# Wireless and Mobile Network Architecture

## Chapter 9
## General Packet Radio Service (GPRS)

Prof. **Yuh-Shyan Chen**

Department of Computer Science and Information Engineering

National Taipei University

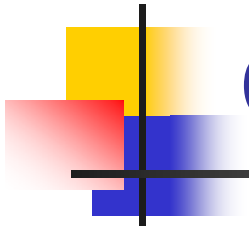
Nov. 2006

# Outline

- Introduction
- GPRS Functional Groups
- GPRS Architecture
- GPRS Network Nodes
- GPRS Interfaces
- GPRS Procedures
- GPRS Billing
- Evolving from GSM to GPRS
- Summary

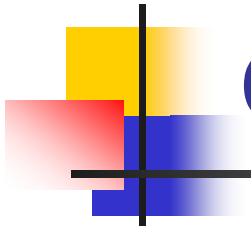
# GPRS vs. GSM

- In early 2000, only a small portion of GSM subscribers used data services
  - GSM do not support **easy access**, **high data rate**, and **attractive prices**.
- GPRS reuses the existing GSM infrastructure to provide end-to-end **packet-switched services**.
  - GPRS standardization was initiated by ETSI/SMG in 1994, and completed in 1999, GPRS products were developed in 1999.



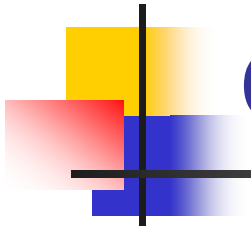
# GPRS

- The GPRS core network has been developed for IS-136 TDMA systems, and is anticipated to evolve as the core network of the third-generation mobile system.
- To accommodate GPRS, new radio channels are defined. The allocation of these channels is flexible.
  - One to eight time slots can be allocated to a user
  - Several active users can share a single time slot



# GPRS

- Various radio channel coding schemes are specified to allow bit rates from 9 Kbps to 150 Kbps per user.
- GPRS fast reservation is designed to start packet transmission within 0.5 to 1 second.
- GPRS security functionality is equivalent to the existing GSM security, where a ciphering algorithm is optimized for packet data transmission



# GPRS

- GPRS is a relatively **inexpensive** mobile data service compared to Short Message Service (SMS) and **Circuit-Switched Data**.

# 18.1 GPRS Functional Groups

(1) **Network access**

(2) **Packet routing and transfer**

(3) **Mobility management**

- Keeps track of the current location of an MS
- Cell update, routing area update, combined routing area, and location area update

(4) **Logical link management**

(5) **Radio resource management**

(6) **Network management**

- provides mechanism to support OA&M functions

# Network Access

- Registration
- Authentication and authorization
- Admission control
- Message screening
- Charging information collection for packet transmission in GPRS and external networks

# Packet Routing and Transfer

- Packet routing and transfer function route the data between an MS and the destination through the serving and gateway GPRS support Nodes (GSNs)
  - Relay function
  - Routing
  - Address translation and mapping
  - Encapsulation and tunneling
  - Compression and ciphering
  - Domain name service functions

# Logical Link Management

- Logical link establishment
- Logical link maintenance
- Logical link release

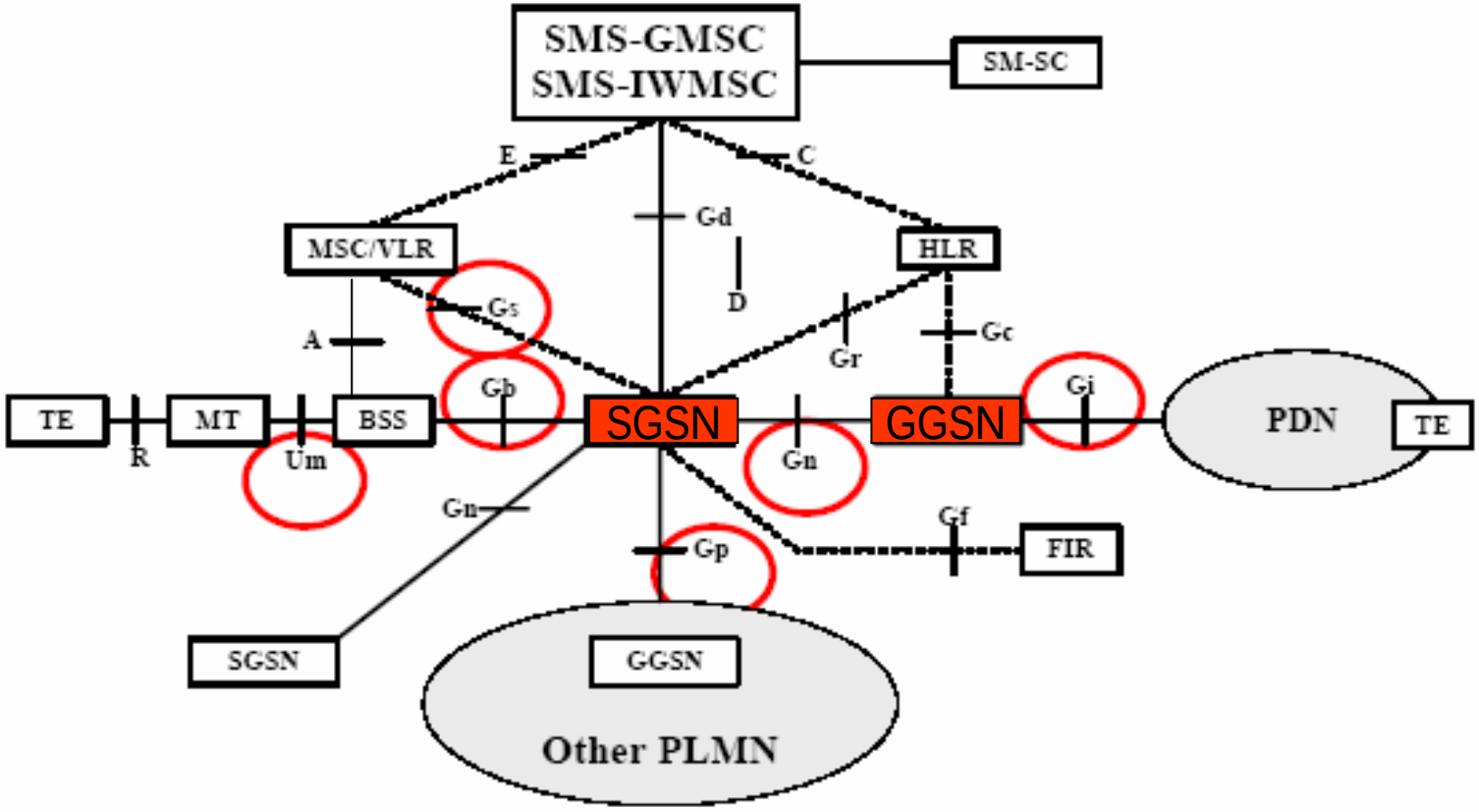
# Radio Resource Management

- Um management
- Cell selection
- Um-tranx, which provides packet data transfer capability
  - Medium access control, etc.
- Path management

# 18.2 GPRS Architecture

- **MS**, **BSS (Base Station System)**, **mobile switching** center/visitor location register (MSC/VLR), and **home location register** (HLR) in the existing GSM network are modified
- Two new network nodes are introduced in GPRS network
  - The serving GPRS support node (**SGSN**) is the GPRS equivalent to the MSC
  - The gateway GPRS support node (**GGSN**) provides interworking with external packet-switched network

# GPRS Interfaces



# 18.2 GPRS Architecture

- **Gr** and **Gc** follow the GSM MAP protocol
- **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

# 18.3 GPRS Network Nodes

- **Mobile Station**
  - A GPRS **MS** consists of a mobile terminal (**MT**) and terminal equipment (**TE**).
  - An MT communicates with the BSS over the air.
  - The MT is equipped with software for GRPS functionality in order to **establish links to the SGSN**
  - The existing GSM For example, GSM MS does not support GPRS
  - For example, GPRS MS utilizes **automatic retransmission (ARQ)** at the data link layer to retransmit the error frames

# 18.3.2 Base Station System

- **Base Station System**
  - To accommodate GPRS, the **base transceiver station** (**BTS**) and the base station controller (BSC) on the BSS are modified.
  - A new component, the **packet control unit** (**PCU**), is introduced.
  - The BTS is modified to support new GPRS channel coding schemes.
  - The BSC forwards circuit-switched calls to the MSC, and **packet-switched data** (through the **PCU**) to the SGSN.

# 18.3.3 **GPRS Support Node**

- A serving GSN (**SGSN**)
  - The role of an SGSN is equivalent to that of the MSC/VLR in the current GSM network
- A gateway GSN (**GGSN**)
  - The GGSN is primarily provisioned by a router, which supports traditional gateway functionality
    - Publishing subscriber addresses
    - Mapping addresses
    - Routing and tunneling packets
    - Screening messages
    - Counting packets

# 18.3.4 **HLR** and **VLR**

- **New fields in the MS** record are introduced in HLR
  - They are accessed by SGSN and GGSN using IMSI as the index key
  - These fields are used to map an MS to one or more GGSNs
- In **MSC/VLR**, new field, SGSN number, is added to indicate the SGSN currently serving the MS.

# 18.4 GPRS Interfaces

- Um (BSS ↔ MS)
- Gb (BSS ↔ SGSN)
- Gn (SGSN ↔ GGSN)
- Gp (SGSN ↔ GGSN in Other GPRS Network)
- Gs (SGSN ↔ MSC/VLR)
- Gi (GGSN ↔ PDN)

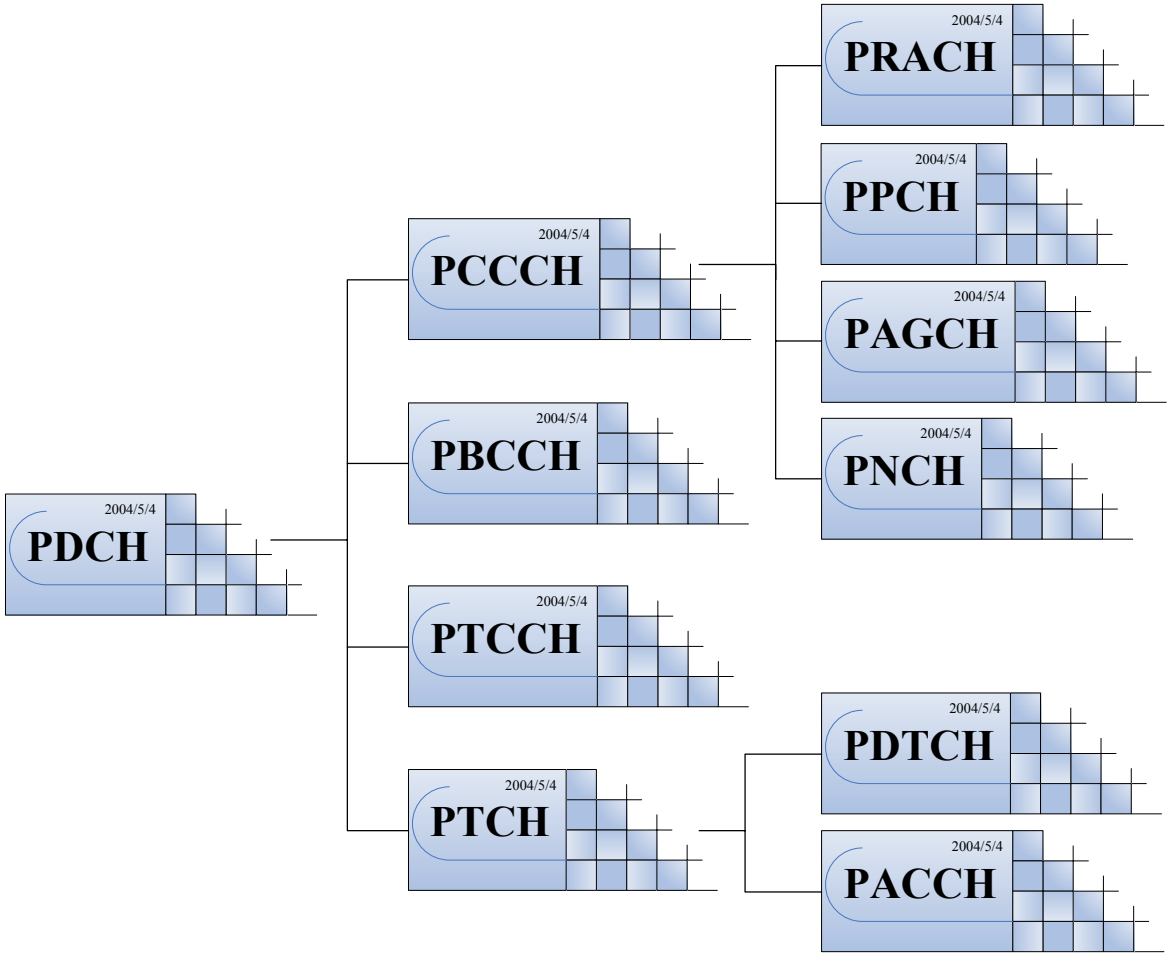
# 18.4.1 Um Interface (BSS ↔ MS)

- Um radio interface: radio interface between MS and BTS
- GPRS radio technology
  - Based on the GSM radio architecture
  - New logical channel structure
    - To control signaling and traffic flow over the Um radio interface

# Radio Channel Structure

- The physical channel dedicated to packet data traffic is called a *packet data channel* (**PDCH**).
- Different logical channels can occur on the same PDCH.

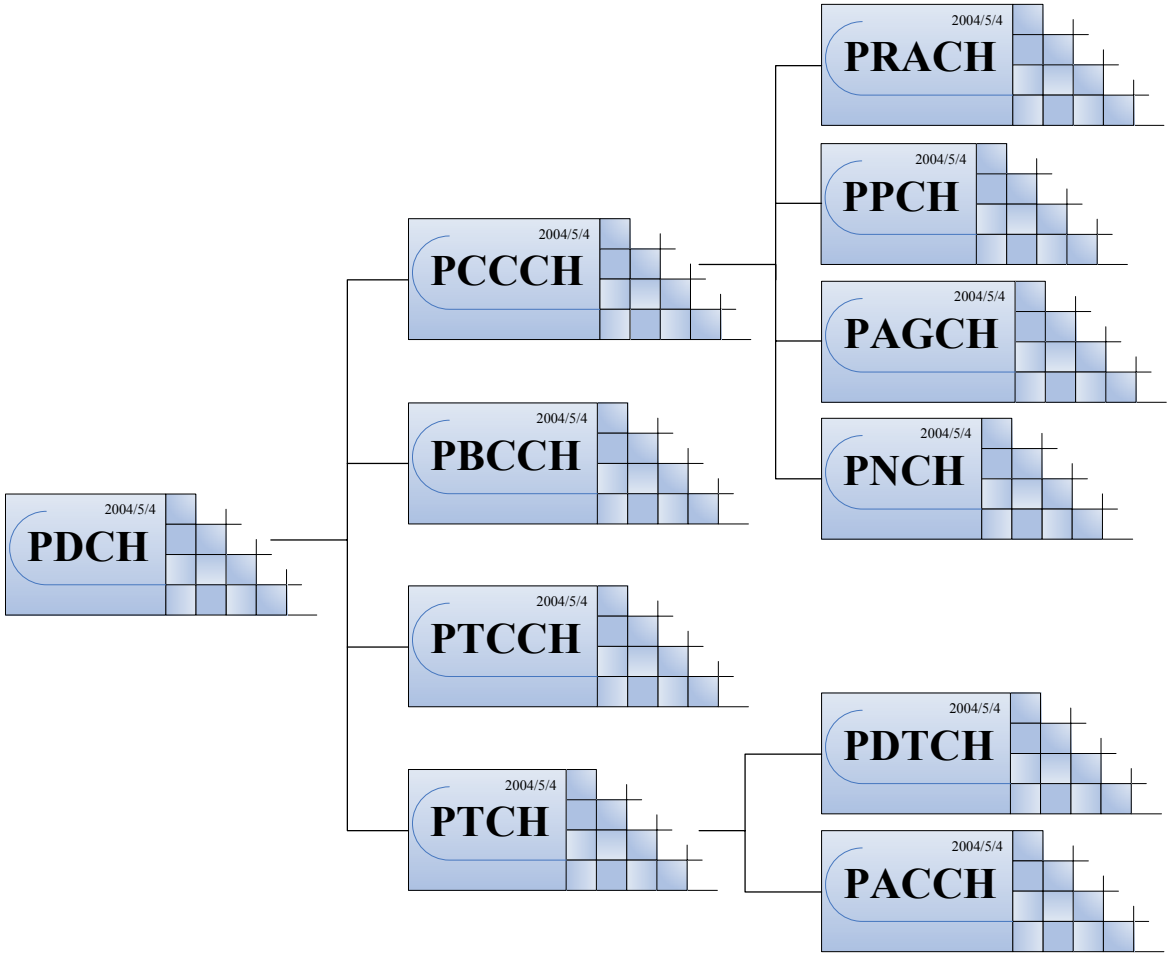
# Logical Channel Map



# Logical Channels (PCCCH) (1/2)

- Packet **Common** Control Channel (**PCCCH**)
  - Convey common control channel
  - Whether PCCCH is allocated or not, CCCH can be used to initiate a packet transfer.
  - PCCCH includes PRACH, PPCH, PAGCH, PNCH.
- Packet Random Access Channel (PRACH) (**MS → BTS**)
  - To initiate uplink transfer for data or signaling

# Logical Channel Map



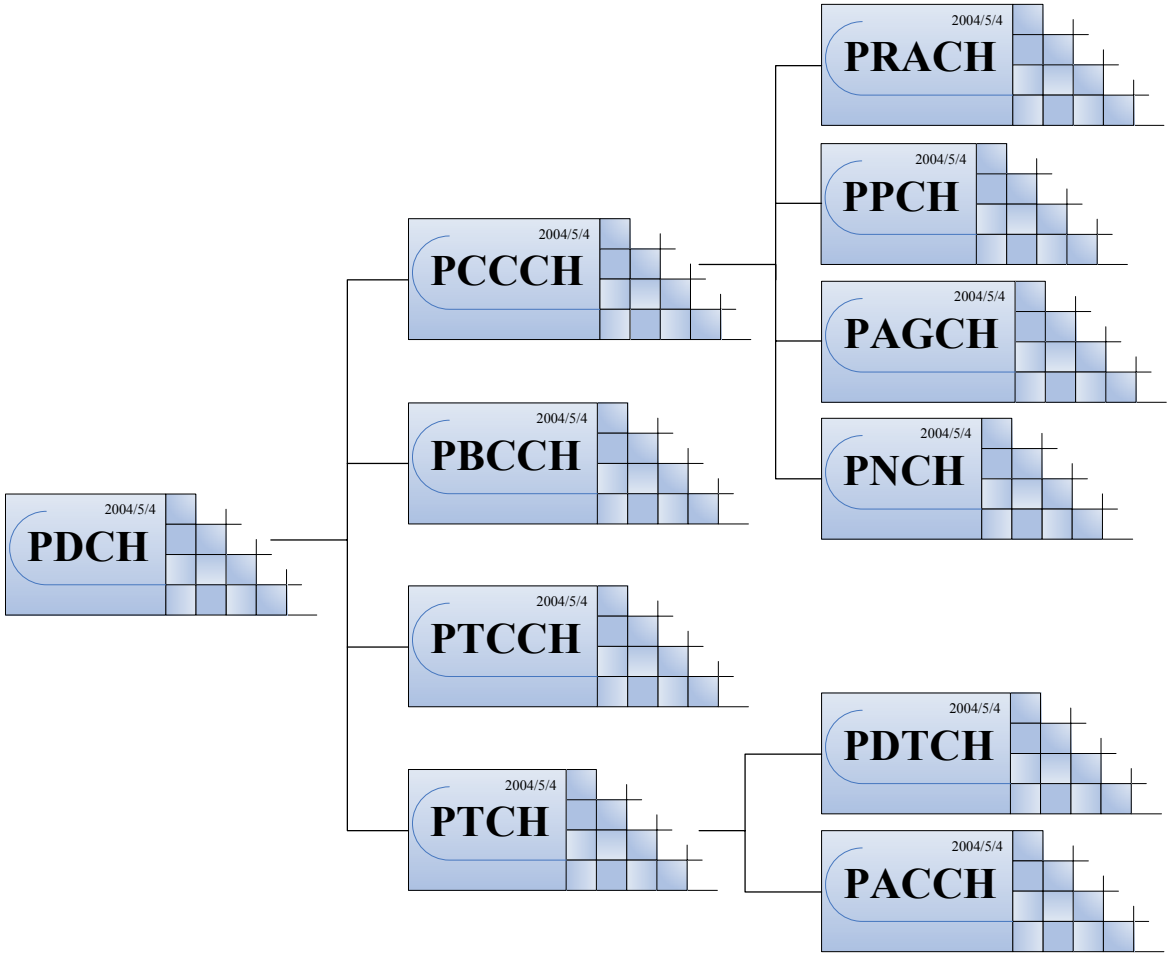
# Logical Channels (PCCCH) (2/2)

- Packet Paging Channel (PPCH) (BTS → MS)
  - Page an MS for both circuit-switched and packet data services
- Packet Access Grant Channel (PAGCH) (BTS → MS)
  - Resource assignment in the packet transfer establishment phase
- Packet Notification Channel (PNCH) (BTS → MS)
  - Used to send a Point-To-Multipoint Multicast (PTM-M) notification for resource assignment.

# PBCCH & PTCCH

- Packet **Broadcast** Control Channel (**PBCCH**)
  - Broadcast system information specific for packet data
  - If PBCCH is not allocated, GSM BCCH can be used for broadcast.
- Packet **Timing** Advance Control Channel (**PTCCH**) (BTS ↔ MS)
  - Transmit a random access burst
  - BSS estimates timing advance. BSS to transmit timing advance information updates to MS.

# Logical Channel Map



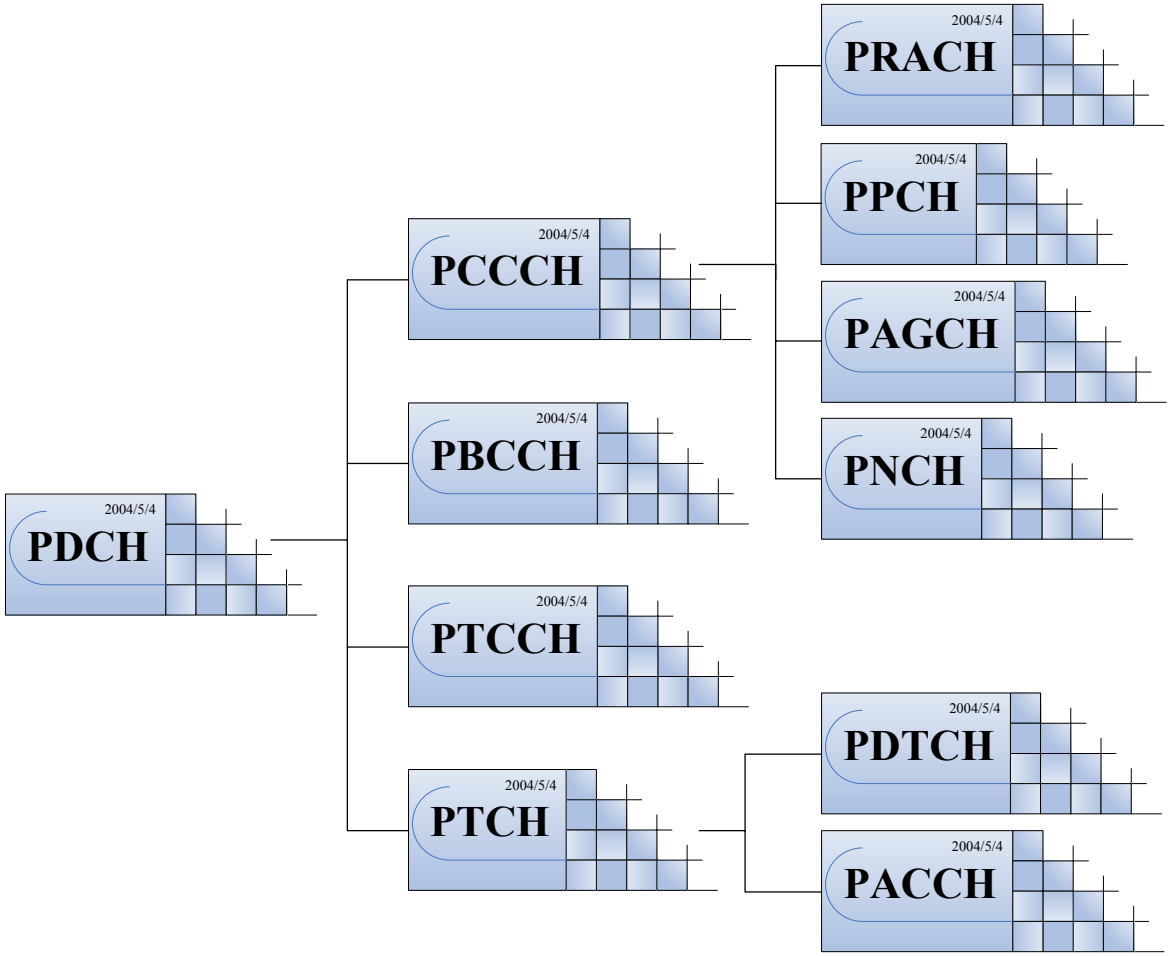
# Packet **Traffic** Channels (**PTCH**)

- Packet **Data** Traffic Channel (PDTCH)
  - One PDTCH ↔ one physical channel
  - Up to eight PDTCHs per MS
- Packet Associated Control Channel (PACCH)
  - Conveys **power control**, **resource assignment** and **reassignment information**.
  - PACCH shares resources via PDTCHs.
  - An MS currently involved in packet transfer can be paged for circuit-switched services on PACCH.

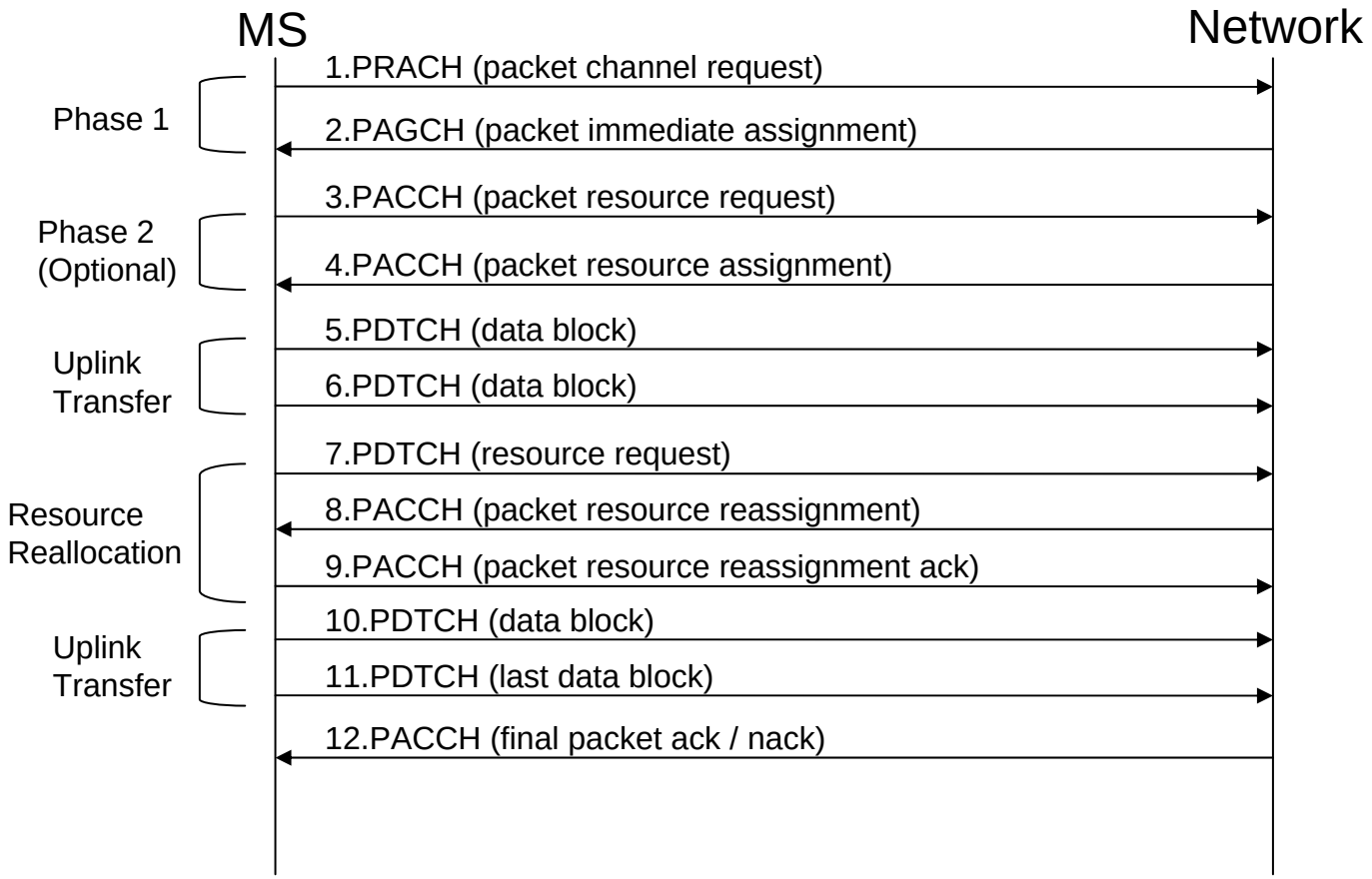
# Two Concepts for GPRS Channel Management

- Master-Slave
  - Master: at least one PDCH
    - PCCCH: control signalling for initiating packet transfer.
  - Salves: Other PDCHs
    - PDTCH: for user data transfer
    - PACCH: for dedicated signalling
- Capacity on Demand
  - The allocation of capacity for GPRS is based on the needs for actual packet transfers.
  - The operator decides the allocation of physical resources (i.e. PDCHs) for the GPRS traffic.
  - PCCCH and PBCCH are not necessary to exist.

# Logical Channel Map



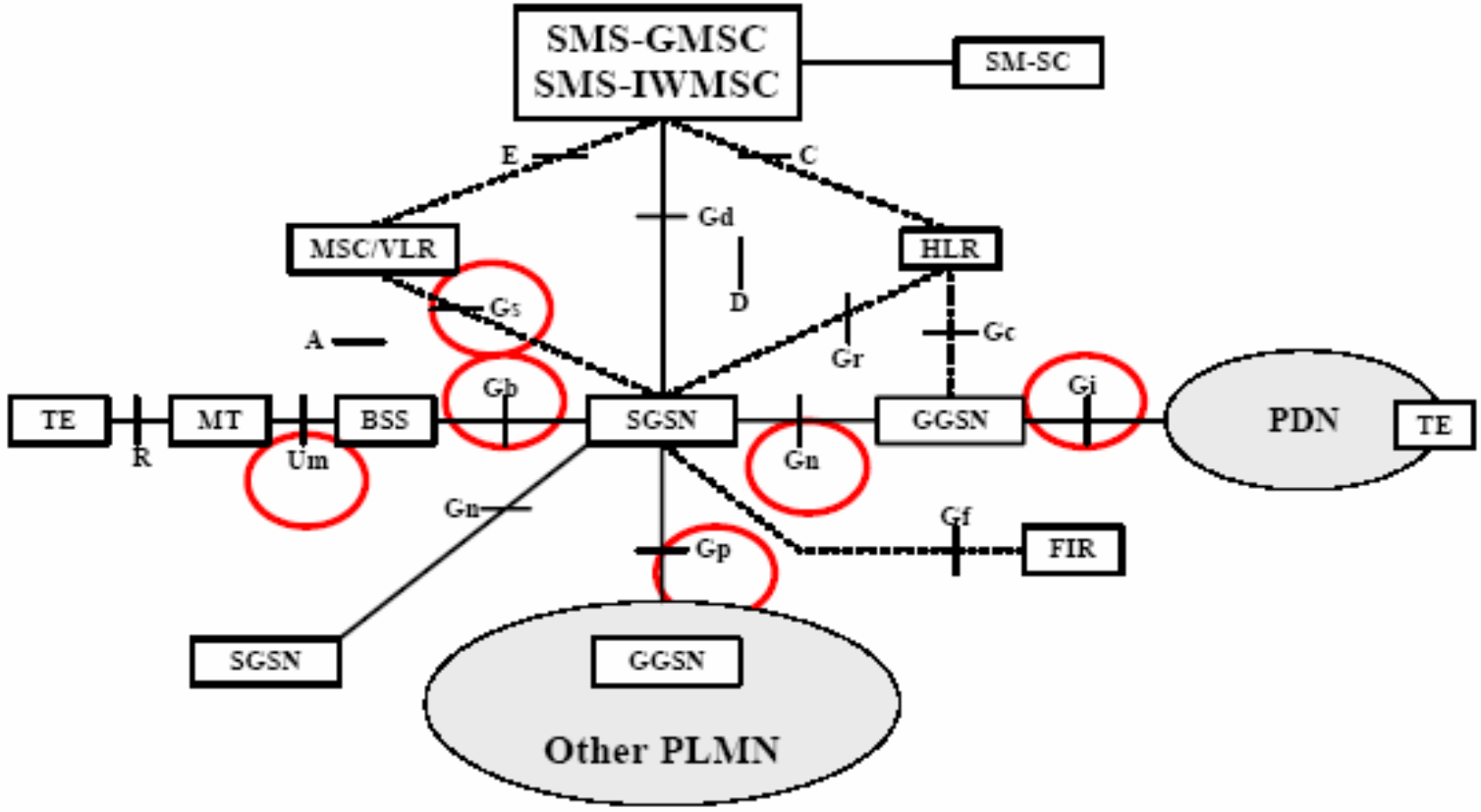
# Figure 18.5 GPRS Uplink **Packet** Transfer



# 18.4.1.2 Um Protocol Layers

- RF Layer (RFL)
  - Performs modulation/demodulation .
- Physical Link Layer (PLL)
  - Provides services for information transfer over a physical channel.
- Medium Access Control (MAC)
  - MAC is responsible for channel access (scheduling, queuing, contention resolution), PDCH multiplexing, and power control.
- Radio Link Control (RLC)
  - Block segmentation and reassembly, buffering, and retransmission with backward error correction.

# GPRS Interfaces



# Um Protocol Layers

- Four GPRS coding scheme – CS1, CS2, CS3, and CS4 – are defined.
  - The GPRS channel coding schemes increase the data rate, but at the cost of decreasing protection (correction capability).

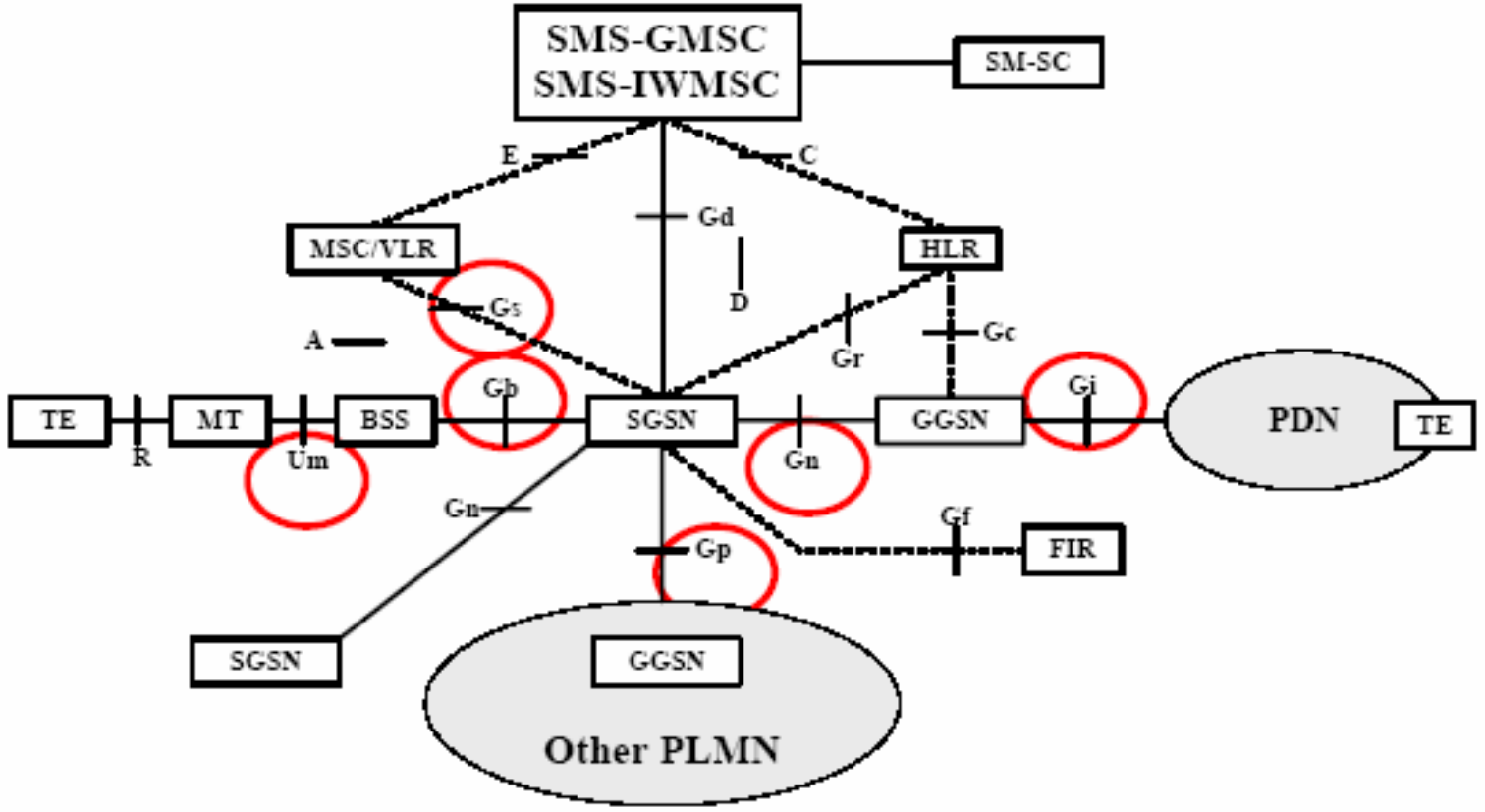
# Table 18.1 Four GPRS Coding Schemes

| Coding Scheme | CS1 | CS2 | CS3 | CS4 |
|---|---|---|---|---|
| User Data Rate | 9.05Kbps | 13.4Kbps | 15.6Kbps | 21.4Kbps |
| Correction Capability | Highest | | | None |
| Worst-Link Budget | 135dB | 133dB | 131dB | 128.5dB |
| Maximum Cell Range | 450m | 390m | 350m | 290m |

# 18.4.2 Gb Interface (MS ↔ BSS ↔ SGSN)

- The Gb interface allows many users to be
  - Multiplexed over the same physical resource.
- The Gb interface includes
  - Physical Layer
  - Layer 2
    - NS (Network Service; Frame Relay)
    - BSSGP (Base Station System GPRS Protocol)
    - Relay Function
    - LLC (Logical Link Control)
  - Layer 3
    - SNDCP (SubNetwork Dependent Convergence Protocol)
    - GMM SM (GPRS Mobility Management Session Management)

# GPRS Interfaces




5

# Network Service (NS)

- The NS layer delivers encapsulated packets between the SGSN and BSS that are connected directly by a frame link or indirectly through cascading links in a frame relay network.
- Physical layer (BBS ↔ SGSN): frame relay link
- Each frame relay link supports one or more **Network Service Virtual Links** (NS-VLs).
  - To construct an end-to-end virtual path between BSS and SGSN.
  - The path is Network Service Virtual Connection (NS-VC)

# Network Service (NS)

- NS manages NS-VCs.
  - Blocking
  - Unblocking
  - Resetting
  - Testing
- Using NS-VCs, **NS** transports data from uplayered

# Network Service (NS)

- BSSGP Packet Data Units (PDUs).
- The NS layer delivers encapsulated packets (SGSN ↔ BSS).
- Load sharing to distribute the packet traffic among the unblocked NS-VCs.

# BSS GPRS Protocol (BSSGP)

- BSSGP provides the radio-related QoS and Routing Information required to transmit user data (BSS ↔ SGSN).
- BSSGP Virtual Connection (BVC) provides communication path between BSSGP entities (i.e., BSS, SGSN).
  - BVC is supported by NS-VCs.
  - Each BVC transports BSSGP PDUs.
- Three service models supported by BSSGP:
  - BSSGP/RL service model
  - GMM Model
  - NM Model

# BSSGP/RL Service Model

- In BSS, Relay function provides buffering and parameter mapping between RLC/MAC and BSSGP.
- In SGSN, BSSGP controls the transfer of LLC frames across the Gb interface.
- PDU contains
  - User information (an LLC packet)
  - RLC/MAC-related information
  - A QoS profile
  - PDU lifetime

# GPRS Mobility Management (GMM) Service Model

- BSSGP GMM service model performs mobility management functions between **SGSN** and **BSS**.
- Examples of GMM service primitives provided by BSSGP are
  - **PAGING**
  - **SUSPEND**
  - **RESUME**

# The Network Management (**NM**) Service Model

- NM service model handles
  - Functions related to **Gb** interfaces
  - BSS and SGSN Node Management Control
    - BSSGP protocol machine
- Examples of BSSGP-supported NM service primitives are
  - FLOW-CONTROL-BVC
  - FLOW-CONTROL-MS
  - No flow control is performed in the uplink direction.
  - There is a downlink buffer for each BVC.

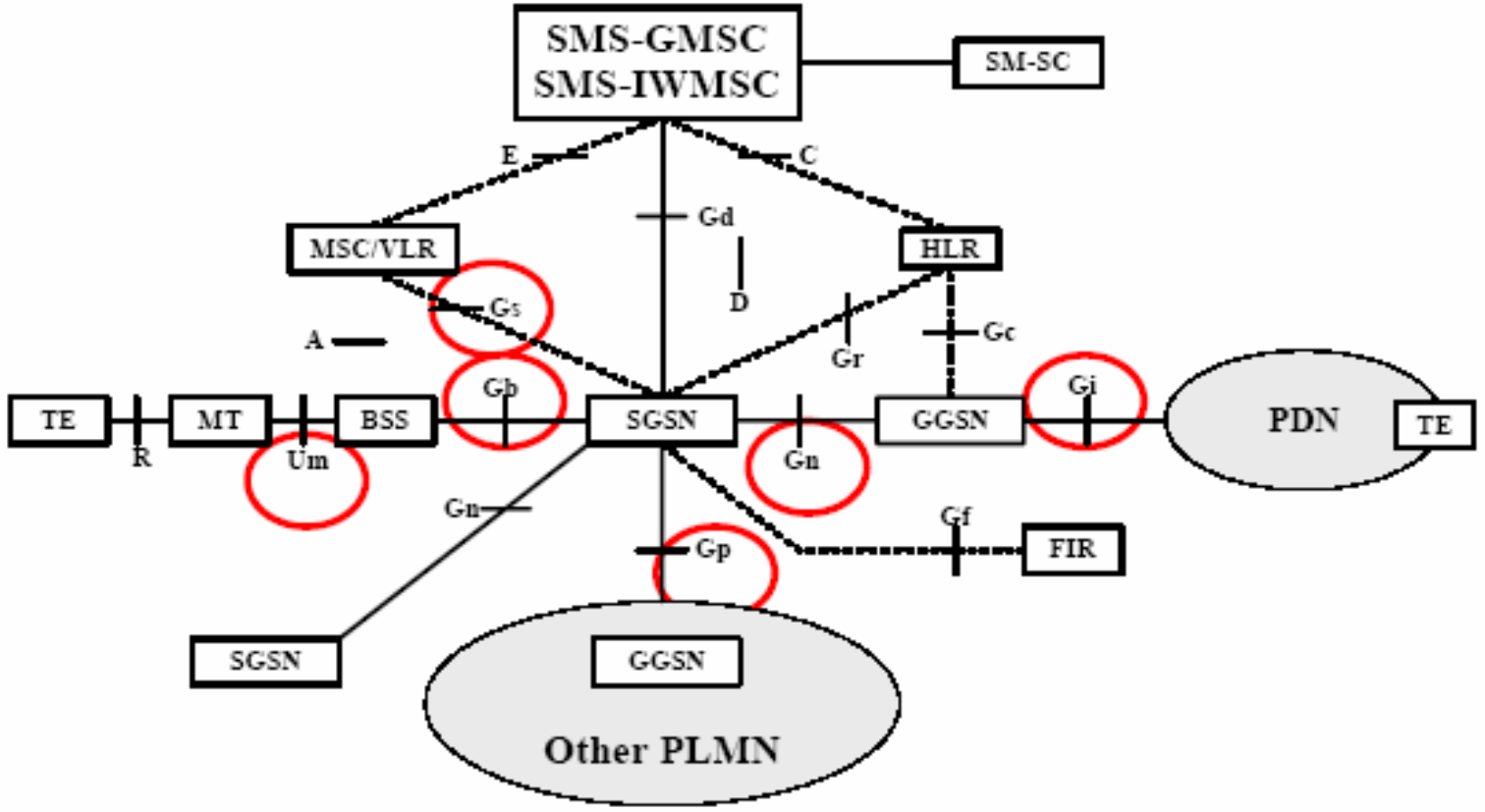
# The Network Management (NM) Service Model

- Flow control message FLOW-CONTROLBVC (FLOW-CONTROL-MS) sent from the BSS to the SGSN
  - To control downlink transmission at the SGSN
  - Parameters: buffer size and the bucket leak rate
- PDU in the downlink is not transferred to the MS before its lifetime expires
  - PDU is deleted from the BVC downlink buffer
  - This action is reported to SGSN.

# 18.4.3 Gn & Gp Interfaces

- Both Gn and Gp interfaces utilizes the **GPRS Tunneling Protocol** (**GTP**).
  - Gn (SGSN ↔ GGSN)
  - Gp (SGSN ↔ External GGSN)
- GTP tunnels user data and signaling messages between GSNs.
- Gp is the same as Gn except
  - Extra security functionality for internetwork communications over the Gp interface.
- With **GTP**,
  - An SGSN may communicate with multiple GGSNs.
  - A GGSN may connect to many SGSNs.

# GPRS Interfaces




5

# Gn & Gp interfaces

- In the transmission plane, **GTP** is supported by the
  - Transmission Control Protocol (**TCP**) for connection-oriented transmission
  - User Datagram Protocol (**UDP**) for connectionless transmission
- GTP transmission uses a tunneling mechanism to carry user data packets.
  - **Two-way**, **point-to-point** path
  - Tunneling transfers encapsulate data between GSNs.
  - GTP implements out-of-band signaling.

# Gn & Gp interfaces

- In the signaling plane, GTP is supported by UDP.
- A GTP tunnel is defined by the associated PDP contexts in two GSN nodes, and is identified with a tunnel ID.
- GTP performs
  - **Path Management**
  - **Tunnel Management**
  - **Location Management**
  - **Mobility Management**

# Path and Location Managements in GTP

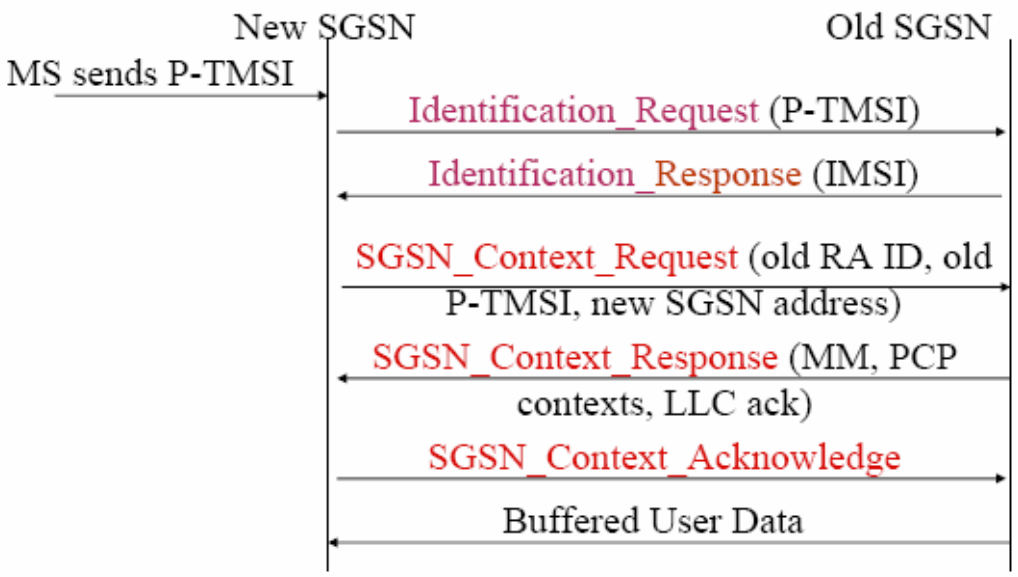
- **Path management**
  - To detect failures occurring in the path
  - Echo_Request and Response message pair
- **Location management**
  - If GGSN does not support SS7 MAP for communication with an HLR.
  - the interaction (GGSN↔HLR) is done indirectly through a specific GSN that performs GTP-MAP protocol conversation (usually through SGSN).

# GTP Tunnel Management

- GTP tunnel management creates, updates, and delete tunnels. Some of the tunnel management messages are described herein.
  - **Creating Tunnels**
    - Create_PDP_Context_Request
    - Create_PDP_Context_Response
  - **Active PDP context**
    - PDU_Notification_Request
    - PDU_Notification_Reponse
  - **Updating Tunnels**
    - Update_PDP_Context_Request
    - Update_PDP_Context_Reponse
  - **Deleting Tunnels**
    - Delete_PDP_Context_Request
    - Delete_PDP_Context_Reponse

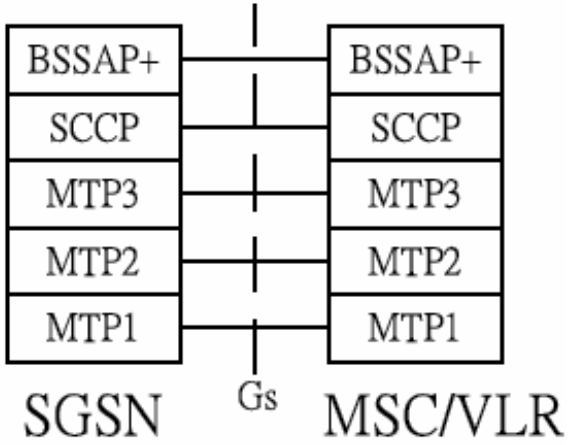
# GTP Mobility Management

- GTP mobility management supports functions such as GPRS attach, GPRS routing area update, and activation of PDP contexts.
- When an MS moves from one SGSN to another SGSN.

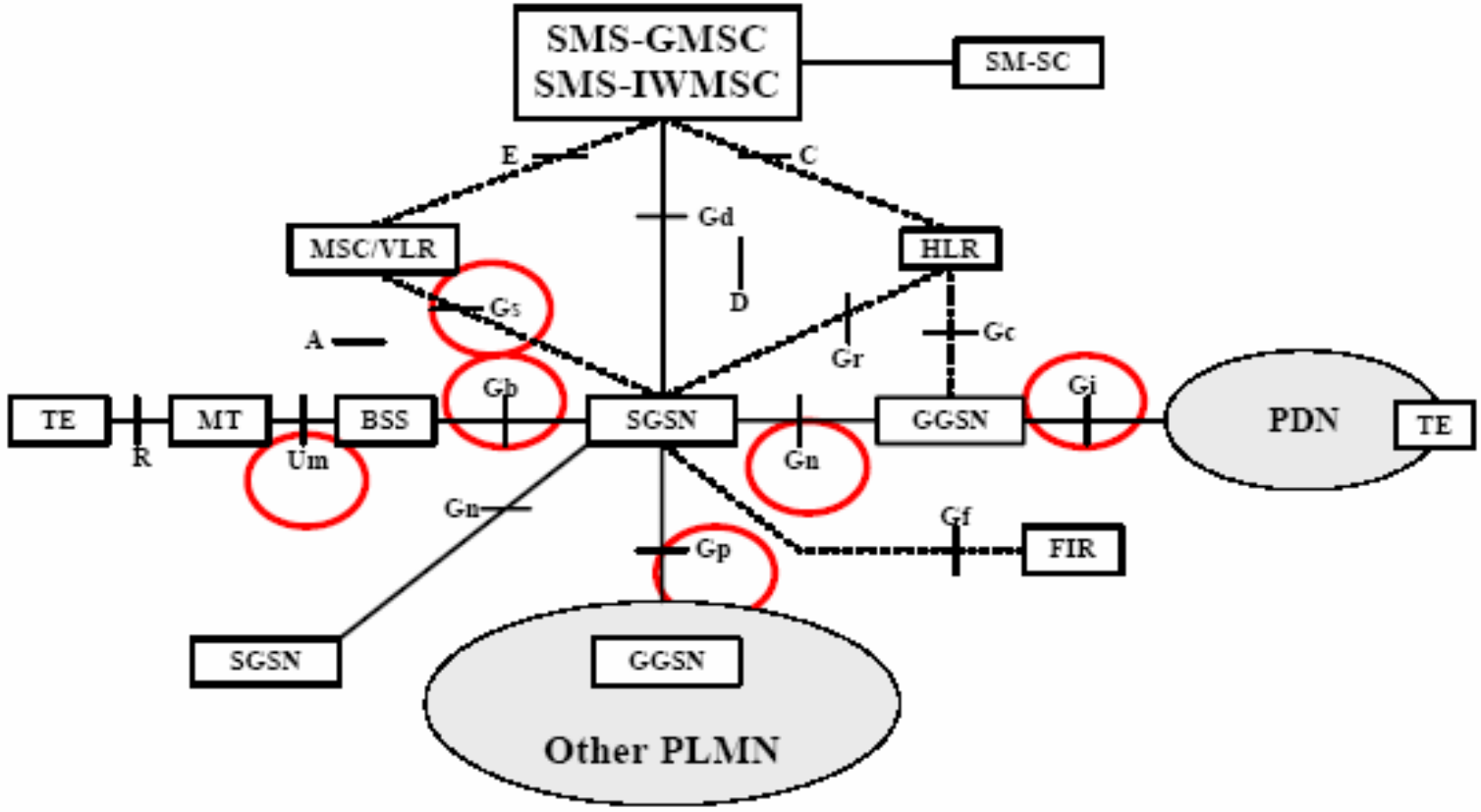


# 18.4.4 Gs Interface (SGSN ↔ MSC/VLR)

- The Gs interface connects the database in the MSC/VLR and the SGSN, which does not involve user data transmission.
- BSSAP+ procedures coordinate the location information of MSs that are both IMSI-attached and GPRS-attached.
- BSSAP+ are used to convey some GSM procedures via the SGSN.
  - Paging Procedure
  - Suspend Procedure
  - Resume Procedure
  - Location Update Procedure



# GPRS Interfaces




5

# Paging Procedure

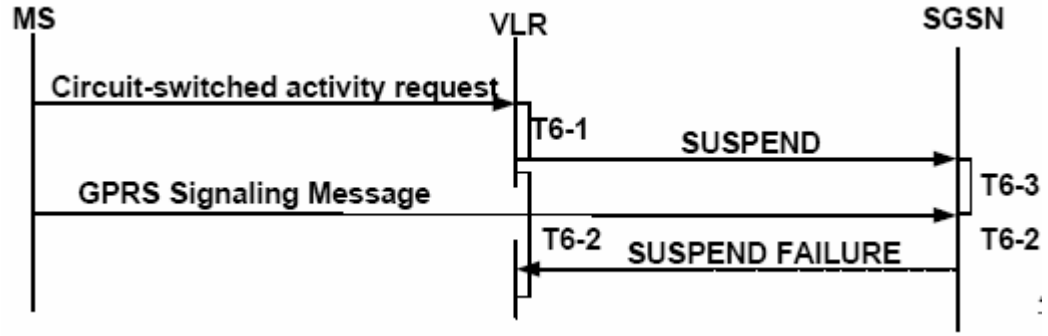
- VLR can use GPRS to page MS for MSC/VLR-based service.
  - Class A or Class B MS can simultaneously IMSI-Attached and GPRS-Attached.
- It is not necessary to page an MS for both GSM and GPRS services.
- Reduce the overall paging load on the radio interface.

# Paging Procedure

- Step 1 : VLR sends the GPRS_PAGING to the SGSN.
- Step 2 : SGSN checks if the MS is GPRSattached and is known by SGSN.
  - Yes: SGSN sends the Gb PAGING to the BSS.
- Step 3 : SGSN forwards the paging result back to the VLR.
  - If the MS does not respond, VLR or BSS retransmits the paging message.
  - The SGSN is not responsible for retransmission of the message.

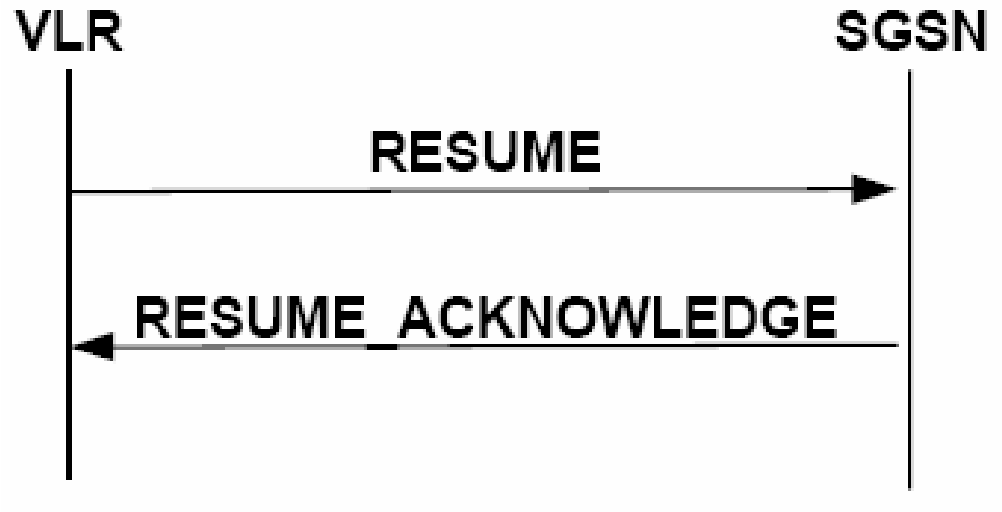
# Suspend Procedure

- To perform circuit-switched activity for a Class B MS (both IMSI- and GPRS-attached).
- VLR uses the SUSPEND procedure to inform the SGSN to suspend the GPRS activities of the MS.



# Resume Procedure

- VLR sends a RESUME message to the SGSN to resume the GPRS activity of the MS.



# Location Update Procedure

- A MS-initiated GPRS location update
  - Step 1 : SGSN sends GPRS_LOCATION_UPDATING_Request to VLR.
  - Step 2 : The VLR Checks to determine if the IMSI is known.
    - If IMSI is unkonw, VLR retrieves the MM context of the MS from the HLR.
  - Success : VLR return a GPRS_LOCATION_UPDATING_Accept to SGSN.

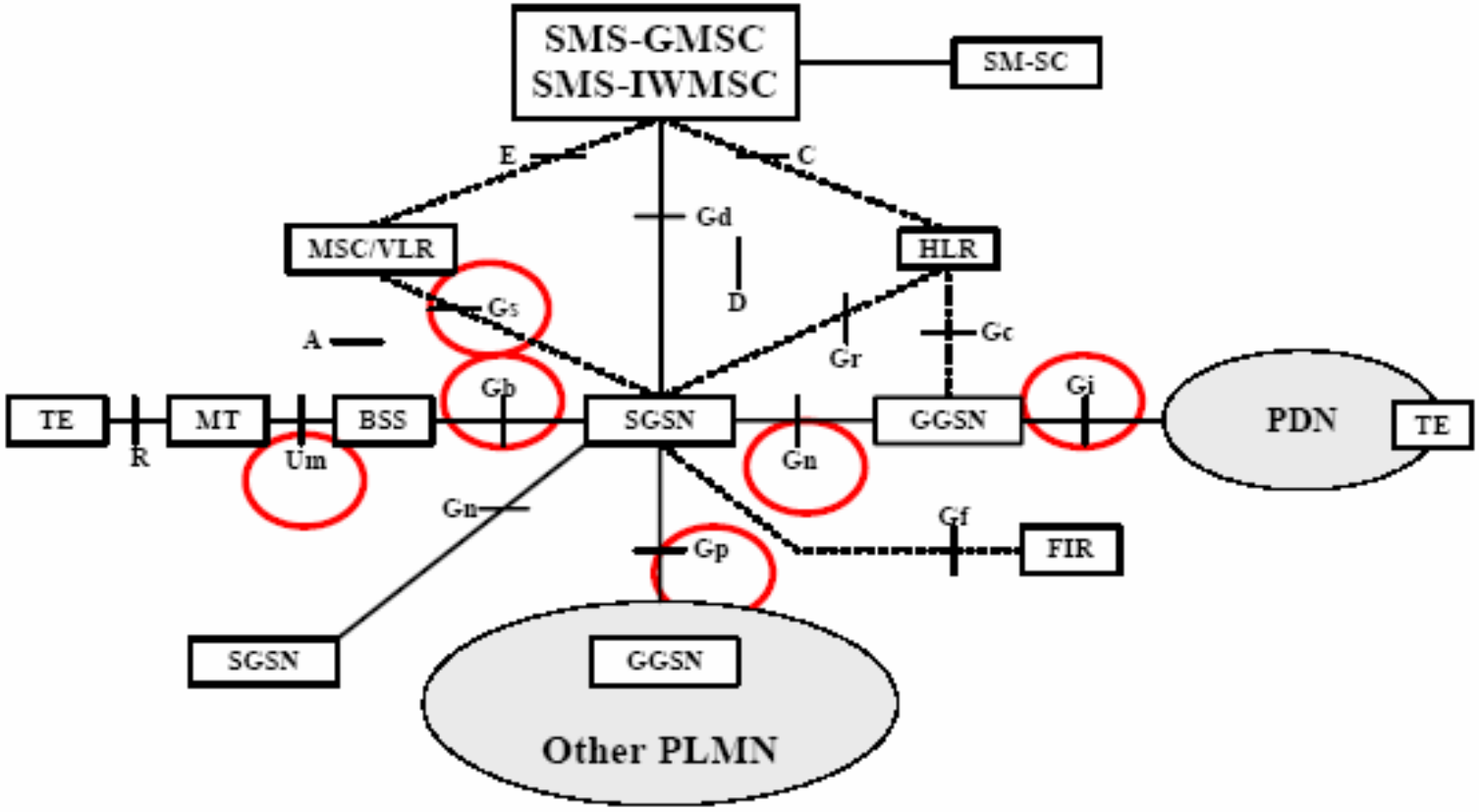
# Location Update Procedure

- Fail : SGSN informs the MS that the location update failed.
  - SGSN does not hear from the VLR within a period T8-1
  - VLR replies with a GPRS_LOCATION_UPDATING_Reject to SGSN

# 18.4.5 Gi Interface (GGSN ↔ PDN) (1/3)

- GGSN interworks with
  - PSDN (Public Switched Data Network)
  - PDN (Packet Data Network)
- Gi: GGSN ↔ PSDN/PDN
  - The interworking models to PSDN includes **X.25** and **X.75**.
    - An MS is assigned an X.121 address. This address dynamically or permanently assigned
  - The interworking models to PDN includes IP and Point-to-point (PPP).
    - The IP address is statically assigned or dynamically allocated when PDP context activation.

# GPRS Interfaces



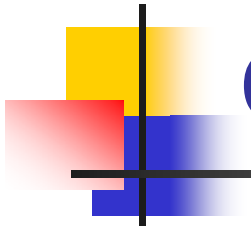

5

# Gi Interface (GGSN ↔ PDN) (2/3)

- GPRS may
  - Transparently access the Internet
  - Non-transparently access the intranet and ISP.
- In transparently access the Internet,
  - IP address from the GPRS operator's addressing space
  - This address is used on GPRS network.
  - No authentication request at PDP context activation
  - Domain name services provided by the GPRS

# Gi Interface (GGSN ↔ PDN) (3/3)

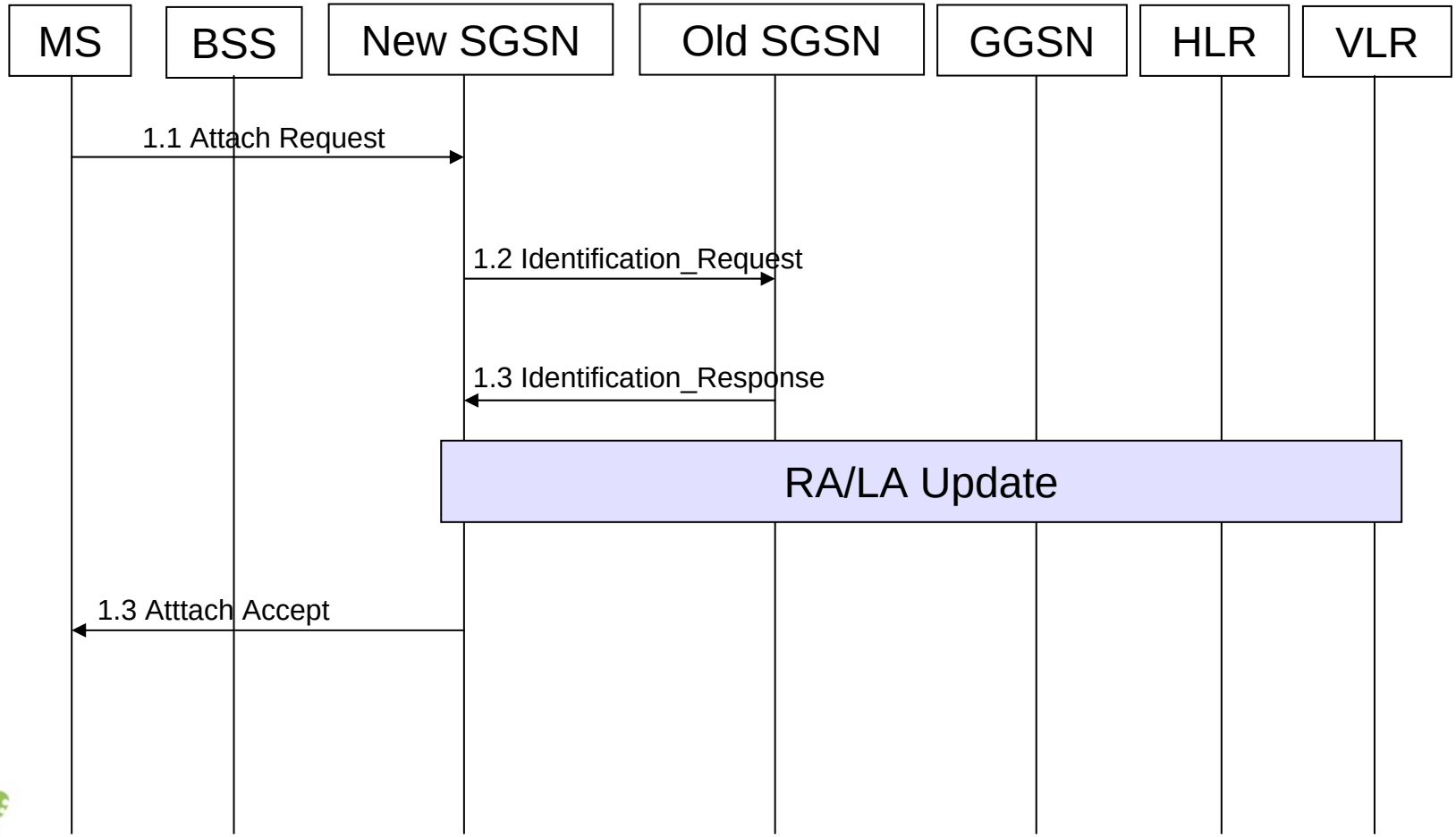
- In nontransparent access to an intranet or ISP,
  - IP address of an MS from the intranet/ISP address space
  - At PDP context activation, the MS must be authenticated by the intranet/ISP.
  - DNS provided by the intranet/ISP



# GPRS Procedures

- GPRS Attach
- GPRS Detach
- PDP context procedure
- RA/LA Update

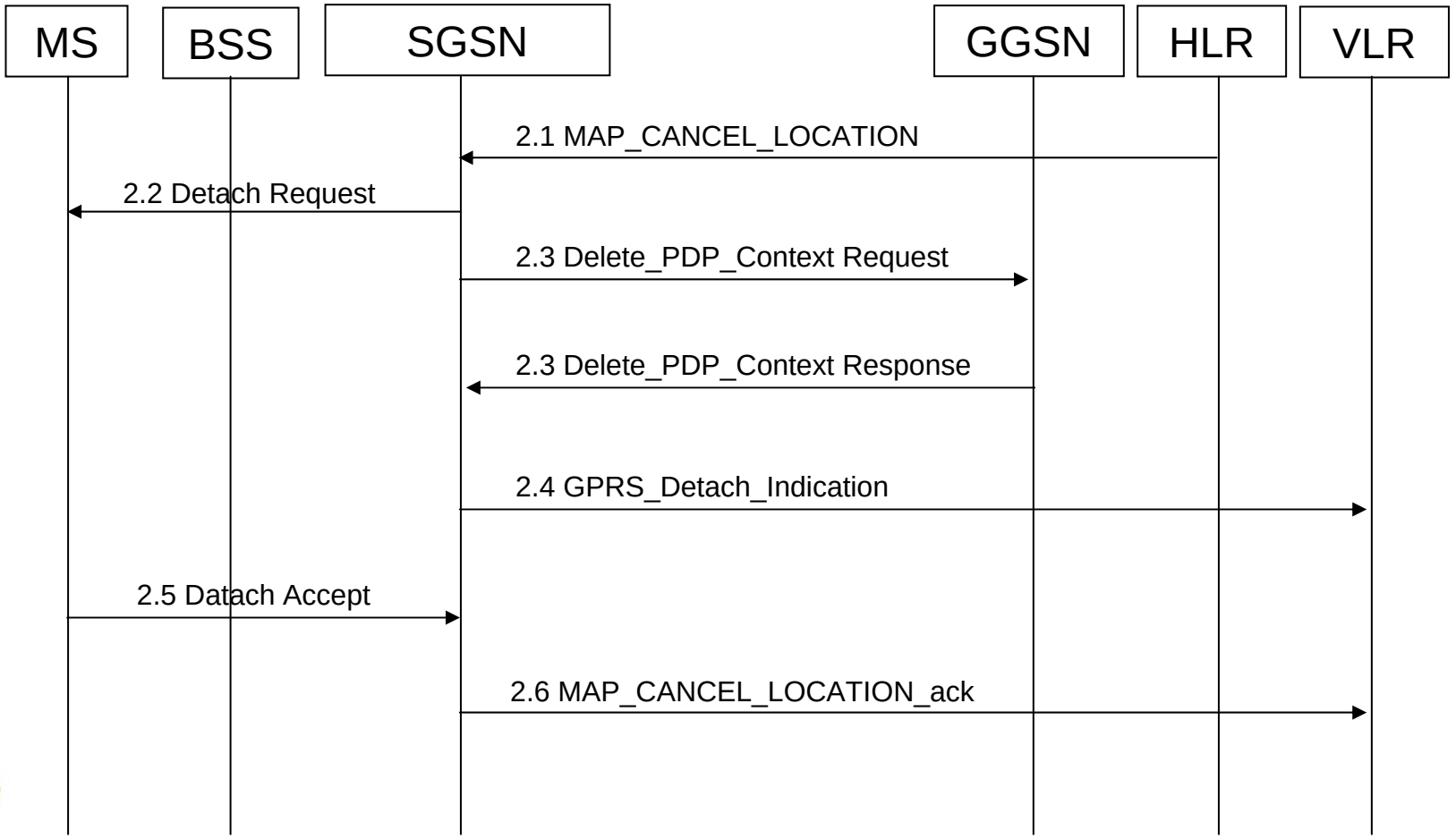
# Figure 18.6 GPRS Attach Procedure



# GPRS Detach

- GPRS detach can be initiated by MS, SGSN, or HLR.
- The different types of detach are:
  - IMSI detach
  - GPRS detach
  - Combined GPRS/IMSI detach (MS-initiated only)

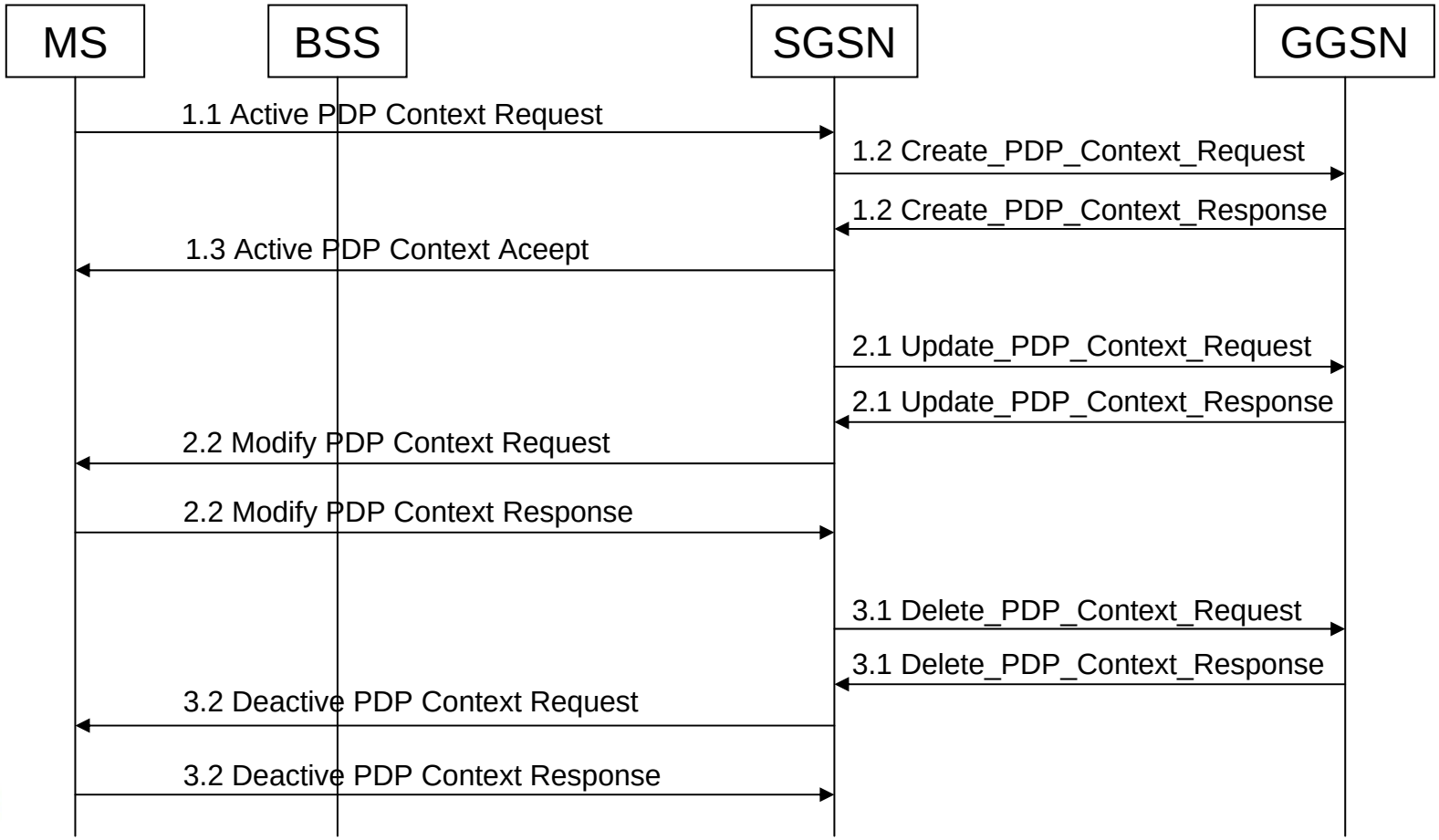
# Figure 18.6 GPRS Detach Procedure



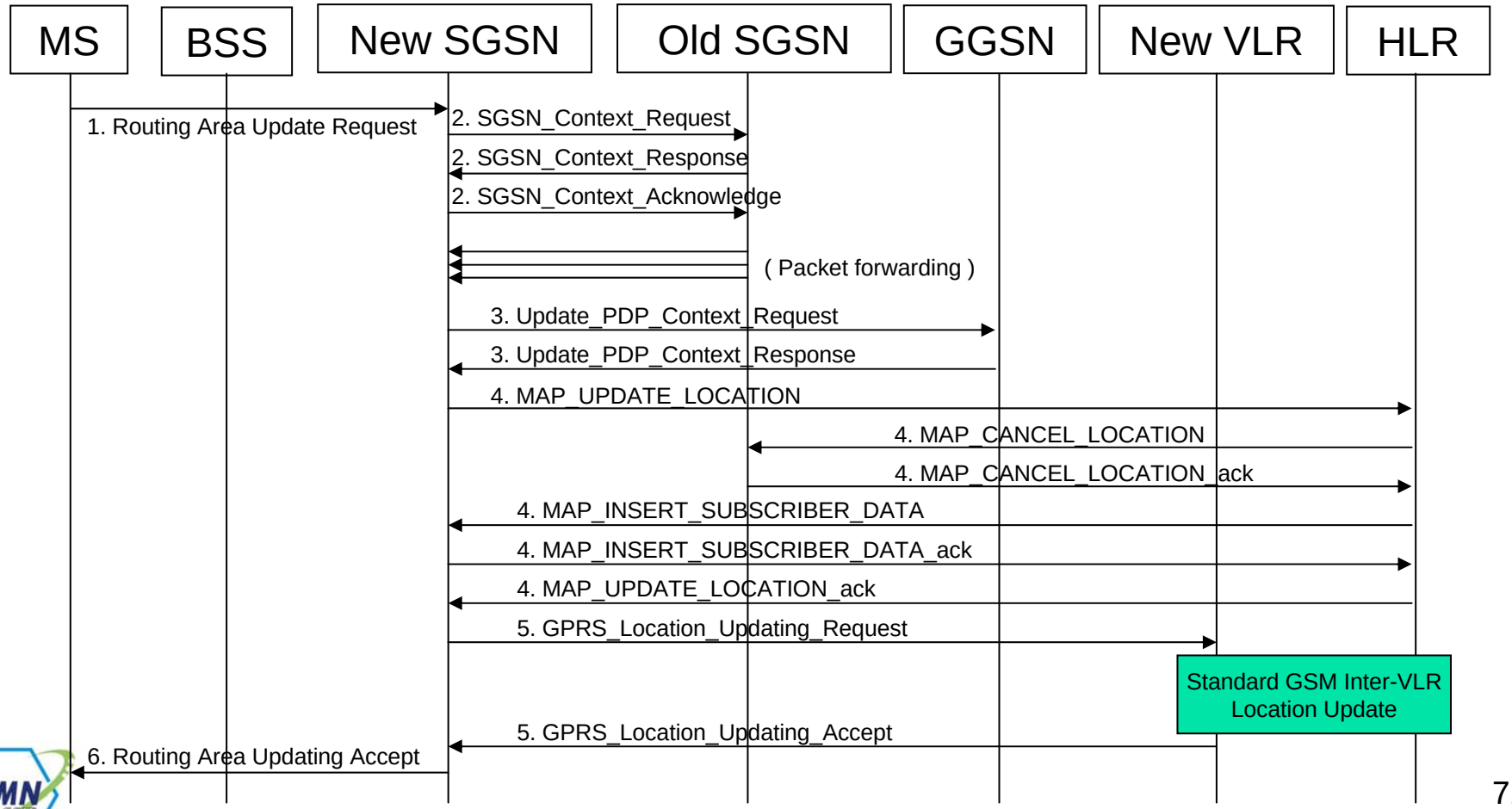
# PDP Context Procedures (1/2)

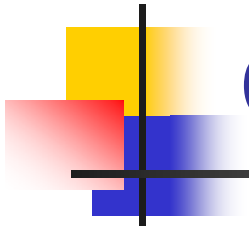
- PDP Context Activation
  - MS-initiated
  - Network-requested
- PDP Context Modification
- PDP Context Deactivation
  - SGSN-initiated
  - MS-initiated
  - GGSN-initiated

# Figure 18.7 PDP Context Procedures (2/2)



# Figure 18.8 The Combined RA/LA Update Procedure





# GPRS Billing

- Charging information is collected by **SGSNs** and **GGSNs**.
- In SGSN
  - Radio resource usage by an MS.
- In external/internal GGSNs
  - Network usage
- The charging of the visited GPRS is gathered and sent to the home GPRS network.

# The Charging Info in SGSN

- Location information
- The amount of data transmitted
- The amount of time
- The amount of GPRS-related network resources..
- The GPRS activity (e.g., MM)
- Note that the data volume counted is at SNDCP level in SGSN.

# The Charging Info in GGSN

- The addresses of the destination and source
- The amount of data delivered
- The period
- Note that the data volume counted is at the GTP level in GGSN.

# Types of Call Detailed Records (CDRs)

- S-CDR for the radio usage by SGSN
- G-CDR for external data network usage by GGSN
- M-CDR for Mobility Management activity by SGSN

# The Generation of CDRs (1/2)

- Every CDR is associated with an active PDP context.
- A CDR is generated by the following criteria:
  - End-of-Call Accounting Schedule
  - Time-of-Day Accounting Schedule
  - Inter-SGSN routing area update

# The Generation of CDRs (2/2)

- Charging for packet-switched is more difficult.
  - The cost of measuring packet is large.
  - Existing GSM billing system may not able to handle GPRS real time CDR information.
- Charging gateway

# Evolving From GSM to GPRS

- Reusing the GSM infrastructure
  - Software-related cost
    - GPRS software is remotely downloaded to BTSs.
  - Hardware cost
    - PCU-module to BSC, GGSN and SGSN
- MS development
  - Resolve the power consumption
  - Multiple time-slot transmission (much more power)

# Table 18.2 GSM Network Elements Impact by GPRS

| ELEMENT | SOFTWARE | HARDWARE |
|---|---|---|
| MS | Upgrade required | Upgrade required |
| BTS | Upgrade required | No change |
| BSC | Upgrade required | PCU interface |
| TRAU | No change | No change |
| MSC / VLR | Upgrade required | No change |
| HLR | Upgrade required | No change |
| SGSN | New | New |
| GGSN | New | New |

# GPRS Phase 1 Implementation (1/2)

- Standard Packet Services Delivery
- CS-1 and CS-2 Channel Coding Scheme
- Gn, Gb, Gp, Gs interfaces
- Flexible Radio Resource Allocation
- Classes B and C MSs
- GPRS Charging
- IP and X.25 interfaces to packet data network

# GPRS Phase 1 Implementation (2/2)

- Static and dynamic IP Address Allocation
- Anonymous Access
- Security

# GPRS Phase 2 Implementation

- Enhanced QoS support in GPRS
- Unstructured octet stream GPRS PDP type
- Access to ISPs and Intranets
- GPRS Prepaid
- GPRS Advice of Charge
- Group Call
- Point-to-multipoint services

# Applications in GPRS (1/2)

- Specific Data Communication Requirement of Companies:
  - Traffic Management (Fleet Management, Vehicle Tracking, Vehicle Control, Guidance)
  - Monitoring Automation (Telemetry and Security)

# Applications in GPRS (2/2)

- Applications for Individual Users
  - Entertainment (Games and Music)
  - Location Information (Restaurants, Cinema, Hotels, Parking)
  - Commerce Transactions (Banking, Airlines, trains, Online Shopping.)