VCC) + Visitor National destination Code (VNDC) + Current MSC code + temporary subscriber number
 - generated by VLR for all visiting users
 - helps HLR to determine current location area
 - hides the IMSI inside the network

SIM Card (Subscriber Identity Module)

GSM 14

- » Uniquely associated to a user
- » Stores user and location addresses
 - IMSI - International Mobile Subscriber Identity
 - TMSI - Temporary Mobile Subscriber Identity
 - LAI - Location Area Identification
- » Supports authentication and encryption mechanisms
 - PIN - Personal Identity Number
 - PUK - PIN Unblocking Key
 - Ki - subscriber secret authentication key
 - A3 - authentication algorithm
 - A8 - cipher key generation algorithm
- » Contains personal data
 - list of subscribed services
 - RAM for user directory

Base Transceiver Station, Base Station Controller

GSM 15

- BTS comprises radio specific functions
- BSC is the switching center for radio channels: switches calls from MSC to correct BTS

Functions	BTS	BSC
Management of radio channels		X
Frequency hopping (FH)	X	X
Management of terrestrial channels		X
Mapping of terrestrial onto radio channels		X
Channel coding and decoding	X	
Rate adaptation	X	
Encryption and decryption	X	X
Paging	X	X
Uplink signal measurements	X	
Traffic measurement		X
Authentication		X
Location registry, location update		X
Handover management		X

Mobile Switching Center - Functions

- ◆ Switching of 64 kbit/s channels
- ◆ Paging and call forwarding
- ◆ Termination of SS7 (signaling system no. 7)
- ◆ Mobility specific signaling
- ◆ Location registration and forwarding of location information
- ◆ Generation/ forwarding of accounting and billing information

Home Location Register (HLR)

- ◆ Central master database
 - » data from every user that has subscribed to the operator
 - » one database per operator
 - » may be replicated

- ◆ Subscriber data
 - » IMSI - International Mobile Subscriber Identity
 - » List of subscribed services with parameters and restrictions

- ◆ Location data
 - » current MSC/VLR address

Visitor Location Register (VLR)

- ◆ Local database
 - » data about all users currently in the domain of the VLR
 - » includes roamers and non-roamers
 - » associated to each MSC
- ◆ Subscriber identity
 - » IMSI - International Mobile Subscriber Identity
- ◆ Temporary location
 - » LAI - Location Area Identification
- ◆ Temporary addresses
 - » MSRN - Mobile Station Roaming Number
 - » TMSI - Temporary Mobile Subscriber Identity

GSM Location / Mobile Addresses ^{GSM 19}

Summary

HLR - Home Location Register	
Permanent	IMSI - International Mobile Subscriber Identity
Temporary	MSRN - Mobile Station Roaming Number

VLR - Visitor Location Register	
Permanent	IMSI - International Mobile Subscriber Identity
Temporary	LAI - Location Area Identification
	MSRN - Mobile Station Roaming Number
	TMSI - Temporary Mobile Subscriber Identity

SIM - Subscriber Identity Module	
Permanent	IMSI - International Mobile Subscriber Identity
Temporary	LAI - Location Area Identification
	TMSI - Temporary Mobile Subscriber Identity

AuC, EIR

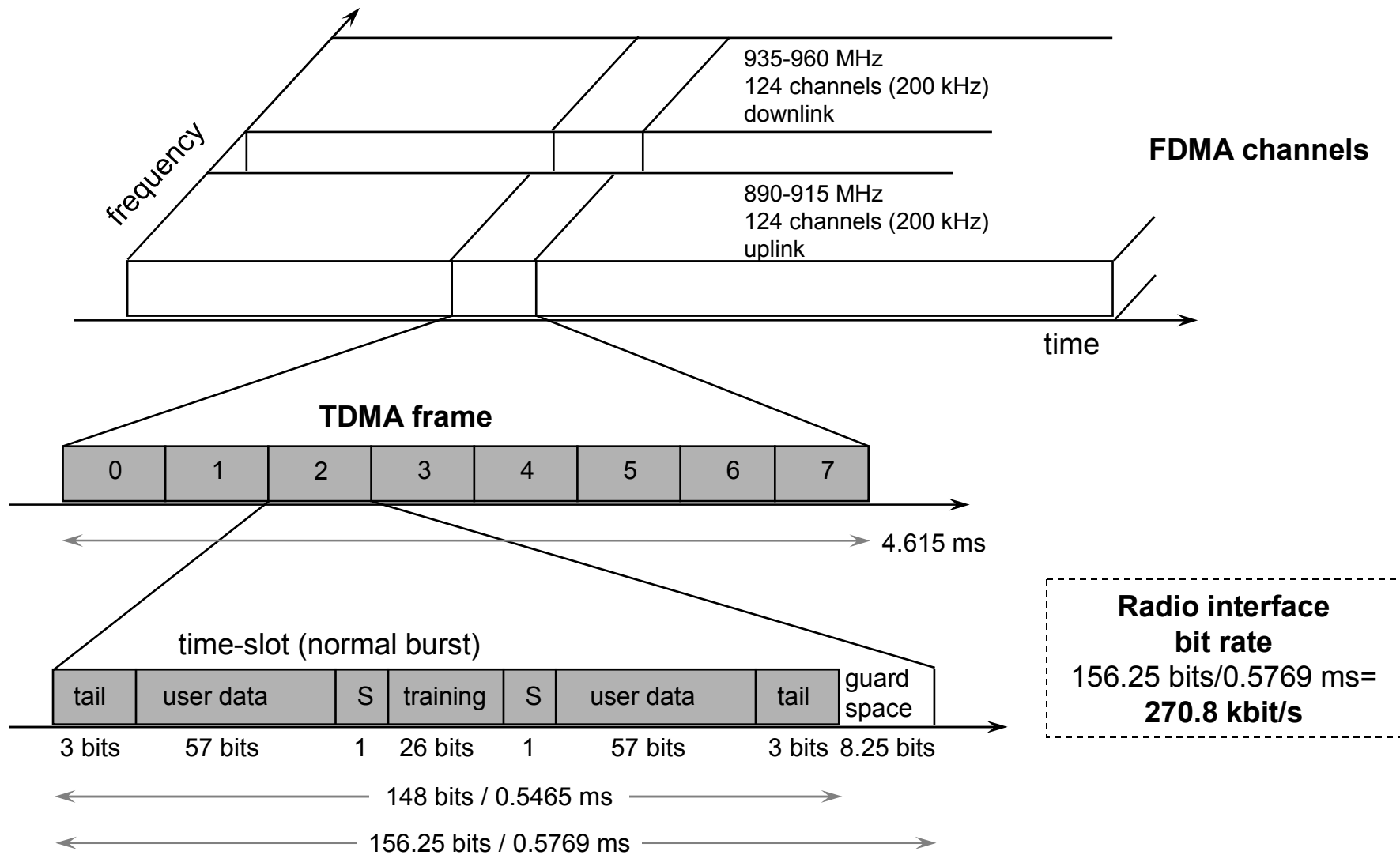
» Authentication Center (AuC)

- associated to HLR
- search key: IMSI
- supports authentication and encryption mechanisms
 - ◆ Ki - subscriber secret authentication key
 - ◆ A3 - authentication algorithm
 - ◆ A8 - cipher key generation algorithm

» Equipment Identity Register (EIR)

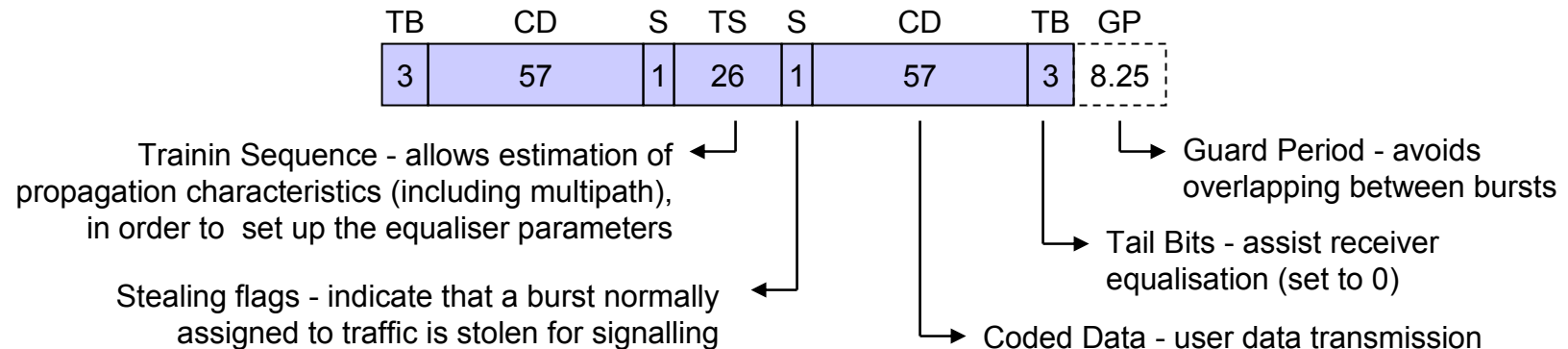
- stores mobile stations IMEI (International Mobile Equipment Identity)
- white list - mobile stations allowed to connect without restrictions
- black list - mobile stations locked (stolen or not type approved)
- gray list - mobile stations under observation for possible problems

GSM - TDMA/FDMA

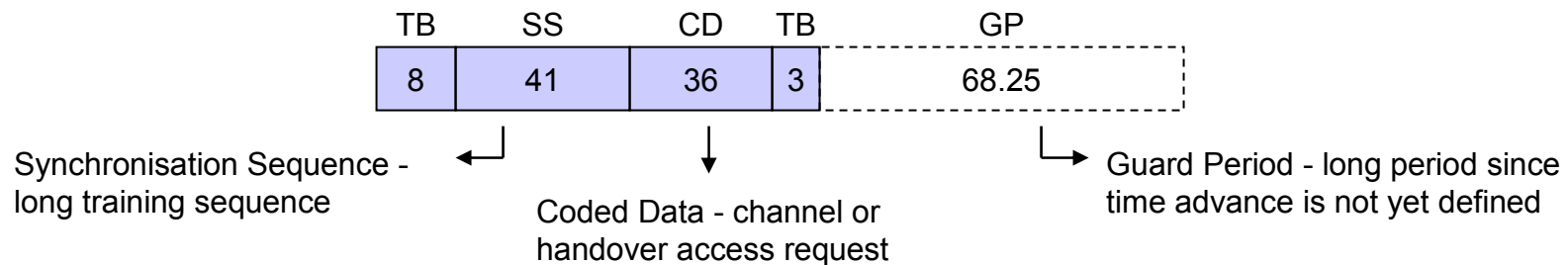


Burst Structures

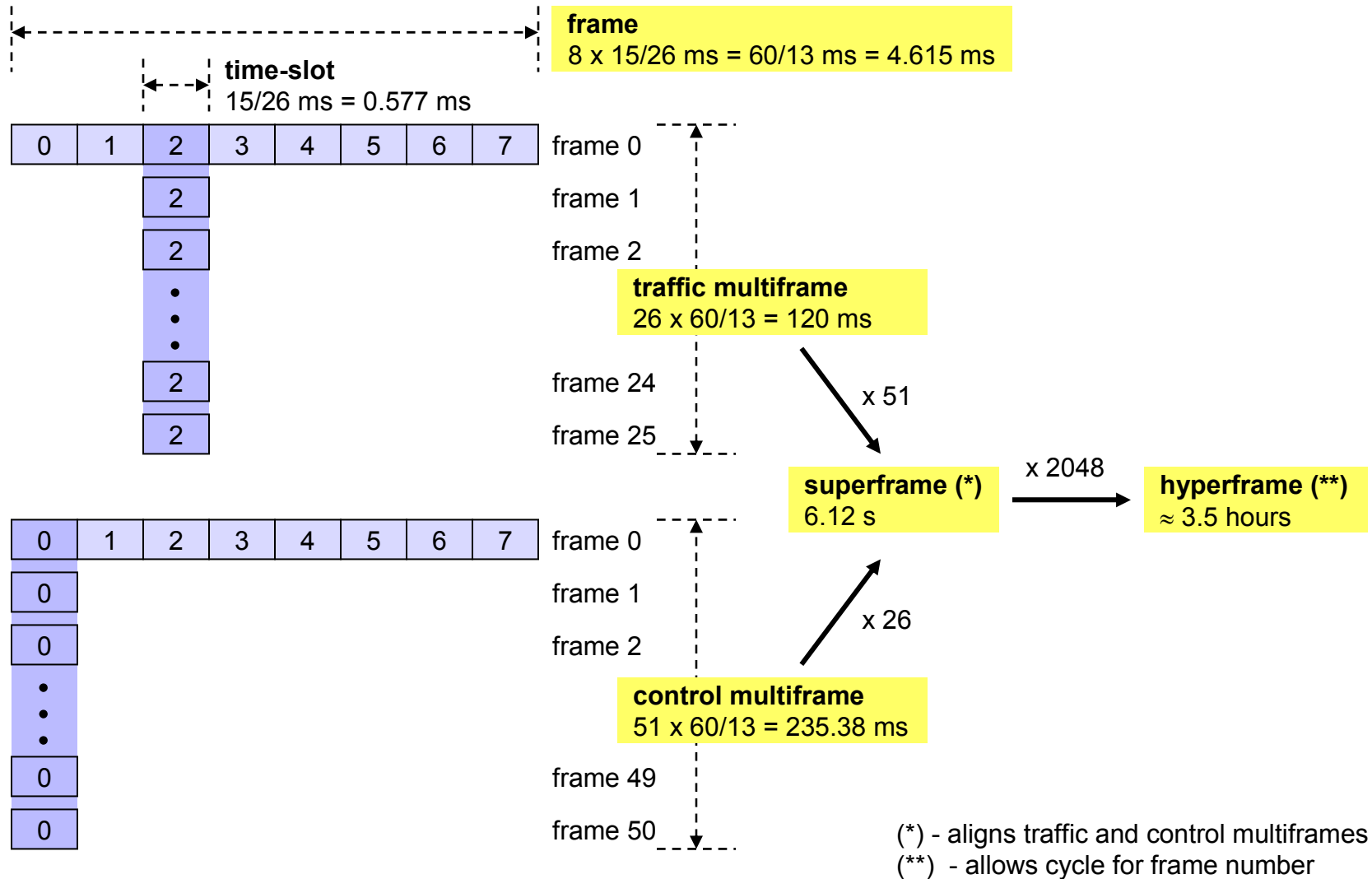
◆ Normal Burst: normal data transmission



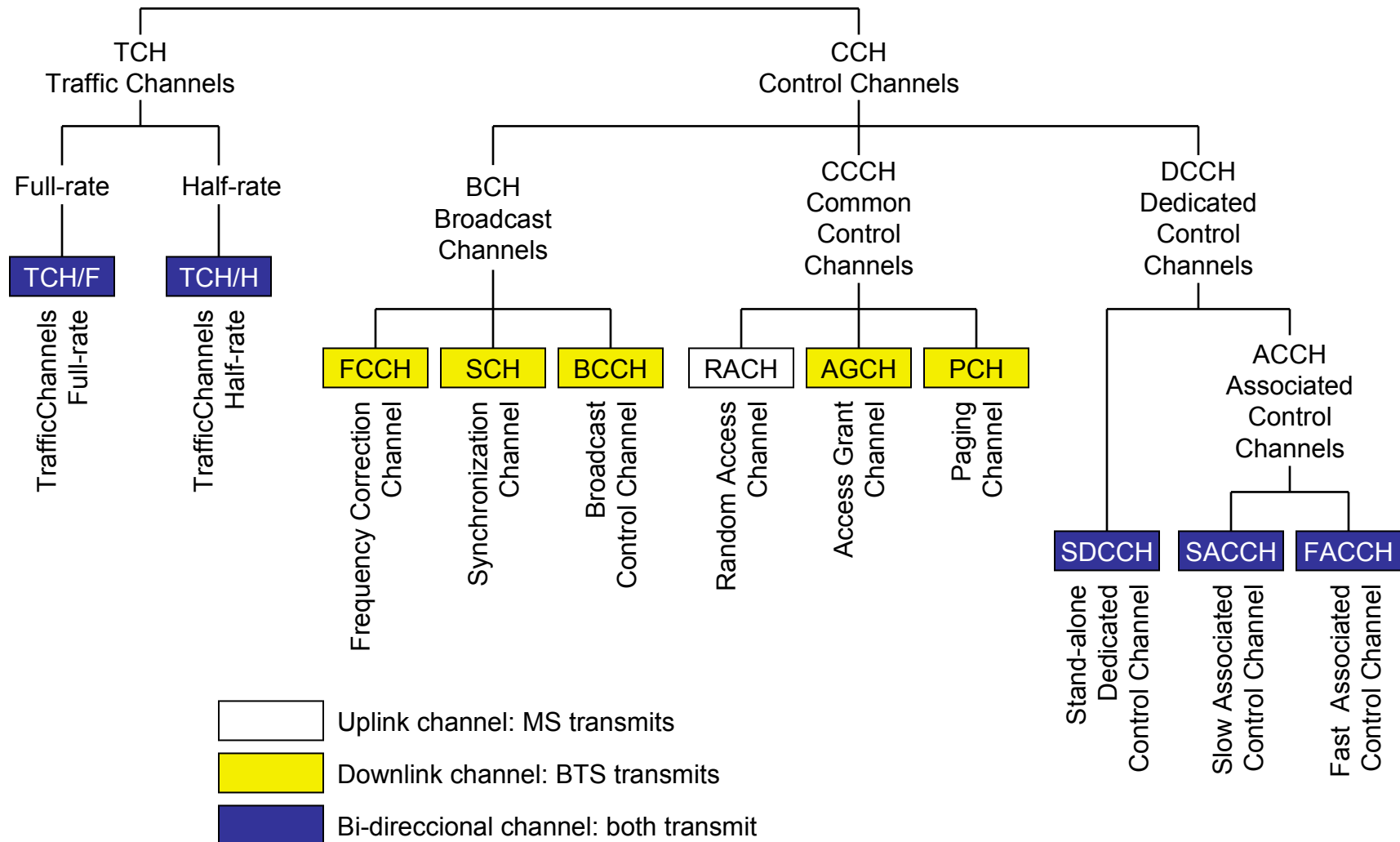
◆ Access Burst: MS first time access



Frame Hierarchy



Logical Channels



Logical Channels

Channel		Direction	Application	Allocation
TCH Traffic Channels	TCH/H	BTS ↔ MS	User data	Allocated by network on demand by MS
	TCH/F			
BCH Broadcast Channels	FCCH	BTS → MS	Carrier synchronization	Permanent
	SCH		Frame synchronisation	
	BCCH		General network information Cell information (present and adjacent)	
CCCH Common Control Channels	RACH	BTS ← MS	Request SDCCH for signalling Request TCH for handover	Multiple access with slotted Alhoa contention between MS
	AGCH	BTS → MS	Confirmation of SDCCH or TCH request	Permanent
	PCH		Allert MS to a call originated in the network	
DCCH Dedicated Control Channels	SDCCH	BTS ↔ MS	Registration / location updating Call control procedures	Allocated by network on demand
	SACCH		Control information between MS and BTS during the progress of a call or call set up	Associated to a specific TCH or SDCCH
	FACCH		Exchange of time critical control information during the progress of a call	Allocated by network or MS (*)

(*) Fast allocation by setting S bit; bits are stolen from TCH

Logical channels

Channel		Burst type	Time-slot	Multiframe	Bursts / Multiframe	Capacity
TCH Traffic Channels	TCH/H	Normal (114 data bits)	Any	26 frames (120 ms)	24	$24 \times 114 / 120 = 22.8 \text{ kbit/s}$
	TCH/F				12	$12 \times 114 / 120 = 11.4 \text{ kbit/s}$
BCH Broadcast Channels	FCCH	Frequency correction	TS0 - base channel (*) TS0/TS2/TS4/TS6 (**)	51 frames (235.38 ms)	5	$4 \times 114 / 235.38 = 1.94 \text{ kbit/s}$
	SCH	Synchronisation			5	
	BCCH	Normal (114 data bits)			4	
CCCH Common Control Channels	RACH	Random access	TS0 - base channel (*) TS2/TS4/TS6 (**)	51 frames (235.38 ms)	27 minimum 51 typical	$12 \times 114 / 235.38 = 5.81 \text{ kbit/s}$ minimum
	AGCH	Normal (114 data bits)			12 minimum	
	PCH					
DCCH Dedicated Control Channels	SDCCH	Normal (114 data bits)	TS0 - base channel (*) TS0/TS2/TS4/TS6 (**)	51 frames (235.38 ms)	4	$4 \times 114 / 120 = 3.8 \text{ kbit/s}$
	SACCH		Same TS as SDCCH		2 (***)	$2 \times 114 / 120 = 1.9 \text{ kbit/s}$
			FACCH	Same TS as TCH	26 frames (120 ms)	1
	Same TS as TCH (bits stolen from TCH)			Same as TCH		Same as TCH

(*) Low capacity cells

(**) High capacity cells

(***) 4 bursts in 2 multiframe

equivalent to 2 bursts/ multiframe

Transmit Time Advance

» Principle of operation

- correct timing of uplink bursts at the BTS is required to avoid overlapping
- different path delays (MS-BTS distances) must be compensated
- transmission from the MS is advanced 0-63 bits under BTS control
- maximum time advance of 63 bits allows 0.233 ms round trip delay
- maximum cell radius is approximately 35 km

» Initial ranging

- Access Burst is transmitted without time advance
- Guard Period of 68.25 bits allows for a path delay due to 37 km distance
- BTS measures path delay and sends required time advance on SACCH
- MS introduces time advance on all bursts

» Adaptive control

- BTS monitors burst and measures delays with specified time advance
- if path delay varies more than 1 bit period, the new value is signalled on SACCH

Frequency hopping

- » Application of frequency hopping
 - optional, but usually implemented
 - channels with no frequency hopping: BCH and CCCH


- » Hoping sequence
 - several possible hopping algorithms
 - selected algorithm broadcast on BCCH

- » Slow frequency hopping characteristics
 - in a given time-slot, successive TDMA frame are transmitted on different carriers
 - main hopping parameters
 - ◆ period: 4.615 ms
 - ◆ frequency: 217 hops/s
 - ◆ number of bits: 1250 bits/hop

Transmission power

◆ Mobile station power classes

GSM 900			GSM 1800		
8 W	39 dBm	vehicular	4 W	36 dBm	vehicular
5 W	37 dBm	portable	1 W	30 dBm	portable
2 W	33 dBm	portable	0.25 W	24 dBm	portable
0.8 W	29 dBm	portable			

 usual classes

◆ Discontinuous transmission (DTX) for voice

- » no data transmission during periods of silence (approx. 60% of time)
 - Voice Activity Detector (VAD) algorithm suppresses TCH transmission
- » silent frames are sent to synthesise comfort noise at the receiver
- » several advantages
 - reduces interference, on average, by 3 dB
 - Increases MS battery life

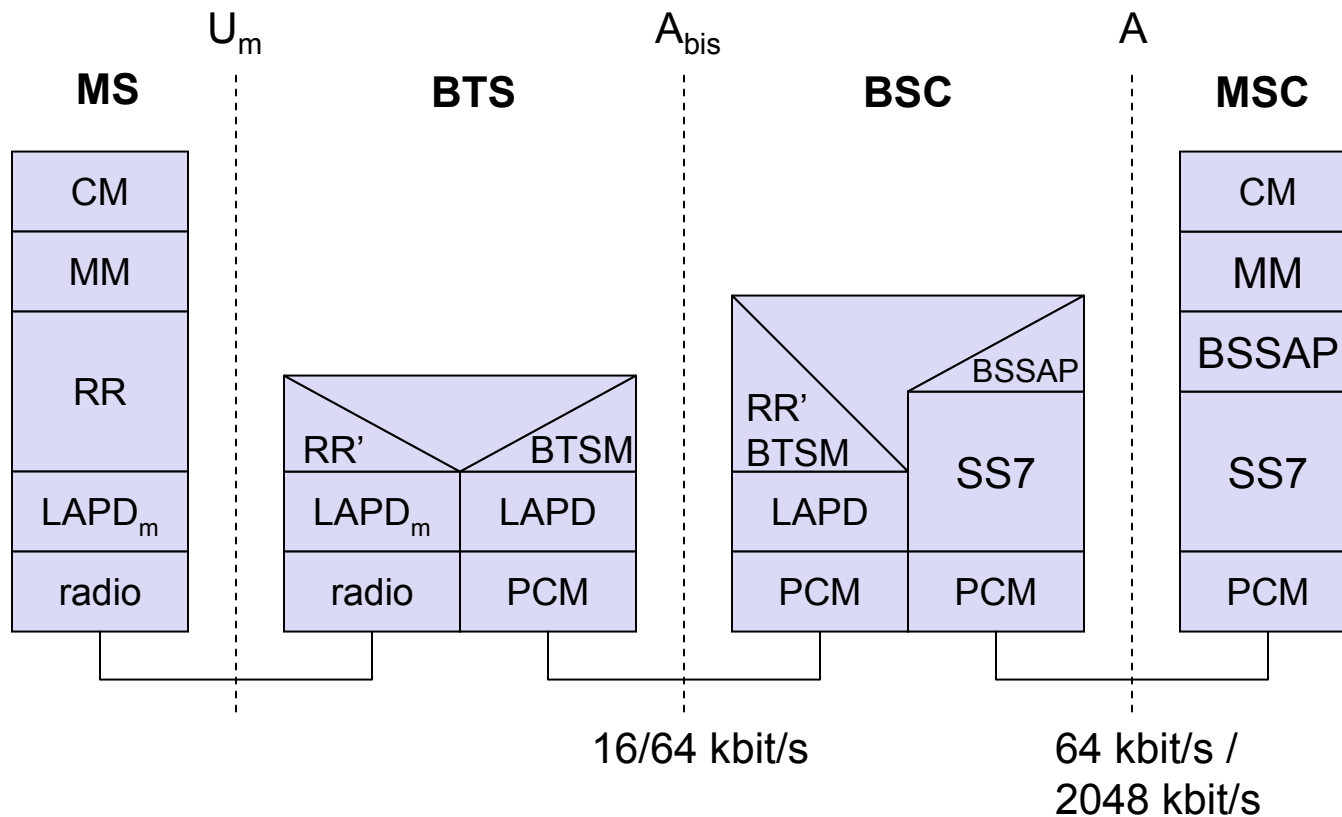
Power Control

- » Implemented on both links
- » Objective: lowest power level which provides desired quality (BER)
- » Procedure
 - MS measures power received and BER and sends result on SACCH
 - BTS sends new power level on SACCH, if and when necessary
- » control range

GSM 900	GSM 1800	Comments
5 - 39 dBm	0 - 36 dBm	effective maxima depend on cell size and MS capability control steps of 2 dB

- » channels with no power control - use maximum power for the cell
 - downlink BCH and CCCH: power set by BTS
 - uplink RACH
 - ◆ BCCH broadcasts maximum power level for the cell
 - ◆ MS uses this value to set RACH transmission power

GSM Protocol Layers for Signaling

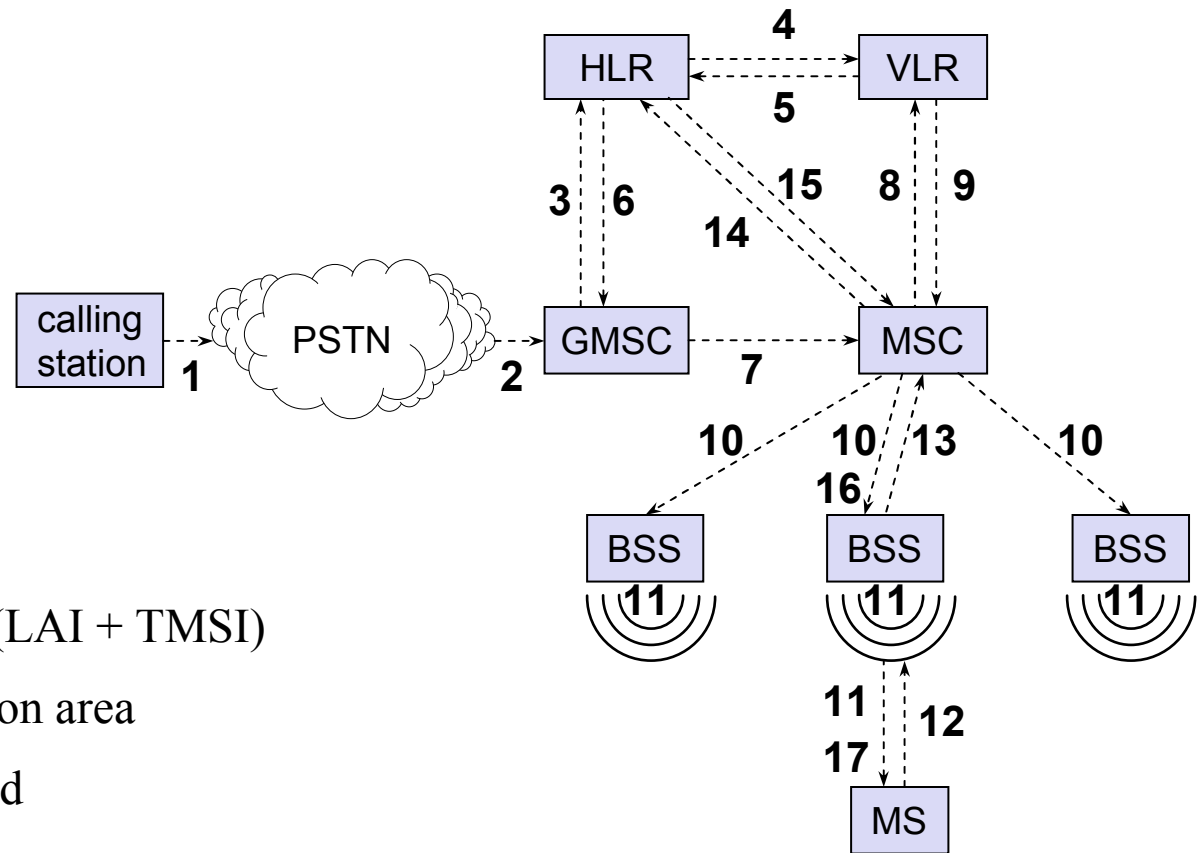


GSM Protocol Layers for Signaling

- » CM (Connection Management)
 - call control, short message service and supplementary service
- » MM (Mobility Management)
 - registration, authentication, location and handover management
- » RR (Radio Resource Management)
 - setup, maintenance and release of radio channels
 - control of radio transmission quality
- » LAPDm (“Link Access Protocol D-channel” modified)
 - modified version of ISDN LAPD protocol
- » BTSM (Base Transceiver Station Management)
 - radio resources control messages between BSC and BTS
- » BSSAP (Base Station System Application Part)
 - control of BSC by MSC

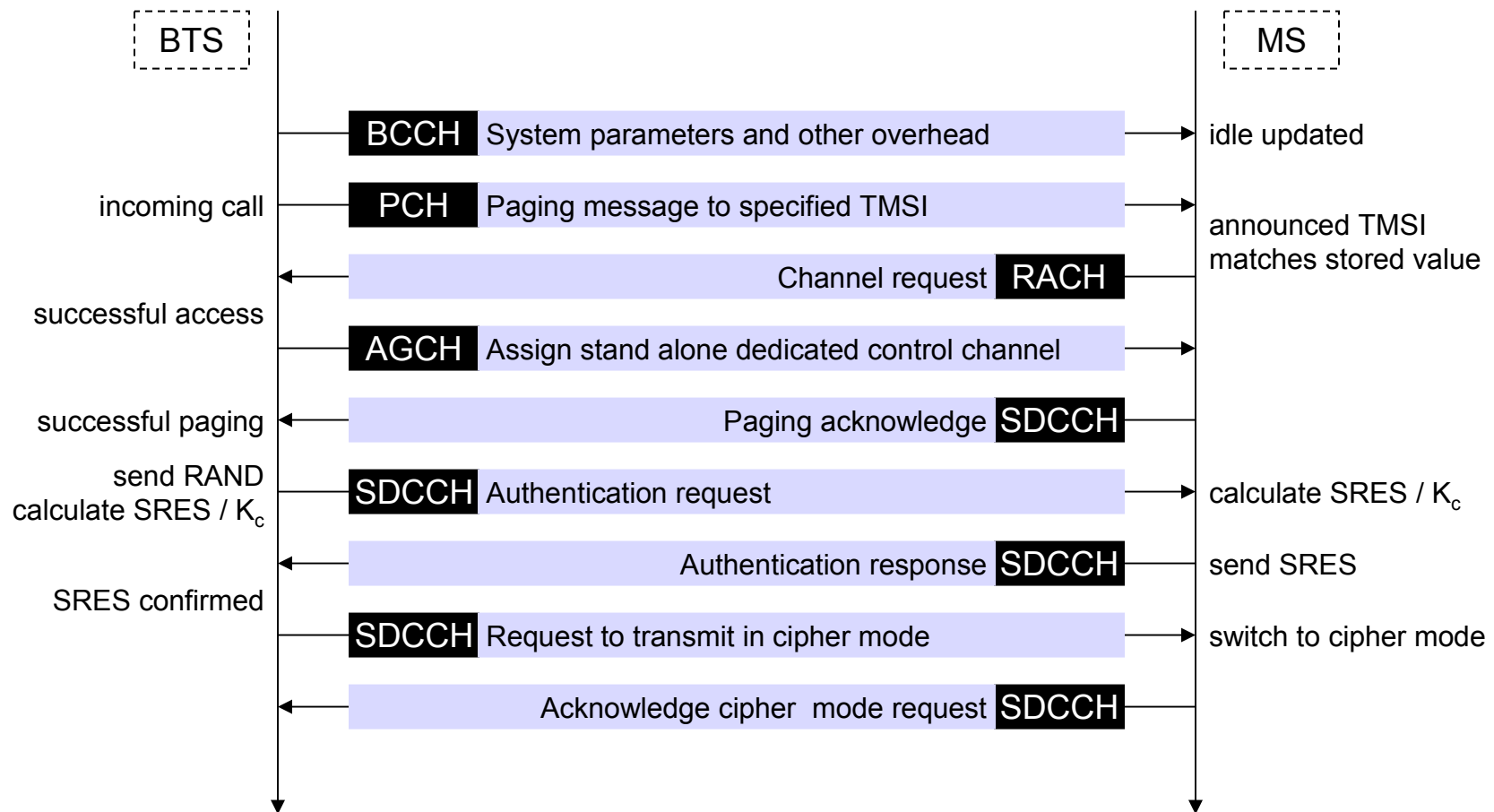
Mobile Terminated Call

- 1: calling a GSM subscriber
- 2: forwarding call to GMSC
- 3: signal call setup to HLR
- 4, 5: get routing info (MSRN) from VLR
- 6: forward routing info to GMSC
- 7: route call to current MSC
- 8, 9: get current status of MS (LAI + TMSI)
- 10, 11: paging of MS in location area
- 12, 13: MS answers paging and authentication request
- 14, 15: security checks
- 16, 17: set up connection



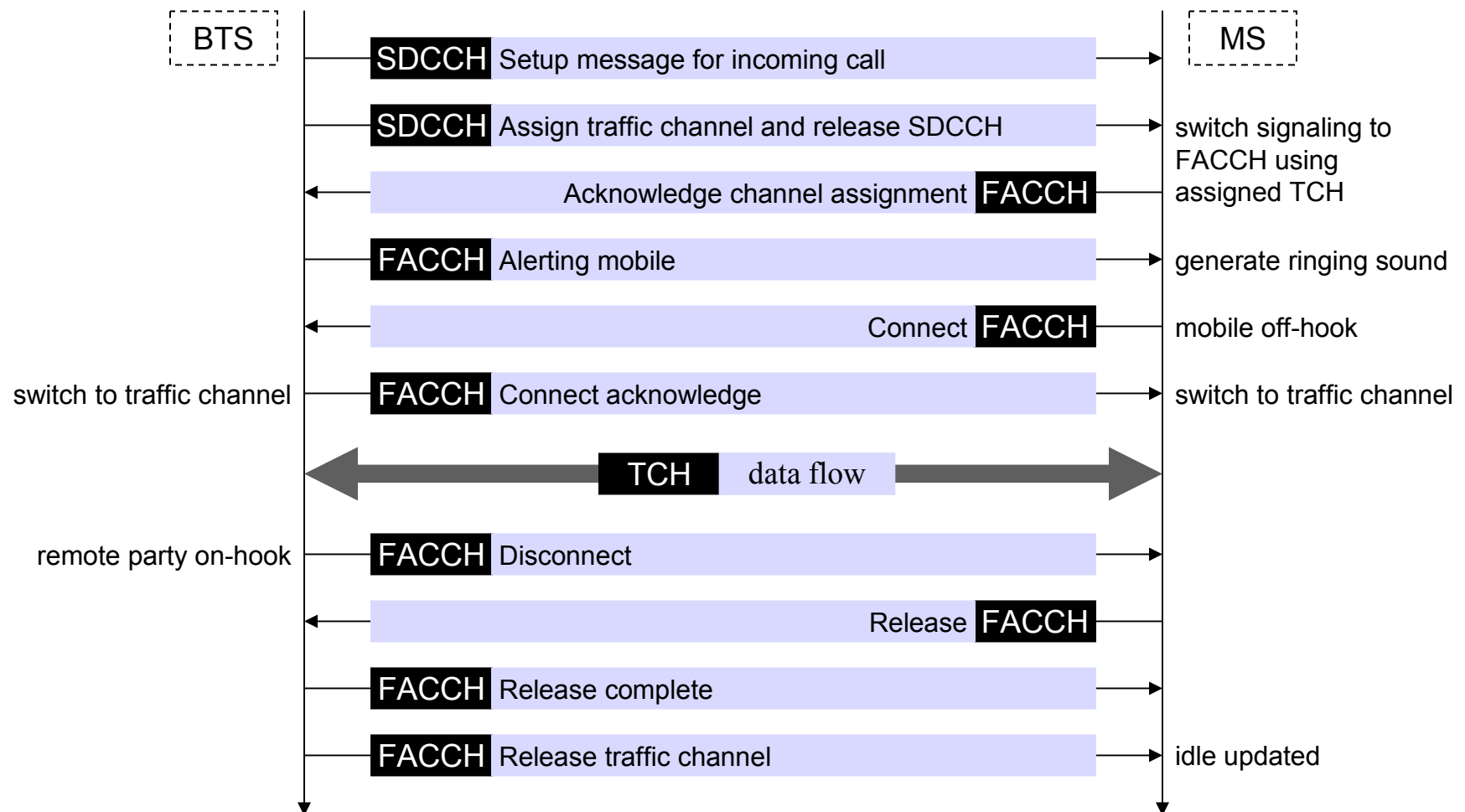
Mobile Terminated Call

Channel activity at radio interface



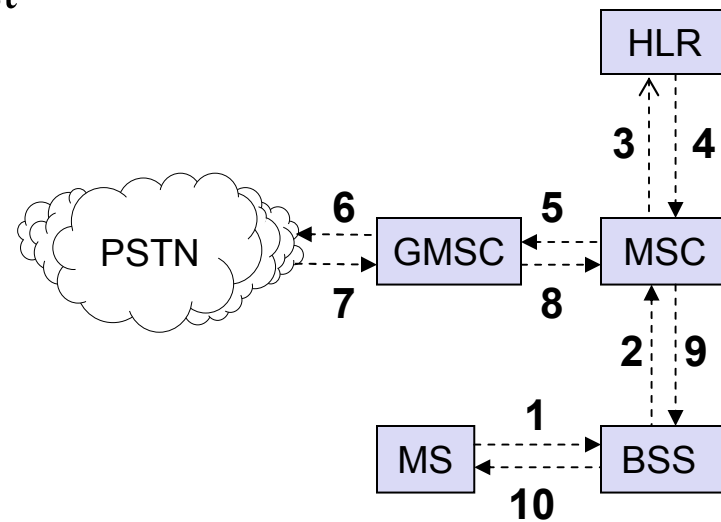
Mobile Terminated Call

Channel activity at radio interface (cont.)



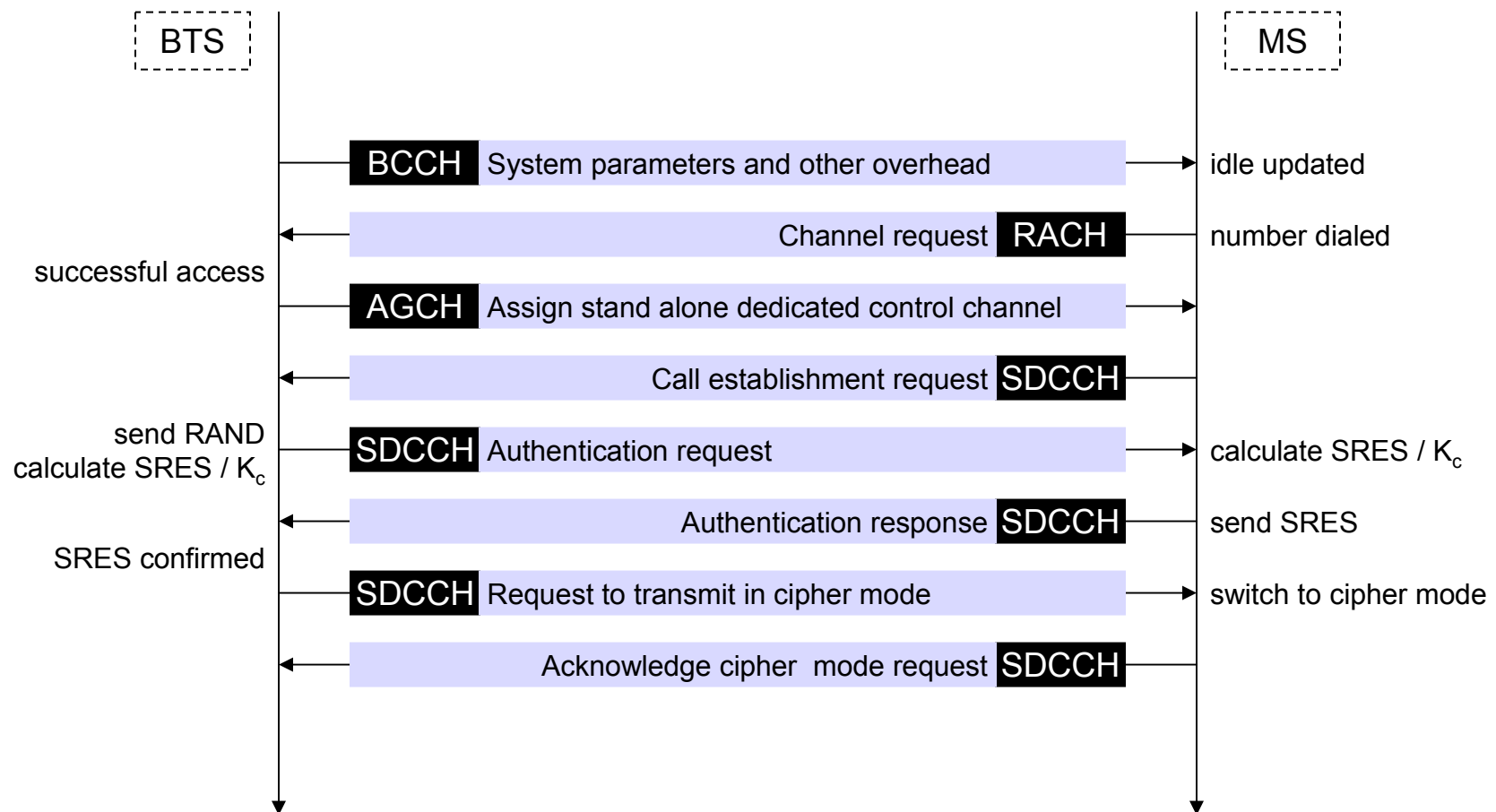
Mobile Originated Call

- 1, 2: connection and authentication request
- 3, 4: security check
- 5-8: check resources (free circuit)
- 9-10: set up call



Mobile Originated Call

Channel activity at radio interface



Mobile Originated Call

Channel activity at radio interface

