Lecture 11
GPRS
Data Over Cellular Networks

Architecture and Components

Ilenia Tinnirello
Data over cellular networks

- CDPD (Cellular Digital Packet Data, over AMPS)
- GPRS-136 (over IS-136 TDMA)
- IS-95B (over CDMA)
- HSCSD (High-Speed Circuit-Switched Data)
- GPRS (General Packet Radio Service, over GSM)
- EDGE (Enhanced Data Rates for GSM Evolution)
  - ECSD (Enhanced Circuit-Switched Data; circuit-mode)
  - EGPRS (Enhanced GPRS; packet-mode)
GPRS Benefits

➔ Higher data rates
  ➔ Using all 8 Packet Data Channels (PDCH) GPRS can achieve up to 160 kbps (actually the theoretical maximum achievable)

➔ Packet switched principle
  ➔ efficient for burst traffic (e.g., Internet traffic)
  ➔ radio channel allocated only when needed
  ➔ spectrum efficiency

➔ User-friendly billing
  ➔ payment based on the amount of transmitted data
  ➔ Data charged by-the-byte not per minute

➔ Reuse of existing GSM infrastructure
  ➔ GSM, Internet

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A Paradigm Shift

“For the operator, the big step from an overall business model perspective is going from GSM (voice) to GPRS, not from 2G GPRS to 3G”

- Business model
- Position in value chain
- Services
- Customer support

UMTS adds capabilities
## GPRS vs. GSM

<table>
<thead>
<tr>
<th>GSM circuit switched</th>
<th>GPRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network nodes (MSC) based on PSTN/ISDN switch</td>
<td>Network nodes (GSN) based on IP routers</td>
</tr>
<tr>
<td>Interface towards external PSTN/ISDN networks by means of GMSC</td>
<td>Interface towards wired packet networks (IP, X.25) by means of GGSN</td>
</tr>
<tr>
<td>BSS to manage radio resource towards MSs</td>
<td>BSS extended with Packet Control Units</td>
</tr>
<tr>
<td>Inter-MSC links based on PCM PDH and/or SDH</td>
<td>Inter-GSN packet transport based on ATM + protocols</td>
</tr>
<tr>
<td>FDMA/TDMA with 8 slots; each Traffic Channel (TCH) occupies a single slot all the call long</td>
<td>New logical and control channels occupying up to 8 slots; slots assigned only when required</td>
</tr>
<tr>
<td>Coverage area divided into Location Areas</td>
<td>More precise localization: each Location Area is divided into Routing Areas</td>
</tr>
<tr>
<td>Users addressed by means of phone numbers (MSISDN)</td>
<td>Terminals addressed by means of IP addresses (either public or private)</td>
</tr>
</tbody>
</table>
**GPRS Architecture**

- **Channel Codec Unit (CCU)**
  - Channel Coding
  - Radio Channel Measurements

- **Packet Control Unit (PCU)**
  - channel access control
  - radio channel management
  - data packet segmentation and re-assembly

- **Serving GPRS Support Node (SGSN)**
  - functions comparable to MSC/VLR

- **Gateway GPRS Support Node (GGSN)**
  - functions comparable to GMSC

- **HLR Extension**
  - GPRS subscriber data
  - routing information

- **Visited MSC/VLR**

- **Gateway MSC/VLR**

- **BSS**

- **External Data Network**

- **PSTN**
Serving GPRS Support Node (SGSN)

→ **Basic functionalities**
  
  ➔ Authentication and encryption
  
  ➔ Admission control
  
  ➔ Mobility management
    
    ➔ It includes a database, called Location Register (LR) equivalent to VLR, with localization information (cell, VLR for phone calls, IMSI, IP address) for the users in the SGSN area
  
  ➔ Receiving and delivering the packets
    
    ➔ Routing and relay to next SGSN hop; LLC logical connection to MSs
  
  ➔ Address translation and mapping
  
  ➔ Encapsulation and tunneling
    
    ➔ Encapsulation for delivery within the GPRS core network (i.e. between SGSN nodes)

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Gateway GPRS Support Node (GGSN)

➡️ Basic functionalities

➡️ Gateway to extern Packet Data Networks
   ➡️ Filtering to/from extern PDNs for unauthorized or unrequired messages

➡️ Access functionality
   ➡️ Memorizes in its LR SGSN addresses, service profiles and PDP contexts for ready or standby MSs
   ➡️ Creates PDP contexts describing requirements of connections to external networks, assigning dynamic IP addresses

➡️ Subscriber addresses publish

➡️ Routing
   ➡️ Packet Data Units tunneling to the SGSN currently serving the MS; encapsulation/decapsulation at the GPRS domain border
   ➡️ Normal router to external networks, implementing OSPF, RIP, BGP, Ipsec, etc.

➡️ Charging data

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Packet Control Unit (PCU)

Software update for BSS

- Supporting dynamic channel assignment between GSM/GPRS
  - Physical channel scheduling
- Segmentation/reassembling of LCC frames into MAC blocks
- Error detection and correction
  - ARQ, buffering, retransmissions
- Channel access control
  - Channel request, channel access, power control, congestion control, etc.

Usually added to BSC and talking with Channel Coded Unit (CCU) added on the BTS
Other elements

**BG (Border Gateway)**
- (Not defined within GPRS)
- Routes packets from SGSN/GGSN of one operator to a SGSN/GGSN of an other operator
- Provides protection against intruders from external networks

**DNS (Domain Name Server)**
- Translates addresses from ggsn1.oper1.fi-format to 123.45.67.89 format (i.e. as used in Internet)

**Charging Gateway**
- Collects charging information from SGSNs and GGSNs

**HLR**
- Enhancements of GSM HLR for containing GPRS data and interfacing to SGSN

**MSC/VLR, SMS Service Center**
- new interfaces for GPRS nodes
GPRS Interfaces
GPRS Interfaces (2)

- **Gb**: between BSC and SGSN, for transparent PDU transfers
- **Gr**: between SGSN and HLR, for Registration, Authentication and Localization
- **Gs**: between SGSN and MSC, for combined mobility management
- **Gn**: between different SGSN nodes belonging to the same PLMN.
  - e.g. UniGate for TIM network
- **Gi**: between GGSN and extern IP networks
- **Gp**: between GSN of different operators

Frame Relay

Signaling Link at 64Kbps, over E1

IP-based
Terminals

⇒ Class A
⇒ MS supports simultaneous operation of GPRS and GSM services

⇒ Class B
⇒ MS able to register for both GPRS & GSM services simultaneously. It can only use one of the two services at a given time

⇒ Class C
⇒ MS can attach for either GPRS or GSM services
GPRS Protocols

- **IP/X.25**: end-to-end network protocol; X.25 defined in the standard but practically not used
- **GTP**: GPRS Tunnelling protocol, for encapsulating data and signals from GGSN to SGSN
- **IP**: routing in the GPRS backbone; L1 and L2 operator-dependent
- **LLC**: logical data link between MS and SGSN (ciphering, QoS)
- **SNDCP**: Sub-network Dependent Convergence Protocol, for managing segmentation, compression, multiplexing, in order to adapt applications to LLC layer
- **BSSGP**: for transferring frames and QoS information from BSS and SGSN
- **GSM RF**: physical layer providing physical channels to RLC/MAC, responsible of modulation/demodulation, interleaving, power control, channel monitoring.
Services
Services

► Bearer services (data channels)
  ➞ PTP(Point-To-Point)
    ➞ transfer data packets between two users
    ➞ connectionless mode (e.g., for IP)
    ➞ connection-oriented mode (e.g., for X.25)
  ➞ PTM(Point-To-Multi-point)
    ➞ transfer data packets from one user to multiple users
    ➞ multicast service: data packets are broadcast in a certain geographical area

► Supplementary services
  ➞ SMS's, call forwarding on unconditional, unreachable or closed user group
  ➞ Access to data bases, messaging services and tele-action services (credit card)
GPRS QoS

- GPRS allows Quality of Service (QOS) profile based on:
  - Service precedence: the priority of service in relation to another
  - Reliability: the transmission characteristics required by an application
  - Delay parameters: define maximum values for mean delay and 95% delay
  - Throughput: the maximum/peak bit rate and mean bit rate

- Using the previously mentioned classes, the QOS profiles can be negotiated for each session based on QOS demand and current available resources

- The billing is then based on actual transmitted data volume, type of service and chosen profile
GPRS QoS

- Bearer Service For GSM – Wireless extension to packet data networks

- An “Always ON” service with Radio Resources (time-slots) consumed on Demand

- Radio Resources shared between GSM & GPRS
  - Typically, Networks Operators give strict priority to voice traffic (GSM).
  - For GPRS, time-slots (PDCHs) are generally dynamically allocated.

- Reliable in-order delivery using RLC’s (radio link control) reliable mode. Very Effective.
Radio Interface
GSM Logical Channels

**BCCH**
- Frequency correction

**SCH**
- Frame synchronisation + BSIC

**BCCH**
- Broadcast of cell information, e.g. channel combination

**PCH**
- Paging mobiles

**RACH**
- Requesting dedicated channel

**AGCH**
- Allocating dedicated/traffic CH

**SDCCH**
- Signalling between MS and BTS e.g. Authentication, SMS, LUP

**SACCH**
- Measurements, TA, PC, ...

**FACCH**
- Extra signalling within 26 TDMA Multiframe

**TCH/F**
- Full rate traffic channel

**TCH/H**
- Half rate traffic channel
Additional GPRS Logical Channels

- **PBCCH**: Broadcast of packet data specific information
- **PPCH**: Paging MSs for packet data and circuit switched services
- **PRACH**: MS initiates uplink transfer
- **PAGCH**: Resource assignment to an MS
- **PNCH**: Notifying PtM Packet Transfer
- **PDTCH**: Packet Data Transfer; (multislot)
- **PACCH**: Signalling: resource allocation, acknowledgements, PC
- **PTCCH**: For calculating and transmitting TA
PH: Packet Header; FH: Frame Header; BH: Block Header
FCS: Frame Check Sequence; BCS: Block Check Sequence

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**GSM Normal Burst**

<table>
<thead>
<tr>
<th>TB</th>
<th>DATA</th>
<th>S</th>
<th>Training sequence</th>
<th>S</th>
<th>Data</th>
<th>TB</th>
<th>GP</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>57</td>
<td>1</td>
<td>26</td>
<td>1</td>
<td>57</td>
<td>3</td>
<td>8.25</td>
</tr>
</tbody>
</table>

- **Symmetric structure**
- **DATA**: 2 x 57 data bits
  - 114 data bits per burst
  - "gross" bits (error-protected; channel coded)
- **S**: 2 x 1 stealing bit
  - Also called stealing flags, toggle bits
  - Needed to grab slot for FACCH (other signalling possible)
- **All channels are transmitted using normal bursts, except the PRACH and PTCCH/U where the mobile transmits random access bursts**
GPRS Physical Channel

1 time slot @ a given frequency under the control of GPRS is called Packet Data Channel (PDCH)
- It carries both data and control information
- The number of PDCH channels varies on demand

1 PDCH is organized in a multi-frame of 52 frames
- 3 blocks of 4 slots plus a final idle slot (for measurements and PTCCH), repeated 4 times
- Optional master PDCH for data channel broadcast information and common channels (otherwise, on GSM BCCH)
Mapping between logical and physical channels

Three possible combinations:

- PBCH + PCCCH + PDTCH + PACCH + PTCCH or
- PCCCH (e.g. PRACH) + PDTCH + PACCH + PTCCH or
- PDTCH + PACCH + PTCCH (additional space for data only)
### Radio Block Structure

<table>
<thead>
<tr>
<th>BLOCK Header</th>
<th>DATA or SIGNALLING</th>
<th>BCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAC Header</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 byte</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RLC Header</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2/3 byte</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Header Fields
- **(USF) 3 bit**
- **PT 2 bit**
- **(CV) 4 bit**
- **TFI 5 bit**
- **(BSN) 7 bit**
- **…**
- **(PR) 2 bit**

#### Field Descriptions
- **Uplink State Flag:**
  - Assigned to each mobile within a PDCH, it is used in **downlink** for allocating the next radio block.
  - Only 7 values for MS; 111 used for PRACH
- **Payload Type:**
  - For distinguishing data or signalling
- **Countdown value:**
  - Used only in **uplink** for indicating the remaining number of data blocks within a temporary block flow (TBF)
- **Temporary Flow Identity:**
  - To identify the TBF the radio block belongs to
- **Block Sequence Number:**
  - Only in **downlink** for distinguishing each data block within a block flow
- **Power Reduction:**
  - Only in **downlink** for indicating power reduction
Radio Block Coding and Bursting

Radio Block Building

MAC Header
ULSF
RLC Header
Data
BCS

Channel Coding

half rate convolutionary coding (except CS-4)
Puncturing (CS-1, CS-2)

Inter-leaving

57 Bit 57 Bit 57 Bit 57 Bit 57 Bit 57 Bit 57 Bit 57 Bit

One Radio Block (gross) = 4 normal bursts
# Coding Schemes

<table>
<thead>
<tr>
<th>Coding Scheme</th>
<th>Code Rate</th>
<th>Radio Block excl. USF and BCS</th>
<th>BCS bits</th>
<th>USF bits coded</th>
<th>Tail bits</th>
<th>Number of Bits when coded</th>
<th>Punct. bits</th>
<th>Data rate in kbps</th>
<th>Net rate in kbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS-1</td>
<td>1/2</td>
<td>181</td>
<td>40</td>
<td>3</td>
<td>4</td>
<td>456</td>
<td>0</td>
<td>9.05</td>
<td>8</td>
</tr>
<tr>
<td>CS-2</td>
<td>≈2/3</td>
<td>268</td>
<td>16</td>
<td>6</td>
<td>4</td>
<td>588</td>
<td>132</td>
<td>13.4</td>
<td>12</td>
</tr>
<tr>
<td>CS-3</td>
<td>≈3/4</td>
<td>312</td>
<td>16</td>
<td>6</td>
<td>4</td>
<td>676</td>
<td>220</td>
<td>15.6</td>
<td>14.4</td>
</tr>
<tr>
<td>CS-4</td>
<td>1</td>
<td>428</td>
<td>16</td>
<td>12</td>
<td>0</td>
<td>456</td>
<td>---</td>
<td>21.4</td>
<td>20</td>
</tr>
</tbody>
</table>

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Radio Block Allocation

➔ On each PDCH, blocks are not statically allocated as in the case of GSM TCH

➔ When a MS requires a PDCH, it receives (in the PAGCH) one or more physical channel (TS@f) + an identifier (USF) for polling in each physical channel
  ➔ Channel allocations are managed by the network!
  ➔ Dynamic allocations can be performed either for one or four consecutive radio blocks

➔ Uplink and downlink channels are allocated separately
Dynamic Block Allocation

- When an MS reads its USF identifier on the downlink channel, it either transmits one or four radio blocks on the downlink.
  - It indicates in each block the number of remaining blocks.
- The network will continue to assign radio blocks to the mobile until the mobile indicates that it has no more blocks to transmit.
Fixed Block Allocation

This resource assignment method specified in the PAGCH the PDCH (i.e. TS@f), a bit map of 1 to 127 bits for each allocated blocks, and a start frame number.

Start frame: 5
TS5, f0
Bit map: 1100111
GPRS Timing Advance

➔ **In packet-switched mode, transmission is not continuous**
  ➔ The interval between two radio blocks can be significant and previous estimated delays could originate inter-timeslot interference

➔ **New solution for correct burst timing:**
  ➔ **Initial timing advance**, similar to circuit-switching, by measuring the initial propagation delay via PRACH/RACH reception
  ➔ **Continuous timing advance**, carried out on the PTCCH logical channels
    ➔ 2 PTCCH channels in each 52-frame multiframe, grouped into 8 multiframest to have 16 PTCCH channels
    ➔ Each MS receives a Timing Advance Index (TAI) from 0 to 15 in the assignment message
    ➔ In each PTCCH of its index, the MS will transmit an access burst for helping the BS to track the mobile
    ➔ The new TA value is returned to the mobile in the downlink PTCCH message, which includes up to 16 TA values.

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Timing Advance Signaling Example

MS1, TAI 2

PTCCH message 2, with 16 TA values and 4 updates from message 1

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Mobility Management
Regional Organization of GPRS

- **CGI**: Cell Global Identity
- **RAI**: Routing Area Identifier
- **MCC**: Mobile Country Code
- **MNC**: Mobile Network Code
- **LAC**: Location Area Code
- **LAI**: Local Area Identifier
- **CI**: Cell Identity
- **RAC**: Routing Area Code

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Why smaller Routing Areas?

- Packet data transfer is inherently discontinuous: paging is in principle required for each new data flow!
  - Tradeoff between location tracking frequency and signaling overhead
    - If SGSN knows the MS cell, it does not require paging (reducing delays) but location updates are required from each cell change: convenient during data transfers.
    - A routing area including more cells limits the signaling overhead and limits the paging to a limited area: convenient when the MS is not involved in data transfer.

- For optimization purposes, location management is differentiated according to the MS different states
  - **Idle**: MS is not reachable and paging is not possible.
  - **Standby**: MS is localized in a RAI, stored at the SGSN; routing area updates are required periodically or upon RA changes. MS can be paged and receive signaling data, but not packet data.
  - **Ready**: MS is localized within a given cell, defined with the Cell Global Identity (CGI); paging is not required an packet data sessions can be activated.
Attach and routing area and/or location area updates are very similar to GSM ones!
GPRS Attach Example

It can be combined with an IMSI attach, in which the SGSN also required a LU to MSC/VLR.
RA Update Example

RA update request [P-TMSI, RAI]

context request [P-TMSI, RAI, TLLI, SGSN addr.]
context response [Mobility and Session context]
context ack
Buffered PDU Forwarding
Session Context Request [addr. SGSN, TID, QoS]
Session Context Response [TID]
Update Location [addr. SGSN, IMSI]

Cancel Location [IMSI]
Cancel Location ACK [IMSI]
Insert Subscriber Data [IMSI, User contract data]
Insert Subscriber Data ACK [IMSI]
Update Location ACK [IMSI]

RA accept and ACK [P-TMSI]
Session Management
Packet Data Protocol (PDP)

→ Each user subscribes a given number of IP services, identified by means of an Access Point Name.
   → e.g. uni.tim.it for Internet&Email; mms.tim.it for MMS, etc.

→ To access to these services, it is necessary to activate a session, called packet data context.
   → IP address acquisition, QoS negotiation

![Diagram]:

- **INACTIVE**
  - no routing and mapping of PDP PDUs possible
  - no data transmission

- **ACTIVE**
  - routing and mapping of PDP PDUs possible
  - location update takes place

Activate PDP Context

Deactivate PDP Context

MM state change to IDLE
IP address allocation

» Static IP address, acquired with subscription
  ➢ PDP context activated by MS or by GPRS network when IP packets destined to such an IP are received. Not common today, but possible with IPv6

» Dynamic IP address
  ➢ Given by home PLMN or visited PLMN
  ➢ GGSN includes DHCP function for address assignment
  ➢ Only MS can activate a PDP context

» Private IP address
  ➢ Valid within PLMN domain, if GGSN implements NAT functions
PDP activation Example

1. The SGSN assigns a GW IP according to the APN

2. The GGSN identifies the APN and allocates a new PDP context

3. A tunnel between GGSN and SGSN is activated by means of the GTP protocol
# PDP Context Example

<table>
<thead>
<tr>
<th>Subscriber Data</th>
<th>Active PDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMSI</td>
<td>Id</td>
</tr>
<tr>
<td>2220133333333333</td>
<td>1</td>
</tr>
<tr>
<td>Mobile Subscriber ISDN No.</td>
<td>NSAFI</td>
</tr>
<tr>
<td>39333333333333</td>
<td>5</td>
</tr>
<tr>
<td>Roaming Status</td>
<td>Type requested</td>
</tr>
<tr>
<td>Home</td>
<td>Ipv4</td>
</tr>
<tr>
<td>HLR Address</td>
<td>Address requested</td>
</tr>
<tr>
<td>39333333333333</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Home PLMN APN Operator Id</td>
<td>APN requested</td>
</tr>
<tr>
<td>mnc001.mcc222.gpzu</td>
<td>wap.tim.it</td>
</tr>
<tr>
<td>Subscribed Teleservices</td>
<td>Addressing nature</td>
</tr>
<tr>
<td>MO/MT SMS</td>
<td>Dynamic</td>
</tr>
<tr>
<td>Network Access Mode</td>
<td>Address in use</td>
</tr>
<tr>
<td>Packet/Circuit Switched</td>
<td>10.228.0.34</td>
</tr>
<tr>
<td>Mobility Management State</td>
<td>AFN in use</td>
</tr>
<tr>
<td>Paging Proceed Flag</td>
<td>GGSN in use</td>
</tr>
<tr>
<td>Set</td>
<td>Quality of service requested</td>
</tr>
<tr>
<td>Routing Area [RAI]</td>
<td>delay class</td>
</tr>
<tr>
<td>222-01-33333-0</td>
<td>4</td>
</tr>
<tr>
<td>Cell [CGI]</td>
<td>reliability class</td>
</tr>
<tr>
<td>222-01-33333-11111</td>
<td>3</td>
</tr>
<tr>
<td>P-TMSI</td>
<td>peak throughput</td>
</tr>
<tr>
<td>4075083299</td>
<td>4</td>
</tr>
<tr>
<td>MSC/VLR Address</td>
<td>precedence class</td>
</tr>
<tr>
<td>Not Gs connected</td>
<td>2</td>
</tr>
<tr>
<td>Location Confirmed in HLR</td>
<td>mean throughput</td>
</tr>
<tr>
<td>true</td>
<td></td>
</tr>
<tr>
<td>Data Confirmed by HLR</td>
<td></td>
</tr>
<tr>
<td>true</td>
<td></td>
</tr>
<tr>
<td>Subscribed PDP</td>
<td></td>
</tr>
<tr>
<td>Id</td>
<td>Quality of service negotiated</td>
</tr>
<tr>
<td>1</td>
<td>delay class</td>
</tr>
<tr>
<td>Type</td>
<td>4</td>
</tr>
<tr>
<td>Ipv4</td>
<td>reliability class</td>
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<tr>
<td>Address</td>
<td>3</td>
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<tr>
<td>Dynamic</td>
<td>peak throughput</td>
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<tr>
<td>Quality of service</td>
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<td>reliability class</td>
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<td>31</td>
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<tr>
<td>peak throughput</td>
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<td>4</td>
<td></td>
</tr>
<tr>
<td>precedence class</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>mean throughput</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
</tr>
</tbody>
</table>

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Routing Principle

MS logical link

SGSN tunnel

GGSN

Internet/ PDN

IP Network

Host

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GPRS identities (1)

- **IMSI (international mobile subscriber identity)**
  associated with a SIM card, is the same for GPRS and GSM service. Even a SIM for a GPRS-only subscription have an IMSI.

- **P-TMSI (packet temporary mobile subscriber identity)**
  similar to TMSI, but assigned by the SGSN (rather than the VLR), when the MS perform a GPRS attach procedure.

- **TLLI (temporary logical link identifier)**
  identity used during a data session to identify the MS at the RLC/MAC layer. It can be local (valid within a routing area), foreign (if allocated in a different routing area), random (when the MS does not have a valid P-TMSI).

- **TBF (temporary block flow)**
  identity of the physical connection between MS and BSS for the duration of a given packet data transfer. Each TBF corresponds to the fragmentation of an LLC frame.
GPRS identities (2)

- **TFI (temporary flow identifier)**
  each TBF is addressed by a TFI, allocated for both uplink and downlink packet transfer. (values from 0 to 31)

- **USF (uplink status flag)**
  used for polling and data block assignments. Multiple users can be multiplexed on the same timeslot, transmitting only when the USF value indicates their turn.

- **RAI (routing area identity)**
  a subset of the location area, similar to LAI. When a MS moves from a routing area to another, it performs a routing area update. A SGSN may control one or more routing areas. Therefore, RAI is required for routing the packets correctly.

- **NSAPI (Network Layer Service Access Point Identifier)**
  application identifier in the range 0-15
Addressing and Identification

The subscriber:
- IMSI (International Mobile Subscriber Identity)
- P-TMSI (Packet TMSI)

Network layer Service Access Point Identifier
- PDP address (application)
- (NSAPI) SNDCP

Temporary Logical Link Identity
- TLLI
- uniquely identifies Logical Link

GGSN
- NSAPI identifies
- Tunnel Identifier (IMSI + NSAPI)
- GSN Addresses = (IP addresses)

SGSN
- TID

GSN Number
- HLR

Access Point Name
- PDP context
- Ilenia Tinnirello