# GPRS Protocol Testing in the Wireless World



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In the early days of wireless communication, service was limited to the range of a single base station that covered a small geographic area known as a cell[1]. The advantages of wireless communication became readily apparent, but users were still “tied” to the base station by their limited range. Truly “mobile” communication would require a greater freedom for the user.

Technical innovations such as automatic switching and reductions in hardware costs, size and weight led to the *first generation* of mobile communication systems to meet this requirement. First generation systems were based on analog cellular technology. Well-known examples include Advanced Mobile Phone Service (AMPS), Nordic Mobile Telephone (NMT), and Total Access Communication System (TACS).

The transmission quality of these first generation systems, however, left much to be desired and each system used proprietary architecture which made cooperation nearly impossible. With the development of ISDN and digital switching, subscribers enjoyed a range of new features and conveniences on the fixed network which were unavailable on the analog-based mobile networks.

To overcome some of the disadvantages of the first generation systems, a new digital system was developed – the Global System for Mobile Communication (GSM). Often referred to as a *second generation* system, GSM increased the transmission quality and air interface efficiency and introduced services similar to ISDN. Security features such as ciphering and authentication were taken very seriously, and international roaming became possible. The CCITT began developing a consistent and open GSM standard to ensure unlimited mobility and a competitive market for this technology. (This work was later continued by ETSI.)

GSM proved to be extraordinarily successful. In the early 1990s, experts estimated that there would be 10 million subscribers in Europe by the year 2000. Today, more than 250 million GSM subscribers can be found all over the world. Many countries adopted the European standard and over 250 operators worldwide now offer GSM service. It soon became obvious that GSM would need to be developed as an evolutionary system, so that new features could be added based on market demands.

- GSM Phase 1 was passed in 1991. User data and full rate voice transmission (up to 9.6 kbps) were introduced. Some supplementary services were specified.
- GSM Phase 2 was realized in 1995. An extensive set of supplementary services was introduced along with a half rate speech codec and downward compatibility.
- GSM Phase 2+ refers to the ongoing process of adding new features to GSM in Annual Releases. Recent advancements include HSCSD, GPRS, CAMEL, EFR, and EDGE.

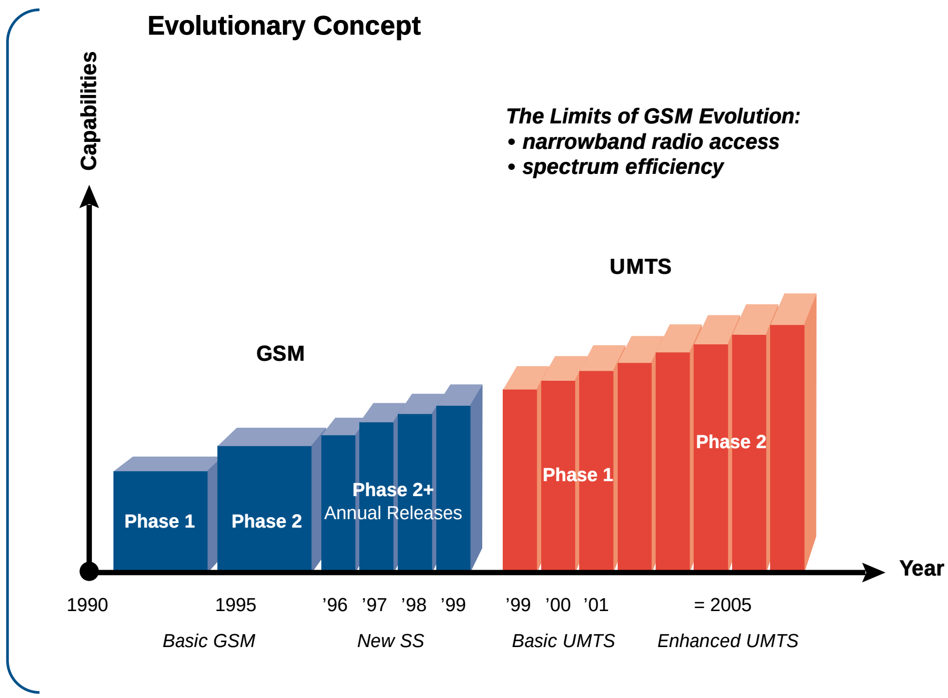



**Figure 1:** *GSM Evolution Concept*

*Third generation* (3G) mobile communication systems currently in development will further extend the range of applications available to mobile users. These technologies are referred to as Universal Mobile Telecommunication Service (UMTS), Wideband Code Division Multiple Access (WCDMA) and International Mobile Telephony 2000 (IMT-2000)[2]. Because of the wide distribution of mobile communication networks, the focus lies not only on increasing the efficiency of the air interface and broadband data transmission, but also on the reuse of existing investments in second generation mobile communication networks. With UMTS, a new Terrestrial Radio Access Network (UTRAN) will be integrated in the existing core network solutions (GSM-NSS, IS-41[3]). GPRS is the first step in creating an enhanced GSM core network solution for UMTS.

[1] This historical fact is still evident in the use of the word “cellular” or “cell phone” when referring to mobile communication.

[2] Additional information is available in “UMTS Protocols and Protocol Testing” Lit. No. 2FW-14251-0

[3] IS-41 is the core network for IS-95, D-AMPS, and AMPS.

## The Internet: Challenging/Changing GSM Networks

In recent years, Internet applications have become extremely popular, and the demand for mobile access to Web-based applications is increasing accordingly. But the Internet is a packet switched network, and GSM is a circuit switched network. While packet switched services can be provided over the current circuit switched network, the network architecture was not designed for this purpose and does not perform this task particularly well.

Internet traffic is characterized as "bursty" traffic, as data is transmitted in spurts, or bursts, rather than in a continuous stream. This type of data traffic is poorly suited for circuit switched networks, since the connection exists even when no data is transferred. This is extremely costly for the end user and makes inefficient use of the operator's air interface capacities.

In addition to this basic architectural difference, current mobile networks also share other technical restrictions that must be addressed in order to enable mobile Internet applications:

- 9.6 kbps transmission rate too slow for Internet use
- 160 character limitation for SMS
- Long call establishment times make the network seem even slower – delays due to transfer networks between the Public Land Mobile Network (PLMN) and the external Packet Data Network (PDN) are common
- Connections are released when transmission quality over the air interface drops below a certain threshold value. Often the subscriber gets unusable fragments instead of complete files.

Considering these drawbacks, packet switching over a circuit switched mobile communication network proves unreliable and expensive. A new standard was developed to address these issues and make mobile communication networks "Internet ready".

## GPRS: Preparing GSM Networks for the Internet

With its initial release in 1997, General Radio Packet Service (GPRS) Phase 1 was specified to create a sound foundation for packet switching in GSM networks. The standard defines central requirements such as point-to-point data transfer, identities, coding schemes, billing schemes based on data volume, security features, and TCP/IP and X.25 bearer capabilities. With

GPRS Phase 2 (specified in 1999), point-to-multipoint support and additional services are to be introduced. The following paragraphs describe the central ideas of GPRS and the key features defined in the standard:

Packet-switched methods are applied to efficiently transfer both data and signaling information. Using encapsulation and tunneling techniques, data is transparently transferred between the mobile station and the external packet data networks. (Among other advantages, this method helps overcome the 160-character limit currently placed on short messages.) GPRS supports the most common data protocols (IPv4 and X.25) and is open for additional interworking protocols in the future. Direct access to external packet data networks helps to increase data transmission rates and reduce call establishment time.

Billing is typically based on the amount of data transferred. This method provides a  fairer pricing scheme for bursty traffic, as rates are directly related to actual usage volume.

Security features such as ciphering[4] and authentication are implemented as they are in existing GSM networks.

Quality of Service features allow for the definition of precedence between subscribers, determination of delay classes and data transmission reliability as well as the mean and peak throughput rates.

Strict separation of Base Station Subsystem (BSS) and Network Switching Subsystem (NSS) via an open interface to allow multi-vendor environments and the evolution to UMTS where a new radio access network is attached to the NSS.

Increased efficiency on the air interface is ensured using several methods:

- Capacity on Demand: A cell's physical channels can be dynamically allocated for circuit switched and packet switched use. For example, in a cell with two transceivers, there are 14 physical channels available to transmit traffic. If the operator wants to ensure a call completion probability of 98% for circuit switched calls, on average less than 9 physical channels are used. The remaining resources are used as a spare for peak traffic situations. Those spare resources can be used for packet switched traffic. If circuit switched traffic increases, more physical channels can be allocated for circuit switched use "on demand" and some packet switched users may have to wait to continue downloading their data.

| Codec | Data rate (kbps) |
|---|---|
| CS-1 | 9.05 |
| CS-2 | 13.4 |
| CS-3 | 15.6 |
| CS-4 | 21.4 |

- Increased data transmission rates are achieved using channel bundling and new coding schemes. With channel bundling, up to 8 timeslots per

[4] Referred to as encryption in packet switching contexts.

TDMA frame can be combined. Depending on the codec speed (see sidebar table), this allows for transmission speeds of up to 171.2 kbps (8 timeslots @ 21.4 kbps).

(Note: CS-3 and CS-4 require modifications to the Base Tranceiver Station and won't be implemented by most operators in the beginning.)

- Asymmetric resource allocation: Uplink and downlink resources are allocated separately and may differ in size/capacity/rate.

EDGE (Enhanced Data Rates for Global Evolution) increases the data throughput of GSM systems to over 473 kbps per carrier and is also called EGRPS (Enhanced General Radio Packet Service). As the term EDGE suggests, this technology supports higher data rates via enhanced modulation schemes on the radio interface, known as 8-PSK (Phase Shift Keying) and GMSK (Gaussian Minimum Shift Keying). EDGE, expected to be deployed in 2001, is a mayor step in providing 3G services over GSM systems. As an overlay solution to existing networks, EDGE does not require modifications to the existing air interface. EDGE is especially designed for operators that do not have additional spectrum allocated for UMTS, but still wish to offer competitive applications (e.g. multimedia) using the existing band allocation.

## Network Architecture

### The GSM Environment Today

Existing GSM networks (Phase 1or Phase 2) consist of a radio access network called a Base Station Subsystem (BSS), a core network solution referred to as a Network Switching Subsystem (NSS), and an Operation Subsystem (OSS). The BSS consists of Base Station Controllers (BSC) which are responsible for the radio resource control, Base Transceiver Stations (BTS) which handle ciphering, encoding, burst generation, radio frequency generation, etc. The Transcoder and Rate Adaptor Unit (TRAU) compresses 64 kpbs voice data to 13 kbps (Full Rate), 12.2 kbps (Enhanced Full Rate), and 5.6 kbps (Half Rate) and performs rate adaptation for data applications.

The NSS is made up of Mobile Services Switching Centers (MSC), which perform classical exchange tasks including traffic switching, flow control, and signaling data analysis. In cooperation with other network elements, the NSS handles mobile-specific tasks such as mobility management and authentication. Logically, MSCs may be either Visited MSCs (VMSC), which are responsible for all the mobile devices in its supply area, or Gateway MSCs (GMSC), which are the interworking nodes to the external public telephone networks. The Visitor Location Register (VLR) associated with the VMSC holds relevant subscriber data for all subscribers currently within the range of the VMSC - including international mobile subscriber identity (IMSI) and a record of subscribed services. The Home Location Register (HLR) supplies the VLRs with this data and supports the Mobile Terminating Calls (MTC). The Authentication Center (AC or AuC) generates the Triplets (RAND, SRES, kc) necessary for the authentication of the subscriber. Finally, the optional Equipment Identity Register (EIR) is used to check the validity of the subscribers' handheld. GSM networks are circuit switched and normally use SS7 for signaling and control information.

### GPRS Enhancements to the GSM Network

With the introduction of GPRS, both the BSS and the NSS must be enhanced to support the key features outlined above (see GPRS: Preparing GSM Networks for the Internet). Several new logical network elements[5] enable the following high-level GPRS functions:

Network Access Control – A set of procedures are defined in GPRS to control access to the network's services and facilities. The subscriber may access the network via the air interface or an external packet data network. The operator can offer support for several protocols (X.25, IPv4, etc.) for access to external PDNs. The operator determines the extent to which services and access are restricted; six network access control functionalities are defined within the GPRS recommendations:

1. Registration: The user and the services to which he or she has subscribed must be known at the HLR. This includes the packet data protocols (PDP) subscribed for, the external PDNs (so-called access points) he or she is allowed to use, and the addresses (X.25, IPv4, etc.) of the mobile device.
2. Authentication and Authorization: These processes verify the subscriber's right to access the network and to use a specific service. The accompanying procedures correspond to those used in GSM.
3. Admission Control: When a subscriber requests a certain minimum amount of resources (quality of service) with a service, admission control checks whether they can be made available.
4. Message Screening: This functionality is used to filter unsolicited and unauthorized messages/data to and from the subscriber. In GPRS Phase 1, this is only network controlled.
5. Packet Terminal Adaptation: The maximum size of packets which can be transmitted via the GPRS network is limited to 1500 octets. Larger packets have to be segmented.
6. Billing Data Collection

[5] These new network elements are described below in the GPRS Network Element Overview section.

**Packet Routing and Transfer** – Routing is the process of determining the paths available for transmitting data packets from their source to their destination, selecting the most appropriate path and adapting datagram formats to fit the underlying transmission technology. If a connectionless network service is applied, datagrams can take different routes between the same source and destination. Several functions are closely related to packet routing and transfer: *Relay, Address Translation* and *Mapping, Encapsulation, Tunneling, Compression, Encryption,* and *Domain Name Server*. This last function is used to translate logical names into the corresponding network element addresses. The logical name "Internet" can be translated so that the subscriber is connected to the closest network element providing Internet access.

**Mobility Management** – Keeping track of subscribers' locations is a crucial task in mobile networks. Instead of administrative sets of cells organized into Location Areas, Routing Areas are introduced in GPRS. Each Routing Area is assigned to an SGSN.

**Logical Link Management** – When running bursty applications, subscribers only require physical resources when sending or receiving data. While there is no transmission, these physical resources can be released and allocated to other subscribers. By doing so, higher resource efficiency can be realized on both the air interface and the transmission lines. But as long as the subscriber has not terminated the session, a logical link must continue to exist, so that downloads can be continued after a break, etc.

**Radio Resource Management** – This function comprises three functional groups:

- **$U_m$ Interface**: realizes the "capacity on demand" concept.
- **$U_m$ Tranx**: Medium access, the packet multiplexing, error detection and correction of the packet switched traffic via the air interface must be controlled and combined with a flow control.
- **Path Management**: The operator can determine the maximum amount of packet switched traffic realized by a set of cells. Hence, only a certain capacity of transmission resources are necessary between the BSS and the packet switched part of the NSS. The data rate over an established link for an individual subscriber can fluctuate over time. Therefore, the subscribers' traffic should be multiplexed on the transmission line between the BSS and NSS.

**Network Management** – Existing Operation and Maintenance Systems must be enhanced to supply the operator with all the necessary information to guarantee smooth running of the GSM-GPRS network. This includes alarms, remote control and statistical data collection.

## GPRS Network Element Overview

To prepare existing GSM networks for GPRS, six new network elements are introduced.

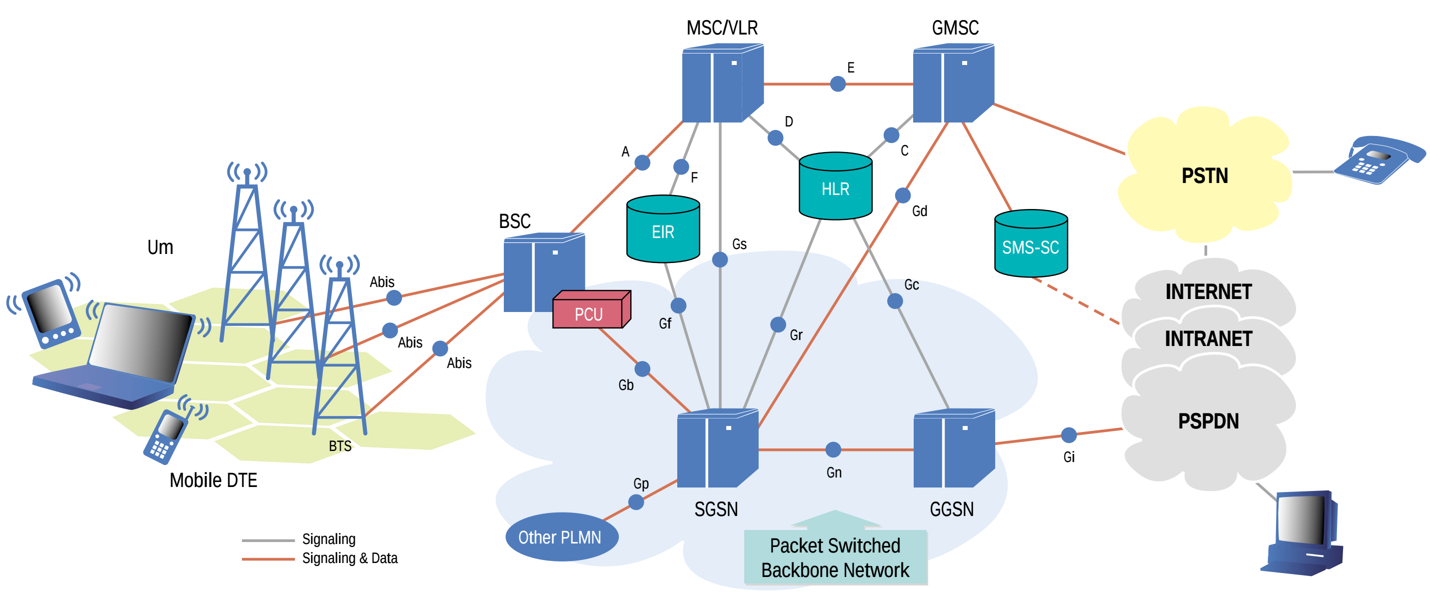



**Figure 2:** *GPRS Network Architecture*

1. GPRS Mobile Station: On the subscriber side, new handhelds are necessary to handle packet switched traffic over the air interface. Three different classes are defined:
   - Class A mobiles can handle both GSM circuit services and GPRS packet switched services simultaneously. GSM and GPRS signaling and control are also carried out simultaneously.
   - Class B mobiles can handle both GSM and GPRS signaling, but only GSM or GPRS traffic can be transmitted at any one time. If for example, a subscriber accepts a circuit switched call while downloading information from the Internet, GPRS data transmission is interrupted. As soon as the voice call is terminated, the download continues since the logical link between the mobile and the GPRS network still exists.
   - Class C mobiles can handle either GSM or GPRS. If a mobile station is connected to a GSM call, it is not available for GPRS traffic (and vice versa).

   Two of the new logical network elements are introduced to upgrade the BSS:
2. Packet Control Unit (PCU): The PCU is responsible for the capacity on demand feature. It decides which radio resources are dynamically allocated to packet switched and circuit switched use. The Base Station Controller (BSC) then manages the radio resources allocated for circuit switched use, while the PCU manages radio resources for the GPRS traffic itself. This includes channel access control, channel bundling, and data packet segmentation and re-assembly. The Um-Management Function and the Um-Tranx-Function are implemented by the GPRS mobile station and the PCU. The location of the PCU can be next to the SGSN (as stand alone unit), it can be next to or within the BSC cabinet, or at the BTS site.
3. Channel Codec Unit (CCU): The CCU implements the new coding schemes, power control, and timing advance procedures. In the beginning, most operators will only introduce the CS-1 and CS-2 codecs, because they can normally be implemented with a BTS software upgrade. The CS-3 and CS-4 codecs, however, require modifications to the BTS and may not be implemented as rapidly.

   In the NSS, a packet switched network is implemented parallel to the circuit switched domain. Three of the new logical network elements are introduced here:
4. Serving GPRS Support Node (SGSN): The SGSN is located on the same hierarchical level as the VMSC/VLR and performs similar tasks as outlined below. An SGSN is connected to the BSS, to neighboring SGSNs and GGSNs.
   - During the Network Access Control process, the SGSN is involved in the authentication and authorization procedures. The admission control procedure includes determination of QoS availability.
   - Mobility Management is realized based on the same principles as in the MSC/VLR. Note: There is a database in the SGSN which realizes the same tasks as the VLR, but is not a logical network element of its own.
   - The SGSN is responsible for switching traffic to the BSS and the network elements which establish the interconnection to external PDNs. An SGSN thus also performs the tasks of an ordinary (packet) router.
   - As several subscribers can be dynamically multiplexed onto a single timeslot, ciphering can no longer be performed by the BTS (as in circuit switched transmission) and is thus outsourced from the BTS to the SGSN. User data must be compressed before it is encrypted, so compression is also performed in the SGSN. On the other end, the same functions are performed by the GPRS mobile station.
   - The domain name server is logically associated with the SGSN.
   - Logical link management is realized between the SGSN and the mobile station, independent of the radio access system. A logical link between the SGSN and the handheld can be maintained even if there are no physical resources in use. Logical link management includes establishment, maintenance, and release.
   - Physical resources are managed between the SGSN and BSS (PCU) as part of the path management.
   - Billing information and statistical data are collected at the SGSN.
   - Interfaces to the BSS (PCU), the GGSNs, neighboring SGSNs, HLRs, EIRs, SMS-Centers, other PLMNs and the MSC/VLR are specified.
5. Gateway GPRS Support Node (GGSN): The GGSN is the interworking node between the external packet data networks and the packet switched part of the Network Switching Substation. It is located on the same hierarchical level as the GMSC in GSM networks and performs comparable tasks.
   - The GGSN is responsible for the packet routing and transfer procedures. The SGSNs and GGSNs are connected via an IP backbone. IPv4 can be implemented initially, but on the long run IPv6 shall be put into action.
   - The GGSN is involved in the Mobility Management process: When a call is placed to a mobile handheld, the GGSN sends a request to the Home Location Register to determine the SGSN currently serving the subscriber.
   - In GPRS Phase 1 it is responsible for the network orientated screening.
   - Billing information and statistical data are collected at the GGSN.
   - Interfaces to the SGSNs, external PDNs, and HLRs are specified.

| | | BSS | | NSS | | |
|---|---|---|---|---|---|---|
| **Function** | **MS** | **PCU** | **CCU** | **SGSN** | **GGSN** | **HLR** |
| **Network Access Control** | | | | | | |
| Registration | • | | | • | | • |
| Authentication and Authorization | • | | | • | | • |
| Admission Control | • | • | | • | • | |
| Packet Terminal Adaptation | • | | | | | |
| Charging Data Collection | | | | • | • | |
| **Packet Routing and Transfer** | | | | | | |
| Relay | • | • | | • | • | |
| Routing | • | • | | • | • | |
| Address Translation and Mapping | • | | | • | • | |
| Encapsulation | • | | | • | • | |
| Tunneling | | | | • | • | |
| Compression | • | | | • | | |
| Ciphering | • | | | • | | • |
| Domain Name Server | | | | • | | |
| **Mobility Management** | • | | | • | • | • |
| **Logical Link Management** | | | | | | |
| Logical Link Establishment | • | | | • | | |
| Logical Link Maintenance | • | | | • | | |
| Logical Link Release | • | | | • | | |
| **Radio Resource Management** | | | | | | |
| Um Management | • | • | | | | |
| Cell Selection | • | • | | | | |
| Um-Tranx | • | | • | | | |
| Path Management | | • | | • | | |

***Figure 3:*** *GPRS Functions and Logical Architecture*

6. HLR Extension: The HLR must be extended to store new subscriber data associated with packet switching. While the GGSNs and SGSNs are new hardware elements, the HLR Extension normally is just a software upgrade. The HLR (Extension) is involved in
   - registration, authentication and authorization processes,
   - ciphering (cipher key) and
   - mobility management.

### GPRS Interface Overview

In addition to the GSM interfaces, 9 new interfaces are specified in GPRS, all of them beginning with the letter “G”. The GPRS reference model of the European Telecommunications Standards Institute (ETSI) in Figure 5 shows the basic GSM and GPRS network elements and the interfaces specified between them. As shown in the figure, both the GSM circuit switched network and the GPRS packet switched network are connected to the BSS. Additional external networks can also be seen: The GPRS NSS part is connected to external packet data networks, while the GSM NSS part is attached to external PSTNs. Additionally the GPRS network can be directly connected to GGSNs in other operators’ mobile networks. The solid lines represent all GPRS interfaces which are used both as transmission and signaling planes, while the dotted lines indicate interfaces used only as signaling planes.

The central task of GPRS is the transmission of packet data from external networks to the mobile and vice versa. When a user data packet arrives at the GGSN, it must be routed to the SGSN in the supply area where the subscriber is currently located. The packet is then delivered to the BSS for transmission via the air interface. Finally, the packet arrives at the mobile station, where higher level applications process the user data packet.

Hence following transmission and signaling planes are mandatory for GPRS:

- The $G_i$ **interface** is the reference point between the external PDNs and the GPRS network. The network operator and the external ISP must agree on the transmission technology (layer 1 and 2) used to connect their packet data networks. Interworking with the X.25 and IPv4 protocols is specified; extensibility to future protocols is given.
- Once the GGSN has accepted the packet, it determines the SGSN where the subscriber is currently located and transmits the packet to the SGSN via the $G_n$ **interface**. IP routing is used between GPRS Support Nodes.

GPRS network.

- When the user data packet arrives at the SGSN, it must be transmitted to the GPRS mobile station. The logical link to the GPRS mobile station is managed via the $G_b$ **interface**. In order the perform the physical transmission, the SGSN has to be connected to the BSS (PCU). The PCU receives instructions as to the quality of service with which the user data packet is to be transmitted via the air interface. This information is also sent over the $G_b$ interface from the SGSN to the BSS (PCU).

There are two additional interfaces over which both transmission and signaling planes are implemented, though both are optional and often unnecessary for a basic GPRS network:

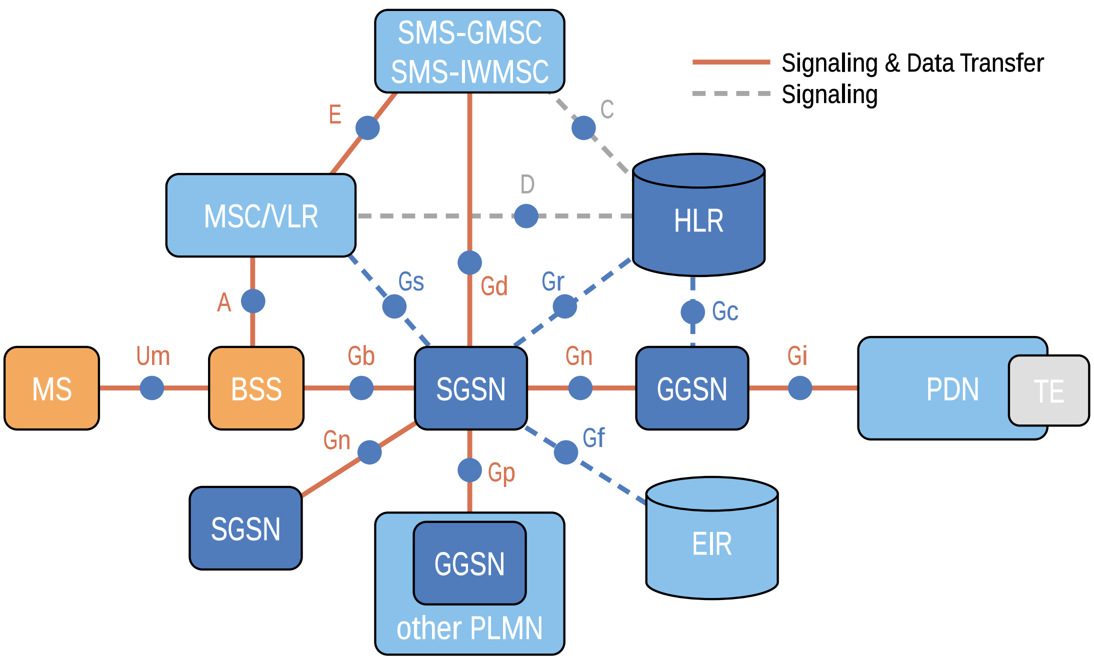



**Figure 4:** *The GPRS Reference Model*

The user data must be transparently transferred between the external packet data network and the GPRS mobile station. The transmission is split into two segments between the GGSN and SGSN, and the SGSN and GPRS mobile station. Methods known as encapsulation and tunneling are applied: The user data packet is equipped with $G_n$-specific protocol information which reduces the amount of interpretation of the user data packet by the GPRS network and enables an easy introduction of future interworking protocols.

Note: the $G_n$ interface is also defined between different SGSN of the same

- The $G_p$ **interface** is used between the SGSN and the GGSN in another operator's network. In its functionality it is quite similar to the $G_n$ interface.
- The $G_d$ **interface** is specified between the SGSN and an SMS gateway (SMS-GMSC/SMS-IWMSC). This interface is based on the SS7 protocol stack and enables the GPRS network to transmit long SMS messages.

In addition to the aforementioned interfaces, four pure signaling interfaces were defined in the ETSI GSM recommendations. The first three are connections to the registers - their protocol stacks are an enhancement of the

GSM interfaces to the databases:

- The $G_r$ **interface** between the SGSN and the HLR is the only mandatory interface of these 4 interfaces. It is based on the SS7 MTP, SCCP, TCAP, and MAP signaling stacks. If a subscriber appears in the supply area of an SGSN, the SGSN can request subscriber information from the HLR via the $G_r$ interface.
- The $G_c$ **interface** between the GGSN and the HLR is optional. If the first user data packet arrives at the GGSN and the subscriber has a fixed address, the subscriber's location must be retrieved from the HLR. The $G_c$ interface offers a direct path for this query. If this interface does not exist, the request can be sent via the $G_n$ interface to a home SGSN, which then forwards the request to the HLR via the $G_r$ interface. The routing information is then delivered by the HLR to the SGSN, which passes it on to the GGSN.
- The $G_f$ **interface** from the SGSN to the EIR is not mandatory, as the EIR is optional in both GSM and GPRS networks.

The fourth optional signaling interface is a connection between the MSC/VLR and the SGSN:

- The $G_s$ **interface** between the SGSN and the MSC/VLR can be used for common procedures like location updates. If, for example, a subscriber moves from one Location Area to another Location Area, then both location and routing area must be updated. If the $G_s$ interface does not exist, both update procedures must be performed separately over the air interface. If the interface is present, a GPRS routing update can be initiated, and the SGSN informs the MSC/VLR that a location update must also be initiated. The use of the $G_s$ interface thus conserves valuable resources on the air interface. The $G_s$ interface is a strongly reduced version of the A interface protocol stack.

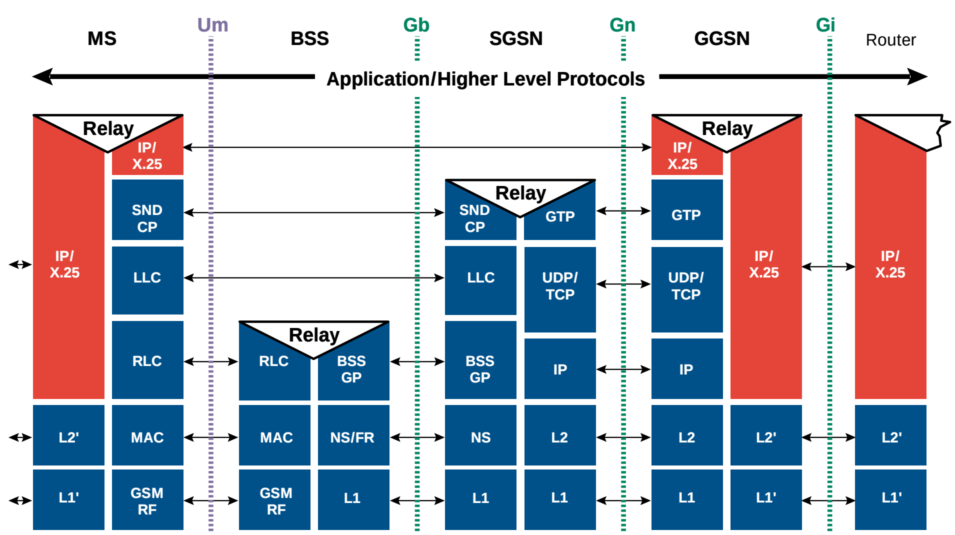
## Protocol Layers

### Overview

The layered protocol structure realized over the GPRS interfaces distinguishes between transmission and signaling planes. Transmission planes transfer user information, associated with transfer control information such as error correction, error recovery, flow control, multiplexing and de-multiplexing, and segmentation and re-assembly.

The NSS platform is based on a packet switched IP backbone, and is kept independent of the BSS and the radio interface using the $G_b$ interface. Operators interested in migrating their networks to UMTS in the future can reuse investments in the SGSNs, GGSNs, and the transmission network in between.

A logical connection between the GPRS mobile station and the SGSN is maintained using the Logical Link Control Layer (LLC). Above this layer, Subnetwork Dependent Convergence Protocol packets can be transmitted. LLC packets are transparently transmitted between the GPRS mobile station and SGSN.




| | | | |
|---|---|---|---|
| **BSSGP:** | BSS GPRS Protocol | **MAC:** | Medium Acces Control |
| **FR:** | Frame Relay | **RLC:** | Radio Link Control |
| **GTP:** | GPRS Tunneling Protocol | **SNDCP:** | SubNetwork Dependent Convergence Protocol |
| **IP:** | Internet Protocol | **TCP:** | Transmission Control Protocol |
| **LLC:** | Logical Link Control | **UDP:** | User Datagram Protocol |

***Figure 5:*** *GPRS Transport Protocol Layer*

### Physical Layers

If not otherwise specified in this document, the standard used on the physical layer and the (data) link layer is determined by the operator or defined in agreements between operators and external PDN providers.

Although a great variety exists, E1 is the most popular solution for GPRS (in North America T1). Frame Relay (FR) is commonly applied, although its use is somewhat complicated, as two implementations exist, one defined by the International Telecommunication Union (ITU), and another by the American National Standards Institute (ANSI). There are also three different modes of operation in Frame Relay: channelized, unchannelized, and fractional. With the variety of operators and vendors, measurement solution providers must provide support for all possible variants.

In packet switched networks, Ethernet (such as 100baseT) is also very popular.

ATM technology will be used in the UMTS terrestrial radio access network, and it is expected to gain in popularity in the future as GPRS network switching subsystems are implemented.

State-of-the-art measurement equipment therefore has to cope with a vast range of interfaces including STM1 (electrical and optical), STM4, DS1, DS3, E1, and E3. The ATM data link layer is presently based on AAL5 (which corresponds to Frame Relay QoS) but with UMTS, AAL2 must be supported as well.

### Transmission Plane

As shown in Figure 5, the highest layer "application" is located at the top of the mobile station's protocol stack. Common applications include those based on the Internet Protocol (IP) such as Hypertext Transmission Protocol (HTTP) over the Transmission Control Protocol (TCP). GPRS maintains a logical link, over which user data packets are transmitted. In the GSM recommendations, two common packet types (IP and X.25) are explicitly mentioned.

The GPRS task is to accept the user data packet at one access point (the GGSN), and deliver it to another access point (the GPRS mobile station). The following paragraphs offer a closer look at the interfaces and protocol layers affected by a user data packet's transport from the external PDN to the mobile.

### The $G_i$ Interface

Via the $G_i$ **interface**, the user data packet is delivered from the external PDN to the GGSN (see Figure 6). To the external PDN , the GGSN looks like an ordinary router. The standard used on the physical layer and the (data) link layer depend on mutual agreements between the mobile network operator and the external ISP. The most common data protocols (IPv4 and X.25) are supported and others may be added in the future.

### The $G_n$ Interface

Within the GPRS network switching subsystem, the user data protocol must be encapsulated before it is tunneled via the $G_n$ interface to the SGSN. User data packets, signaling and control information are exchanged between the GSNs through the IP backbone. The following protocols are commonly used on this interface[6]:

- GPRS Tunneling Protocol (GTP) [GSM 09.60]

  GTP is used as a transmission protocol to tunnel multi-protocol packets between GSNs. Several subscribers in the supply area of a single SGSN may be simultaneously connected to an external data network via the same GGSN. The IMSI is used to uniquely identify each subscriber in the

[6] The protocol stack of the Gn interface is also applied on the Gp interface.

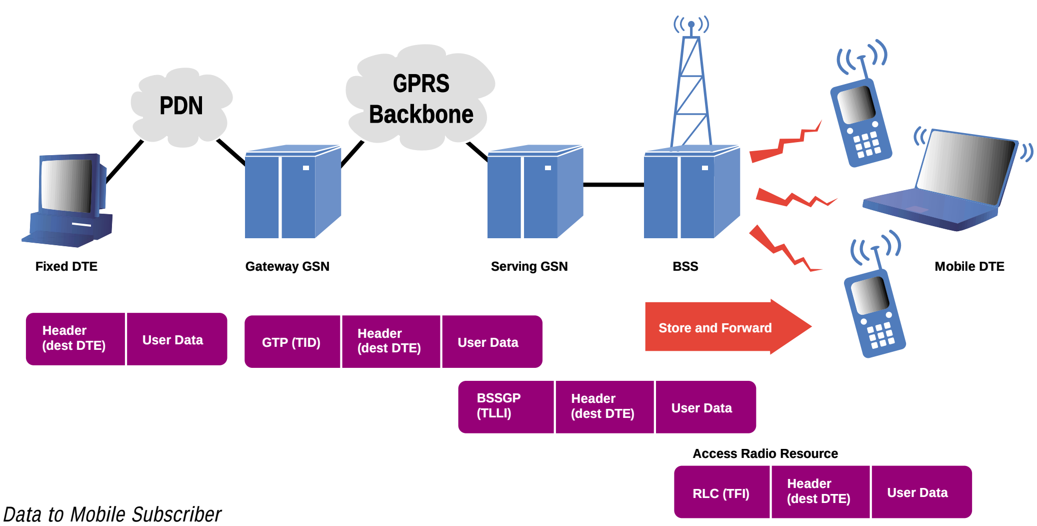



**Figure 6:** *Packet Data to Mobile Subscriber*

network switching subsystem.

A subscriber may also run several applications simultaneously; each of them using different external PDNs connected to the same GGSN. Therefore, each application must also be uniquely identified in the NSS. The Network Service Access Point Identifier (NSAPI) is used for this purpose. The NSAPI is assigned when the GPRS mobile station requests a call setup, a process referred to as the Packet Data Protocol (PDP) Context Activation Procedure. A PDP context describes the properties of a link between the GPRS mobile station and the GGSN, such as which PDP is transmitted via the link, which QoS level is used for the transmission, the access point in use, etc.

The user identity (IMSI) and the application identifier (NSAPI) are integrated into the Tunnel Identifier (TID)[7] which uniquely identifies the subscriber's sublink between the GSNs. The TID is part of the GTP header, which is added to the user data packet during the encapsulation process in the GTP. The user data packet can then be easily tunneled to the SGSN without further interpretation. This feature makes GPRS open to future user data protocols.

- Internet Protocol (IP) [RFC 791], User Datagram Protocol (UDP) [RFC 768], Transfer Control Protocol (TCP) [RFC 793]
  User data, signaling and control information are exchanged between the GSNs and tunneled through the IP backbone in the form of GTP packets. Either UDP or TCP are applied by the endpoints of the tunnels (SGSNs and GGSNs), depending on the user data protocol. Each link on the transmission path between the (external) Data Terminal Equipment (DTE) and the mobile DTE is either reliable or unreliable. GPRS between the two access points $G_i$ and $U_m$ is just one link in the overall transmission of the user's data packet.

  If IP is used as user data protocol, transmission between the external DTE and the mobile DTE is unreliable. Therefore, the GPRS link between the GSNs can also be unreliable and UDP can be applied on the "sublink" over the NSS part.

  If the user data protocol is X.25, reliability is ensured on each link and must therefore also be guaranteed between the GSNs. In this case, the reliable transport layer protocol TCP must be used.

On the $G_n$ and $G_p$ interfaces, the GPRS Tunneling Protocol (GTP) presents the greatest challenge to measurement equipment; TCP/UDP/IP measurement procedures are already well defined.

### The $G_b$ Interface

Most new protocol layers can be found on the $G_b$ interface. As with all other interfaces on the transmission plane, this interface is used to exchange both user data and signaling information. This interface allows several users' connections to be multiplexed over the same physical resources. Due to the bursty nature of most packet switched applications, this is done based on the users' activity. (This is one major difference to the A interface, where the physical resources are permanently allocated to one subscriber as long as a circuit switched call is maintained.) The two highest layers (SNDCP and LLC) are used for peer-to-peer communication between the SGSN and the GPRS mobile station, while the lower layers are applied between the SGSN and the BSS (PCU).

- SubNetwork Dependent Convergence Protocol (SNDCP) [GSM 04.65]
  The SNDCP layer is located above the LLC layer in the SGSN and GPRS mobile station. Its central task is to improve the channel efficiency. To do so, the SNDCP layer compresses header information and user data using separate algorithms to minimize the amount of information transmitted over the air interface. To meet the lower LLC layer's maximum frame length restrictions, the SNDCP layer segments larger user data packets and re-assembles these on the receiver's end. The SNDCP layer can also multiplex several "small" user data packets into a single LLC frame and de-multiplex these on the receiving end. This layer is also responsible for ensuring that user packet data is transmitted and received according to the negotiated QoS level.

  Network Service Access Points (NSAPI) are opened between the SNDCP layer and the application layer above on the GPRS mobile station end to transfer user packets to/from the respective application.

- Logical Link Control (LLC) [GSM 04.64]
  The LLC layer is responsible for handling the virtual connection between the SGSN and the GPRS mobile station and exists even when no physical resources are available between the two. It supports peer-to-peer data transfer between the SGSN and the GPRS mobile station. For each Temporary Logical Link Identifier (TLLI) the LLC offers various services using the Service Access Point Identifier (SAPI). These services may include Quality of Service classes for user data, GMM/SM signaling information and/or SMS data.

  In addition to managing the logical link, the LLC layer ensures user data confidentiality using ciphering/encryption features.

  The transmission of LLC PDUs is possible in the acknowledged and unacknowledged mode. In the acknowledged mode, each LLC PDU is

[7] See GSM 03.60 Version 7.1.1 Release 98, chapter 14.5 TID

confirmed by the receiver's side. This is a service provided by SNDCP request.

While LLC layer information is transmitted directly and transparently to the mobile station via the BSS, the lower layers in the Gb interface protocol stack are used between the BSS (PCU) and the SGSN for the transmission of LLC PDUs.

On the GSM A interface, a physical resource is dedicated to a single subscriber for the duration of a call, independent of information flow. On the $G_b$ interface, however, several subscribers can be multiplexed on a common physical resource. Usage rates can vary between zero and the maximum possible data rate. In addition to user data, signaling information can also be sent over the common physical resource.

- Base Station System GPRS Protocol (BSSGP) [GSM 08.18]
  The BSSGP provides radio-related, QoS, and routing information between the MAC/RLC layer of the PCU and the SGSN. The BSSGP layer also performs node management control functions between a remote BSS (PCU) and the SGSN. The BSSGP layer provides a connectionless link between the SGSN and BSS handles paging requests from the SGSN to the BSS, and provides flow control between the SGSN and BSS, etc.
- Network Service (NS) [GSM 08.16]
  The NS is responsible for the transmission and reception of higher layer packets across the $G_b$ interface. Load sharing is supported as well as virtual connections (NS-VC) for peer-to-peer communication between remote devices using NS. The NS is based on Frame Relay connections between the SGSN and BSS (PCU). In the future, a variant using IP over Ethernet is to be expected.
- $L1_{bis}$ [GSM 08.14]
  Physical layer configurations and protocols can be applied as specified in GSM 08.14: ANSI T1.403, X.21, V35, ITU G.703, and ITU G.704.

When the LLC packet arrives at the BSS (PCU), it is forwarded to the GPRS mobile station. There the Radio Link Control is responsible for efficient use of the physical link on the air interface and the MAC for handling access to the physical link:

- Radio Link Control/ Medium Access Control (RLC/MAC) [GSM 04.60]
  These sub-layers are responsible for packet switched radio resource management. The RLC is responsible for segmentation and re-assembly of the LLC packets. The segmentation results in RLC blocks. Control information is added to each RLC block to allow Backward Error Correction (BEC). The size of these segments is such that when applying the coding schemes, they precisely fit on four normal bursts (= radio block). With BEC, both acknowledge and unacknowledged mode are possible.

  The MAC layer handles procedures related to common transmission resource management. The layer allows point-to-point transfer of signaling and user data within a cell. As several subscribers can be multiplexed on one physical channel, each connection has to be (temporarily) uniquely identified. These connections are referred to as Temporary Block Flows (TBF). A TBF is a physical connection between the mobile station and the PCU. The TBF is unidirectional; uplink and downlink resources are separated in the block flow – this allows for asymmetric allocation of uplink and downlink resources. The TBF is maintained only for the duration of the data transfer. During the flow, one or several LLC PDUs are (successfully) transmitted. The TBF is identified by a Temporary Flow Identifier (TFI). The TFI is added to the RLC block.

  The medium access can be realized by fixed, dynamic, and extended dynamic allocation. While the TFI is sufficient for fixed allocation, the Uplink State Flag (USF) must be used downlink for dynamic medium access. Up to 8 subscribers can dynamically share one physical channel, but which of them is allowed to temporarily use next the uplink resources must be indicated on the downlink channel.
- GSM RF
  This layer is based on the GSM 05 specification, which describes the physical characteristics of the air interface.

### The $A_{bis}$ interface

While The RLC/MAC layer is implemented in the PCU, the GSM RF layer is located in the Base Transceiver Station. The PCU is normally located at the Base Station Controller or SGSN site. Some aspects of the $A_{bis}$ interface – which connects the BTS and the BSC – are relevant here:

- $A_{bis}$ interface [GSM 08.60]
  When the PCU is remote to the BTS, fixed-length frames of 320 bits (20 ms) are transferred from the BSC to the BTS. In GSM, they are referred to as TRAU frames; in GPRS they are called PCU Frames. The PCU frames hold both GPRS data and GPRS RLC/MAC associated control information.

  Depending on the vendor, the BTS (including the CCU) may control some functions of the PCU (in the BSC), but the PCU also may control some functions of the remote CCU. Remote control information is carried inband in the PCU frames. Tektronix offers customized measurement solutions for these environments.

### Signaling Plane

The signaling plane provides supplementary services[8] and supports transmission plane functions by controlling:

- GPRS network access connections
- attributes of established network connections
- routing paths to support user mobility
- assignment of network resources to meet changing user demands

The following paragraphs offer a closer look at the interfaces and protocol layers that comprise the GPRS signaling plane.

The GPRS Tunneling Protocol (GTP) on the $G_n$ and $G_p$ interfaces is not only used to transmit user information on the transmission plane but also carries information on the signaling plane, for example the “Create PDP Context Request” of the PDP Context Activation Procedure.

In GSM networks, Mobility Management (MM) and Connection Management (CM) are realized between the VMSC/VLR and the mobile station in peer-to-peer communication. The Base Station Subsystem is only used as a relay. The same is true for the GPRS mobility management, which is located above the LLC, and where separate Service Access Points are used to address this management protocol layer:

- GPRS Mobility Management/Session Management (GMM/SM)
  Mobility Management and PDP Context Activation, Modification, and Deactivation Function are implemented. In the PDP Context Activation process, for example, the mobile station requests a packet data protocol, QoS level. (see Figure 7)

The remaining signaling planes are based on the SS7 protocol stack. SS7 is used for signaling on the $G_r$, $G_c$, $G_f$, and $G_d$ interfaces between SGSN and HLR, GGSN and HLR, SGSN and EIR, and SGSN and SMS-GMSC/SMS-IWMSC.

- Mobile Application Part (MAP)
  This protocol layer was already applied in GSM to realize mobile-specific signaling between exchanges and databases (HLR, VLR, etc.) It is enhanced to include GPRS-specific functions.
- Transaction Capabilities Application Part (TCAP)
  The TCAP supports MAP and is used as a dialog handler between the databases. (HLR, VLR, etc.)
- Signaling Connection Control Part (SCCP)
  SCCP is an SS7 protocol. It offers connectionless and connection oriented services for switches and databases. It is used to address switches in the worldwide SS7 network (Global Title Translation, GTT)
- Message Transfer Protocol (MTP)
  MTP covers the SS7 signaling on layer 1 to 3. It is responsible for managing signaling links, signaling routes, and signaling traffic.

The $G_s$ interface is the only signaling plane interface not based on the MAP. It is used for common GSM/GPRS procedures such as location updates. Above

[8] Source: GSM 02.60, Version 6.1.1, Release 1997, p. 23.

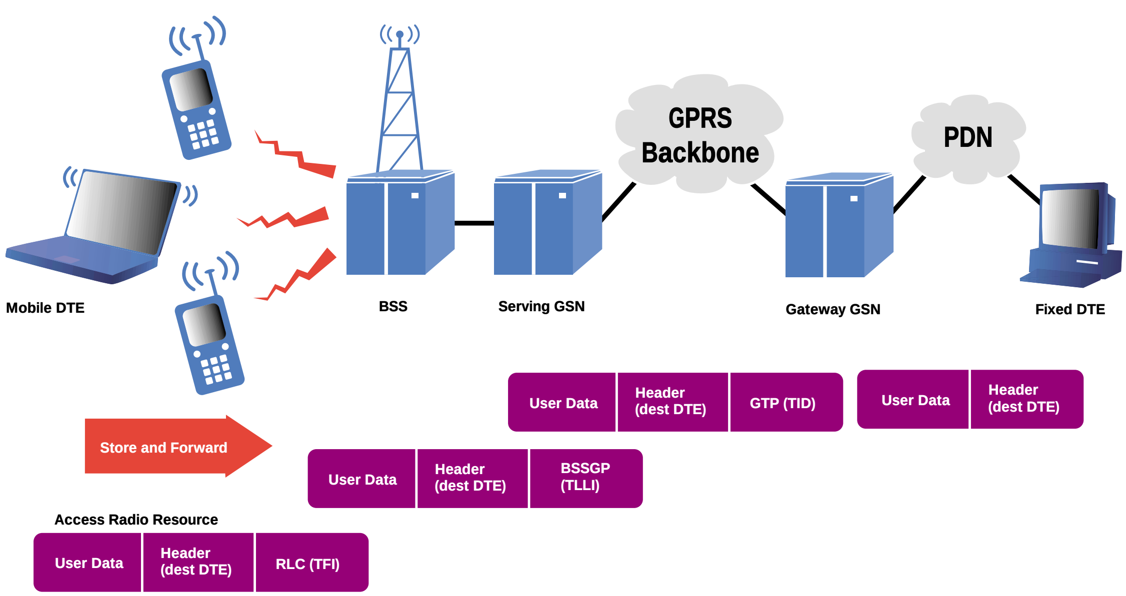



**Figure 7:** *Packet Data from Mobile Subscriber*

the SCCP and MTP there is the

- Base Station System Application Part + (BSSAP+) [GSM 09.18, GSM 03.60] The BSSAP+ is a subset of the A interface's BSSAP, used for common GSM/GPRS procedures including Mobility Management.

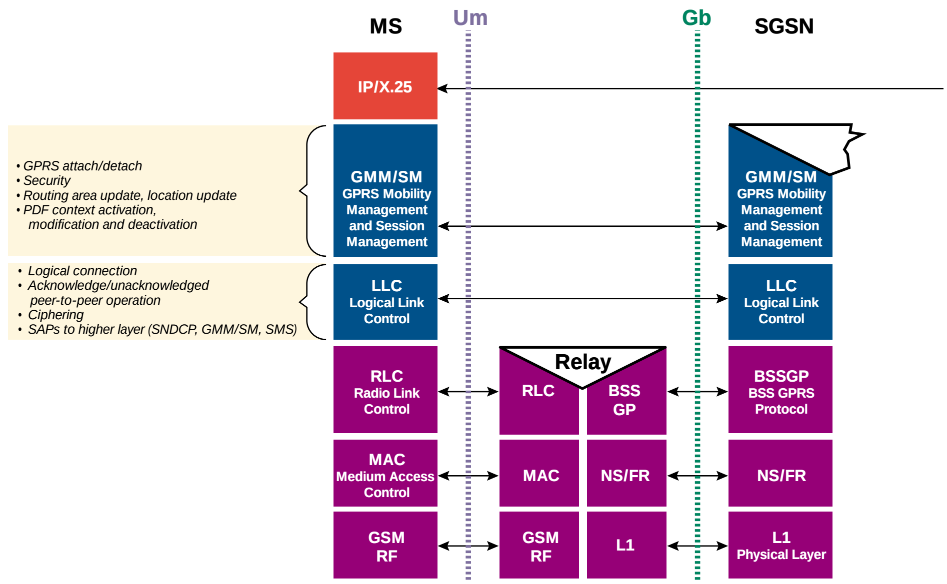



**Figure 8:** *Signaling Planes between SGSN and Mobile Station*

## Measurement Issues

### Monitoring and Performance Measurement

The main reason for operators and manufacturers to collect data is to retrieve the necessary information to assist in decision making in order to reach a specified objective. Data collection and recording can be part of the mobile network performance evaluation. In this case, data is collected from each network element (NE) according to a schedule established by the Operations System (OS). Performance measurement can also be performed on individual network elements by the manufacturer and/or operator to determine the limitations of the NE before introducing it into an existing network.

The major objectives for data collection are:

- to receive an overall view about the actual performance level of an item. An item can be a NE, a part of a network, the PLMN, or the OS. This information is used to decide which measures need to be taken in

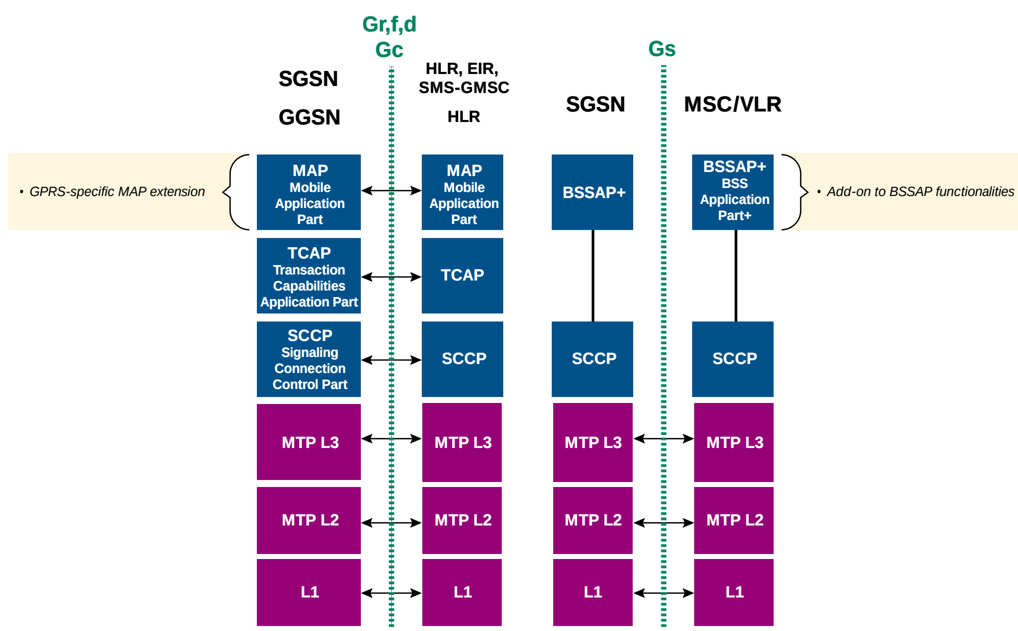



**Figure 9:** *GPRS Signaling Planes*

the planning process, the operation and maintenance field, training of employees, etc.

- to determine a possible **need for an improvement** of the item. This can affect both installed items already in operation and items under development.
- to discover the **differences** in the specified/predicted characteristics of the item and its field characteristics.
- to improve forecasts on the item's behavior and problems.

Tektronix GPRS equipment is especially suited for GPRS interface testing. Monitoring can be performed with both the K1205, a pure monitoring device, and the K1297, which is used also for simulation and emulation. With Tektronix measurement equipment, two main ways to present results are available:

- **statistics method**: counts the occurences of specific events such as overload situations, failures, tracing, etc.
- **online data analysis**: received data can be filtered to focus on particular aspects of communication. (Show all TCP user data larger than 140 octets, for example.)

## Emulation and Simulation

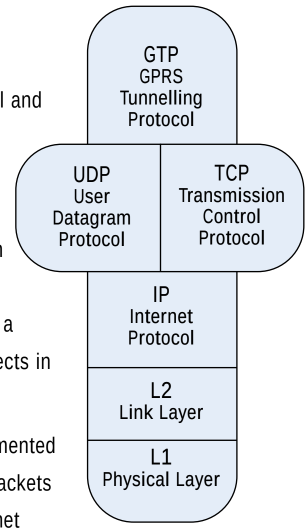
**Simulation** is the representation or imitation of one process or system through the use of another. In a test environment, a simulator can be used to substitute a network element up to a particular part of the network. For instance, when testing an SGSN, the BSS behavior can be simulated by test equipment.

Major applications for simulators include:

- Collecting information about a network element's dependability. Within the simulation, certain normal and abnormal situations can be created, and the NE's ability to cope with the simulated environment offers the operator and manufacturer an approximation of the unit's field characteristics. Simulations are also often used for conformance testing.
- Substitution for missing NEs or parts of a network during the development process of an entity. The simulation helps to approximate the item's ability to perform in a real life environment.
- Cost savings for the development of an entity. The strong and weak points of an entity can be identified early in the development process or before introducing it into a running network.

The term **Emulation** is often used in computer science when a device is imitated with the help of another (such as terminal emulation). For Tektronix, emulation represents a higher form of simulation. Here, the behavior of certain communication protocol layers is simulated automatically and in conformance with the protocols. The targets set for the emulation are usually similar to those of the simulation.

## The $G_n$ Interface




With GPRS, monitoring becomes an essential and demanding task because of the complex behavior in the multiple interfaces between the GPRS and GSM NEs and on the GPRS backbone. The goal is the rapid identification of problems, malfunctions, reactions, and performance issues. The $G_n$ ($G_p$) interface is a good example of the new measurement aspects in GPRS.

The GPRS Tunneling Protocol (GTP) is implemented on the $G_n$ interface to allow multi-protocol packets to be tunneled between the GSNs. The Internet Protocol stack (network layer and transport layer) is used to transmit the GTP packets between the GSNs. The data link layer and physical layer depend on the operator's network configuration. When testing the $G_n$ ($G_p$) interface, the features and functionality of the new GTP layer must be verified. With the IP transmission technology, new **statistical data** is necessary. In GSM networks, measured values may have included the number of pages per location area per hour, busy hour call attempts (BHCA) per BSC and/or MSC, handovers per BSC per hour, etc. The GPRS network, however, transmits user data packets. Therefore, the concept of BHCAs or Erlang is no longer applicable. Concepts to monitor and judge this kind of traffic must be adopted from the packet switched environment.

Using the **$G_n$, $G_p$ and $G_i$ interfaces** as an example, the following list offers an impression of the new and modified aspects related to monitoring, simulation, performance measurement and packet transfer:

- Monitoring and statistics:
  One new statistical "parameter" is the mean packet delay: in the SGSN, GGSN, and PCU network elements, packets are processed and encapsulation and de-capsulation, header modification and address translation takes place. In case of short-term congestion, packets can be buffered. The mean packet delay depends both on the processing power of the NE and on the subscribers' overall traffic behavior. These two factors determine the field characteristics of the NE. Given the mean

packet delay at each network element, the overall mean delay between the operator's access points can be determined.

If the operator's network offers the QoS "Delay class 1", the operator must guarantee that the mean transfer delay between the two network access points is less than 0.5 seconds for Service Data Units of 128 octets. 95% of the SDUs must be transmitted in less than 1.5 seconds. Other GPRS QoS classes to be considered include reliability classes and throughput classes.

Note: the limiting factor is normally not the transfer rate in kilobytes per second, but rather the amount of packets which can be processed and switched by a NE in one second.

Other new statistical values include kilobytes per second, mean packet size, kilobytes per user, etc. There is a long list of statistics which can be compiled from packet switched networks. Both the K1205 and K1297 can provide these statistics.

- Simulation
  For GPRS, it is expected that a certain number of subscribers wants to download information from the Internet and/or their company's Intranet. For this group, the traffic behavior can be determined in advance: the average size of the files to be downloaded, the number of IP packets required to transmit files of this size; delay between packets, etc. Here "bursty" behavior can often be detected: several packets are sent very quickly one after the other, then there is a longer break before the next group of packets is transmitted. Given several subscriber traffic profiles, manufacturers and operators can use test equipment to simulate this traffic behavior to gain an impression of the network element's field characteristics.

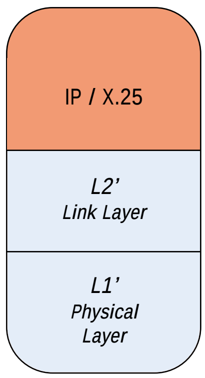
  In simulation, the K1297 Protocol Tester represents one or several communication partners – in a protocol-conformant or an error simulation mode. All protocol layers from layer 2 can be set according to the OSI reference model. Test scripts can be created in the form of state machines using the test manager and run dynamically. The integrated Message Building System is a tool for creating messages interactively. Generated messages can also be dynamically modified during run time. Messages and message frames can be stored in a pool.

- Packet Transfer and TCP timing problems
  Subscriber mobility can cause problems with TCP connections. TCP connections are normally optimized during the transmission of data (for example, timer settings for retransmission of IP packets are optimized). If a GPRS mobile station moves from a cell where a data transmission rate of 100 kbps was possible to another cell where a data transmission rate of only 10 kbps is possible, the TCP timer will expire for packets which have not yet been transmitted over the air interface. This leads to an

excessive amount of retransmitted TCP/IP packets.

- Interworking between GSNs and the packet switched backbone
  The interworking of GSNs with the GPRS IP based backbone must be tested to verify correct packet routing and addressing. Access to the DNS Server must also be verified. The DNS Server is responsible for mapping logical names to IP addresses. When provided with a logical name for an external packet data network (such as the Internet) the SGSN can retrieve the closest GGSN and its IP address from the DNS Server.

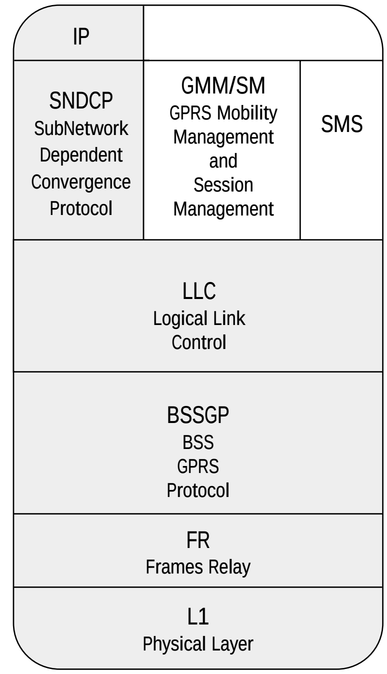
### The $G_i$ Interface




The $G_i$ interface specifies how the mobile network (GGSN) is connected to external packet data networks. The physical layer and data link layer are subject to agreements between the operator and the ISPs. On the network layer, interworking with IP and X.25 is specified. On the $G_i$ interface, test equipment must be able to cope with various transmission solutions such as STM1, ATM, or Ethernet. The demands placed on test equipment on this interface are similar to those on the $G_n$ interface for layer 1 to 3.

### The $G_b$ Interface

Most new GPRS protocol layers can be found on the $G_b$ interface. On the transmission plane, the two highest protocol layers are the Subnetwork Dependent Convergence Protocol (SNDCP) layer and the Logical Link Control (LLC) layer. The peer entities of the two layers are the SGSN and the GPRS mobile station. The LLC is responsible for handling the logical link between the peer entities, independent of the physical resources allocated between them. The SNDCP is responsible for processing user data (compression, segmentation, and multiplexing). The Base Station System GPRS Protocol (BSSGP) and Network Service (NS) layers are used between the SGSN and the BSS (PCU). The BSSGP provides radio-related, QoS, and routing information between the SGSN and PCU (for MAC/RLC). The NS is used to establish a virtual connection between the SGSN and PCU. The NS layer performs load balancing, multiplexing, and bandwidth allocation tasks. The layer 1 technology can be selected from the GSM Rec. 08.14.E1, ANSI T1.403 and X.21 are two of the possible physical layer technologies.




On the signaling plane, the $G_b$ interface offers GPRS Mobility Management (GMM) and Session Management (SM). The GMM/SM is located in part on the LLC, in part on the BSSGP. The SMS Service is implemented directly above the LLC.

Monitoring, performance testing, simulation and emulation and conformance testing of all new protocol layers are demands on testing equipment. The following examples show test applications on the $G_b$ interface:

1. In Figure 10 BSP1, the K1297 emulates and simulates the GPRS core network solution (SGSN, GGSN, and register). The BSS is attached to the K1297. The Implementations Under Test are both the BSS and the mobile stations (MS). The K1297 itself consists of three major components:
   - The Primary Rate Interface Monitoring Emulation (PRIME) provides the E1 interface to the BSS and $G_b$ traffic is routed via this connection. The

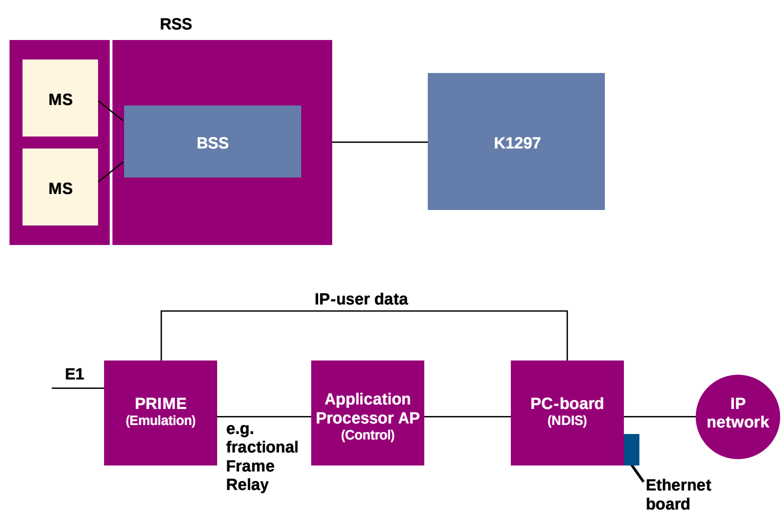



**Figure 10:** *BSP1*

SGSN protocol stack facing the $G_b$ interface is emulated on the PRIME board. This enables rapid processing of both incoming and outgoing data via this interface.

- The Application Processor (AP) controls the PC and PRIME boards. This component is responsible for directing the emulation, simulation scripts, monitor applications, and the ARP proxy.
- The Ethernet interface provides a means to connect the K1297 to an external packet data network. This is necessary if the K1297 is to emulate and simulate the Network Switching Subsystem's packet switched domain. The Ethernet interface is handled by the PC board, on which an NDIS driver is installed.

  (The external PDN or any IP client application can also be realized on the PC board itself. In this case, the NDIS driver emulates an Ethernet board to provide access from the PC side to all emulation stacks on the PRIME with IP on top. This feature may be used to simulate mobiles running PC applications connected to an SGSN via a BSS. When a connection is successfully established between the K1297 and the BSS, the IP data – user data – is directly transferred between the PRIME and the PC boards.)

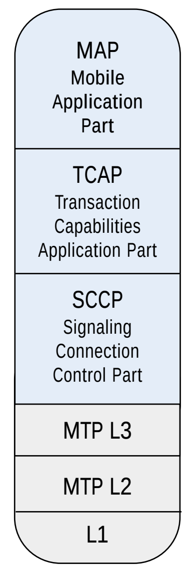
To realize an Attach Request with a fixed IP address (of the GPRS mobile station), proceed as follows: First, a default state for the signaling connection and one point-to-point connection must be defined. The next step is to realize the GPRS attach itself, which includes the BSSGP flow control and acknowledgement, and the realization of the Attach Request message on the GMM/SM layer. When finally the Attach Complete message is sent to the mobile station, the attach was successful. To carry out this process, the K1297 user applies predefined messages in the K1297 in combination with specific values entered via changes in scripts, entries in tables, and by selecting menu options. Following the attach, the PDP context activation process begins with the PDP context request. If the subscriber uses a dynamic IP address, the IP address for this connection is generated by the K1297. (This is a GGSN task.) Furthermore, the QoS, Radio Status, etc. is determined given the entries in the tables, menus, etc. When the PDP Context Activation is accepted, data can be downloaded from a Web server.

2. Another common application of the K1297 and K1205 is passive monitoring.  With the K1205, up to 4 bi-directional channels can be monitored by each board. After selecting the physical channel and the Frame Relay mode, the K1205 user can apply filtering options to retrieve specific information including the elements belonging to a GMM/SM attach request, IP packets of a specific size, etc. This information is stored in a log file. In the monitor application, additional filters can be used to select information for presentation, such as statistics and counters.

3. Conformance testing on the $G_b$ interface is also possible with the Tektronix K1297. This is described separately in the last section of this chapter (see page 29).

### The $G_r$, $G_f$, $G_c$, and $G_d$ Interfaces

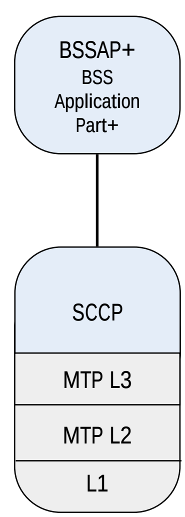
The interfaces carrying SS7 signaling information also require enhancements for GPRS operation. The highest layer Mobile Application Part (MAP) must be enlarged to support transmission of new GPRS subscriber profiles. The remaining layers - MTP, SCCP, and TCAP - require no modification, as they perform the same tasks as in GSM.




For the MTP, SCCP, and TCAP layers, the monitoring, performance testing, simulation and emulation tools can be adopted from GSM. This is partially true for the MAP, as well. Yet a special focus lies on the functionality and dependability of the MAP, and GPRS-specific monitoring, emulation and/or simulation routines can be of help here:

An SDL style test manager, integrated in the monitor functionality of the K1297, allows the system to react directly to certain events with user-defined actions. For example, statistical values are obtained by increasing a counter when certain SS7 IAM (Initial Address Messages) are received. Active monitoring is also possible and useful, for example, if a parallel connection between the measuring device and the transmission lines cannot be established.

### The $G_s$ Interface




An optional interface between the SGSN and VMSC/VLR is specified for common procedures like combined LA and RA updates. This interface implements a reduced version of the GSM A interface for the signaling plane. On the highest layer, the Base Station System Application Part + (BSSAP+) is realized. The remaining layers are adopted from the A interface: SCCP and MTP.

Hence, for monitoring, performance testing, emulation, and simulation, the test equipment can be "easily" adapted to the $G_s$ interface. A special focus is placed on the BSSAP+ layer.

## Summary

Monitoring, performance testing, simulation, and emulation are crucial steps in the process of verifying the functionality and efficiency of individual network elements or the operator's entire network. With the K1297, Tektronix offers a protocol tester and software to support these tasks.

During the installation process, the user of the Tektronix K1297 can set up the tester's operating mode. When setting up the K1297, the user determines [1] whether to test the SS7 signaling plane (starting with the MTP protocol) or the GPRS interfaces (beginning with Frame Relay).

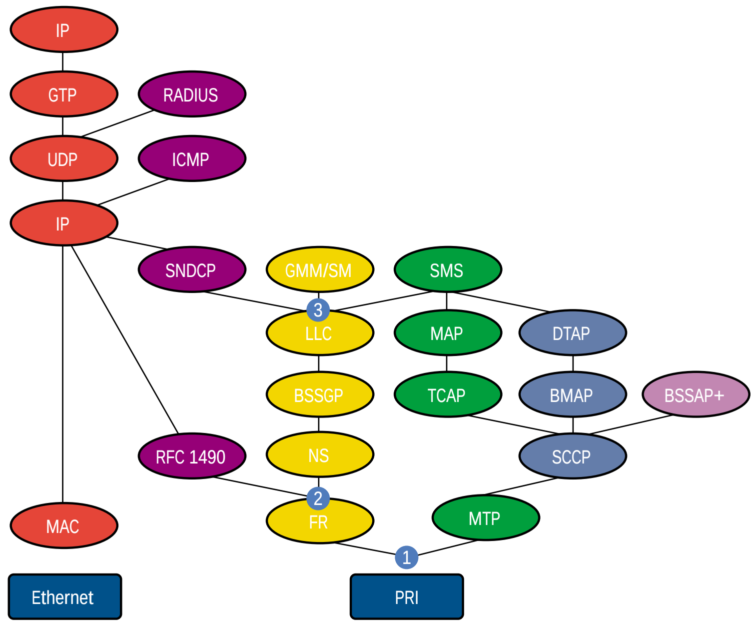
With the decision for SS7, both the Gr "MAP" interfaces and the Gs (BSSAP+) interface can be tested.

When GPRS interfaces are tested, the DLCI value of the Frame Relay header indicates whether complete Frame Relay data is present [see 2, DLCI=0], or if the information is a full GPRS stack (Gb interface). If RFC1490 PDUs are found, the corresponding user part is selected (Gi and Gn interfaces).

In case of the Gb interface, for the emulation of the LLC and higher layers, the LLC SAPI (Service Access Point Identifier) [see 3] determines whether user data or short messages should be transmitted (SNDCP, SMS) or Mobility Management (GMM/SM) will be handled.

On the Ethernet interface, the lower layers are replaced by Ethernet and MAC (Media Access Control). Above the MAC layer, a complete IP stack is found.

With these options, the Tektronix K1297 covers the full range of GPRS interface testing.




### Conformance Testing [ETSI ETR 021]

The principal idea of standards is to allow the development of systems by different manufactures which can interoperate with each other. **Conformance testing** is the verification process in which an independent body determines if a system, piece of equipment or implementation satisfies the criteria of a particular standard. "During the test phase, the implementation is referred to as the **Implementation Under Test** (IUT)."[9]

The **conformance assessment process** specifies test methods to ensure the comparability of test results generated by different test laboratories. This process can be divided into three steps:

1. **Test Preparation**: the client (manufacturer) and the test laboratory agree on the test and the how to conduct it (including testing method and tested protocols). Here there are two important documents:

- Protocol Information Conformance Statement (PICS): describes the capabilities and the used options of the client's IUT. It also states which features have been omitted.

- Protocol Implementation eXtra Information for Testing (PIXIT): holds additional information about the IUT important for the test laboratory, such as addressing information, complements for the range of values stated in the PICS.

2. **Test Operation**: During this step, the tests are carried out. Normally a collection of executable tests are available, called Executable Test Suites (ETS). These are based on an abstract description of the tests, the so-called (standard) Abstract Test Suite (ATS).

3. **Conformance Test Reports**: Finally, the conformance test results must be made available. The Protocol Conformance Test Report (PCTR) holds the conformance test results for a single protocol layer including all necessary information (PICS, PIXIT, IUT). The System Conformance Test Report (SCTR) summarizes the conformance test results, identifying the participants (such as test laboratory, client, SUT) and a system report summary with a reference to the different standard components (such as protocols, PICS).

### Simulation and Conformance Testing Example: Block Procedure NS

There are two new layers which enable peer-to-peer communication between the SGSN and the GPRS mobile station, the Subnetwork Dependent

[9] ETSI ETR 021: September 1991, p. 8

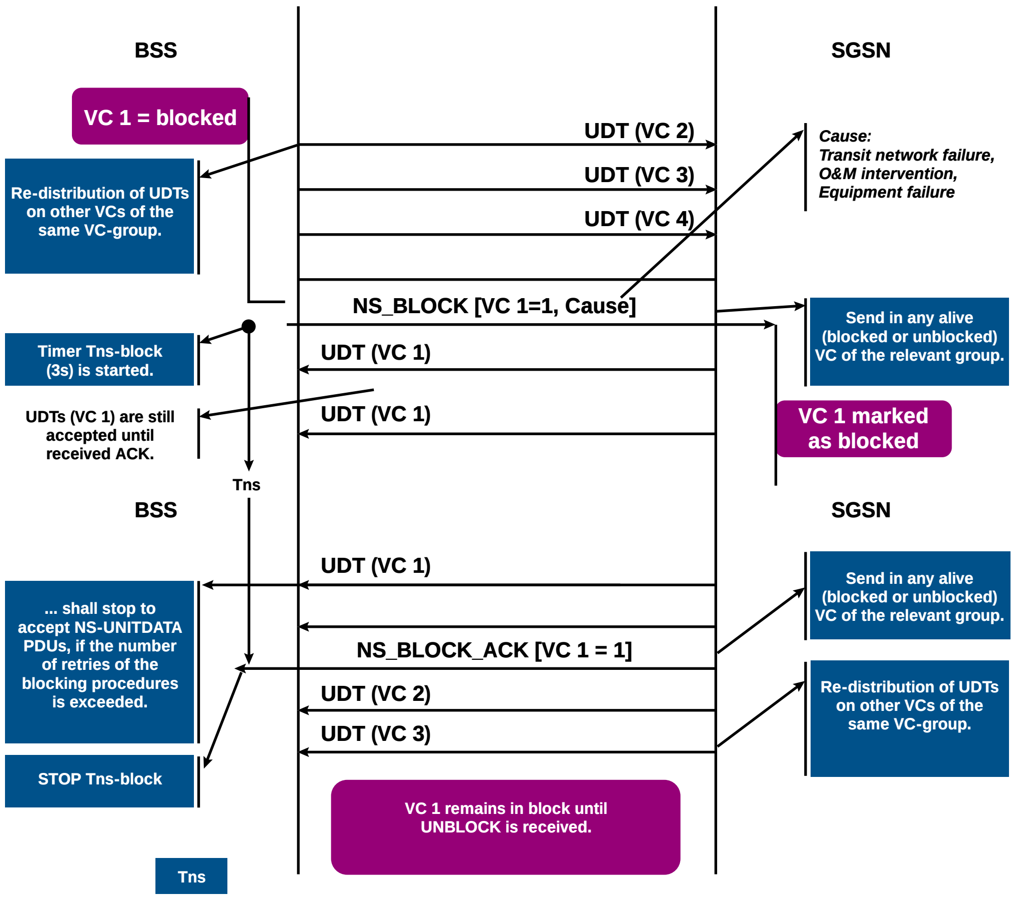



***Figure 11:*** *Block Procedure NS*

Convergence Protocol (SNDCP) layer and the Logical Link Control (LLC) layer. The Base Station System GPRS Protocol (BSSGP) and the Network Service (NS) are used between the BSS and SGSN.

Figure 11 shows a conformance test scenario for the NS layer. The “Remote Single Layer” testing method is applied (only functions and tasks are tested here, independent of lower and higher layers). For conformance testing, a set of Abstract Test Suites (ATS) is defined. Several refer to a specific event of the Network Service Virtual Connection (NS-VC) management: a blocking procedure is used by the NS entity to inform its NS peer entity when an NS-VC becomes unavailable for the NS user traffic (see Figure 11). The NS-VC management is part of the Network Service Control entity, which is also responsible for NS SDU transmission and load sharing.

User data traffic is transmitted on several virtual connections of one NS-VC group between the BSS and the SGSN. NS-VCs between the same peer entities are arranged in one NS-VC group. NS-VC grouping therefore has only local significance between the BSS and SGSN.

- In Figure 11, the user data is transmitted on virtual connections 1 through 4.
- The BSS side then blocks the virtual connection VC1. The NS block packet contains the Virtual Connection Identifier (VCI, here 1) and a cause element, which indicates the reason for blocking the virtual connection. The most common reasons for blocking a virtual connection are transit network failure, O&M intervention, and equipment failure. The VC block packet may be sent on any alive (= blocked or unblocked) NS-VC that belongs to the same NS-VC group.[10] When blocking the VC 1, the BSS must be capable of redistributing the user data traffic (NS-UNITDATA PDUs[11]) on other virtual connections of the same NS-VC group.
- When blocking the VC 1, there can still be unitdata PDUs on the VC 1 from the SGSN to the BSS. Therefore, the BSS must still accept incoming user data traffic on VC 1. This happens either until the BSS side gets an

[10] Some cases may require different handling.

[11] By the means of the NS-UNITDATA PDU, NS SDUs are transmitted in an unacknowledged mode via the $G_b$ interface.

NS block acknowledge packet, or until the number of retries specified for the blocking procedure is exceeded. Then the TNS block timer stops.

- After sending the NS block acknowledge packet, the SGSN must distribute the user data traffic on the unblocked virtual connections.

Two possible conformance tests will be shortly portrayed. The conformance test of one entity can be realized via simulation: the BSS side or the SGSN can be simulated by a system simulator. If the SGSN is simulated, there are two possible test configurations shown in Figure 12: Test Configurations I & II:

- A test configuration for testing the Network Service Protocol and the BSSGP part where no GPRS mobile station is needed. The IUT is the BSS.
- A configuration for testing the BSSGP where the GPRS mobile station is needed. If the full implementation of the Gb interface has to be tested, then the LLC and SNDCP can also be examined. (The LLC and SNDCP can be partially tested by directly attaching the MS higher layers to a system simulator.)

So a system/network element simulator can be used for conformance test of one interface's entity.

Given the NS blocking procedure, the following two confirmation tests can be performed:

- Normal sequence of events when IUT receives an NS block acknowledge packet[12]:

  When the IUT (BSS) receives an NS block acknowledge packet as a response to the O&M initiated NS block in the "NS-VC unblocked" state (the NS block acknowledge is received on another NS-VC belonging to the same group), the IUT should stop the blocking procedure and remain in the "NS-VC blocked & alive" state.

- Abnormal sequence of events when IUT receives an NS block acknowledge packet [13]:

  When the IUT receives an unexpected NS block acknowledge packet for an NS-VC which is locally blocked (in the "NS-VC blocked & alive" state), the IUT should discard it and remain in "NS-VC blocked & alive" state.

The test case only passes if the IUT acts as specified in the Abstract Test Suites.

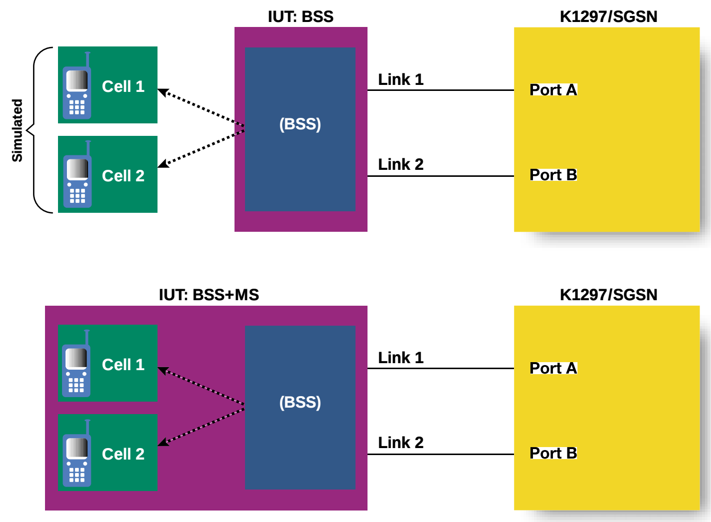



***Figure 12:*** *Test Configurations I & II*

[12] Tektronix, Protocol Tester: K1297, Conformance Tests for GPRS, C73000-M6076-C757-1, Test case description NS_B_N_003

[13] Tektronix, Protocol Tester: K1297, Conformance Tests for GPRS, C73000-M6076-C757-1, Test case description NS_B_E_003

## Glossary

### Specifications:

ITU Recommendation E.880: "Field data collection and evaluation on the performance of equipment, network, and services."

ITU Recommendation G.704 (Blue Book): Synchronous frame structures used at 1544, 6312, 2048, 8488 and 44 737 kbit/s hierarchical levels.

ETSI ETR 021: "Advanced Testing Methods (ATM); Tutorial on protocol conformance testing (Especially OSI standards and profiles) (ETR/ATM-1002)

GSM 04.08: "Digital cellular telecommunications system (Phase 2+); Mobile radio interface layer 3 specification".

GSM 04.60: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Mobile Station (MS) - Base Station System (BSS) interface; Radio Link Control / Medium Access Control (RLC/MAC) protocol".

GSM 04.64: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Logical Link Control (LLC)".

GSM 04.65: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Subnetwork Dependent Convergence Protocol (SNDCP)".

GSM 07.60: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Mobile Station (MS) supporting GPRS".

GSM 08.14: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN) interface; Gb interface layer 1".

GSM 08.16: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN) interface; Network Service".

GSM 08.18: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Base Station System (BSS) - Serving GPRS Support Node (SGSN); BSS GPRS Protocol (BSSGP)".

GSM 09.02: "Digital cellular telecommunications system (Phase 2+); Mobile Application Part (MAP) specification".

GSM 09.16: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Serving GPRS Support Node (SGSN) - Visitors Location Register (VLR); Gs interface network service specification".

GSM 09.18: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); Serving GPRS Support Node (SGSN) - Visitors Location Register (VLR); Gs interface layer 3 specification".

GSM 09.60: "Digital cellular telecommunications system (Phase 2+); General Packet Radio Service (GPRS); GPRS Tunneling Protocol (GTP) across the Gn and Gp interface".

GSM 09.61: "Digital cellular telecommunications system (Phase 2+); General requirements on interworking between the Public Land Mobile Network (PLMN) supporting General Packet Radio Service (GPRS) and Packet Data Networks (PDN)".

GSM 12.04: "Digital cellular telecommunication system (Phase 2); Performance data measurements".

## Index

| | |
|---|---|
| A | interface between BSS and GSM-NSS |
| AAL | ATM Adaptation Layer |
| $A_{bis}$ | interface between BTS and BSC |
| AC | Authentication Center |
| AMPS | Advanced/American Mobile Phone Service |
| ANSI | American National Standards Institute |
| ATM | Asynchronous Transfer Mode |
| ATS | Abstract Test Suite |
| AuC | Authentication Center |
| BEC | Backward Error Correction |
| BHCA | Busy Hour Call Attempt(s) |
| BSC | Base Station Controller |
| BSS | Base Station Subsystem |
| BSSGP | Base Station Subsystem GPRS Protocol |
| BTS | Base Transceiver Station |
| CAMEL | Customized Application for Mobile Enhanced Logic |
| CCS7 | Common control signaling system No 7 (SS7) |
| CCU | Channel Codec Unit |
| CM | Connection Management |
| CN | Core Network |
| CS | Circuit Switched |
| CT | Conformance Test |
| DL | Downlink |
| DLCI | Direct Link Connection Identifier |
| DNS | Domain Name Server |
| DTE | Data Terminal Equipment |
| E1 | 2.048 kbps |
| EDGE | Enhanced Data Rates for GSM Evolution |
| EIR | Equipment Identity Register |
| EFR | Enhanced Full Rate |
| ETR | ETSI Technical Report |
| ETS | Executable Test Suite |
| ETSI | European Telecommunication Standards Institute |
| FR | Frame Relay |
| $G_b$ | interface between BSS and SGSN |
| $G_c$ | interface between GGSN and HLR |
| $G_d$ | interface between SGSN and GMSC |
| $G_i$ | interface between GGSN and external PDN |
| $G_f$ | interface between SGSN and EIR |
| GGSN | Gateway GPRS Support Node |
| GMM | GPRS Mobility Management |
| GMSC | Gateway MSC |
| $G_n$ | interface between SGSN and GGSN |
| $G_p$ | interface between SGSN and GGSN of external PLMN |
| GPRS | General Packet Radio Service |
| $G_r$ | interface between SGSN and HLR |
| $G_s$ | interface between SGSN and VMSC/VLR |
| GSM | Global System for Mobile Communications |
| GSN | GPRS Support Node |
| GTP | GPRS Tunneling Protocol |
| GTT | Global Title Translation |
| HLR | Home Location Register |
| HR | Half Rate |
| HSCSD | High Speed Circuit Switched Data |
| HTTP | Hypertext Transmission Protocol |
| IMT-2000 | International Mobile Telephony 2000 |
| IP | Internet Protocol |
| ISP | Internet Service Provider |
| ITU | International Telecommunication Union |
| IUT | Implementation Under Test |
| kbps | kilobits per second |
| LLC | Logical Link Control |
| MAC | Medium Access Control |
| MAP | Mobile Application Part |
| MM | Mobility Management |
| MS | Mobile Station |
| MSC | Mobile Switching Center |

| | |
|---|---|
| MTC | Mobile Terminating Call |
| MTP | Message Transfer Part |
| NE | Network Element |
| NMT | Nordic Mobile Telephony |
| NS-VC | Network Service - Virtual Connection |
| NSS | Network Switching Subsystem |
| OS | Operations System |
| OSS | Operation Subsystem |
| PCU | Packet Control Unit |
| PDN | Public Data Network |
| PDP | Packet Data Protocol |
| PDU | Protocol Data Unit |
| PICS | Protocol Implementation Conformance Statement |
| PIXIT | Protocol Implementation eXtra Information for Testing |
| PLMN | Public Land Mobile Network |
| QoS | Quality of Service |
| RLC | Radio Link Control |
| RFC | Request for Comment |
| SAP | Service Access Point |
| SAPI | Service Access Point Identifier |
| SCCP | Signaling Connection Control Part |
| SDU | Service Data Unit |
| SGSN | Serving GPRS Support Node |
| SM | Session Management |
| SMS | Short Message Service |
| SNDCP | Subnetwork Dependent Convergence Protocol |
| SS7 | Signaling System Number 7 |
| SUT | System Under Test |
| TBF | Temporary Block Flow |
| TBI | Temporary Block Identifier |
| T1 | 1544 kbps |
| TACS | Total Access Communication System |
| TCP | Transmission Control Protocol |
| TCAP | Transaction Capabilities Application Part |
| TID | Tunnel Identifier |
| TRAU | Transcoder and Rate Adaptor Unit |
| TRX | Transceiver |
| UDP | User Datagram Protocol |
| Um | air interface |
| UMTS | Universal Mobile Telecommunication Service |
| UP | Uplink |
| USF | Uplink State Flag |
| UTRAN | UMTS Terrestrial Radio Access Network |
| VC | Virtual Connection |
| VLR | Visitor Location Register |
| VMSC | Visited MSC |
| W-CDMA | Wideband CDMA, Wideband Code Division Multiple Access |

Notes:

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