UNIVERSITÀ DELLA CALABRIA

Master Degree in Telecommunications Engineering

"Mobile Radio Networks" Class

3 – From 2G to 3G (part 2)

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Mobile Radio Networks

- GPRS (General Packet Radio Service)

GPRS (General Packet Radio Service)

The GPRS is a packet data service

Radio Interface

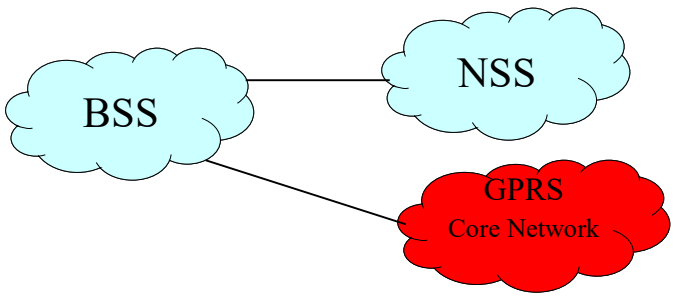
- At the radio interface the number of TDMA slots are assigned to the GPRS data channels and then shared dynamically in uplink and downlink by different UEs
- Therefore, statistical multiplexing of multiple flows on the same physical resources (time slots) is adopted

Core Network

- The fixed part of the network is basically an IP (Internet Protocol) network
- Core network elements (SGSN and GGSN) are basically IP routers

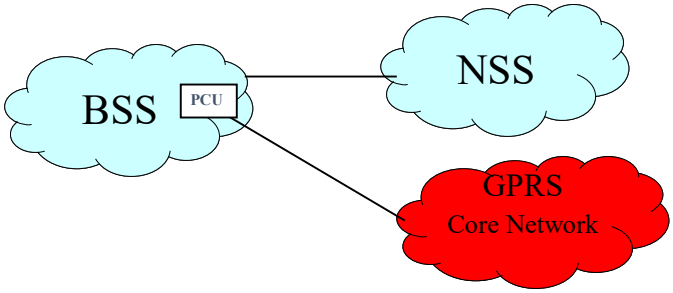
Evolution from GSM to GPRS - the approach followed

- Leave GSM's Base Station Subsystem (BSS), almost unchanged
- Add devices that allow packet switching (a so-called Packet Switched Core Network) to the GSM switching subsystem, the GSM-Network Switching Subsystem (NSS)



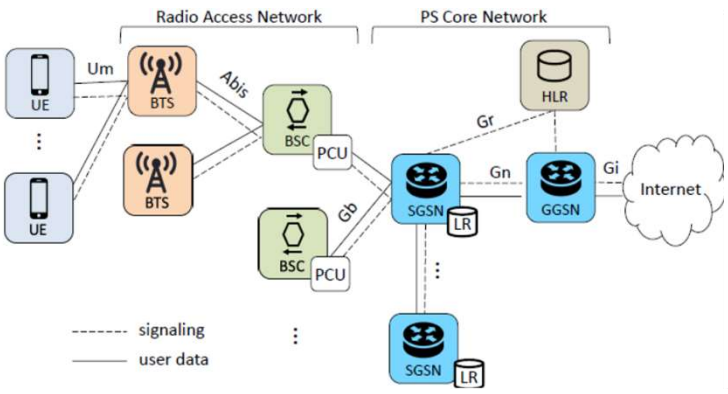
Evolution from GSM to GPRS - the approach followed

- However, a "small" extension within the BSS is needed
- A *Packet Control Unit (PCU)* must be added in order to
  - Interface data packets with the pre-existing GSM-BSS
  - Control and manage most of the functions related to the radio interface typical of GPRS



Resulting GPRS architecture for data services

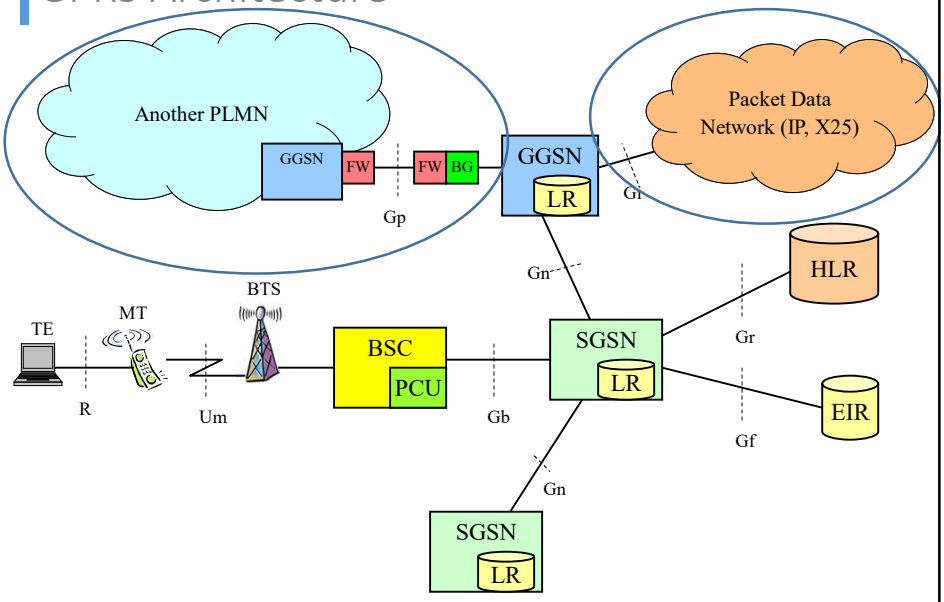
- With the introduction of packet switched data services of GPRS/EDGE, the architecture evolved to include a PS Core



GPRS/EDGE architecture: nodes

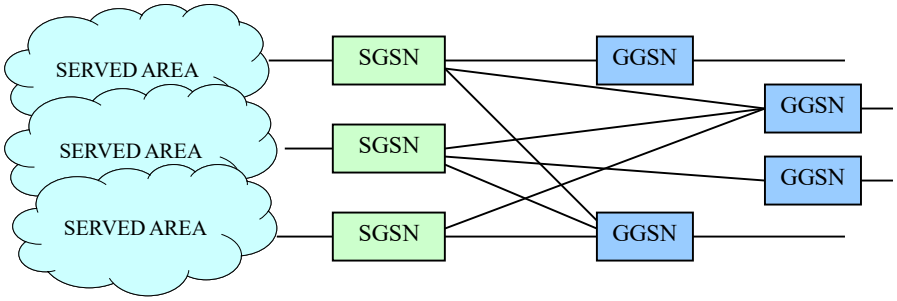
- PCU (Packet Control Unit): it is an additional module of the BSC for managing protocols and resources of the packet service in the radio access
- SGSN (Serving GPRS Support Node): It is basically an IP router that plays in the packet core network of the GPRS the same role of the MSC in the circuit switched core; it has additional functionalities w.r.t. a standard IP router for the management of the interfaces and protocols towards the BSS, for mobility support, and for the forwarding of packets to GGSN
- GGSN (Gateway GPRS Support Node): It is the interworking node between the GPRS network (cellular packet core) and an external PDN (Packet Data Network), typically an IP network; it manages the activation of external connectivity for UEs (typically assigning them an IP address)

GPRS Architecture



Geographic considerations

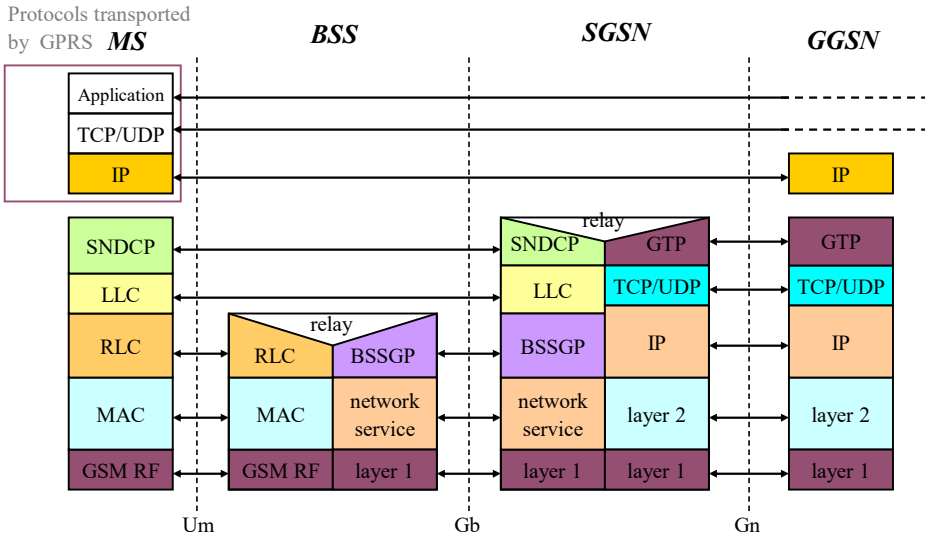
- The SGSN is dedicated to a limited area
  - Since SGSN supports a limited number of BSS's, it is limited to the area strictly covered by those BSS's. This confirms that it operates similarly to the MSC
- The GGSN is instead dedicated to the entire PLMN.



Mobile Radio Networks

❑GPRS protocol stack

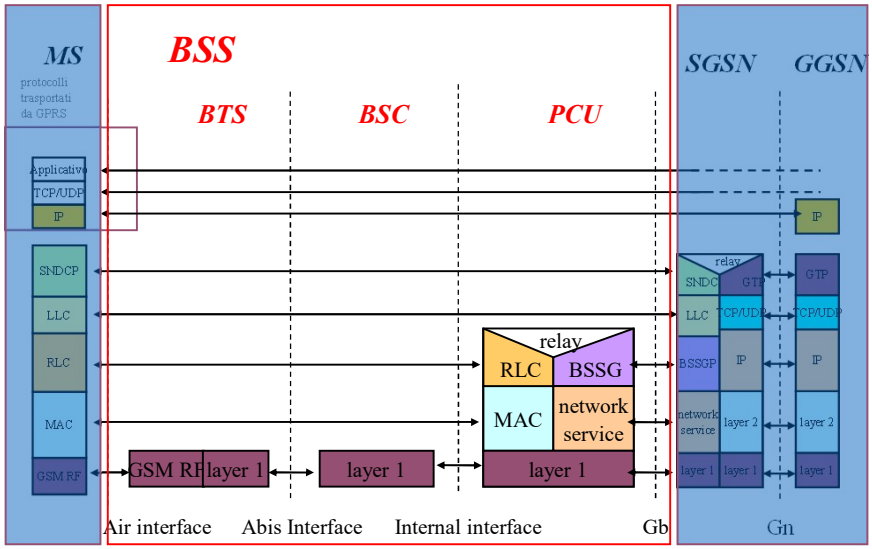
Protocols: user plane



Protocols: user pane

- **MAC (Medium Access Control):** It allows the resource sharing of GPRS channels at the radio interface managing packet multiple access in uplink and dynamic multiplexing in the downlink
- **RLC (Radio Link Control):** it implements an ARQ scheme on RLC blocks (Selective Reject)
- **LLC (Logical Link Control):** it is a layer 2 protocol similar to LAPD that is used to implement a virtual and encrypted point-to-point connection between SGSN and UE
- **SNDCP (Simple Network Dependent Convergence Protocol):** it has basically the task of adapting the upper layer protocol (typically IP) to the transport offered by GPRS
- **BSSGP (BSS GPRS Protocol):** it is also a convergence protocol that provides a virtual connection between PCU and SGSN over the network service (typically IP)
- **GTP (GPRS Tunneling Protocol):** It allows the transparent transfer of packets (IP) between GGSN and SGSN crossing the IP network of the GPRS provider; it is similar to tunneling protocols of IP world (like IPSec) but it makes use of a transport layer (TCP or UDP)

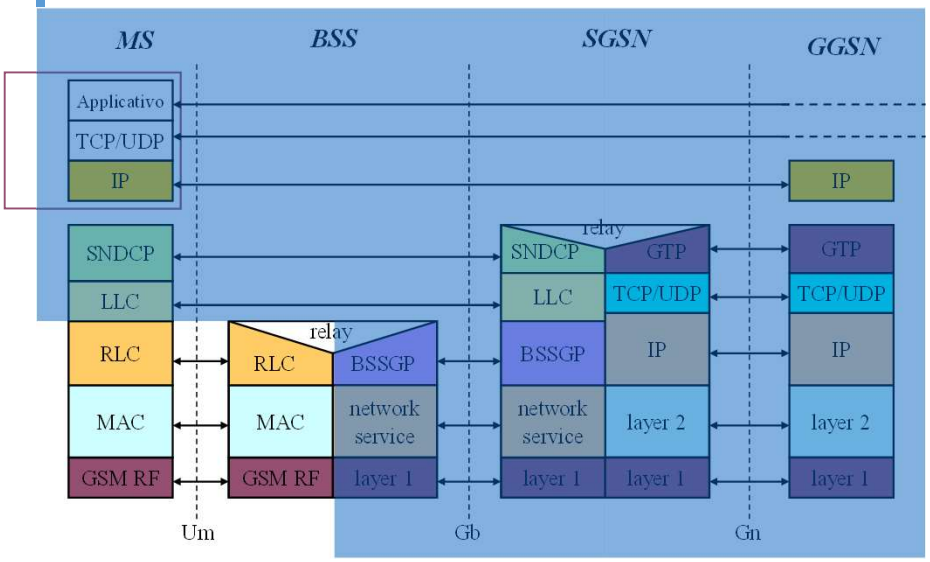
Protocols: user plane (a better view)



Protocols…implications of the previous slide

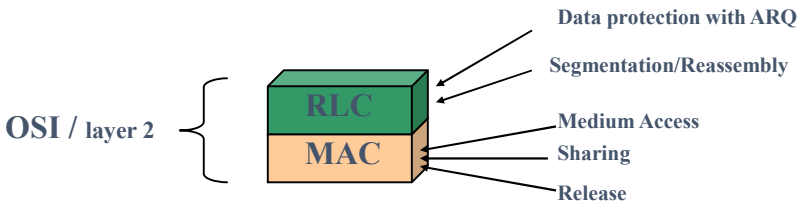
- Of course, the BSC and BTS are almost completely transparent to the GPRS network. The PCU takes care of all tasks related to packet management which are the responsibility of the BSS
- The SGSN and the mobile station are the main peer entities of the GPRS protocol stack
- Note that LLC is the lowest protocol layer of GPRS which is independent of the underlying air interface standard

Protocols: user plane (a better view)



Tasks and objectives of the MAC (Medium Access Control)

- It is a protocol used to manage the sharing of resources in "broadcast" environments
- In the case of GPRS it is used on the air interface to manage problems of access, sharing, and release of the physical medium (radio)
- In reference to ISO/OSI :



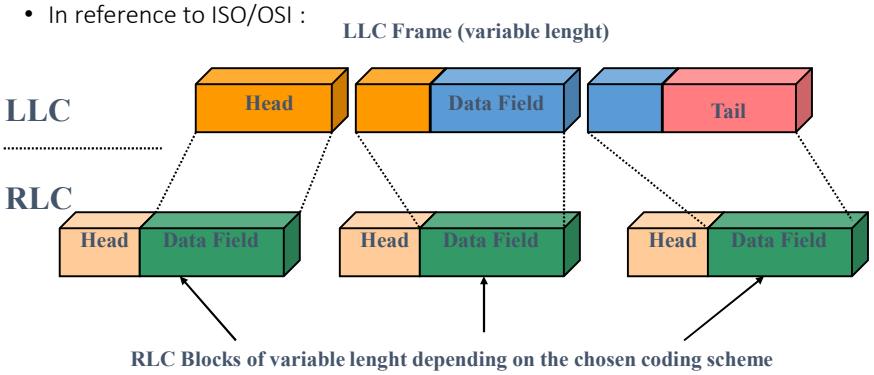
Tasks and objectives of the MAC in GPRS

Dynamic sharing of radio resources:

- It manages the multiplexing of downlink information flows
- Manage access and possible uplink collisions
- In uplink it is based on a mechanism that involves sending requests for slots in contention and a subsequent allocation by signaling in downlink

Tasks and goals of the RLC (Radio Link Control)

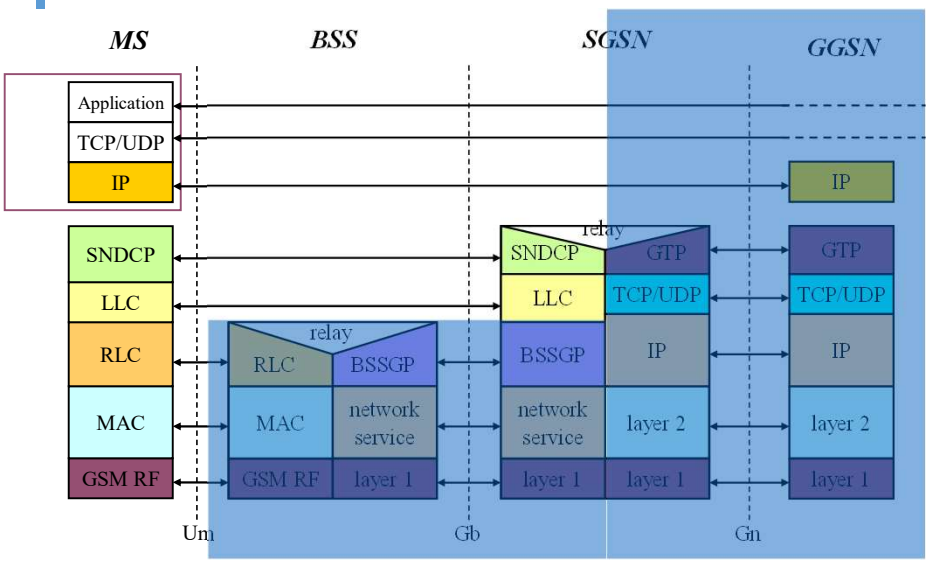
- It is a protocol that is mainly used to manage the segmentation and reassembly of data coming from the higher levels
- In the case of an acknowledged operating mode, RLC also ensures data protection during transmission over the air interface:
- In reference to ISO/OSI :



Tasks and goals of the RLC in GPRS

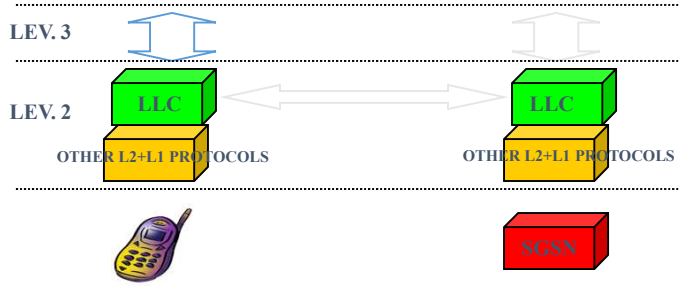
- Implement ARQ procedures by dividing information units into RLC blocks with error detection codes
- The ARQ is of the Selective Reject type
- The blocks are numbered modulo 128
- The transmission window is 64
- Use cumulative ACKs and NACKs
- It also has an unacknowledged mode

Protocols: user plane (a better view)



How does the LLC fit into the GPRS protocol

- It is a layer 2 protocol of the ISO/OSI model
- It is the lowest GPRS protocol level that is independent of the network interface used (makes the core network as independent as possible from the air interface)
- LLC provides services at the network protocol layer that GPRS is using

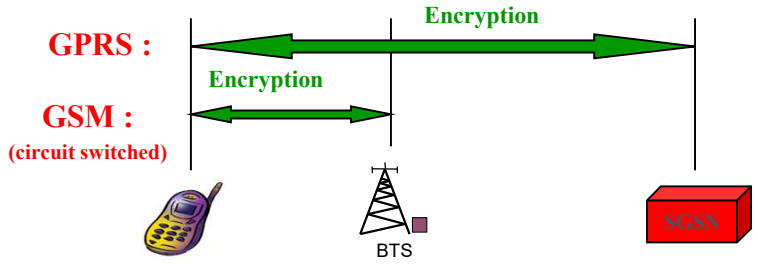


LLC functionality

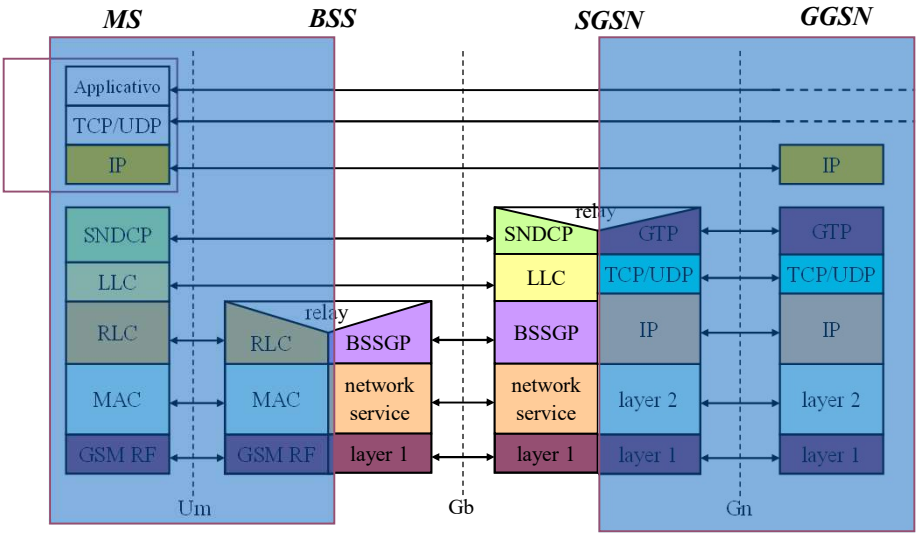
- It is used to implement a logical encrypted point-to-point connection between SGSN and MS
- In addition to the typical ISO/OSI layer 2 functions, it is responsible for encryption procedures
- Encapsulates top-level units into LLC units
- Deliver data units to higher levels in the correct sequence.

LLC: important considerations

- GPRS encryption is performed between the SGSN and the mobile station, unlike GSM.



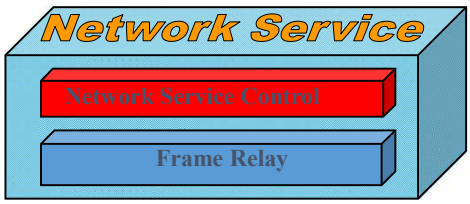
Protocols: user plane (a better view)



What is at the interface between PCU and SGSN?

Network Service:

- Allows transport between SGSN and BSS which are not normally connected by dedicated links
- Usually based on a Frame Relay network (a packet switching network in which a Permanent Virtual Circuit is established between SGSN and BSC)
- Network Service Control on top of Frame Relay:
  - Its purpose is to administer the virtual connections and links (VC/VL) between SGSN and the various PCUs

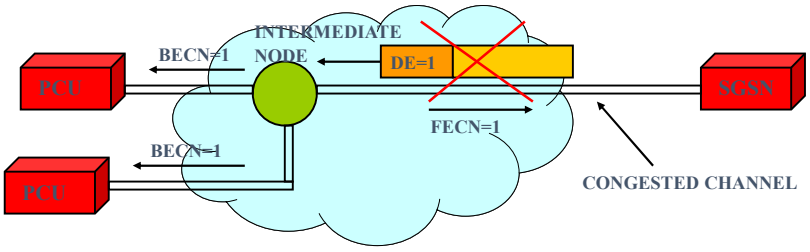


Frame Relay - basics

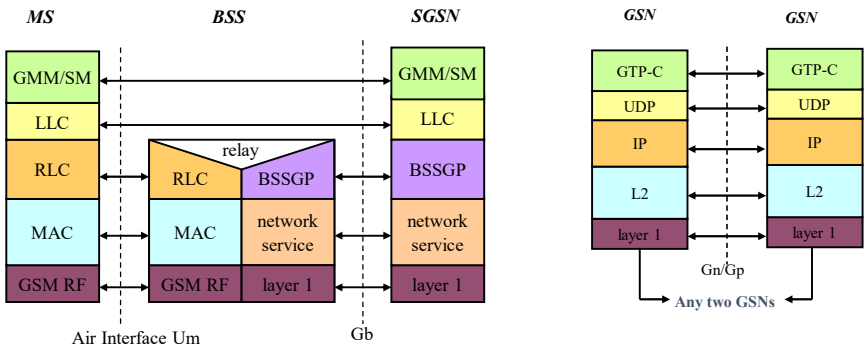
- Frame Relay has two main functions:
  - Performs the transfer of user data between two endpoints of a so-called "Permanent Virtual Circuit" (PVC)
  - User data is usually that specified by higher protocol levels
  - Addressing information is given by the "Data Link Connection Identifier" which is unique within a Frame Relay network
- It provides the means to control congestion
  - the frame bits used for this function are: BECN (Backward Explicit Congestion Notification), FECN (Forward Explicit Congestion Notification), DE (Discard Eligibility)
- It offers no means of checking for errors. Incorrect frames are simply discarded!

Congestion Control in Frame Relay: basics

- If a node realizes that there is an overloading situation then:
  - Informs all involved nodes about the congestion situation by setting the FECN and BECN bits respectively
  - Eliminates all the frames that have the DE bit equal to 1. DE=1 indicates that this frame exceeds the guaranteed transmission speed and subscribed in the contract with the operator (CIR= Committed Information Rate)



Protocol: control plane



- **SM (Session Management):** it is used for session setup and tear down
- **GMM (GPRS Mobility Management):** it is used for mobility management procedures
- **GTP-C:** GTP for the control plane

Mobile Radio Networks

- GPRS air interface

Physical and Logical Channels

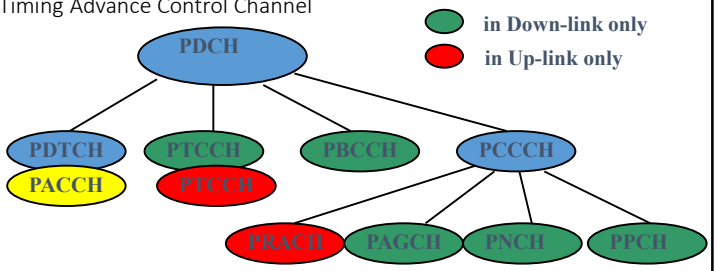
- The logical channel used by GPRS to transport data is the PDCH (Packet Data Channel)
- The GPRS air interface is organized by frames:
  - Each frame is composed of 8 timeslots (577 microsec/slot)
- Frames can be organized on a multi-frame basis, and Multiframes are grouped into Superframes and superframes into Hyperframes:
  - Multiframes can be composed of 26, 51, or 52 frames (for TCH, Signaling, and GPRS, respectively)

Physical and Logical Channels

- The minimum transmissible unit is a Radio Block
- The Radio Block is a sequence of 456 coded bits passed from the MAC/RLC to the physical layer which is transmitted in 4 normal bursts
- Each Radio Block consists of 4 consecutive manifestations of the same slot in 4 consecutive frames
- The radio resource assignment dynamics in Uplink and Downlink is that of a Radio Block and not that of a physical slot
- The various logical channels are mapped on one or more slots of one or more carriers (remember that GPRS is based on an MF-TDMA)

Logical Channels (grouped by category)

- PPCH – Packet Paging Channel
- PRACH – Packet Random Access Channel
- PAGCH – Packet Access Grant Channel
- PNCH – Packet Notification Channel
- the set of these channels is referred to as PCCCH (Packet Common Control Channel)
- PBCCH – Packet Broadcast Control Channel
- PDTCH – Packet Data Traffic Channel (Up or Down)
- PACCH – Packet Associated Control Channel
- PTCCH – Packet Timing Advance Control Channel



Names and functions of GPRS logical channels

Common Control Channels

- PPCH – Packet Paging Channel
  - (Downlink) used to call the MS before sending it the data
- PRACH – Packet Random Access Channel
  - (Uplink) used by the MS as a response to paging or to communicate the intention to initiate a transmission;
- PAGCH – Packet Access Grant Channel
  - (Downlink) on which the network communicates to the MS which traffic channels (PDTCH) have been assigned to it
- PNCH – Packet Notification Channel
  - (Downlink) used to notify multiple MSs in a group that data is to be transmitted to them (Multicast)

Names and functions of GPRS logical channels

Broadcast Common Channel

- PBCCH – Packet Broadcast Control Channel
  - (Downlink) to broadcast system information, i.e. parameters that MS must use to access the network

Traffic Channel

- PDTCH – Packet Data Traffic Channel (Up or Down)
  - (unidir. Uplink or Downlink) on which packet data transfer takes place
  - it is only temporarily assigned to the MS for the time necessary to transfer the useful data
  - a multislot MS can use multiple PDTCHs in parallel

Names and functions of GPRS logical channels

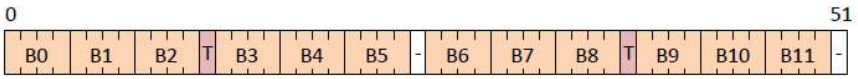
Dedicated Control Channels

- PACCH – Packet Associated Control Channel
  - (Bidirectional) for signaling exchange of a precise MS
  - it can be associated with one or more PDTCHs assigned to the same MS
  - info examples: power control, acknowledgments (ACK/NAC) of transmitted RLC/MAC blocks, downlink data channel assignments for MSs already using uplink data channels, etc.
- PTCCH – Packet Timing Advance Control Channel
  - (Uplink and Downlink) used in the uplink to send Access Bursts to the network in order to allow the network to calculate the timing advance
  - which is then communicated on the downlink PTCCH to more MS

NEW

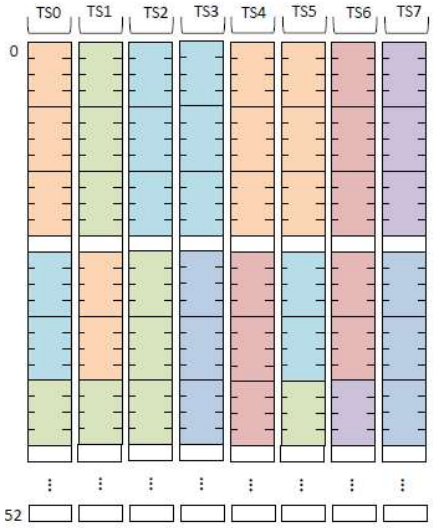
Mapping of logical channels

- A multi-frame of 52 frames is created
- in multi-frame 48 frames are used to transmit 12 Radio Blocks, 2 are used for PTCCH transmission, 2 are left idle
- Mapping of logical to physical channels is dynamic (packet)
- the type of information (payload type field) and therefore the logical channel are written in the MAC header of the radio block



Mapping of logical channels

- UEs can simultaneously monitor multiple PDCHs on different time slots (usually up to 6) in uplink or in downlink
- The medium access control (MAC) can assign multiple blocks on the same or different time slots for transmission/reception to a UE
- Uplink and downlink allocations are independent

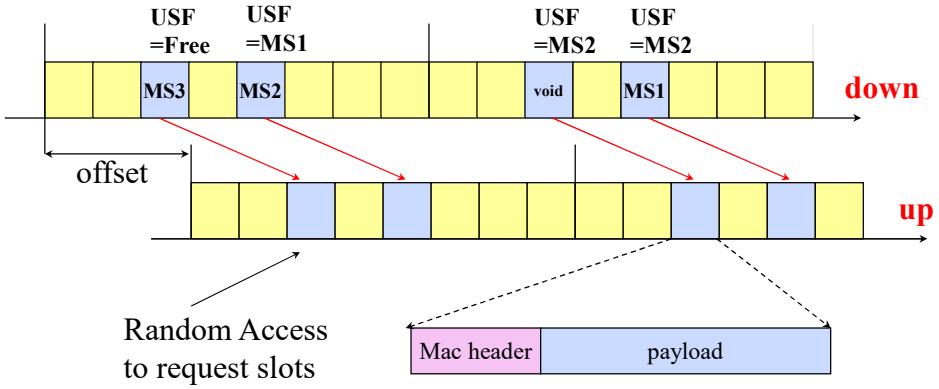


Channel access control

- The allocation of resources by the MAC is dynamic
- The set of transmission resources requested by a terminal (in transmission or reception) is called TFB (Temporary Flow Block)
- Terminals can use multiple time-slots (multiple PDTCHs) at the same time
- the set of PDTCHs that can be used is communicated (assigned) by the network to the MS (MAC level) together with a 3-bit USF (Uplink State Flag) value
- The effective possibility of using a PDTCH by an MS depends on the value of the USF included in the MAC header of the radio blocks transmitted in downlink
- USF=111 indicates FREE or the PRACH channel that can be used to send TFB requests; the answers and the assignment arrive downlink on the PAGCH

Channel access control (2)

- Resources (slots) are shared
- Explicit addressing in the MAC header
- The slots vacated by the voice can be used



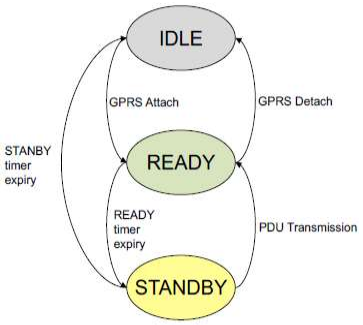
Mobile Radio Networks

❑ GPRS procedures

Mobility management

Mobility management depends on the state of the UE

- IDLE
  - not attached to GPRS
  - EU is not reachable
- READY
  - UE can receive/transmit packets and paging is not required
  - EU is traced on a cell basis
- STANDBY
  - EU attached to GPRS
  - UE can receive packets only through paging
  - EU is traced on a Routing Area basis
  - UE can transmit packets (this generates a transition to READY state)



GPRS Attach

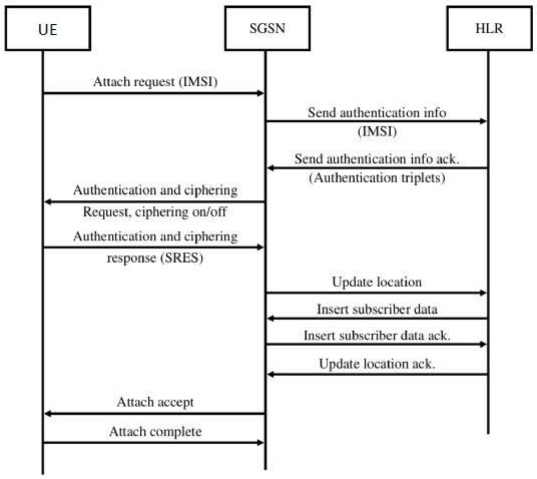
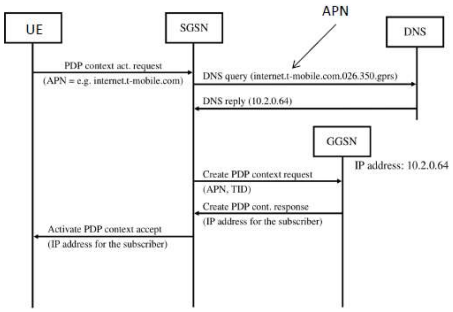


Figure source: M. Sauter, From GSM to LTE-Advanced Pro and 5G, Wiley, 3rd Ed. 2017

Session management

- In order to send and receive packets from and to an external network it is necessary to activate a Packet Data Protocol (PDP) context
- A PDP context is a logical connection to the Internet and, in particular, with a gateway identified by an *APN (Access Point Name)*
- In the case of activation of a session with an external IP network, an IP address (static or dynamic, private or public) and, optionally, some quality parameters are also assigned



Session management: PDP Context Creation (1/2)

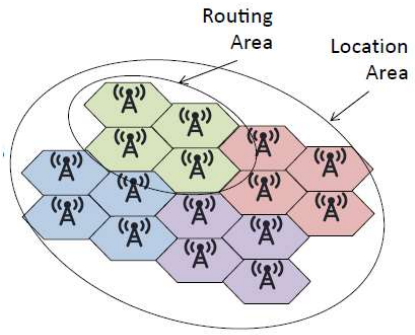
- The MS (after a successful attach) must have one (or more) addresses used in the external Packet Data Network (PDN): the PDP address (e.g. IP address if the external network is IP based)
- The PDP Context contains: the type of PDP address (e.g. IP), the PDP address assigned to the MS, the requested QoS, the address of the GGSN used as access point to the considered PDN
- The PDP Context is saved in the MS, in the specific SGSN, in the GGSN.
- An active PDP Context makes the user "visible" to the external PDN and it is possible to send/receive packets.
- A user can have multiple PDP Contexts active at the same time.

Session management: PDP Context Creation (2/2)

- The PDP address can be allocated statically or dynamically
- In static allocation, the home network operator permanently assigns its user a PDP address.
- In dynamic allocation, upon activation of the PDP Context, the PDP address can be assigned by the operator of the user's home network or by the operator of the visited network. The home operator decides which of the two choices to adopt
- In dynamic allocation, the GGSN is responsible for the allocation itself and for activating/deactivating the addresses.

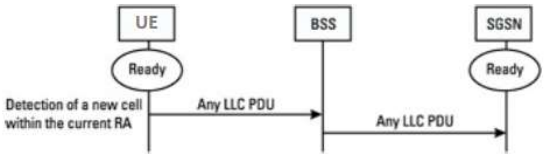
Mobility Management

- Mobility management in GPRS follows the same principles of that in GSM, with some differences
- In STANDBY state, UE is traced on a Routing Area basis with its RAI (Routing Area Identifier)
- In READY state, UE is traced on a cell basis, but there is no handover procedure but just cell reselection operated by UE (there is also a NACC – Network Assisted Cell Change mode)



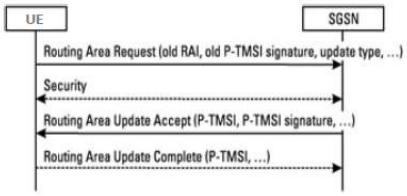
Call update

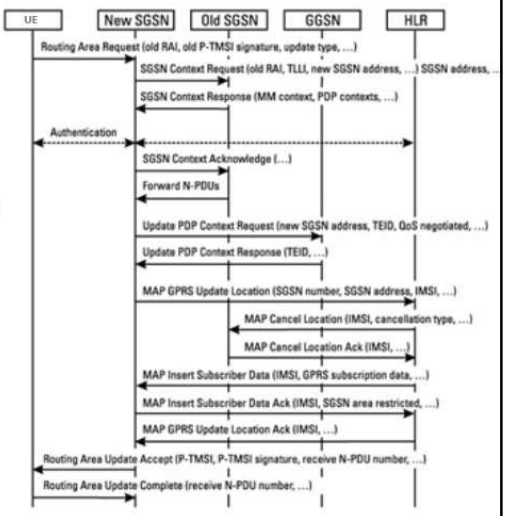
- When a UE in READY state detects a new cell within its current RA, it performs a cell update procedure by sending any LLC frame containing its identity.



Routing Area update

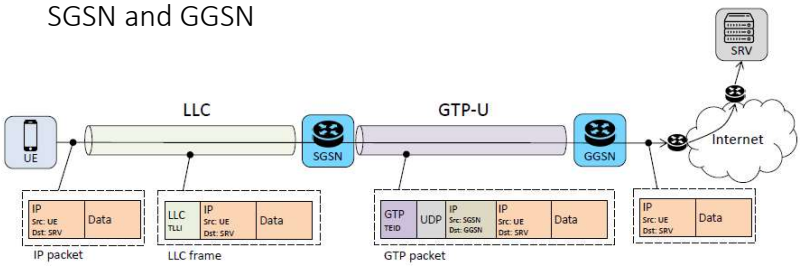
- RA update can be between RAs of the same SGSNs or of different SGSNs



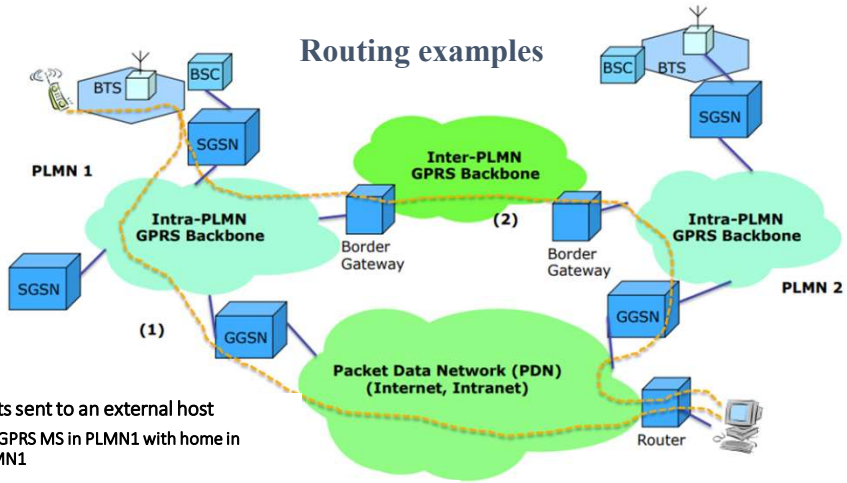


Packet forwarding

- IP packet forwarding in GPRS, and also all subsequent mobile technologies, is based on tunnels
- In the specific case of 2G and 3G technologies there are two tunnels,
  - a level 2 tunnel managed by the LLC protocol between UE and SGSN
  - a level 4 tunnel managed by the GTP protocol between SGSN and GGSN



GPRS: Application Scenarios

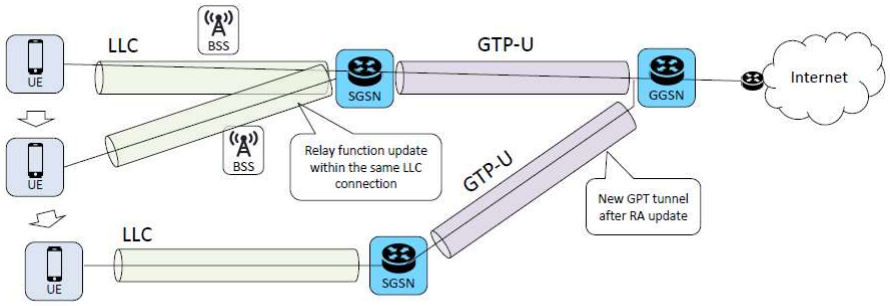


Packets sent to an external host

- *(1)* GPRS MS in PLMN1 with home in PLMN1
- *(2)* GPRS MS in PLMN1 with home in PLMN2. The GTP tunnel has to connect with the home GGSN through the Inter-PLMN GPRS backbone

Mobility management and tunnels

- Tunnels are also used to modify packet forwarding according to UE mobility



Physical Layer

- For GPRS, 4 coding schemes (by channel) up to 20 kb/s are defined
- EDGE (Enhanced Data Rate for Global Evolution) extends these rates with lightweight coding and multi-level modulation (8PSK)