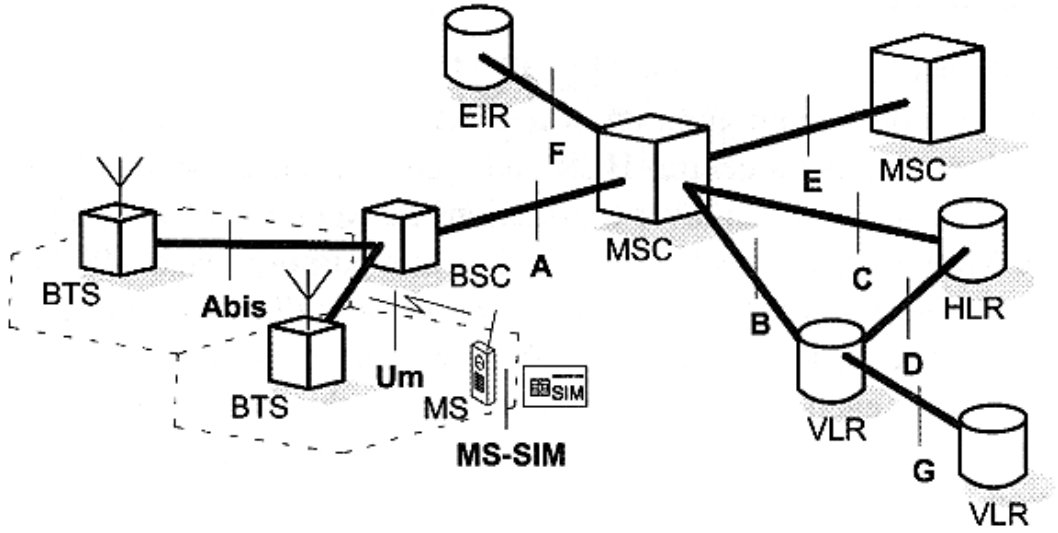
Cellular Mobile Networks - GSM
GSM Protocol Architecture

Contents - GSM - GSM Protocol Architecture

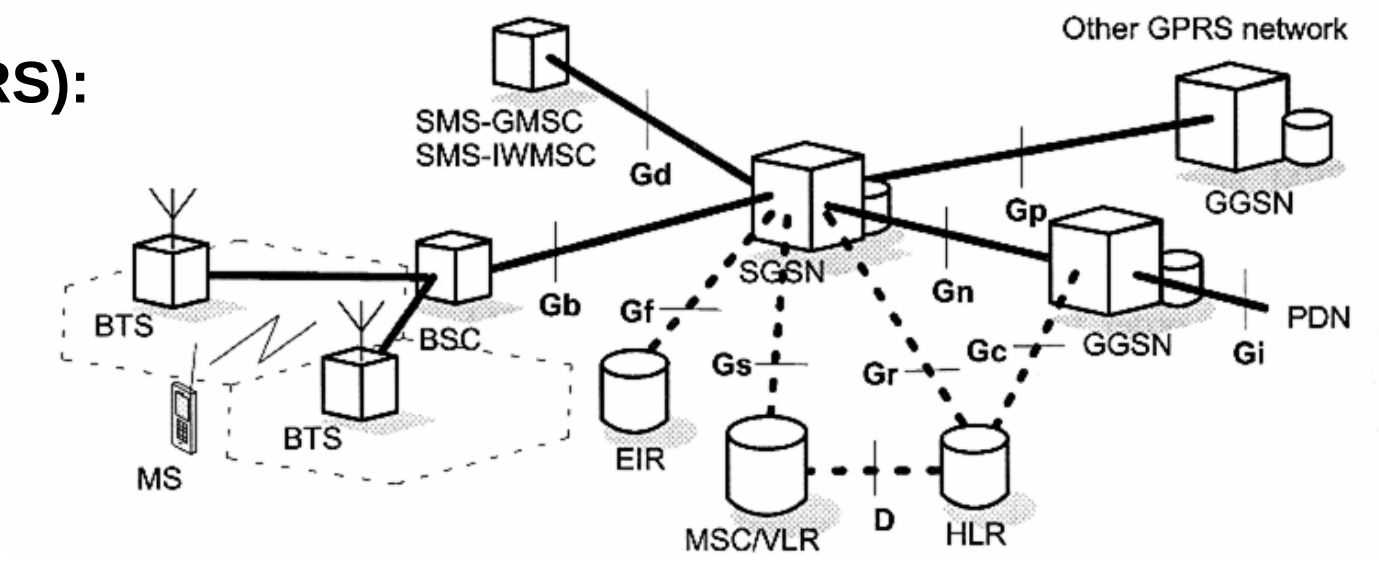
Introduction

GSM/GPRS System Architecture and Interfaces

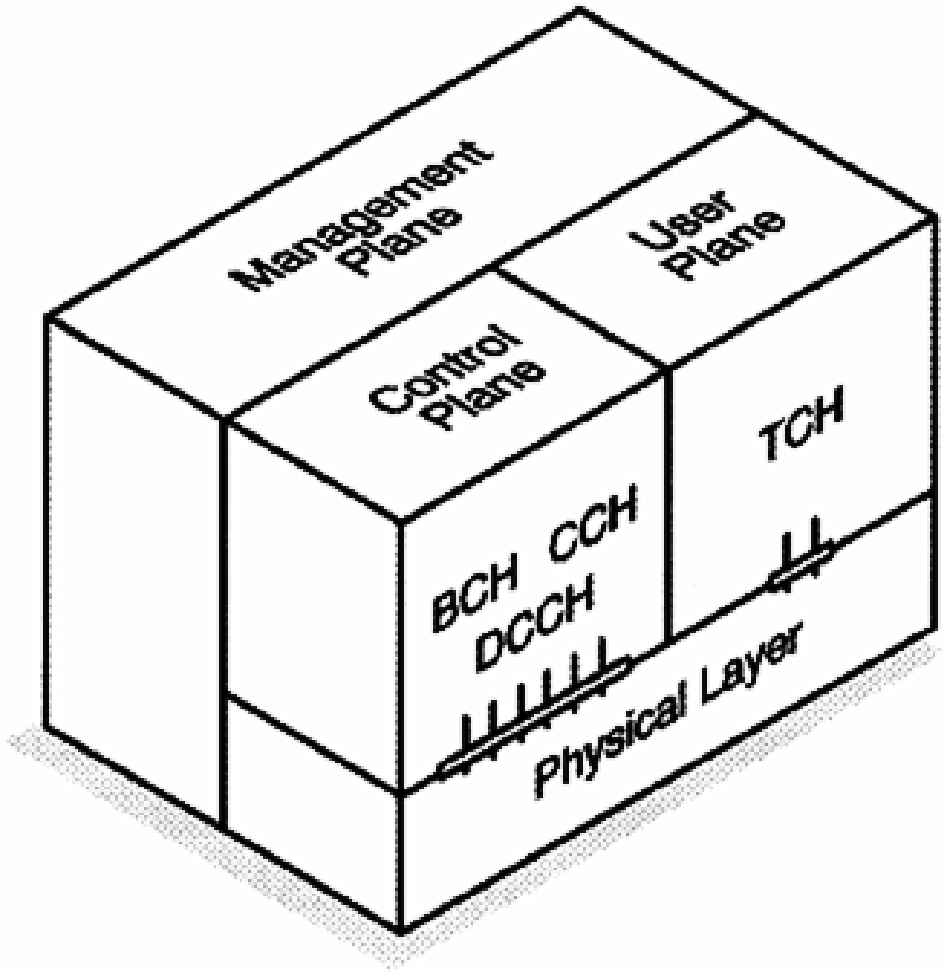
- **CS-Domain:**



- **PS-Domain (GPRS):**



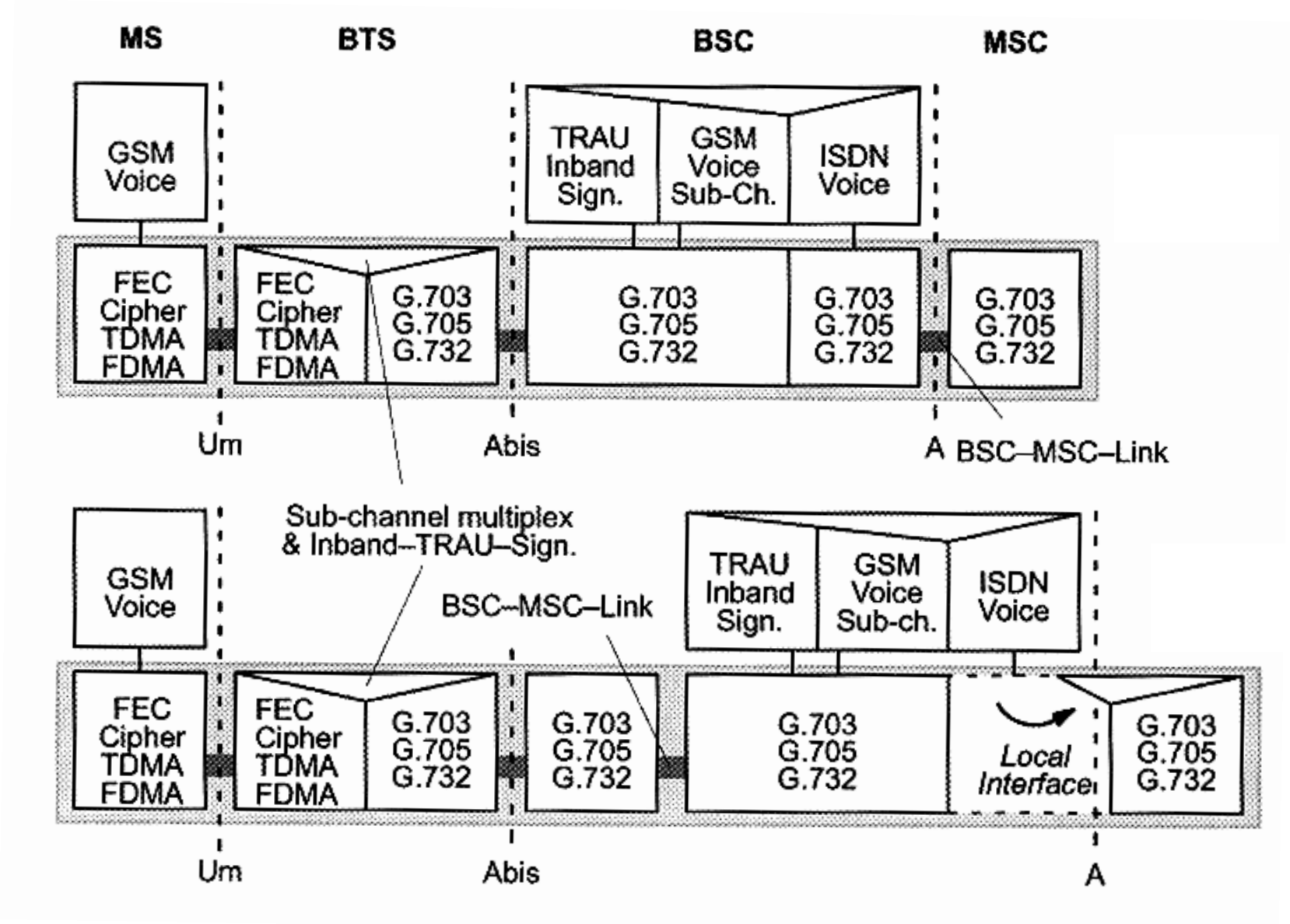
GSM Protocol Reference Model



User Plane Protocol Architecture

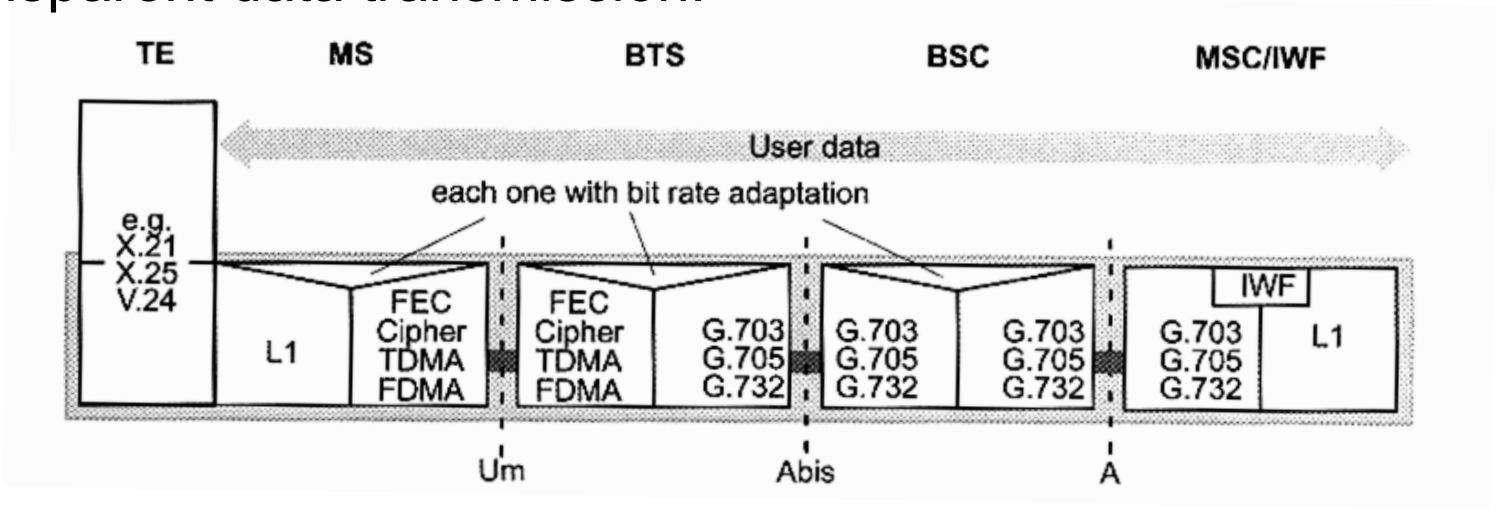
User Plane Protocols (CS-Domain) - CS Voice

- Option 1: (TRAU in BSC)
- Option 2: (TRAU in MSC)

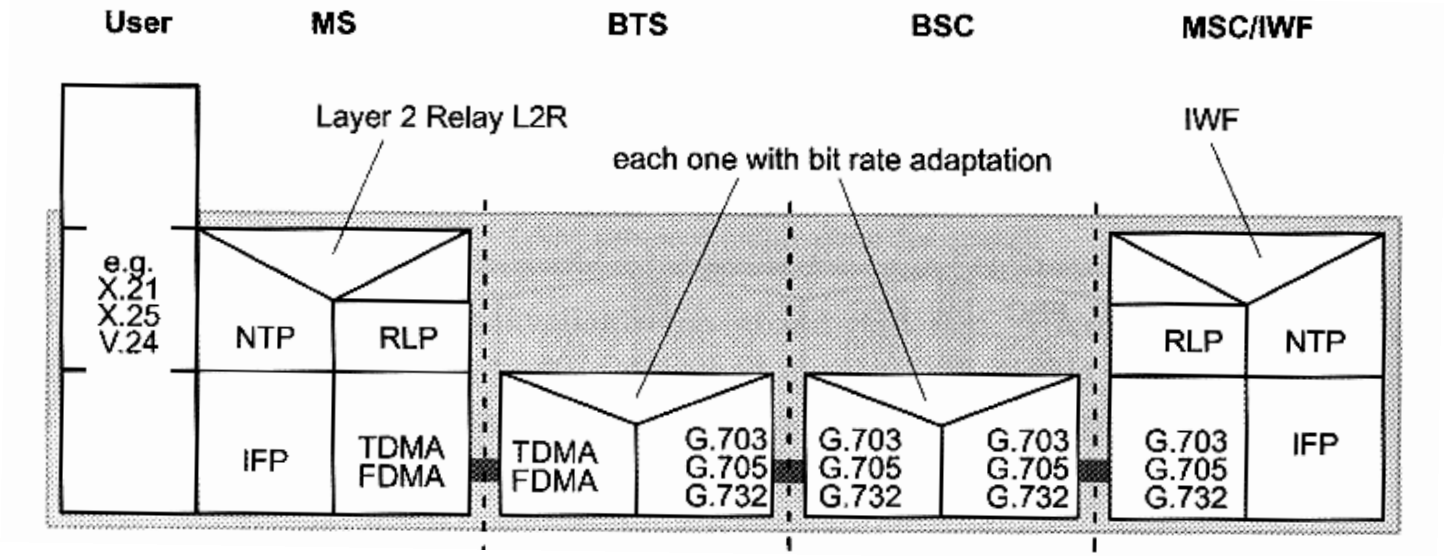


User Plane Protocols (CS-Domain) - CS Data

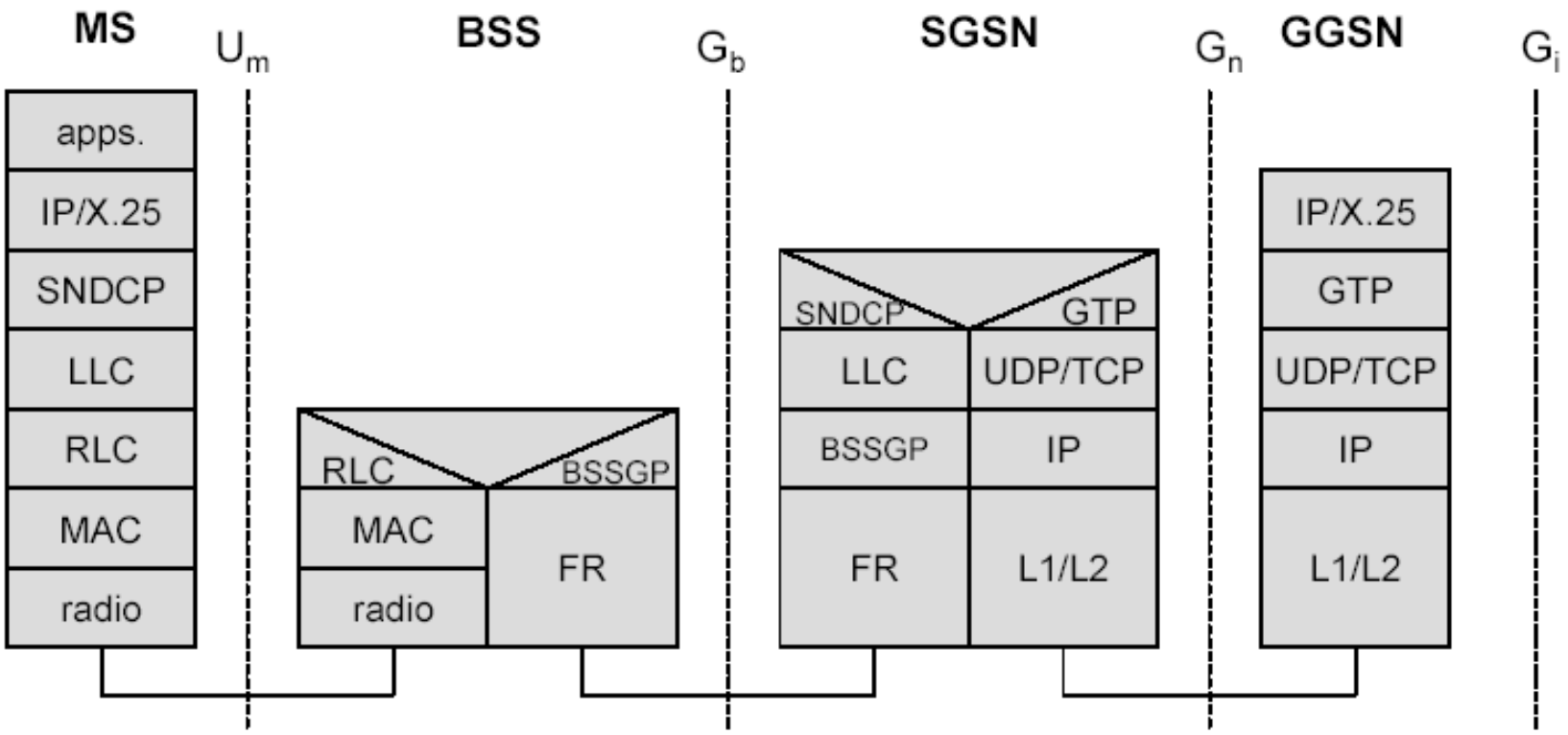
- Transparent data transmission:



- Non-transparent data transmission:



User Plane Protocols (PS-Domain) - Overview



BSSGP: BSS GPRS Protocol
FR: Frame Relay
LLC: Logical Link Control
GTP: GPRS Tunneling Protocol
RLC: Radio Link Control Protocol
SNDCP: Subnetwork Dependent Convergence Protocol

User Plane Protocols (PS-Domain) - SNDCP Protocol

Subnetwork Dependent Convergence Protocol (SNDCP)

- SNDCP is located between network layer (layer 3) and LLC (layer 2)
- SNDCP supports several protocols of the network layer, e.g. IP or X.25; the network layer protocols share the use of SNDCP
- Tasks of SNDCP:
  - multiplexing and demultiplexing of data streams
  - segmentation/reassembling of (layer 3) packets to/from (layer 2) LLC frames
  - compression and decompression of (layer 3) packets, e.g. IP Header Compression

User Plane Protocols (PS-Domain) - LLC and RLC/MAC

LLC Protocol and RLC/MAC Protocol

- identically used in the control plane of the PS-Domain ⇒ see chapter "Control Plane Protocols / PS-Domain"

User Plane Protocols (PS-Domain) - GTP Protocol

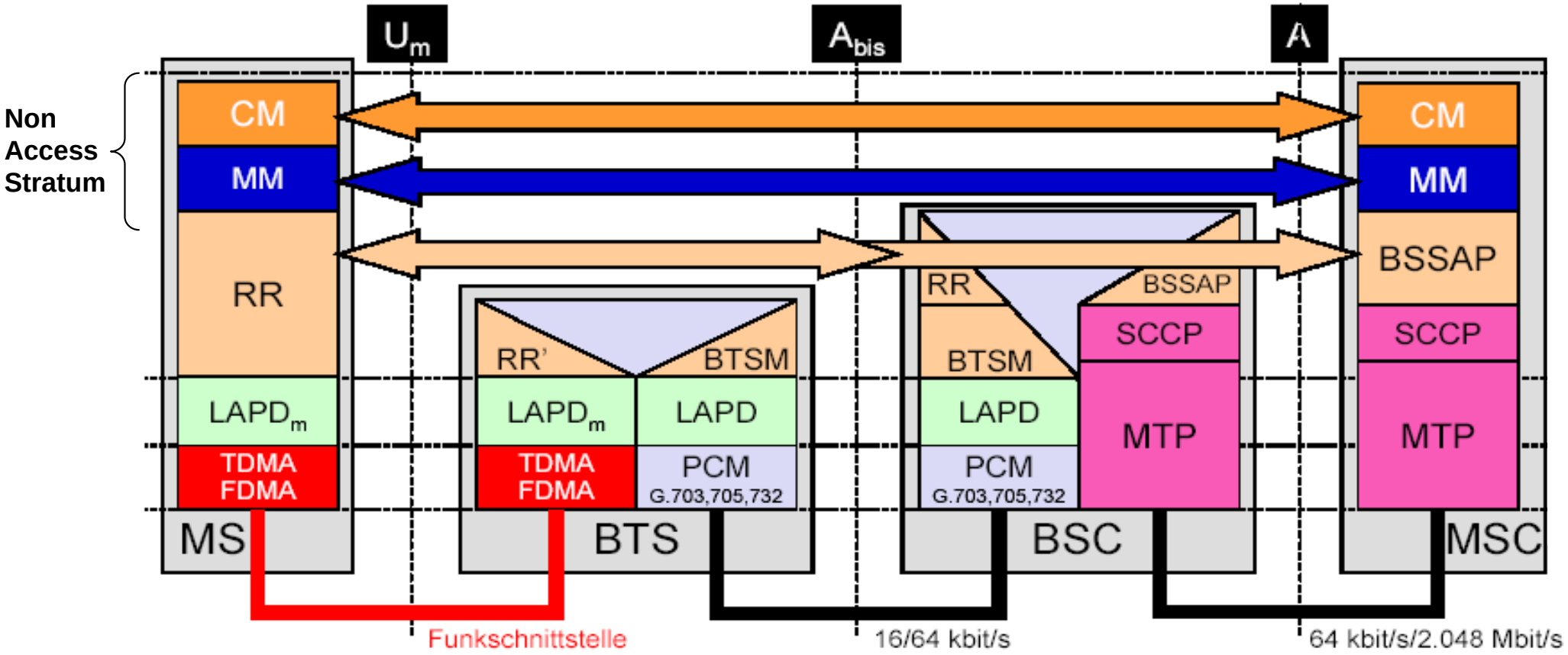
GPRS Tunneling Protocol (GTP)

- GTP enables a tunneled transport of multi-protocol (layer 3) packets through the GPRS backbone, i.e. between SGSN and GGSN
- GTP consists of 2 parts:
  - GTP user plane part (**GTP-U**): tunneled transport of user data
  - GTP control plane part (**GTP-C**): control and management of the GTP-U tunnel (e.g. for tunnel creation, deletion or modification)

    examples for GTP management:
    - PDP context management (SGSN → GGSN)
    - network requested PDP context activation (GGSN → SGSN)
    - mobility management (required if the SGSN is changed)

Control Plane Protocol Architecture

Control Plane Protocols (CS-Domain) - Overview



CM: Connection Management
MM: Mobility Management
RR: Radio Resource Management

BTSM: BTS Management
BSSAP: BSS Application Part

LAPD: Link Access Procedure for the D-Channel
$LAPD_m$: LAPD mobile

Control Plane Protocols (CS-Domain) used in BSS

Protocols at the air interface (U_m-Interface):

- Connection Management (CM) (layer 3)
- Mobility Management (MM) (layer 3)
- Radio Resource Management (RRM) (layer 3)
- Data link protocol $LAPD_m$ (layer 2)
- Physical channels (TDMA, FDMA) and logical channels (layer 1)

Additional protocols between BTS and BSC (A_{bis}-Interface) and between BSC and MSC (A-Interface):

- BTS Management (BTSM)
- BSS Application Part (BSSAP = BSSMAP+DTAP)

Control Plane Protocols (CS-Domain) used in BSS - CM

Connection Management (CM)

- Layer 3 protocol between MS and MSC
- Control of user data connections
  - setup, maintenance and teardown of normal calls (incoming/outgoing)
  - setup of emergency calls (outgoing)
- Control of supplementary services
- Control of short message (SMS) exchange

Control Plane Protocols (CS-Domain) used in BSS - MM

Mobility Management (MM)

- Layer 3 protocol between MS and MSC
- Mobility support for MS:
  - initial MS localization (at registration)
  - location update
- Additional security functions:
  - MS / subscriber identification (via IMEI, IMSI)
  - authentication
  - subscriber identity protection (the subscriber identity is kept confidential through the assignment of a temporary identity (TMSI))

Control Plane Protocols (CS-Domain) used in BSS - RRM

Radio Resource Management (RRM)

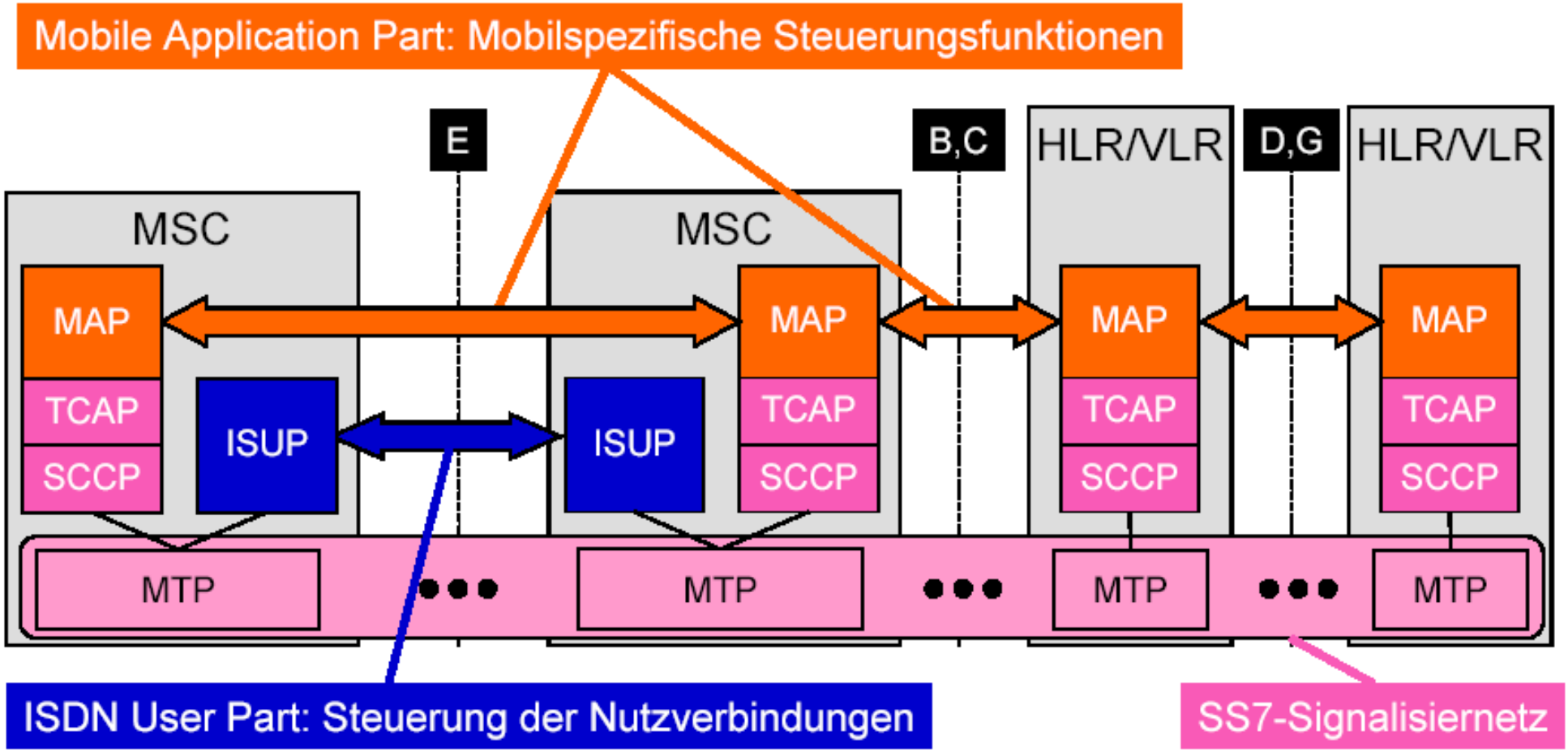
- Frequency channel and time slot (burst) management
- Setup, maintenance and teardown of dedicated (point-to-point) RRM connections between MS and network (remark: RRM connections use dedicated control channels)
- Overhearing of (uni-directional) BCCH and CCCH channels
- Management of RACH
- Performing cell selection/reselection in MS idle mode and handover in MS active mode
  - supplementary functions: channel quality measurement, transmit power control, synchronization
- Remark: the RRM functions are distributed among BTS, BSC and MSC (however, most RRM functions are realized in the BSC)

Control Plane Protocols (CS-Domain) used in BSS - $LAPD_m$

$LAPD_m$

- Layer 2 protocol between MS and BTS
- $LAPD_m$ is a version of LAPD, adapted to the air interface
- $LAPD_m$ service variants:
  - unconfirmed service: for all common control channels (CCCH) except RACH
  - confirmed service: only for dedicated control channels (DCCH)

Control Plane Protocols (CS-Domain) used in NSS



Control Plane Protocols (CS-Domain) used in NSS

Message Transfer Part (MTP) (like in ISDN)

- Transport of signaling data (SS7 signaling)

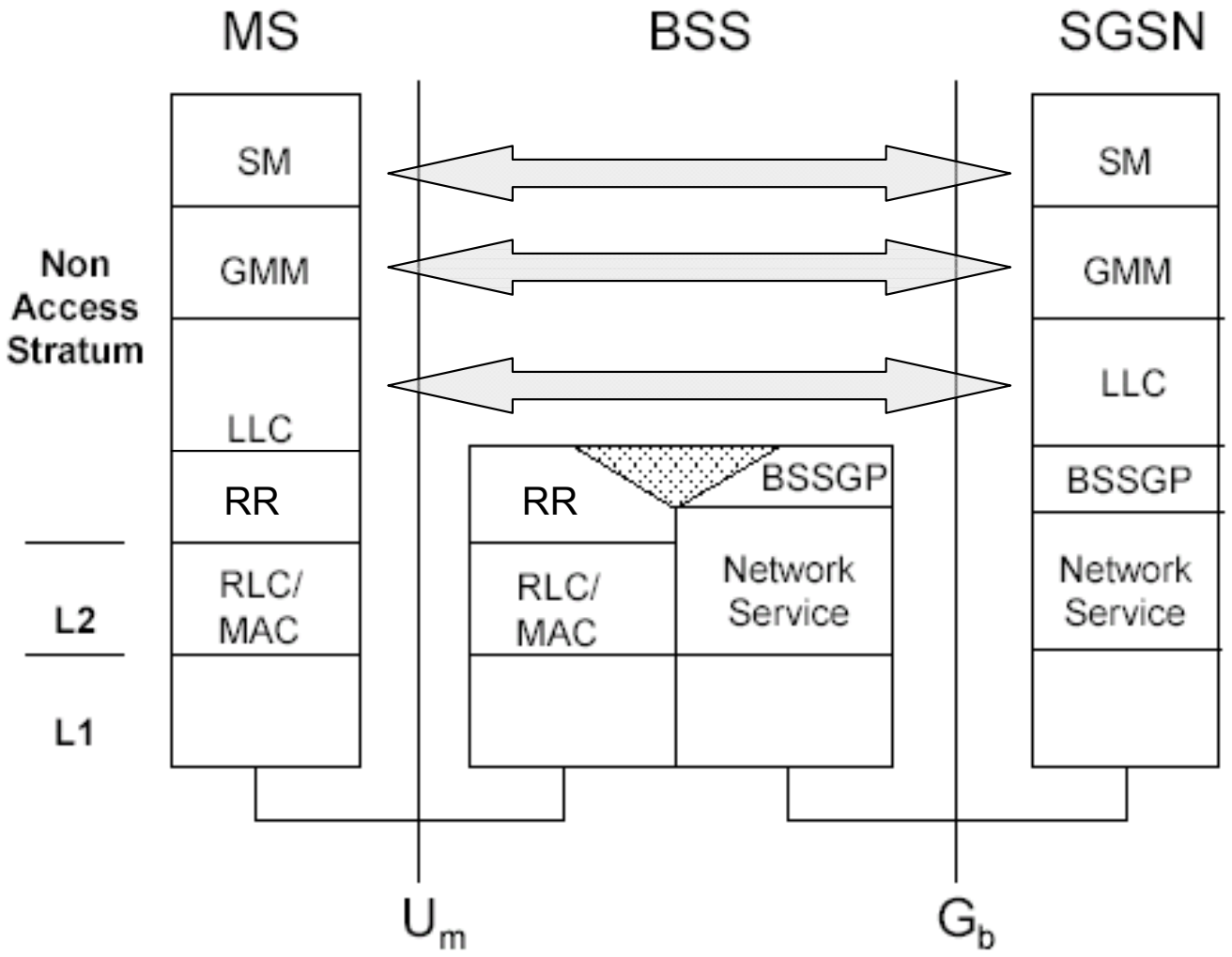
ISDN User Part (ISUP) (like in ISDN)

- Control of user data connections (calls)

Mobile Application Part (MAP)

- Mobile specific control functions:
  - update, storage and query of location informations (in HLR/VLR)
  - storage, update and extension of user profile data (in HLR)
  - control of handover of connections between MSCs
- MAP is supported by transaction oriented services of SS7:
  - Signaling Connection Control Part (SCCP)
  - Transaction Capability Application Part (TCAP)

Control Plane Protocols (PS-Domain) - Overview



Control Plane Protocols (PS-Domain) used in BSS

Protocols at the air interface (U_m-Interface):

- Session Management (SM) (layer 3)
- GPRS Mobility Management (GMM) (layer 3)
- Logical Link Control (LLC) (layer 3)
- Radio Resource Management (RRM) (layer 3)
- Radio Link Control / Medium Access Control (RLC/MAC) (layer 2)
- physical channels (TDMA, FDMA) and logical channels (layer 1)

Additional protocols between BSC and SGSN (G_b-Interface):

- BSS GPRS Application Protocol (BSSGP)

Control Plane Protocols (PS-Domain) used in BSS - SM

Session Management (SM)

- In order to exchange data with external **Packet Data Networks (PDNs)** the MS requires an address out of the address range of the PDN. In general this address is called **Packet Data Protocol address (PDP address)**. In case of an IP network it is an IP address.
- For every session a **PDP Context** is created, which describes the properties of the session. It contains the following informations:
  - **PDP type** (e.g. IPv4, IPv6, X.25, PPP)
  - **PDP address**, which is assigned to the MS (static or dynamic)
  - **Quality of Service (QoS) class** requested
  - **Address of the GGSN**, which serves as gateway to the PDN
- As soon as the MS owns an active PDP context, it is visible to the external PDN and can receive or transmit packets

Control Plane Protocols (PS-Domain) used in BSS - GMM

GPRS Mobility Management (GMM)

- The main task of mobility management is to support MS mobility. Additionally it contains also some security functions (authentication and keeping the subscriber identity confidential (via TMSI assignment)).
- Main MM procedures:
  - **location management** (registration and location updates)
  - **security functions** (authentication and TMSI assignment)
- Remarks:
  - location management procedures are only performed for MS being in idle mode (i.e. MS without active connections) - otherwise the location of the MS is known anyway (at cell-level granularity)
  - an efficient location management exhibits a tradeoff between tracking the location of the MS and paging the MS → see chapter "GSM Mobility Management"

Control Plane Protocols (PS-Domain) used in BSS - LLC

Logical Link Control (LLC)

- In GPRS the LLC sublayer is responsible for reliable data transmission **between MS and SGSN**. Its functionality is based on the HDLC protocol and is independent of the underlying protocols of the radio interface.
- Main functions of LLC (for GPRS):
  - management of LLC connections **between MS and SGSN**
  - confirmed and unconfirmed data transfer
  - support of point-to-point and point-to-multipoint connections
  - support of variable LLC frame lengths
  - support of different QoS-classes and transfer delays
  - reliable transmission of LLC-frames: error detection, Automatic Repeat Request (ARQ), correct sequence
  - flow control (transmit window size between 1 and 255 LLC frames)
  - encryption

Control Plane Protocols (PS-Domain) used in BSS - RRM

Radio Resource Management (RRM)

- General tasks of radio resource management procedures:
  - setup, maintenance and teardown of RRM connections between MS and the network (dedicated point-to-point connections); RRM connections are used to control functions like cell selection/reselection or handover; despite RRM connections haven't been established some RRM functions might be performed - this is possible by overhearing the unidirectional BCCH and CCCH channels
  - management of transmission resources at the radio interface (frequencies, time slots (physical channels, bursts), logical channels)
- In GPRS the RRM procedures also comprise the management of radio interface transmission resources for packet data traffic (this also includes the broadcast of system information to support MS in packet idle mode or packet transfer mode)

Control Plane Protocols (PS-Domain) used in BSS - RLC

Radio Link Control (RLC) for GPRS

- In GPRS the Radio Link Control (RLC) sublayer is responsible for the reliable data transmission (within one TBF) on the radio interface **between MS and BSS**
- Main functions of RLC (for GPRS):
  - management of RLC connections **between MS and BSS**
  - confirmed and unconfirmed data transfer
  - reliable transmission of RLC data blocks: error detection, selective ARQ, correct sequence
  - flow control (Transmit Window Size = 64 RLC data blocks)
  - segmentation / reassembling of LLC frames to / from RLC data blocks

Control Plane Protocols (PS-Domain) used in BSS - MAC

Medium Access Control (MAC) for GPRS

- In GPRS the Medium Access Control (MAC) sublayer is used by MS for getting access to radio resources for packet data traffic
- Main functions of MAC (for GPRS):
  - control of statistical multiplexing of different data streams (TBFs); this includes the scheduling and prioritization of MAC/RLC data blocks
  - avoidance/resolution of bottlenecks (access collisions)
- Remark: the initiation of the resource allocation in uplink direction (packet channel request message) is based on the Slotted ALOHA principle (at the P-RACH and RACH)

Control Plane Protocols (PS-Domain) used in BSS - MAC

Medium Access Control for GPRS: Multiplexing of TBFs on PDTCHs

- A **Temporary Block Flow (TBF)** is a physical connection for the unidirectional transmission of LLC frames on one or more Packet Data Traffic Channels (PDTCHs)
- A TBF is kept only during the duration of a data transfer, i.e. until no RLC/MAC frames are waiting for transmission and all acknowledgements have been received
- A **Temporary Flow Identity (TFI)** is assigned to every TBF by the network; RLC/MAC data blocks contain the TFIs; the TFIs have to be unique for TBFs that use the same PDTCHs
- Therefore different TBFs (from/to different MS) can be multiplexed on the same packet data channels (PDTCH); by means of the TFI the TBFs can be identified and distinguished

Control Plane Protocols (PS-Domain) used in BSS - MAC

Medium Access Control for GPRS: Setup of a TBF

- Setup of a TBF through a MS:
  - the MS sends a Packet Channel Request message
    - on the P-RACH (or on the RACH), in case the MS has no Packet Data Traffic Channel (PDTCH) yet
    - on the Packet Associated Control CHannel (PACCH), in case the MS has already a PDTCH
  - the BSS replies with a Packet Uplink Assignment message on the Packet Access Grant Channel (or at the AGCH) and informs the MS about the resource assignment for the TBF
  - Remark: in case the network doesn't reply to request messages that are sent on the P-RACH (or RACH) the MS sends the message again (Slotted-ALOHA principle)
- Setup of a TBF through the network:
  - the network sends a Packet Downlink Assignment message on the corresponding Downlink PCCCH

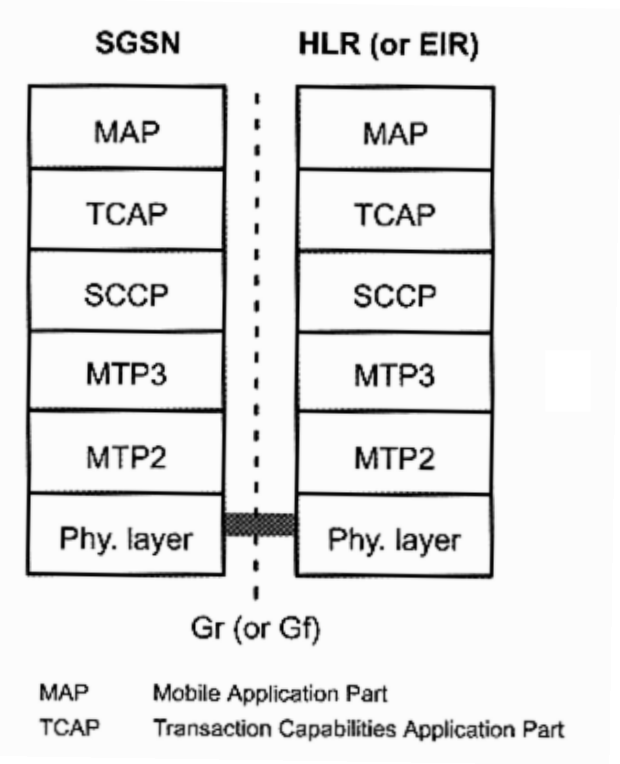
Control Plane Protocols (PS-Domain) used in BSS - MAC

Medium Access Control for GPRS: Scheduling of TBFs on PDTCHs

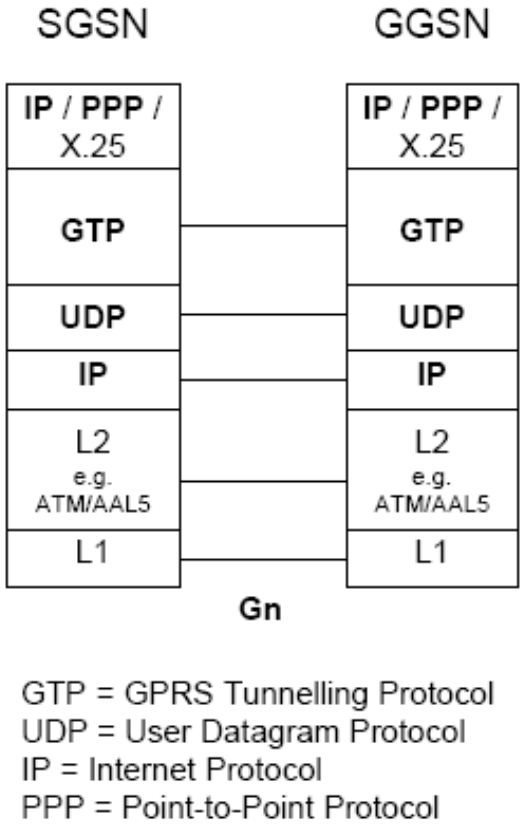
- The dynamic scheduling of TBFs on shared packet data channels (PDTCHs) is fully controlled by the network
- In downlink direction the BSS schedules and transmits the different MAC/RLC data blocks (belonging to different TBFs) according to its internal scheduling algorithms
- In uplink direction, the BSS controls the channel access of the MS according to its internal scheduling algorithms. The BSS informs the MS via the Uplink State Flags (USF) in the MAC header of the downlink time slot about the assignment of the corresponding uplink time slot. The uplink state flag length is three bits. The value 111 (= FREE) means that the uplink time slot is used for the P-RACH. The remaining seven bit patterns allows a multiplexing of TBFs from of up to 7 different MSs on the uplink time slot (that in this case is used as PDTCH). All MS that want to transmit TBFs on the PDTCH read the USF in the corresponding downlink time slot - only one MS gets (according to the USP value) the right to transmit on the uplink time slot.

Control Plane Protocols (PS-Domain) used in NSS

protocols at the G_r and G_f interface:



protocols at the G_n interface:



protocols at the G_s interface: