UMTS Network and Protocol Architecture

UMTS NETWORK AND PROTOCOL ARCHITECTURE
UNIT LESSONS

UMTS Architecture Evolution from GSM and GPRS

UTRAN Upper Layer Control Protocols (e.g., RRC, RANAP, NBAP, etc.) and ATM Transport

UMTS Protocol Architecture

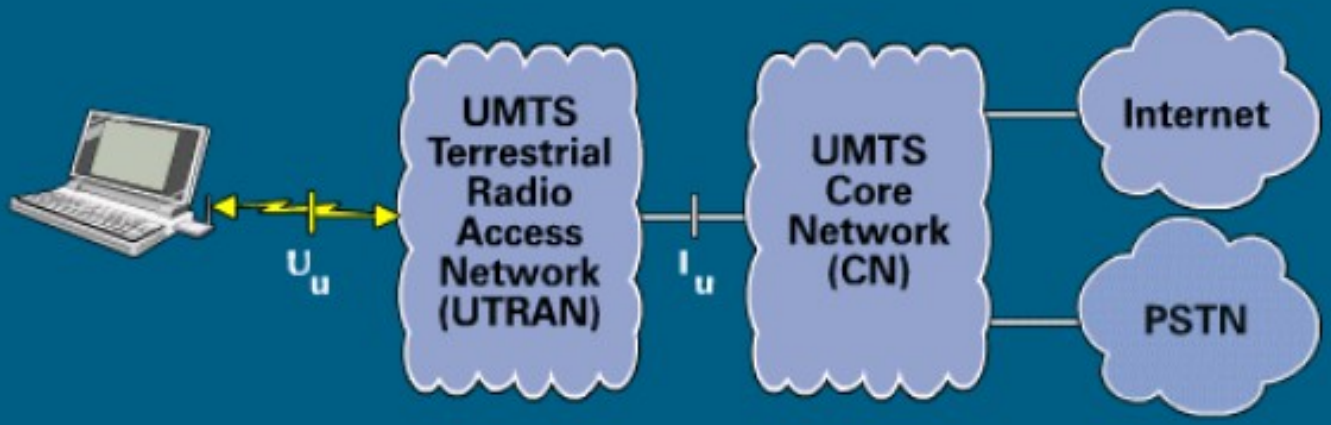
Operational Scenario for UTRAN Configuration and Call/Session Establishment

UMTS ARCHITECTURE EVOLUTION FROM GSM AND GPRS

TOPICS

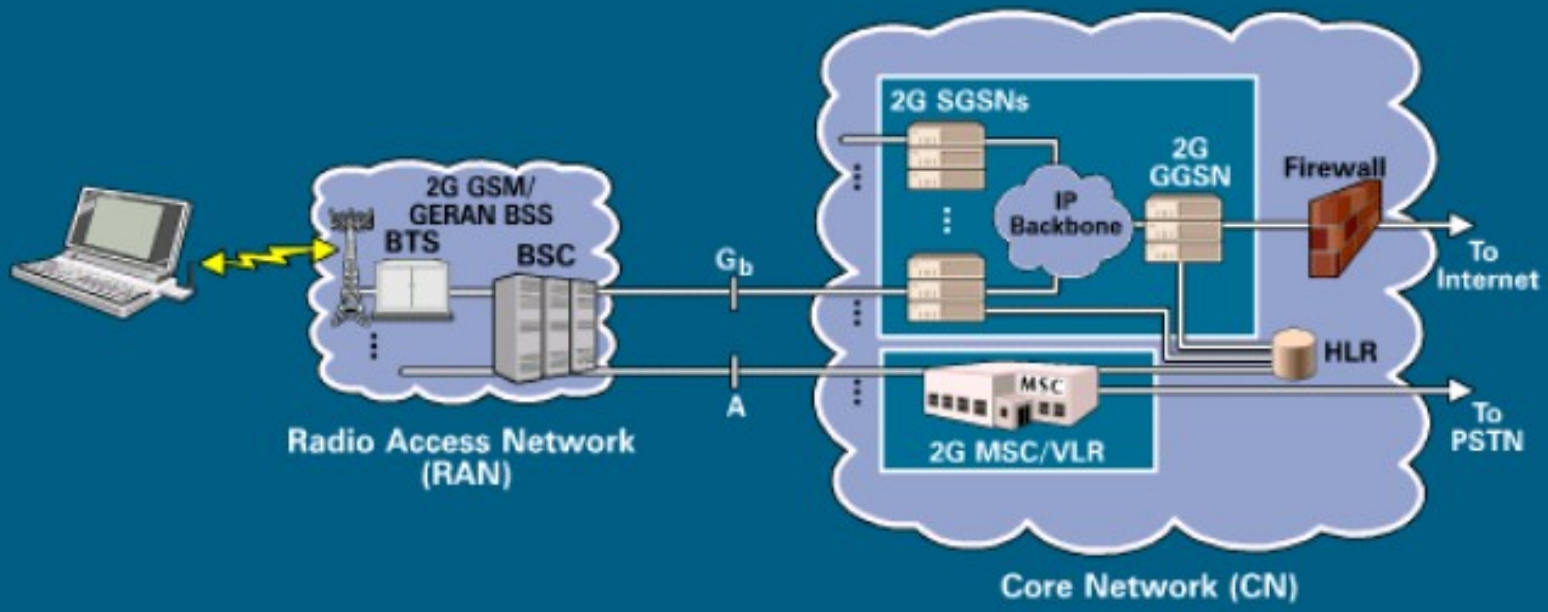
- UMTS Architecture Overview
- The GSM and GPRS Foundation
- UMTS Architecture Evolution Scenarios

UMTS GENERAL ARCHITECTURE

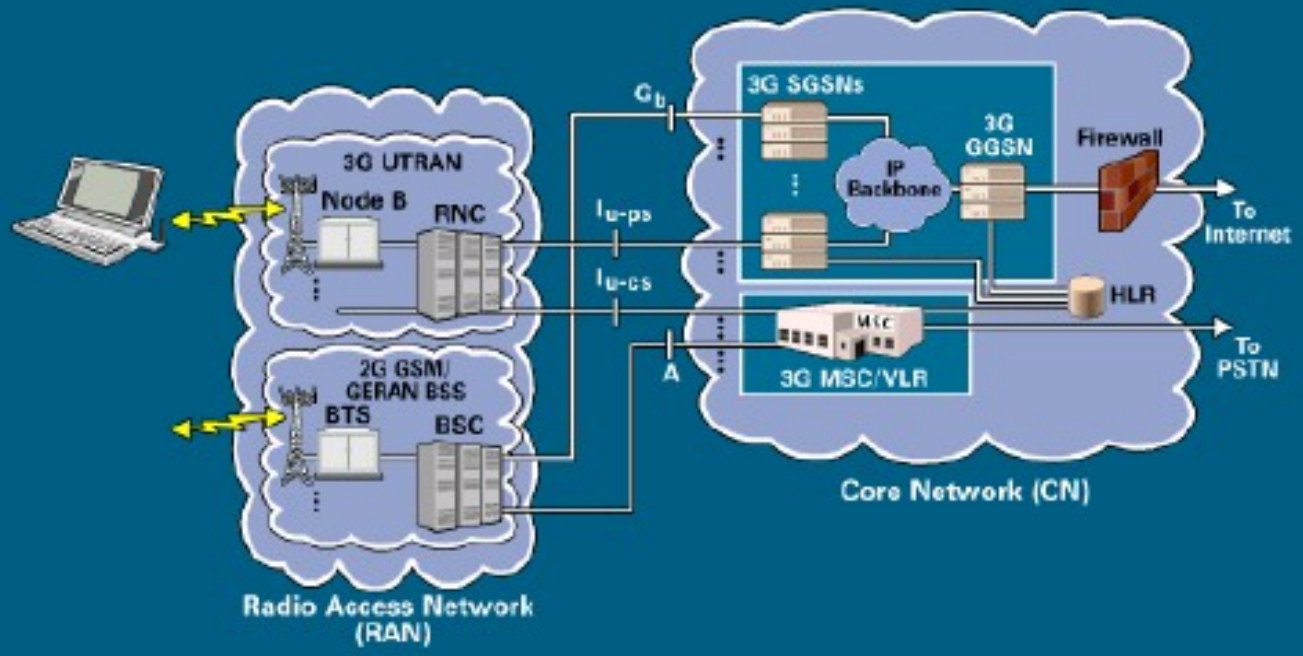


Source: ETSI 3G TS 25.401

2G GSM/EDGE ARCHITECTURE
MAJOR COMPONENTS



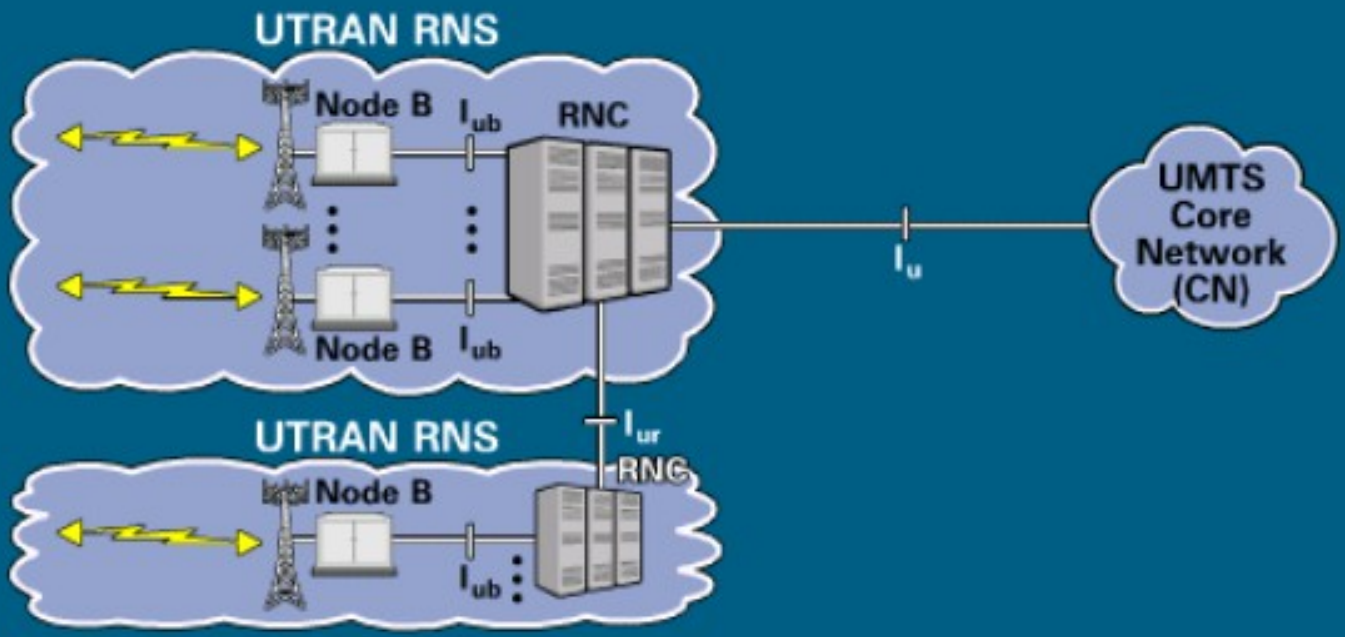
RELEASE 1999 UMTS ARCHITECTURE
MAJOR COMPONENTS



UMTS R1999 MAJOR CHARACTERISTICS
UTRAN ... PRIMARILY

- UTRAN (UMTS Terrestrial Radio Access Network) is the major new capability
  - Data rates up to 384 Kb/s or more for pedestrian users in microcells
  - Enhanced wireless Internet access
- CN (Core Network) is primarily just
  - MSC enhanced with the I_u interfaces to the UTRAN, and
  - GPRS enhanced 3G SGSNs and 3G GGSNs supporting
    - I_u interfaces (in addition to Gb to 2G Base Stations)
    - Higher data rates and capacity
- Major changes in the CN capabilities are planned for Release 4 (March, 2001) and Release 5 (December, 2001)
  - Evolution towards an "All IP" network architecture

UTRAN GENERAL ARCHITECTURE



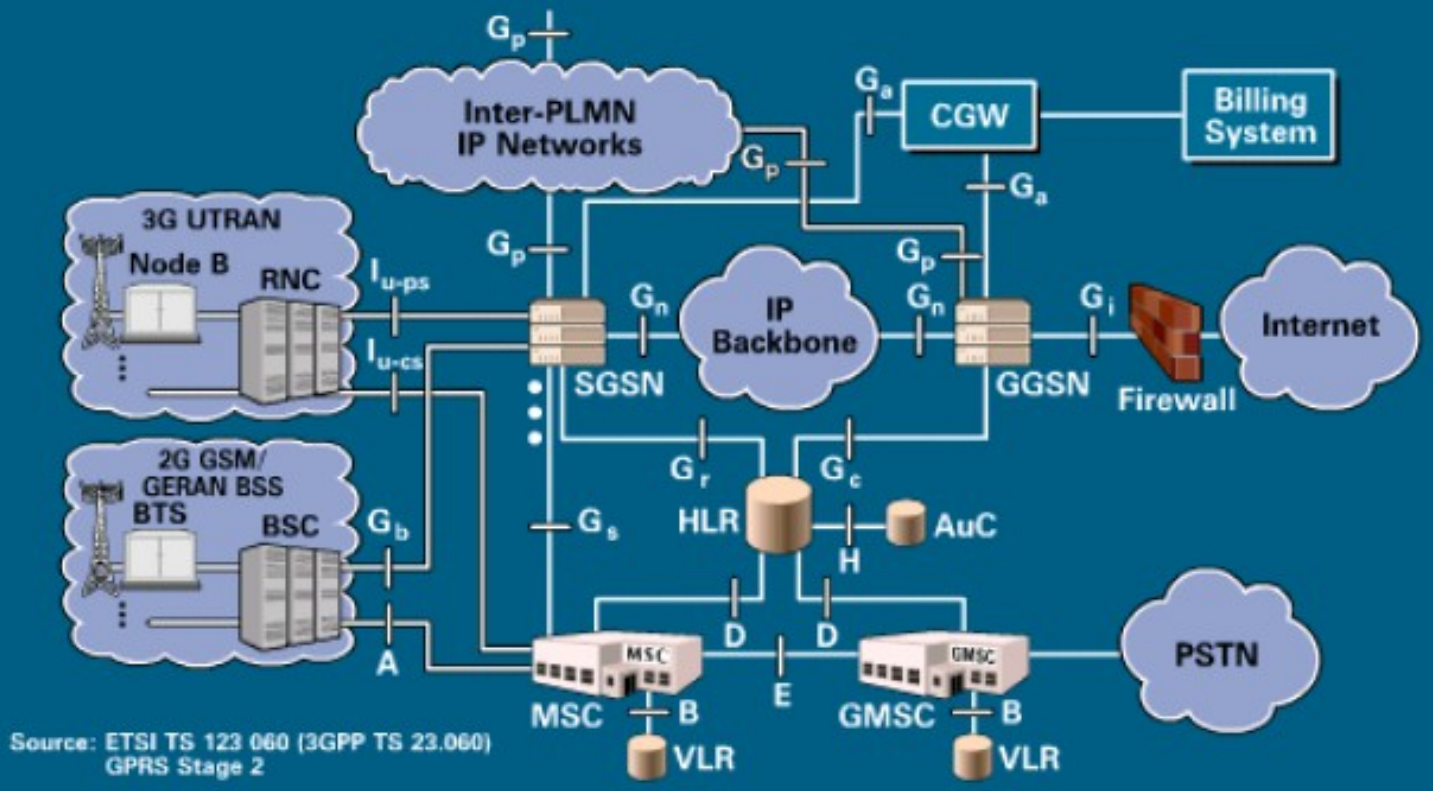
- Radio Network Subsystem (RNS)
- Radio Network Controller (RNC)
  - Similar to a Base Station Controller in 2G
- Node B: Radio Transceiver Node for one or more cells (or sectors)
  - Similar to a Base Transceiver Station (BTS) in 2G

Source: ETSI 3G TS 25.401

UMTS ARCHITECTURE EVOLUTION FROM GSM AND GPRS
TOPICS

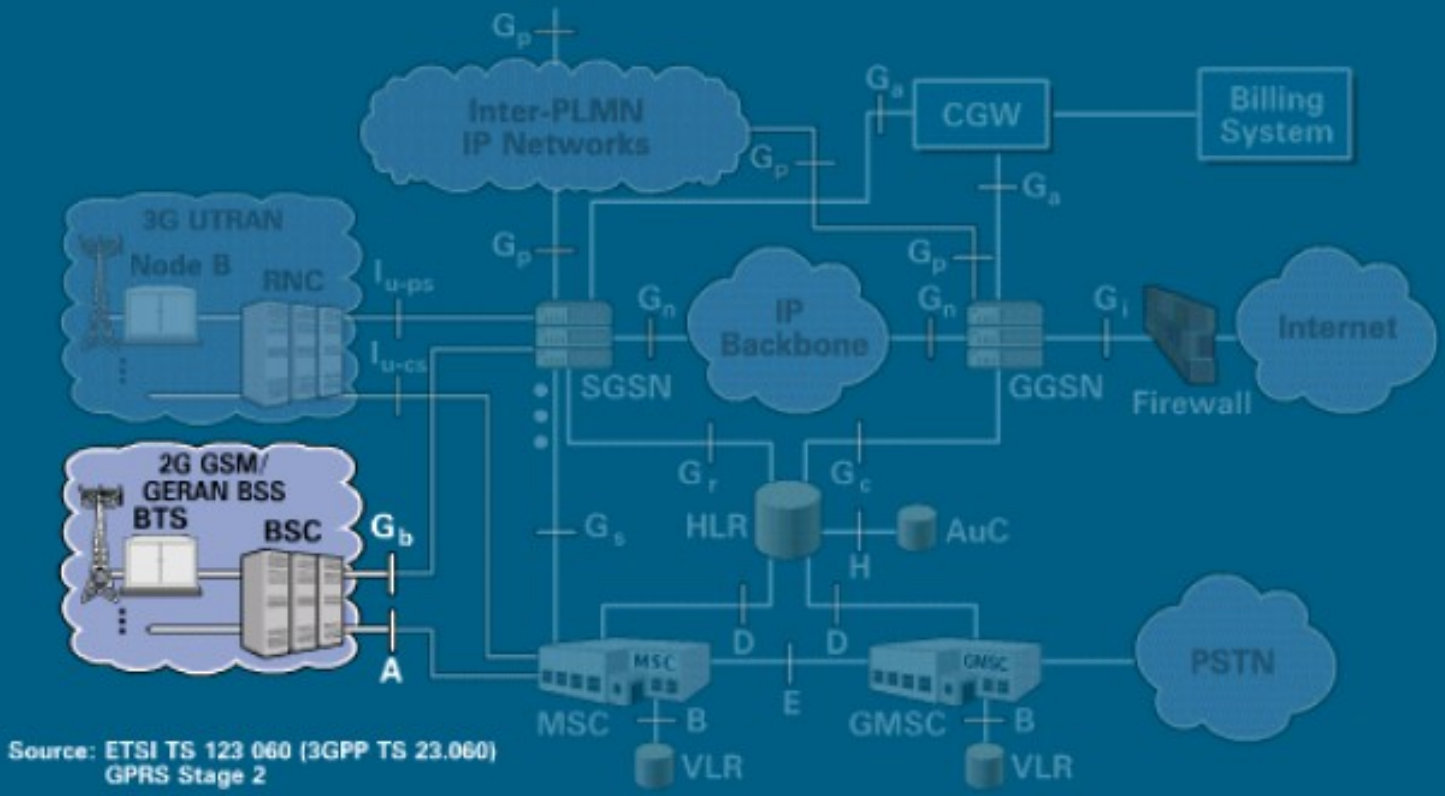
- UMTS Architecture Overview
- **The GSM and GPRS Foundation**
- UMTS Architecture Evolution Scenarios

GSM/GPRS/UMTS ARCHITECTURE



Source: ETSI TS 123 060 (3GPP TS 23.060)
GPRS Stage 2

2G GSM RAN (RADIO ACCESS NETWORK)



Source: ETSI TS 123 060 (3GPP TS 23.060)
GPRS Stage 2

2G GSM RAN
RADIO ACCESS NETWORK

- RAN (Radio Access Network), called the BSS (Base Station System) including
  - BTS (Base Transceiver Station) - Base Station containing the radio transmitters, receivers, and antennas
  - BSC (Base Station Controller) - Typically able to control up to ~128 or more BTSs for radio-intensive procedures, to offload the MSC
- GSM Radio Transceivers
  - Use TDMA in 200 KHz* carrier bandwidth with 8 time slots (TS) per 4.615 ms frame
  - Use GMSK Modulation to support:
    - One voice call per TS, typically**
    - One 9.6 or 14.4 Kb/s data call per TS, circuit switched
  - Can be evolved to GPRS to support packet services
  - Can be evolved to EDGE for higher data rates***

* In each direction
** With a 13 Kb/s "full rate" or "enhanced full rate" vocoder
*** With EDGE, the RAN is often called GERAN

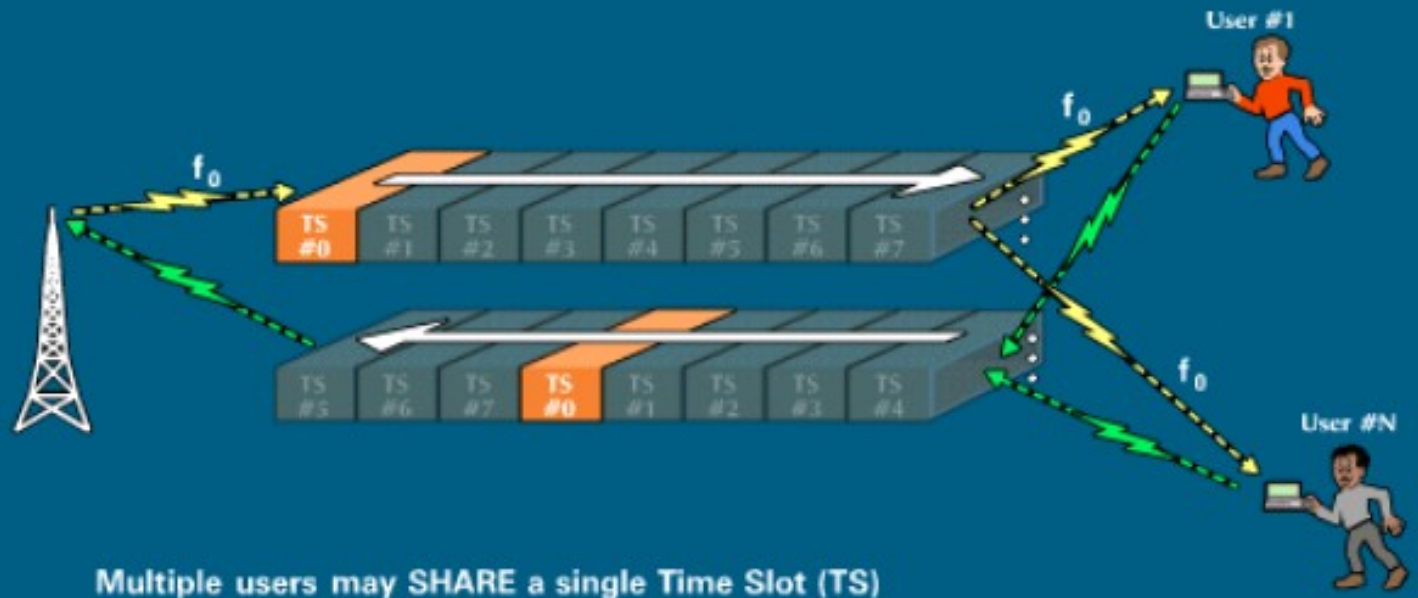
2G GPRS AND EGPRS PACKET RADIO
MULTIPLE USERS SHARE A CHANNEL

- GPRS*
  - Allows multiple users to share a 9.6 or 14.4 Kb/s time slot (TS) for packet data
  - Up to 8 TS can be aggregated for up to ~115 Kb/s [=8 x 14.4K] shared
  - A more typical scenario will be 38 Kb/s [=4 x 9.6K] downlink and 9.6 Kb/s uplink
  - Software upgrade only required for the BSs, but new GPRS infrastructure must be added
  - New handsets are required
- EGPRS (EDGE-enhanced GPRS)
  - Allows increased data rates with 8-PSK modulation (in addition to GMSK)
  - Up to ~48 Kb/s per TS, or
  - Up to ~384 Kb/s [=8 x 48K] if all 8 TS were aggregated
  - A more typical scenario might be 128 Kb/s [=4 x 32K] downlink and 28.8 K uplink
  - New radios required in the BSs and increased capacity in the GPRS infrastructure
  - New handsets are required

* First GPRS commercial service in 2000, but widespread availability not expected until 2002
* First EGPRS commercial service targeted for late 2001 or 2002

Source: ETSI TS 100 909 (3GPP TS 05.03)

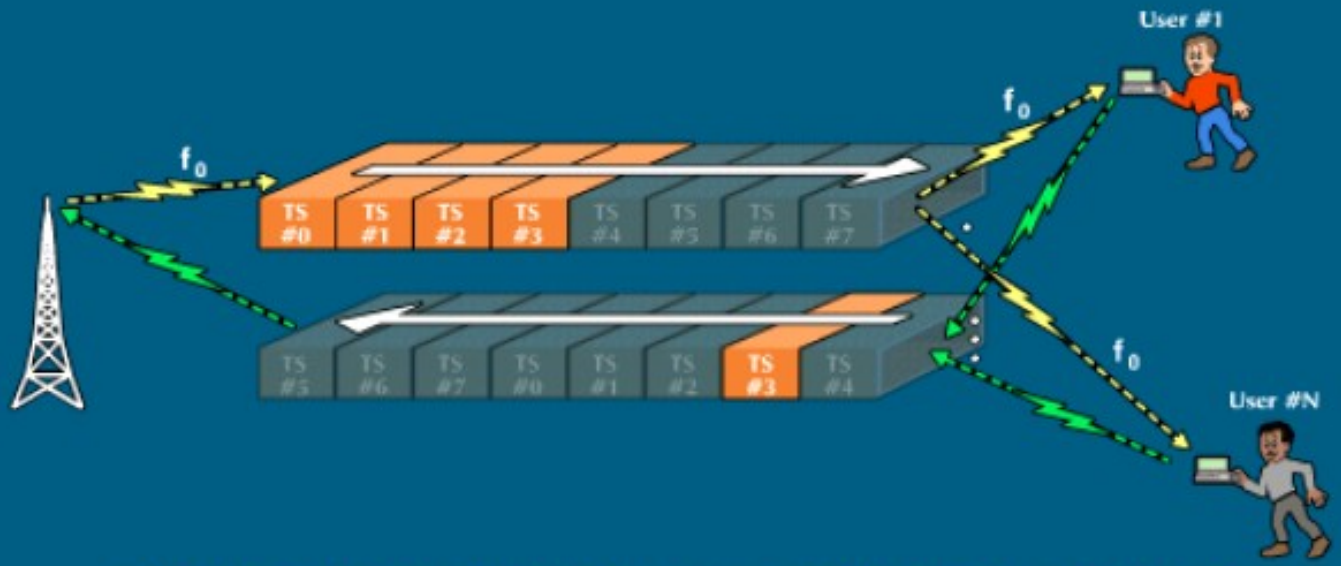
SHARING A CHANNEL WITH GPRS
EXAMPLE: MULTIPLE USERS ON 1 TIME SLOT



Multiple users may SHARE a single Time Slot (TS)

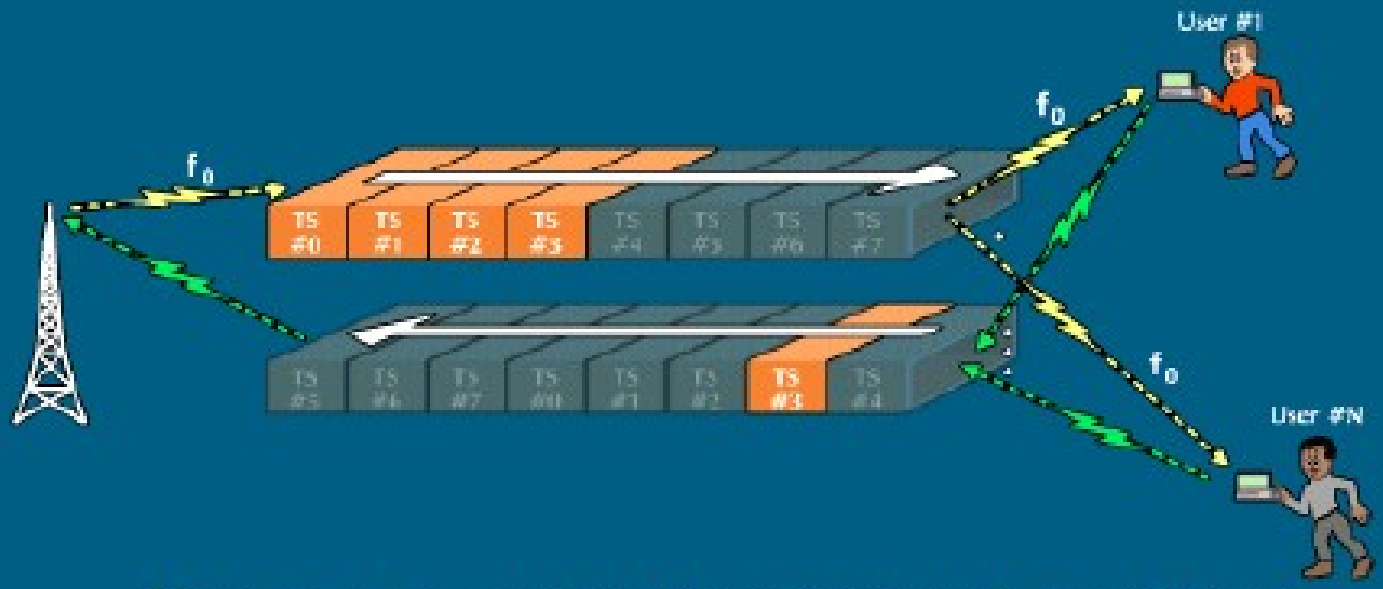
- With users being served sequentially, using a . . .
- MAC (Medium Access Control) Protocol to control the users' access to the shared channel
- The number of users that may share the TS depends on many things including:
  - The number that are likely to want to be active at any specific time
  - The volume of data which they want to transfer

GPRS (GENERAL PACKET RADIO SERVICE)
A TYPICAL CASE



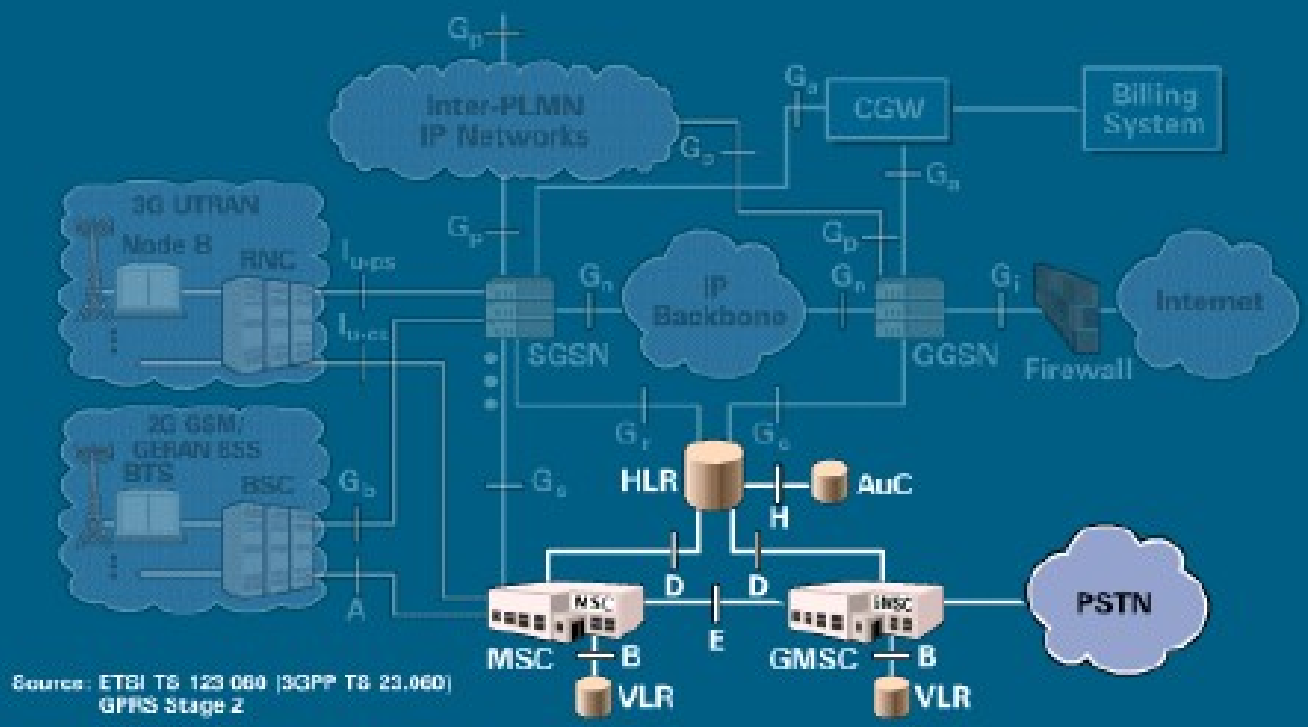
- 4 TS on the downlink (DL), for ~ 38 Kb/s (= 4 × 9.6 Kb/s)
- 1 TS on the uplink (UL), for ~ 9.6 Kb/s
- Suitable for asymmetric web access
- Minimizes handset power requirements

EGPRS (GPRS WITH EDGE)
A TYPICAL CASE



- 4 TS on the downlink (DL), for ~ 128 Kb/s (= 4 × 32 Kb/s)
- 1 TS on the uplink (UL), for ~ 28.8 Kb/s
- Suitable for asymmetric web access
- Minimizes handset power requirements

2G GSM CORE NETWORK
CIRCUIT-SWITCHED (CS) DOMAIN



Source: ETSI TS 123 060 (3GPP TS 23.060)
GPRS Stage 2

2G GSM CORE NETWORK
CIRCUIT-SWITCHED (CS) DOMAIN

- MSC (Mobile-services Switching Center)
  - The "brains" of the CS Domain
  - Call control and switching functions, based on circuit-switching
  - Mobility management, e.g., location database updates as the mobile moves
- GMSC (Gateway MSC)
  - Provides the interface to external (non-GSM) networks, e.g., PSTN
  - The first point of contact for a call origination from outside the PLMN
    - GMSC is responsible for accessing the HLR to locate the mobile and route the call
  - Can serve several MSCs
- Or, a single (G)MSC can implement both GMSC and MSC functions in an integrated unit
- Databases including the HLR, VLR, AuC, and EIR

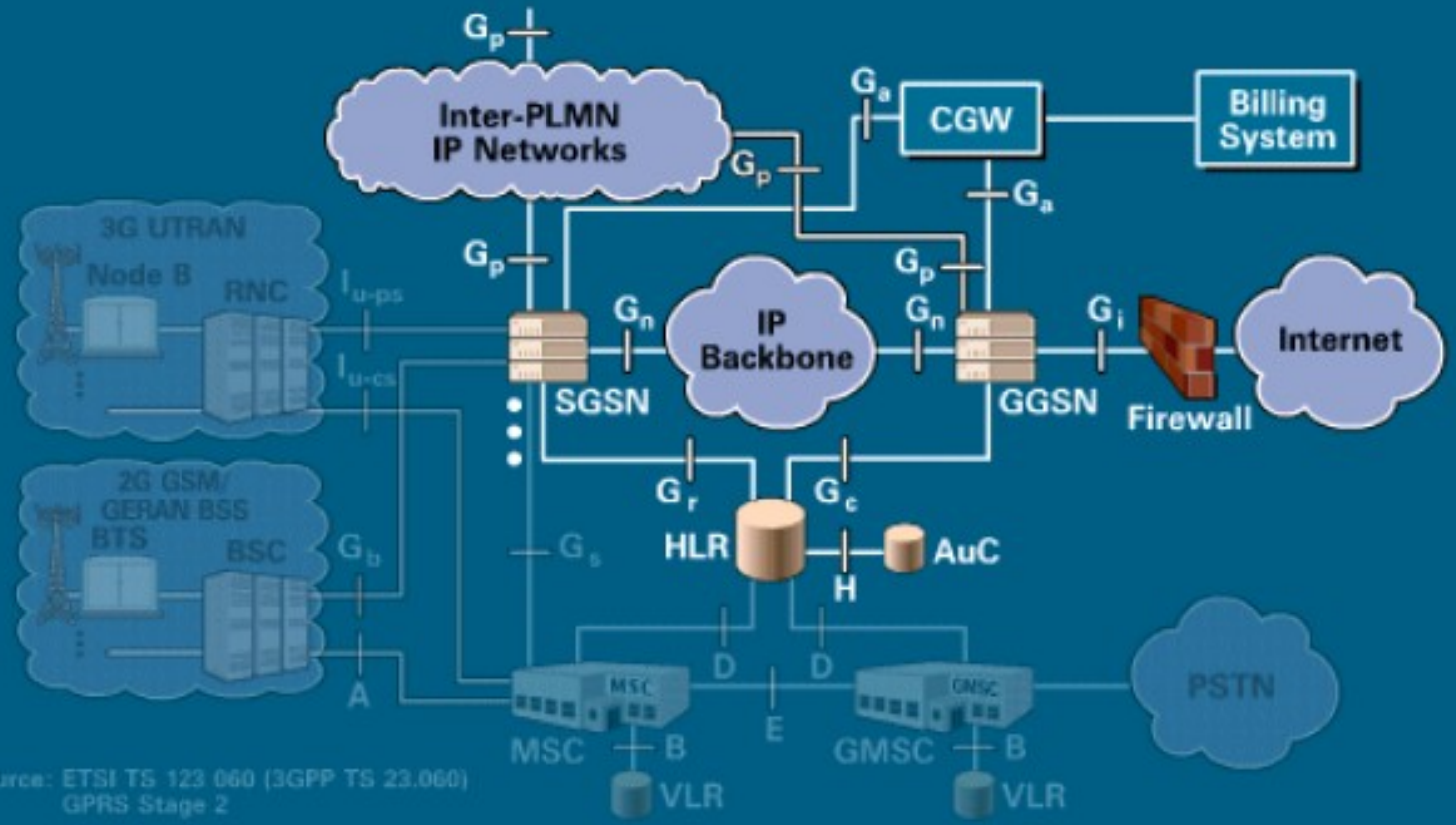
2G GSM CORE NETWORK
MAJOR DATABASES

- HLR (Home Location Register)
  - Database of subscriber information, including IMSI, MSISDN, etc.
  - Services subscribed by each subscriber
  - Subscriber status, e.g.,
    - Are they registered? If so...
    - How can they be reached? (i.e., What is the current VLR?)
  - Keeps track of active subscribers to within a PLMN and a VLR
  - Associated with the (G)MSC
- VLR (Visitor Location Register)
  - Local (to MSC) database of subscribers currently in the MSC service area, including
    - Visitors (roamers)... as well as home subscribers
  - Keeps track of active mobiles to within "location areas" served by the MSC
  - Often integrated with the MSC

2G GSM CORE NETWORK
MAJOR DATABASES

- AuC (Authentication Center)
  - Stores a unique authentication key, Ki, for each subscriber
  - Supports ciphering (encryption) for voice or data
  - Often integrated with the HLR
- EIR (Equipment Identity Register)
  - Database of IMEIs
  - Database of stolen or defective phones

2G GSM CORE NETWORK
PACKET-SWITCHED (PS) DOMAIN



Source: ETSI TS 123 060 (3GPP TS 23.060) GPRS Stage 2

2G GSM CORE NETWORK (CN)
PACKET-SWITCHED (PS) DOMAIN : GPRS

- SGSN (Serving GPRS Support Node)
  - Analogous to the MSC/VLR in the CS Domain
  - Provides packet switching, routing, and database functions for GPRS services
- GGSN (Gateway GPRS Support Node)
  - Analogous to the GMSC in the CS Domain
  - Provides the interface to external (to GPRS) networks, e.g., the Internet
  - Provides packet switching, routing, and database functions for GPRS services
- IP Backbone Network - Often not shown explicitly. May be implemented with standard IP routers
- Inter-PLMN IP Network - Enabling roaming GPRS services
- Databases in common with the CS Domain, including HLR, AuC, EIR, and, optionally, VLR
- Interface to Charging Gateway (CGW) and Billing Systems

SGSN (SERVING GPRS SUPPORT NODE)
MAJOR FUNCTIONS

- Provides packet switching and routing for GPRS services
  - Analogous to MSC circuit switching in the CS Domain
- Contains a database of subscribers currently served, including visitors (roamers) and home subscribers
  - Analogous to the VLR database in the CS Domain
- Handles authentication and admission control for originating packet sessions
  - Analogous to MSC/HLR/AuC procedures in the CS Domain
- Supports "GPRS Attach" procedures
  - Analogous to "mobile registration" in the CS Domain
- Supports "PDP (Packet Data Protocol) Context Activation"
  - Analogous to "call setup" in the CS Domain

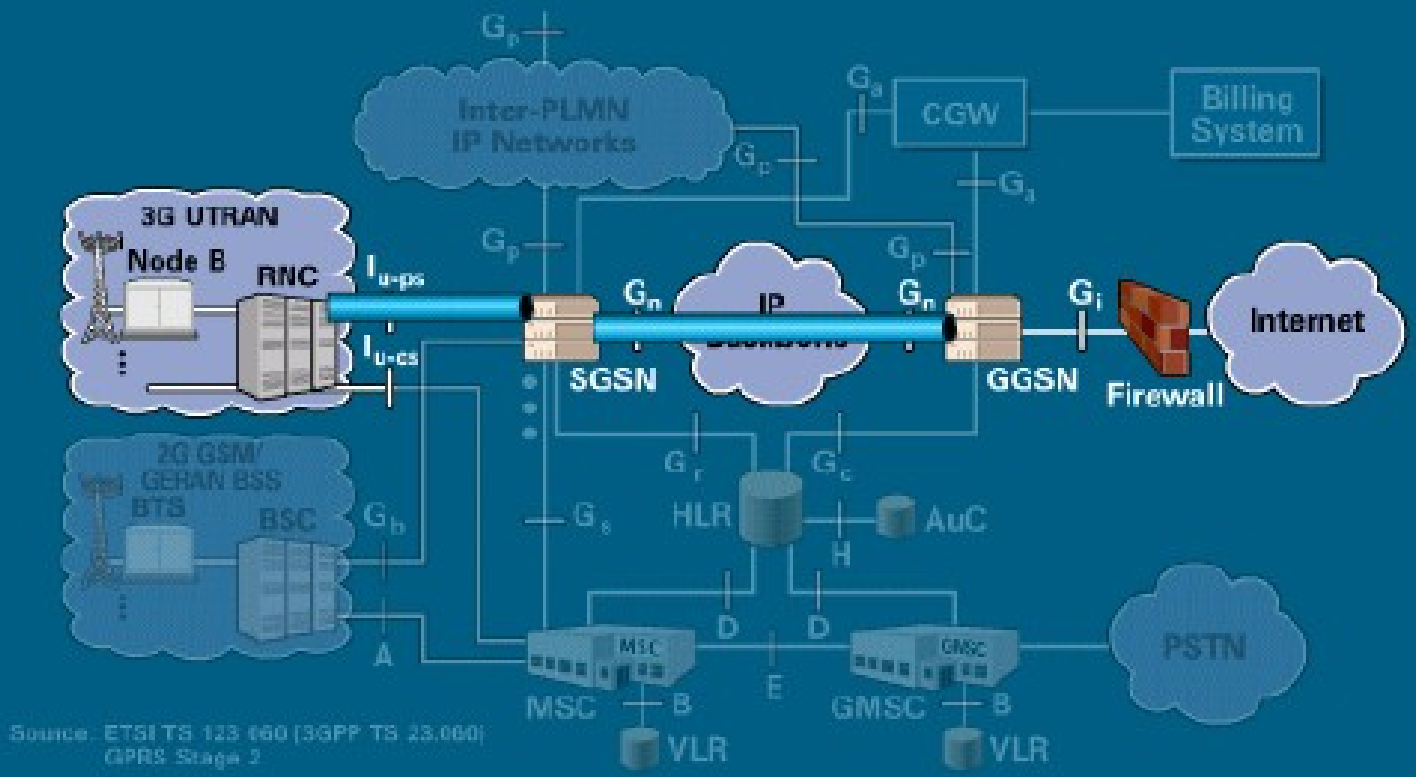
Source: ETSI TS 123 060 (3GPP TS 23.060) GPRS Stage 2

GGSN (GATEWAY GPRS SUPPORT NODE)
MAJOR FUNCTIONS

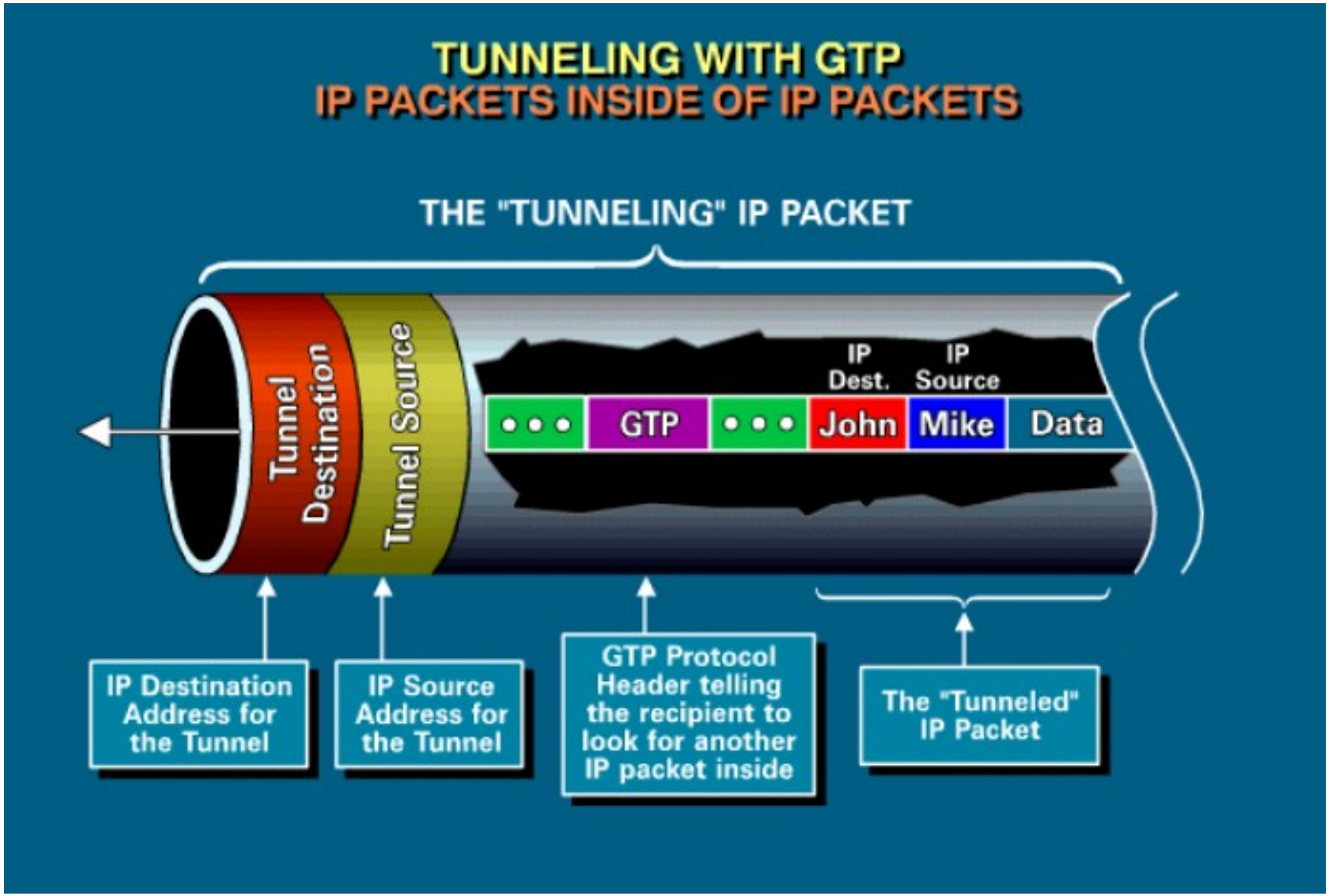
- Provides packet switching and routing for GPRS services
- Provides the interface to external (to GPRS) Public Data Networks (PDNs), e.g. the Internet
  - Analogous to the GMSC in the CS Domain
- The first point of contact for a packet session originating outside the PLMN
  - Accesses the HLR to locate and determine routing to the destination mobile
  - Analogous to the way the GMSC uses the HLR in the CS Domain
- Capable of using statically assigned IP addresses
  - Also capable of dynamically assigning IP addresses using DHCP
- Capable* of supporting the Foreign Agent (FA) functionality for interworking with the IETF's Mobile IP**

* See ETSI TS 123 121 (3GPP TS23.121)
** Mobile IP is defined by RFC 2002 and related documents
Source: ETSI TS 123 060 (3GPP TS 23.060) GPRS Stage 2

GTP TUNNELS
GPRS TUNNELING PROTOCOL (GTP)



Source: ETSI TS 123 060 (3GPP TS 23.060)
GPRS Stage 2


TUNNELING WITH GTP
IP PACKETS INSIDE OF IP PACKETS
THE "TUNNELING" IP PACKET
Tunnel Destination
Tunnel Source
IP Dest.
IP Source
GTP
John
Mike
Data
IP Destination Address for the Tunnel
IP Source Address for the Tunnel
GTP Protocol Header telling the recipient to look for another IP packet inside
The "Tunneled" IP Packet

TUNNELS
WHY AND HOW ARE THEY USED ?

Tunnels are used to transport packets* through a network transparently (like a tunnel through a mountain or a body of water)

- With routing determined by the tunnel rather than by the tunneled packets themselves
- By "encapsulating" the packets in an "envelope" (another packet) whose destination and source addresses specify the tunnel endpoints
- The most common "envelope" is a IP packet, since the IP protocol is most ubiquitous
- "Tunneling Protocols" are used to specify how the user-supplied packets are "packaged" within the encapsulating IP packet

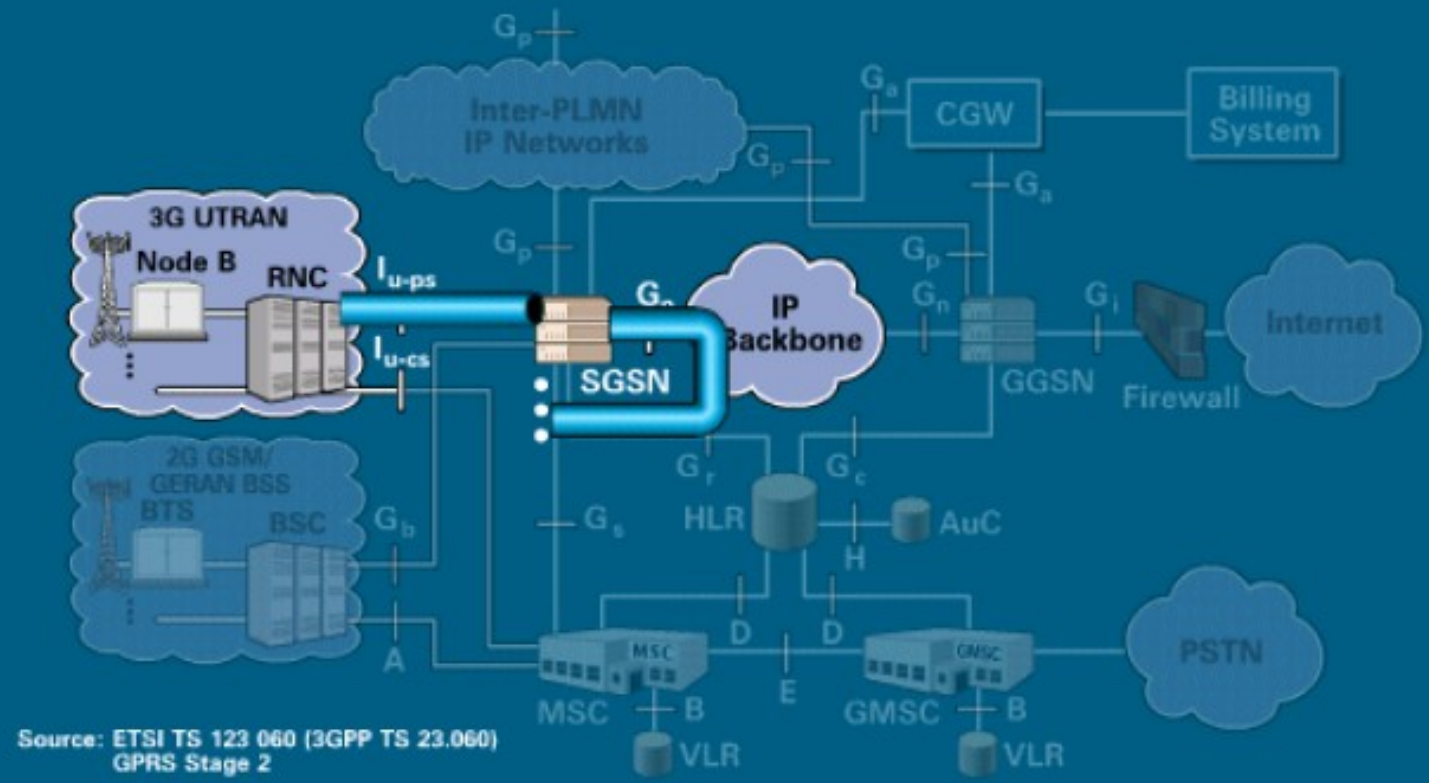
* Or Layer 2 frames, as in the case of Layer 2 tunneling of PPP frames

GPRS GTP TUNNELS
WHY AND HOW ARE THEY USED ?

- GPRS defines the GTP (GPRS Tunneling Protocol) in 3GPP TS 29.060
- GPRS transports User TCP/IP or UDP/IP packets within UDP/IP packets (providing the GTP Tunnel) through the GPRS network
- GPRS will allow Layer 2 PPP frames to be transported transparently from a corporate employee through the GPRS PLMN and the Public Internet all the way to the Corporate Private Network site
  - By encapsulating the PPP frames within a UDP/IP packet for transport through the GPRS PLMN and the Internet

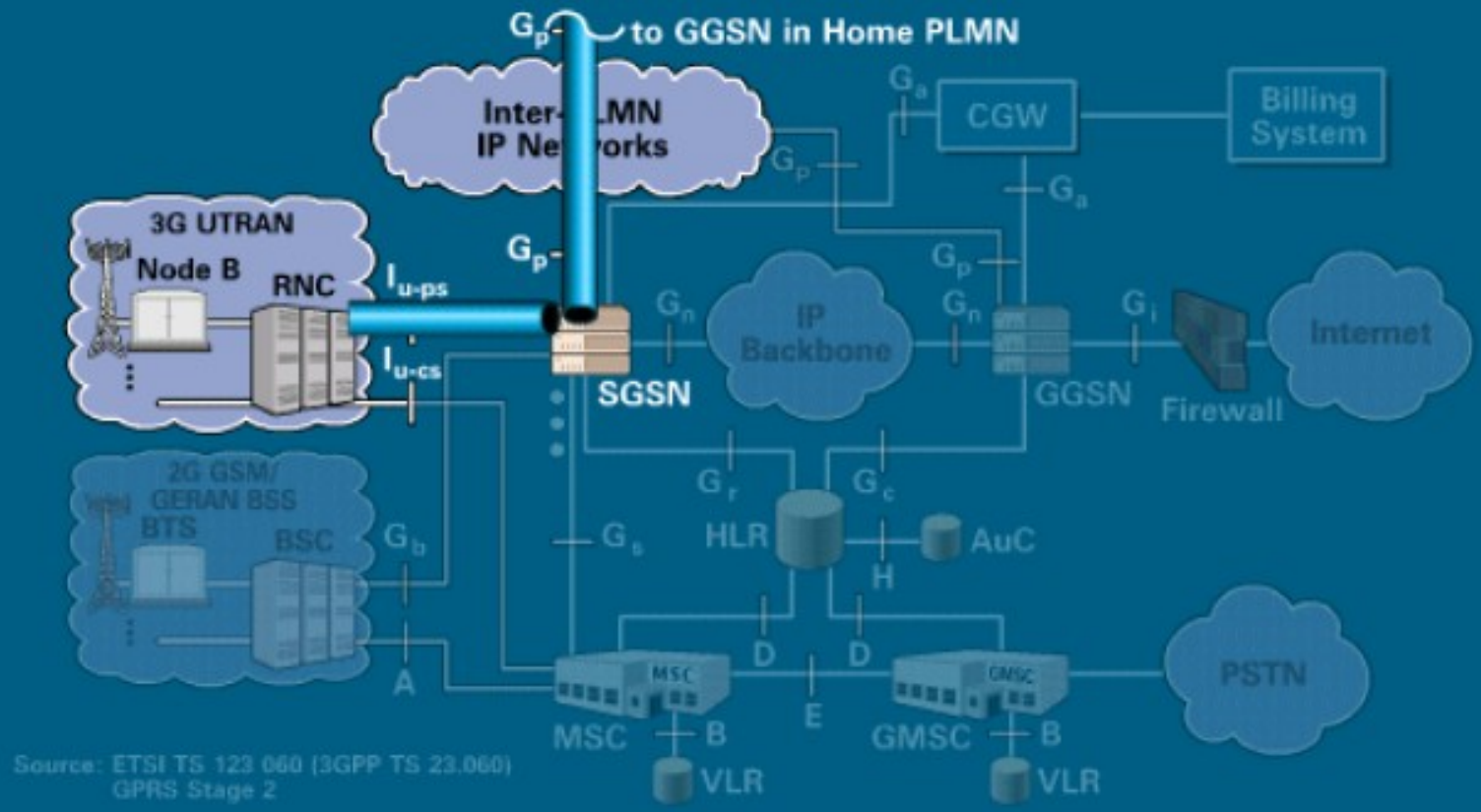
* Or Layer 2 frames, as in the case of Layer 2 tunneling of PPP frames

GTP TUNNELS INTRA-PLMN
TO ANOTHER SGSN



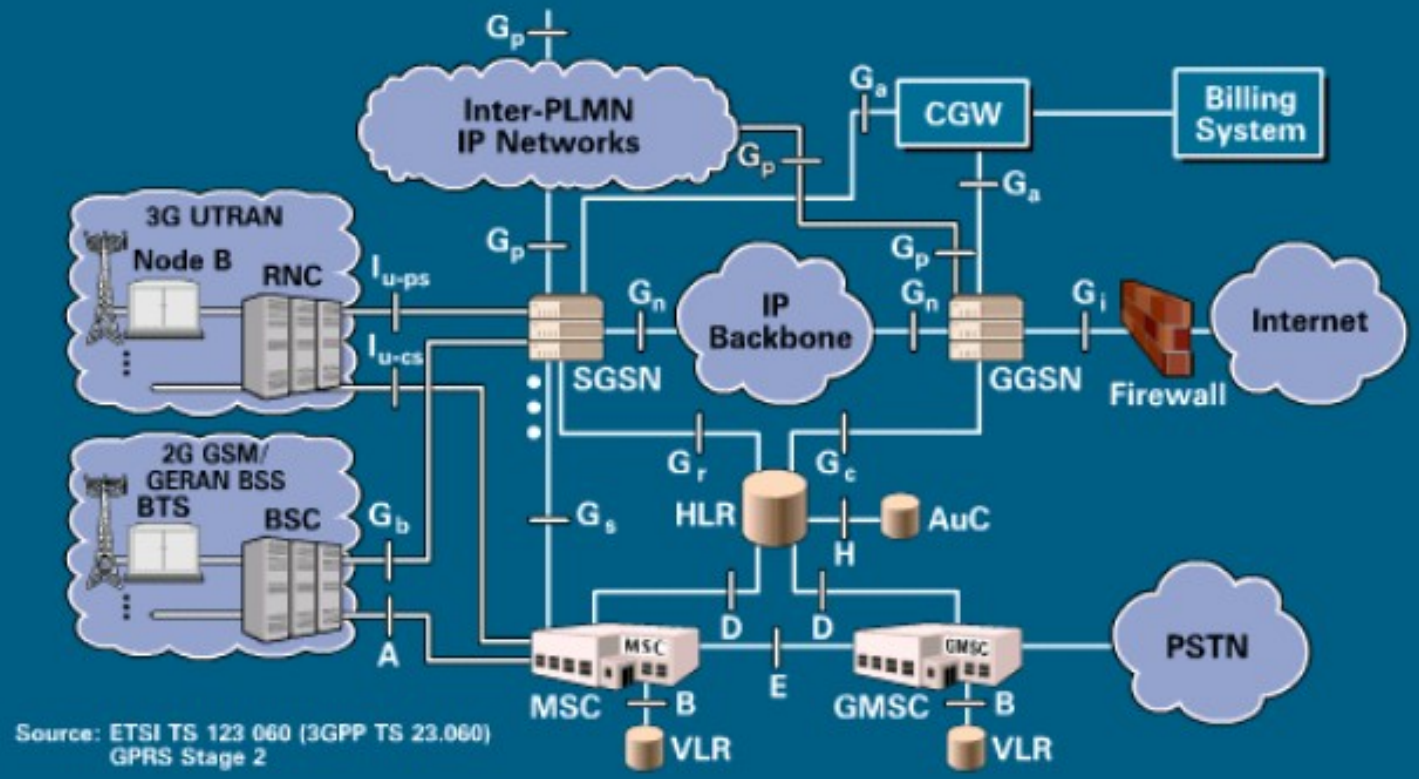
Source: ETSI TS 123 060 (3GPP TS 23.060)
GPRS Stage 2

GTP TUNNELS TO HOME PLMN
FOR ROAMING USERS

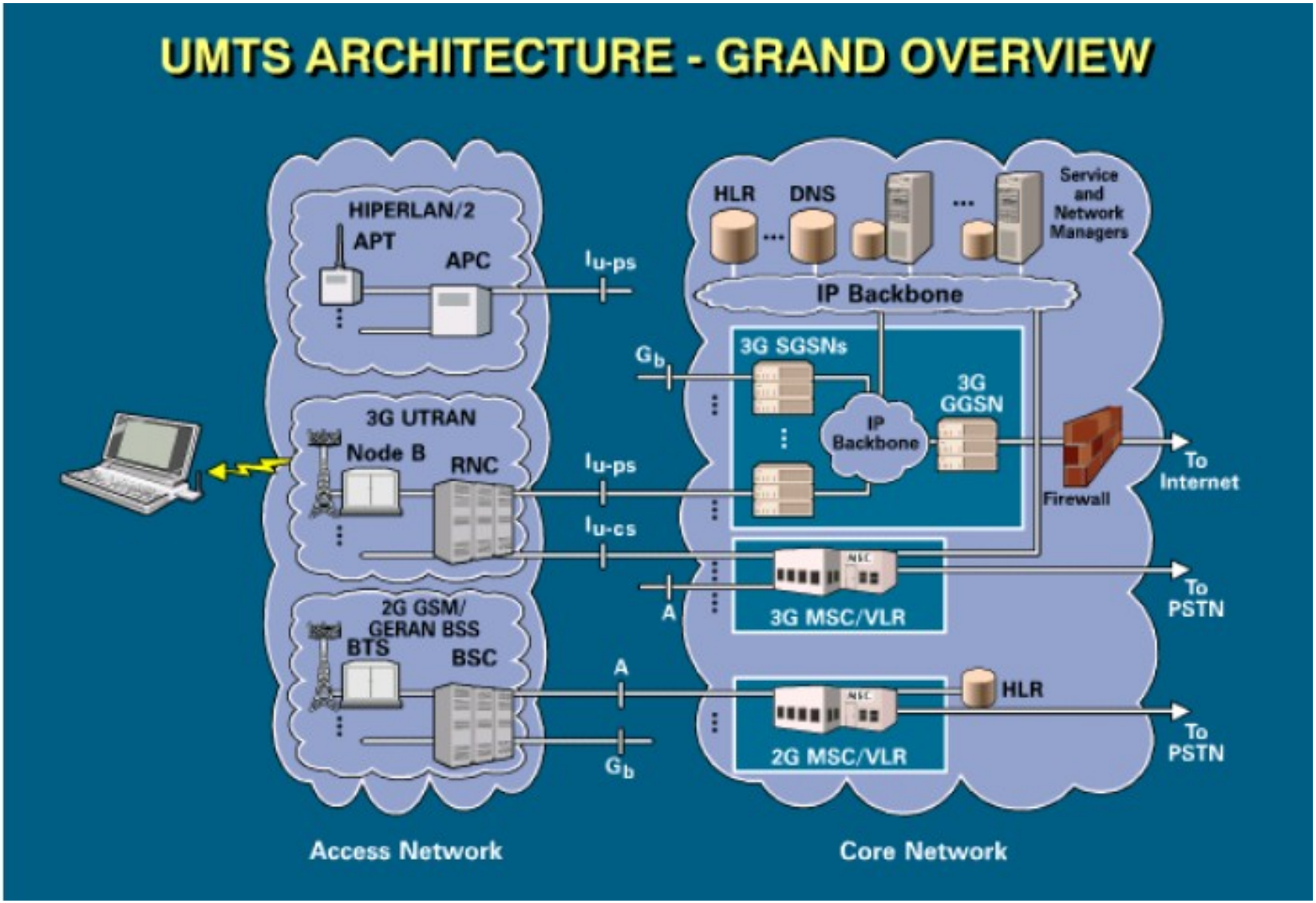


Source: ETSI TS 123 060 (3GPP TS 23.060)
GPRS Stage 2

GSM/GPRS/UMTS ARCHITECTURE



Source: ETSI TS 123 060 (3GPP TS 23.060)
GPRS Stage 2


UMTS ARCHITECTURE - GRAND OVERVIEW
HIPERLAN/2
APT
APC
3G UTRAN
Node B
RNC
2G GSM/
GERAN BSS
BTS
BSC
Iu-ps
Iu-ps
Iu-cs
Gb
A
A
Gb
HLR
DNS
Service
and
Network
Managers
IP Backbone
3G SGSNs
IP
Backbone
3G
GGSN
Firewall
To
Internet
3G MSC/VLR
To
PSTN
HLR
2G MSC/VLR
To
PSTN
Access Network
Core Network

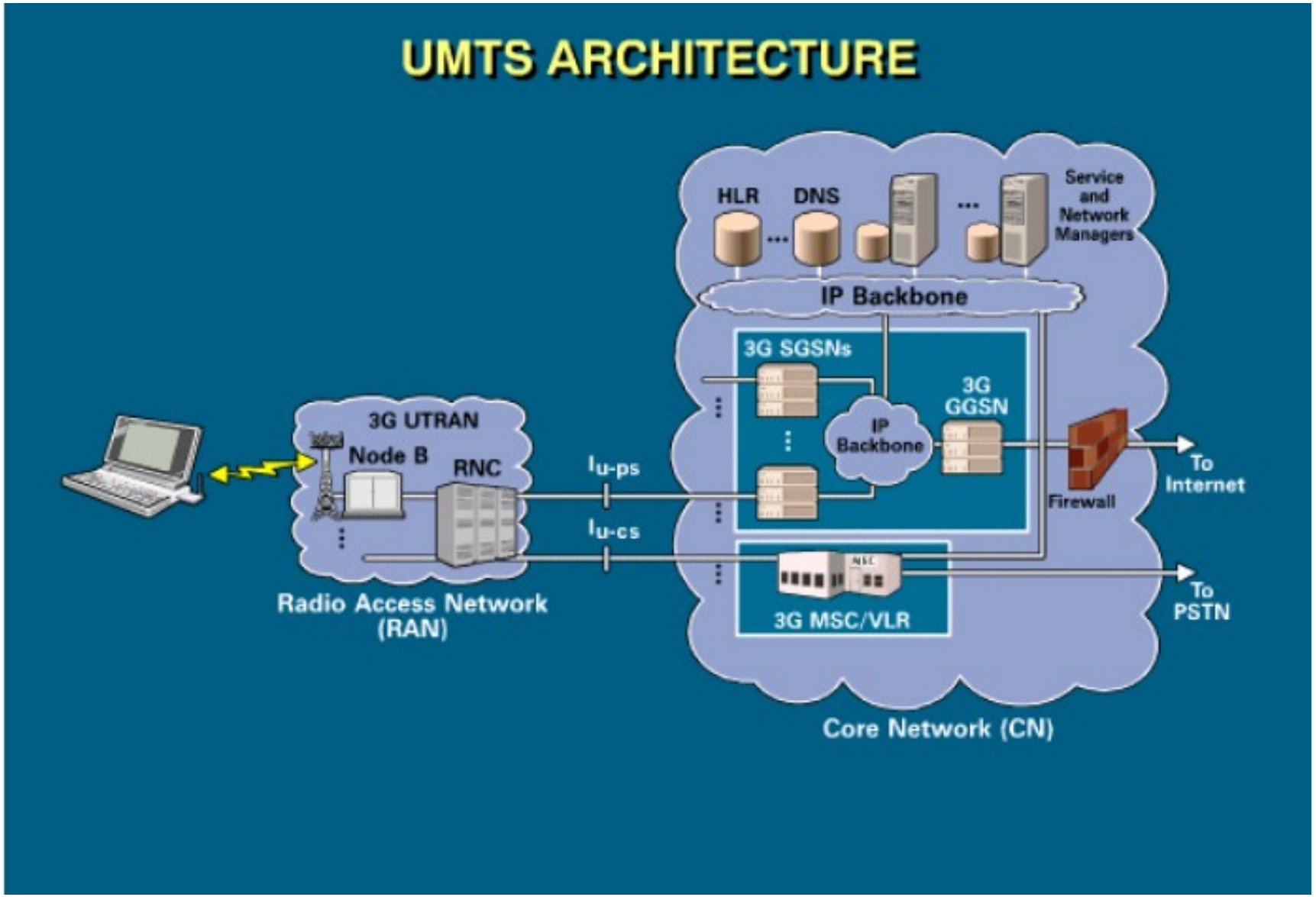
UMTS ARCHITECTURE*
MAJOR COMPONENTS

- Access Networks, including
  - 3G UTRAN (UMTS Terrestrial Radio Access Network)
  - 2G GSM/GERAN (GSM/EDGE Radio Access Network) for graceful evolution
  - HIPERLAN/2** (ETSI's HIgh PErformance Radio LAN) for 24 Mb/s LAN terminals and/or multimode 3G terminals
- UMTS Core Network, including
  - Packet Switched (PS)*** Domain based on an evolution of GPRS with its SGSNs and GGSNs
  - Circuit Switched (CS)*** Domain based on an evolution of a 2G GSM MSC
  - IP Backbone (often not explicitly shown, but typically assumed)
  - Service, Mobility, and Network Managers/Processors
  - 2G MSC/VLR, possibly, for evolution

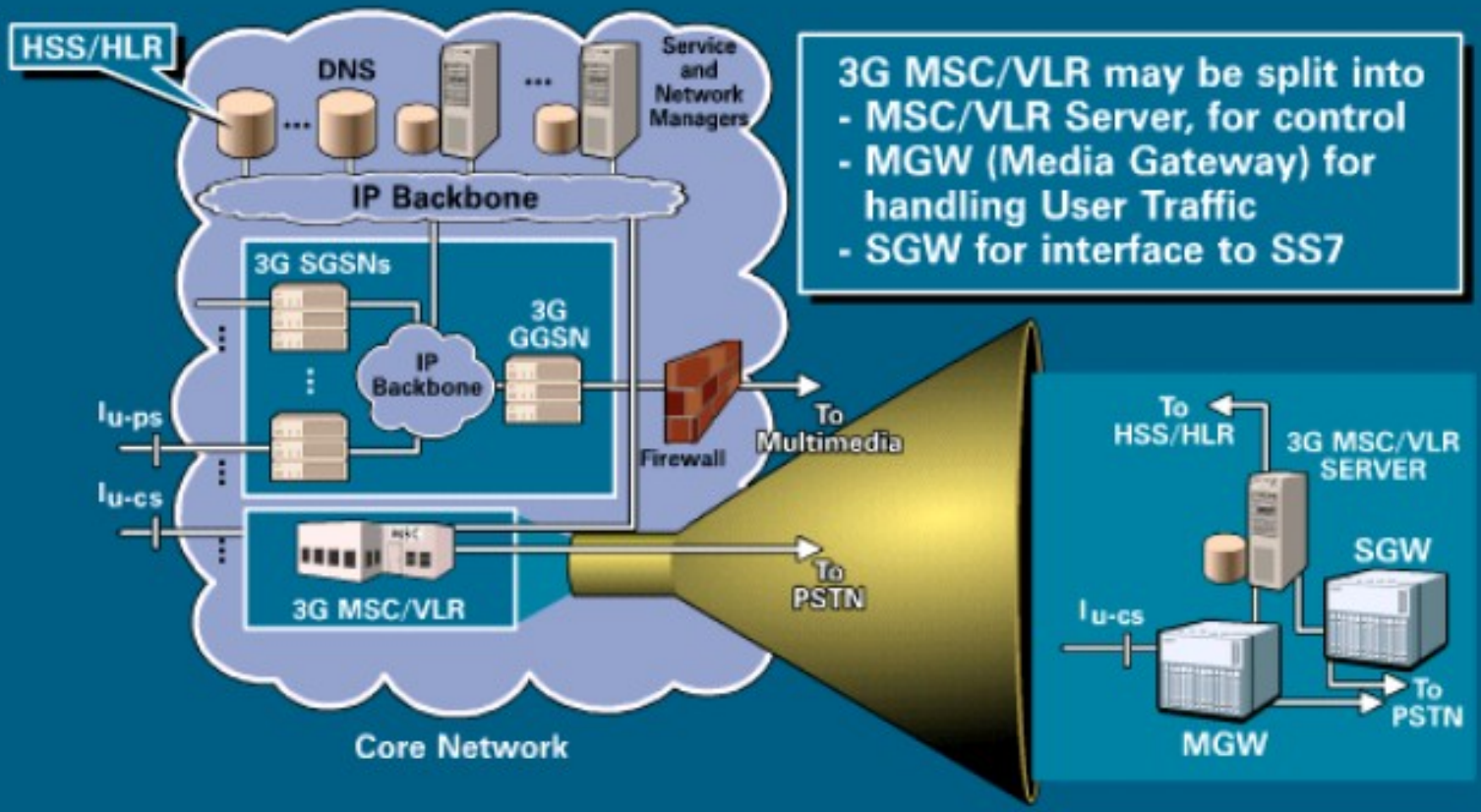
* Ref: TS 23.002 (3G Network Architecture for Release 4)
** Ref: TS 23.121 (3G Architectural Requirements for Release 1999) and ETSI TR101 683 (HIPERLAN/2)
*** Ref: TS 23.121, 23.101, and 25.410; The PS and CS Domains may be either separate or integrated

UMTS ARCHITECTURE EVOLUTION FROM GSM AND GPRS
TOPICS

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- The GSM and GPRS Foundation
- **UMTS Architecture Evolution Scenarios**

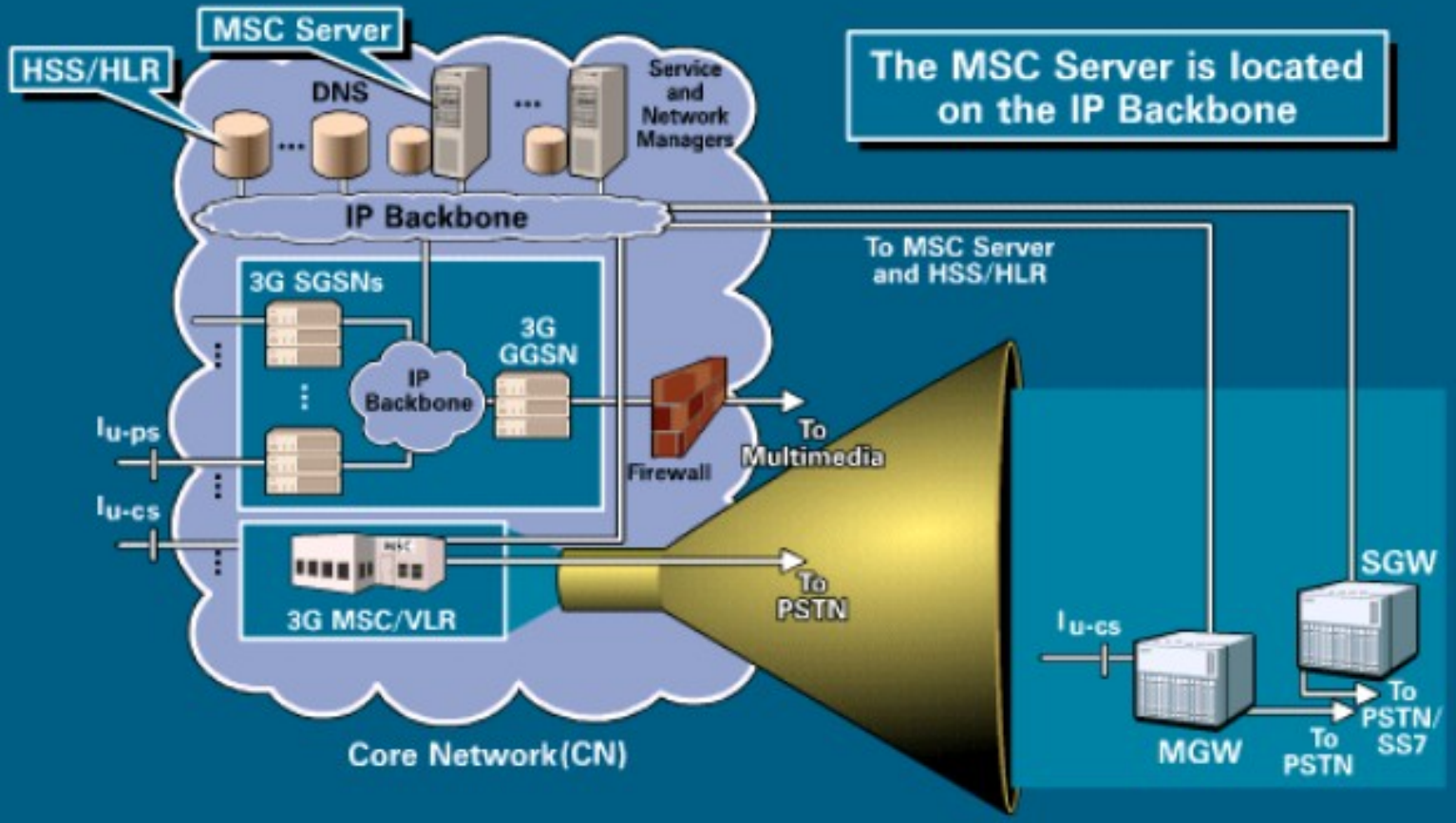

UMTS ARCHITECTURE
HLR
DNS
Service and Network Managers
IP Backbone
3G SGSNs
3G GGSN
IP Backbone
Firewall
To Internet
3G UTRAN
Node B
RNC
Iu-ps
Iu-cs
3G MSC/VLR
To PSTN
Radio Access Network (RAN)
Core Network (CN)

3G MSC EVOLUTION IN RELEASE 4
OPTION ONE : MSC SERVER AND MGW



Source: TS 23.002 Network Architecture for Release 4

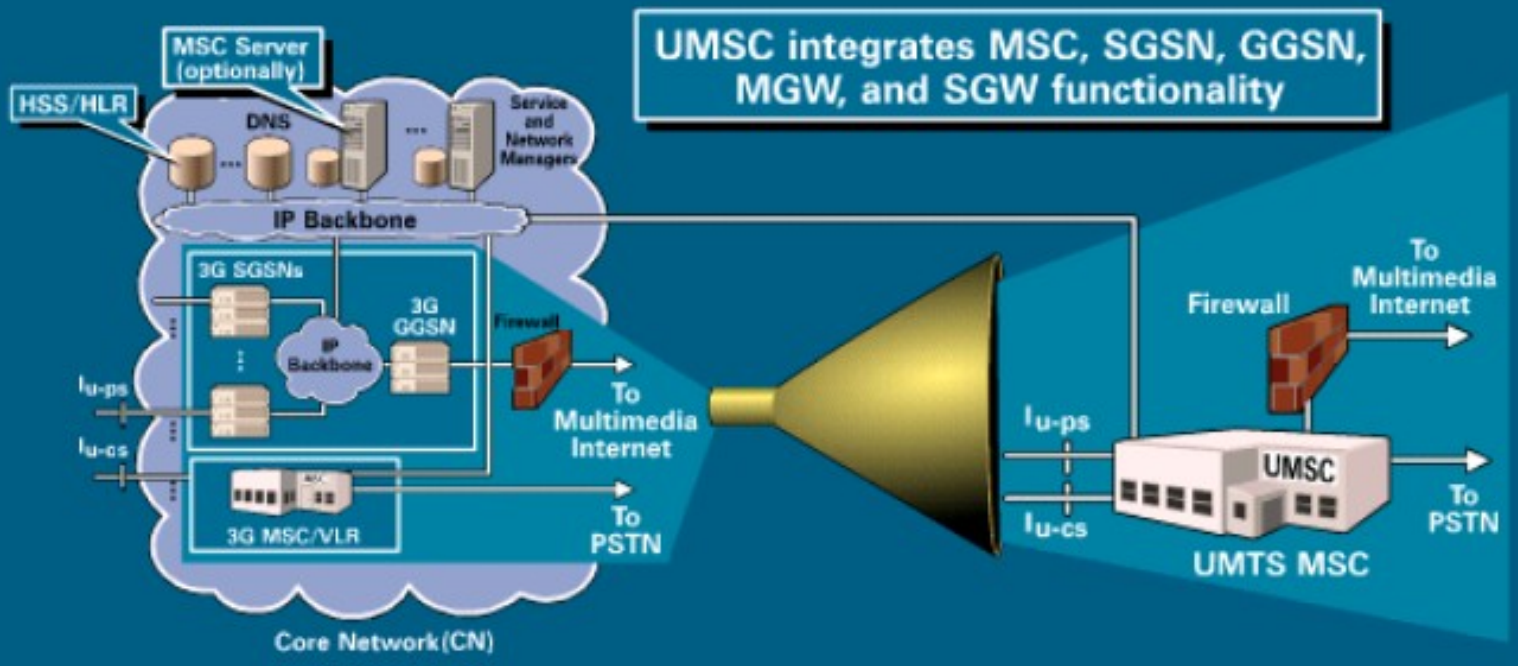
3G MSC EVOLUTION IN RELEASE 4
OPTION TWO : DISTRIBUTED* MSC SERVER



Source: TS 23.002 Network Architecture for Release 4

* Distributed, i.e., not collocated with the MGW or SGW

3G MSC EVOLUTION IN RELEASE 4
OPTION THREE : UMTS MSC (UMSC)



Source: TS 23.002 Network Architecture for Release 4

UMTS ARCHITECTURE EVOLUTION FROM GSM AND GPRS

LESSON SUMMARY (1)

- The UMTS CS Domain is based on the GSM MSC
- The UMTS PS Domain is based on GPRS
- The major change in release 1999 is the addition of a W-CDMA UTRAN
- The G_b and G_b interfaces supercede the A and Gb interfaces for 3G, although the 2G interfaces continue to be supported for backward compatibility

UMTS ARCHITECTURE EVOLUTION FROM GSM AND GPRS
LESSON SUMMARY (2)

- The GTP protocol allows GPRS-specific control and data protocols to be "tunneled" through the GPRS backbone using standard IP routers
- The UMTS architecture may evolve with the separation of call/session control from connection/transport functionality into call/session control Servers and Media Gateways (MGW)