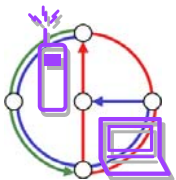
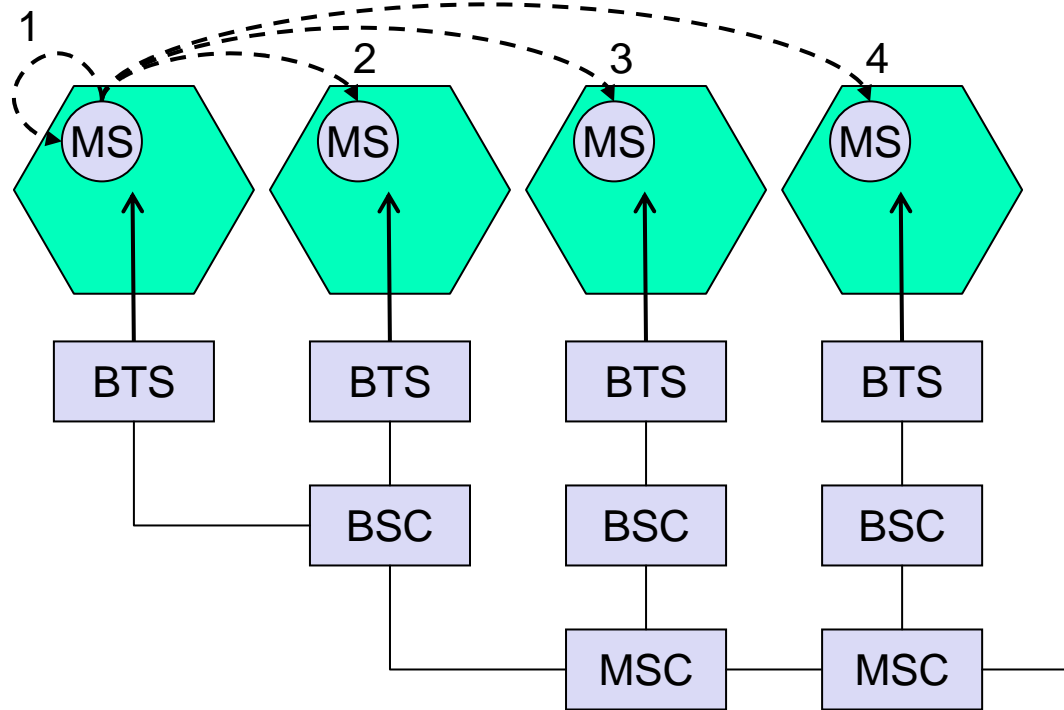
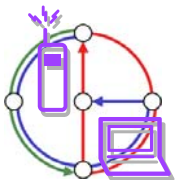
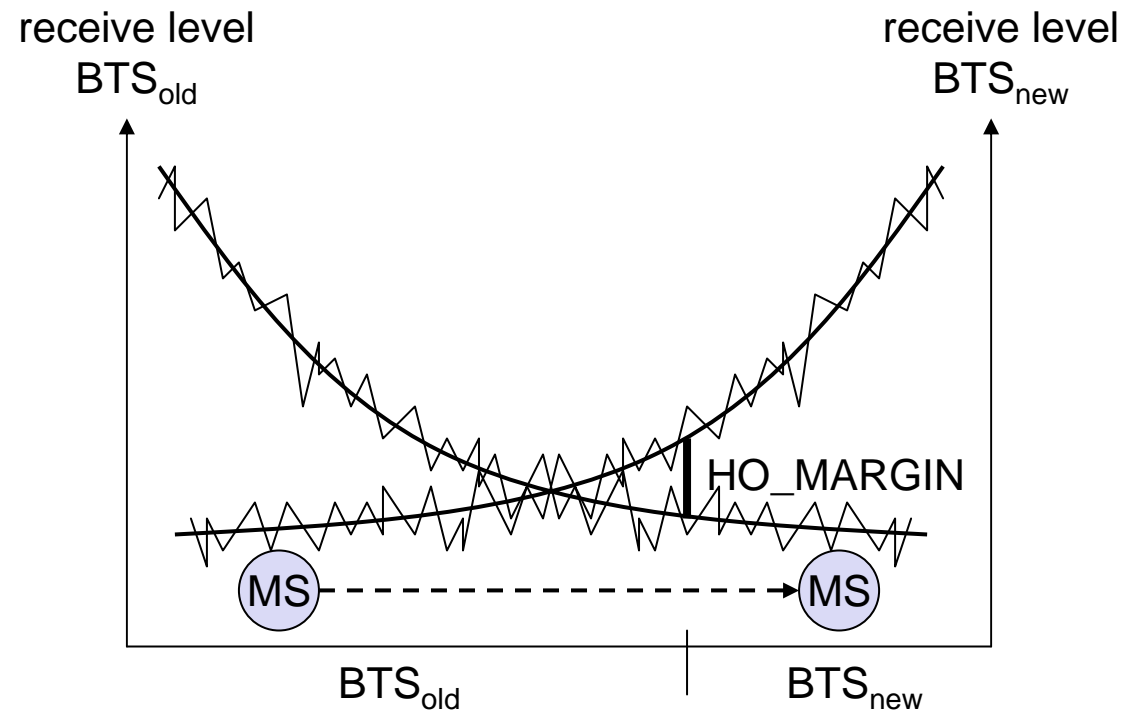


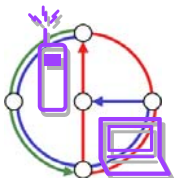
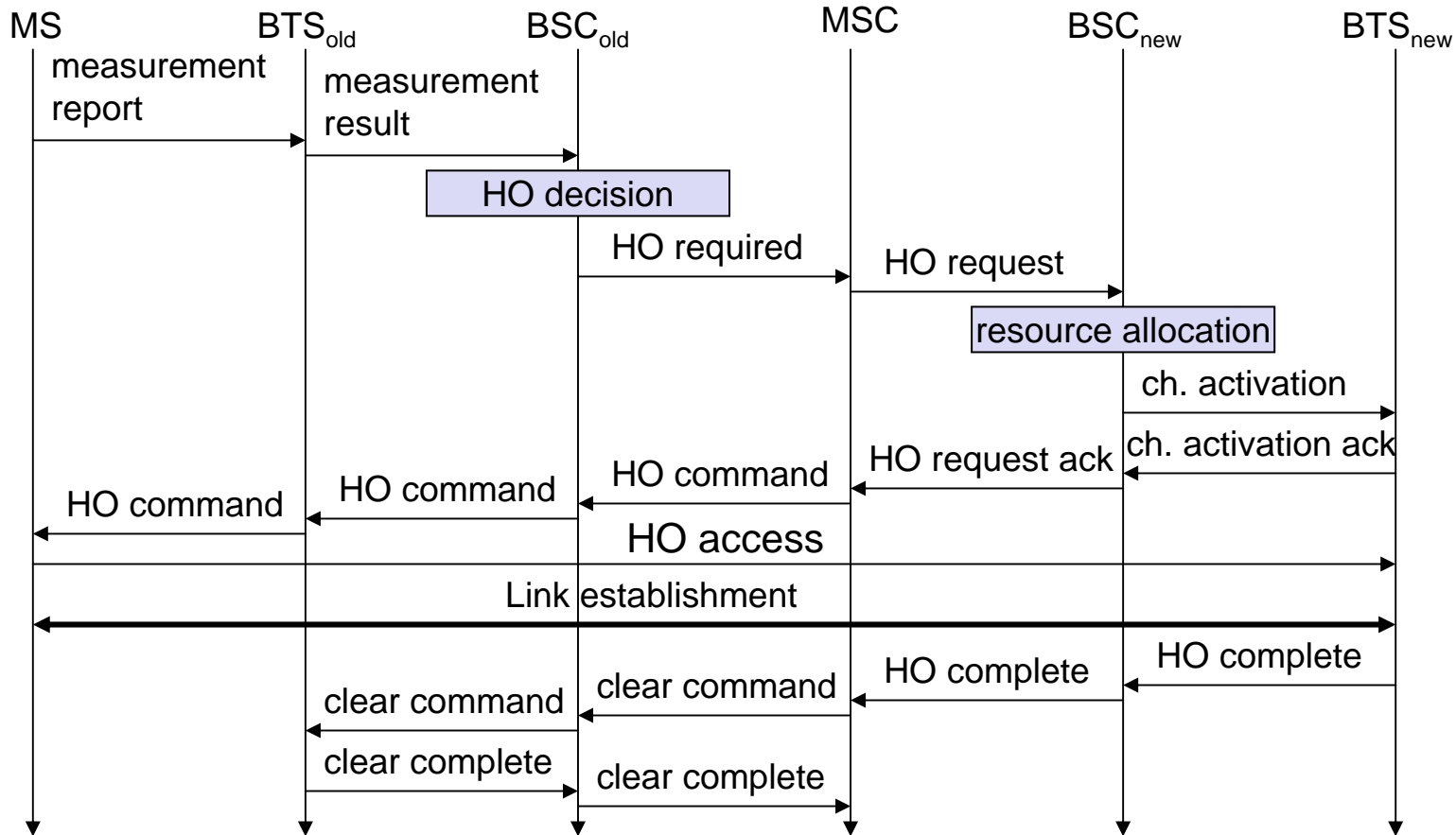
# Various types of handover



# Handover decision



# Handover procedure

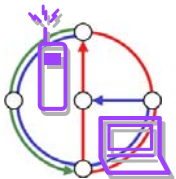


# Security in GSM

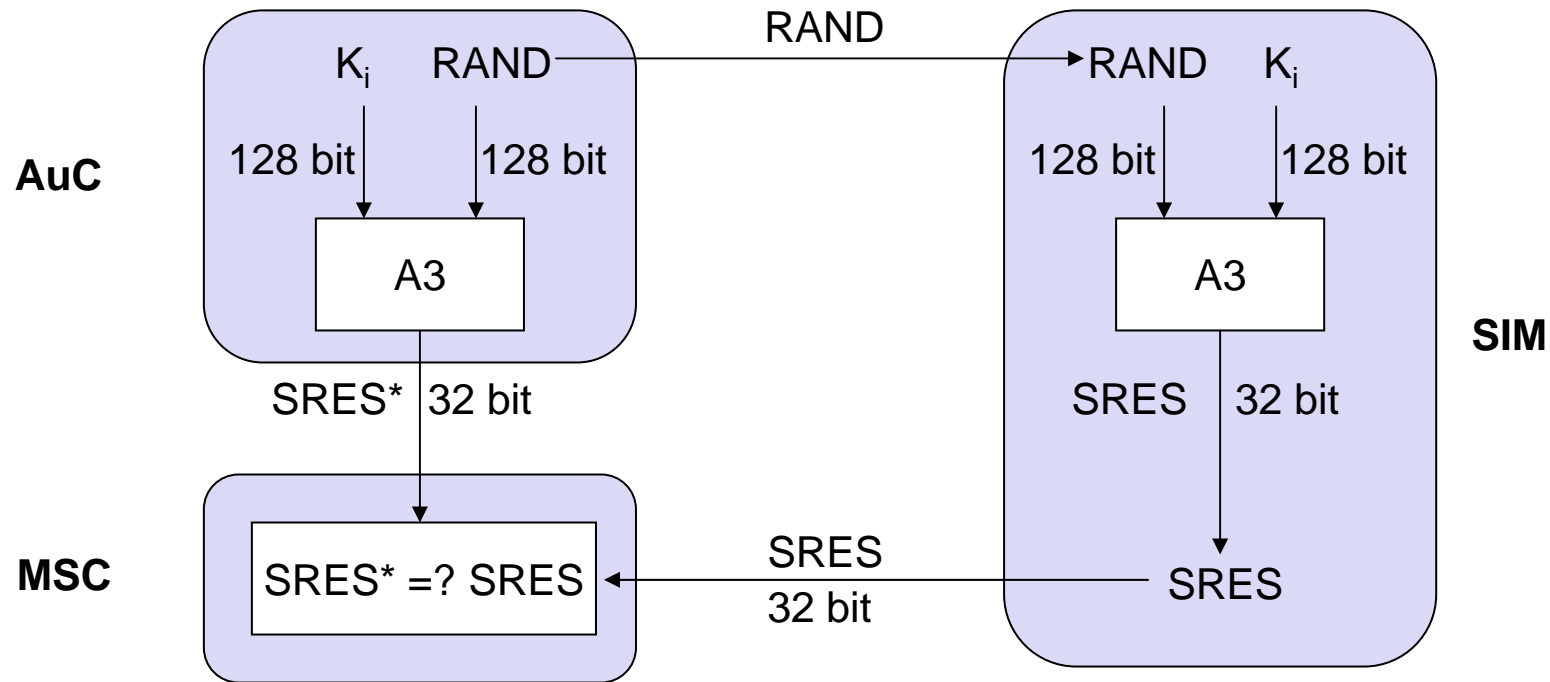
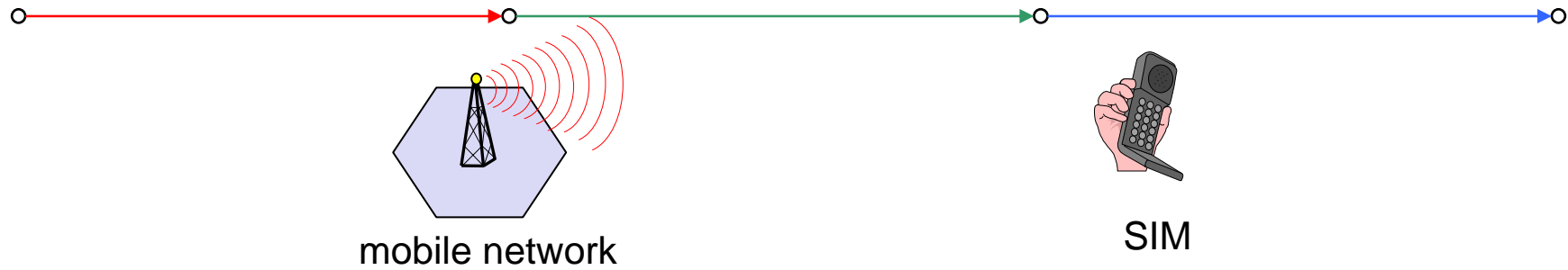


- Security services
  - access control/authentication
    - user ! SIM (Subscriber Identity Module): secret PIN (personal identification number)
    - SIM ! network: challenge response method
  - confidentiality
    - voice and signaling encrypted on the wireless link (after successful authentication)
  - anonymity
    - temporary identity TMSI (Temporary Mobile Subscriber Identity)
    - newly assigned at each new location update (LUP)
    - encrypted transmission
- 3 algorithms specified in GSM
  - A3 for authentication (“secret”, open interface)
  - A5 for encryption (standardized)
  - A8 for key generation (“secret”, open interface)

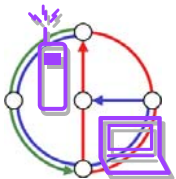
“secret”  
A3 and A8 available via the Internet  
network providers can use stronger mechanisms



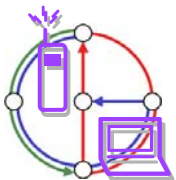
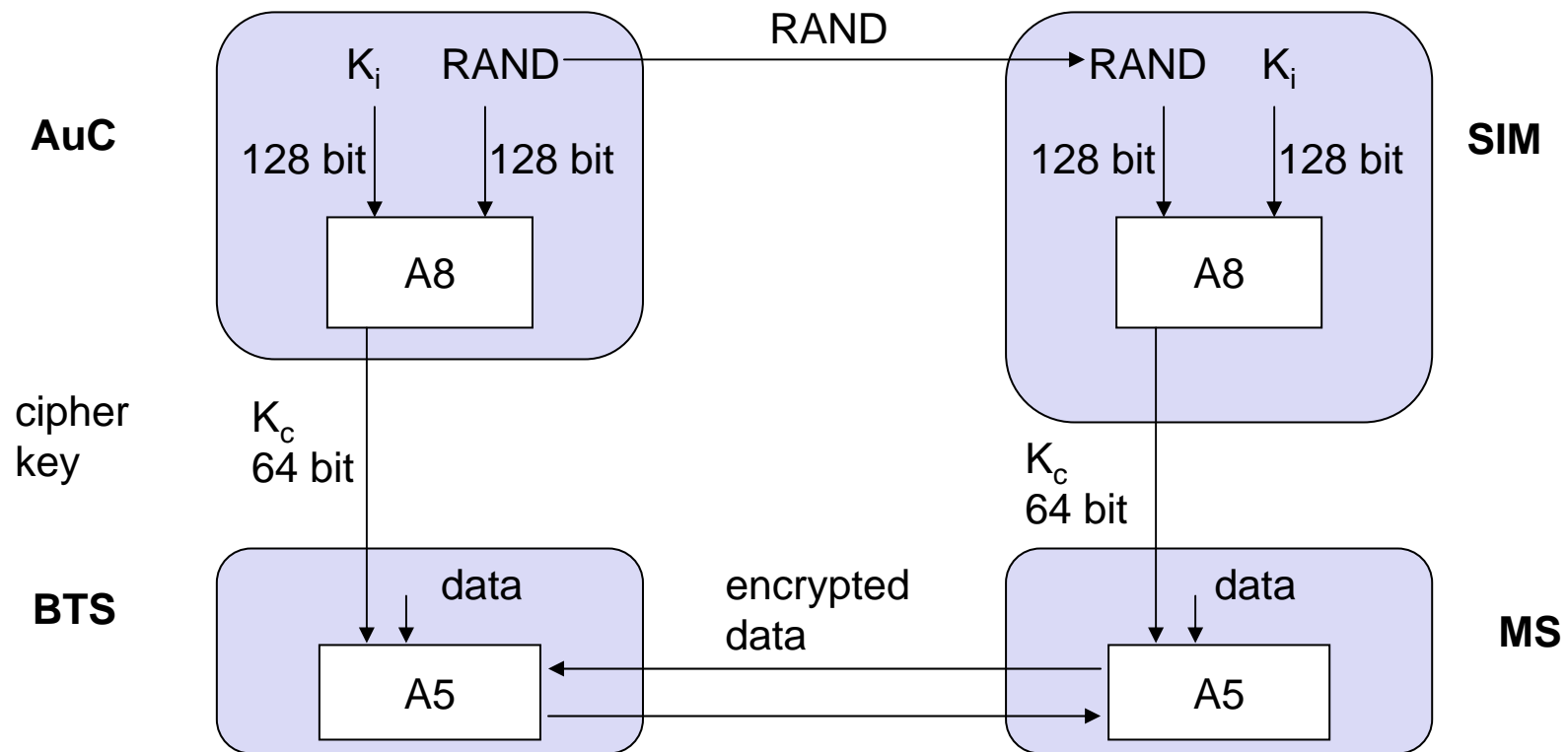
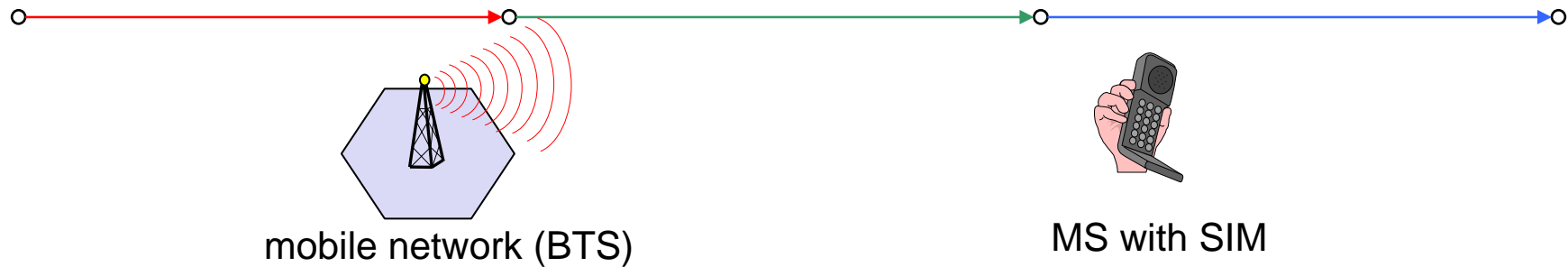
# GSM - authentication



$K_i$ : individual subscriber authentication key    SRES: signed response



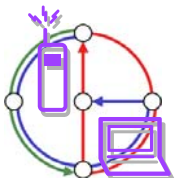
# GSM - key generation and encryption



# Data services in GSM: HSCSD

- Data transmission standardized with only 9.6 kbit/s
  - advanced coding allows 14,4 kbit/s
  - not enough for Internet and multimedia applications
- HSCSD (High-Speed Circuit Switched Data)
  - already standardized
  - bundling of several time-slots to get higher AIUR (Air Interface User Rate)  
(e.g., 57.6 kbit/s using 4 slots, 14.4 each)
  - advantage: ready to use, constant quality, simple
  - disadvantage: channels blocked for voice transmission

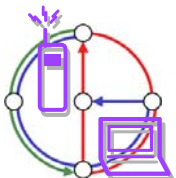
AIUR [kbit/s]	TCH/F4.8	TCH/F9.6	TCH/F14.4
4.8	1		
9.6	2	1	
14.4	3		1
19.2	4	2	
28.8		3	2
38.4		4	
43.2			3
57.6			4



# Data services in GSM: GPRS



- GPRS (General Packet Radio Service)
  - packet switching
  - using free slots only if data packets ready to send (e.g., 115 kbit/s using 8 slots temporarily)
  - standardization 1998, introduced 2000
- GPRS network elements GSN (GPRS Support Nodes)
  - GGSN (Gateway GSN)
    - interworking unit between GPRS and PDN (Packet Data Network)
  - SGSN (Serving GSN)
    - supports the MS (location, billing, security)
  - GR (GPRS Register)
    - user addresses





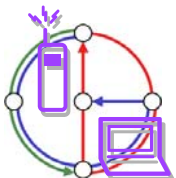
# GPRS quality of service



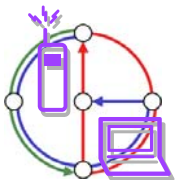
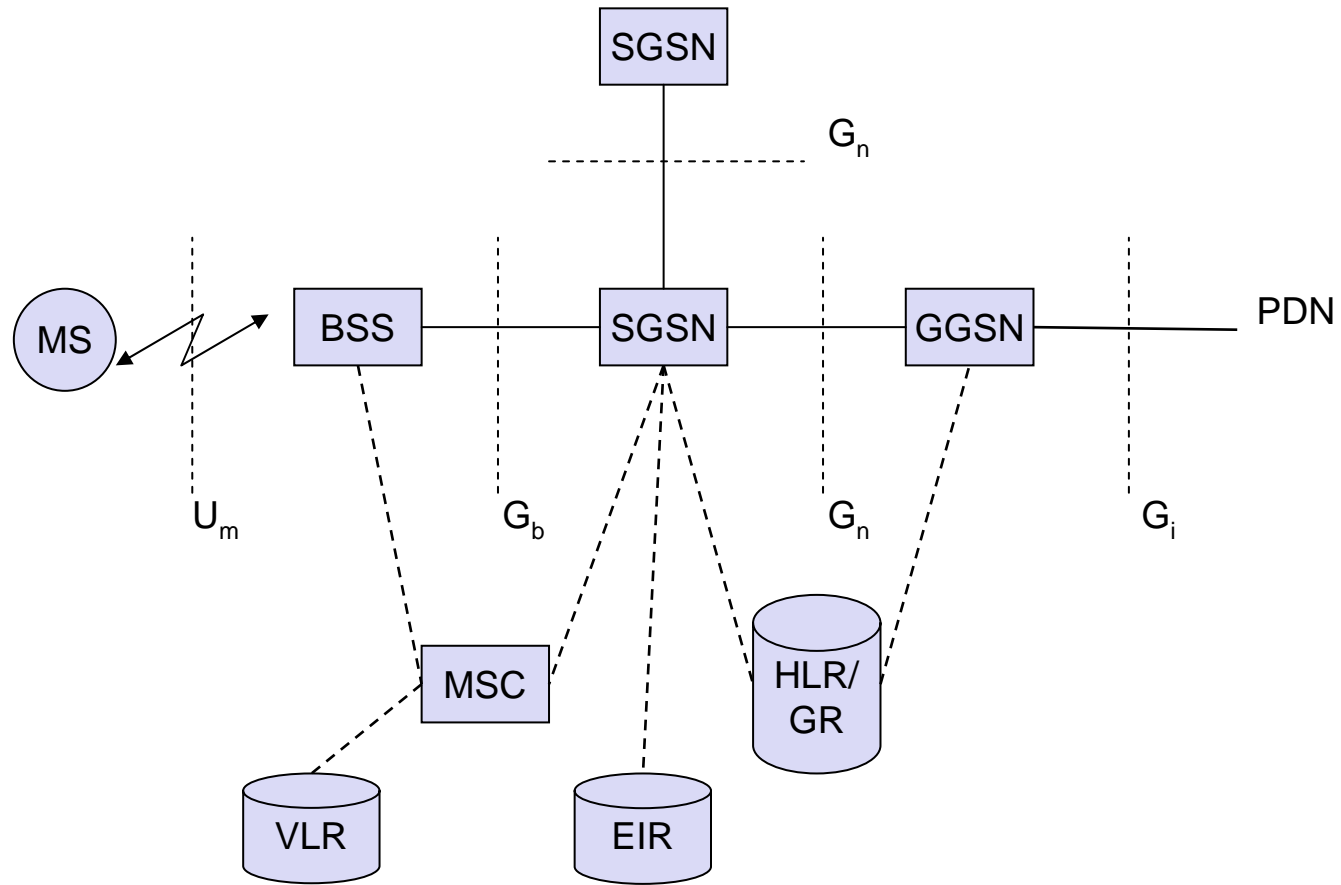
Reliability class	Lost SDU probability	Duplicate SDU probability	Out of sequence SDU probability	Corrupt SDU probability
1	$10^{-9}$	$10^{-9}$	$10^{-9}$	$10^{-9}$
2	$10^{-4}$	$10^{-5}$	$10^{-5}$	$10^{-6}$
3	$10^{-2}$	$10^{-5}$	$10^{-5}$	$10^{-2}$

Delay class	SDU size 128 byte		SDU size 1024 byte	
	mean	95 percentile	mean	95 percentile
1	< 0.5 s	< 1.5 s	< 2 s	< 7 s
2	< 5 s	< 25 s	< 15 s	< 75 s
3	< 50 s	< 250 s	< 75 s	< 375 s
4	unspecified			

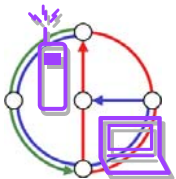
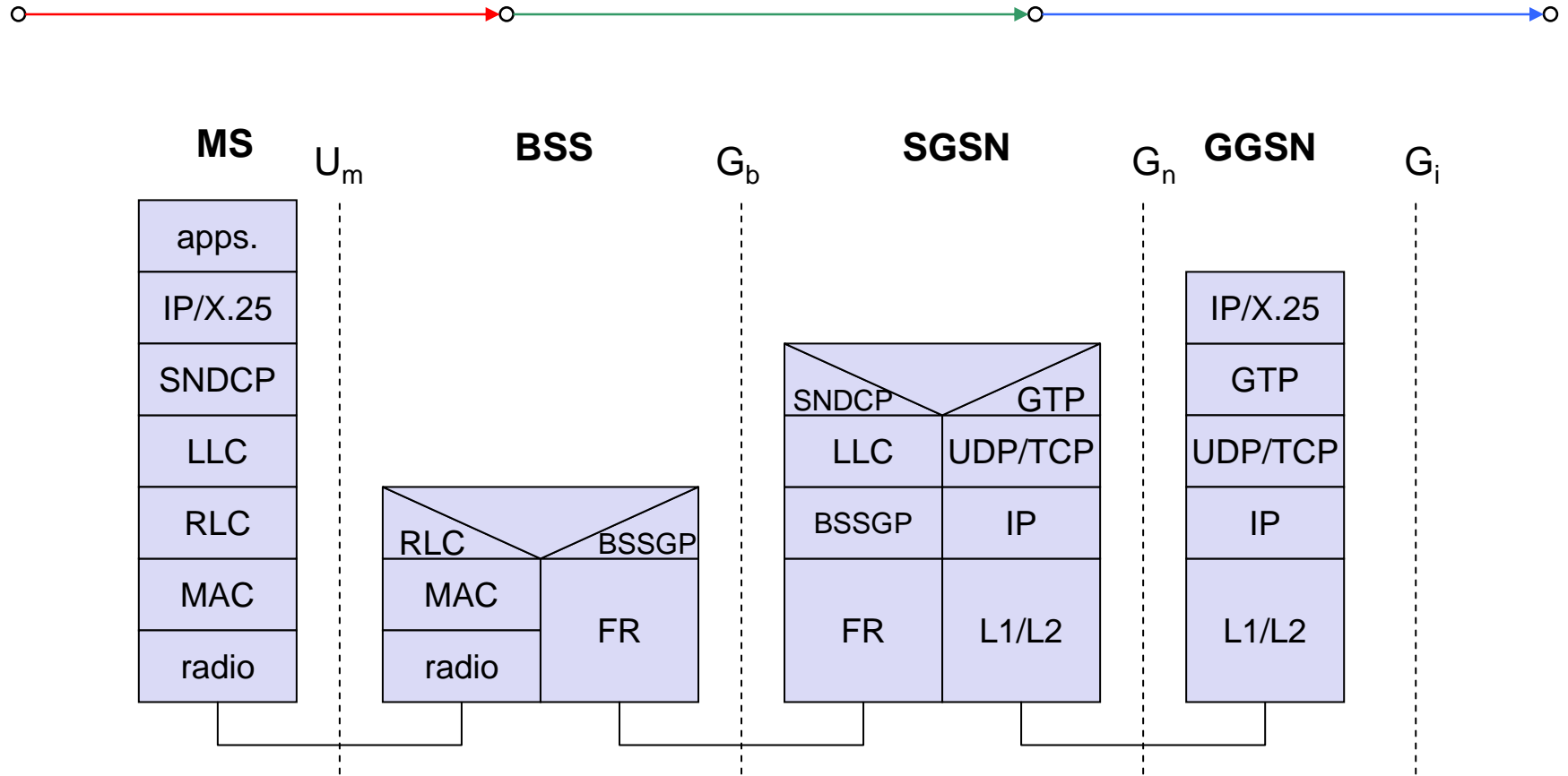
[J. Schiller]



# GPRS architecture and interfaces



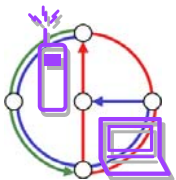
# GPRS protocol architecture



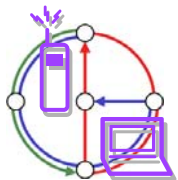
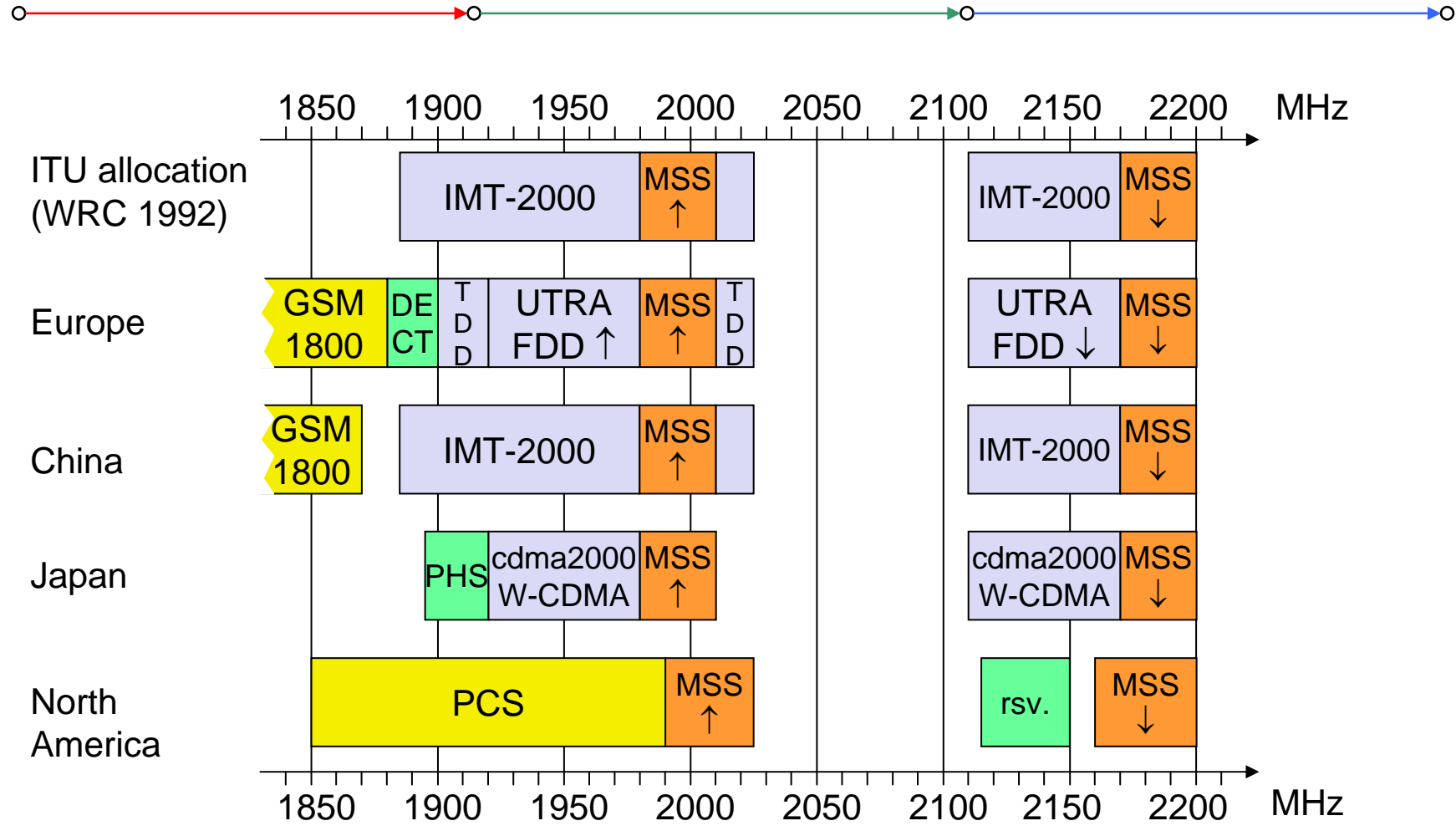
# UMTS and IMT-2000



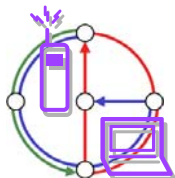
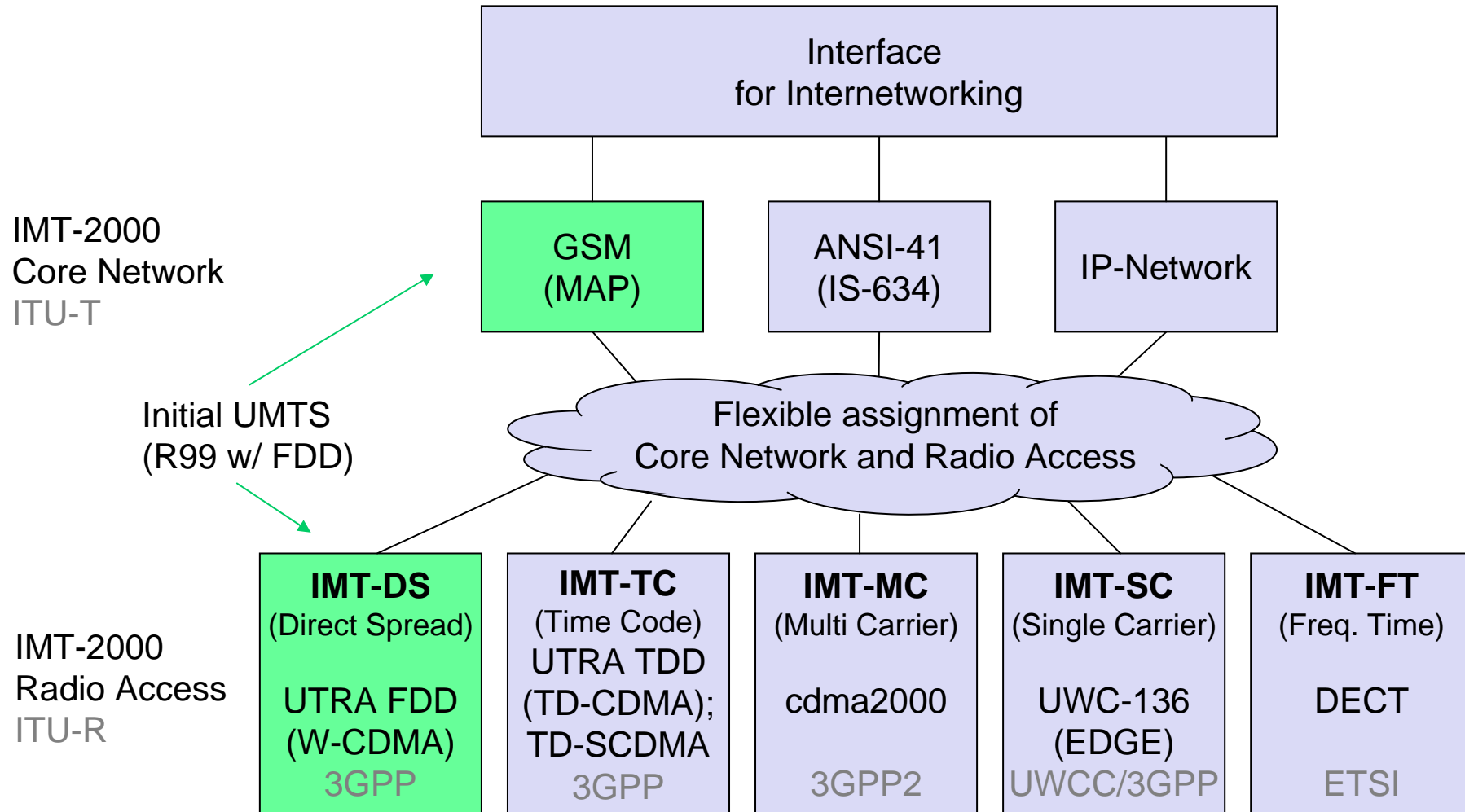
- Proposals for IMT-2000 (International Mobile Telecommunications)
  - UWC-136, cdma2000, WP-CDMA
  - UMTS (Universal Mobile Telecommunications System) from ETSI
- UMTS
  - UTRA (was: UMTS, now: Universal Terrestrial Radio Access)
  - enhancements of GSM
    - EDGE (Enhanced Data rates for GSM Evolution): GSM up to 384 kbit/s
    - CAMEL (Customized Application for Mobile Enhanced Logic)
    - VHE (virtual Home Environment)
  - fits into GMM (Global Multimedia Mobility) initiative from ETSI
  - requirements
    - min. 144 kbit/s rural (goal: 384 kbit/s)
    - min. 384 kbit/s suburban (goal: 512 kbit/s)
    - up to 2 Mbit/s urban



# Frequencies for IMT-2000



# IMT-2000 family



# Licensing Example: UMTS in Germany, 18. August 2000

STAND DER LIZENZVERGABE

Versteigerung UMTS/IMT-2000-Lizenzen

Runde 173 Datum 17.08.00 Uhrzeit 15:51:26

Höchstgebote für Frequenzblöcke (mind. 2 Blöcke erforderlich für Lizenz)

Bieter	Anzahl der Frequenzblöcke			Lizenzgebot	
	1	2	3	(TDM)	(€ in Tsd)
E-Plus Hutchison	2 x 5 MHz	2 x 5 MHz		16.418.200	8.394.492
Group 3G	2 x 5 MHz	2 x 5 MHz		16.446.000	8.408.706
Mannesmann Mobilfunk	2 x 5 MHz	2 x 5 MHz		16.473.800	8.422.920
MobilCom Multimedia	2 x 5 MHz	2 x 5 MHz		16.370.000	8.369.848
T-Mobil	2 x 5 MHz	2 x 5 MHz		16.582.200	8.478.344
VIAG Interkom	2 x 5 MHz	2 x 5 MHz		16.517.000	8.445.008
debitel Multimedia	ausgeschieden				
<b>Lizenzsumme</b>				<b>98.807.200</b>	<b>50.519.319</b>

RÜNDENERGEBNIS

Versteigerung UMTS/IMT-2000-Frequenzen

Runde: 9

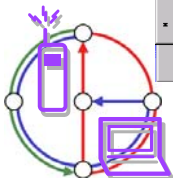
Lfd. Nr.	Umfang	Höchstbieter	Höchstgebot (TDM)	Höchstgebot* (€ in Tsd)
13	1 x 5 MHz konkret	E-Plus Hutchison	73.600	37.631
14	1 x 5 MHz	MobilCom Multimedia	121.000	61.866
15	1 x 5 MHz	T-Mobil	122.700	62.736
16	1 x 5 MHz	Mannesmann Mobilfunk	121.000	61.866
17	1 x 5 MHz	Group 3G	122.700	62.736
			<b>Summe Höchstgebote</b>	<b>561.000</b>
				<b>286.835</b>

\* Eurowerte gerundet

VIAG Interkom ausgeschieden

- UTRA-FDD:
  - Uplink 1920-1980 MHz
  - Downlink 2110-2170 MHz
  - duplex spacing 190 MHz
  - 12 channels, each 5 MHz
- UTRA-TDD:
  - 1900-1920 MHz,
  - 2010-2025 MHz;
  - 5 MHz channels
- Coverage: 25% of the population until 12/2003, 50% until 12/2005

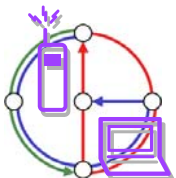
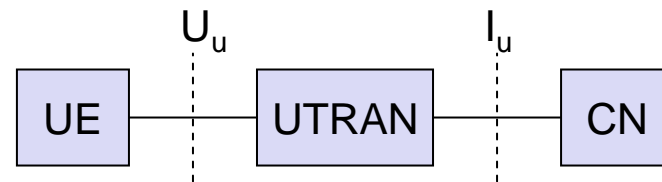
**Sum: 50.81 billion €**



# UMTS architecture (Release 99 used here!)

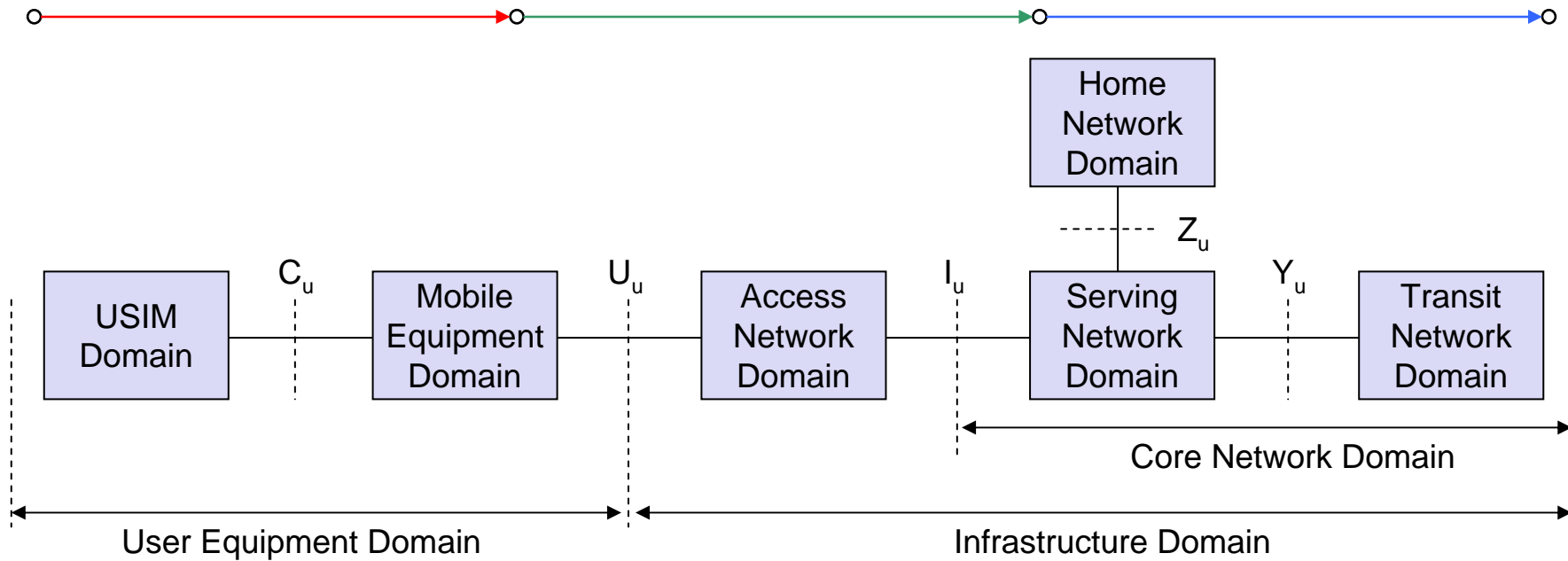


- UTRAN (UTRA Network)
  - Cell level mobility
  - Radio Network Subsystem (RNS)
  - Encapsulation of all radio specific tasks
- UE (User Equipment)
- CN (Core Network)
  - Inter system handover
  - Location management if there is no dedicated connection between UE and UTRAN

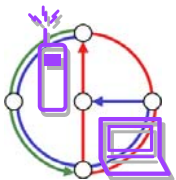




# UMTS domains and interfaces I



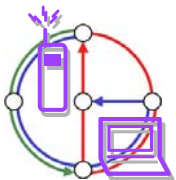
- User Equipment Domain
  - Assigned to a single user in order to access UMTS services
- Infrastructure Domain
  - Shared among all users
  - Offers UMTS services to all accepted users



# UMTS domains and interfaces II

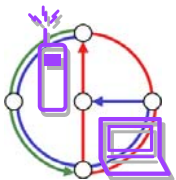
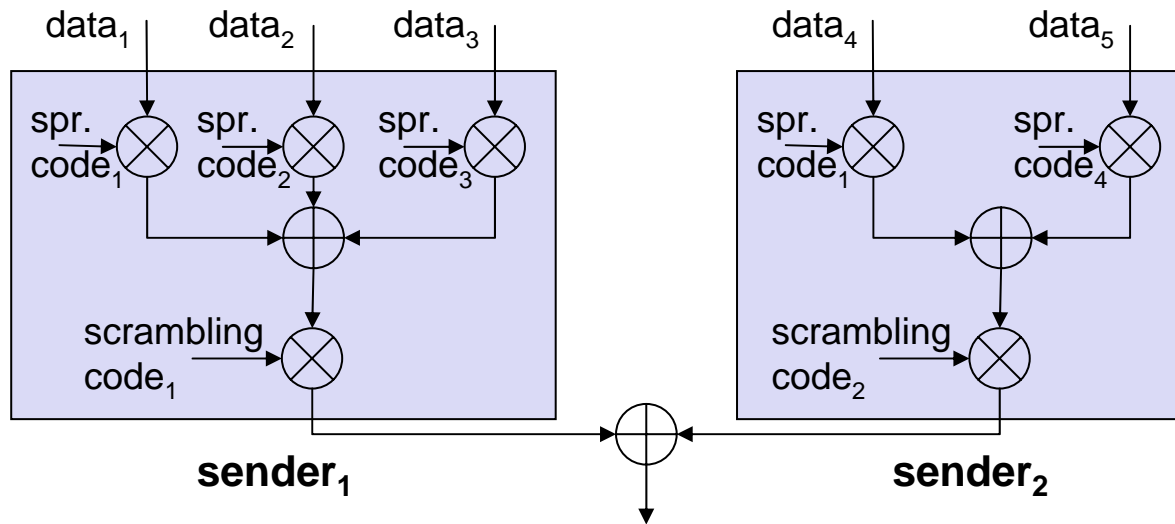


- Universal Subscriber Identity Module (USIM)
  - Functions for encryption and authentication of users
  - Located on a SIM inserted into a mobile device
- Mobile Equipment Domain
  - Functions for radio transmission
  - User interface for establishing/maintaining end-to-end connections
- Access Network Domain
  - Access network dependent functions
- Core Network Domain
  - Access network independent functions
  - Serving Network Domain
    - Network currently responsible for communication
  - Home Network Domain
    - Location and access network independent functions

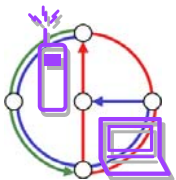
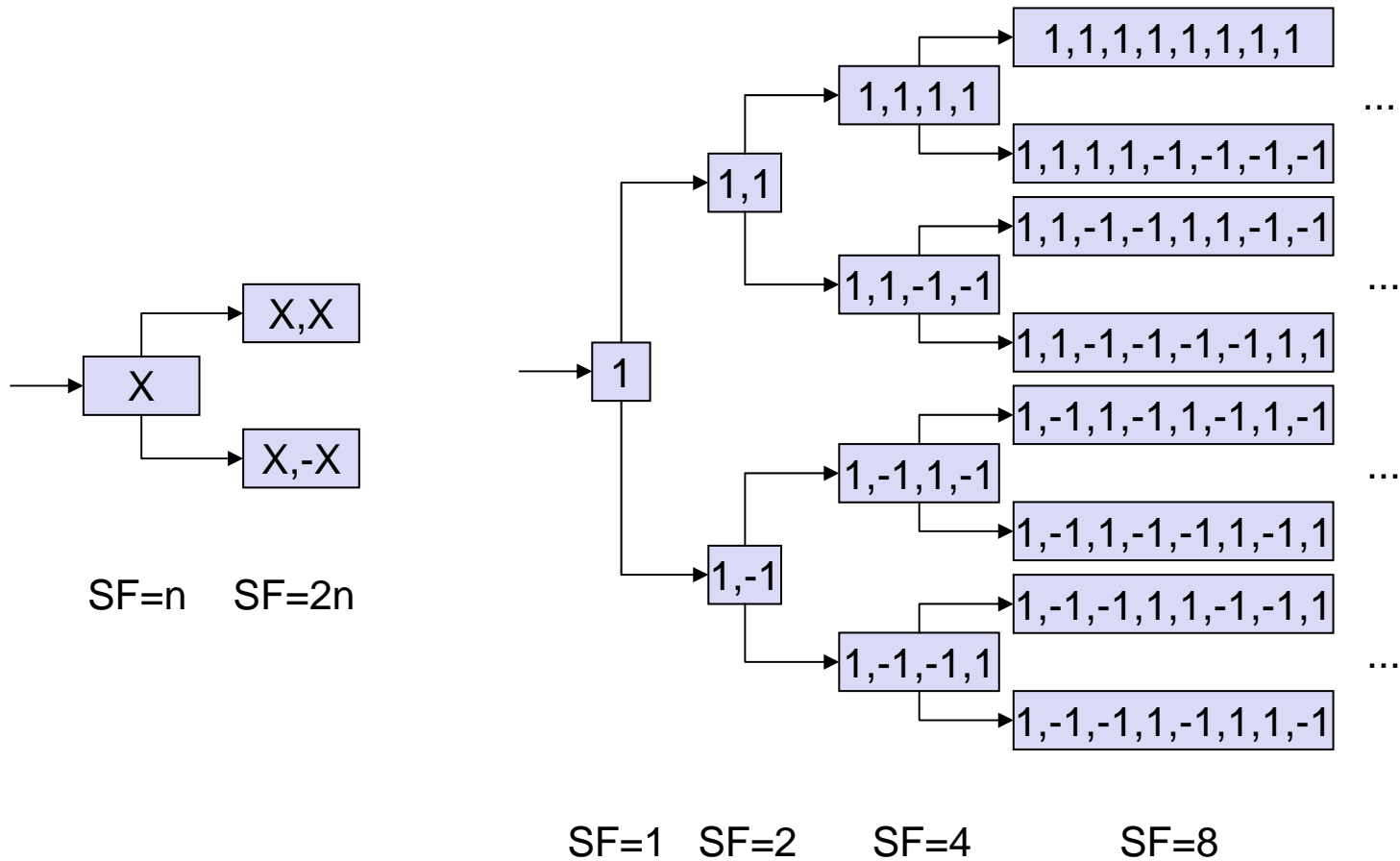


# Spreading and scrambling of user data

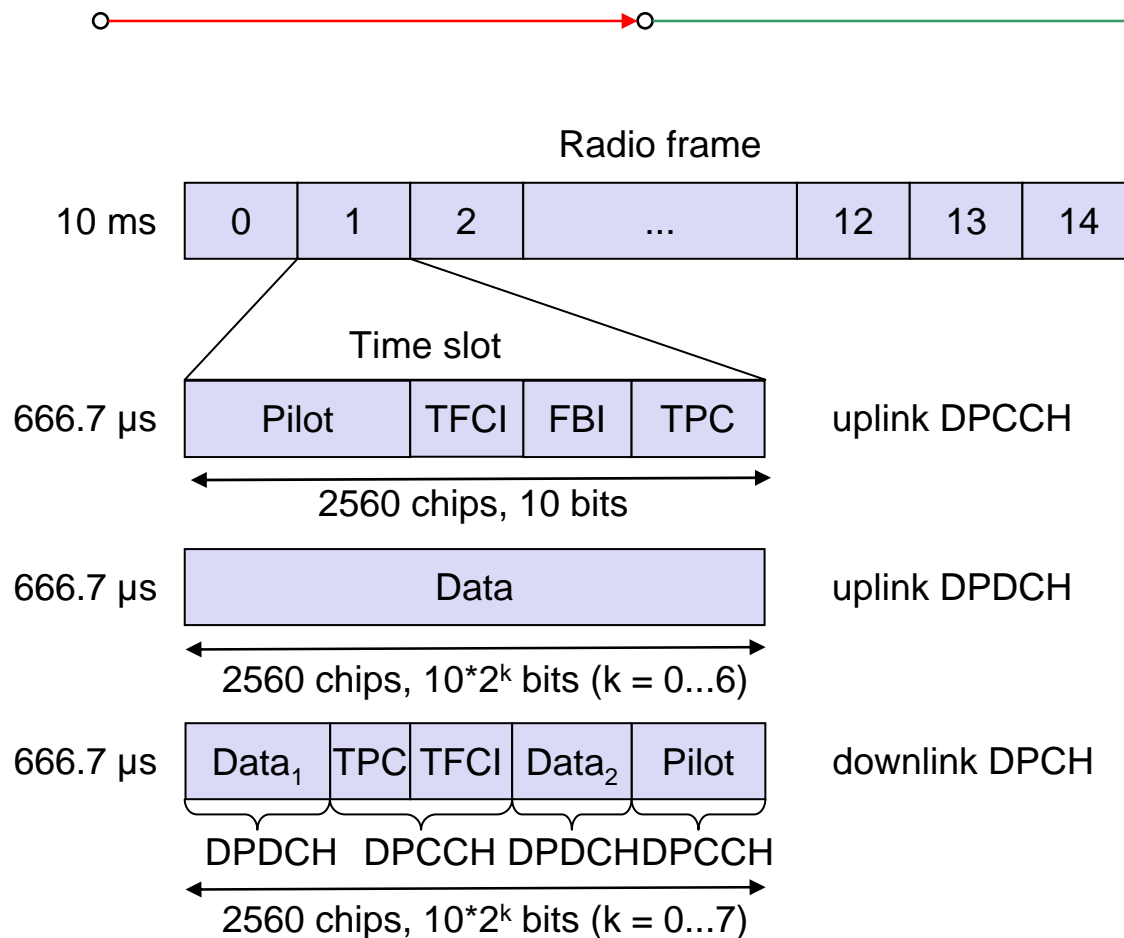
- Constant chipping rate of 3.84 Mchip/s
- Different user data rates supported via different spreading factors
  - higher data rate: less chips per bit and vice versa
- User separation via unique, quasi orthogonal scrambling codes
  - users are not separated via orthogonal spreading codes
  - much simpler management of codes: each station can use the same orthogonal spreading codes
  - precise synchronisation not necessary as the scrambling codes stay quasi-orthogonal



# OSVF coding



# UMTS FDD frame structure

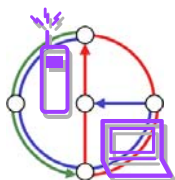


## W-CDMA

- 1920-1980 MHz uplink
- 2110-2170 MHz downlink
- chipping rate: 3.840 Mchip/s
- soft handover
- QPSK
- complex power control (1500 power control cycles/s)
- spreading: UL: 4-256; DL:4-512

FBI: Feedback Information  
 TPC: Transmit Power Control  
 TFCI: Transport Format Combination Indicator  
 DPCCH: Dedicated Physical Control Channel  
 DPDCH: Dedicated Physical Data Channel  
 DPCH: Dedicated Physical Channel

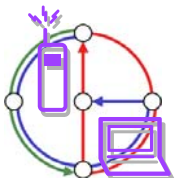
**Slot structure NOT for user separation but synchronisation for periodic functions!**



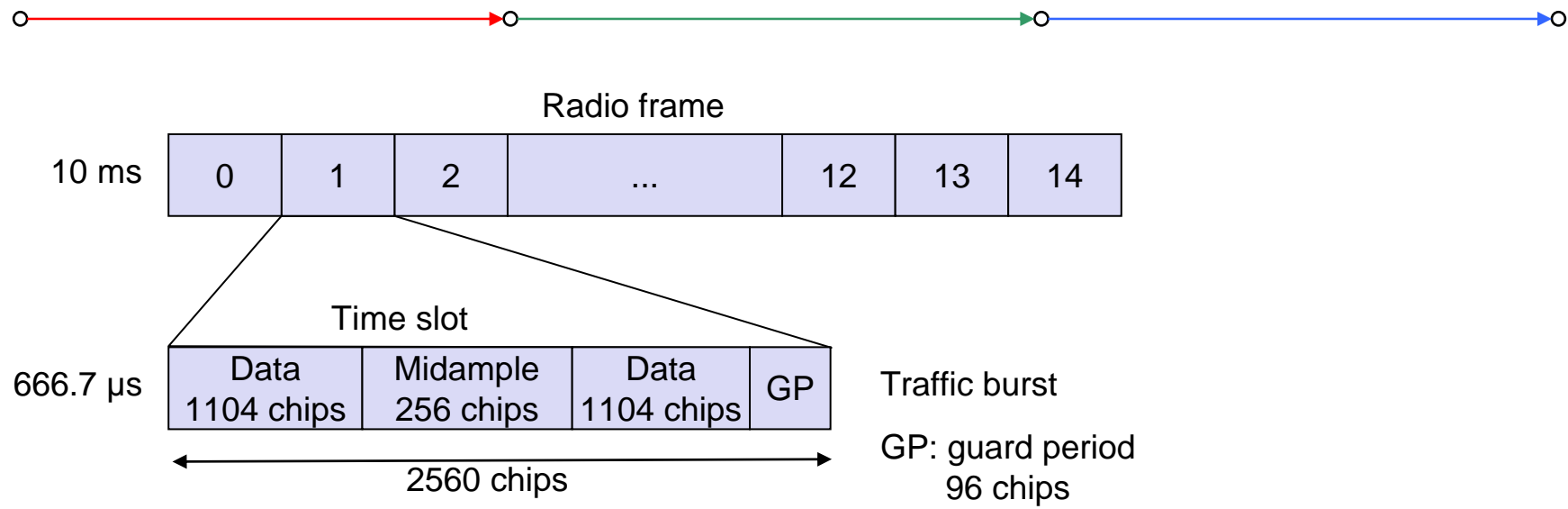
# Typical UTRA-FDD uplink data rates



User data rate [kbit/s]	12.2 (voice)	64	144	384
DPDCH [kbit/s]	60	240	480	960
DPCCH [kbit/s]	15	15	15	15
Spreading	64	16	8	4

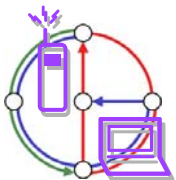


# UMTS TDD frame structure (burst type 2)

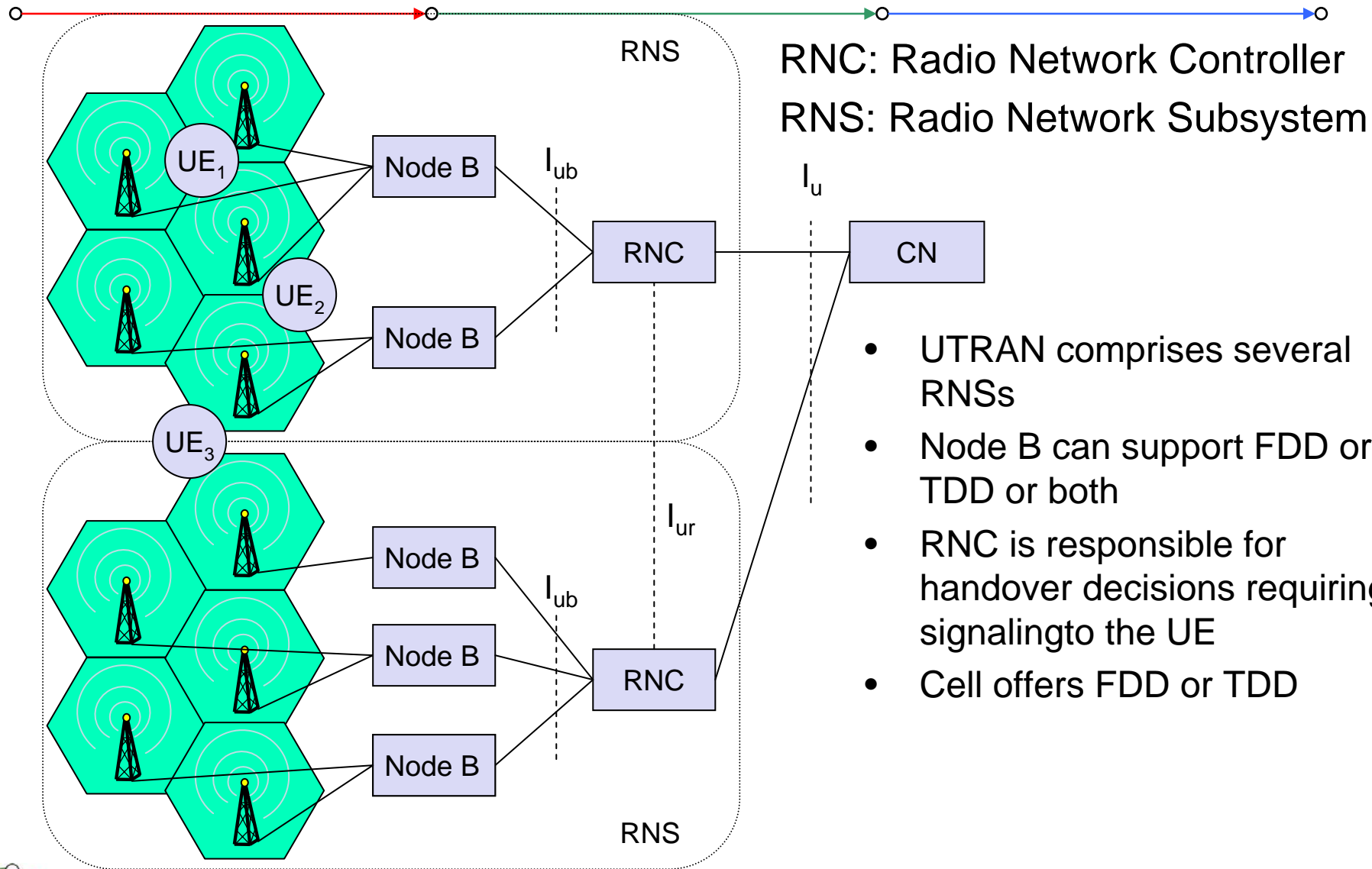


## TD-CDMA

- 2560 chips per slot
- spreading: 1-16
- symmetric or asymmetric slot assignment to UL/DL (min. 1 per direction)
- tight synchronisation needed
- simpler power control (100-800 power control cycles/s)

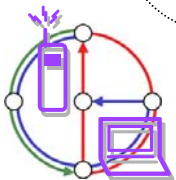


# UTRAN architecture



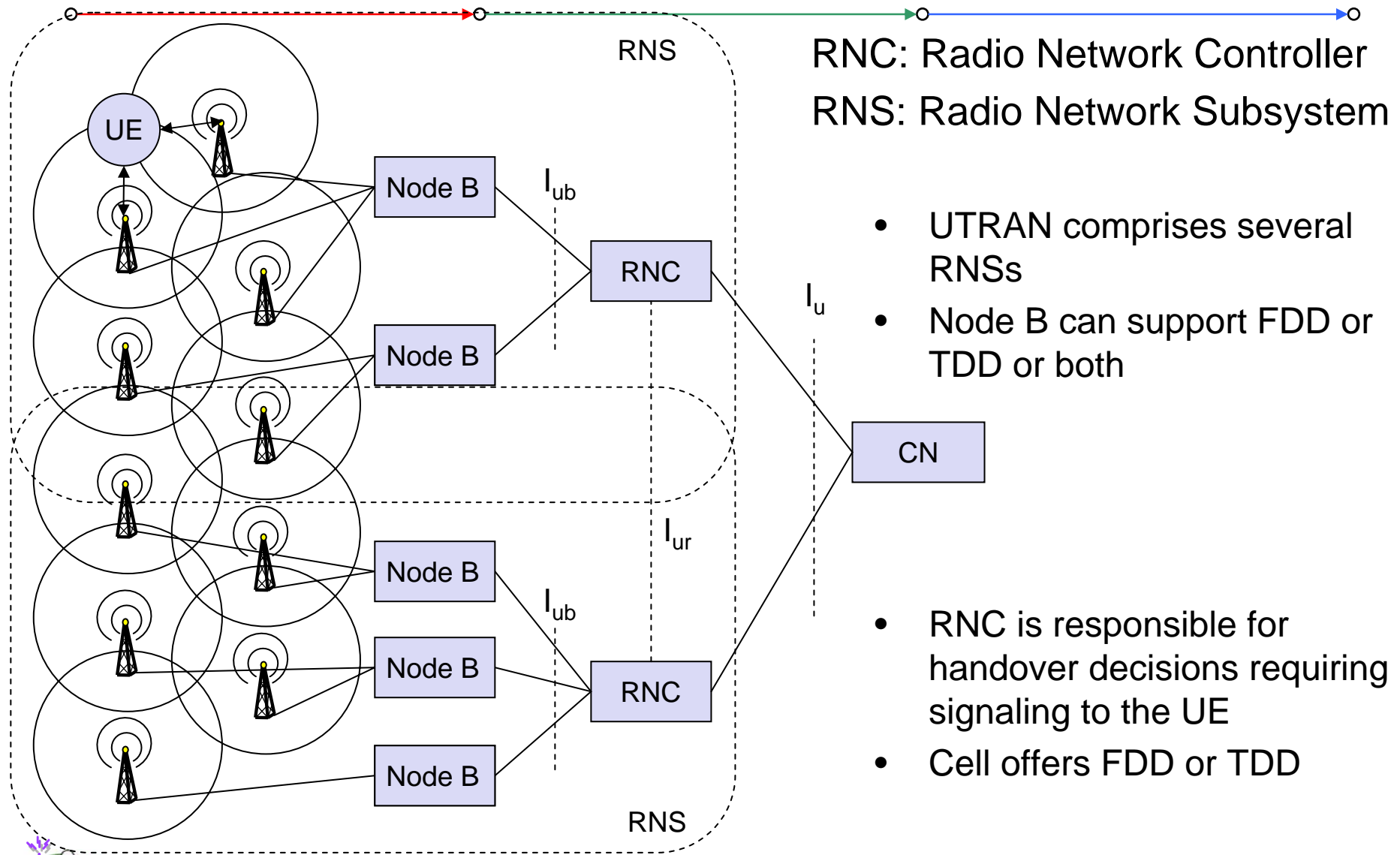
RNC: Radio Network Controller  
 RNS: Radio Network Subsystem

- UTRAN comprises several RNSs
- Node B can support FDD or TDD or both
- RNC is responsible for handover decisions requiring signaling to the UE
- Cell offers FDD or TDD



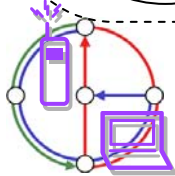


# UTRAN architecture



RNC: Radio Network Controller  
 RNS: Radio Network Subsystem

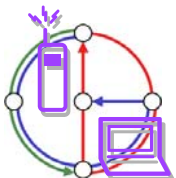
- UTRAN comprises several RNSs
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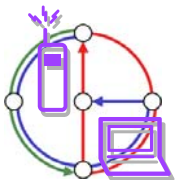
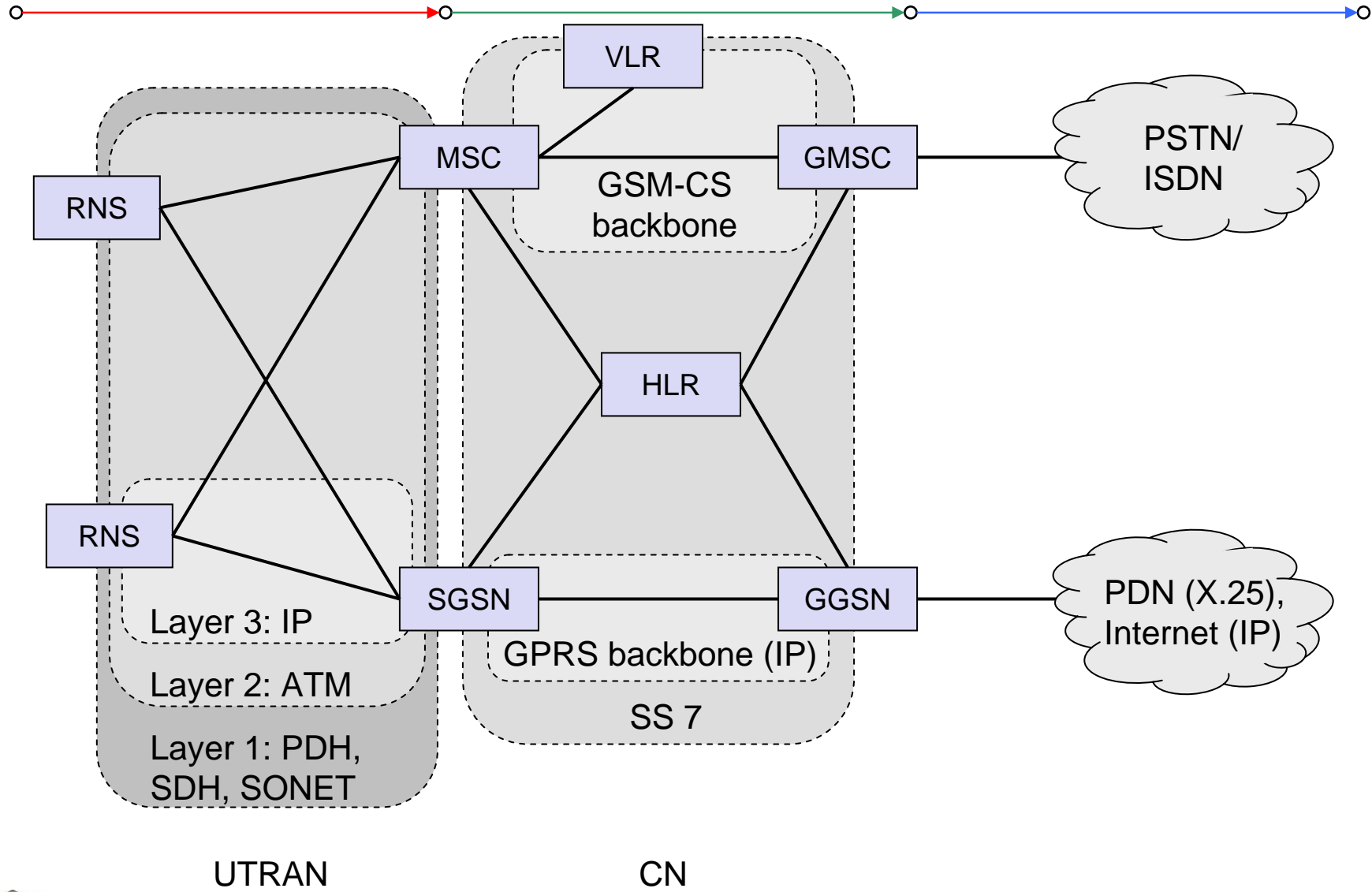
# UTRAN functions



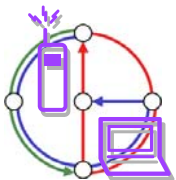
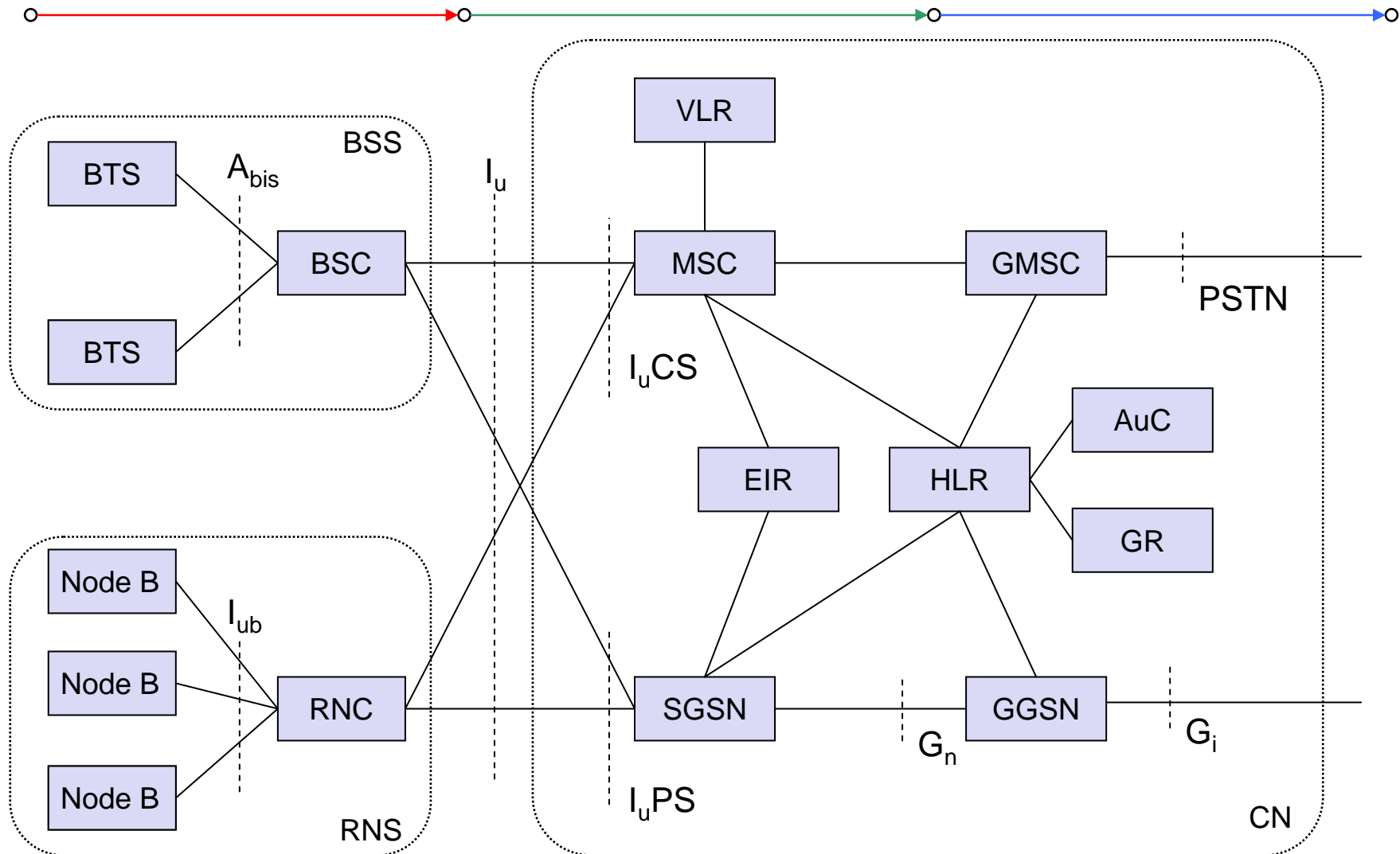
- Admission control
- Congestion control
- System information broadcasting
- Radio channel encryption
- Handover
- SRNS moving
- Radio network configuration
- Channel quality measurements
- Macro diversity
- Radio carrier control
- Radio resource control
- Data transmission over the radio interface
- Outer loop power control (FDD and TDD)
- Channel coding
- Access control



# Core network: protocols



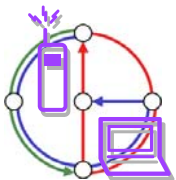
# Core network: architecture



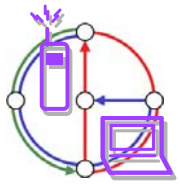
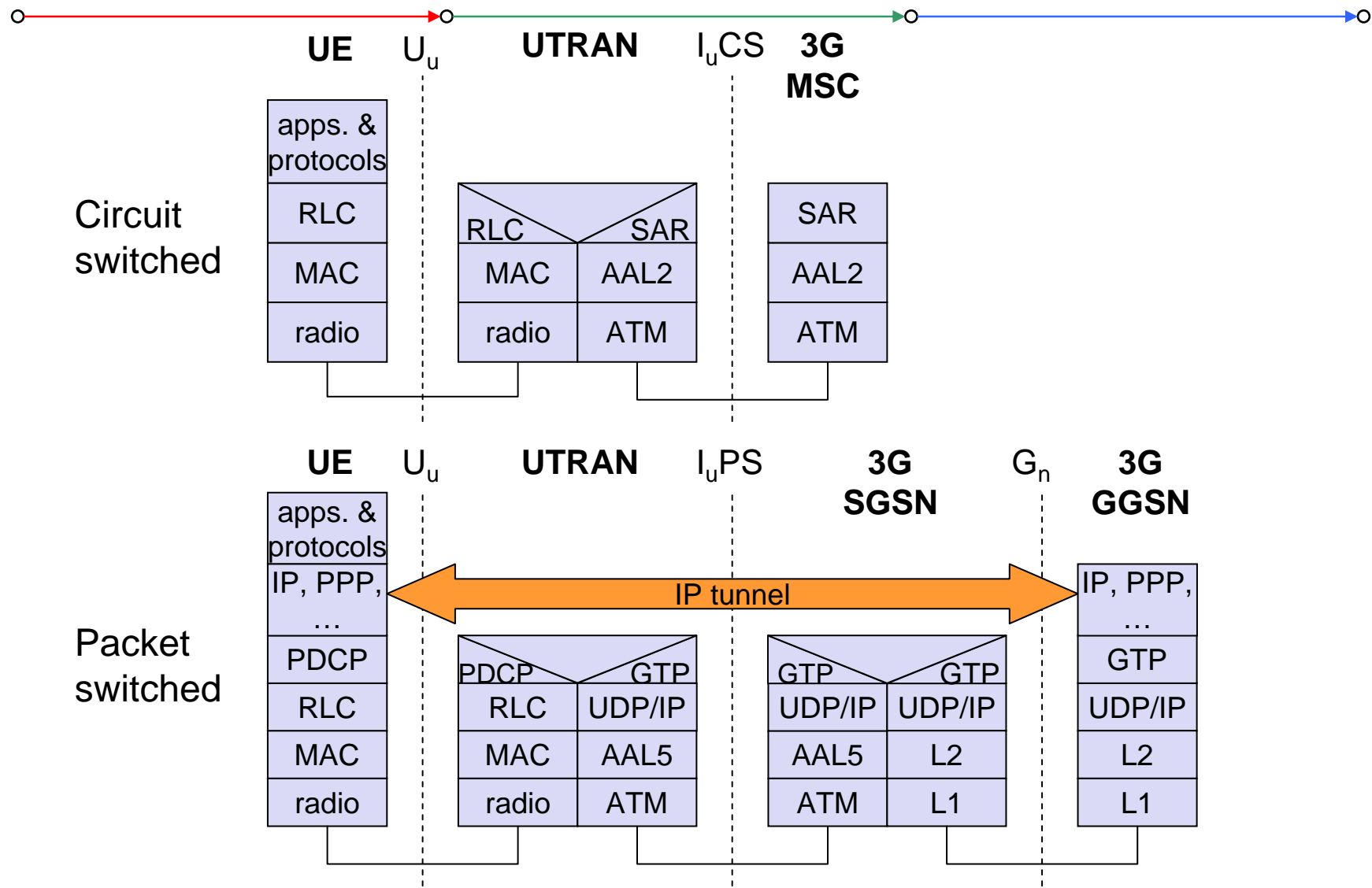
# Core network



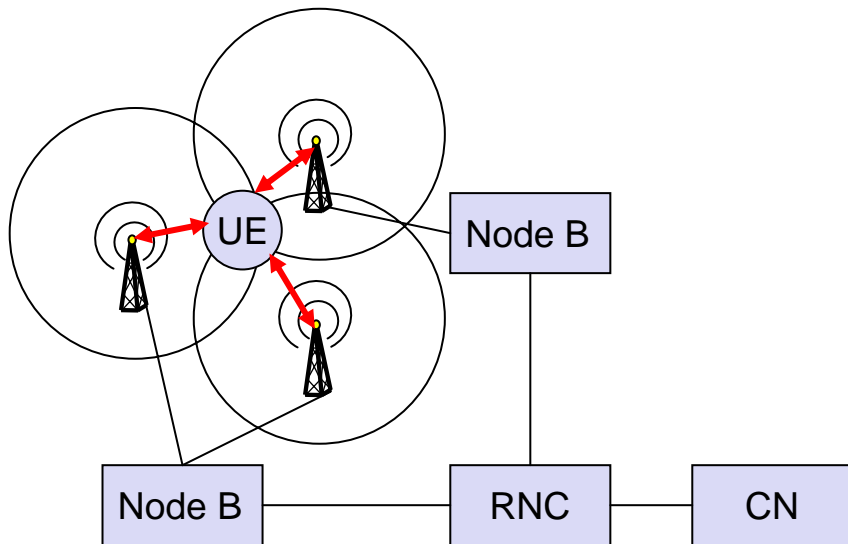
- The Core Network (CN) and thus the Interface  $I_u$ , too, are separated into two logical domains:
- Circuit Switched Domain (CSD)
  - Circuit switched service incl. signaling
  - Resource reservation at connection setup
  - GSM components (MSC, GMSC, VLR)
  - $I_u^{CS}$
- Packet Switched Domain (PSD)
  - GPRS components (SGSN, GGSN)
  - $I_u^{PS}$
- Release 99 uses the GSM/GPRS network and adds a new radio access!
  - Helps to save a lot of money ...
  - Much faster deployment
  - Not as flexible as newer releases (5, 6)



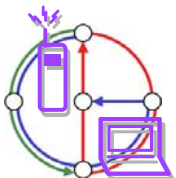
# UMTS protocol stacks (user plane)



# Support of mobility: macro diversity

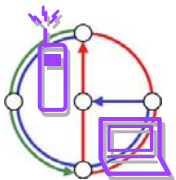
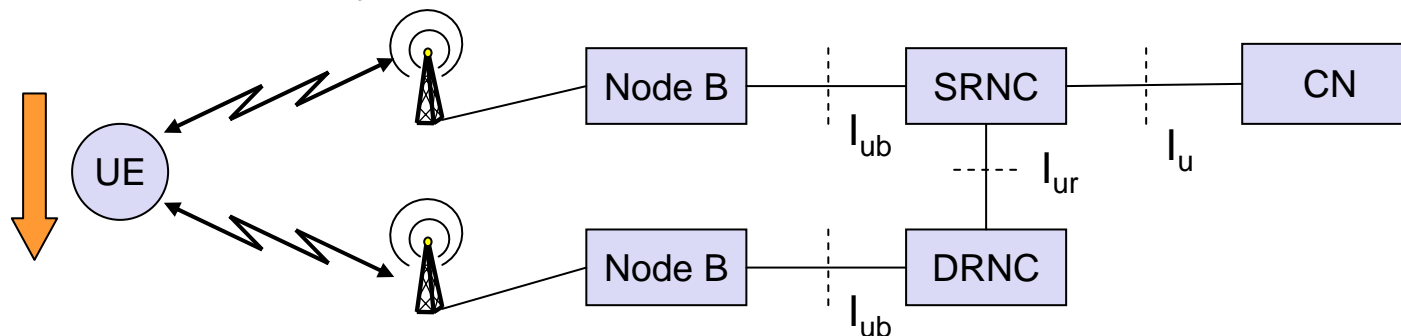


- Multicasting of data via several physical channels
  - Enables soft handover
  - FDD mode only
- Uplink
  - simultaneous reception of UE data at several Node Bs
  - Reconstruction of data at Node B, SRNC or DRNC
- Downlink
  - Simultaneous transmission of data via different cells
  - Different spreading codes in different cells



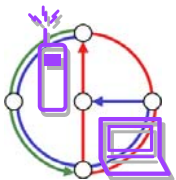
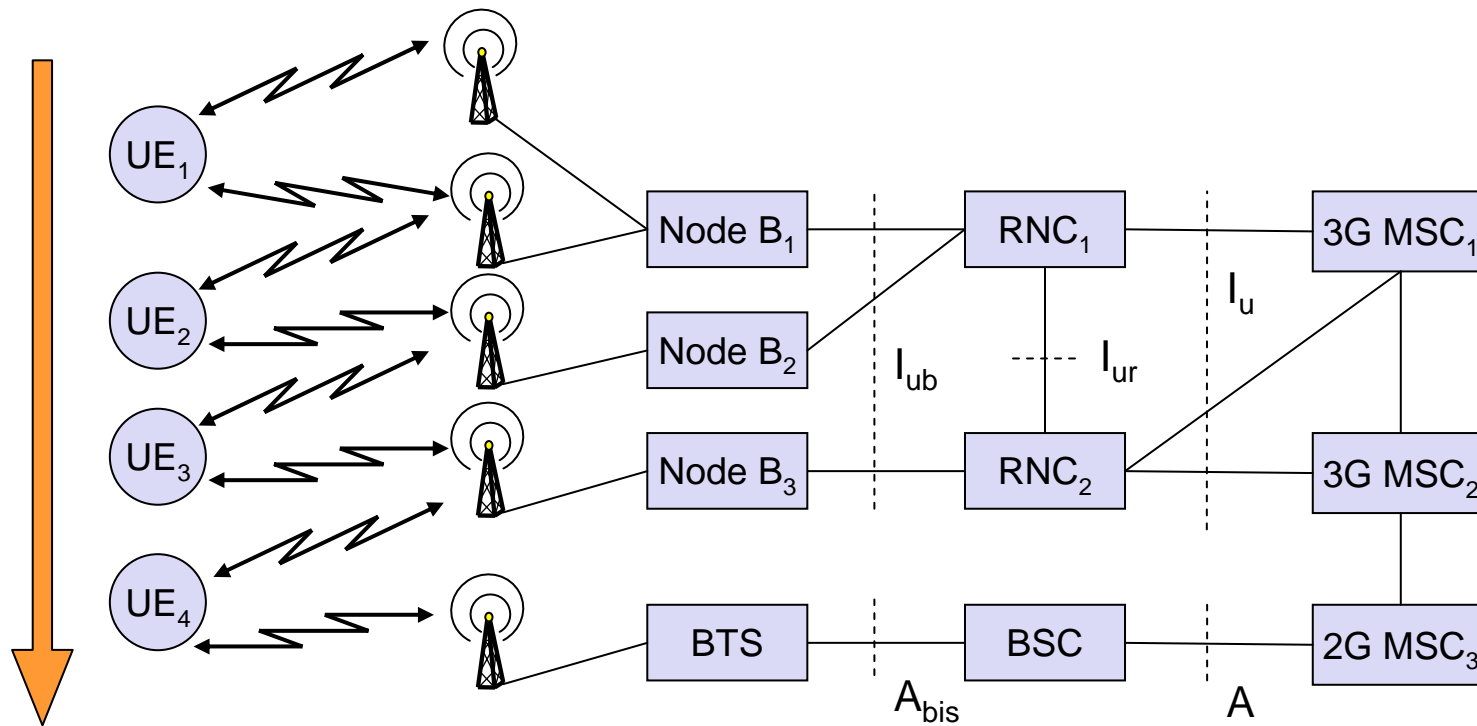
# Support of mobility: handover

- From and to other systems (e.g., UMTS to GSM)
  - This is a must as UMTS coverage will be poor in the beginning
- RNS controlling the connection is called SRNS (Serving RNS)
- RNS offering additional resources (e.g., for soft handover) is called Drift RNS (DRNS)
- End-to-end connections between UE and CN only via  $I_u$  at the SRNS
  - Change of SRNS requires change of  $I_u$
  - Initiated by the SRNS
  - Controlled by the RNC and CN





# Example handover types in UMTS/GSM



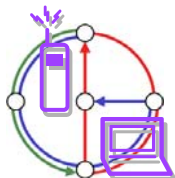
# UMTS services (originally)



- Data transmission service profiles

Service Profile	Bandwidth	Transport mode	
High Interactive MM	128 kbit/s	Circuit switched	Bidirectional, video telephone
High MM	2 Mbit/s	Packet switched	Low coverage, max. 6 km/h
Medium MM	384 kbit/s	Circuit switched	asymmetrical, MM, downloads
Switched Data	14.4 kbit/s	Circuit switched	
Simple Messaging	14.4 kbit/s	Packet switched	SMS successor, E-Mail
Voice	16 kbit/s	Circuit switched	

- Virtual Home Environment (VHE)
  - Enables access to personalized data independent of location, access network, and device
  - Network operators may offer new services without changing the network
  - Service providers may offer services based on components which allow the automatic adaptation to new networks and devices
  - Integration of existing IN services



# Future mobile telecommunication networks

