General Packet Radio Service (GPRS)

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Outlines

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Introduction (1/2)

- GPRS reuses the existing GSM infrastructure to provide **end-to-end packet-switched** services.
- GPRS standard was initialized by ETSI/SMG in 1994.
- The main set of GPRS specifications was approved by SMG#25 in 1997, and was completed in 1999.
- GPRS core network has also been developed for **IS-136**, and is anticipated to evolve as the core network for the third-generation mobile system as well.

Introduction (2/2)

- 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, or several active users can share a single time slot, where the uplink and the downlink are allocated separately.**
  - **Various radio channel coding schemes are specified to allow bit rates from 9 Kbps to 150 Kbps.**
  - **GPRS fast reservation is designed to start packet transmission within 0.5 to 1 seconds.**
- GPRS security functionality is equivalent to the existing GSM security.
  - **A Ciphering algorithm is optimized for packet date transmission.**

Part I: GPRS Functional Groups

GPRS Functionality Groups

- Network Access
- Packet Routing and Transfer
- Mobility Management
- Logical Link Management
- Radio Resource Management
- Network Management

Network Access

- Supporting the standard
  - point-to-point data transfer and
  - Anonymous Access (without authentication and Ciphering)
- The functions include
  - Registration (associates the MS identity with the packet data protocols)
  - Authentication and Authorization
  - Administration Control (determines (1) the radio and (2) network resources to be used for communication of an MS)
  - Message Screening (filters out unsolicited messages)
  - Packet termination adaptation (adapts data transmission across the GPRS network)
  - Charging Information Collection for Packet Transmission in GPRS and external networks.

Packet Routing and Transfer (1/2)

- Routing the data between an MS and the destination through the SGSN and GGSN.
- Relay Function
  - used by the BSS to forwards packets (MS<->BSS<->SGSN).
  - used by a SGSN to forward packets (BSS<->SGSN<->GGSN).
- Routing Function
  - determines the destinations of packets.
- Address Translation and Mapping
  - That converts a GPRS network address to an external data network address and vice versa.

Packet Routing and Transfer (2/2)

- **Encapsulation and Tunneling**
  - encapsulate packets at the source of a tunnel,
  - Deliver the packets through the tunnel and
  - Decapsulate them at the destination.
- **Compressing and Ciphering.**
- **Domain Name Service Functions**
  - Which resolve logical GSN names to their IP addresses.

Logical Link Management

- Maintaining the communication channel
  - (MS <->SGSN) across the radio interface.
- **Logical Link Establishment**
- **Logical Link Maintenance**
- **Logical Link Release**

Radio Resource Management (1/2)

- Allocating and Maintaining **radio communication path**.
- **Um Management**
  - Determines the amount of radio resources to be allocated for GPRS usage.
- **Cell Selection**
  - Enables the MS to select the optimal cell for radio communication.

Radio Resource Management (2/2)

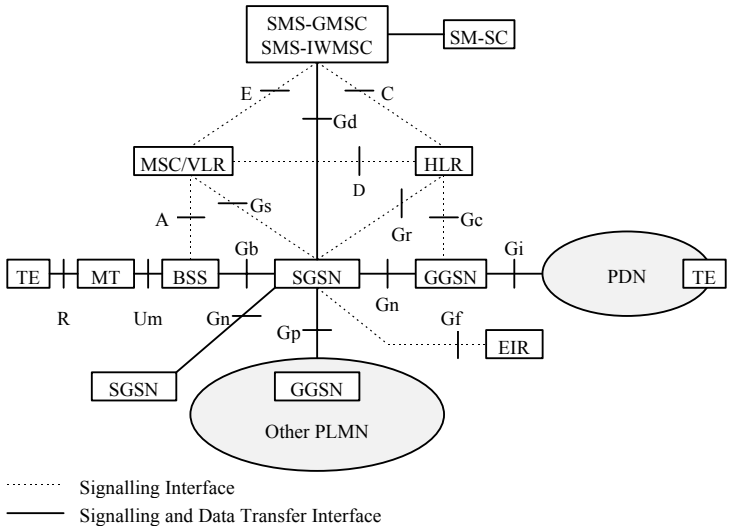
- **Um-tranx** provides packet data transfer capability (e.g.,
  - Medium Access Control,
  - Packet Multiplexing,
  - Packet Discrimination,
  - Error Detection and Correction,
  - Flow Control Across the Radio Interface (MS<->BSS)
- **Path Management**
  - Maintains the communication paths (BSS<->SGSNs).
  - Note that the establishment and release of these paths may be dynamic (based upon the amount of data traffic).

Mobility Management

- Keeps track of the current location of an MS.
- Three different scenarios can exist when the MS enters a new cell and possibly a new routing area
  - Cell Update
  - Routing Area Update
  - Combined Routing Area and Location Area Update.

Part II: GPRS Architecture

GPRS Architecture (1/2)



GPRS Architecture (2/2)

- MS, BSS, MSC/VLR, and HLR in the existing GSM network are modified.
  - **E.g., the HLR is enhanced with GPRS subscriber information.**
- Two new network nodes are introduced in GPRS.
  - **The Serving GPRS Support (SGSN) node is GPRS equivalent to the MSC.**
    - **At GPRS attach, the SGSN establishes a mobility management context (related to mobility and security for the MS).**
    - **At PDP context activation, the SGSN established a PDP context, to be used for routing purpose.**
  - **The Gateway GPRS Support (GGSN) node provides interworking with external packet-switched networks, and is connects with SGSN via an IP-based GPRS backbone network.**

Mapping of Functions to General Logical Architecture

Function	MS	BSS	SGSN	GGSN	HLR
Network Access Control:					
Registration					X
Authentication and Authorisation	X		X		X
Admission Control	X	X	X		
Message Screening				X	
Packet Terminal Adaptation	X				
Charging Data Collection			X	X	
Packet Routeing & Transfer:					
Relay	X	X	X	X	
Routeing	X	X	X	X	
Address Translation and Mapping	X		X	X	
Encapsulation	X		X	X	
Tunnelling			X	X	
Compression	X		X		
Ciphering	X		X		X
Mobility Management:	X		X	X	X
Logical Link Management:					
Logical Link Establishment	X		X		
Logical Link Maintenance	X		X		
Logical Link Release	X		X		
Radio Resource Management:					
Um Management	X	X			
Cell Selection	X	X			
Um-Tranx	X	X			
Path Management		X	X		

The Interfaces in GPRS Architecture (1/3)

- The **MS** and **BSS** communicate via the **Um** interface.
- The **BSS** and the **SGSN** are connected by the **Gb** interface using **frame relay**.
- Within the same GPRS network, **SGSNs/GGSNs** are connected through the **Gn** Interface.
- When **SGSN and GGSN are in different GPRS networks**, they are interconnected with **Gp** interface.
- The **GGSN** connects to **external networks** through **Gi** interface.

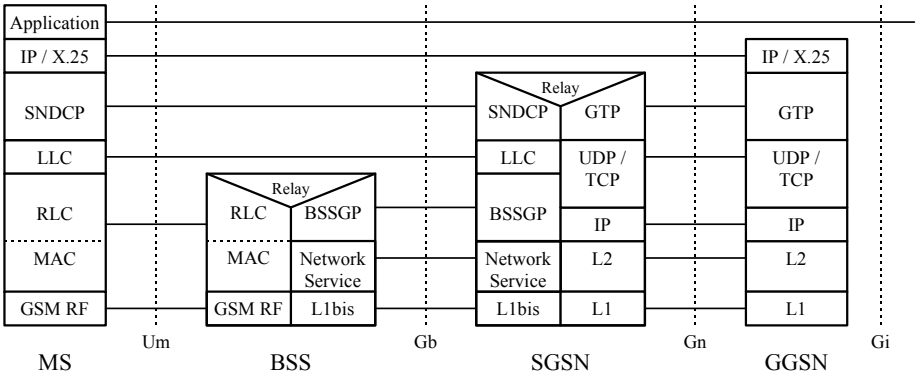
The Interfaces in GPRS Architecture (2/3)

- The **MSC/VLR** communicates with the **BSS** using the existing GSM **A** interface.
  - **A interface is used for both signaling and voice transmission in GSM.**
- The **MSC/VLR** communicates with the **SGSN** using the **Gs** interface (Optional).
  - **SGSN may send location information to/from MSC/VLR.**
  - **SGSN may receive the paging request.**
- The **HLR** connects to the **SGSN** via the **Gr** interface, and to the **GGSN** via the **Gc** interface.
- Both **Gr** and **Gc** follow **GSM MAP protocol**.
- The **HLR** and **VLR** are connected through the existing **GSM D interface**.

The Interfaces in GPRS Architecture (3/3)

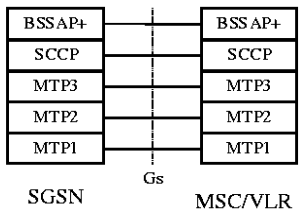
- Interfaces **A, Gs, Gr, Gc**, and **D** are used for signaling, without involving user data transmission in GPRS.
- Interfaces **Um, Gb, Gn, Gp,** and **Gi** are used for both signaling and transmission in GPRS.

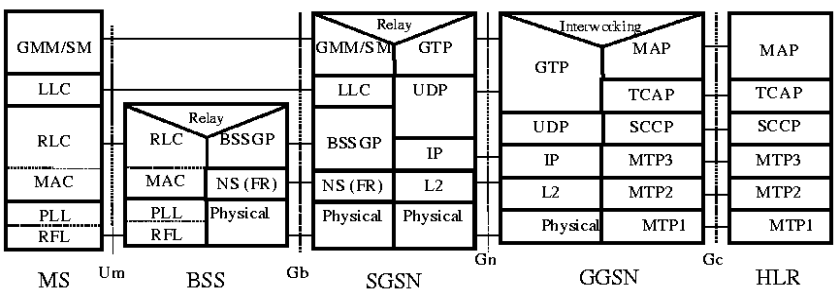
GPRS Transmission Plane



GPRS Signaling Plane

BSSAP+: Base Station System Application Part+
GMM: GPRS Mobility Management
MAP: Mobile Application Part
MTP: Message Transfer Part
SCCP: signaling connection control part
SM: Session Management
TCAP: Transaction Capabilities Application Part





GPRS Transmission & Signaling Planes

- **The 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.**
- **The GPRS Signaling Plane** consists of protocols for control and support of the transmission plane functions.
- **The GPRS-specific protocols** include
  - **SNDCP, LLC, RLC, MAC, BSSGP, BSSAP+, and GTP.**
- **PLL, RFL, GMM/SM, and MAP** are **GSM protocols**.
- **TCAP, SCCP, and MTP** are **SS7 layers**.

The GPRS Relay Functions

- **In BSS**,
  - **The relay function relays logical link control (LLC) Packet Data Units (PDUs) (Um <-> Gb).**
- **In SGSN**,
  - **The relay function relays Packet Data Protocol (PDP) PDUs (Gb <-> Gn).**
  - **The Gb/Gn relay function adds sequence number to PDP PDUs received from the SNDCP and from Gi interface.**
- To transparently, transport PDP PDUs **(external network <-> MSs)**, the **PDP PDUs** are encapsulated and decapsulated for routing.

Mobility Management (MM) Context (1/2)

- **MM context stored in MS and SGSN** contains
  - **MM state** and
  - **MM-related information**
- **MM states** specify the **MM activities of an MS**
  - **MM State = IDLE** (if the MS is not attached to the GPRS mobility management)
  - **MM State = STANDBY** (if the MS is attached to GPRS mobility management **but has not obtained detailed location information**)
  - **MM State = READY** (if the location information for the MS has been identified on **cell level**)
- **Note that** a GPRS MS can be **IMSI-** and/or **GPRS-attached**.

Mobility Management (MM) Context (2/2)

- The **IMSI attach** is the same as that for a GSM MS.
- In GPRS attach procedure,
  - **Step 1. Both the MM states in MS and the SGSN are moved to the READY state.**
  - **Step 2. An MM context is created in each of MS and SGSN.**
  - **Step 3. Authentication/Ciphering may be performed.**
  - **Step 4. A logical link is established between MS and SGSN.**

Packet Data Protocol (PDP) Context (1/2)

- The PDP contexts stored in **MS, HLR, SGSN, and GGSN** contains
  - **Mapping and routing information for packet transmission between (MS<->SGSN).**
- For each GPRS communication of an MS, a PDP context is created to characterize the session.
  - **After the PDP context activation, the MS is known to the GGSN, and communication to external networks is possible.**
  - **An MS may have several activated PDP contexts if the terminal supports several IP addresses.**
  - **When the MS is detached from GPRS, all PDP contexts are deactivated.**
  - **A PDP context can be in one of the two PDPD states:**

    ACTIVE or INACTIVE

Packet Data Protocol (PDP) Context (2/2)

- An MS in STANDBY or READY MM state may activate a PDP context, and moves its PDP state from INACTIVE to ACTIVE.
- The ACTIVE PDP context becomes INACTIVE when the PDP context is deactivated.

QoS Profile (1/2)

- A QoS profile is maintained in the PDP context to indicate radio and network resources required for data transmission. The QoS attributes include
- Presence class
  - specifies 3 transmission levels (during congestion, the packets with lower priorities are discarded).
- Delay class
  - specifies 4 delay levels. In 128-octet transfer, the expected transfer time for each class may be
  - Class 1 (less than 0.5 sec)
  - Class 2 (less than 5 sec)
  - Class 3 (less than 50 sec)
  - Class 4 (best-effort transmission without specifying the transfer constraints)

QoS Profile (2/3)

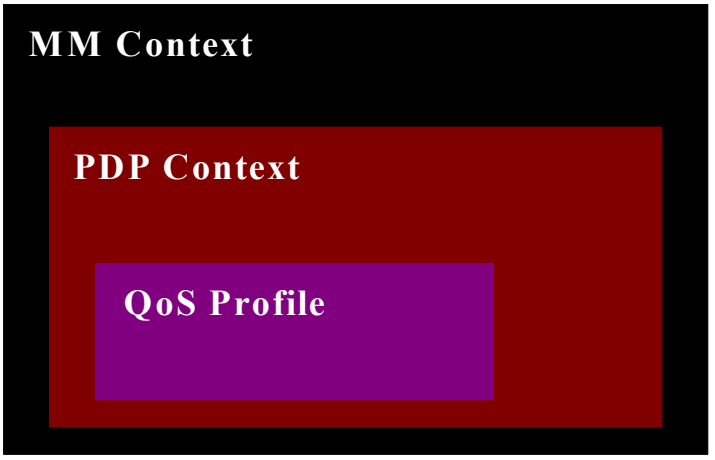
- Reliability class defines error rate (i.e., probability) for data loss, out-of-sequence delivery, and corrupted data. Five Reliability classes

Reliability Class	GTP Mode	LLC Frame Mode	LLC Data Protection	RLC Block Mode	Traffic Type
1	Ack	Ack	Protected	Ack	Non real-time traffic, error-sensitive application (cannot cope with data loss)
2	Unack	Ack	Protected	Ack	Non real-time traffic, error-sensitive application (cope with infrequent data loss).
3	Unack	Unack	Protected	Ack	Non real-time traffic, error-sensitive application that can cope with data loss, GMM/SM, and SMS.
4	Unack	Unack	Protected	Unack	Real-time traffic, error-sensitive application that can cope with data loss.
5	Unack	Unack	Unprotected	Unack	Real-time traffic, error non-sensitive application that can cope with data loss.

QoS Profile (3/3)

- Peak Throughput Class specifies the expected maximum data transmission rate. 9 classes are defined (from 8 Kbps to 2,048 Kbps).
- Mean throughput class specifies the average data transmission rate. 19 classes are defined (from best-effort to 111 Kbps).

Relationship between MM Context, PDP Context, and QoS Profile



Part III: GPRS Network Nodes

GPRS Mobile Station (1/2)

- GPRS MS utilizes automatic retransmission (ARQ) at the data link layer to retransmit the error frames.
- Class-A mode of operation
  - The MS is attached to both GPRS and other GSM services.
  - The MS supports simultaneous of GPRS and other GSM services.
- Class-B mode of operation
  - The MS is attached to both GPRS and other GSM services, but the MS can only operate one set of services at a time.
  - Class B MS involved in packet transfer can receive a page for circuit-switched activity.
- Class-C mode of operation
  - The MS is exclusively attached to GPRS services.

GPRS Mobile Station (2/2)

- The MSs that access GPRS services may or may not contain GPRS-aware SIM.
- An MS maintains MM and PDP contexts to support GPRS mobility management.
- If the SIM is GPRS-aware SIM
  - **The IMSI, P-TMSI, P-TMSI Signature, Routing Area, Kc, and CKSN stored in the GPRS-aware SIM shall be used when accessing the GPRS services.**
- If the SIM is not GPRS-aware SIM
  - **P-TMSI, P-TMSI Signature, Routing Area, Kc, and CKSN stored in the ME shall be used if and only if the IMSI stored in the SIM is identical to the IMSI image maintained in the MS.**
  - **If the IMSI image ≠ IMSI in SIM, MS shall identify itself with the IMSI stored in the MS after the GPRS attach has been successfully.**

GPRS MS MM and PDP Contexts

Field	SIM	Description
IMSI	X	International Mobile Subscriber Identity.
MM State		Mobility management state, IDLE, STANDBY, or READY.
P-TMSI	X	Packet Temporary Mobile Subscriber Identity.
P-TMSI Signature	X	A signature used for identification checking purposes.
Routeing Area	X	Current routeing area.
Cell Identity		Current cell.
Kc	X	Currently used ciphering key.
CKSN	X	Ciphering key sequence number of Kc.
Ciphering algorithm		Selected ciphering algorithm.
Classmark		MS classmark.
DRX Parameters		Discontinuous reception parameters.
Radio Priority SMS		The RLC/MAC radio priority level for uplink SMS transmission.
Each MM context contains zero or more of the following PDP contexts:		
PDP Type		PDP type, e.g., X.25, PPP or IP.
PDP Address		PDP address, e.g., an X.121 address.
PDP State		Packet data protocol state, INACTIVE or ACTIVE.
Dynamic Address Allowed		Specifies whether the MS is allowed to use a dynamic address.
NSAPI		Network layer Service Access Point Identifier.
TI		Transaction Identifier.
QoS Profile Requested		The quality of service profile requested.
QoS Profile Negotiated		The quality of service profile negotiated.
Radio Priority		The RLC/MAC radio priority level for uplink user data transmission.

GSM Chip Sets for GPRS MS

- Siemens SMARTi (PMB6250)
  - A single-chip GSM multiband transceiver that supports multi-time-slot data
- Lucent's Sceptre 3 system-on-a-chip solution
  - Enables full GPRS to 115.2 Kbps

Base Station System (BSS)

- To accommodate GPRS, BTS and BSS are modified, and a new component Packet Control Unit (PCU) is introduced.
  - The BTS is modified to support new GPRS channel coding schemes [gsm0364].
    - (Note CS-1-CS-4 are defined for channel coding, where CS-1 is the same as GSM, CS-2-CS-4 are for Forward Error Correction)
  - The BSC forwards circuit-switched calls to the MSC, and packet-switched data (through PCU) to the SGSN.
  - A BSC can connect to only one SGSN.
  - BSS should also manage GPRS-related radio rsources.

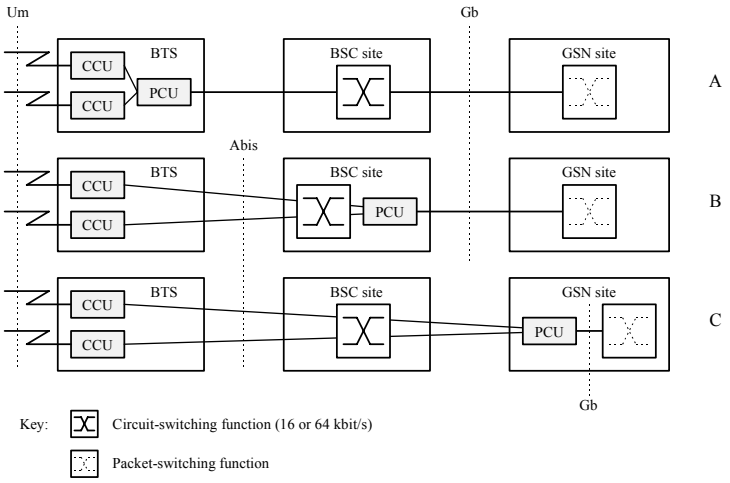
Packet Control Unit (PCU)

- The PCU is responsible for GPRS MAC and RLC layer functions [gsm0364]
  - **LLC layer PDU segmentation into RLC blocks for downlink transmission**
  - **LLC layer PDU reessembly form RLC blocks for uplink transmissions.**
  - **PDCH scheduling functions for uplink and downlink data transfers**
  - **PDCH uplink ARQ functions (including RLC block ack/Nak)**
  - **PDCH downlink ARQ function (including buffering and retransmission of RLC blocks)**
  - **Channel access control functions (e.g., access request and grants)**

Channel Codec Unit (CCU)

- The functions inside the Channel Codec Unit (CCU) are
  - **The Channel Coding Functions (including FEC and interleaving)**
  - **Radio Channel Measurement Functions (including received quality level, received signal level, and information related to timing advance measurements)**

Remote Packet Control Unit Positions



Serving GPRS Support Node (SGSN)

- The role of an SGSN is equivalent to that of the MSC/VLR in the current GSM network, which provides
  - **Ciphering**
  - **Mobility Management (e.g., inter-SGSN routing area update and inter-PLMN roaming)**
  - **Charging, and**
  - **Statistics collection (i.e., support of billing records)**
- To provide services to a GPRS MS, the SGSN establishes an MM context (that contains mobility and security information for the MS).
- At PDP context activation, the SGSN established a PDP context (used to route data between the MS and GGSN).
- SGSN maintains MM/PDP context information when the MS is in one of the two MM state (STANDBY or READY).

SGSN MM Context (for Each User) (1/2)

- **IMSI (the main reference key in SGSN)**, P-TMSI, P-TMSI Signature (used for identification checking purposes), MSISDN, IMEI (International Mobile Equipment Identity)
- **MM state** (Mobility Management state, IDLE, STANDBY, or READY)
- **Routing Area** (Current Routing Area)
- **Cell Identity** (Current Cell in READY state, last known cell in STANDBY or IDLE state), **Cell Identity age** (Time elapsed since the last LLC PDU was received from the MS at the SGSN)
- **VLR Number** (The VLR number of the MSC/VLR currently serving this MS).

SGSN MM Context (for Each User) (2/2)

- **New SGSN Address** (The IP address of the new SGSN where buffered and not sent N-PDUs should be forwarded to).
- **Authentication, Ciphering Parameters, Current Ciphering key Kc, and the selected ciphering algorithm**.
- **Radio Access Classmark** (MS radio access capabilities)
- **SGSN Classmark** (MS network capabilities)
- **Mobile station Not Reachable for GPRS flag (MNRG)** (indicates whether activity from the MS shall be reported to the HLR).
- **Non-GPRS Alert Flag (NGAF)** (Indicates whether activity from the MS shall be reported to the MSC/VLR).
- **Paging Proceed Flag (PPF)** (Indicates whether paging for GPRS and non-GPRS services can be initiated).

SGSN PDP Context (each MM context associates with 0 or more)

- **PDP context Identifier** (Index of PDP context), **PDP type** (e.g., X.25, PPP or IP), **PDP address** (e.g., an X.25 address), **PDP state** (Active, or Inactive).
- **Access Point Name (APN)** to the external data network.
- **QoS Profile Subscribed, QoS Profile Requested, QoS Profile Negotiated**.
- **GGSN Address in Use** (IP Address of the GGSN currently used by the activated PDP context).
- **Charging ID** (Charging identifier, identifies charging record generated by SGSN and GGSN)

SGSN Solution

- **Lucent's solution** supports 40,000 attached users and 4,000 simultaneous active GPRS data sessions.
- **Nortel's Passport** 8380G and Symmetry's UWS-GMS support 50,000 attached users and 20,000 simultaneous active GPRS data sessions.
- **Alcatel's SGSN** supports 52,000-96,000 attached users.

Gateway GPRS Support Node (GGSN)

- The GGSN is primarily provisioned by a router, which supports traditional gateway functionality, e,g,.
  - **Publishing Subscriber Addresses**
  - **Mapping Addresses,**
  - **Routing and Tunneling Packets,**
  - **Screening Messages, and**
  - **Counting Packets**
- A GGSN may contain
  - **DNS (Domain Name Server) functions to map routing area identifier with serving SGSNs, and**
  - **DHCP (Dynamic Host Configuration Protocol) functions to allocate dynamic IP addresses to MSs.**
- The GGSN maintains **an activated PDP context** for tunneling the packets of the attached MS to the corresponding SGSN.

An Activated PDP Context in GGSN

- IMSI
- PDP Type (e.g., X.25, PPP or IP), PDP Address
- Dynamic Address (Indicates whether PDP Address is static or dynamic).
- QoS Profile Negotiated (The quality of service profile negotiated).
- SGSN Address (The IP address of the SGSN currently serving this MS).
- Access Point Name (APN) (The APN requested by the MS).
- MNRG (Indicates whether the MS is marked as not reachable for GPRS at the HLR).
- Charging ID (Charging Identifier) (identifies charging records generated by SGSN and GGSN).

GGSN Solutions

- Most suppliers use existing router platforms to provide GGSN.
- Alcatel GGSN is developed based on the Cisco 7200 series router.
- Nokia's GGSN is based on its commercial IP routing platform.
- Existing GGSN implementations typically support 5,000-48,000 simultaneous data tunnels, and 25,000-48,000 simultaneously attached data users.

Home Location Register (HLR)

- To accommodate GPRS subscription and routing information, new fields in 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,**
  - **Update the SGSN of the MS at attach and detach, and**
  - **Store the fixed IP address and QoS profile for a transmission path.**

The GSN-Related Information in HLR

- **IMSI** (the main reference key), MSISDN
- **SGSN Number** (The SS7 number of the SGSN currently serving this MS), **SGSN Address** (The IP addresses of the SGSN currently serving this MS).
- **MS Purged for GPRS** (Indicates that the MM and PDP contexts of the MS are deleted from the SGSN).
- **MNRG** (indicates whether the MS is not reachable for GPRS service).
- **GGSN-list**
  - (GSN number, optional IP address) related to the GGSN that shall be contacted when activity from the MS is detected and MNRG is set.

Each IMSI contains 0 or More PDP Contexts in HLR

- **PDP Context Identifier** (Index of PDP Context)
- **PDP Type** (e.g., X.25, PPP, or IP)
- **QoS Profile Subscribed** (QoS Profile Subscribed is the default level if a particular QoS profile is not requested)
- **VPLMN Address Allowed** (Specifies if the MS is allowed to use the APN in the domain of the HPLMN only, or additionally the APN in the domain of the VPLMN).
- **Access Point Name** (A label according to DNS naming conventions describing the access point to the external packet data network).

MSC/VLR

- The MSC/VLR may store the **SGSN number of GPRS-attached MSs that are also IMSI-attached**.
- The MSC/VLR may contact SGSN to request location information or paging for voice call.
- IMSI (the main reference key)
- SGSN Number (The SGSN number of the SGSN currently serving this MS)