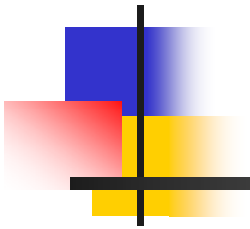
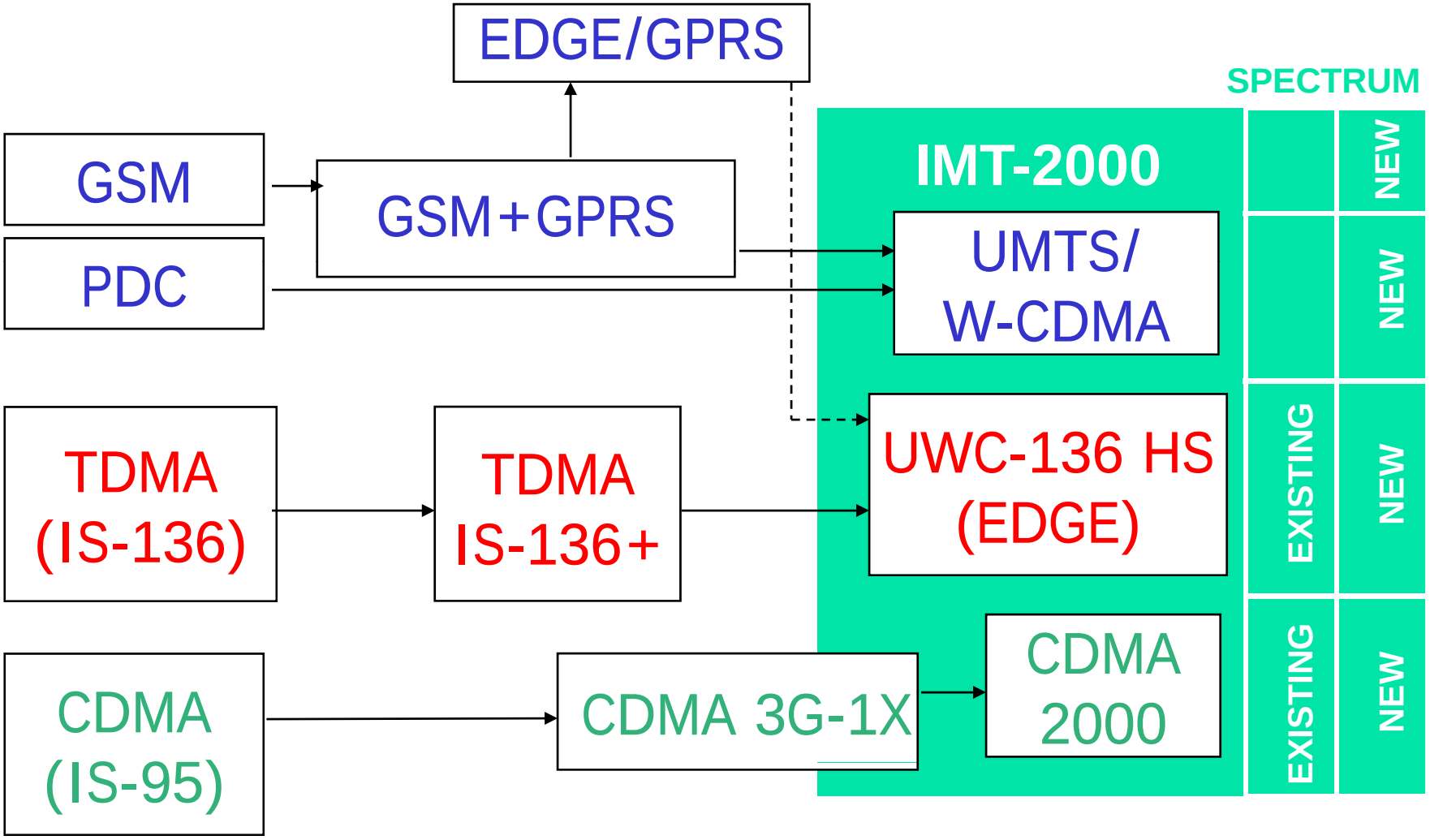


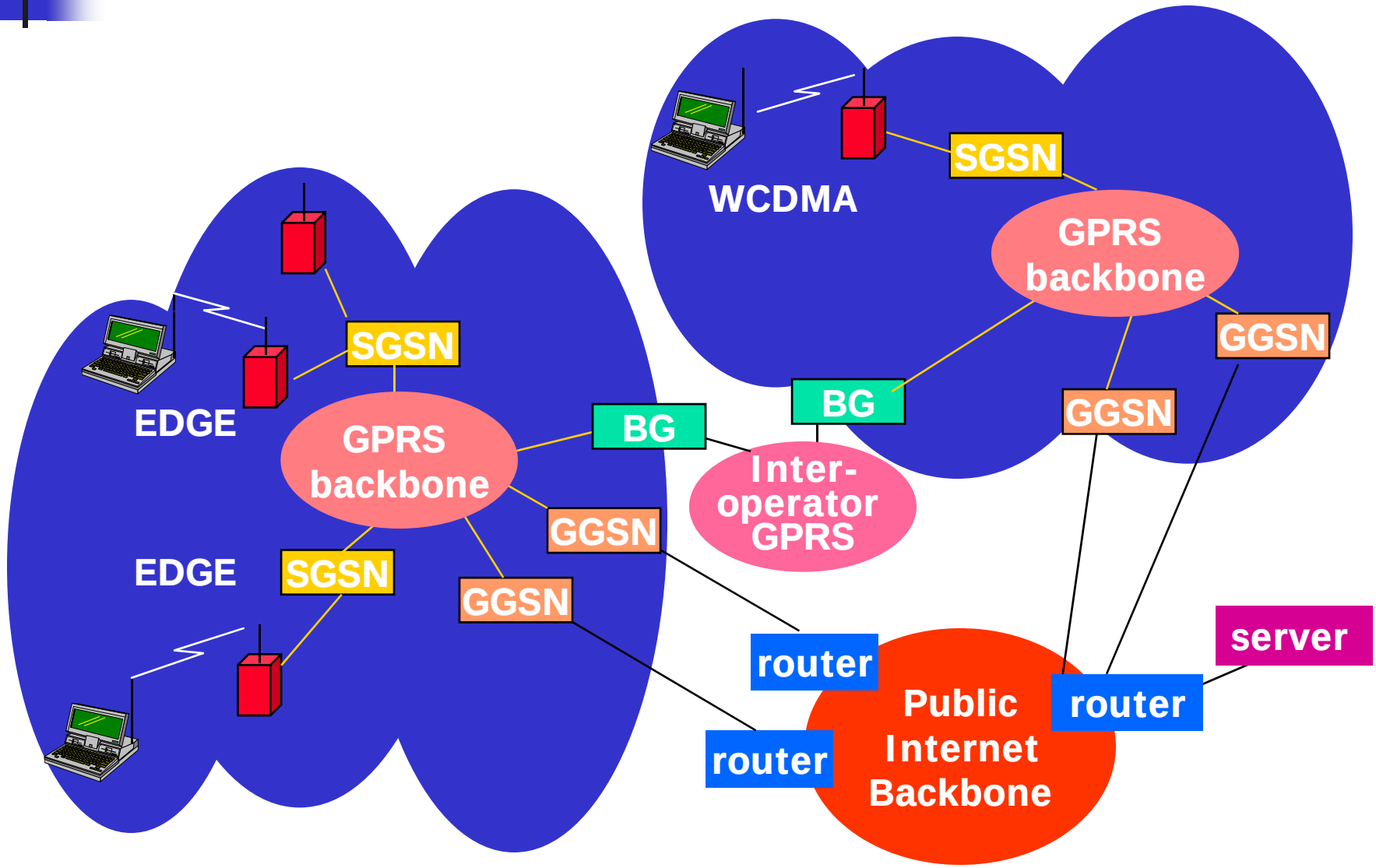
FROM GSM TO EDGE:

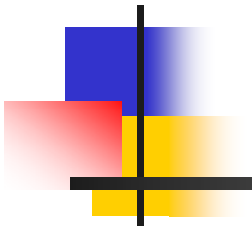
AN OVERVIEW OF DATA EVOLUTION

TECHNOLOGY EVOLUTION TO IMT-2000 RADIO ACCESS



INTERSYSTEM CONFIGURATION





FROM GSM TO GPRS:

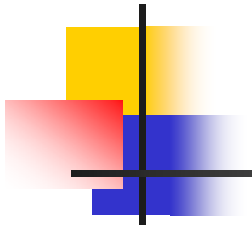
AN OVERVIEW OF DATA EVOLUTION

GSM

SMS

HSCSD

GPRS



History of development

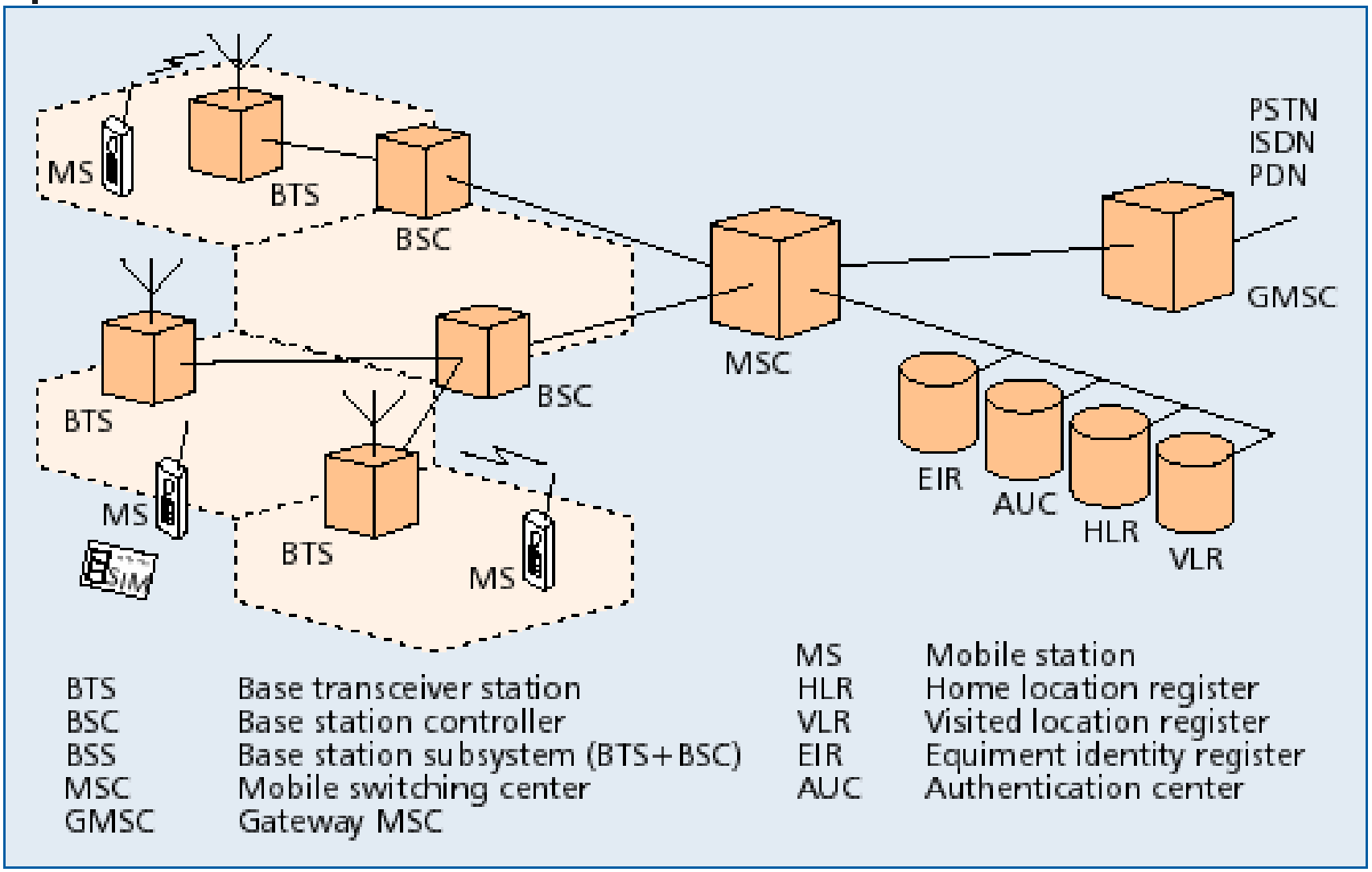
GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS (GSM):

- **1982: standardization group GSM established in 1982**
- **1986: field trial**
- **1987: TDMA selected as access scheme**
- **1988: MoU signed**
- **1989: validation of GSM**
- **1990: pre-operation system**
- **1991: commercial system start-up**
- **1992: coverage of larger cities/airports**
- **1993: coverage of main roads**
- **1995: coverage of rural areas**

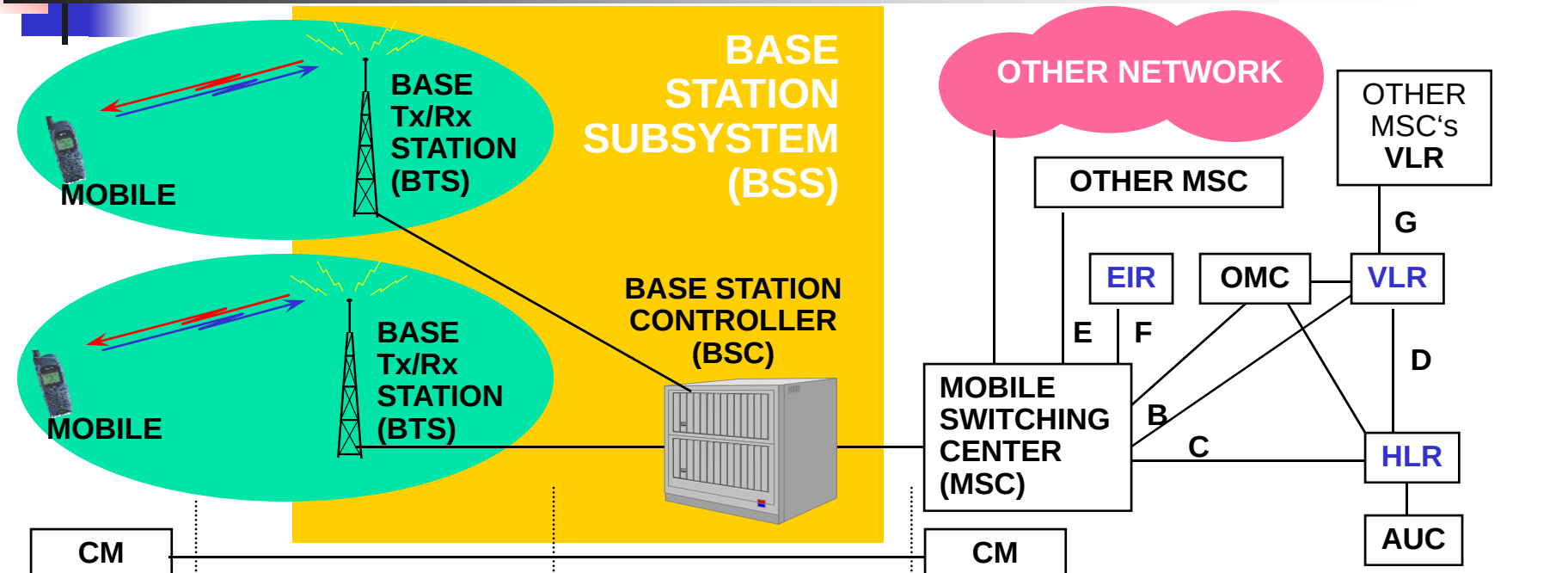
MOBILE COMM. SYSTEMS:

- **1981: Nordic Mobile Telephone (NMT) 450**
- **1983: American Mobile Phone System (AMPS)**
- **1985: Total Access Communication System (TACS)**
- **1986: NMT900**
- **1991: American Digital Cellular (ADC)**
- **1991: GSM**

GSM Architecture



GSM NETWORK REFERENCE MODEL



EIR: EQUIPMENT ID REGISTER

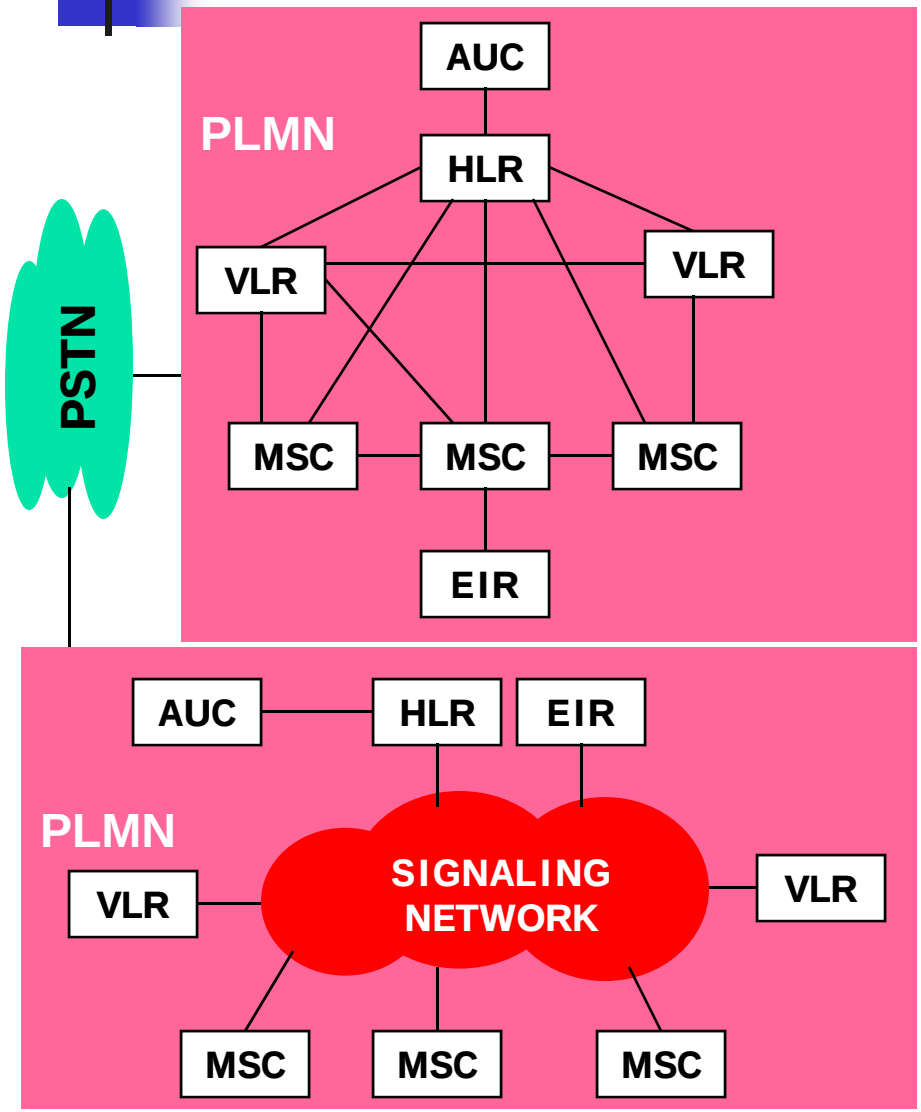
VLR: VISITOR LOCATION REGISTER

HLR: HOME LOCATION REGISTER

AUC: AUTHENTICATION CENTER

OMC: OPERATION & MAINTENANCE CENTER

GSM PUBLIC LAND MOBILE NETWORK (PLMN)



- PLMN is a network established and operated by an administration or Recognized Operating Agency (ROA) for the specific purpose of providing land mobile telecommunication services to the public.
- A PLMN may be regarded as an extension of a fixed network, e.g. PSTN, or as an integral part of the PSTN.

PLMN service area is served by one operator

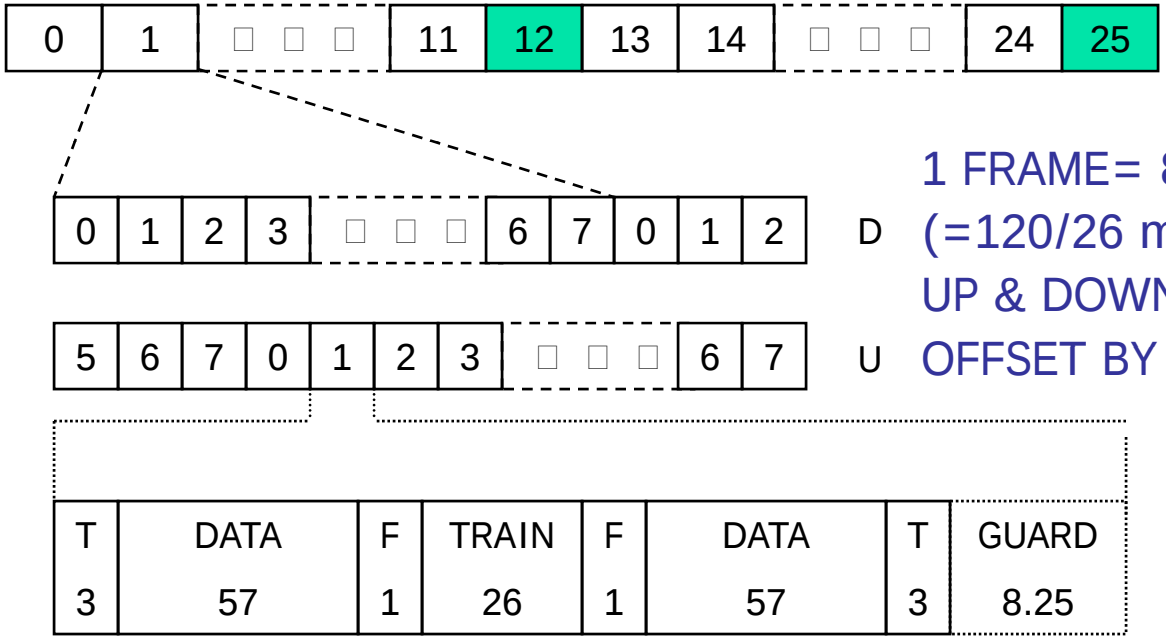
- to provide subscribers a wide range of services and facilities, both voice and non-voice, that are compatible with those offered by existing networks
- to introduce a mobile radio system compatible with ISDN
- to provide facilities for automatic roaming, locating, and updating of mobile subscribers

GSM: PHYSICAL STRUCTURES

- **frequency band:** using Frequency division duplex (FDD) for U & D
  - **GSM-900:** U= 890-915MHz D=935-960MHz: 124 CARRIERS
  - **DCS-1800** (Europe): U=1710-1785MHz D=1805-1880MHz
  - **DCS-1900** (North-America): U=1850-1910MHz D=1930-1990MHz
- **FDM channel:** spacing=200 kHz
- **Modulation:** Gaussian minimum shift keying (GMSK) with BT=0.3. (performance in AWGN: ~3.5dB worse than QPSK)
- **Transmission rate:** 1625/6 »270.833 kbps (1.35b/s/Hz)
- Freq. Reuse Factor: 3 or 4
- **Multi-access:** TDMA & MF-TDMA
- **Speech coding:**
  - full rate: linear predictive coding with regular pulse excitation (LPC-RPE): 20ms block=260bits (13kbps).
  - half-rate: vector sum excited linear prediction (VSELP), 5.6kbps

GSM TDMA FRAME STRUCTURES

- 1 HYPERFRAME=2048 SUPERFRAMES
- 1 SUPERFRAME=51 MULTIFRAME
- MULTIFRAME(120ms)=26 FRAMES (0-11, 13-24: TRAFFIC; 12, 25: CONTROL)



1 FRAME= 8 TIME SLOTS=1250 BITS
(=120/26 ms ≈ 4.615ms)
UP & DOWN FRAMES:
OFFSET BY 3 TIME-SLOTS

TIME-SLOT=156.25 BITS
(=15/26 ms ≈ 576.92 μs)

NORMAL BURST (TCH)

F=FLAG (USER OR FAST ACCESS CONTROL CHANNEL, FACCH),
TRAIN= TRAINING SEQUENCE ; T=TAIL (ENHANCED): FOR EQUALIZER

OTHER BURST TYPES

TIME-SLOT=156.25 BITS (576.92μs)= 148 Tx bits + 8.25-bits GUARD

T	DATA (BTS ID)	TRAIN	DATA (BTS ID)	T	GUARD
3	39 (ENCRYPT.)	64	39 (ENCRYPT.)	3	8.25

SYNCHRONIZATION BURST (SCH)

25-BIT DATA+10-BIT CRC+4 TAIL BITS, RATE-1/2 CC=78 BITS

T	ALL ZEROS	T	GUARD
3	142	3	8.25

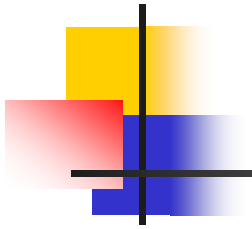
FREQUENCY CORRECTION BURST (FCCH)

T	SYNCH	MESSAGE	T	GUARD
3	48	36 (ENCRYPT.)	3	8.25

ACCESS BURST

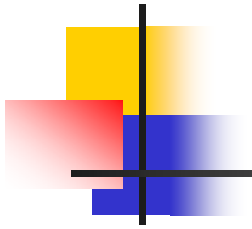
T	MOD. STATES	TRAIN	MOD. STATES	T	GUARD
3	58	26	58	3	8.25

DUMMY BURST



SUBSCRIBER SERVICES

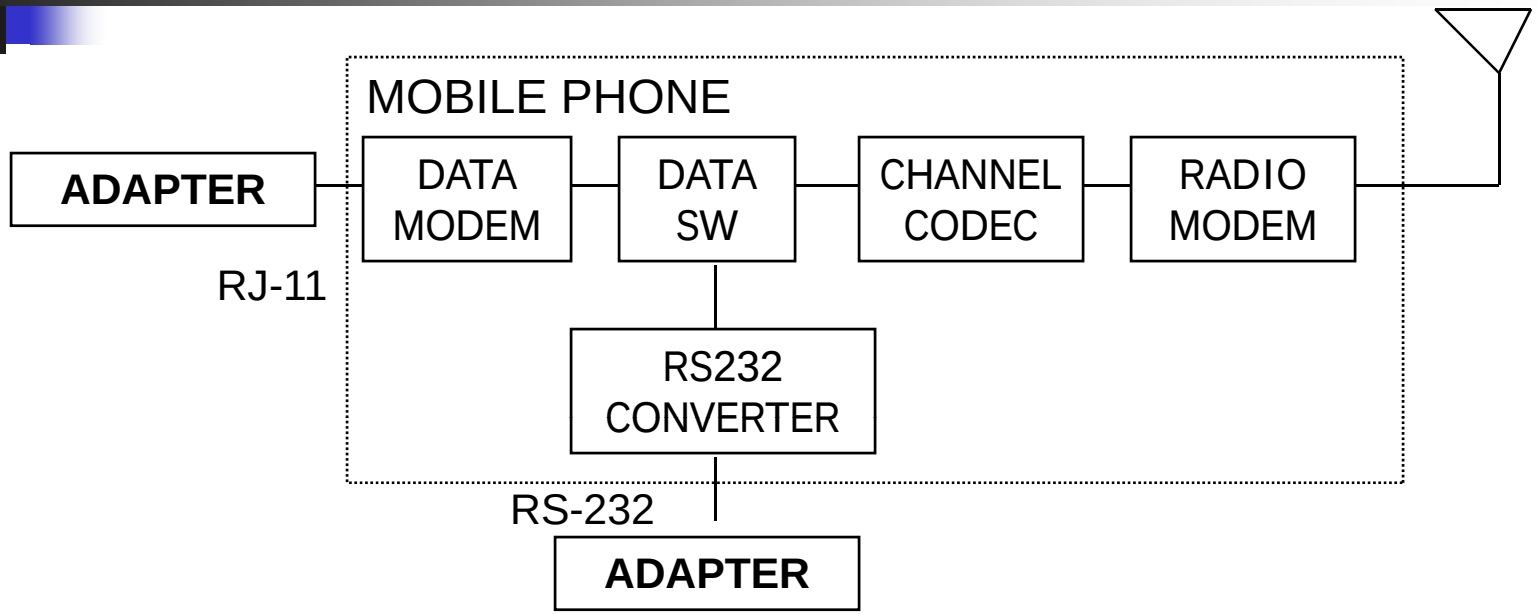
- **Basic:** telephony (teleservices) & data (bearer services): provide the capacity necessary to transmit appropriate data signals between two access points creating an interface to the network.
- **Others:** dual-tone multifrequency (DTMF), facsimile group III (needs a special fax converter), short message (maximum of 160 alphanumeric characters) ; cell broadcast: (maximum of 93 characters, e.g., traffic congestion warnings and reports on accidents); voice mail; fax mail
- **supplementary services:** call forwarding; barring of outgoing calls; barring of incoming calls (all or incoming calls when roaming outside the home PLMN); advice of charge (AoC); call hold; Call waiting (applicable to all GSM telecommunications services using a circuit-switched connection); multiparty service (only applicable to normal telephony); calling line ID presentation/restriction; closed user groups (CUGs generally comparable to a PBX).



DATA SERVICES OVER WIRELESS LINKS

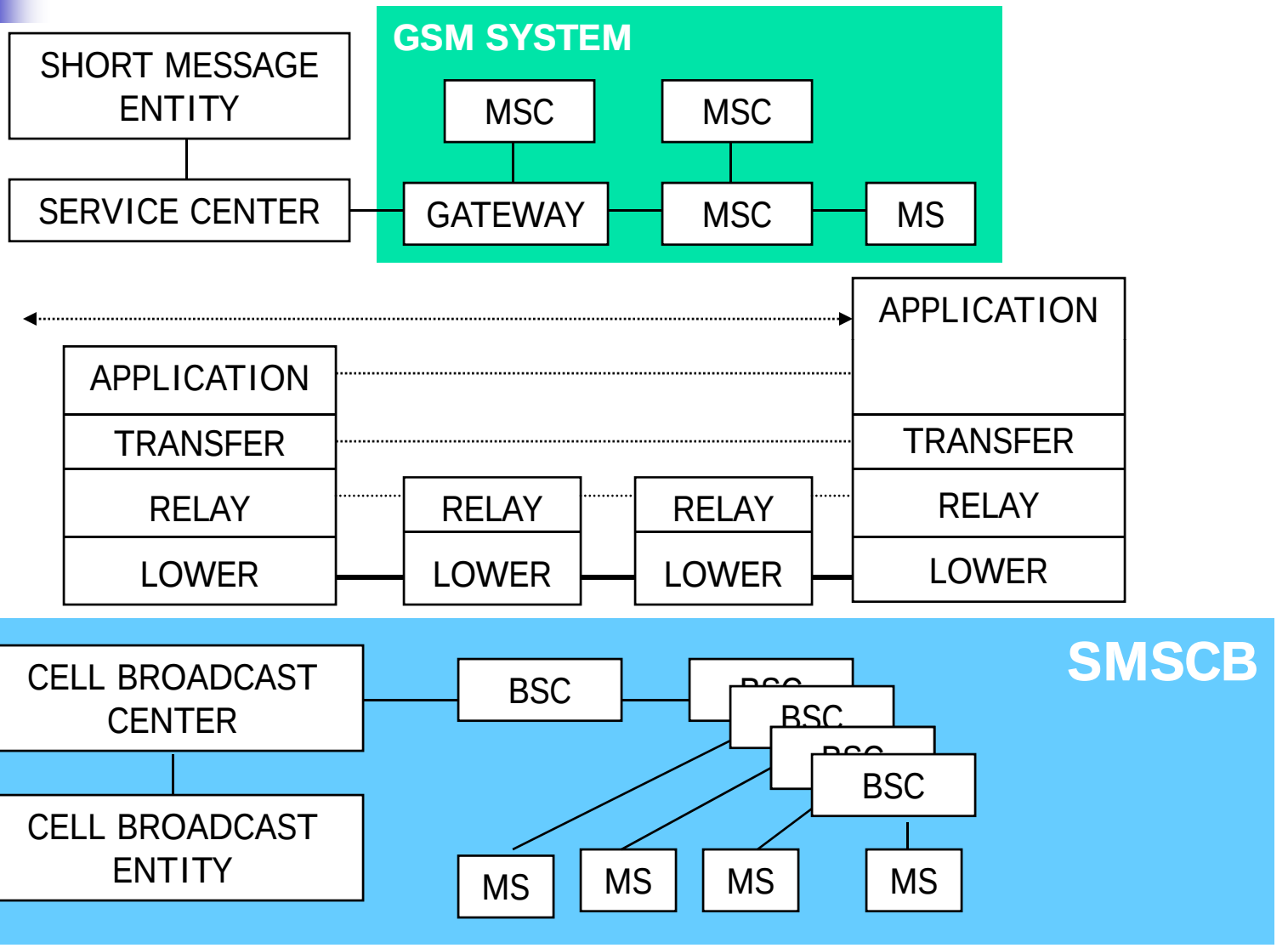
- ACCESSING
  - E-MAIL,
  - REMOTE COMPUTERS
  - INTERNET
- FILE TRANSFERS
- FAX
- TRANSACTION SERVICES
- VIDEO CONFERENCING
- MAINFRAME-TO-MAINFRAME

INTERFACE FOR DATA SERVICES

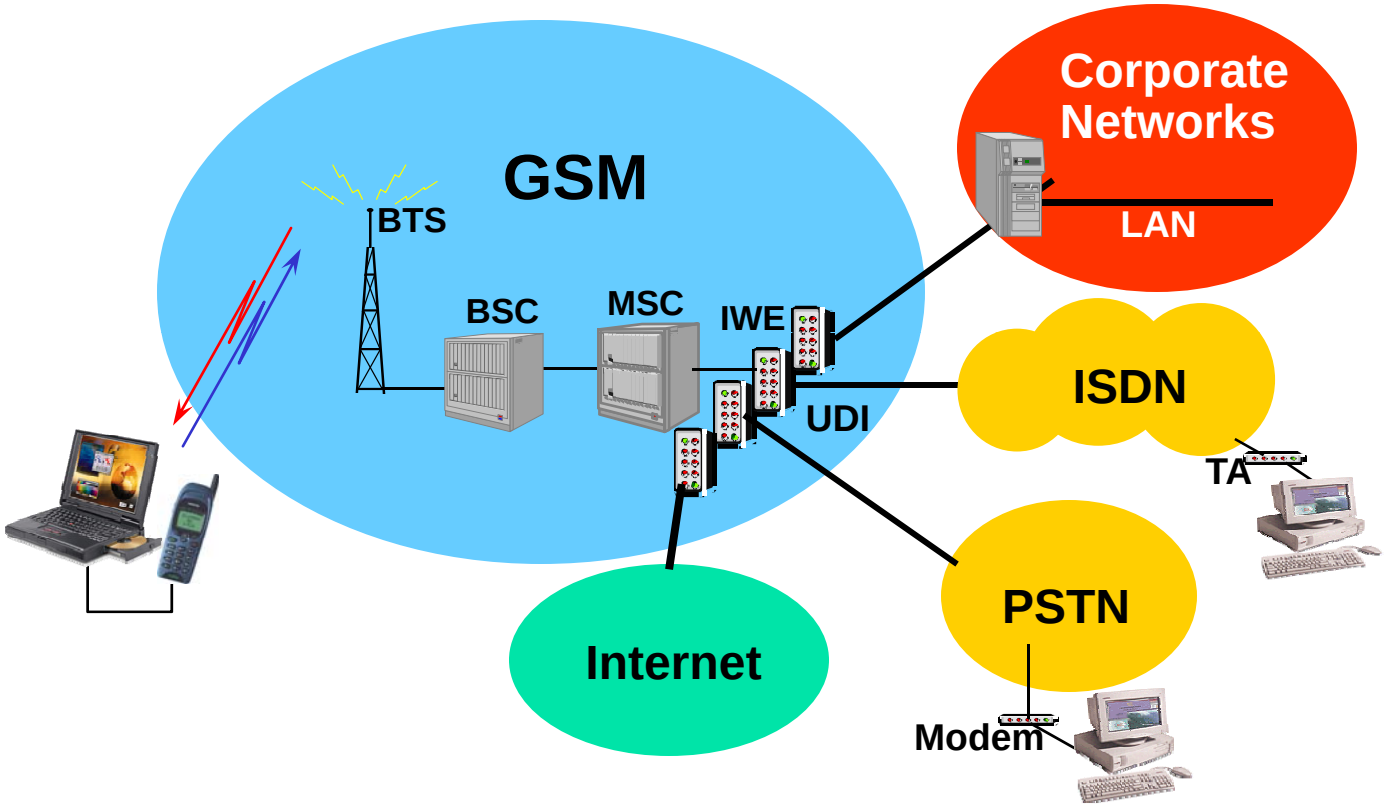


- circuit-switched data transmission over a GSM time-slot is limited to 9.6kbps or 14.4 kbps (The increase from the current baseline 9.6 kbps to 14.4 kbps is due to a nominal reduction in the error-correction overhead of the GSM radio link protocol (RLP), allowing the use of a higher data rate).
- today's digital and PCS technology designs started over five years ago when 9.6 kbps was considered more than adequate
- today, it seems slow with graphical or multimedia content, though it is more than adequate for text-based applications and carefully configured applications.

SHORT MESSAGE SERVICE (SMS, 1997)



WIRELESS DATA BASED ON 9.6/14.4 CSD & SMS IN GSM



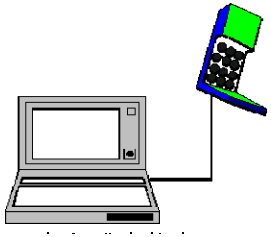
DURING NORMAL OPERATION, MS NEEDS TO SHARE ITS TIME FOR RECEIVING DATA, MONITORING LOCAL BROADCAST CHANNEL (BCH), AND MEASURING THE LEVEL OF ADJACENT CELL BCH's

THE MAX NUMBER OF TIME-SLOTS THAT A MS CAN RECEIVE, WHILE STILL MANAGING TO PERFORM THE LOCAL& ADJACENT CELL BCH's IS 4.

Smart phone versus phone connected to laptop

- smart phones:
  - are cellular phones that include a microbrowser.
  - With these, you can view specially formatted Internet information.

- wireless modems:
  - supplied either in PC Card format or by using a cellphone with a cable connection to a computer.



- both approaches:
  - can give you access to Internet sites and corporate systems, including e-mail, databases, or host-based systems.
  - require that the user take throughput and latency of the network into account.
- In contrast, next generation networks promise throughput, global coverage, and ease-of-use that will greatly expand your mobile computing options.

GSM DATA SERVICES: EVOLUTION

GSM Data

E-mail download
Fax
Internet access

Smart Messaging

Banking
Traffic info & guidance
News
Weather
Ticket ordering
Info- & Entertainment-Services
Fleet management

HSCSD (1999)

File transfer
Corporate access / tele working
Online e-mail
Real-time applications
E-cash & payments
Audio & video on demand
Video surveillance services (e.g. taxi, money transport)
Remote healthcare

GPRS (2000)

Internet
Intranet
E-mail
Scheduler
Access
Remote control
Monitoring

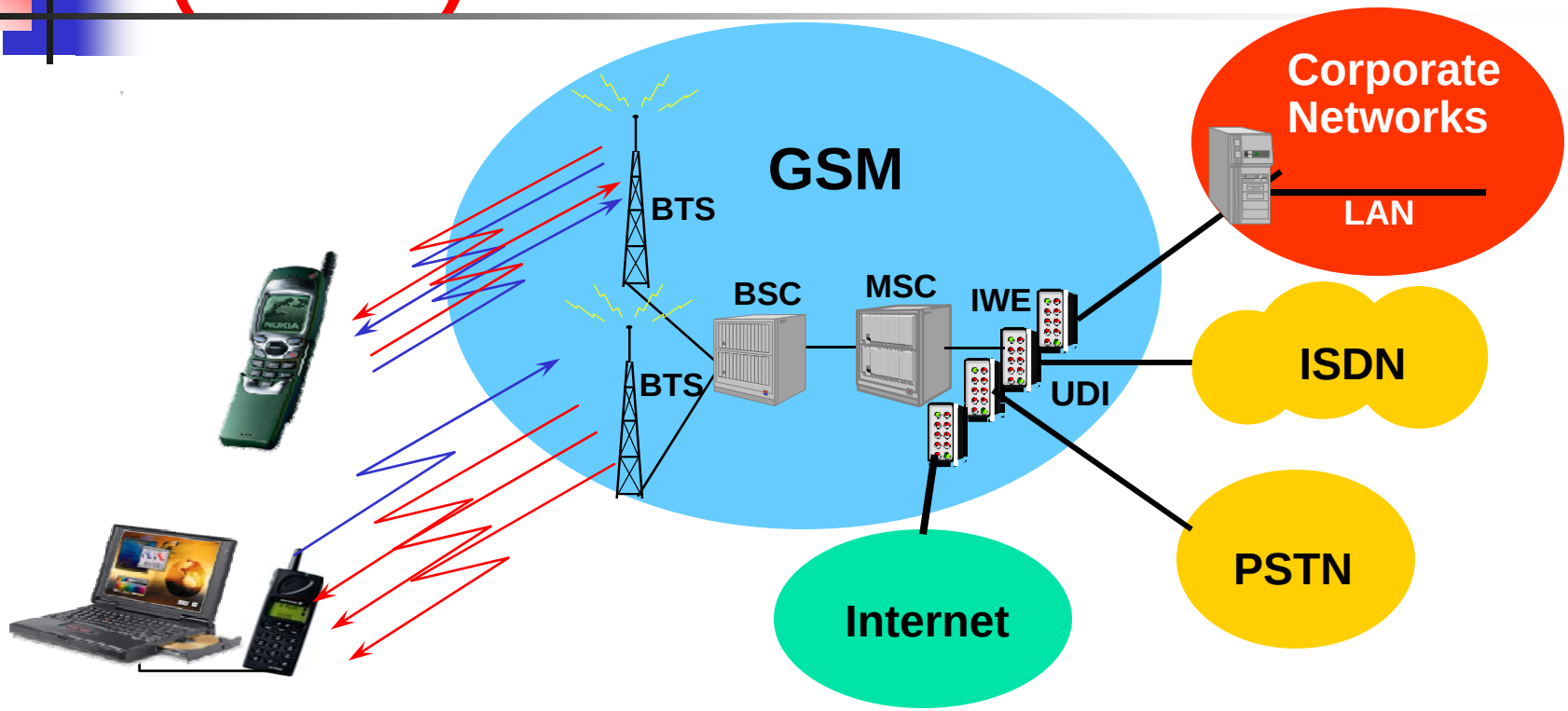
UMTS - 3rd Generation GSM

personal, wireless multimedia

GSM DATA SERVICES: ROADMAP

SERVICES:	**DATA RATES:**	
CSD & SMS	9.6-14.4kbps	
HSCSD	28.8-57.6 kbps	
GPRS	IP and X.25 communications over 100kbps	
EDGE	IP to 384 kbps. Roaming with IS-136 possible.	
WCDMA	Similar to EDGE but adds 2Mbps indoor capability.	

High Speed Circuit Switched Data (HSCSD)



- combines two to four time-slots in each frame (Nx14.4kbps) to provide service from 28.8 kbps to 57.6kbps: (Example: 1U=14.4kbps & 3D=43.2kbps: users can surf the Internet at 38.4 kbps)
- HSCSD is attractive to carriers because it requires minimal new infrastructure.

HSCSD User Data Rates & Services

	transparent service		non transparent service	
up+ downlink	100% coverage	95% coverage	100% coverage	95% coverage
1 + 1	9.6	14.4	9.6	13.2
2 + 2	19.2	28.8	19.2	26.4
1 + 3	---	----	28.8	39.6
1 + 4	---	----	38.4	53.8

- an enhancement of Circuit Switched Data (CSD) services of all current GSM networks allows subscribers to access non-voice services (e.g., LAN, e-mail, Internet, file transfer) at higher rates whilst on the move.
- CS: physical channel is assigned for the duration of the call and physical connection is maintained even if data is not being transferred.
- Charged by the duration
- Suitable for time-critical applications (e.g., videophone, interactive data)
- Complements: PSTN & ISDN

HSCSD SERVICES: AVAILABILITY

- currently available to 90 millions subscribers across 25 countries around the world and with the implementation of International Roaming agreements between all HSCSD Operators life on the move just got easier.
- offered to subscribers using either voice terminals that support the feature, or a special PCMCIA portable computer card, with a built-in GSM phone that turns notebook computers and other portable devices into a complete high-speed mobile office with the ability to make voice calls hands free, as well as data transfer.
- particularly valuable for customers who wish to access the Internet, or their office Intranet, access their mail, or access files stored elsewhere.
- a subscriber who is out of office, or who travels abroad in one of the countries in which HSCSD roaming is available, can connect to a local ISP, or directly to one's office, using the cellular device rather than a fixed line, benefiting from significant improvements in rates of transfer. The service is expected to be offered soon through HSCSD enabled GSM cellular handsets directly, in addition to the PC compatible device.

HSCSD: PROS AND CONS

- HSCSD is available in 1999 and offers four times higher bandwidth than the today's GSM data service thus being very well compatible to the standard fix network connection.
- HSCSD requires minor network upgrades only. No new network elements are required at all. The invest is about a fifth of the one for GPRS.
- HSCSD charging principles are well introduced in the network and well accepted by the customers.
- HSCSD has a well defined QoS and can thus be used to address the high expectation market segment.

- HSCSD is still circuit switched, i.e. the network load is not as efficiently handled as with GPRS and thus an always on service is hard to deliver.
- HSCSD is not the service to address the mass market with.

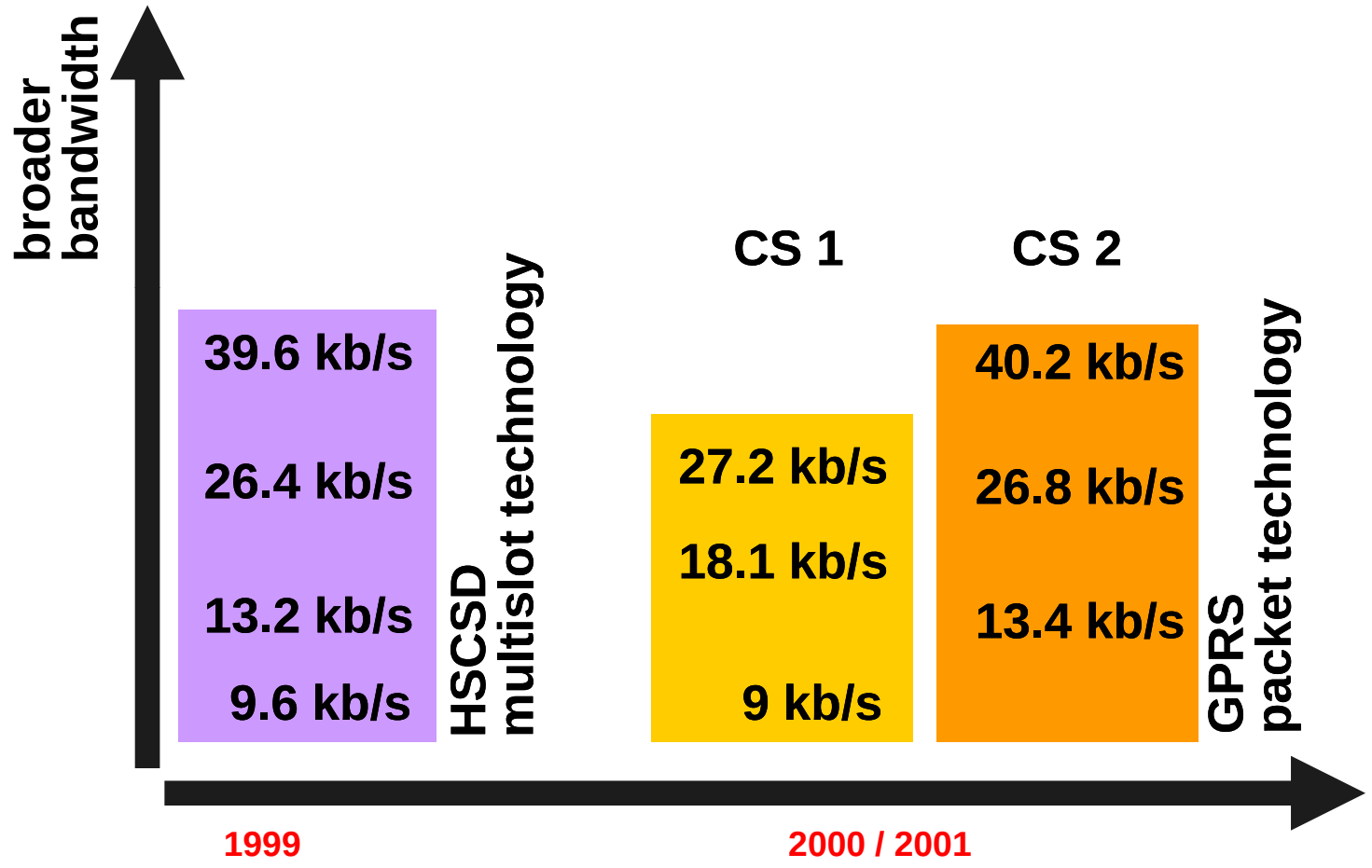
General Packet Radio Service (GPRS):

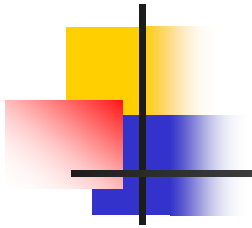
- GPRS can combine up to 8 available time-slots in each time interval for IP-based packet data speeds up to a maximum theoretical rate of 171.2kbps (no error correction & 2 receivers).
- However, a typical GPRS device may not use all 8 time slots.
- One proposed configuration is four time-slots (85.6kbps maximum, 56 kbps typical) for the downlink and one time-slot (21.4kbps maximum, 14.4kbps typical) for the uplink.
- GPRS supports both IP and X.25 networking.
- GPRS is packet-based

GPRS User Data Rate

Coding	# of timeslots							
Scheme	1	2	3	4	5	6	7	8
CS-1	9,05	18,1	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

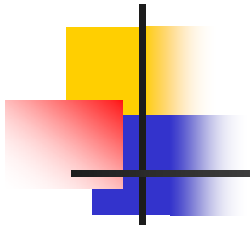
HSCSD & GPRS: INCREASED DATA RATES





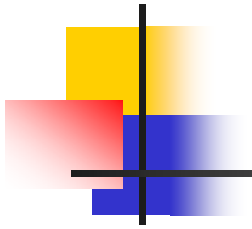
hi-speed data transmission

- removes the needs of wireless middleware required to allow slow speed mobile clients to work with fast networks for applications such as e-mail, databases, groupware or Internet access
- makes multimedia content, including graphics, voice and video practical.



PACKET-SWITCHED NETWORK

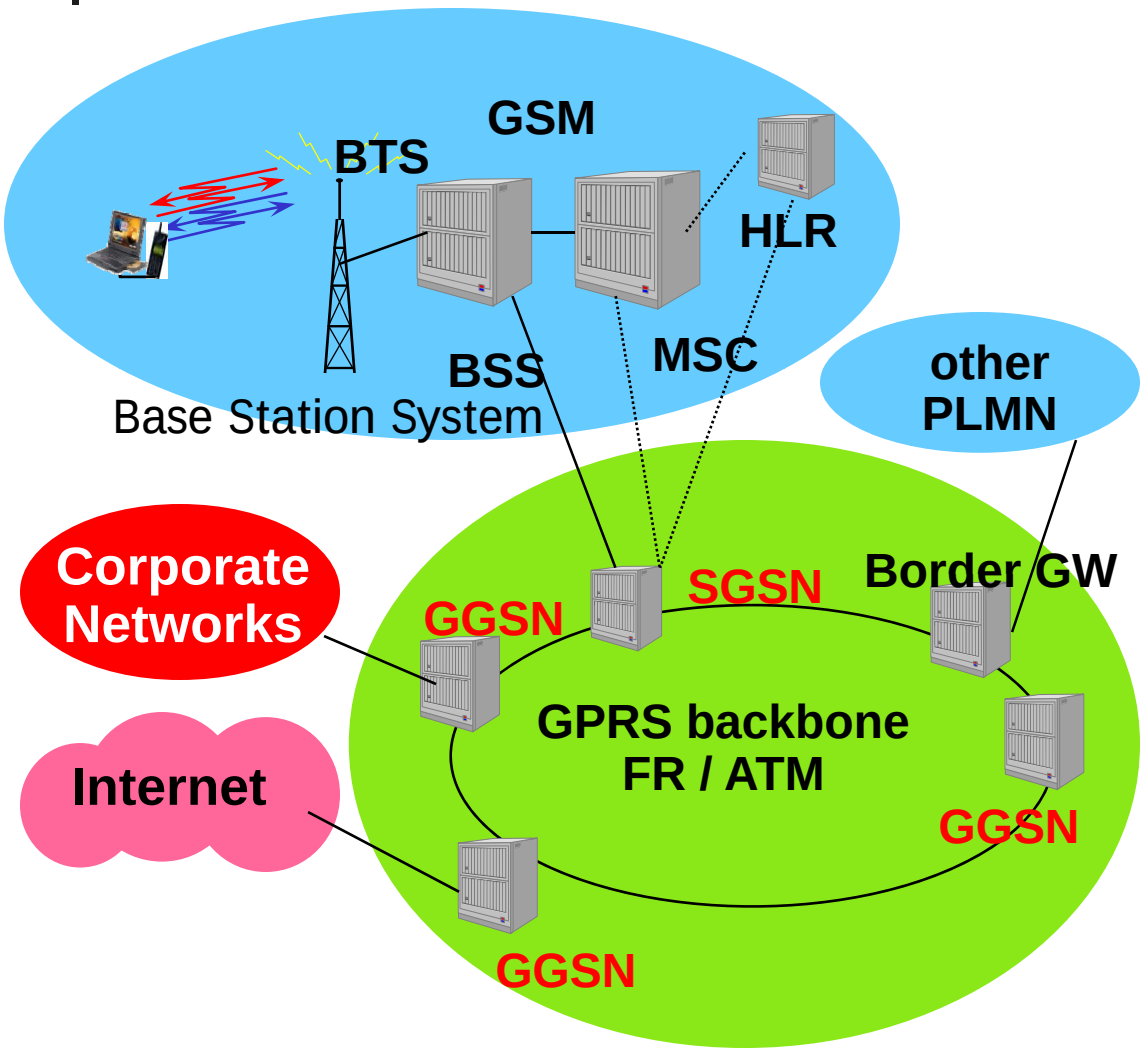
- radio link is only used for the duration of time that data is being sent or received.
- multiple users can share the same radio channel very efficiently
- With packet data, users will only pay for the amount of data they actually communicate, and not the idle time



Internet Protocol (IP) and X. 25

- any existing IP or X.25 application will now be able to operate over a GSM cellular connection: cellular networks with GPRS service as wireless extensions of the Internet and existing X.25 networks.
- provides a seamless and immediate connection from a mobile PC to the Internet or corporate intranet allowing all existing Internet applications such as e-mail and Web browsing to operate smoothly without even needing to dial into an Internet service provider.
- companies are now looking to the Internet as a way for their remote workers to access corporate intranets.
- X.25 defines a set of communications protocols that prior to the Internet constituted the basis of the world's largest packet data networks. These X.25 networks are still widely used, especially in Europe, and so wireless access to these networks will benefit many organizations.

GPRS network configuration

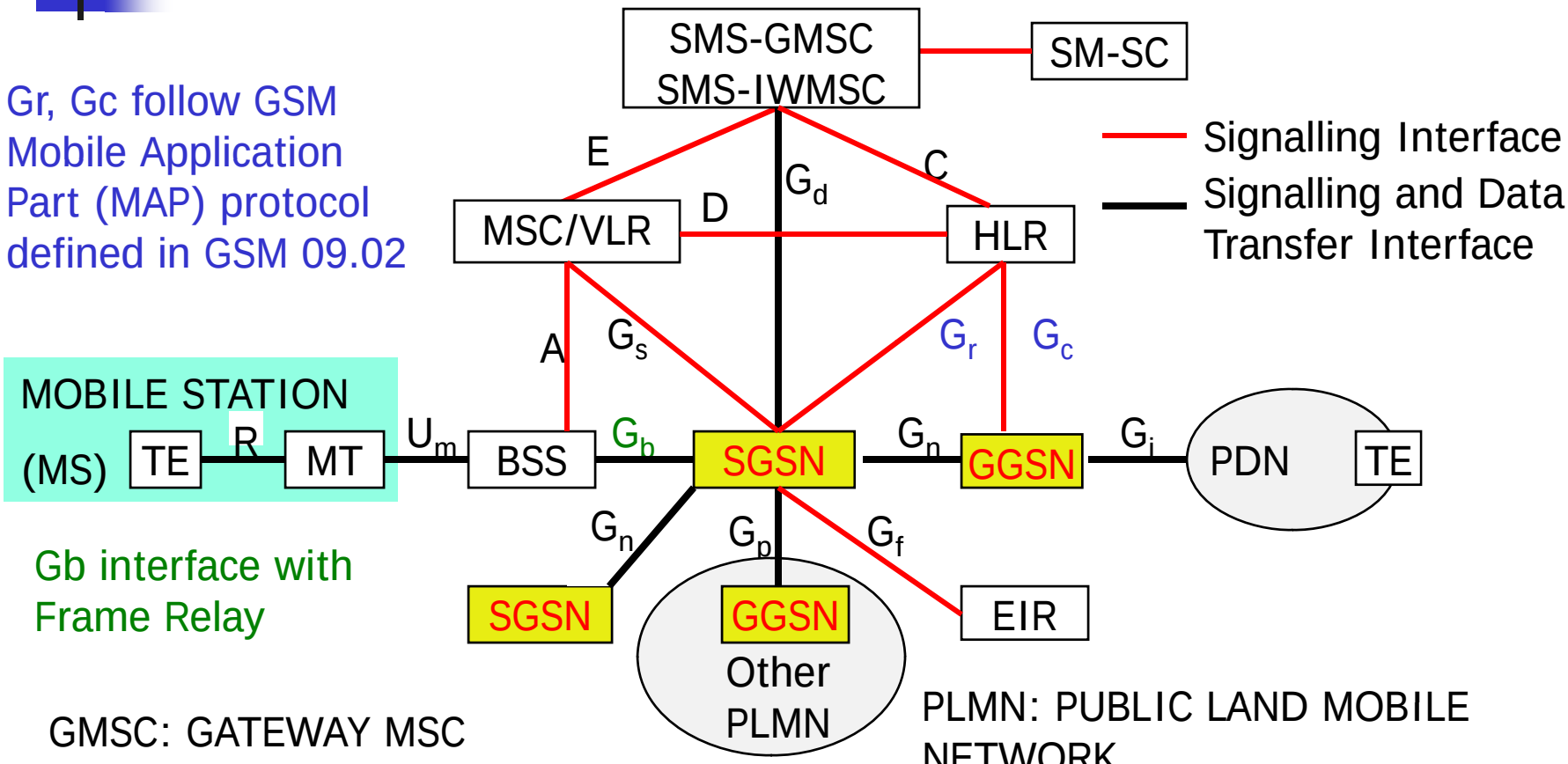


GSN: GPRS SUPPORT NODE

SGSN:SERVING GSN

GGSN: GATEWAY GSN

GPRS Logical Architecture



Gr, Gc follow GSM Mobile Application Part (MAP) protocol defined in GSM 09.02

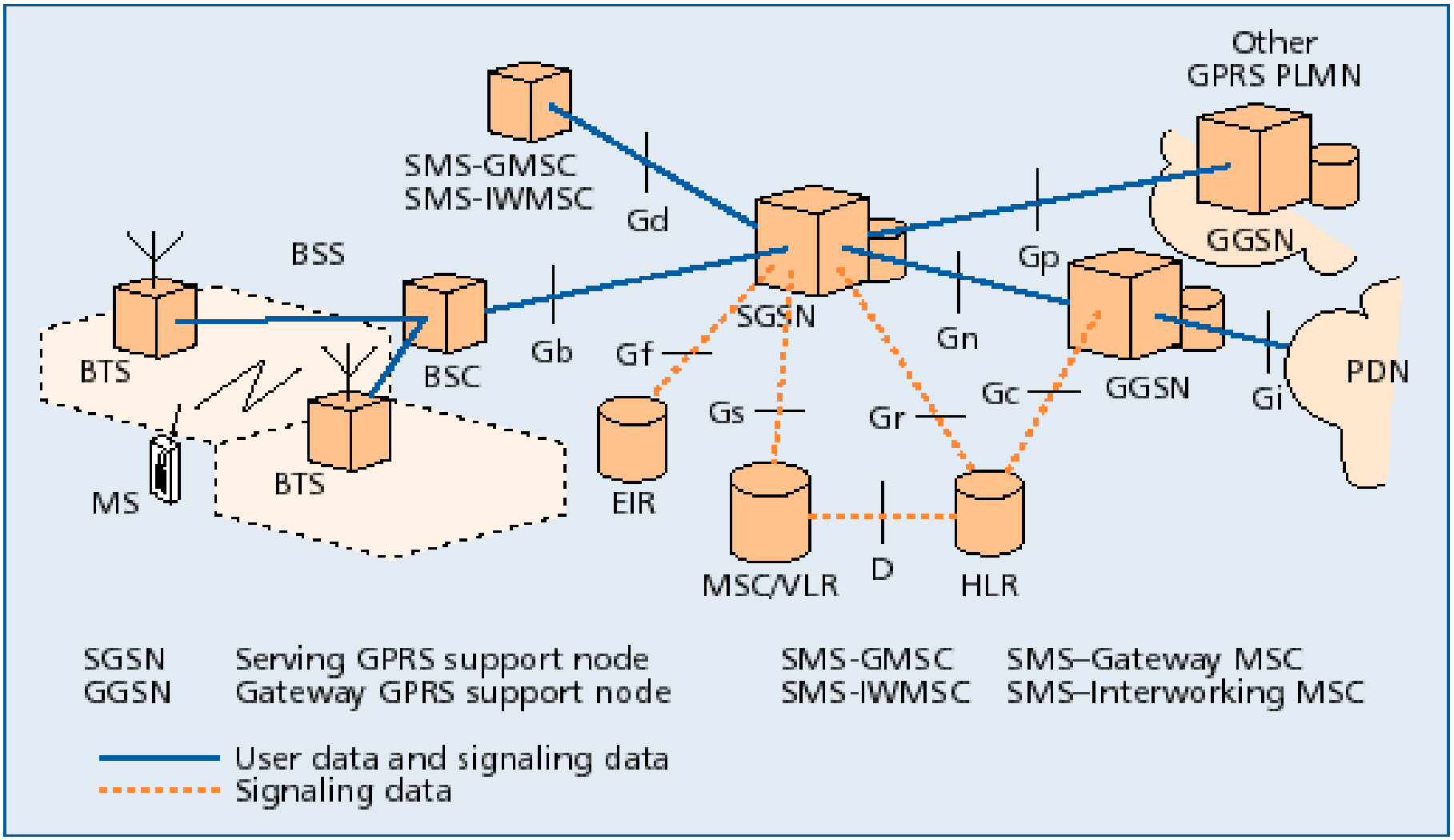
Gb interface with Frame Relay

GMSC: GATEWAY MSC
IWMSC: INTERWORKING MSC
VLR: VISITOR LOC. REG.
HLR: HOME LR
EIR:EQUIPMENT ID REG.

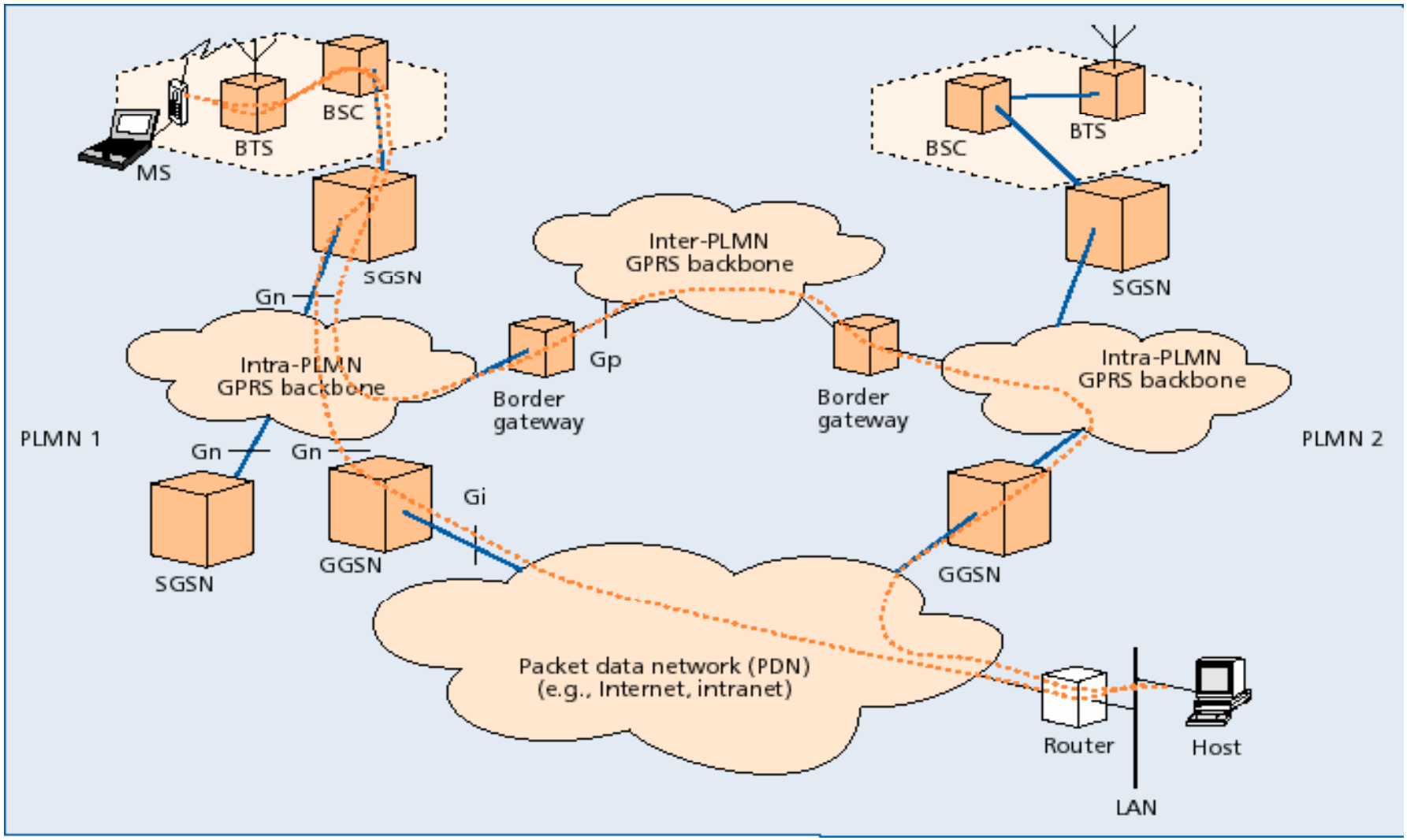
PLMN: PUBLIC LAND MOBILE NETWORK

GSN: GPRS SUPPORT NODE
SGSN:SERVING GSN
GGSN: GATEWAY GSN

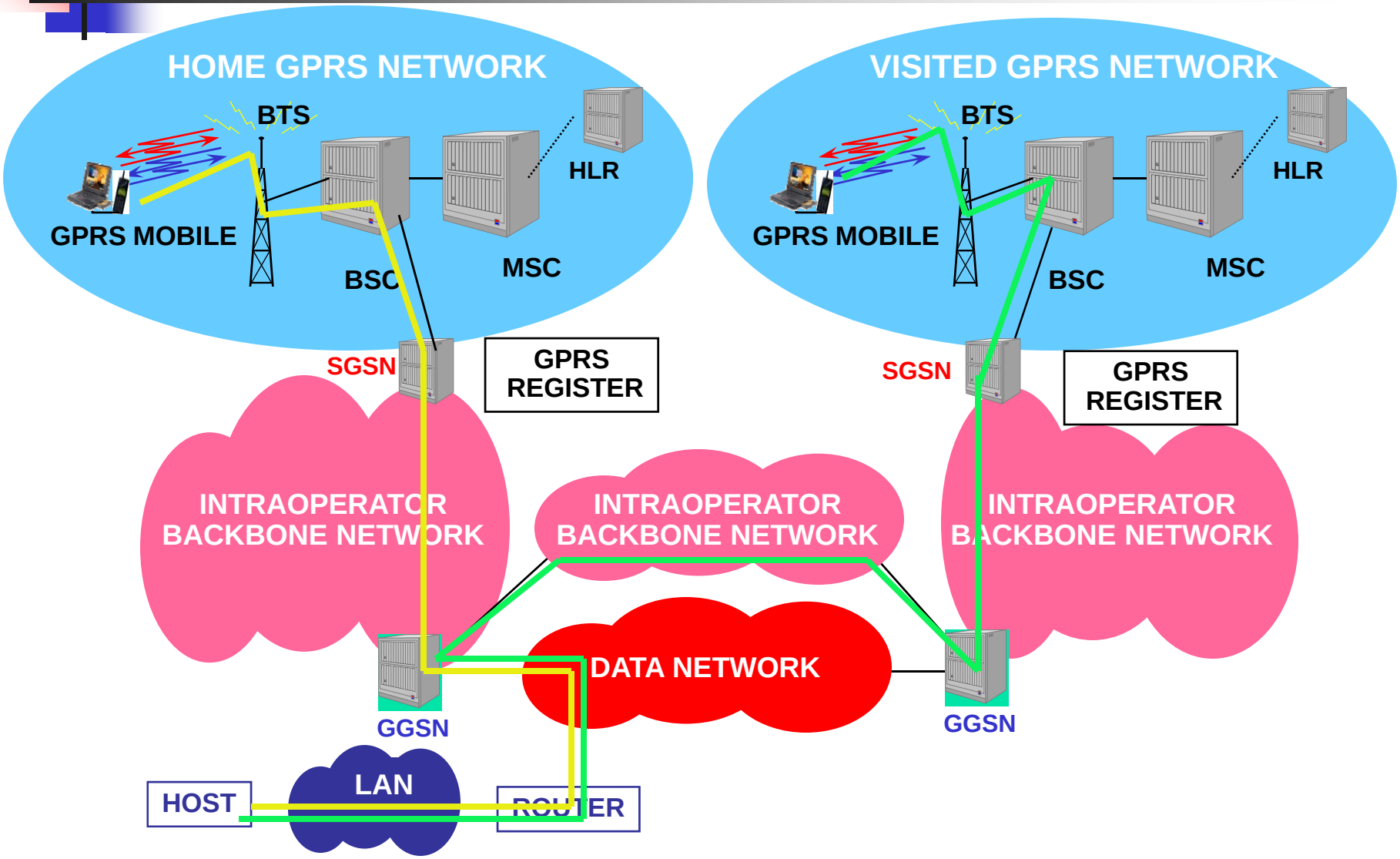
GPRS Architecture



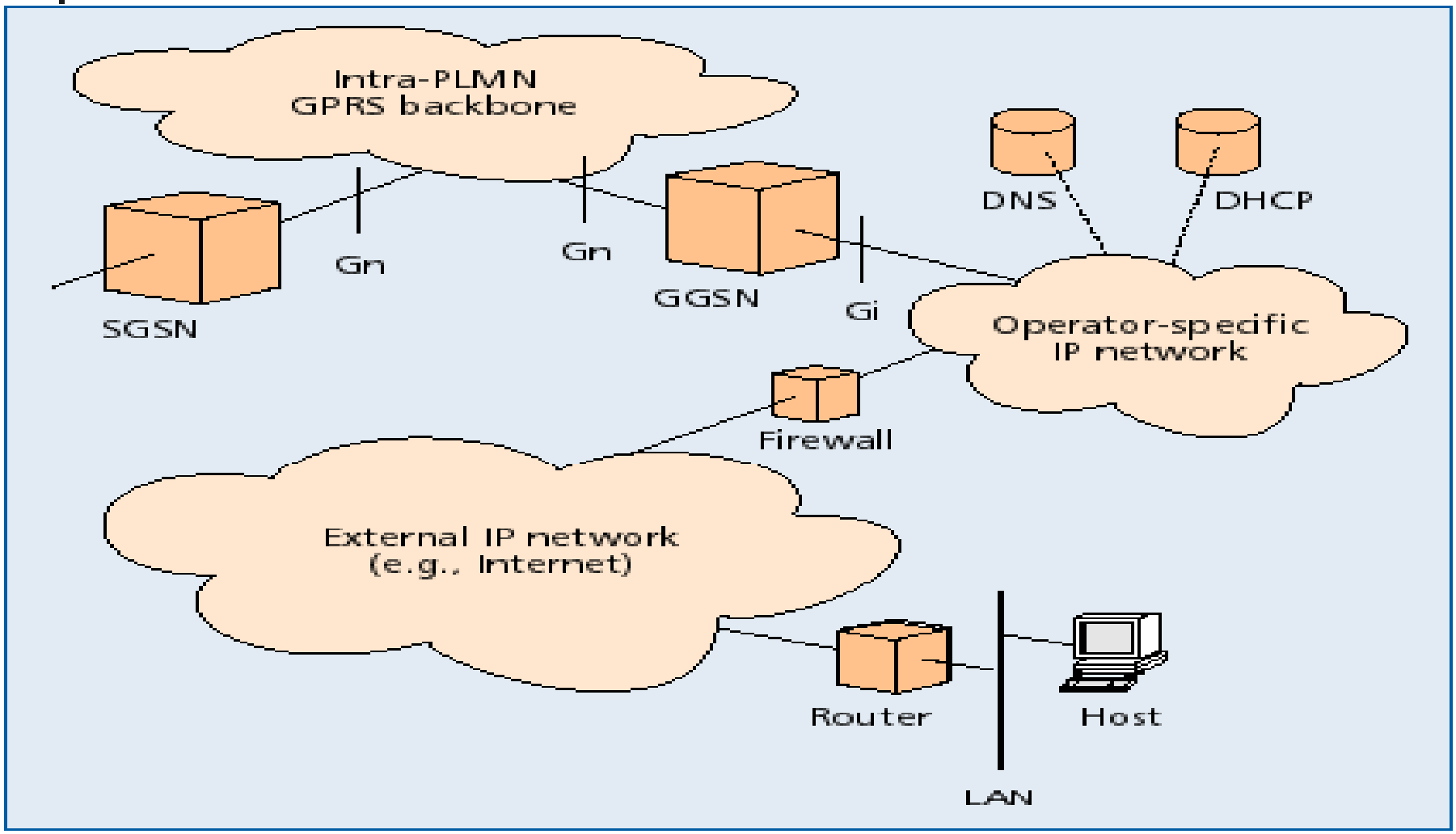
Example for packet routing in GPRS



EXAMPLES OF DATA ROUTING IN GPRS NETWORK



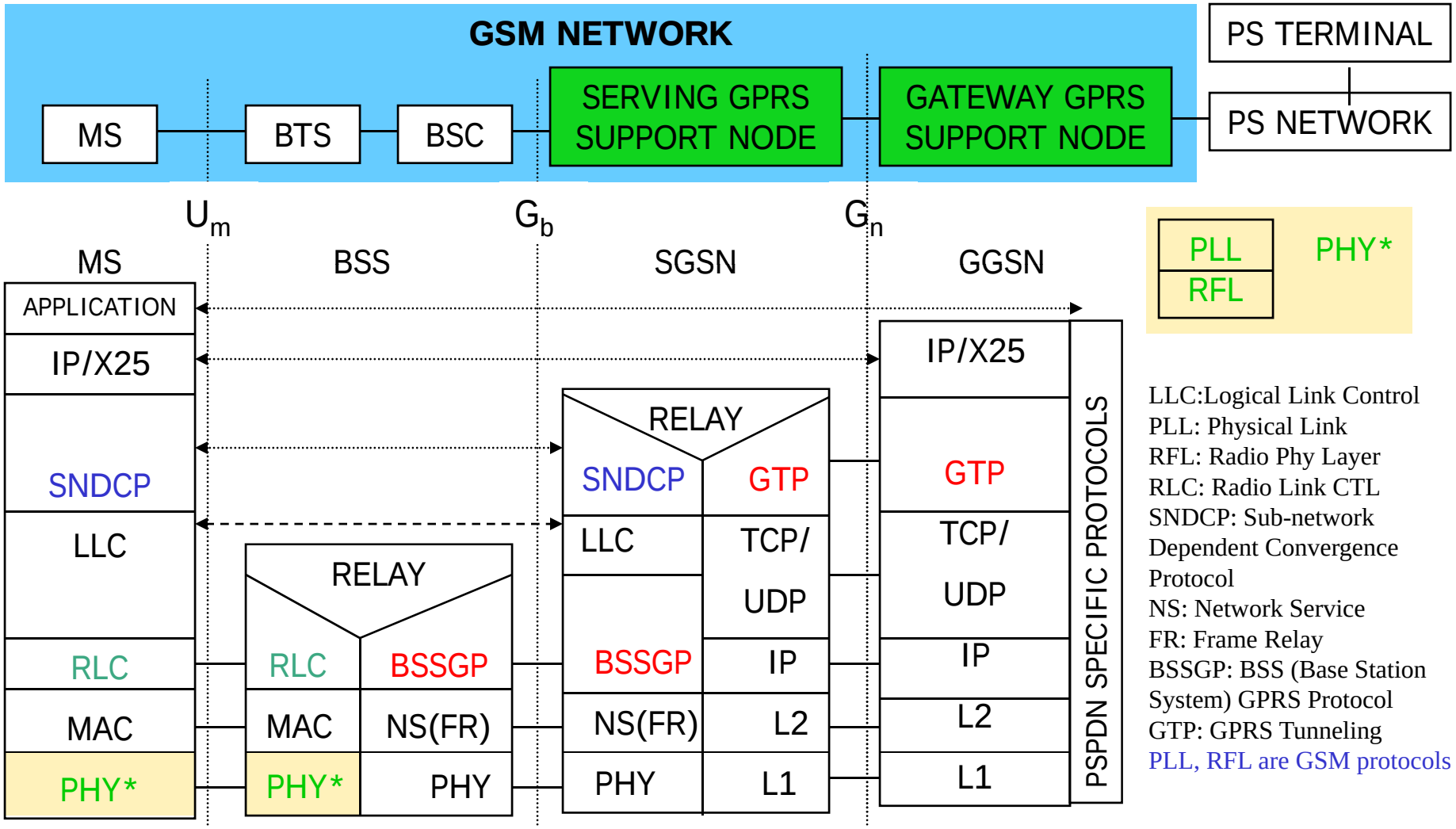
Example of GPRS Internet Connection



GPRS Architecture: what's new?

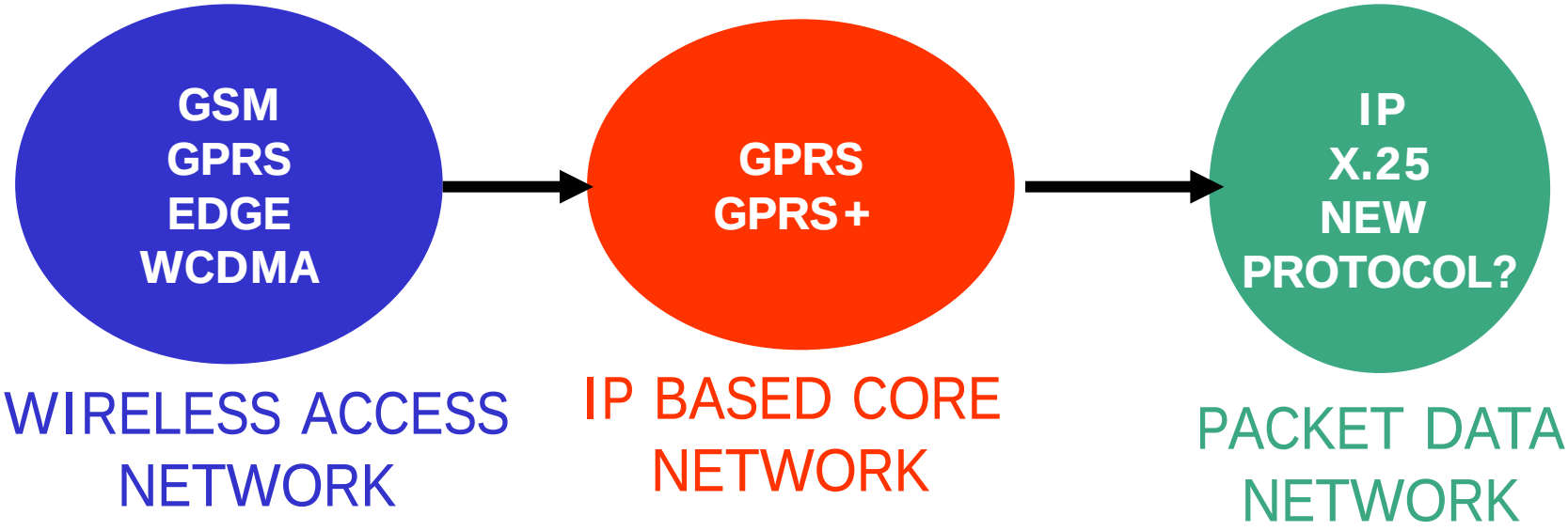
- MS, BSS, Mobile Switching Center/Visitor Location Register (MSC/VLR) and Home Location Register (HLR) in the existing GSM network are modified, e.g., HLR is enhanced with GPRS subscriber information.
- New GPRS Support Node (GSN):
  - The Serving GSN (SGSN) is the GPRS equivalent to the MSC.
  - The Gateway GSN (GGSN), connected with SGSNs via an IP-based GPRS backbone network, provides inter-working with external PS networks
- The HLR and the VLR are connected through the existing GSM D interface.
- Interfaces A, Gs, Gr, Gc, and D are used for signaling without involving user data transmission in GPRS.
- A interface is used for both signaling and voice transmission in GSM.
- Interfaces Um, Gb, Gn, Gp and Gi are used for both signaling and transmission in GPRS.
- GPRS transmission plane consists of a layered protocol structure for user information transfer and the associated control procedures (e.g., flow control, error detection, error correction and error recovery).

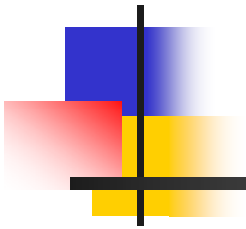
GPRS ARCHITECTURE



LLC:Logical Link Control
PLL: Physical Link
RFL: Radio Phy Layer
RLC: Radio Link CTL
SNDCP: Sub-network Dependent Convergence Protocol
NS: Network Service
FR: Frame Relay
BSSGP: BSS (Base Station System) GPRS Protocol
GTP: GPRS Tunneling
PLL, RFL are GSM protocols

NETWORK ARCHITECTURE EXAMPLE

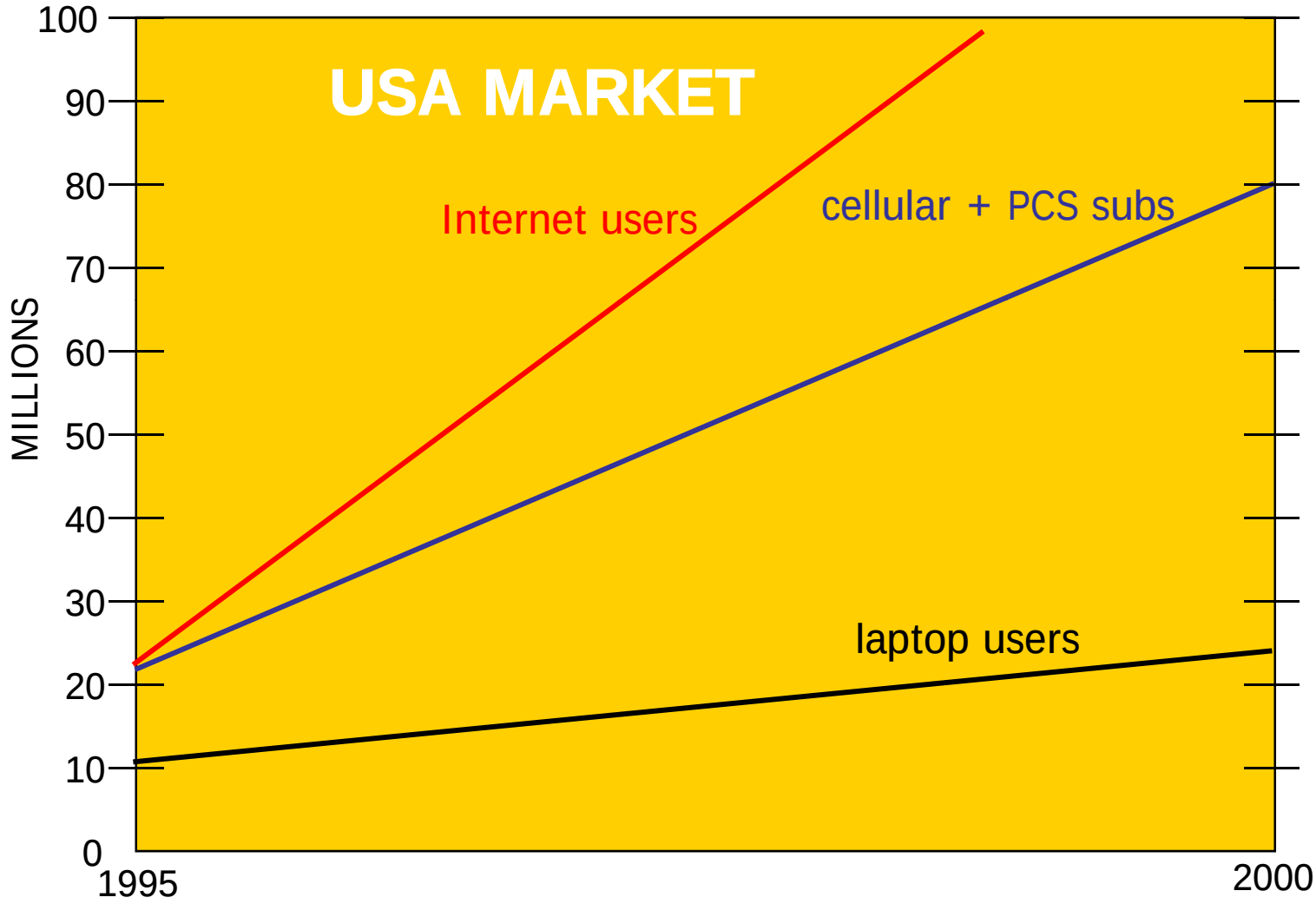




ENHANCED DATA RATES FOR GLOBAL EVOLUTION (EDGE) :

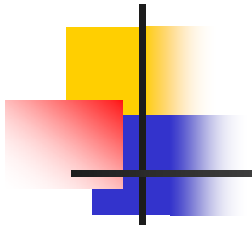
An Overview

DRIVING PARAMETERS



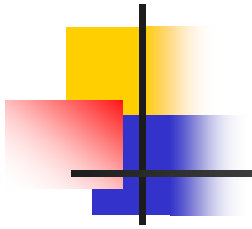
EDGE development activities:

- first proposed to ETSI as an evolution of GSM-GPRS in the beginning of 1997
- feasibility study was completed and approved by ETSI in 1997
- UWCC established high speed packet data requirements in Jan. 98, 136HS:
  - must support 384kbps packet data
  - must be deployed within 1 MHz
  - High spectrum efficiency
  - economy of scale
- In June of 1998 UWCC decided to create a standard for TDMA Packet Data based on the GPRS technology:
  - benefit in economies of scale for development and production of both mobile stations and network infrastructure
  - the existing GPRS standard could be use as a baseline, allowing for a standard that could be developed very quickly
- The decision was connected to the decision to utilize the EDGE structure for the 136HS outdoor component of the UWC-136 3G RTT proposal to ITU, candidate for IMT-2000 (to provide 384 kbps data services with an initial deployment that does not require clearance of more than 1 MHz of spectrum)
- The use of EDGE channels for TDMA packet data will be standardized during 1999 and is called GPRS-136HS (done in the UWCC/GTF/PDFG and TIA TR-45.3 and using the physical layer and the RLC/MAC layers from EDGE). Results: GPRS-136HS EDGE



EDGE development strategy

- Evolutionary path from existing standards for delivering 3G services in existing spectrum bands:
  - fast availability,
  - reuse of existing GSM and TDMA/136 infrastructure,
  - as well as support for gradual introduction, e.g.,
    - as a 1/3 frequency reuse overlay to TDMA/136, EDGE can be deployed using as little as 600 kHz of total bandwidth,
    - In GSM, EDGE can be introduced using a minimum of only one time slot per base station.
- Builds on General Packet Radio Service (GPRS) air interface and networks
- Phase 1 (Release'99) supports best effort packet data at speeds up to about 384 kbps
- Phase 2 (Release' 00) will add Voice over IP capability



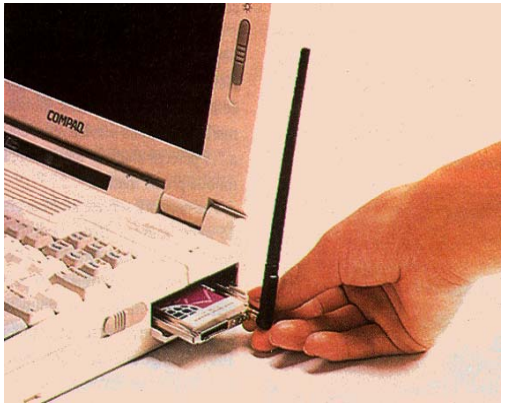
KEY APPLICATIONS

- GSM: ~10 kbps, single time-slot, CS:
  - Fax
  - Short-messaging
- HSCSD, GPRS: ~50-100 kbps peak rate, multiple time-slots
- Needed to make wireless data attractive:
  - Web Browsing - downlink bandwidth hungry
  - FTP or Emails with file attachment - both links
- 3G: “Multimedia,” mainly PS
  - Wide-area, low mobility, 384 kb/s
  - Wide-area, high mobility, 144 kb/s
  - Indoor, 2 Mb/s

Wireless Data Terminals

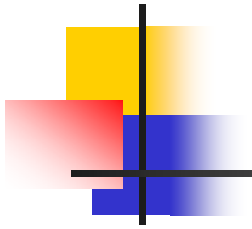
Nokia
3G vision

Sierra PCMCIA CDPD Modem



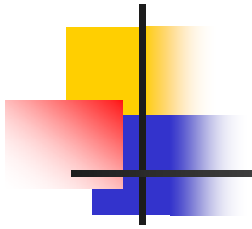
Nokia 9110

Ericsson R380
with wireless data functions



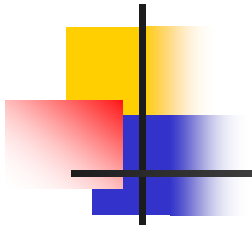
GPRS Airlink

- General Packet Radio Service (GPRS)
- Same GMSK modulation as GSM
- 4 channel coding modes
- Packet-mode supporting up to about 144 kbps
- Flexible time slot allocation (1-8)
- Radio resources shared dynamically between speech and data services
- Independent uplink and downlink resource allocation



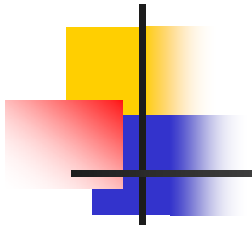
EDGE Airlink

- **Extends GPRS packet data with adaptive modulation/coding**
- **2x spectral efficiency of GPRS for best effort data**
- **8-PSK/GMSK at 271 ksps in 200 kHz RF channels supports 8.2 to 59.2 kbps per time slot**
- **Supports peak rates over 384 kbps**
- **Requires linear amplifiers with < 3 dB peak to average power ratio using linearized GMSK pulses**
- **Initial deployment with less than 2x 1 MHz using 1/3 reuse with EDGE Compact as a complementary data service**



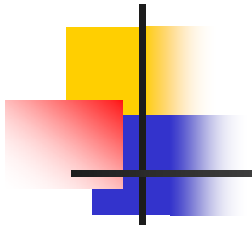
GPRS Networks

- consists of packet wireless access network and IP-based backbone
- shares mobility databases with circuit voice services and adds new packet switching nodes (SGSN & GGSN)
- will support GPRS, EDGE & WCDMA airlinks
- provides an access to packet data networks
  - Internet
  - X.25
- provides services to different mobile classes ranging from 1-slot to 8-slot capable
- radio resources shared dynamically between speech and data services



EDGE Evolution

- Best effort IP packet data on EDGE
- Voice over IP on EDGE circuit bearers
- Voice over IP with statistical radio resource multiplexing
- Network based intelligent resource assignment
- Smart antennas & adaptive antennas
- Downlink speeds at several Mbps based on wideband OFDM and/or multiple virtual channels



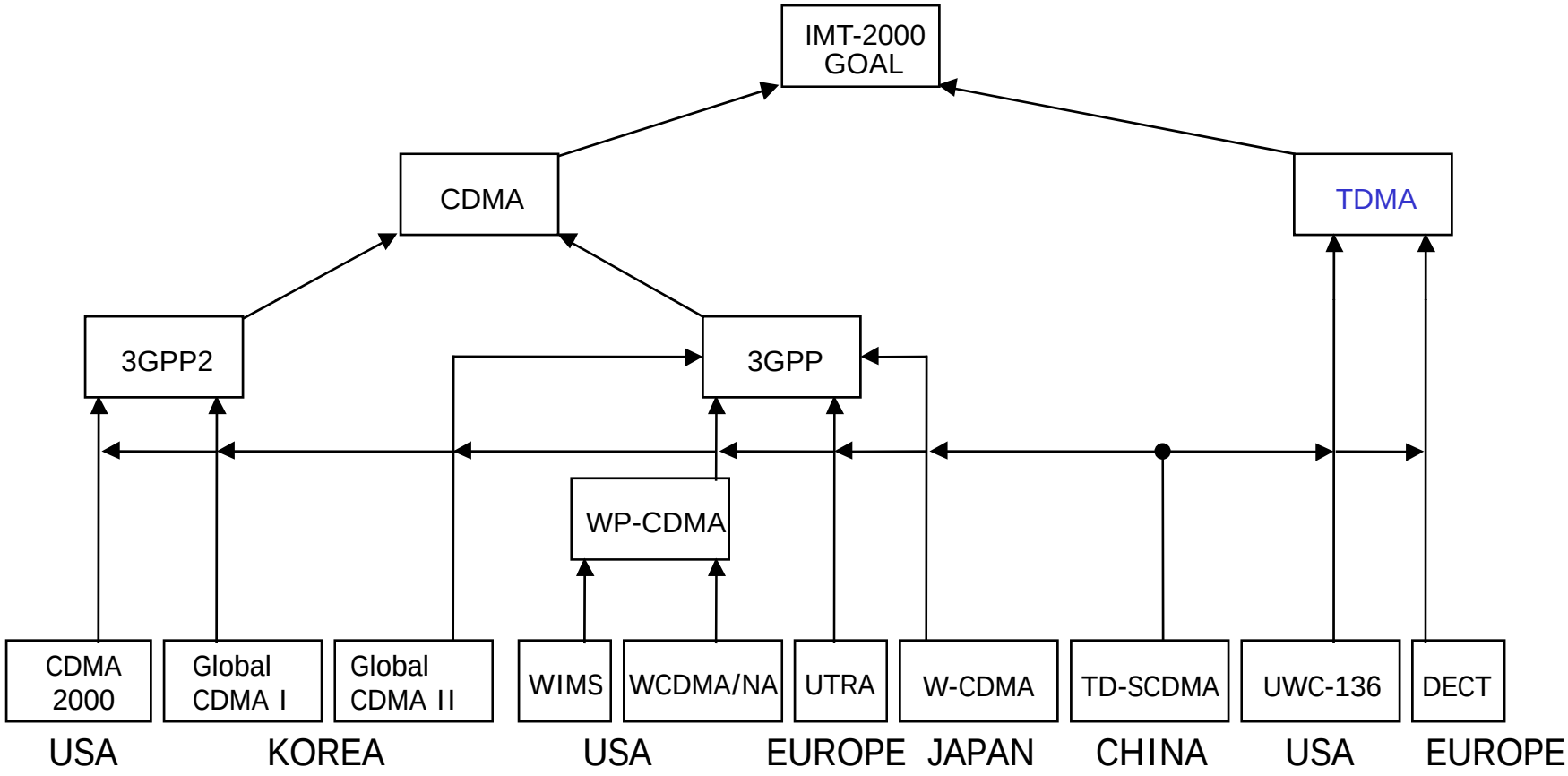
3G according to ITU

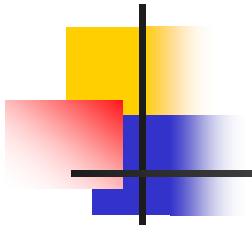
The ITU vision of global wireless access in the 21st century, including mobile and fixed access, IMT is aimed at providing direction to the many related technological developments in this area to assist the convergence of these essentially competing wireless access technologies.....

3G Proposals

http://www.itu.int/imt/2-radio-dev/index.html/

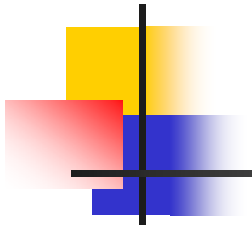
IMT-2000: Terrestrial RTT Harmonization





KET FEATURES

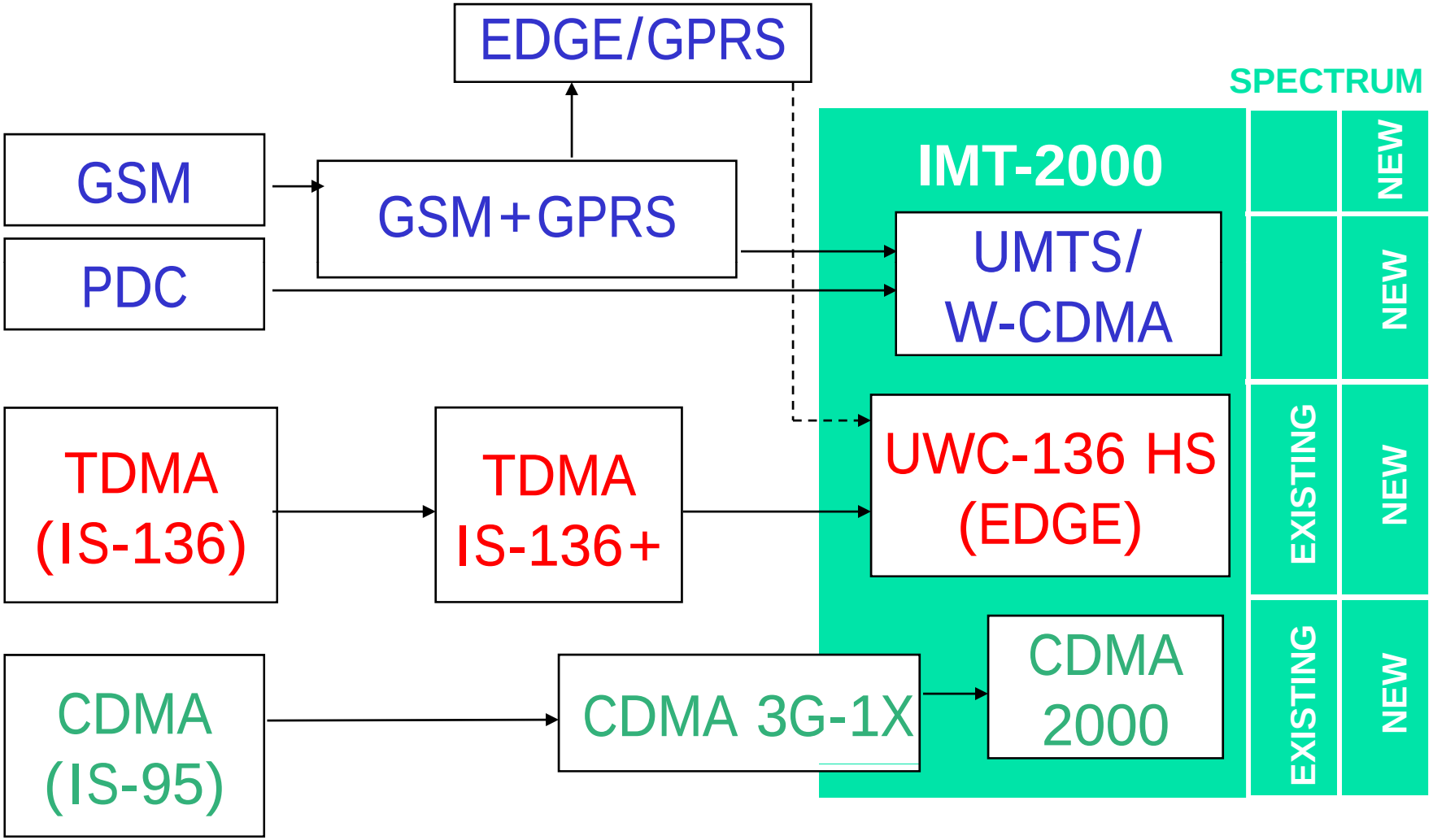
- High Speed Services
  - Nominal Rates:
    - At least 144 kbps macrocell
    - At least 384 kbps outdoor pedestrian
    - At least 2 Mbps indoor
    - => 1-2 Mbps or higher in macrocell
- Support emerging IP-based services
    - Real-time and non real-time
- Optimized for packet-switched operation
    - Support appropriate QoS definitions
    - Data and multimedia services

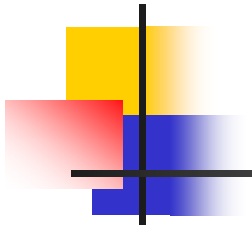


IMT-2000 Spectrum

- WRC'92
  - 50+ MHz x 2
  - 1900 and 2100 MHz
- Prospects
  - Europe - UMTS spectrum similar
  - Japan - yes
  - Asia - mixed but positive
  - US - 1900 spectrum allocated for PCS (requires spectrum clearing for 3G): ~30 MHz at 700 MHz to be auctioned

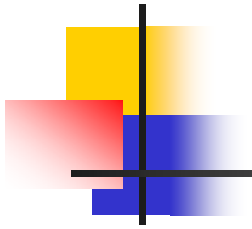
TECHNOLOGY EVOLUTION TO IMT-2000 RADIO ACCESS





Voice-Service Approaches

- Cellular *coverage* is designed for voice service
  - Area outage, e.g. < 10% or < 5%.
  - Minimal, but equal, service everywhere.
- Cellular *systems* are designed for voice
  - 20 ms framing structure
  - Strong FEC, interleaving and decoding delays.
- Spectral Efficiency
  - around 0.04-0.07 bps/Hz/sector
  - comparable for TDMA and CDMA

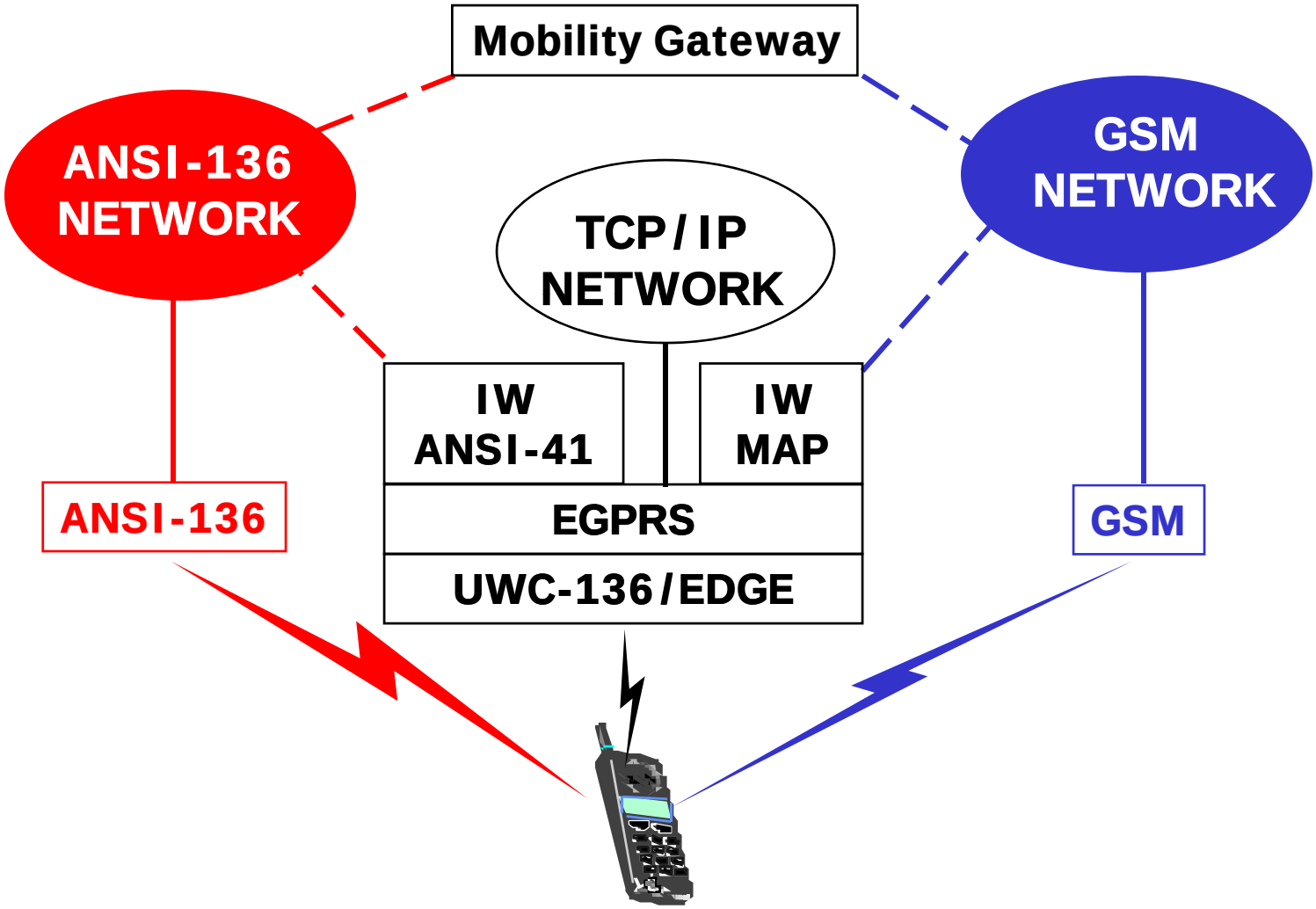


Data-Service Approaches

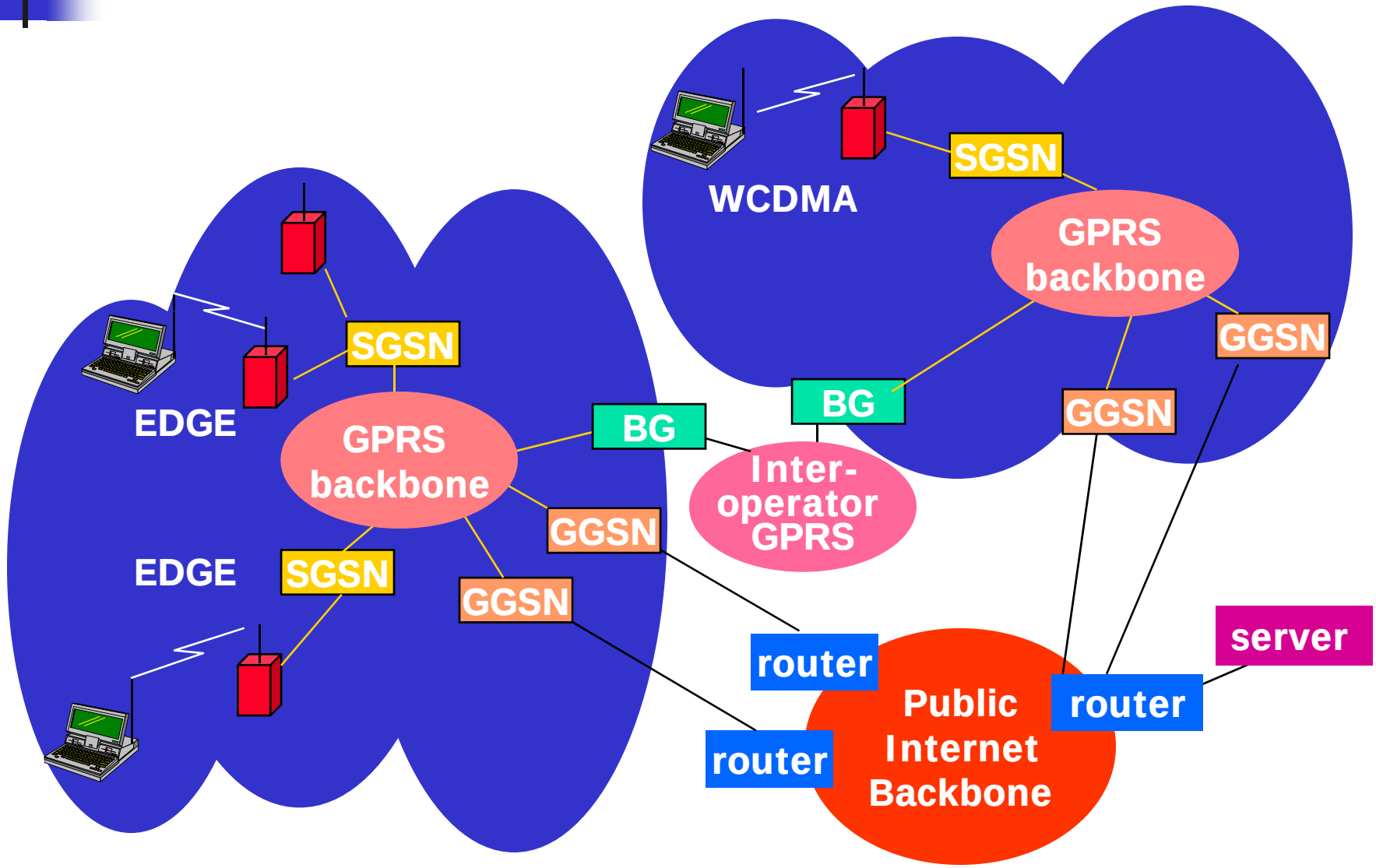
- Bursty: Circuit => Packet
- Need to “widen the data pipe”:
  - Multi-bearer: multi-slot, multi-code
  - Enhanced Tx rate:
    - TDMA: Enhanced/adaptive modulation/coding and Incremental Redundancy (Generalized Hybrid Type II ARQ) e.g., EDGE
    - CDMA: Variable processing gain, e.g., WCDMA
    - New systems, e.g., OFDM with dynamic packet assignment

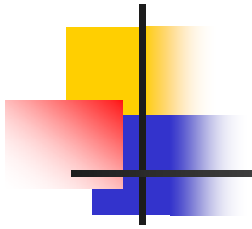
Global TDMA Convergence

Global TDMA Convergence



INTERSYSTEM CONFIGURATION





INTERNET & WIRELESS EVOLUTION

- Explosive traffic growth and service shift in wireless.
- Data will dominate wireless traffic: 70% vs 30% for voice in 2005
- Internet Growth fueled by Wireless:
- Wireless Internet will pass Wireline Internet in 2004 (cross-point of 1 billion subscribers)
- 3G Enables the Wireless Internet
- Unified network: Single distributed network, multiple services, packet architecture

TRENDS & 4G PARAMETERS

	UMTS	4G
AGGREGATE DATA RATES/CELL (UP/DOWN, Mbps)	3.8/3.8	**30/100**
SPEC. EFFICIENCY (bps/Hz/cell)	0.8/0.8	**6/20**
USER PEAK RATE (Mbps)	0.4/0.4	**5/20**
DORMANT TO ACTIVE TRANSITION TIME (sec)	2	**0.1**