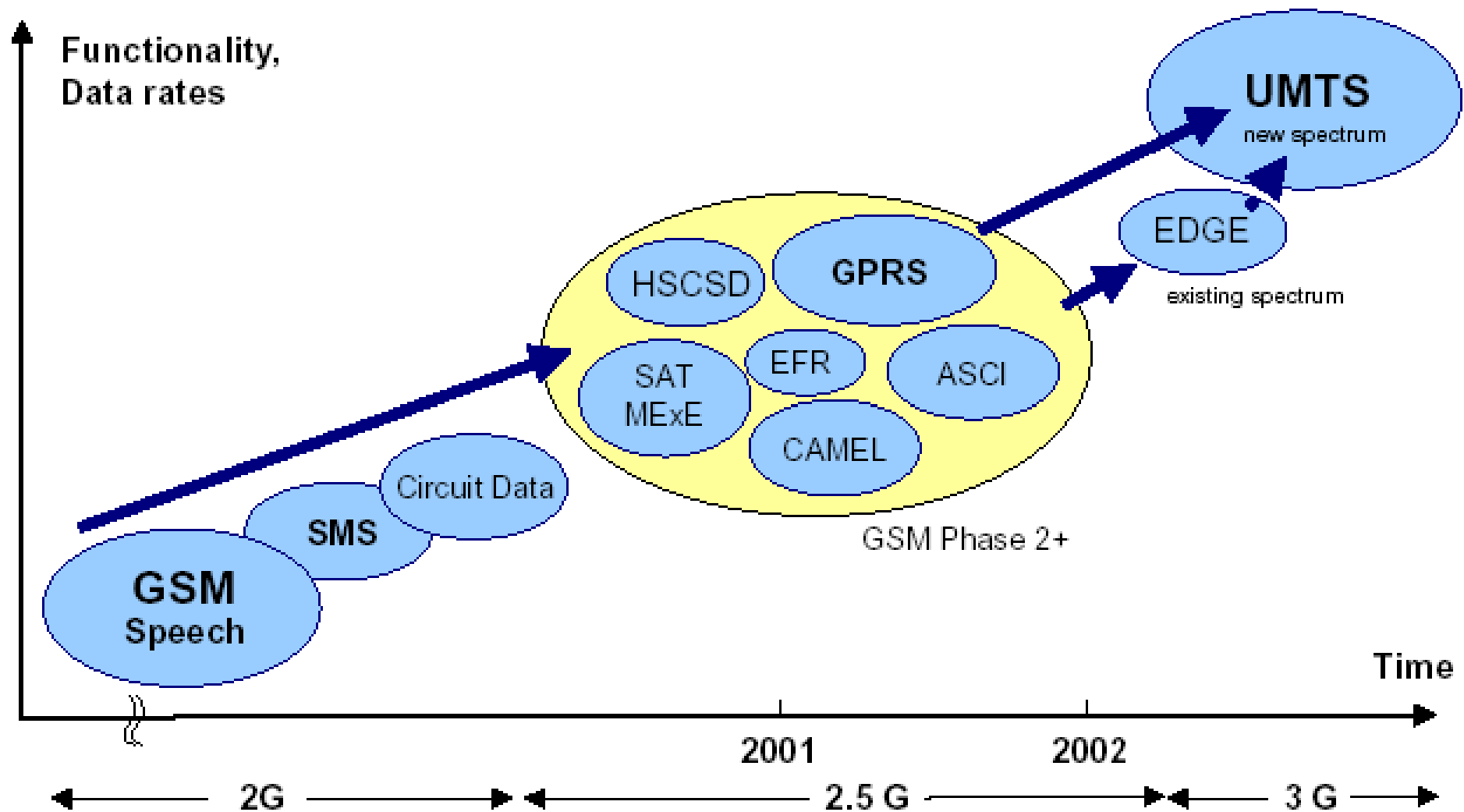

Cellular Mobile Networks - GSM

GSM Evolution

Contents - GSM - GSM Evolution

- GSM Evolution Overview
- Motivation for GSM Extensions
- High Speed Circuit-Switched Data (HSCSD)
- General Packet Radio Service (GPRS)
- Enhanced Data Rates for GSM Evolution (EDGE)
- Further GSM Phase 2+ Features

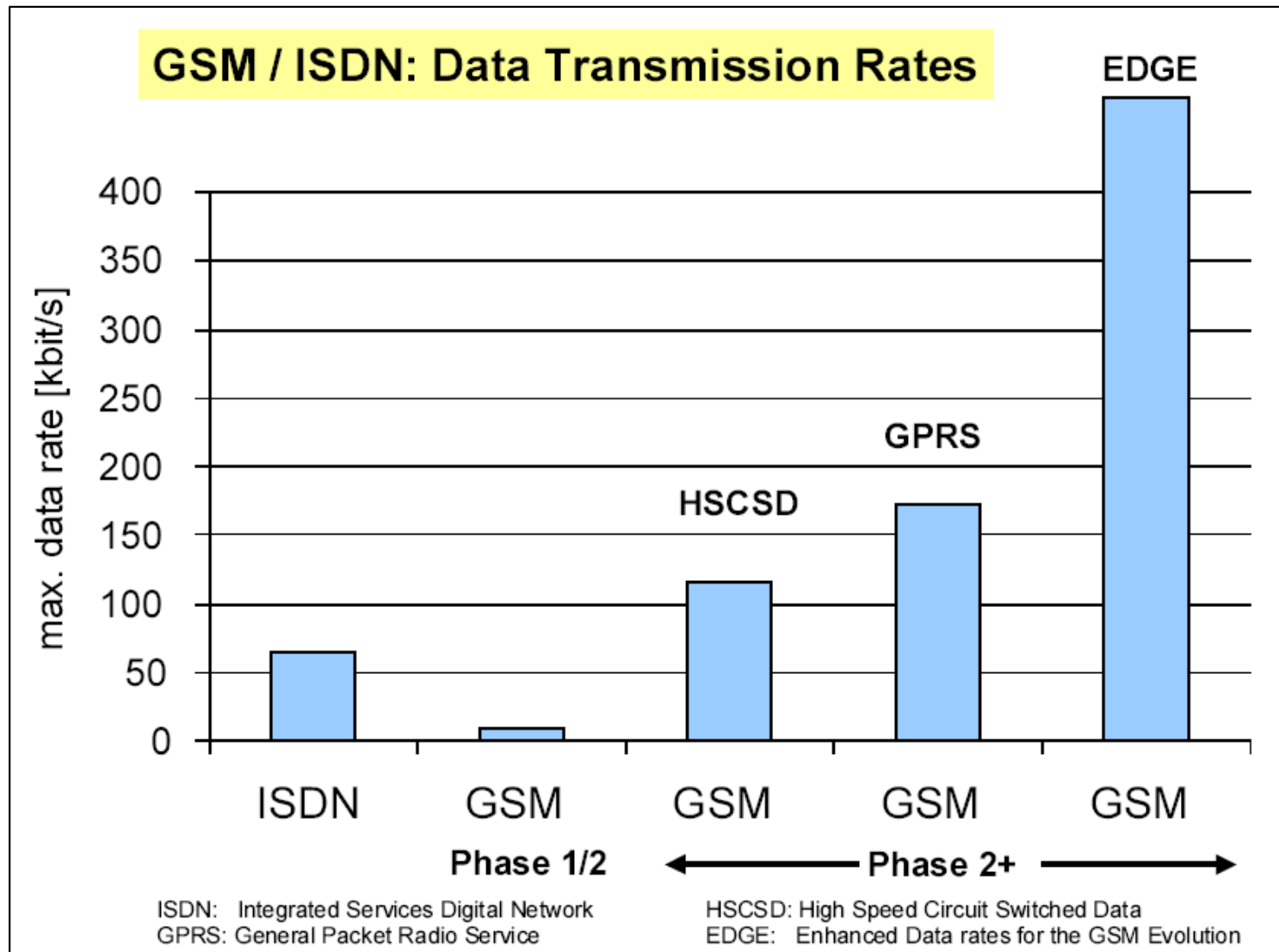
GSM Evolution Overview



Motivation for GSM Extensions

- GSM systems are widely used since the mid nineties
 - original focus was on circuit switched services, especially voice
 - low bitrates (up to a few 10 kbit/s) for data services
- Increasing popularity of Internet services
 - fixed line Internet accesses offer high data rates
 - growing demand for higher data rates also for mobile Internet applications
- Therefore: upgrade of mobile networks for higher data rates
- Important requirements:
 - compatibility to the existing GSM standard
 - no new frequency spectrum needed

Motivation for GSM extensions



High Speed Circuit-Switched Data (HSCSD)

- Originally CS data transmission had been possible with 9,6 kbit/s only
 - more sophisticated channel coding schemes (with reduced error protection) allow up to 14.4 kbit/s - but this is still not enough for Internet applications
- HSCSD (High-Speed Circuit Switched Data)
 - aggregation of several TDMA time slots for higher data rates (AIUR, Air Interface User Rate), e.g. 57,6 kbit/s with 4 Slots a 14,4 kbit/s

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

- HSCSD is realized through software updates at the BTS
- advantages: quickly available, continuous quality (due to circuit-switched operation), easy to implement for the operator
- disadvantages: expensive for the subscriber, higher blocking of voice channels

General Packet Radio Service (GPRS)

- Disadvantages of traditional GSM circuit switched data services (CSD)
 - time slot(s) are permanently assigned to the subscriber for the whole connection time
 - low flexibility
- Characteristic of typical internet applications:
 - data traffic is bursty
 - only for short time periods high transmission rates are necessary
- Advantages of a packet switched data service:
 - allows an always connected operation
 - allows a data transmission on demand (e.g. during reading a web page no data is transmitted)
 - allows a higher flexibility regarding the radio resource management: several subscribers can share one time slot (statistical multiplexing)

General Packet Radio Service (GPRS)

- GPRS was introduced in the year 2000 as a new packet switched GSM bearer service (GSM Phase 2+)
- Properties of GPRS:
 - improved and simplified access to packet switched networks (PDNs) e.g. Internet, X.25
 - direct routing between mobile stations and packet switched networks possible
 - shorter connection setup delay and higher data rates, compared to GSM circuit switched data services

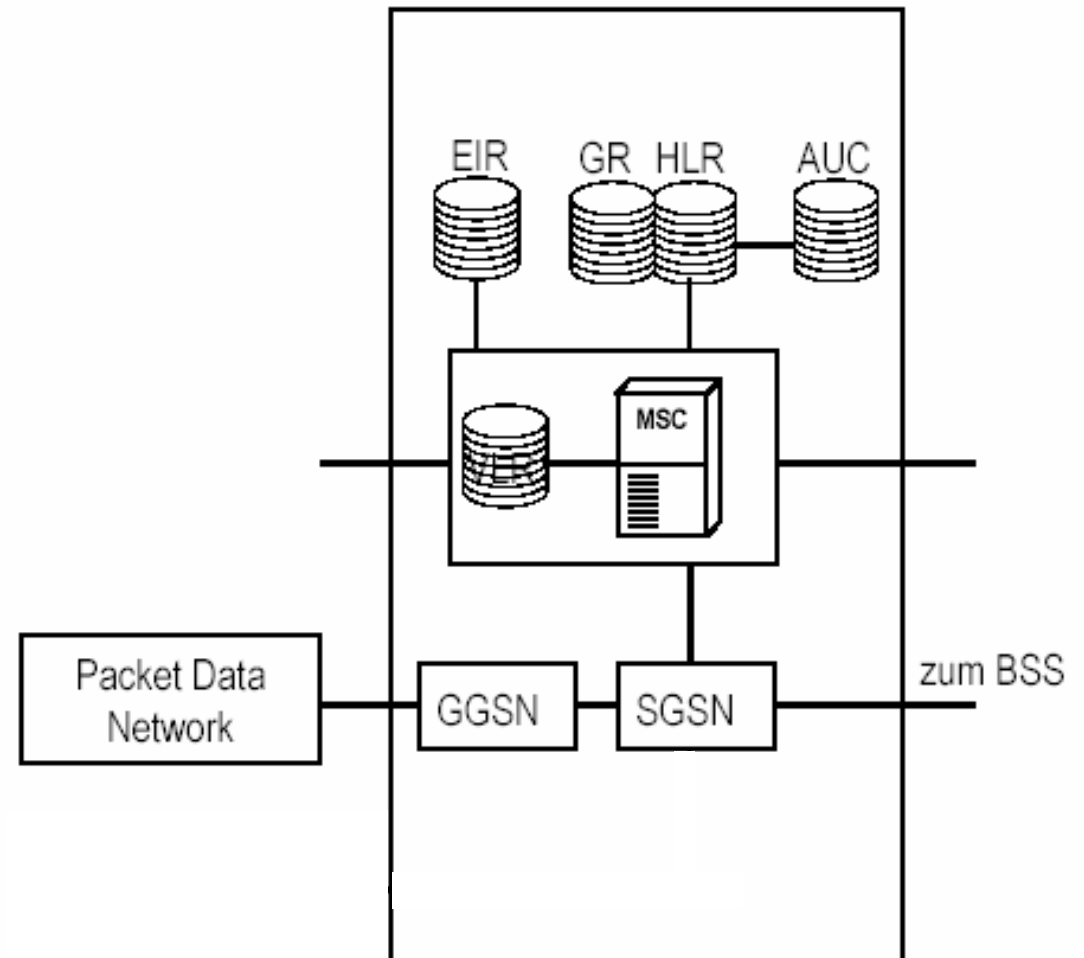
	conventional GSM	GPRS
connection setup	several seconds	< 1 second
data rate	9.6 kbit/s	ISDN like (30..50 kbit/s)

General Packet Radio Service (GPRS) - Pros and Cons

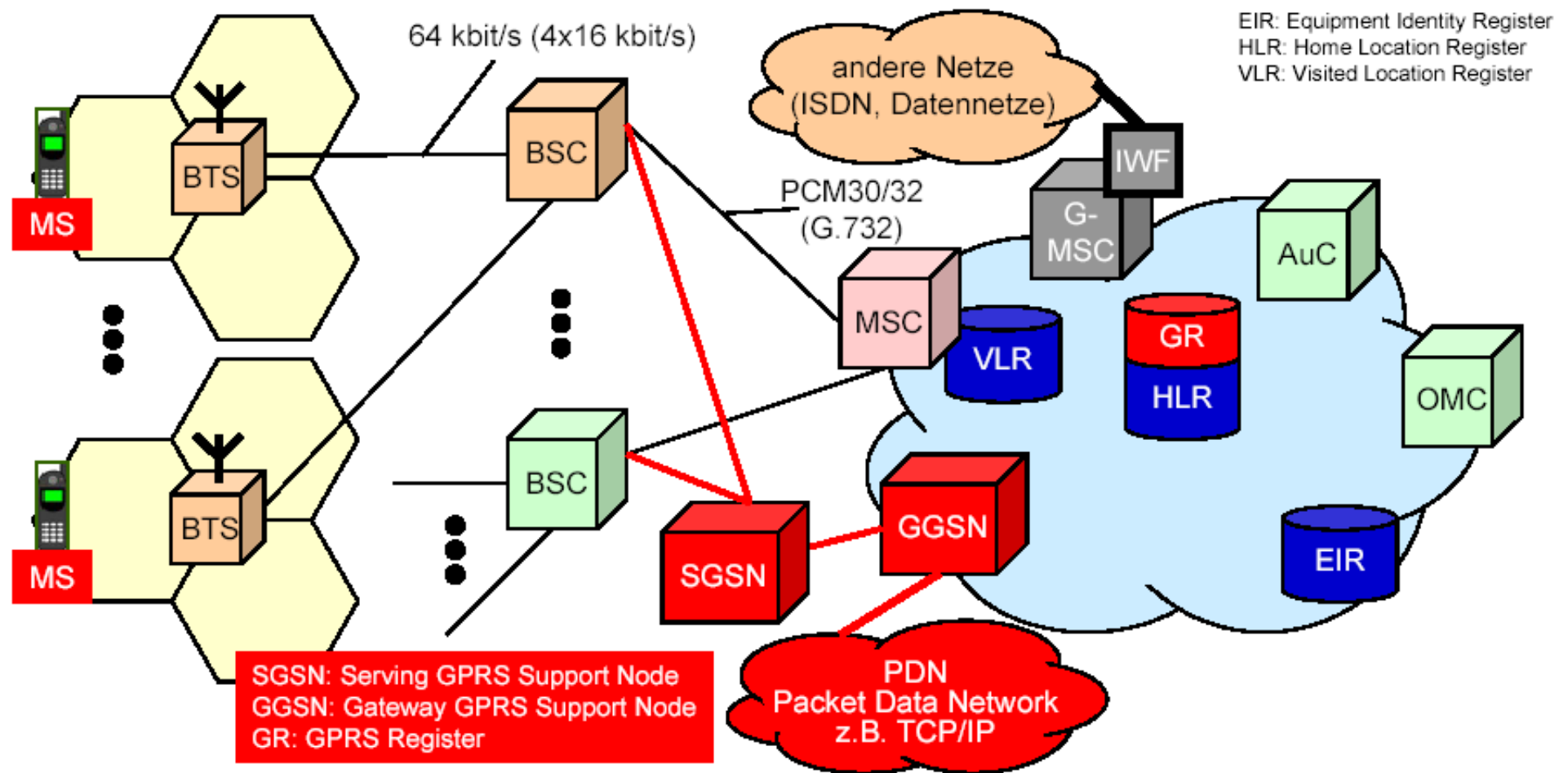
- Advantages for operators:
 - more efficient use of the radio resources (through statistical multiplexing of several subscribers to one time slot)
 - new service offering: high bit rate data services
- Disadvantages for operators:
 - high implementation effort: new network elements (SGSN and GGSN), HW updates for the BSCs, multiple software updates, new MS
- Advantages for subscribers:
 - higher data rates and always on operation
 - new tariff schemes possible (e.g. volume based or flat rate charging) because the resources are not used permanently
- Disadvantages for subscribers:
 - no guaranteed continuous bit rate
 - in case the mobile network is highly loaded with voice connections, only low capacity might be available for GPRS

General Packet Radio Service (GPRS) - Network Elements

- New system architecture in parallel to the SSS: GPRS Switching Subsystem
- **Gateway GPRS Support Node (GGSN):**
allows access to external packet oriented networks
- **Serving GPRS Support Node (SGSN):**
supports GPRS functions similar to the MSC/VLR (e.g. mobility management)
- **GPRS Register (GR)**



General Packet Radio Service (GPRS) - Architecture



General Packet Radio Service (GPRS) - Radio Interface

- Modulation scheme used for GPRS: GMSK
- Dynamic adaption of the channel coding scheme to the quality of the radio channel
 - definition of four Coding Schemes (CS) with different data rates
 - the highest data rate of 21,4kbit/s is reached with CS-4 (code rate 1, no error protection); CS-4 is only possible in case of good C/I
- Bundling of up to 8 time slots per subscriber
 - theoretically a maximum user data rate of $8 \cdot 21,4\text{kbit/s} = 171,2\text{kbit/s}$ can be obtained
- Gain through statistical multiplexing
 - different subscribers can transmit packets on the same time slot at different time instances
 - flexible assignment of data packets to free time slots (which are not occupied by CS connections)
- Asymmetric resource allocation for up- and downlink possible

General Packet Radio Service (GPRS) - Radio Interface

GPRS Coding Schemes (CS)

different redundancy (FEC) → Quality	Coding Scheme	Code Rate	Radio Block*	Coded Bits	Punctured Bits	Data Rate kbit/s	Target C/I
	CS-1	1 / 2	181	456	0	9,05	6 dB
	CS-2	$\approx 2 / 3$	268	588	132	13,4	9 dB
	CS-3	$\approx 3 / 4$	312	676	220	15,6	12 dB
	CS-4	1	428	456	0	21,4	17 dB

* Radio Block without
Uplink State Flag USF &
Block Check Sequence BCS

bundling
1..8 TS

max. 171,2 kbit/s

General Packet Radio Service (GPRS) - Data Rates

Coding scheme	1 time slot	2 time slots	3 time slots	4 time slots	5 time slots	6 time slots	7 time slots	8 time slots
CS-1	9,05	18,2	27,15	36,2	45,25	54,3	63,35	72,4
CS-2	13,4	26,8	40,2	53,6	67	80,4	93,8	107,2
CS-3	15,6	31,2	46,8	62,4	78	93,6	109,2	124,8
CS-4	21,4	42,8	64,2	85,6	107	128,4	149,8	171,2

General Packet Radio Service (GPRS) - QoS Classes

GPRS Quality of Service (QoS) Classes

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 (best effort)			

General Packet Radio Service (GPRS) - Device Classes

GPRS Device Classes

Class	Receive time slots	Transmit time slots	Maximal number of time slots per frame
1	1	1	2
2	2	1	3
3	2	2	3
5	2	2	4
8	4	1	5
10	4	2	5
12	4	4	5

Enhanced Data Rates for GSM Evolution (EDGE)

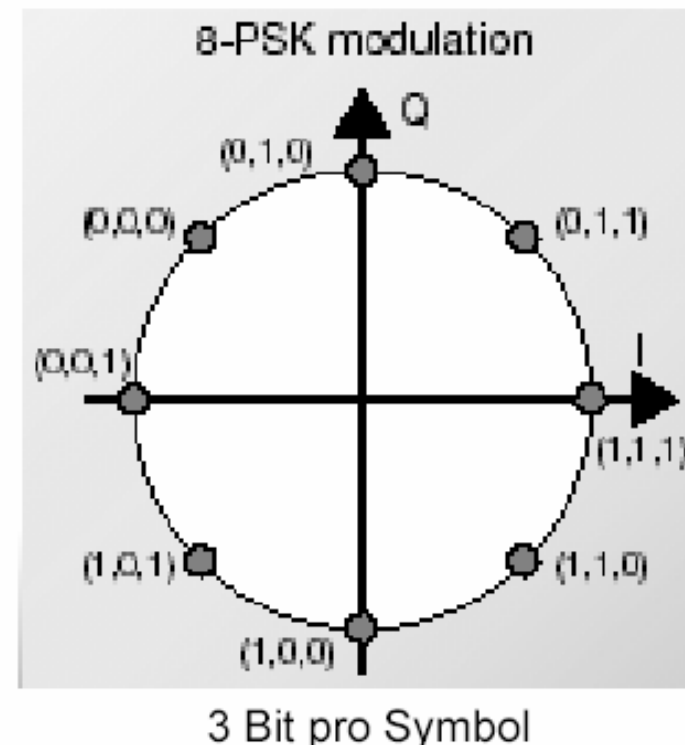
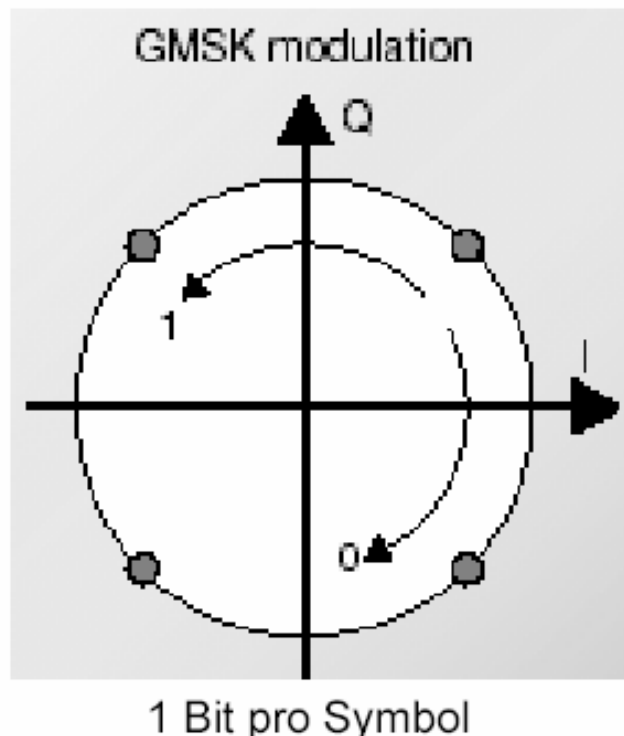
- EDGE comprises extensions for circuit switched and packet switched GSM data services to achieve even higher data rates
 - E-CSD: "Enhanced Circuit Switched Data"
 - E-GPRS: "Enhanced GPRS"
- For EDGE new transceiver hardware in BTS and software updates for MSC, BSC and BTS are required
- For EDGE also new MS are required

Enhanced Data Rates for GSM Evolution (EDGE)

- Normally many (spatially distributed) users have a better C/I as minimal required (for voice services)
- To these users a dynamically adjustable data rate could be offered - the data rate adjustment is achieved through Link Quality Control mechanisms
- Link Quality Control mechanisms for EDGE:
 - **Link Adaption:**
 - continuous monitoring of the connection quality
 - dynamic adaption of the channel coding scheme
 - dynamic change of the modulation scheme
 - **Incremental Redundancy:**
 - Automatic Repeat Request (ARQ) in case of incorrect decoding and incrementally increasing error protection (FEC) at upcoming transmissions

Enhanced Data Rates for GSM Evolution - Radio Interface

- Modulation scheme used for EDGE: 8PSK (Phase Shift Keying) instead of GMSK for the Downlink
 - no continuous and steady phase modulation (CPM), like for GMSK
 - asymmetric realization: 8PSK only possible in the downlink
- Burst format identical to GSM, but now 3 bits per symbol instead of one bit



Enhanced Data Rates for GSM Evolution - Radio Interface

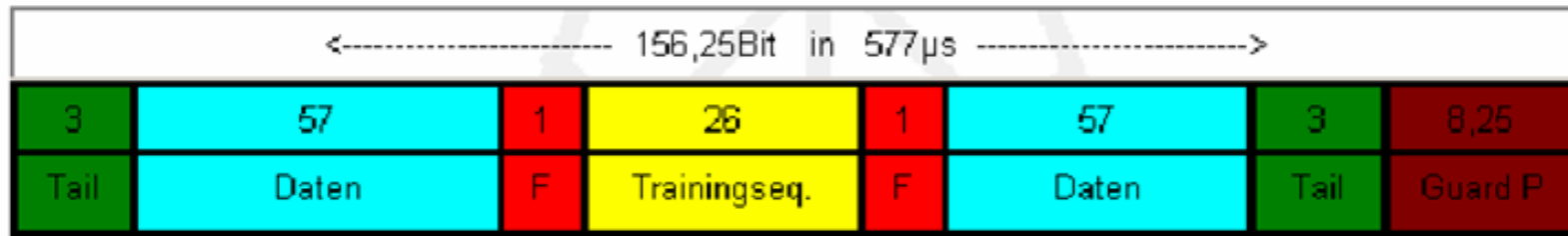
E-GPRS Modulation and Coding Schemes (MCS)

Schema	Modulation	Coderate	Datenrate pro Zeitschlitz
MCS-1	GMSK	0,53	8,8kbit/s
MCS-2	GMSK	0,66	11,2kbit/s
MCS-3	GMSK	0,85	14,8kbit/s
MCS-4	GMSK	1	17,6kbit/s
MCS-5	8PSK	0,37	22,4kbit/s
MCS-6	8PSK	0,49	29,6kbit/s
MCS-7	8PSK	0,76	44,8kbit/s
MCS-8	8PSK	0,92	54,4kbit/s
MCS-9	8PSK	1	59,2kbit/s

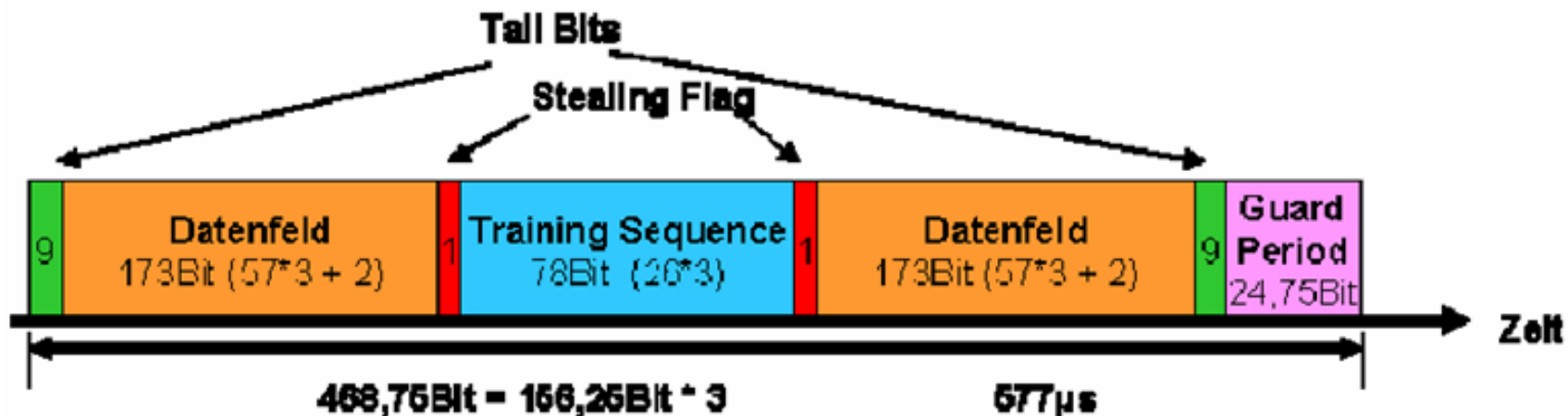
- EDGE allows to bundle up to 8 time slots per subscriber → theoretically a maximum data rate of 473,6kbit/s ($= 8 \cdot 59,2\text{kbit/s}$) is achievable (practically only 384kbit/s is realized)
- Disadvantage: higher distance dependency of the data rate as for GPRS

Enhanced Data Rates for GSM Evolution - Radio Interface

- Normal Burst for GSM services with GMSK modulation:



- Normal Burst for EDGE services with 8PSK modulation:



Annex

Further GSM Phase 2+ Features

Enhanced Full Rate (EFR) Speech Codec

A better quality of speech transmission which uses the same (gross) transmission as the classical Full Rate FR speech codec is offered in GSM Phase 2+ by the **Enhanced Full Rate EFR** speech codec.

Advanced Speech Call Items (ASCI)

An expansion of the existing GSM voice services has been introduced using the term **Advanced Speech Call Items ASCI** in GSM Phase 2+. This is for special user groups, particularly for the usage of railway GSM systems (GSM-R). The ASCI services contain group and broadcast services with a fast call setup and control of priorities.

Voice Group Call Service VGCS

- Speech group call: 1 group call channel
- 1 "speaker", many listeners; group as with VBS
- Changing speaker (call initiator → listener mode)
- "Transmission rights" in speech pauses
- Ended by initiator / VAD

Voice Broadcast Service VBS

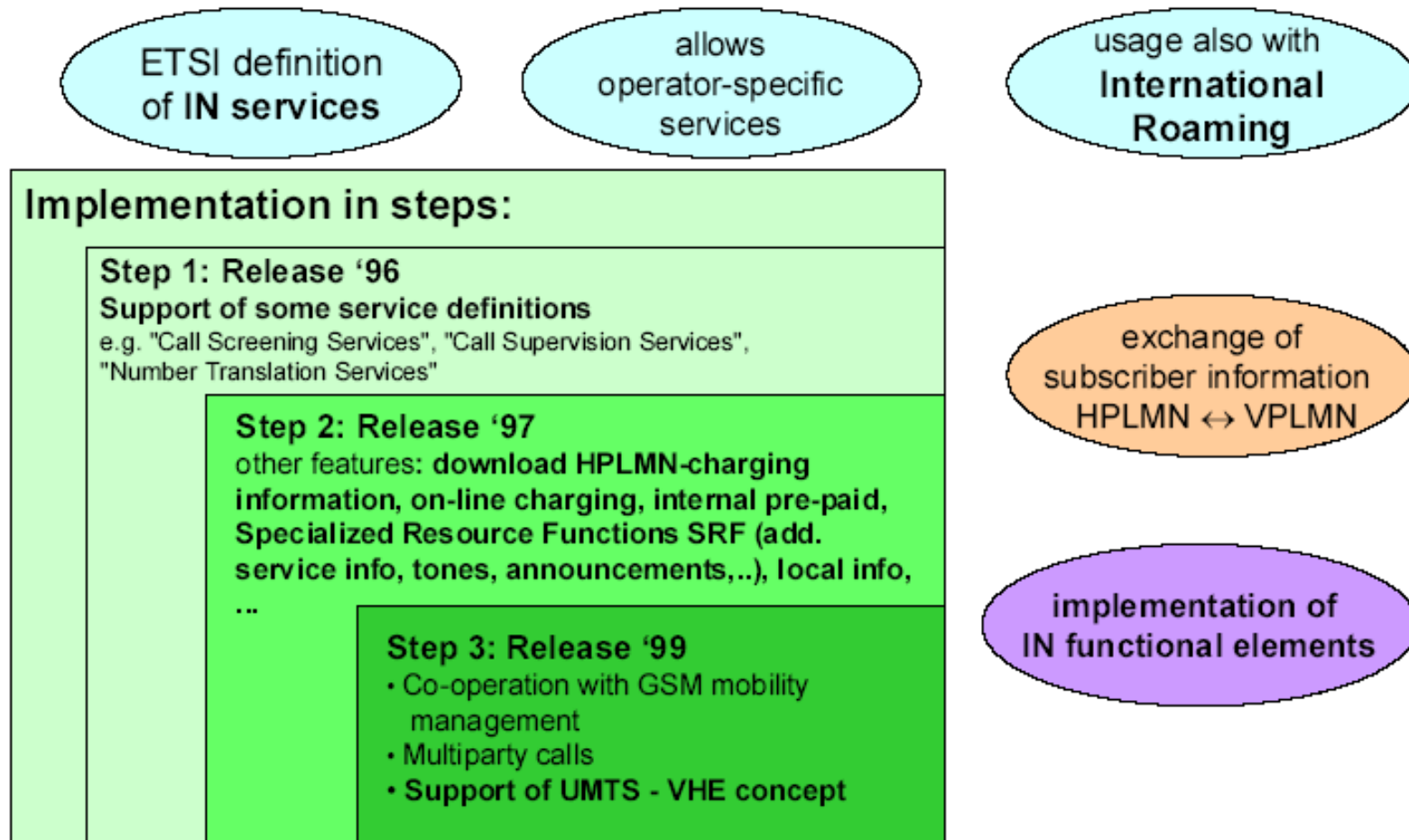
- 1 "speaker" (MS or fixed network), many listeners
- Message for particular groups / particular cells
- Only "speaker" interacts with network
- Notification (instead of paging) & message in def. cells
- "Listener" passive (confirmation message possible)

enhanced Multi-Level Precedence & Pre-Emption eMLPP

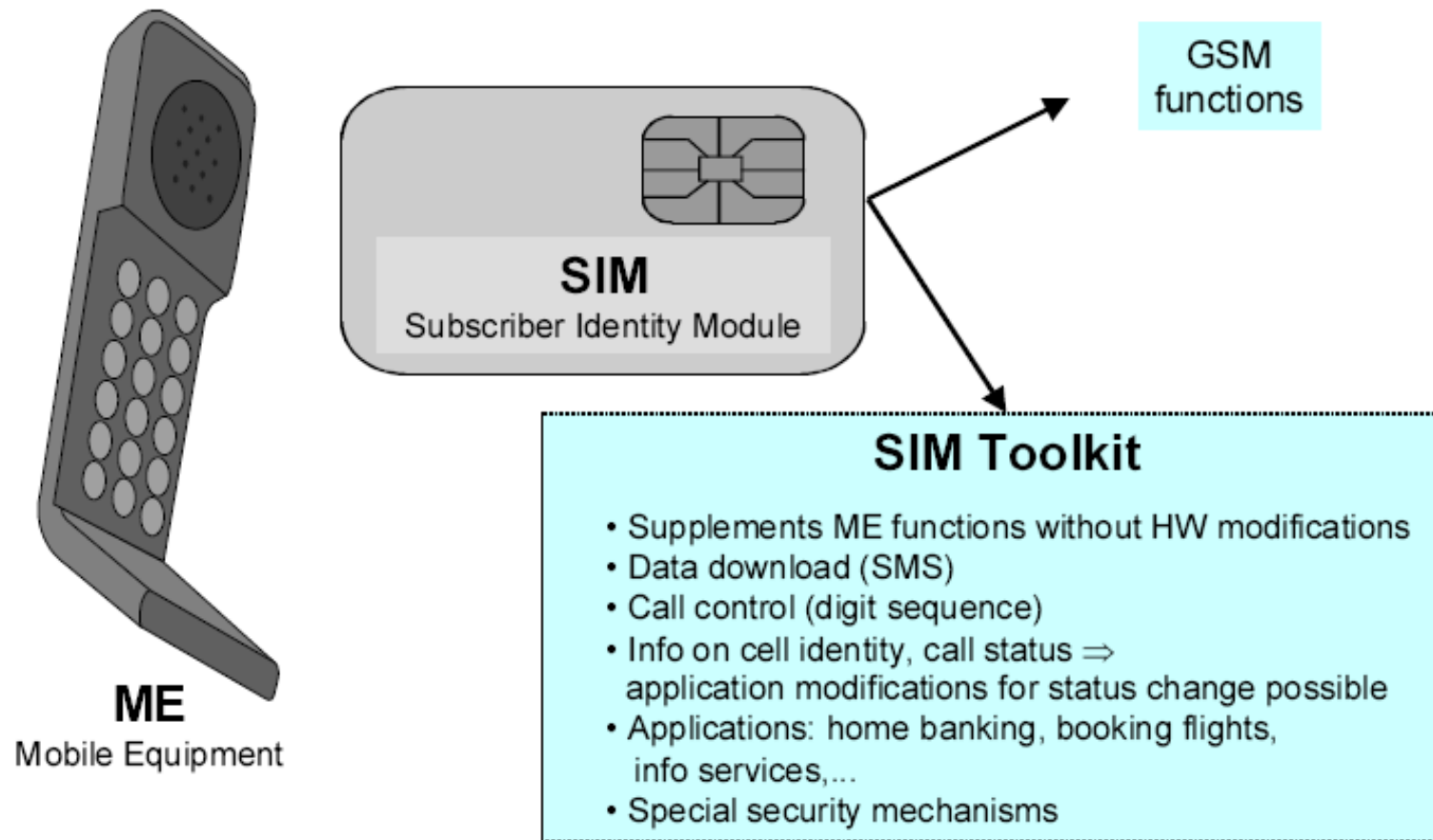
- Priority control for VBS, VGCS
- Priority classes:
5 (subscriber) + 2 (network-internal procedures)
- Priority allocation: service provider / SIM

Customized Application for Mobile Network Enhanced Logic

CAMEL



SIM Application Toolkit



Mobile station application Execution Environment (MExE)

