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.

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

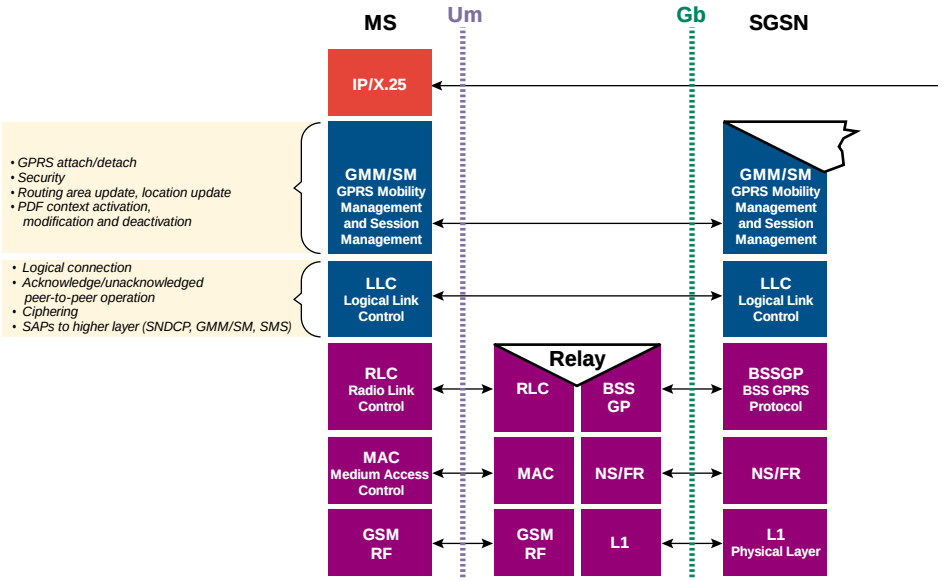


Figure 8: *Signaling Planes between SGSN and Mobile Station*

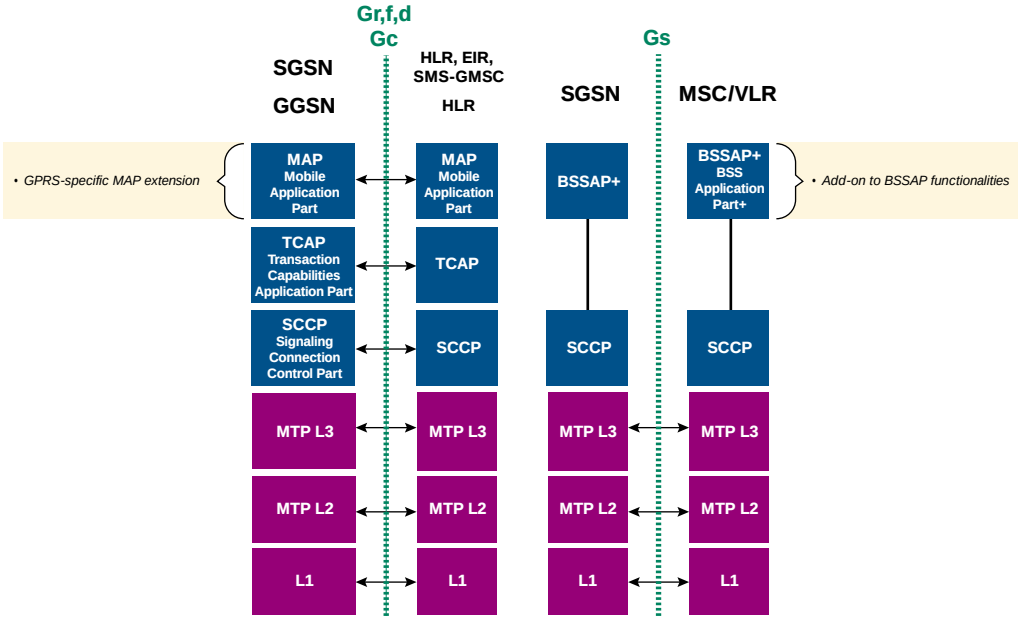


Figure 9: *GPRS Signaling Planes*

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.

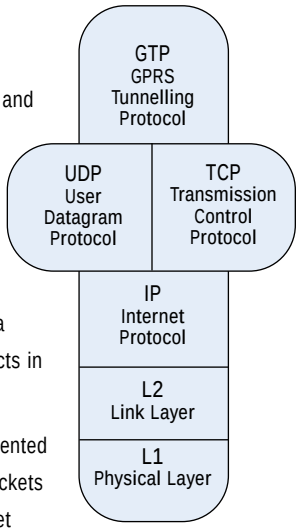
Major applications for simulators include:

- 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.

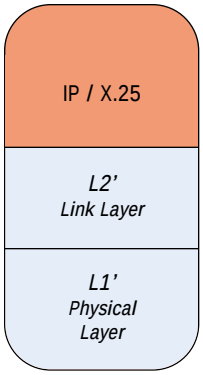
- Packet Transfer and TCP timing problems

  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.

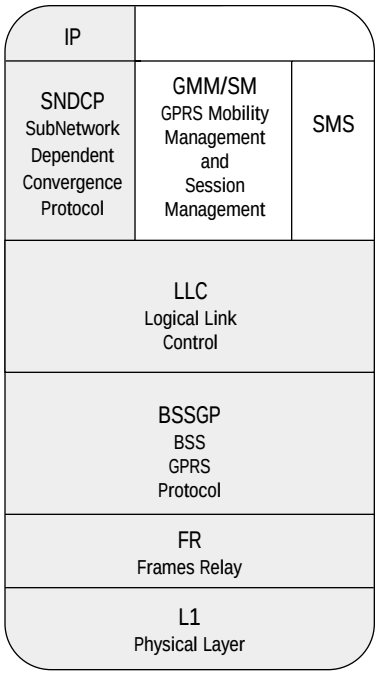
The G_i Interface



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

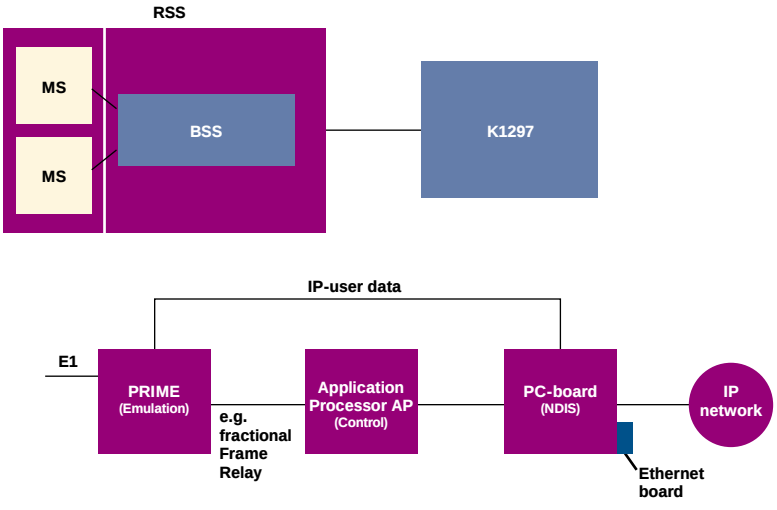
Most new GPRS protocol layers can be found on the G_b interface. On the transmission plane, the two highest protocol layers are the Subnetwork Dependent Convergence Protocol (SNDCP) layer and the Logical Link Control (LLC) layer. The peer entities of the two layers are the SGSN and the GPRS mobile station. 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.

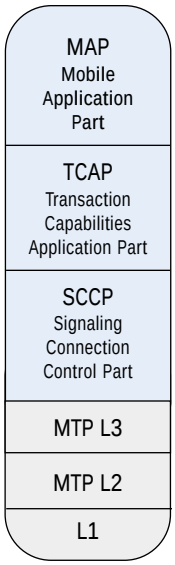
2. Another common application of the K1297 and K1205 is passive monitoring. With the K1205, up to 4 bi-directional channels can be monitored by each board. After selecting the physical channel and the Frame Relay mode, the K1205 user can apply filtering options to retrieve specific information including 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.