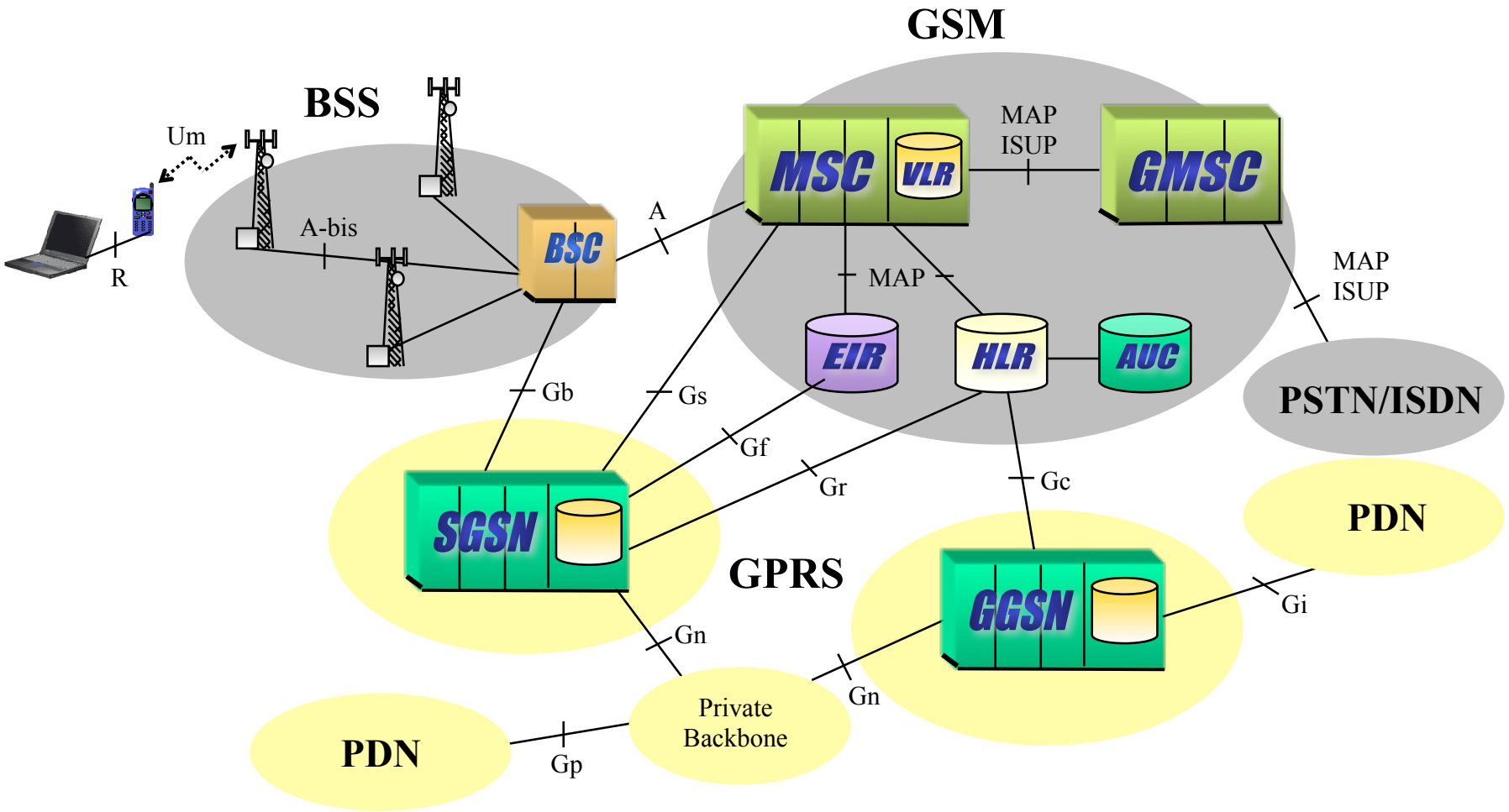
General Packet Radio Service (GPRS)

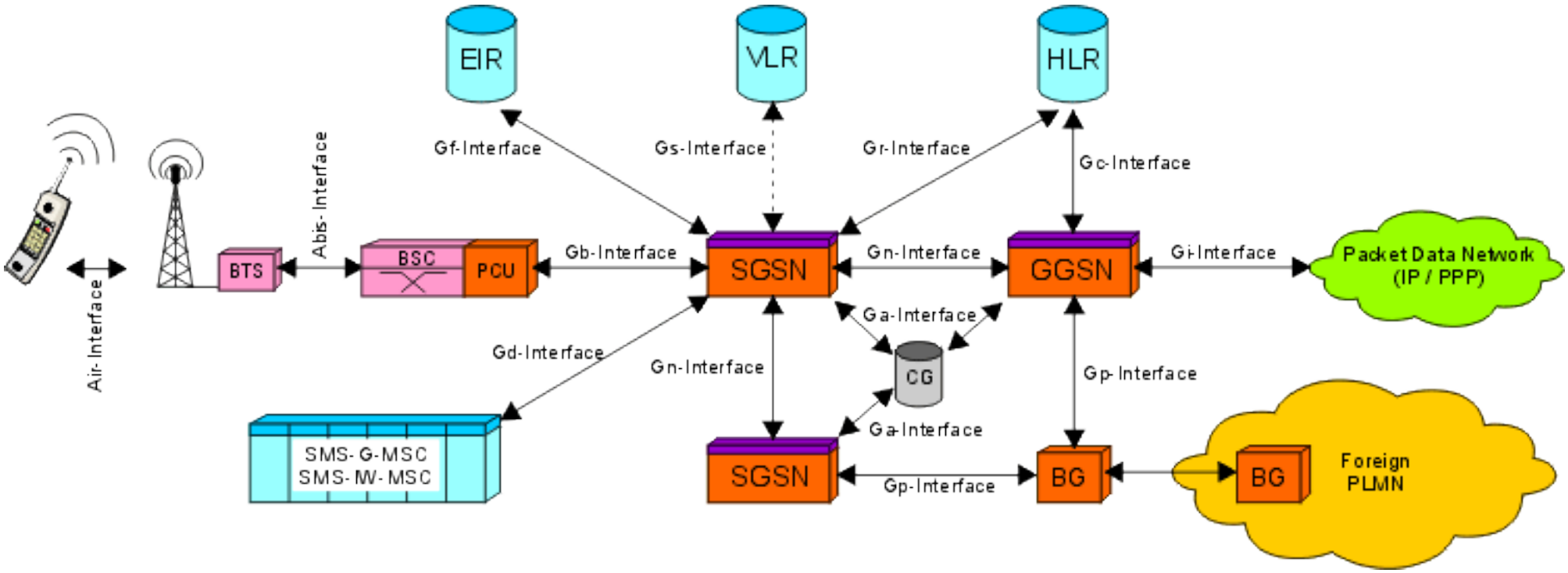
What is GPRS?

- GPRS (General Packet Radio Service)
  - ✓ a packet oriented data service for IP and X.25 over GSM networks
  - ✓ enables packet-switched services on the resources of the already existing GSM network infrastructure
  - ✓ deploying new channel coding schemes and timeslot bundling, GPRS is capable of providing single user throughput rates of up to 160 kbps (in theory)
  - ✓ provides an "always on" functionality, without continuous consumption of resources
  - ✓ requires a major hardware upgrade in the GSM network and it requires new mobile stations
  - ✓ a step toward 3G networks (2.5G)

From GSM to GPRS



GPRS Interfaces



Service GPRS Support Node (SGSN)

- Handles
  - ✓ PDP (Packet Data Protocol) contexts for MSs
  - ✓ determines Quality of Service (QoS) assigned to user
  - ✓ routes packets to MSs
  - ✓ "pages" MSs when data is to be sent
  - ✓ handover/cell change
- Stores
  - ✓ subscriber data for all MSs in the location area (LA)
  - ✓ store not-acknowledged packets in case of a cell change during an ongoing packet data transfer

- Security
  - ✓ authentication, by means of identity or equipment check
  - ✓ P-TMSI is allocated by SGSN
  - ✓ ciphering
- Charging
  - ✓ together with the GGSN, the SGSN collects CDR's (Call Data Records)
  - ✓ opposed to the GGSN, the SGSN collects CDR's for the use of the own network resources
  - ✓ these CDR's are forwarded to the Charging Gateway (CG) via the IP-based intra-PLMN backbone

Gateway GPRS Support Node (GGSN)

- Handles
  - ✓ interconnects a PLMN to the external world (Internet)
  - ✓ routes IP packets to the appropriate SGSN
    - if the MS changes the SGSN during ready mode, the GGSN is used as data packet buffer
  - ✓ activation and deactivation of PDP-contexts / session management
- Stores
  - ✓ subscriber data for active MSs

- Security
  - ✓ firewall
  - ✓ screening
- Charging
  - ✓ the GGSN will, in addition to the SGSN, collect CDRs and forward them to the charging gateway (CG)
  - ✓ opposed to the SGSN, the GGSN will collect call data records based on the usage of external network resources
  - ✓ in other words, charges that arise from other packet data or mobile network operators are collected by the GGSN

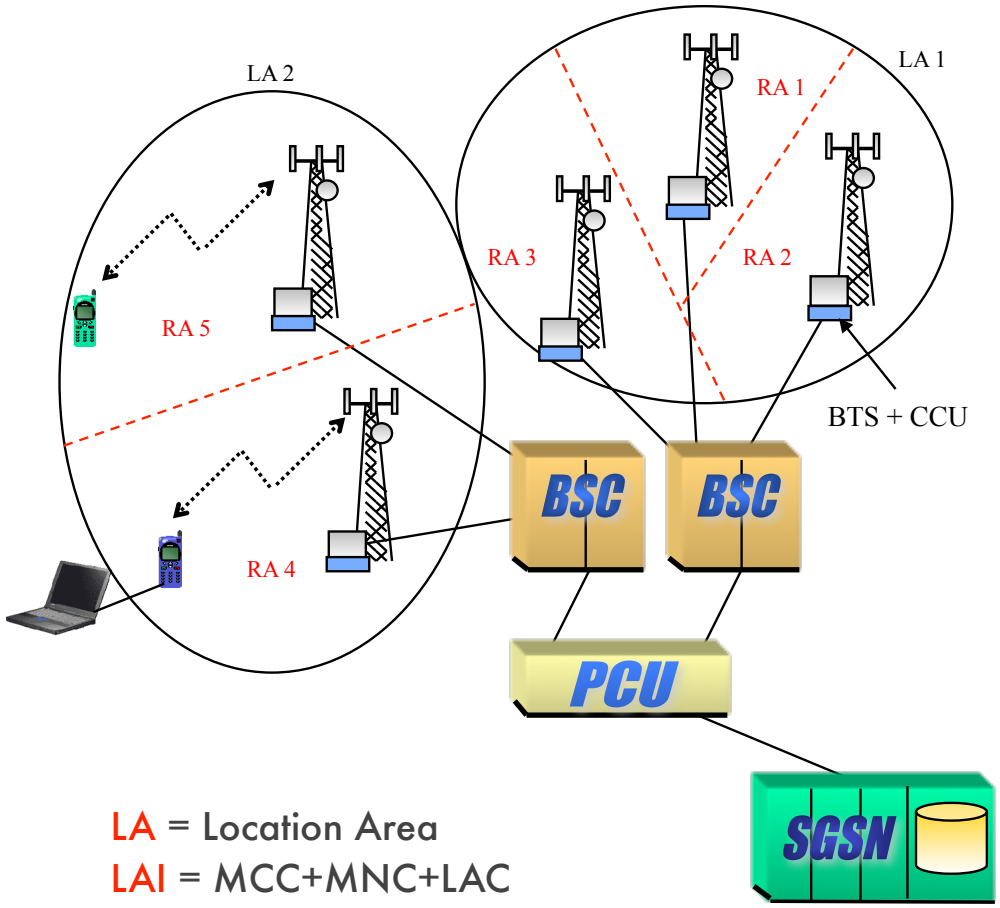
Home Location Register (HLR)

- New fields has been added to the HLR in order to serve the GPRS Network
  - ✓ IMSI is still the reference key
  - ✓ SGSN number
    - the SS7 address of SGSN currently serving the MS
  - ✓ SGSN address
    - the IP address of SGSN currently serving the MS
  - ✓ GGSN list
    - the GGSN number and optional IP address are related to the GGSN which will be contacted when activity from the MS is detected

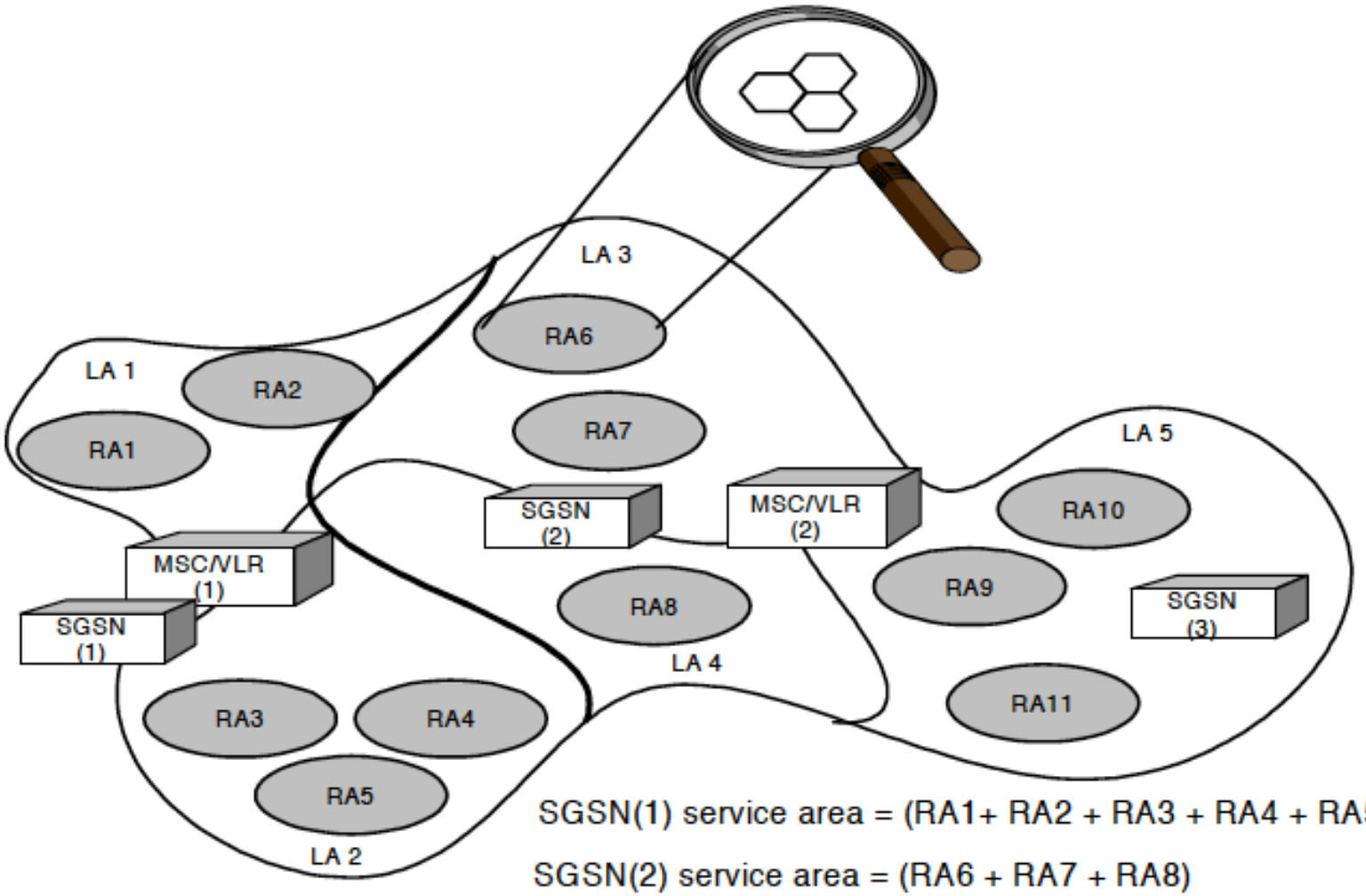
- For each PDP context
  - PDP type (e.g. X25 or IP)
  - PDP address (note: this field will be empty if dynamic IP address is used)
  - QoS profile (QoS profile for this PDP context)
  - VPLMN address allowed
  - Access Point Name (APN)

Base Station Subsystem (BSS)

- In GPRS
  - ✓ LA is divided into RAs
  - ✓ each RA contains one or more cells
  - ✓ in a RA, the RAI is broadcasted as system information
  - ✓ when an MS is crossing an RA border the MS will initiate an RA update procedure
- New elements (CCU , PCU) are added to the BSS in order to support new coding schemes introduced by GPRS



LA = Location Area
LAI = MCC+MNC+LAC
RA = Routing Area (Subset of LA)
RAI = LAI+RA
PCU = Packet Control Unit
CCU = Channel Codec Unit



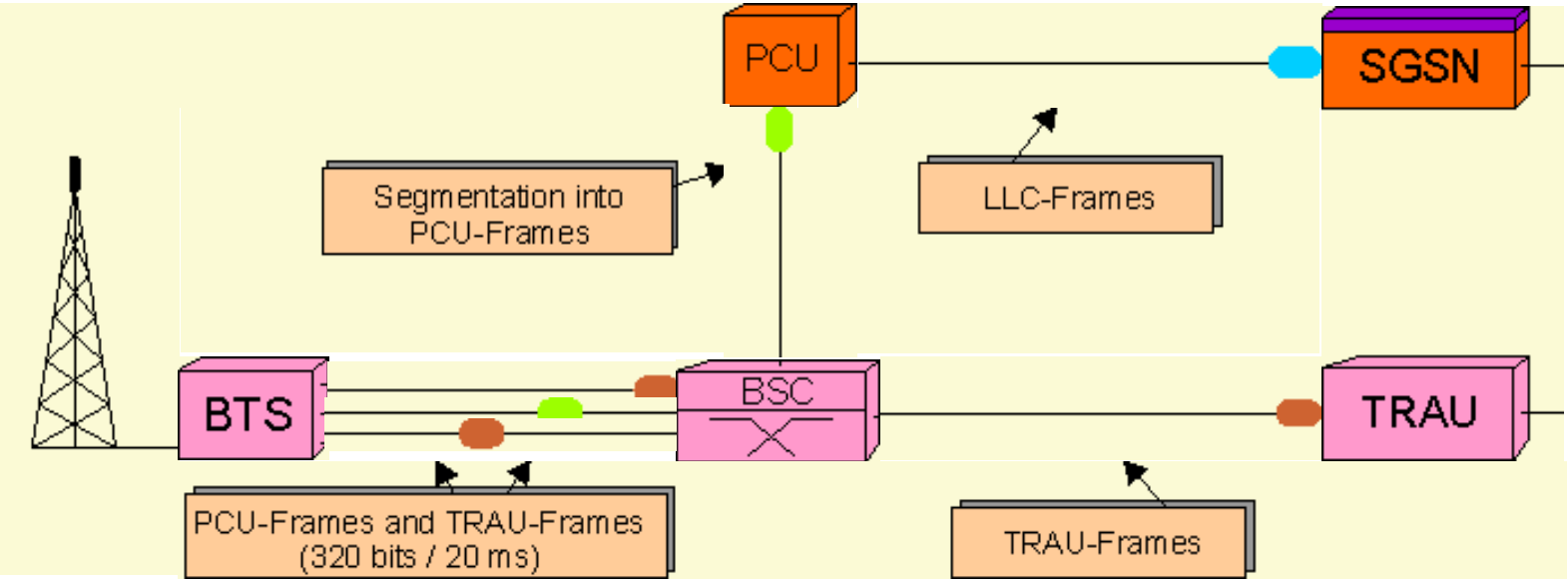
SGSN(1) service area = (RA1+ RA2 + RA3 + RA4 + RA5)

SGSN(2) service area = (RA6 + RA7 + RA8)

SGSN(3) service area = (RA9 + RA10 + RA11)

Packet Control Unit (PCU)

- Interface the new GPRS core network to the existing GSM BSS
  - ✓ converting packet data coming from the SGSN in so called PCU-frames that have the same format as TRAU-frames
  - ✓ these PCU-frames are transparently routed through the BSC and towards the BTS
  - ✓ the BTS needs to determine the respective coding scheme and other options before processing a PCU-frame
- Takes over all GPRS radio related control functions from the BSC



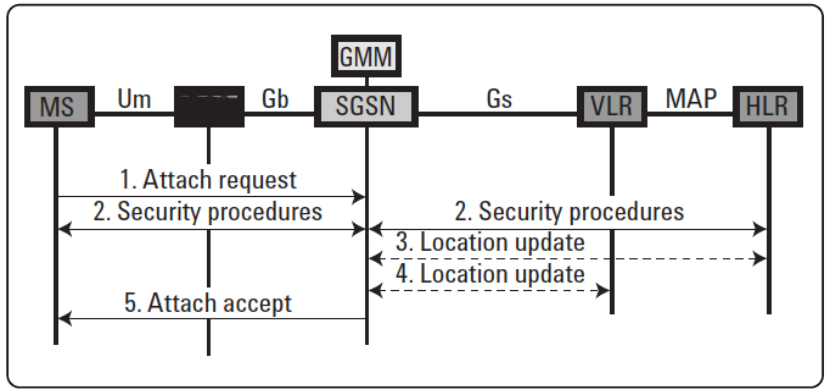
TRAU (Transcoder and Rate Adaptation Unit) : performs transcoding function for speech channels and RA (Rate Adaptation) for data channels in the GSM network

Mobile Station (MS)

- Three different classes of MSs have been defined
  - ✓ Class A
    - supports simultaneous monitoring and operation of packet-switched and circuit-switched services
  - ✓ Class B
    - supports simultaneous monitoring but not simultaneous operation of circuit-switched and packet-switched services
  - ✓ Class C
    - supports either circuit-switched or packet-switched monitoring and operation at a given time

GPRS Mobility Management (GMM)

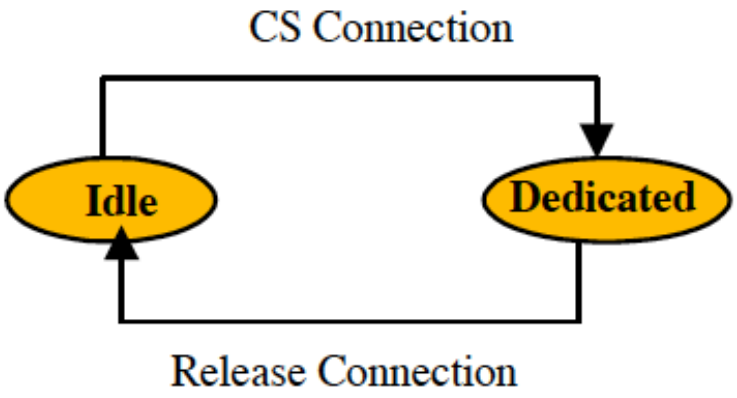
- GMM are used to keep track of the current location of an MS and to initiate security procedures
- GMM is a function that is mainly handled between MS and SGSN (the HLR is also involved)
- There are various scenarios defined in GPRS to update a subscriber's location within the network
  - ✓ Routing Area Update (Intra-SGSN and Inter-SGSN)
  - ✓ GPRS attach and detach
  - ✓ cell update (only while in GMM-Ready State)
- The GMM cell update procedure replaces in GPRS what is known as handover procedure in circuit-switched GSM



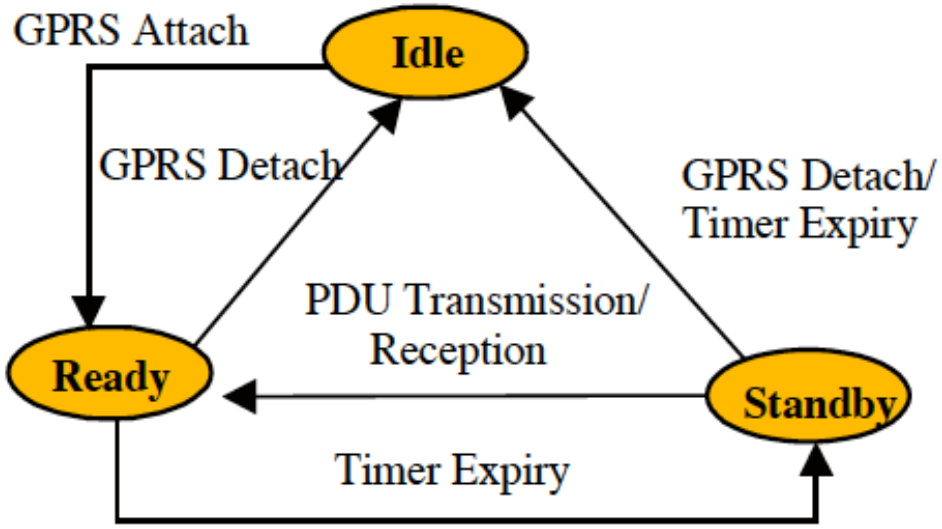
GPRS Attach

GSM and GPRS Functional State Models

- Due to the fact that a GPRS MS is not constantly "connected" to the network, the GMM has introduced a new state, called "Ready State"



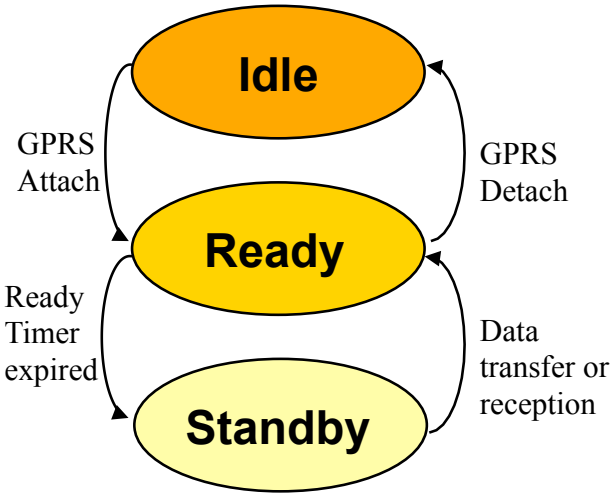
GSM State Model



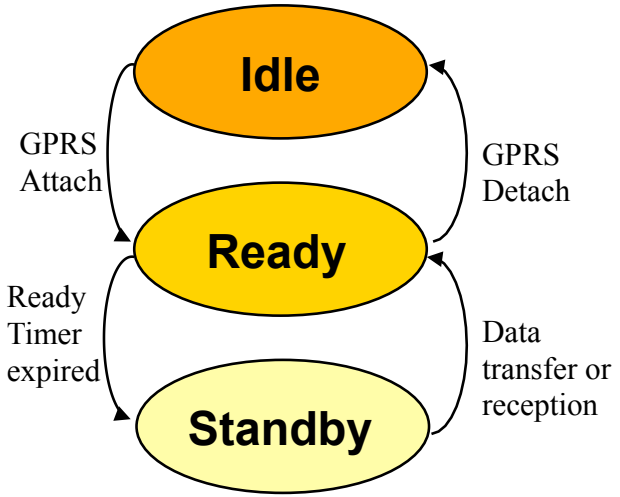
GPRS State Model

GMM States

- Idle mode
  - ✓ MS off or not attached yet
  - ✓ if the MS is on, and is a Class B or Class C MS, the MS will listen to the network, but not make any updating of where the MS is
  - ✓ it is not possible to page an MS
- Standby mode
  - ✓ MS is listening to the Network
  - ✓ only RA update and periodic update is necessary
  - ✓ it is possible to page the MS



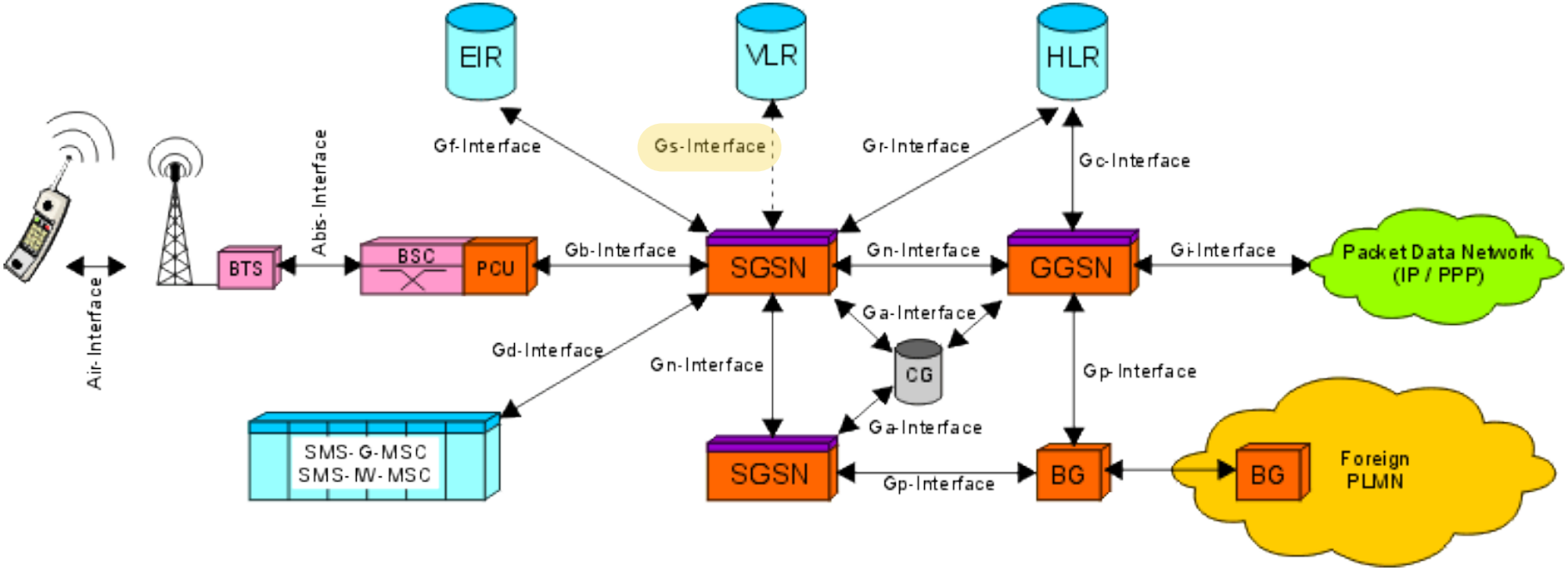
- Ready mode
  - ✓ MS is able to send and receive data
  - ✓ cell updating is necessary
  - ✓ if no activity within the timer (default = 44s) the MS will fall back to a stand-by state
  - ✓ note: an MS can be forced back to standby mode due to lack of recourses



GMM Procedures

- GPRS attach / detach
  - ✓ made towards the SGSN
  - ✓ the MS must provide its identity (P-TMSI/IMSI) and an indication of which type of attach that is to be executed (GPRS or combined GPRS/IMSI)
  - ✓ after GPRS attach the MS is in ”Ready” state and MM contexts are established in the MS and the SGSN
- Routing Area update
  - ✓ when a GPRS-attached MS detects a new RA (Routing Area)
  - ✓ when the periodic RA update counter has expired

- Cell update
  - ✓ when the MS enters a new cell inside the current RA and the MS is in ”Ready” state
- Combined RA/LA update
  - ✓ only if option *Gs*-interface is implemented

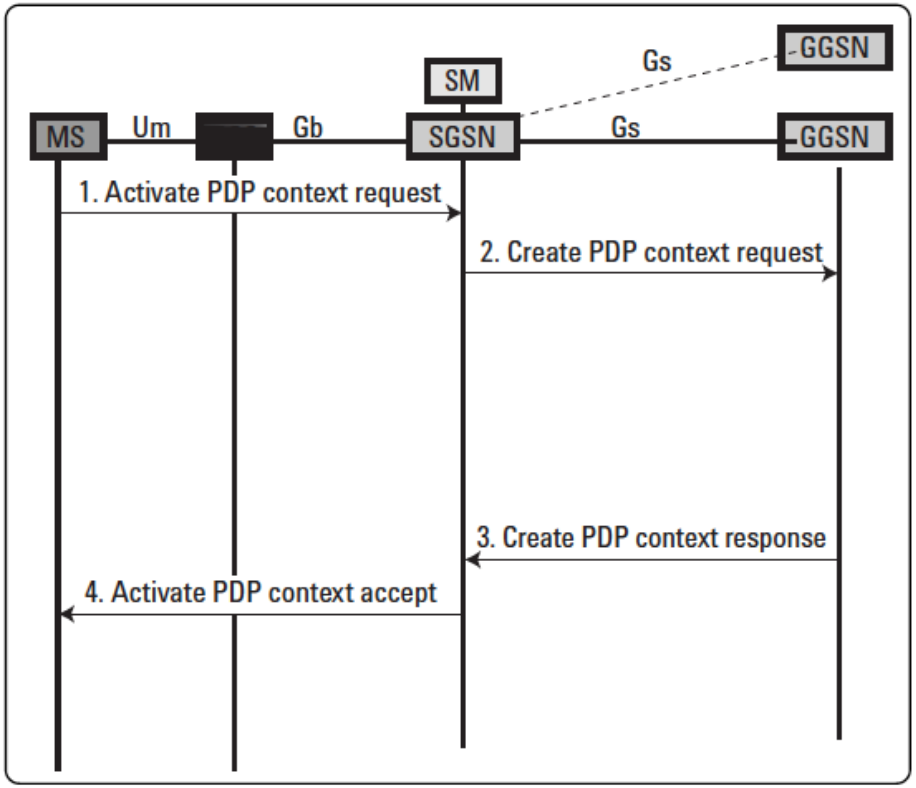


Session Management (SM)

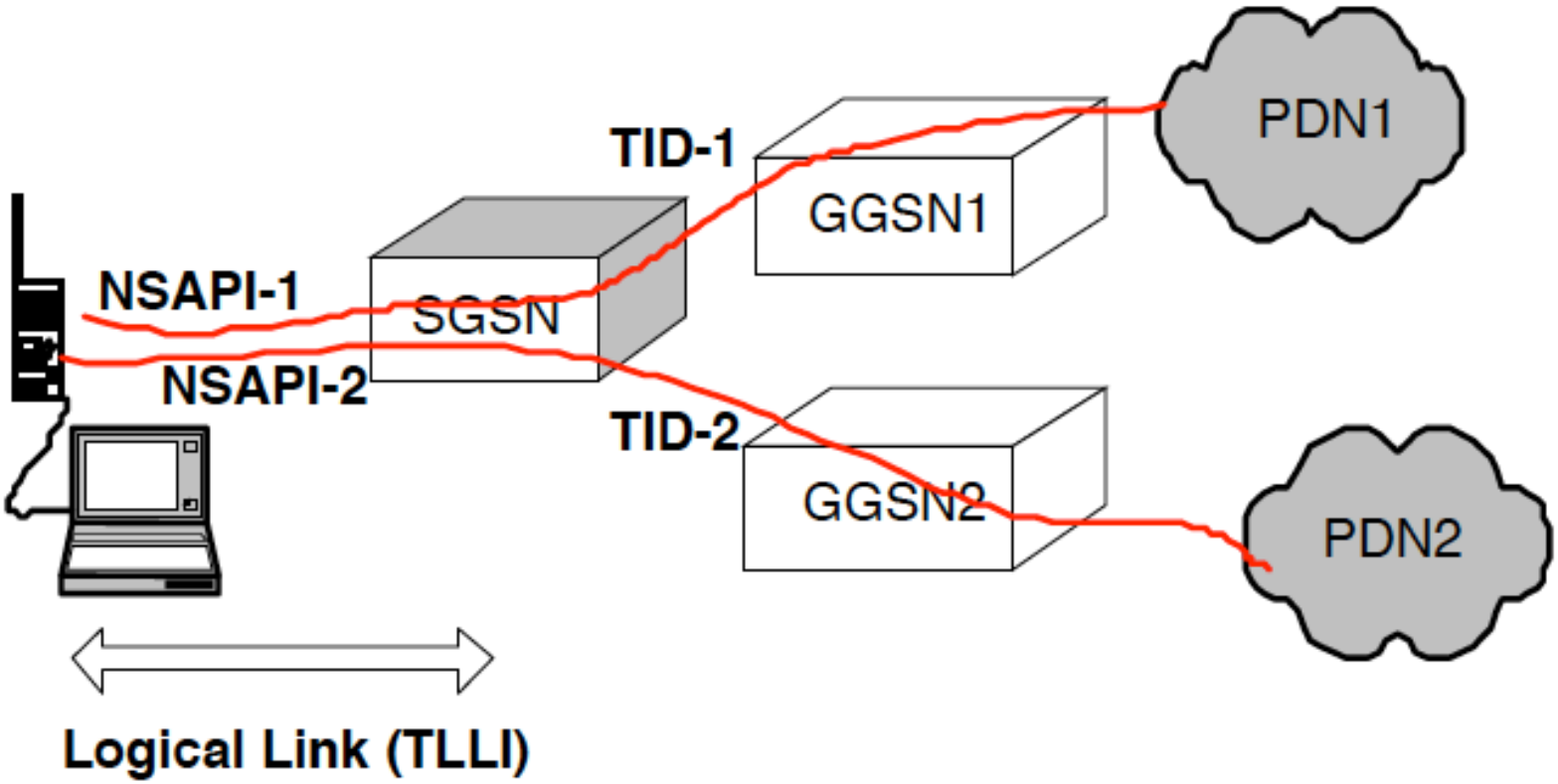
- Allow transfer of user data packets between the MS and some external packet data network
- Before data transmission start, SM involves a handshaking procedure between MS, SGSN and GGSN
- Establish a PDP context between MS and GGSN (includes the negotiated QoS profile)

PDP Context Activation

- Identifies the transaction parameters of an active session of a GPRS MS
  - ✓ note that a GPRS MS may support multiple simultaneous sessions and activate PDP-contexts
- Can be initiated by network or MS (in ”Standby” or ”Ready” state)
- Cannot be activated before a GMM context exists (a GPRS MS first needs to register itself towards the SGSN before a PDP context activation procedure can be initiated)
- Can be deactivated on request of MS or SGSN or GGSN by means of PDP context deactivation procedure



PDP Context Activation

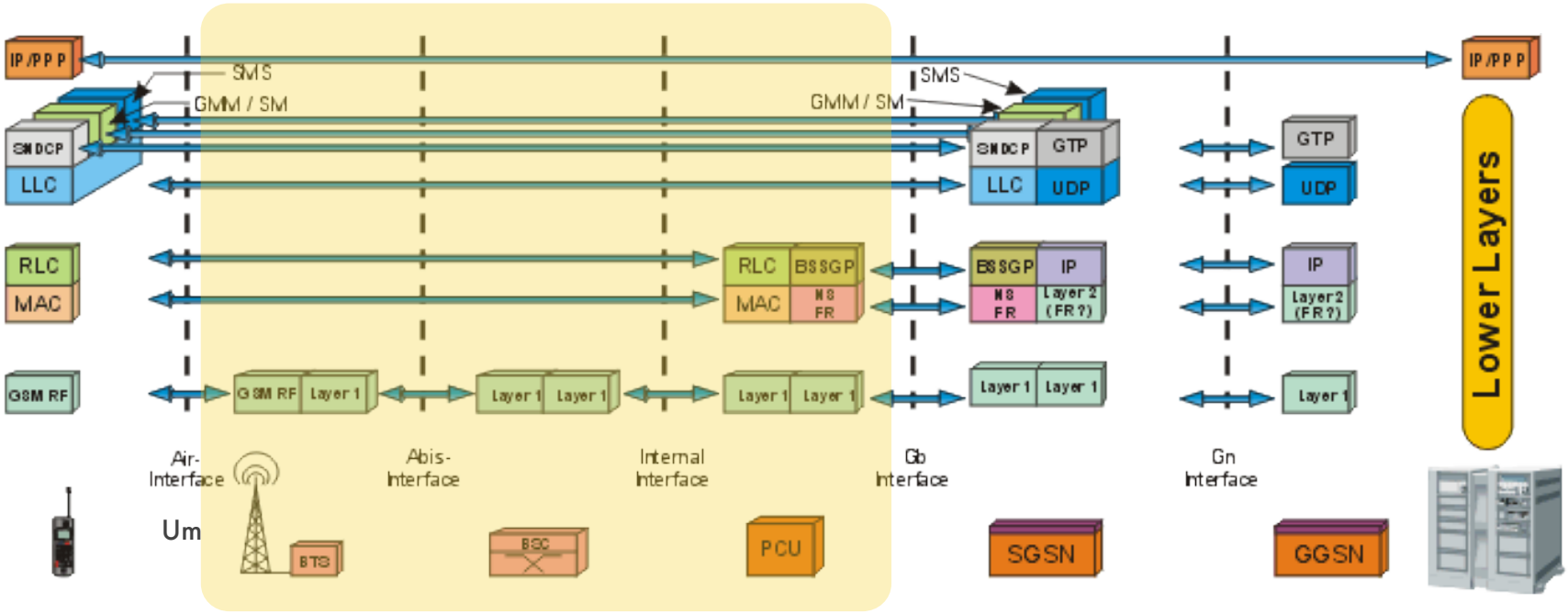


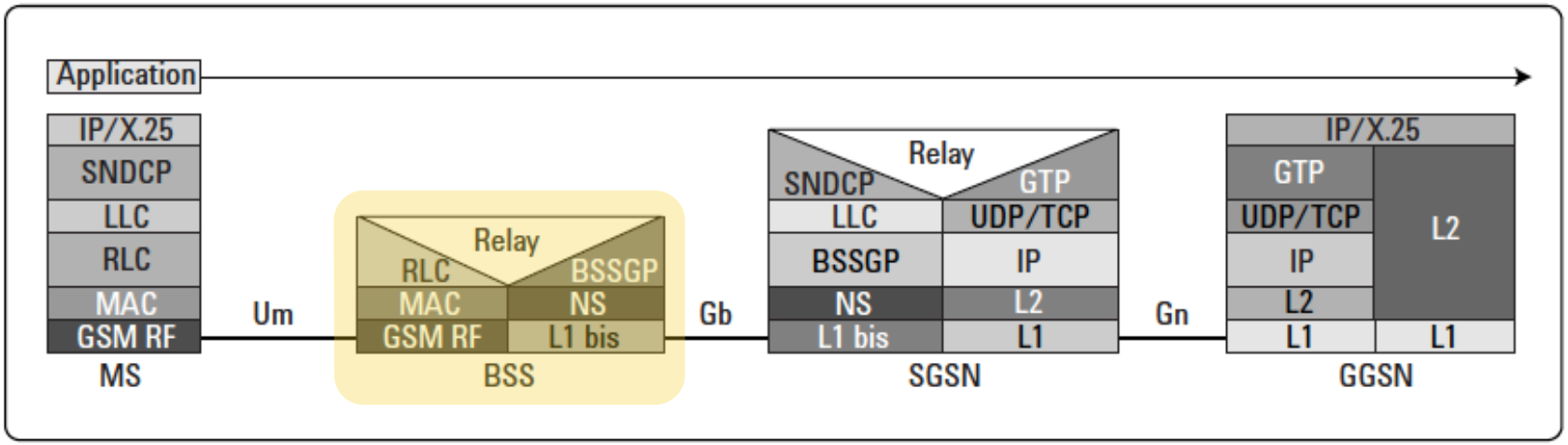
A MS with two PDP Contexts Active

Radio Resource (RR) Management Procedures

- Takes care of the allocation and maintenance of radio communication paths
- Paging procedure
  - ✓ moves the MM state to ”Ready” to allow SGSN to forward downlink data to BSS
- TBF (Temporary Block Flow) establishment/release
  - ✓ a TBF is a physical connection (allocated radio resource) used by two RR entities to support unidirectional transfer of user data or signaling
  - ✓ a TBF is temporary and is maintained only for the duration of the data transfer

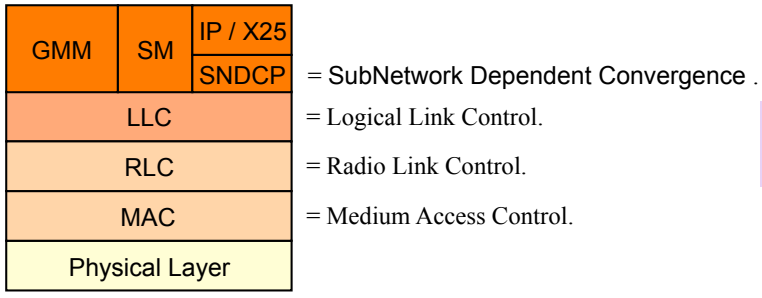
GPRS Protocols



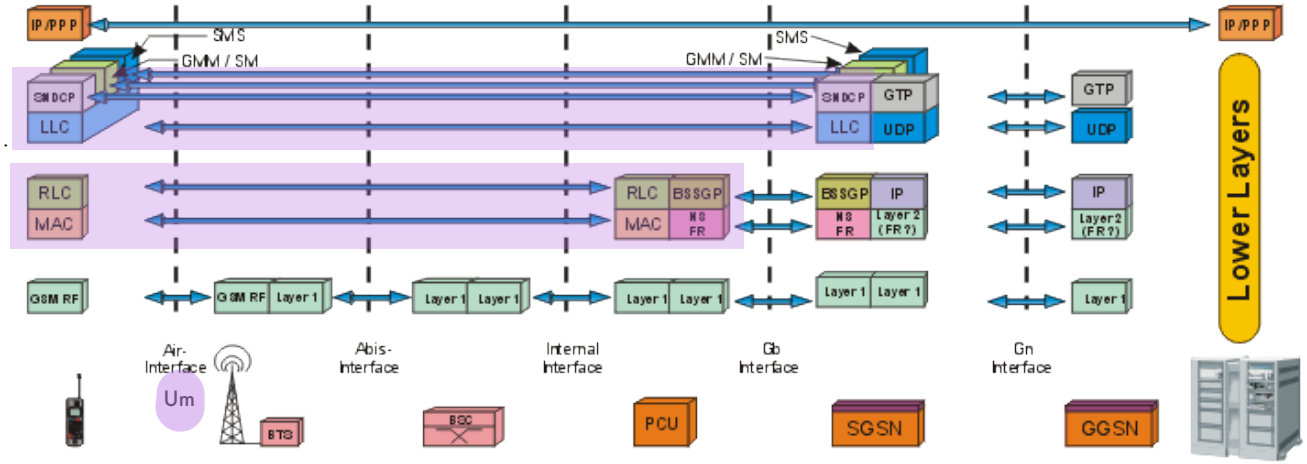


GPRS Um Interface

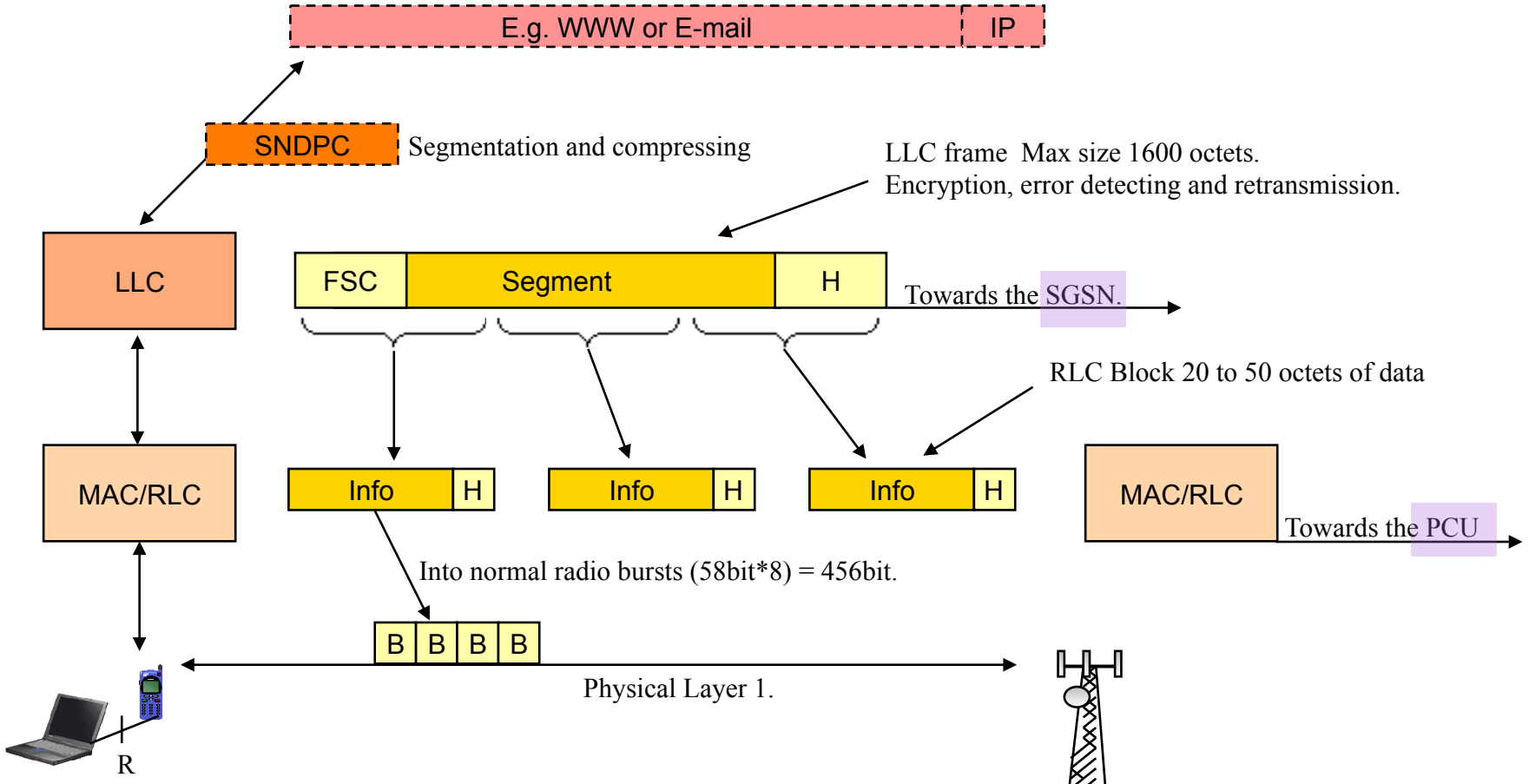
- RLC protocol and MAC protocol is in charge of all radio related control functions on the air interface (PCU and MS)
- LLC protocol is in charge of transmission between SGSN and *MS*
- Delivery of data units to the higher layer in the correct sequence
- SNDCP (Sub Network Dependent Convergence Protocol) protocol is in charge of segmentation and compression of data (SGSN and MS)



GPRS Um protocol stack



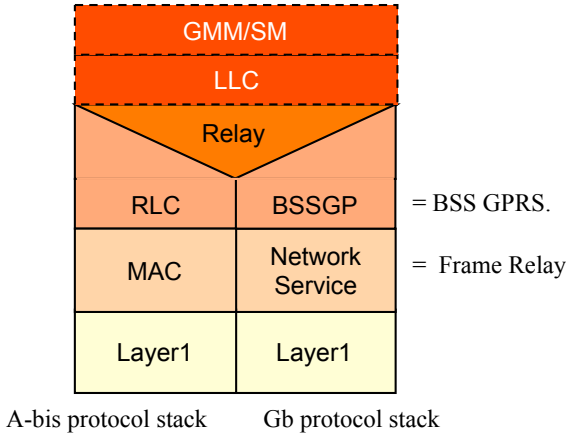
GPRS Um Interface

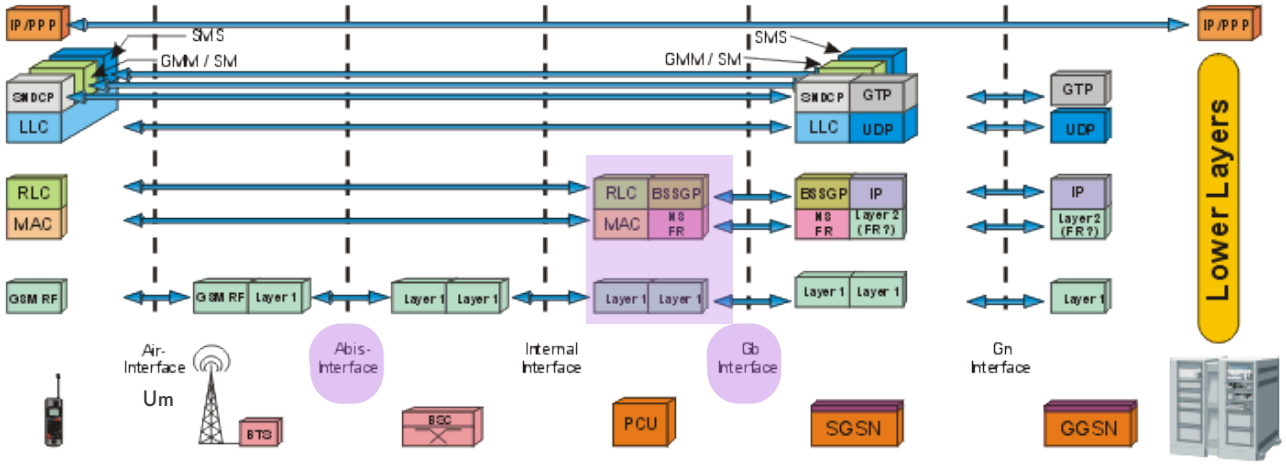


H = Header.
B = Normal Burst, see the GSM recommendation.
FSC = Frame Check Sequence.

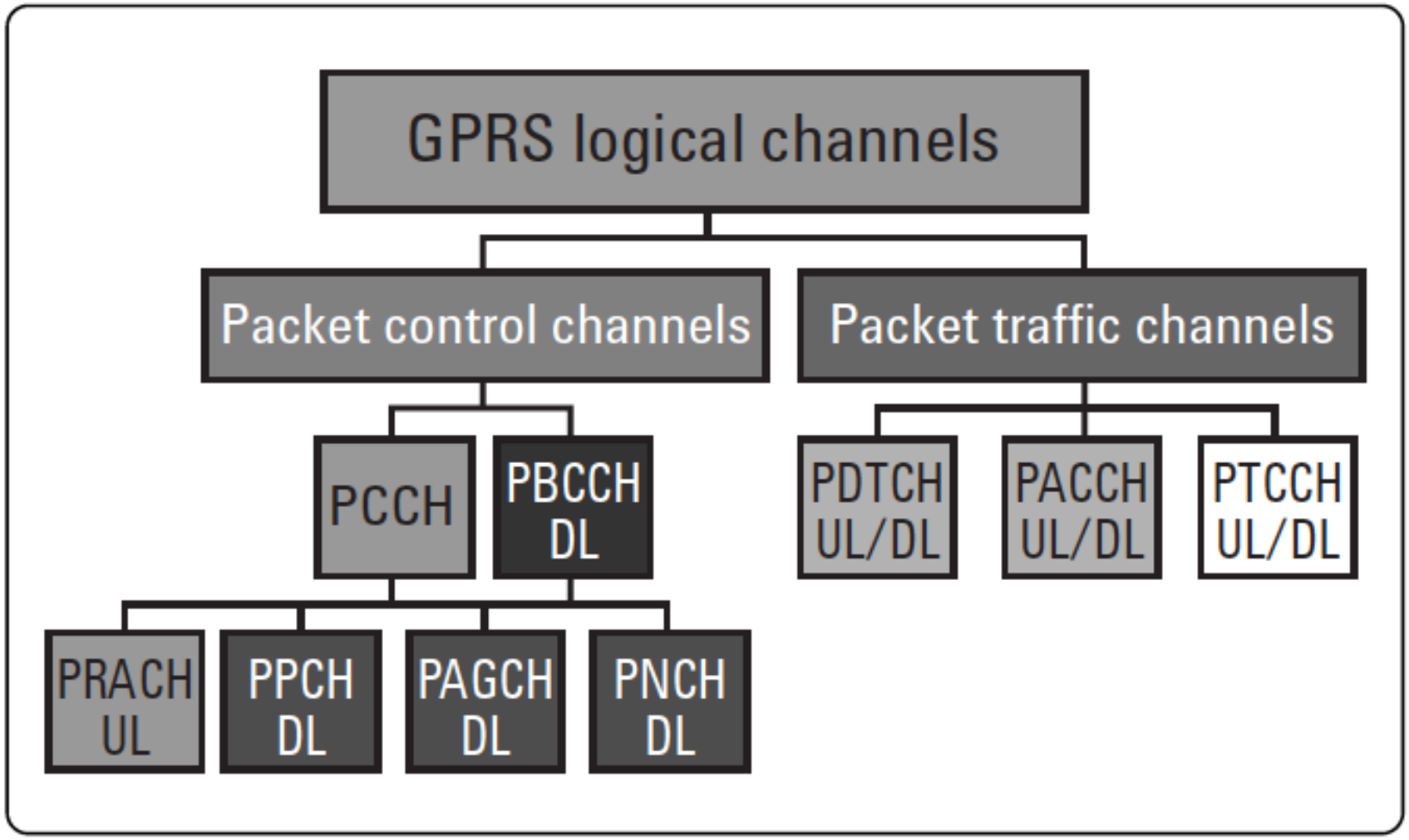
GPRS A-bis Interface

- In GPRS each vendor is making his own version of the A-bis protocol (not specified)
- The BTMS (BTS Management Protocol for GSM) has been changed to BSSGP (Base Station System GPRS Protocol)

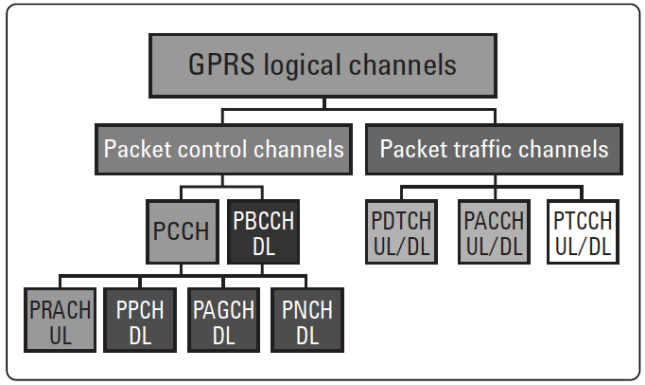




GPRS Logical Channels

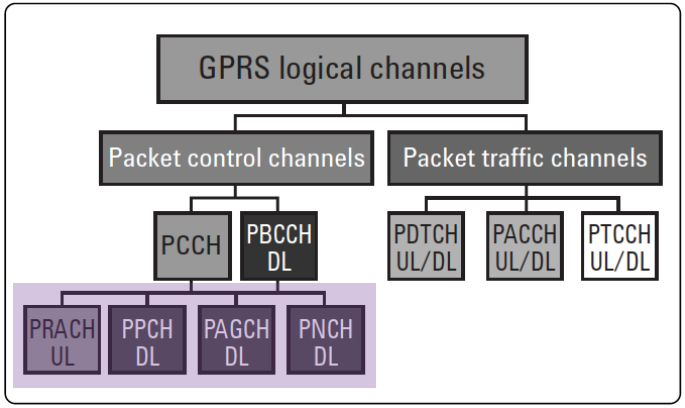


- Logical channels are pre-defined functions supported by frames within a physical channel
- GPRS physical channels generally carry two types of information
  - ✓ control signaling
    - establish and maintain a GPRS service
  - ✓ user data traffic
- GPRS logical channels
  - ✓ packet control channels
    - PCCCH (Packet Common Control Channel)
    - PBCCH (Packet Broadcast Control Channel)
  - ✓ packet traffic channels
    - PTCH (Packet Traffic Channel)



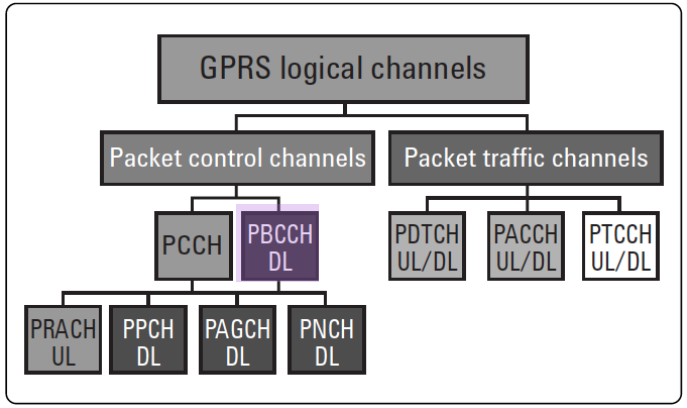
Packet Common Control Channel (PCCCH)

- Used for common signaling between MS and BS
  - ✓ PRACH (Packet Random Access Channel)
    - used only in uplink to initiate uplink transfer
  - ✓ PPCH (Packet Paging Channel)
    - used to page a mobile prior to downlink packet transfer
    - used for paging both circuit-switched and GPRS services
  - ✓ PAGCH (Packet Access Grant Channel)
    - used in the packet transfer establishment phase to send resource assignment messages to a mobile prior to packet transfer
  - ✓ PNCH (Packet Notification Channel)
    - used to send a point-to-multipoint multicast notification to a group of mobiles prior to point-to-multipoint multicast packet transfer



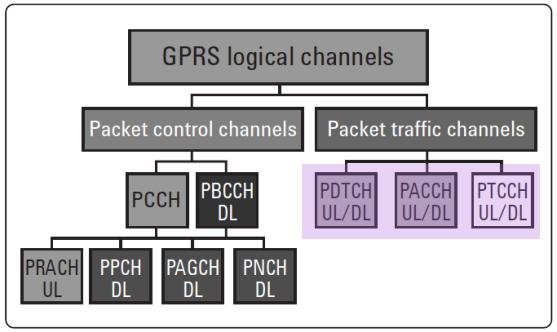
Packet Broadcast Control Channel (PBCCH)

- Used to broadcast packet data system information to all GPRS mobiles in a cell



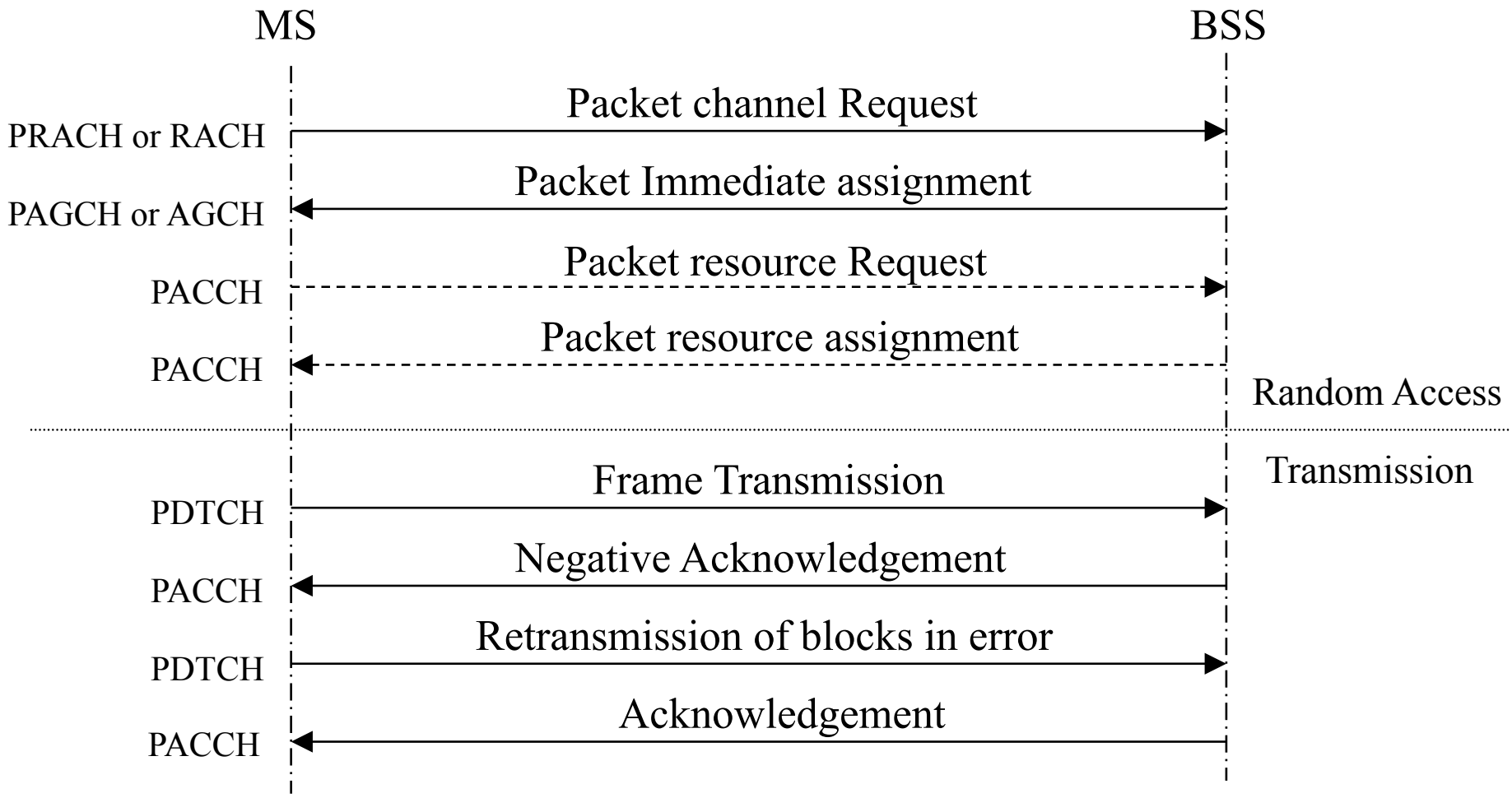
Packet Traffic Channel (PTCH)

- PTCH consists of the following sub-channels associated with traffic
  - ✓ PDTCH (Packet Data Traffic Channel)
    - allocated for data transfer
    - it is dedicated temporarily to one or a group of mobiles for multicast applications
    - one mobile may use multiple PDTCHs in parallel for packet data transfer during multislot operation
  - ✓ PACCH (Packet Associated Control Channel)
    - used to convey signaling information related to a given mobile, e.g., power control, packet acknowledgments, or resource reassignments
    - one PACCH is associated with one or several PDTCHs concurrently assigned to a mobile
  - ✓ PTCCH (Packet Timing Advance Control Channel)
    - used in the uplink for transmission of random access burst
    - it allows the timing advance required by the mobile in the packet transfer mode to be estimated
    - in the downlink, the PTCCH can be used to update the timing advance to multiple mobiles

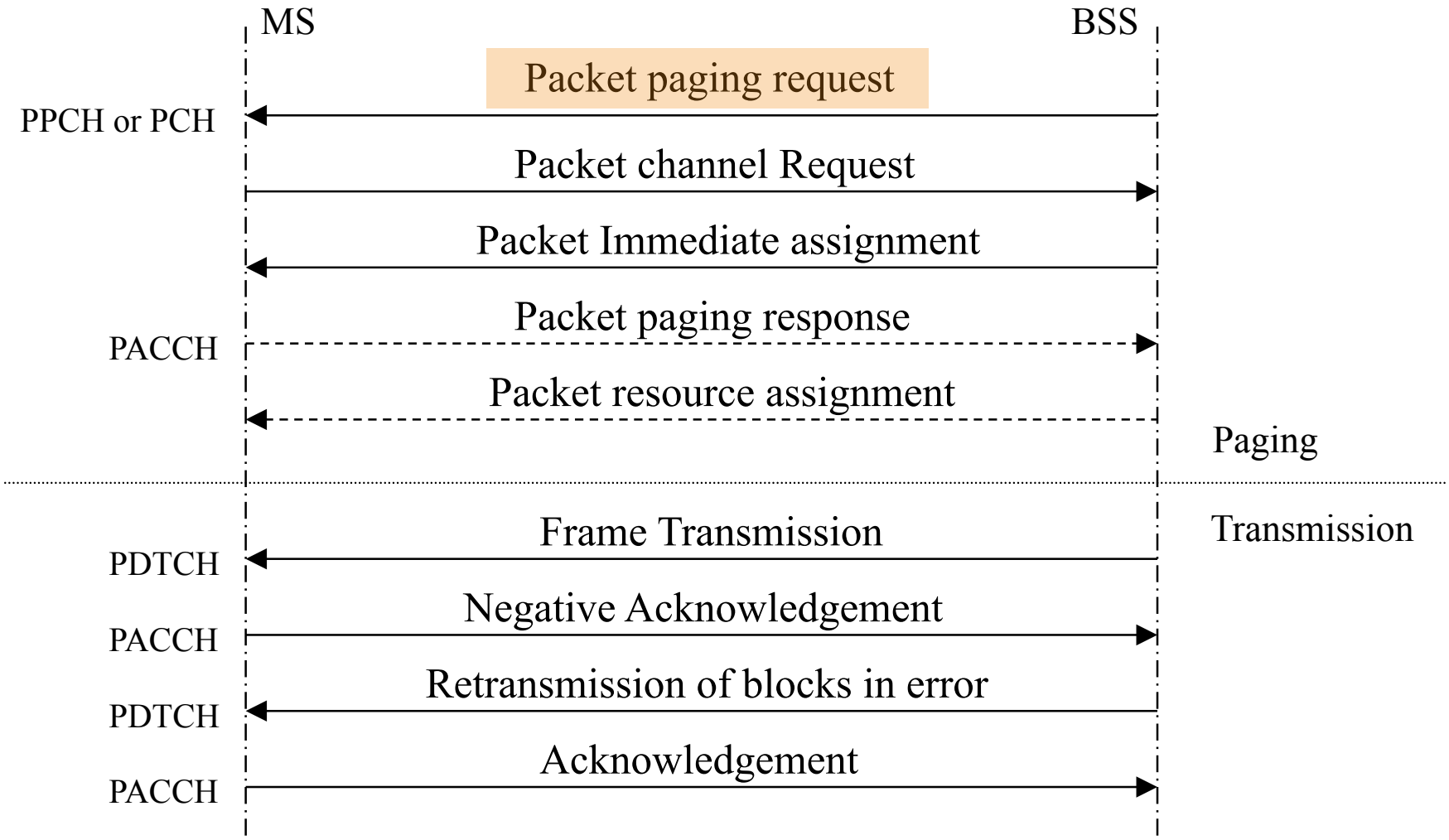


Group	Channel	Function	Direction
Packet data Traffic channel	PDTCH	Data Traffic	MS ⟷ BSS
Packet broadcast control channel	PBCCH	Broadcast Control	MS ⟵ BSS
Packet common Control Channel (PCCCH)	PRACH	Random Access	MS ⟶ BSS
	PAGCH	Access Grant	MS ⟵ BSS
	PPCH	Paging	MS ⟵ BSS
	PNCH	Notification	MS ⟵ BSS
Packet Dedicated Control Channels	PACCH	Associated Control	MS ⟷ BSS
	PTCCH	Timing Advance Control	MS ⟷ BSS

Uplink Data Transfer



Downlink Data Transfer



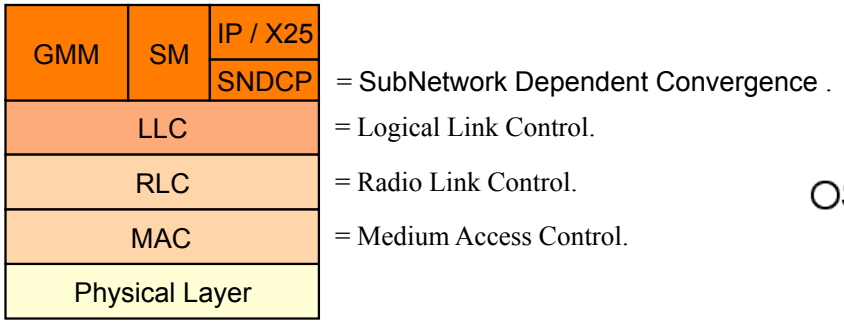
Physical Layer (GSM RF)

- The channel coding functions
  - ✓ four channel coding schemes are defined (CS1-CS4)
- Cell selection/reselection
- Setting of Timing Advance (TA)
- Perform measurements on the neighboring cells

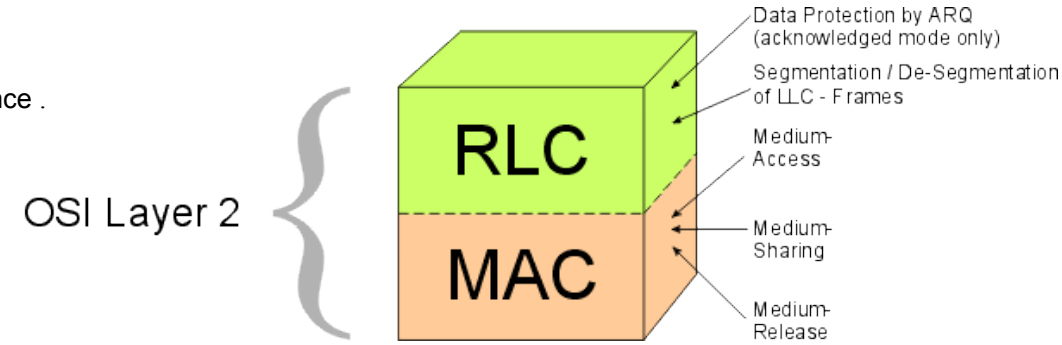
Coding scheme	RLC data and header	RLC/MAC header and data	Data rate-kbps	USF	BCS	Tail bits	Total raw bits	Coding	Puncturing	Encoded bits
1	22 octets	181 bits	9.05	3	40	4	228	Half rate	No	456
2	32 octets	268 bits	13.4	6	16	4	294	Half rate	132	456
3	38 octets	312 bits	15.6	6	16	4	338	Half rate	220	456
4	52 octets	428 bits	21.4	12	16	0	456	No	No	456

Radio Link Control / Medium Access Control (RLC / MAC)

- RLC/MAC protocol is defined between MS and PCU (Packet Control Unit)
- In charge of all radio related control functions on the air interface
- Performs segmentation of LLC frames into radio blocks

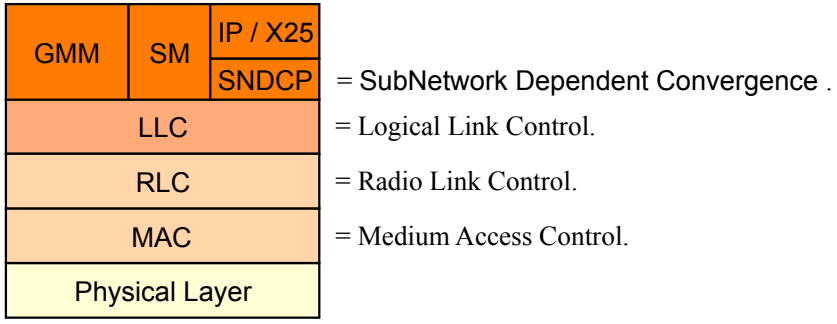


GPRS Um protocol stack



Logical Link Control (LLC)

- LLC provides different types of services to different upper layer applications, namely SNDCP GMM/SM and SMS
- Provides the transport frames for the data transfer between MS and SGSN
- Encapsulation of higher layer protocol data units into LLC data units
- Delivery of data units to the higher layer in correct sequence
- Ciphering and deciphering (if enabled)



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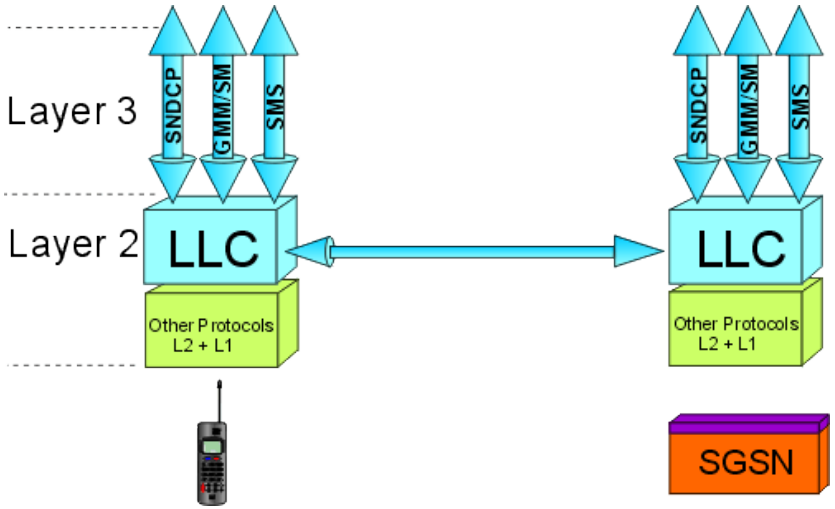
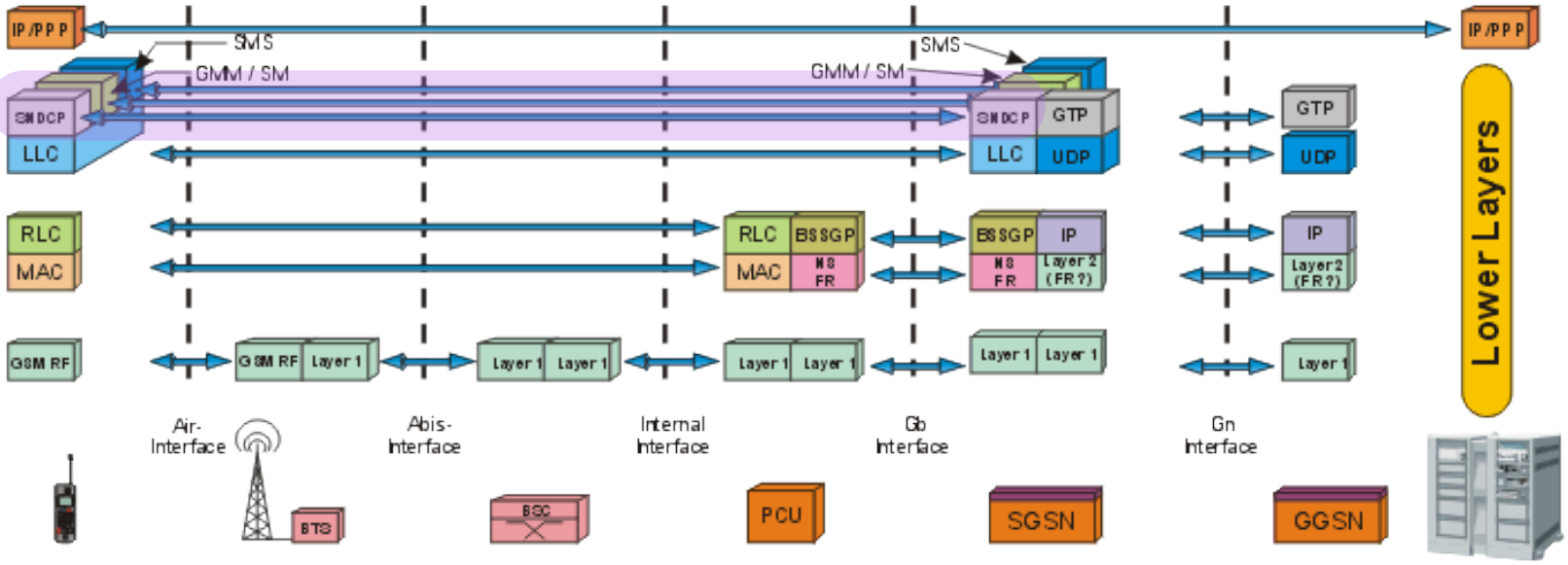


Sub-Network Dependent Convergence Protocol (SNDCP)

- The SNDCP is applicable between MS and SGSN
  - ✓ within SGSN, there is a relay function from SNDCP towards GPRS Tunneling Protocol (GTP)
- Segmentation of user data packets (max 1520 octets)
  - ✓ compression of Packet Data (optional)
- Relies completely on the error recovery and transmission capabilities of LLC

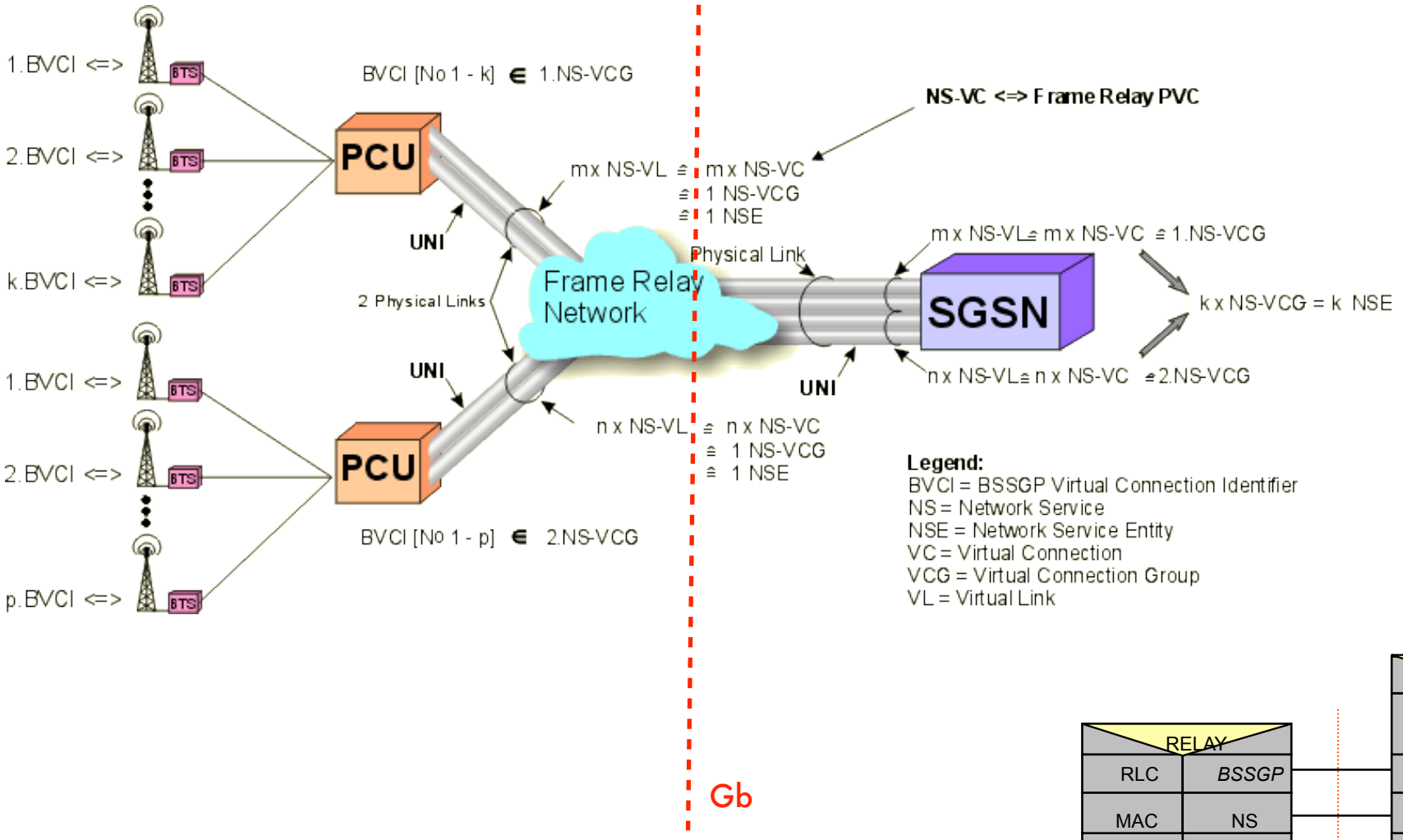


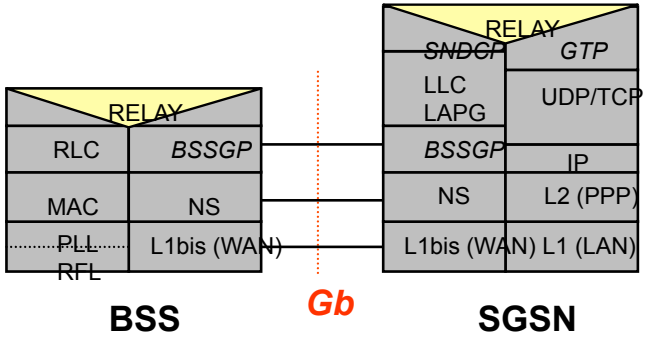
Coding Schemes (CS) in GPRS

- To achieve higher throughput rates per timeslot than plain GSM, GPRS introduces three new coding schemes
  - ✓ CS-1. throughput ≦ 9.05 kbps (also provided by GSM)
  - ✓ CS-2. throughput ≦ 13.4 kbps
  - ✓ CS-3. throughput ≦ 15.6 kbps
  - ✓ CS-4. throughput ≦ 21.4 kbps
- Due to unpredictable environment of the radio transmission the distance between MS and cell impacts the QoS
- The different CS are therefore not always available

Coding scheme	RLC data and header	RLC/MAC header and data	Data rate-kbps	USF	BCS	Tail bits	Total raw bits	Coding	Puncturing	Encoded bits
1	22 octets	181 bits	9.05	3	40	4	228	Half rate	No	456
2	32 octets	268 bits	13.4	6	16	4	294	Half rate	132	456
3	38 octets	312 bits	15.6	6	16	4	338	Half rate	220	456
4	52 octets	428 bits	21.4	12	16	0	456	No	No	456

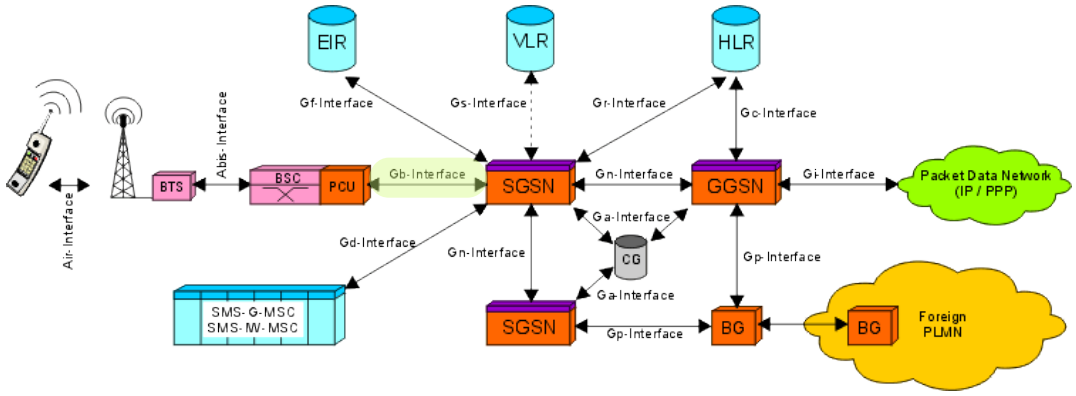
GPRS Gb Interface

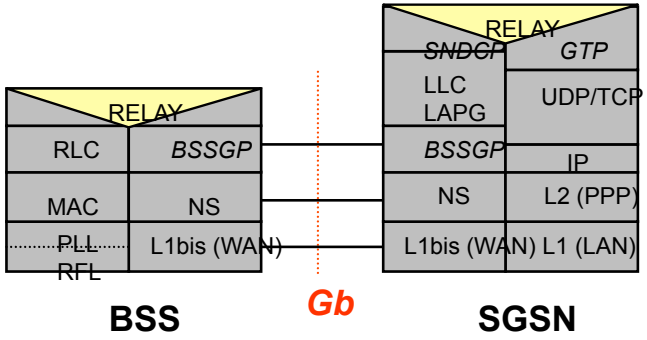




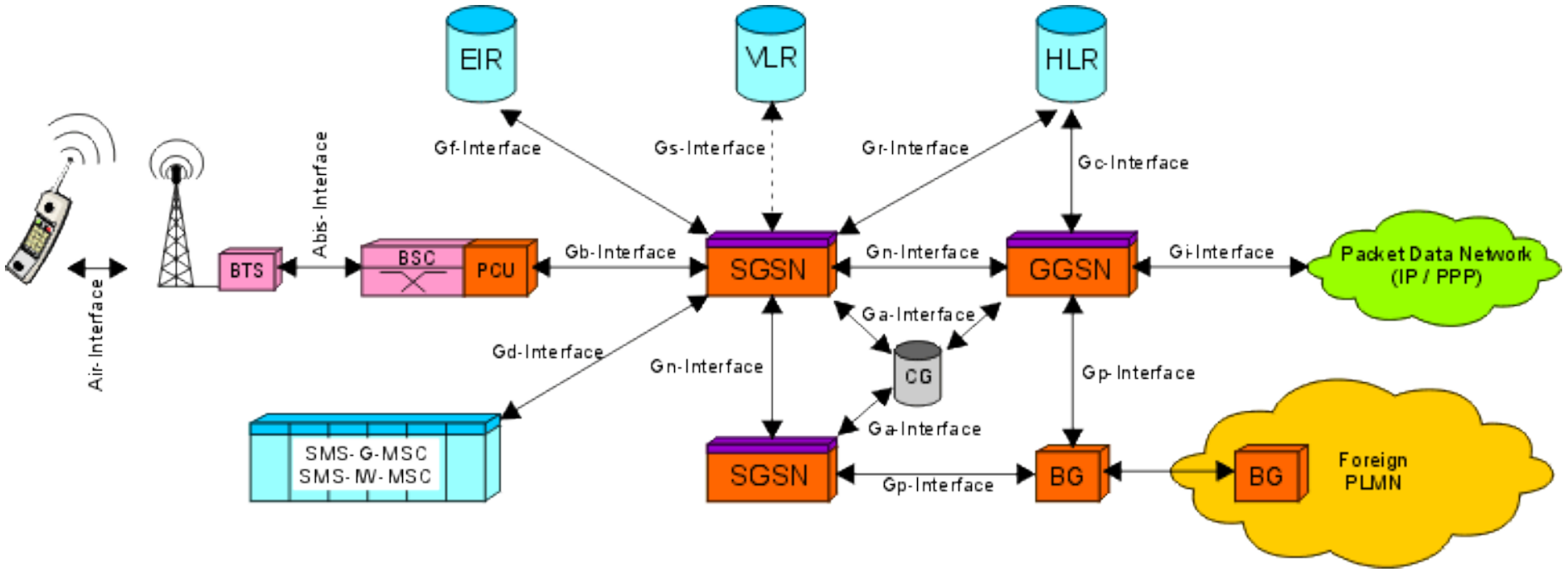
Gb Protocol Layers

- BSSGP (BSS GPRS Protocol)
  - ✓ transparent transfer of signaling and data PDUs between SGSN and PCU
  - ✓ administration of the packet-switched link resources between SGSN and PCU
  - ✓ initiation of packet-switched paging for a particular MS if requested by SGSN
- NS (Network Service) - consists of two sublayers
  - ✓ Network Service Control Protocol
    - provides virtual connections (NS-VC) between the SGSN and the PCU
    - these VCs need to be administrated by the NS protocol
  - ✓ Frame Relay Protocol
    - NS is a packet-switched protocol: a single virtual connection may use resources from 0 kbps up to entire bandwidth of the transmission link
    - transports BSSGP PDUs between BSS and SGSN



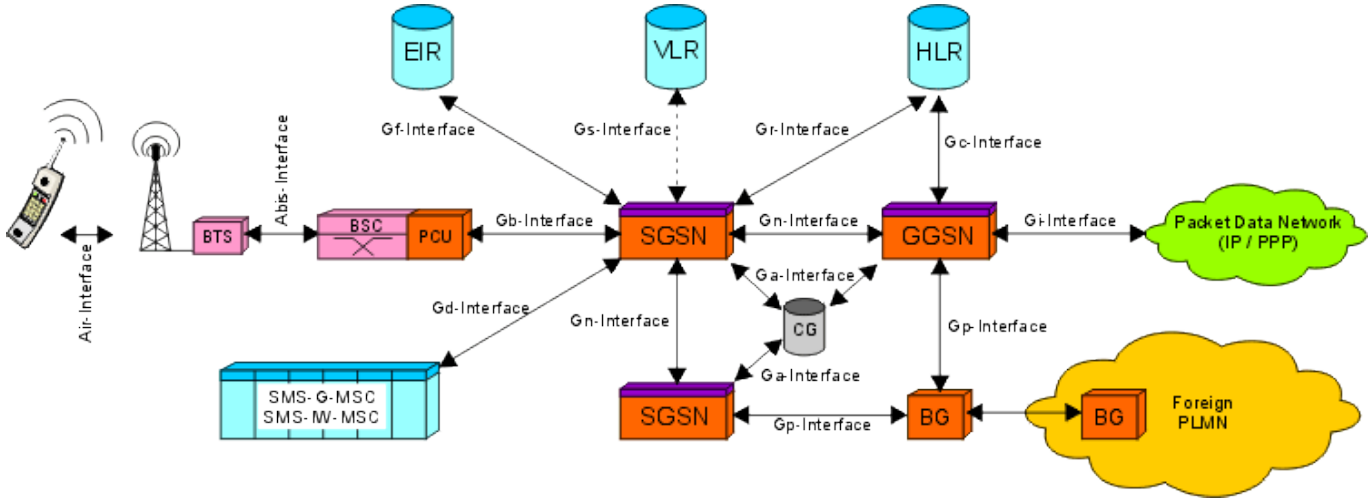


GPRS Interfaces



Other GPRS Interfaces

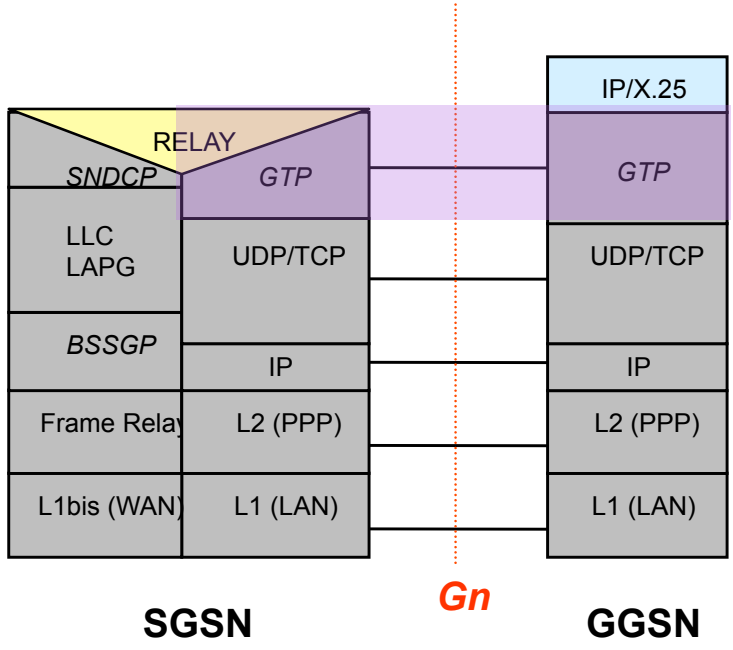
- Gn - GSN backbone network
  - ✓ private IP network intended for GPRS data/signaling only
  - ✓ connects the GPRS Support Nodes (GSNs) together within a GPRS PLMN
- Gp – inter-PLMN backbone network
  - ✓ PLMN to PLMN connection (i.e. roaming) via Border Gateways (BG)
  - ✓ packet data network (public Internet or leased line)
- Gi
  - ✓ interface to external packet data network (IP)



- Gs – SGSN to MSC/VLR
  - ✓ used to perform IMSI attach and GPRS attach simultaneously
  - ✓ combined paging procedures, where all paging is done form SGSN
- Gr – SGSN to HLR
  - ✓ SGSN must contact the HLR whenever a new subscriber enters one of its Routing Areas
- Gd – SGSN to SMS
  - ✓ used if SMS is forwarded over GPRS channels
- Gf – SGSN to EIR
  - ✓ used to check the IMEI number

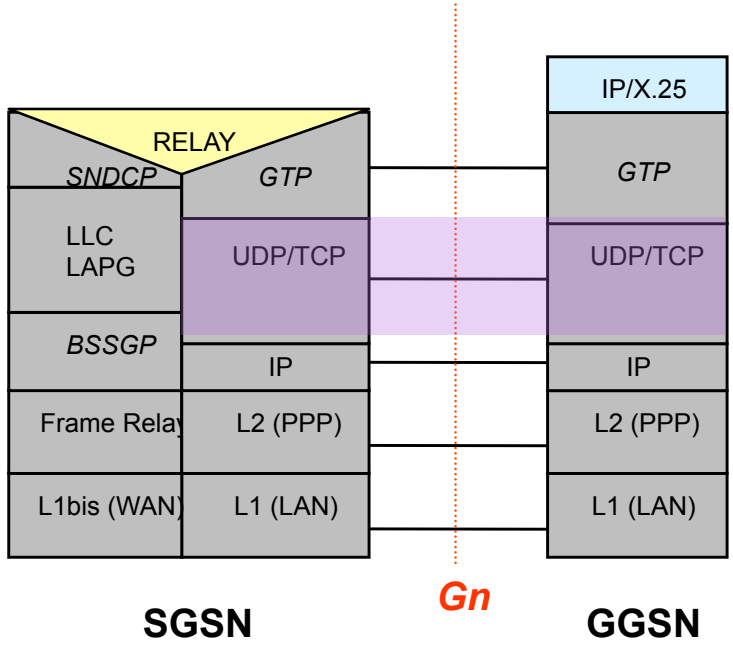
GPRS Tunnel Protocol (GTP)

- Allows multi-protocol packets to be tunneled through GPRS backbone between GPRS Support Nodes (GSNs)
- Responsible for the transmission of both signaling information and application data
- Based on an IP-protocol stack and uses UDP as transport layer (OSI layer 4)
- Also takes care of the transfer of charging information



UDP / TCP

- TCP (Transmission Control Protocol)
  - ✓ manages the segmentation of a message or file into smaller packets that are transmitted over the Internet and received by a TCP layer that reassembles the packets into the original message
  - ✓ a connection-oriented protocol, which means that a virtual connection is established between the two peers of a TCP-transaction
  - ✓ usually, TCP is used together with IP
- UDP (User Datagram Protocol)
  - ✓ offers a limited amount of service compared to TCP
  - ✓ most importantly: UDP does not provide segmentation or sequencing functions
  - ✓ UDP is an alternative to TCP if network applications need to save processing time



GPRS Data Packet Transfer