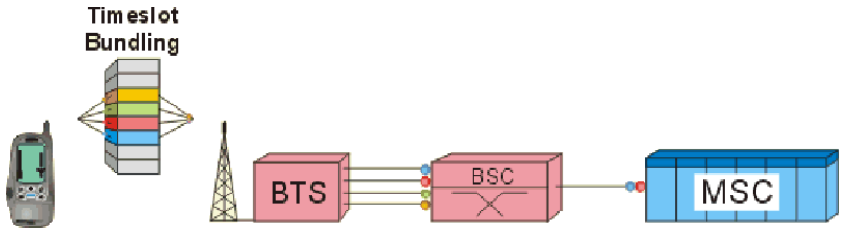
Generation 2.5 (2.5G)

- 2.5G is a term that developed out of enhancements of GSM
- It is an upgrade of 2G-GSM
- In particular support of non-voice applications (data)
- Also higher data rates on the air interface
- Already has several characteristics of 3G
- In particular:
  - General Packet Radio Service (GPRS)
  - High-Speed Circuit-Switched Data (HSCSD)
  - Enhanced Data Rates for GSM Evolution (EDGE)
- 2.5G technology is very important nowadays as a backup for 3G, e.g. in areas where UMTS is not deployed.

Generation 2.5 (2.5G) - HSCSD

- High-Speed Circuit-Switched Data
- HSCSD bundles up to 8 GSM traffic channels into one high speed channel
- offers symmetric or asymmetric data rates
- is a circuit switching technology, i.e. very suitable for constantly high data rates (e.g. telefax), but not for varying data rates (e.g. Internet browsing)



Generation 2.5 (2.5G) - HSCSD

application areas:

- fast data services over GSM (data rates comparable to ISDN)
- real time applications
- telemetry, i.e. constant technical measurements
- surveillance, e.g. webcam
- video telephony

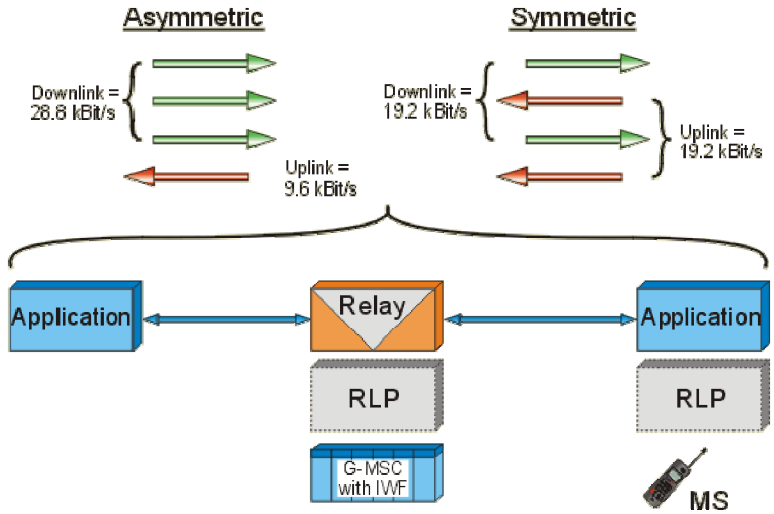
symmetric/asymmetric:

- allows data rates where the downlink has different data rate as uplink

transparent/non-transparent:

- transparent service doesn't use error correction (higher speed)
- non-transparent uses Radio Link Protocol (RLP) for error correction

Generation 2.5 (2.5G) - HSCSD



Generation 2.5 (2.5G) - HSCSD

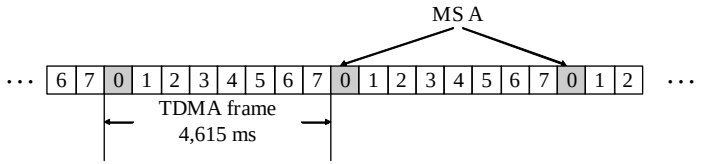
number of bundled channels	14,4 kbit/s per channel	9,6 kbit/s per channel
1	14,4 kbit/s	9,6 kbit/s
2	28,8 kbit/s	19,2 kbit/s
3	43, 2 kbit/s	28,8 kbit/s
4	57,6 kbit/s	38,4 kbit/s

Generation 2.5 (2.5G) - GPRS

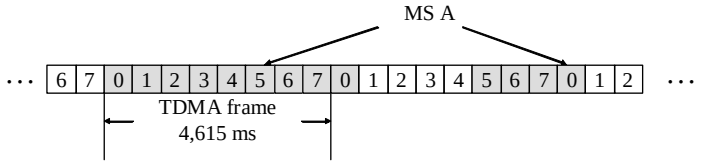
- General Packet Radio Service
- developed for data transmission in GSM networks
- packet switched (efficient for Internet browsing)
- allows sending and receiving of data without occupation of circuit switched resources
- GPRS can occupy wrt one user
  - one time slot in a TDMA frame
  - several time slots in a TDMA frame
  - the whole 200KHz band
- time slots are allocated dynamically according to the needs

Generation 2.5 (2.5G) - GPRS

example of a static allocation of time slots in GSM (voice)



example of a dynamic allocation of time slots by GPRS



Generation 2.5 (2.5G) - GPRS

- maximum of 171 kBit/s (all 8 time slots of a TDMA frame, new form of channel coding, e.g. no error correction), 4 coding schemes:
  - CS1 (full error correction)
  - …
  - CS4 (no error correction)
- advantages of “packet over the air” wrt traditional circuit switched technology:
  - virtual connectivity, “always on”
  - fast resource allocation according to demand
  - alternative ways of accounting, e.g. by data volume, flat rate, “fair” flat
  - asymmetric data rates for uplink and downlink, adjusted dynamically
- is offered by almost all network operators

Generation 2.5 (2.5G) – GPRS data rates

gross data rates with different coding schemes

channel coding	CS1	CS2	CS3	CS4
1 TS Data Rate	9.05 kbit/s	13,4 kbit/s	15,6 kbit/s	21,4 kbit/s
2 TS Data Rate	18,10 kbit/s	26,8 kbit/s	31,2 kbit/s	42,8 kbit/s
3 TS Data Rate	27,15 kbit/s	40,2 kbit/s	46,8 kbit/s	64,2 kbit/s
4 TS Data Rate	36,30 kbit/s	53,6 kbit/s	62,4 kbit/s	85,6 kbit/s
5 TS Data Rate	45,35 kbit/s	67,0 kbit/s	78,0 kbit/s	107,0 kbit/s
6 TS Data Rate	54,40 kbit/s	80,4 kbit/s	93,6 kbit/s	128,4 kbit/s
7 TS Data Rate	63,45 kbit/s	93,8 kbit/s	109,2 kbit/s	149,8 kbit/s
8 TS Data Rate	72,50 kbit/s	107,2 kbit/s	124,8 kbit/s	171,2 kbit/s

Generation 2.5 (2.5G) – GPRS

overview: suitability of different 2G and 2.5G technology

Application	GSM	HSCSD	GPRS
voice	very good	doesn't fit	doesn't fit
E-Mail	medium	medium	very good
mobile Internet access	doesn't fit	not ideal	very good
mobile Intranet access	doesn't fit	not ideal	very good
WAP	medium	not ideal	very good
file transfer	doesn't fit	very good	very good
image	doesn't fit	very good	very good
video streaming	doesn't fit	very good	doesn't fit
surveillance with alarm functionality	not ideal	doesn't fit	gut

Generation 2.5 (2.5G) – Comparison

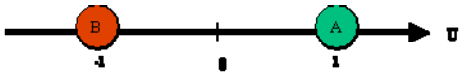
2G, 2.5G and 3G in Germany:	GSM	GPRS	HSCSD	UMTS
Switching	circuit	packet	circuit	circuit and packet
data rate (theoretical)	9,6 and 14,4 kBit/s	171,2 kBit/s	115,2 kBit/s	2 MBit/s with HSDPA 7,2
Data rate (practical)	9,6 kBit/s	50 kBit/s (Downlink) 15 kBit/s (Uplink)	43,2 kBit/s(Downlink) 28,8 kBit/s(Uplink)	mostly less than 1 MBit/s
accounting	connection time	volume and/or connection time	connection time	volume
always-on-function	No	Yes	no	yes
channel bundling	not possible	theoretically 8 channels	theoretically 8 channels	not necessary
availability	since 1992	since April 2001 in all German networks	since 1999 (E-Plus) since 2000 (Vodafone)	since 2005

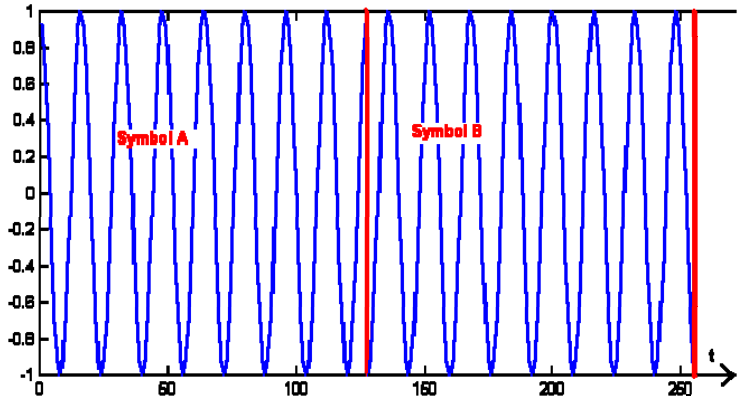
Generation 2.5 (2.5G) - EDGE

- Enhanced Data rates for GSM Evolution
- evolution of GPRS
- EDGE introduces an additional modulation scheme: 8-PSK
- 8-PSK transmits 3 bits per signal state. However, that makes EDGE less robust against interference and low signal quality
- data rates of up to 473,6 Kbps are theoretically possible
- originally EDGE was developed so that network operators who did not succeed in acquiring 3G licenses could still offer high data rates to their customers
- EDGE has an easy deployment, it is just a SW update to most modern GSM base stations.

Generation 2.5 (2.5G) - EDGE

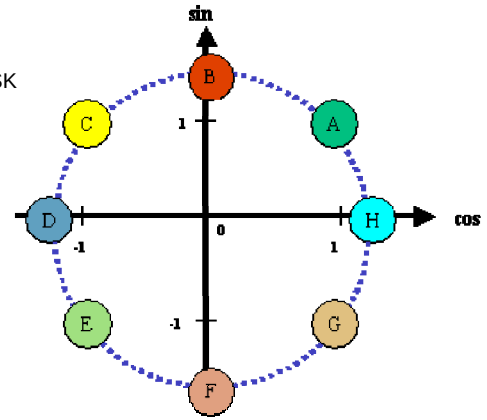
example: 2-PSK = BPSK
(similar to GMSK)





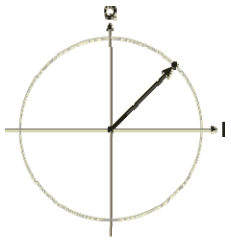
Generation 2.5 (2.5G) – EDGE 8-PSK

8PSK

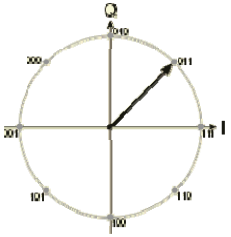


Generation 2.5 (2.5G) - EDGE 8-PSK

GSM:
Gaussian Minimum-Shift Keying (GMSK).



EDGE:
8-Phase Shift Keying (PSK)



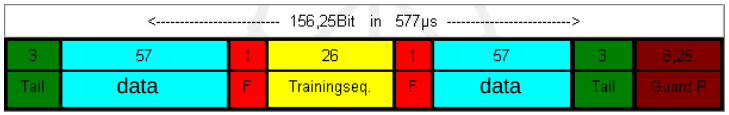
Generation 2.5 (2.5G) - EDGE 8-PSK

symbol	3 bits	coordinates	Phase (rel to x-axis)
C	0 0 0	-1 / 1	135
D	0 0 1	-1,41 / 0	180
B	0 1 0	0 / 1,41	90
A	0 1 1	1 / 1	45
F	1 0 0	0 / -1,41	-90
E	1 0 1	-1 / -1	-135
G	1 1 0	1 / -1	-45
H	1 1 1	1,41 / 0	0

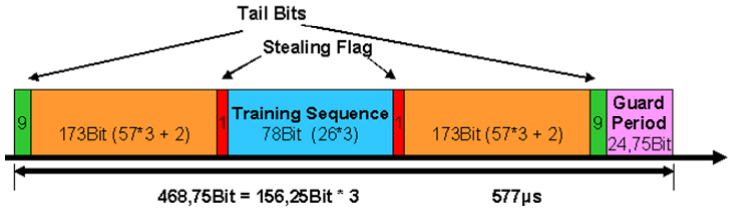
A bitstream of: 00101111010100011111100100000101
separated in groups of 3: 001 011 110 101 000 111 111 001 000 000 101
results in: D, A, G, E, C, H, H, D, C, C, E

Generation 2.5 (2.5G) - EDGE 8-PSK

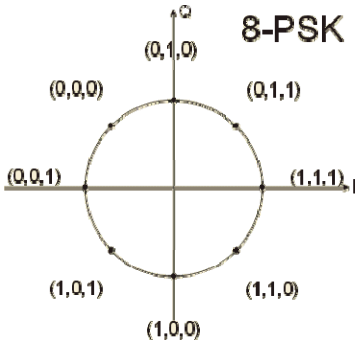
normal burst for GSM with GMSK modulation:



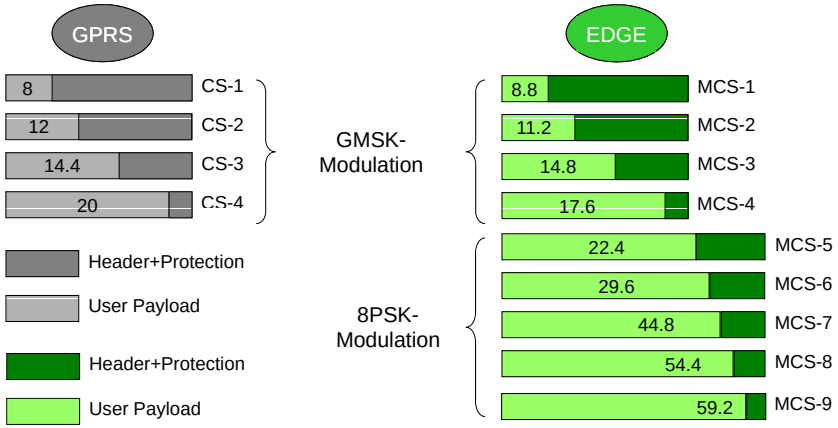
normal burst for EDGE with 8PSK modulation:



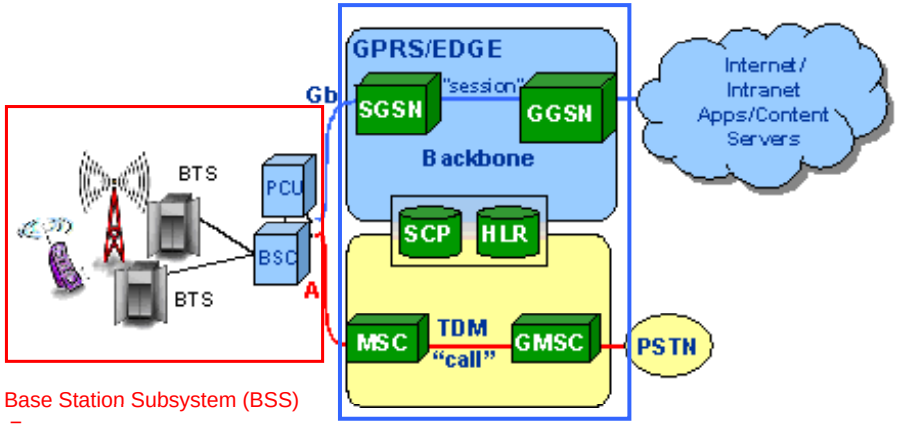
Generation 2.5 (2.5G) - EDGE interference problem



Generation 2.5 (2.5G) - EDGE data rates



Generation 2.5 (2.5G) - EDGE architecture



Base Station Subsystem (BSS)
=
Radio Access Network (RAN)

Core Network (CN)

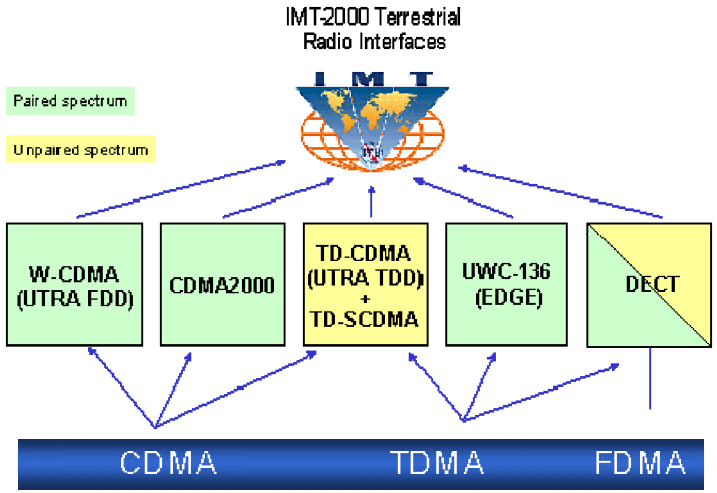
Generation 3 (3G)

- 2G goals: efficient usage of frequency spectrum by digitizing of cellular networks, success story GSM
- 3G goals: efficient integration of voice and data for mobile voice and data services in cellular networks
- in addition
  - worldwide compatibility of terminals and base stations
  - smooth transition from 2G to 3G
  - new frequency spectrum

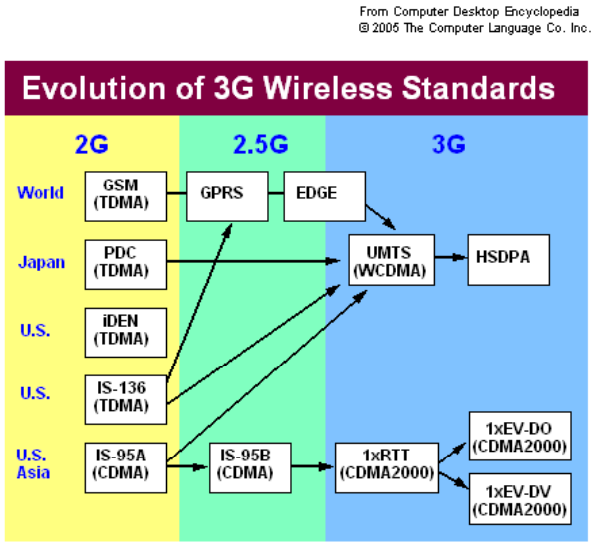
Generation 3 (3G)

- there is not only a single 3rd generation
- standardization in the ITU under des IMT-2000 program
- terrestrial access technology for 3G
  - GSM-based 3. generation: GPRS/EDGE (s. 2.5G)
  - UMTS-based 3. generation: W-CDMA und TD-(S)CDMA
  - IS-95-based 3. generation: CDMA2000
  - DECT (only for cordless phones, private domains)
- industry consortia pushing the standardisation of 3G:
  - 3GPP (Third Generation Partnership Project): W-CDMA and TD-(S)CDMA, mostly driven by Europa, Japan and China
  - 3GPP2: CDMA2000, driven by US companies

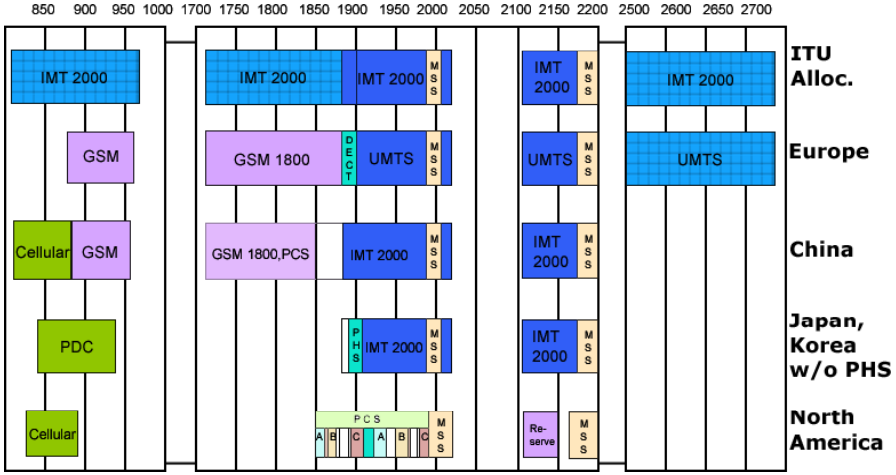
Generation 3 (3G)



Generation 3 (3G)

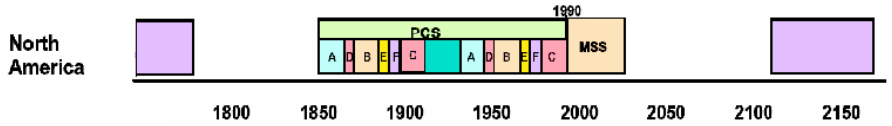


Generation 3 (3G) IMT 2000 Frequency spectrum



Generation 3 (3G) Frequency spectrum US

- in the US the spectrum defined by ITU was already occupied by systems of 2G (IS-95)
- therefore, in September 2006 the Federal Communications Commission (FCC) auctioned the spectrum1710-1755 MHz and 2110-2155 MHz for 3G
- originally the spectrum1710-1755 MHz was occupied by government agencies, air traffic control and sattelite control
- 2110-2155 MHz was occupied by paging systems, local TV stations, …



Generation 3 (3G) Frequency spectrum

spectrum allocation for UMTS:
UMTS: 1900 - 2025MHz and 2110 - 2200MHz

- paired licensed frequencies: 2 x 60MHz = 12 packets á 5MHz
  - uplink: 1920 - 1980MHz
  - downlink: 2110 - 2170MHz
- unpaired licensed frequencies : 1 x 25MHz = 5 packets á 5MHz
  - 1900 - 1920MHz und 2020 - 2025MHz
- unpaired unlicensed frequencies : 2 packets
  - 2010 - 2020MHz
- satellite (optional in future):
  - uplink: 1980 - 2010MHz
  - downlink: 2170 - 2200MHz

Generation 3 (3G) Spectrum auction in Germany

network operator	paired packets	price bill DM	unpaired packets	price bill DM
E-Plus / Hutchinson	2	16,42	1	0,0736
O2	2	16,52		
Vodafone (was Manesmann Mobilf.)	2	16,47	1	0,121
T-Mobil	2	16,58	1	0,1227
Mobilcom (gave up)	*2*	*16,37*	*1*	*0,121*
Group 3G /Quam (gave up)	*2*	*16,45*	*1*	*0,1227*
sum	12	98,81	5	0,561

Generation 3 (3G) UMTS quality of service classes

Class	Traffic Class	Class Description	Example	Relevant QoS Requirements
1	Conversational	Preserves time relation between entities making up the stream conversational pattern based on human perception; real-time	Voice Video telephony Video gaming Video conferencing	Low jitter Low delay
2	Streaming	Preserves time relation between entities making up the stream; real-time	Multimedia Video on demand Webcast Real-time video	Low jitter
3	Interactive	Bounded response time Preserves the payload content	Web-browsing Database retrieval	Low round trip delay time Low BER
4	Background	Preserves the payload content	E-mail SMS File transfer	Low BER

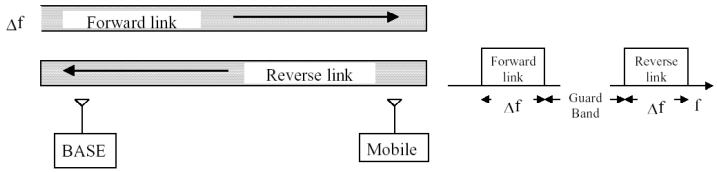
Generation 3 (3G) UMTS typical QoS parameter

		Data rate	One-way Delay	Delay variation	Information loss
Conversational voice	Two-way	4-13 kb/s	<150 msec preferred <400 msec limit	< 1 msec	< 3% FER (Frame Error Rate)
Voice messaging	Primarily one-way	4-13 kb/s	< 1 sec for playback < 2 sec for record	< 1 msec	< 3% FER
High quality streaming audio	Primarily one-way	32-128 kb/s	< 10 sec	< 1 msec	< 1% FER

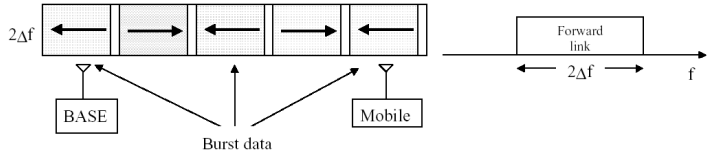
Generation 3 (3G) UMTS FDD and TDD

- there are two types of UMTS:
  - W-CDMA (wideband UMTS with FDD, needs paired spectrum
  - TD-CDMA (Time division UMTS, FDD, only needs unpaired

Transmission by **FDD** method

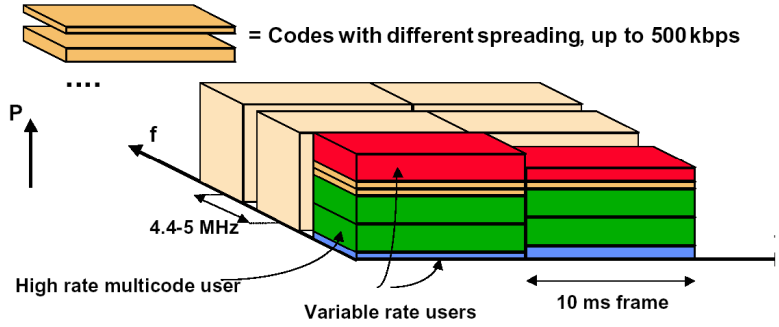


Transmission by **TDD** method



Generation 3 (3G) UMTS FDD and TDD

W-CDMA - Wideband direct sequence CDMA
also called UMTS FDD



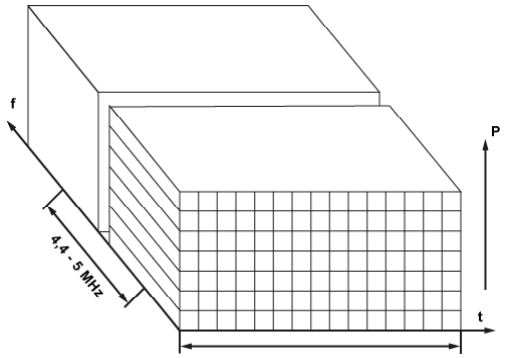
Generation 3 (3G) UMTS FDD and TDD

TD-CDMA, also called UMTS TDD

resembles GSM with spreading each time slot:

16 CDMA channels
in 15 time slots

data rates from 9,6 kBit/s
to 2 MBit/s



1 frame = 10 ms = 15 slots

Generation 3 (3G) UMTS network architecture (Rel.99)

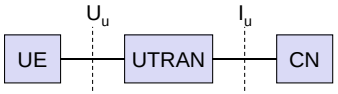
UTRAN (UTRA Network)

- Cell level mobility
- Radio Network Subsystem (RNS)
- Encapsulation of all radio specific tasks

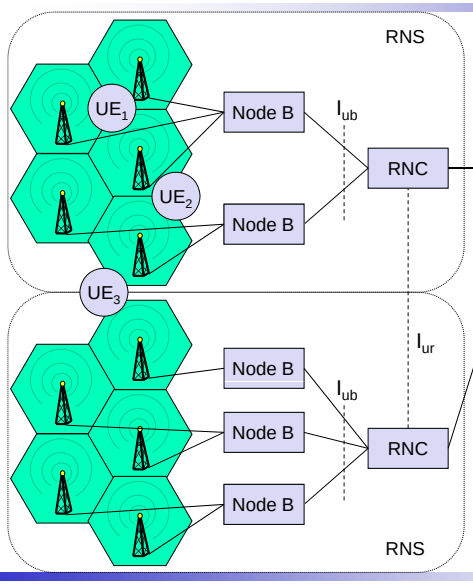
UE (User Equipment)

CN (Core Network)

- Inter system handover
- Location management if there is no dedicated connection between UE and UTRAN



Generation 3 (3G) UTRAN architecture



RNC: Radio Network Controller

RNS: Radio Network Subsystem

I_u

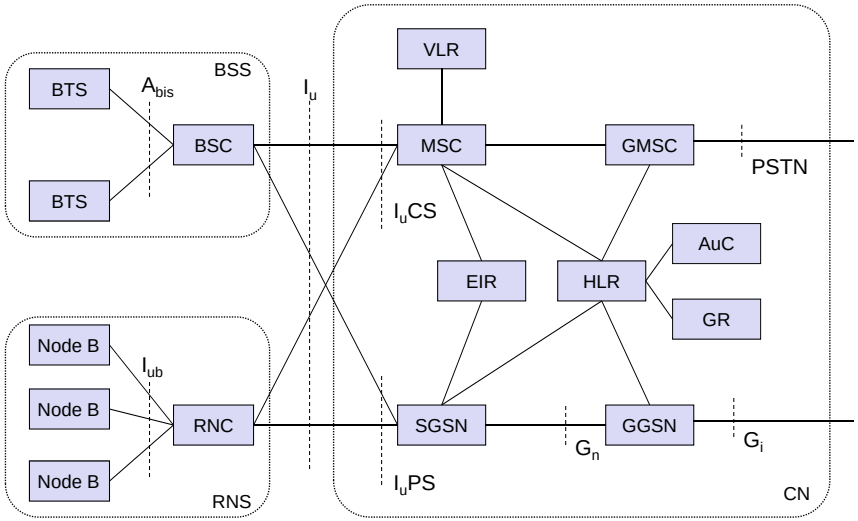
UTRAN comprises several RNSs

Node B can support FDD or TDD or both

RNC is responsible for handover decisions requiring signalingto the UE

Cell offers FDD or TDD

Generation 3 (3G) UMTS core network architecture



Generation 3 (3G) UMTS core network architecture

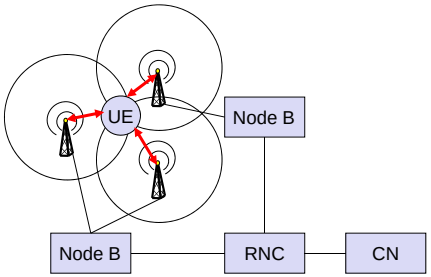
The Core Network (CN) and thus the Interface I_u, too, are separated into two logical domains:

- Circuit Switched Domain (CSD)
  - Circuit switched service incl. signaling
  - Resource reservation at connection setup
  - GSM components (MSC, GMSC, VLR)
  - I_uCS
- Packet Switched Domain (PSD)
  - GPRS components (SGSN, GGSN)
  - I_uPS

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)

Generation 3 (3G) UMTS mobility support



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

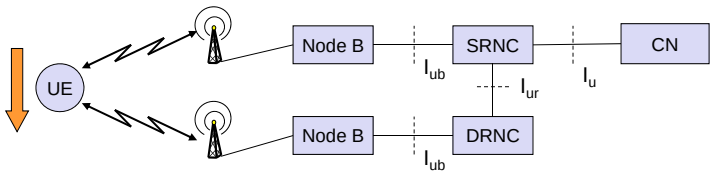
Generation 3 (3G) UMTS mobility support, handover

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



Generation 3 (3G) UMTS cell breathing

GSM

- Mobile device gets exclusive signal from the base station
- Number of devices in a cell does not influence cell size

UMTS

- Cell size is closely correlated to the cell capacity
- Signal-to-nose ratio determines cell capacity
- Noise is generated by interference from
  - other cells
  - other users of the same cell
- Interference increases noise level
- Devices at the edge of a cell cannot further increase their output power (max. power limit) and thus drop out of the cell
  ⇨ no more communication possible
- Limitation of the max. number of users within a cell required

- Cell breathing complicates network planning

Generation 3 (3G) UMTS cell breathing