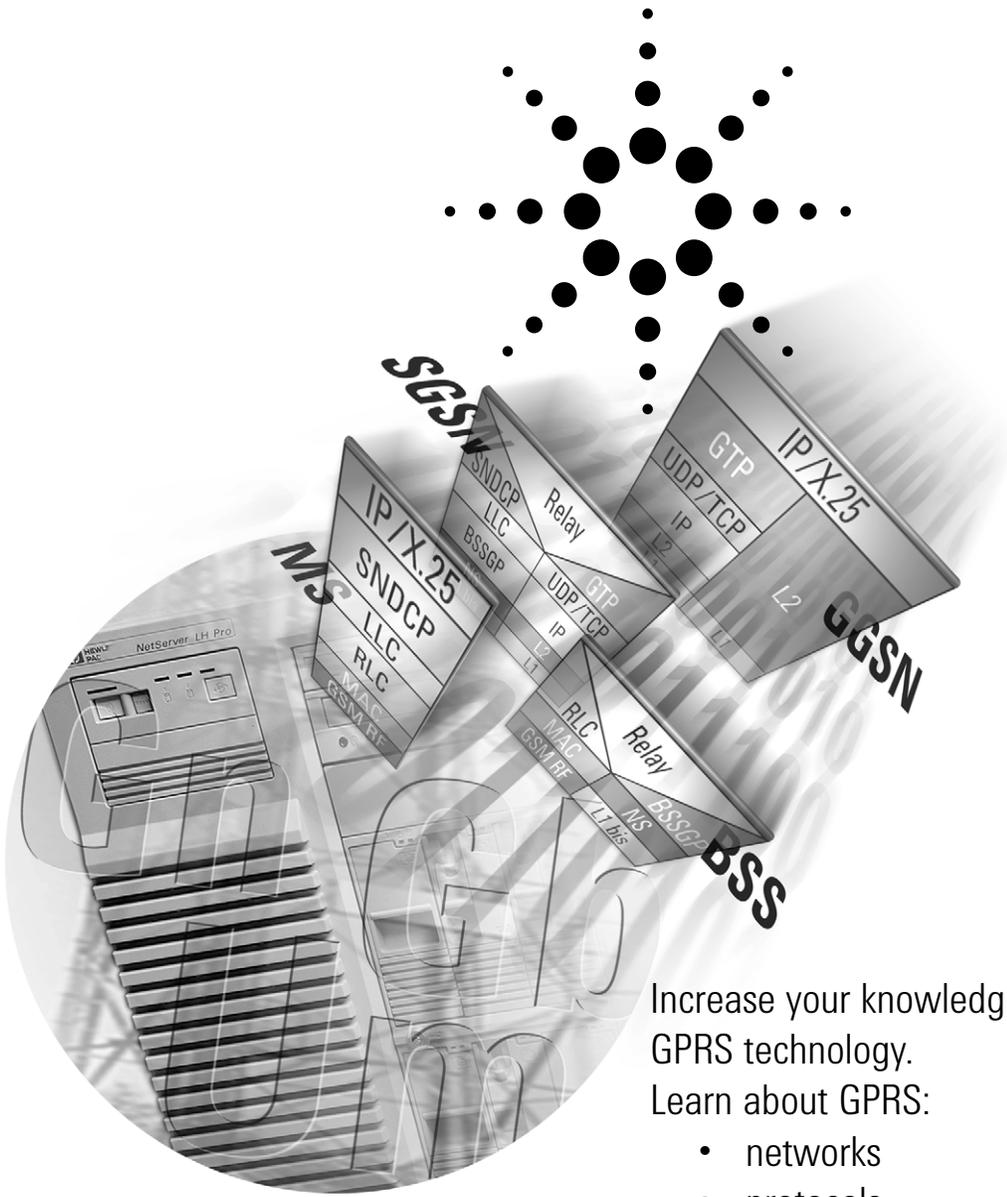


Agilent Understanding General Packet Radio Service (GPRS)

Application Note 1377



Increase your knowledge of GPRS technology.

Learn about GPRS:

- networks
- protocols
- air interface
- packet data transfer methods



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Table of Contents

| | Page |
|--|------|
| Data communication needs | 4 |
| The GPRS network | 5 |
| GPRS protocol layers | 10 |
| GPRS identities | 14 |
| GPRS air interface | 16 |
| Packet data transfer operations | 24 |

Introduction

In response to customer demand for wireless Internet access—and as a stepping-stone to 3G networks—many GSM operators are rolling out general packet radio service (GPRS). This technology increases the data rates of existing GSM networks, allowing transport of packet-based data. New GPRS handsets will be able to transfer data at rates much higher than the 9.6 or 14.4 kbps currently available to mobile-phone users. Under ideal circumstances, GPRS could support rates to 171.2 kbps, surpassing ISDN access rates. However, a more realistic data rate for early network deployments is probably around 40 kbps using one uplink and three downlink timeslots.

Unlike circuit-switched 2G technology, GPRS is an “always-on” service. It will allow GSM operators to provide high speed Internet access at a reasonable cost by billing mobile-phone users for the amount of data they transfer rather than for the length of time they are connected to the network.

This paper will look in detail at the new protocols, procedures, and other technology changes that GPRS brings to GSM networks.

Section 1: Data communication needs

Before examining GPRS technology in detail, let's review some basic terms of data communications.

Data communication applications generally are divided into two categories:

- **Real time** applications involve small data transactions such as sending or receiving a quick e-mail, performing a financial transaction, getting a sports or news update from the web, or chatting on line.
- **Data access** applications are bulkier and involve sending or receiving large amounts of data. Examples are downloading web pages and files from the Internet or transferring large files to other users.

Two techniques are available for moving data across communication networks:

Circuit switching is a mode in which a connection (or circuit) is established from the point of origin of a data transfer to the destination. Network resources are dedicated for the duration of the call until the user breaks the connection. Using these resources, data can be transmitted or received either continuously or in bursts, depending on the application. Since resources remain dedicated for the entire duration of a data call, the number of subscribers that the network can support is limited.

Packet switching is a mode in which resources are assigned to a user only when data needs to be sent or received. Data is sent in packets, which are routed across the network along with other user traffic. This technique allows multiple users to share the same resources, thus increasing capacity on the network and managing resources quite effectively. However, the technique does place some limitations on data throughput.

Experience has shown that most data communication applications do not require continuous data transfer. Users may need to be connected to a data communication network (such as a LAN, WAN, the Internet, or a corporate Intranet), but that does not mean they are sending and receiving data at all times. Furthermore, data transfer needs generally are not symmetrical. In most cases users send out small messages but receive large downloads. At any given time, most of the data transfer is in one direction.

Section 2: The GPRS network

General packet radio service (GPRS) gives GSM subscribers access to data communication applications such as e-mail, corporate networks, and the Internet using their mobile phones. The GPRS service uses the existing GSM network and adds new packet-switching network equipment. See Figure 1.

Existing GSM networks use circuit-switched technology to transfer information (voice or data) between users. However, GPRS uses packet switching, which means there is no dedicated circuit assigned to the GPRS mobile phone. A physical channel is established dynamically, only when data is being transferred. Once the data has been sent, the resource (a timeslot on the air interface) can be re-allocated to other users for more efficient use of the network.

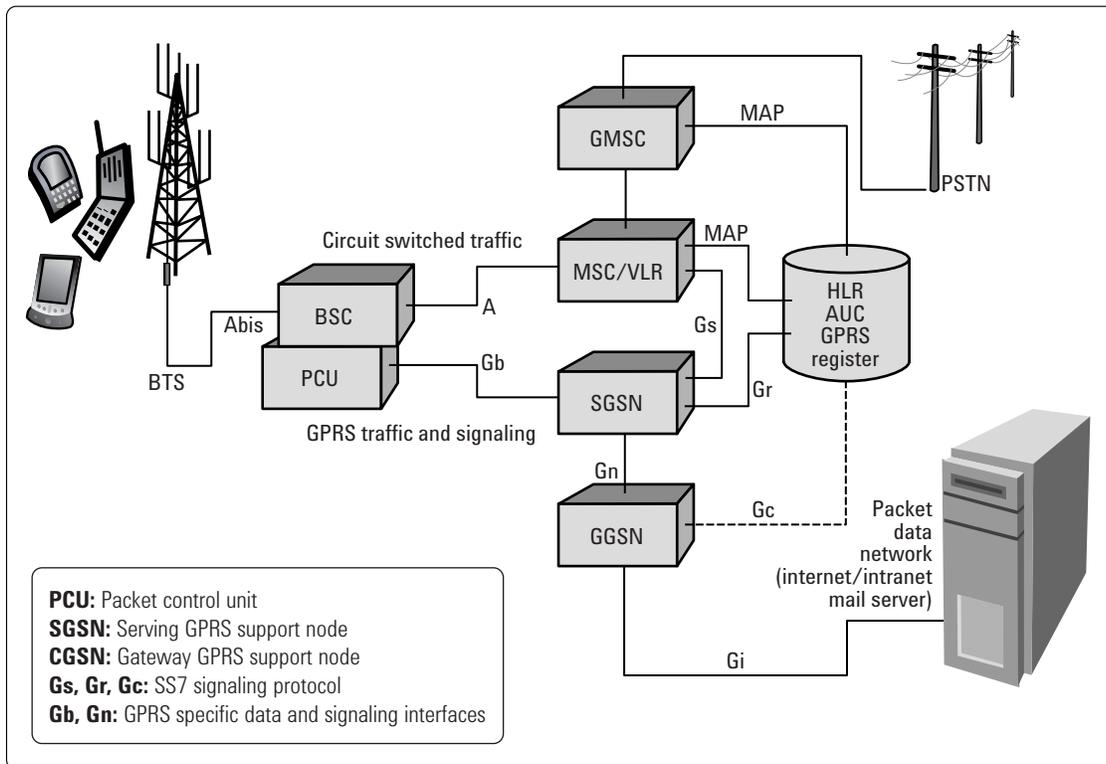
When packet-switched data leaves the GPRS/GSM network, it is transferred to TCP-IP networks such as the Internet or X.25. Thus, GPRS includes new transmission and signaling procedures as well as new protocols for interworking with the IP world and other standard packet networks.

Today's mobile phones will not work with GPRS technology, and so the industry is working on a new generation of mobiles that can handle both GSM and packet-switched communication. In the future, GPRS phones may be integrated into devices such as laptop computers or personal digital assistants. GPRS also has the ability to support short message service (SMS).

To support high data rates, GPRS employs new air interface error coding schemes and multiple timeslots, in a way similar to HSCSD (high-speed circuit-switched data). Theoretically we can get a maximum data rate of 171.2 kbps by using eight timeslots. However, today this seems unlikely due to challenges of designing the mobile phones and to inadequate air interface quality.

Because packet-switched communication allows non-continuous assignment of resources to a user, GPRS billing will not be based on connection time, but rather on resource usage.

Figure 1. GPRS network architecture



GPRS network architecture

GPRS technology brings many changes to the existing GSM network. Most of the changes are amendments made by adding new blocks rather than by modifying existing resources. A simplified view of this new hybrid network shows the elements introduced by GPRS.

The **gateway GPRS support node (GGSN)** is similar to the GSM gateway mobile switching center (GMSC) and provides a gateway between the GPRS network and the public packet data network (PDN) or other GPRS networks. The GGSN provides authentication and location management functions, connects to the home location register (HLR) by means of the Gc interface, and counts the number of packets transmitted for accurate subscriber billing.

The **serving GPRS support node (SGSN)**, like the GSM mobile switching center and visitor location register (MSC/VLR), controls the connection between the network and the mobile station (MS). The SGSN provides session management and GPRS mobility management functions such as handovers and paging. It attaches to the HLR via the Gr interface and to the MSC/VLR via the Gs interface. It also counts the number of packets routed.

Functions of the **packet control unit (PCU)** include converting packet data into a format that can be transferred over the air interface, managing radio resources, and implementing quality of service (QoS) measurements.

The signaling links between the GPRS nodes and the GSM blocks will be SS7 MAP interfaces. The signaling between GPRS nodes is defined by the GPRS specifications. New physical interfaces include the Gb interface, which connects the SGSN to the PCU and is usually located in the base station subsystem (BSS); the **Gn** interface, which connects the GGSN and SGSN; and the **Gc**, **Gr**, and **Gs** interfaces, which carry SS7-based protocols.

GPRS mobile phone operation states

Mobile phones go through different states of communication. For example, when a GSM phone camps onto a network, the phone enters an idle state in which it uses very few network resources. When the user makes a call request or receives a call, however, the phone goes into the dedicated state in which it is assigned a continuous resource until the connection is terminated.

The GPRS mobile phones will also have defined states, which are described below.

GPRS idle is the state in which the mobile phone camps onto the GSM network. The phone receives circuit-switched paging and behaves as a GSM phone. Although it does not interact with the GPRS network in this state, it still possesses GPRS functionality.

GPRS ready is the state achieved when the GPRS mobile attached itself to the network. In this state the mobile phone can activate a packet data protocol (PDP) context, which allows the phone to establish a packet transfer session with external data networks to transmit and receive data packets. Once a PDP context is activated, resource blocks are assigned to the session until data transfer ceases for a specified period and the mobile phone moves into the standby state.

GPRS standby is a state in which the mobile is connected to the GPRS network, but no data transmission occurs. If a data packet for the mobile arrives, the network will page the mobile, which in turn activates a PDP context session to bring the mobile back to the ready state.

GPRS/GSM mobile classes

ETSI defines three different classes of mobiles for the hybrid GPRS/GSM network:

Class A (GSM/GPRS)

Class A mobiles can attach to the GPRS and GSM network simultaneously. They can receive GSM voice/data/SMS calls and GPRS data calls. For this to happen, the mobiles must monitor both the GSM and GPRS networks for incoming calls. Class A mobiles also can make and receive GPRS and GSM calls simultaneously. Operational requirements of this class include an additional receiver in the mobile phone for neighbor cell measurements.

Class B (GSM/GPRS)

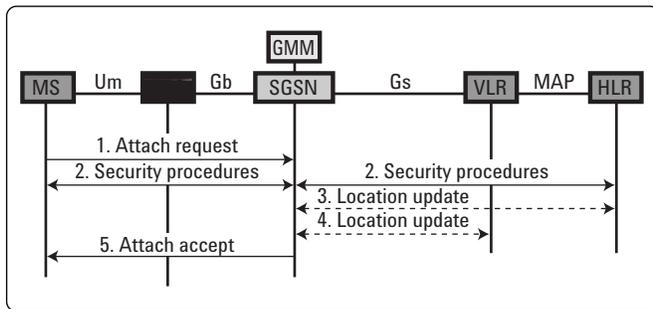
This class is similar to class A with the exception that Class B mobile phones will not support simultaneous traffic. If a GPRS call is ON, the phone cannot receive GSM calls and vice versa.

Class C (GSM or GPRS)

This class of mobile phones will have both GSM and GPRS functionality but will attach to only one network at a time. Thus, if the phone is attached to the GPRS network, it will be detached from the GSM network and will not be able to make or receive GSM calls. Conversely, if it is attached to the GSM network, it will not be able to make or receive GPRS calls.

Today most manufacturers are building Class B phones.

Figure 2. GPRS attach



The GPRS attach procedure

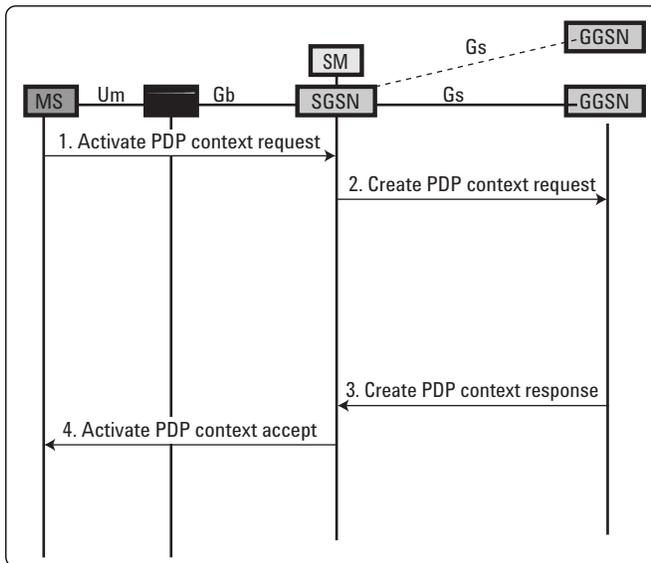
A GPRS attach is a GPRS mobility management (GMM) process that is always initiated by the mobile phone. Depending on the settings of the mobile phone, the GPRS attach may be performed every time the phone is powered on, or it may be initiated manually by the user.

The request for a GPRS attach is made to the SGSN in a process that is transparent to the BSS. First the mobile notifies the SGSN of its identity as an IMSI (international mobile subscriber identity) or P-TMSI (packet temporary mobile subscriber identity). Then it sends its old routing area identification (RAI), classmark, CKSN, and

desired attach type. The latter indicates to the SGSN whether the mobile wants to attach as a GPRS device, a GSM device, or both. The SGSN will attach the mobile and inform the HLR if there has been a change in the RAI. If the desired attach type is both GPRS and GSM, the SGSN will also update the location with the VLR, provided that the Gs interface exists.

Note that a GPRS attach does not enable the mobile phone to transmit and receive data. For this to occur, the mobile has to activate a communication session using PDP context.

Figure 3. PDP context activation



PDP context activation

A PDP context activates a packet communication session with the SGSN. During the activation procedure, the mobile phone either provides a static IP address or requests a temporary one from the network. It also specifies the access point name (APN) with which it wants to communicate—for example, an Internet address or an Internet service provider. The mobile requests a desired quality of service (QoS) and a network service access point identifier (NSAPI). Because a GPRS mobile can establish multiple PDP context sessions for different applications, the NSAPI is used to identify the data packets for a specific application.

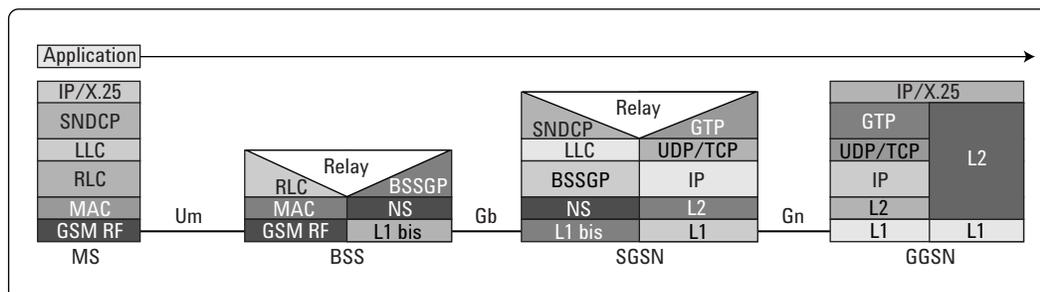
Upon receiving information from the mobile, the SGSN determines which GGSN is connected to the APN and forwards the request. The SGSN also provides a negotiated QoS based on the user's subscription information and the availability of services.

If the mobile phone has a static IP address, the GGSN directly connects the mobile to the desired access point. Otherwise, it obtains a temporary IP address from the APN. The GGSN also provides some transaction identifiers for data communication between GGSN and SGSN.

Once the communication and activation procedure at the GGSN is successful, the appropriate data transfer information is forwarded to the mobile.

Section 3: GPRS protocol layers

Figure 4. GPRS data and signaling plane



The GPRS data and signaling transmission plane consists of standard protocols such as IP and some new, GPRS-specific protocols.

The following are Gn interface protocols:

GTP (GPRS tunneling protocol) receives IP datagram and X.25 packets from the external network and tunnels them across the GPRS support nodes. Because there will be multiple GGSN and SGSN interfaces, the GTP provides for every packet a tunnel identifier (TID) that identifies the destination and transaction to which the packet/datagram belongs. Transactions are identified using logical identifiers as well as the IMSI.

TCP/UDP consists of the transmission control protocol (TCP), which is used to transfer PDUs (protocol data units) across the Gn interface with reliability (acknowledgment and re-transmissions). The user datagram protocol (UDP), is used across the Gn interface to carry the GTP-PDUs for all signaling information and user data that do not require reliability.

IP (Internet protocol) is used to route user data and signaling information across the Gn interface. The IP datagram size will be limited to the physical layer - maximum transmission unit (MTU) capabilities. An IP datagram can be as large as 65,535 octets, but if the physical layer MTU is less than this, fragmentation must be done. The source gateway support node (GGSN or SGSN) has to first decide the MTU size and then carry out the fragmentation. The IP addressing used will route the data across the Gn interface, including any intermediate GSNs (gateway support nodes), to the GSN address at the final destination.

The following are Gb interface protocols:

SNDCP (sub network dependent convergence protocol) is used between the SGSN and the mobile phone. This protocol converts the network layer PDUs (N-PDUs) on the Gn interface into a format suitable for the underlying GPRS network architecture. SNDCP performs a number of functions:

- Multiplexing of N-PDUs from one or several network-layer entities onto the appropriate LLC connection
- Buffering of N-PDUs for the acknowledged service
- Delivery sequence management for each NSAPI
- Compression and decompression of the protocol information and user data
- Segmentation and reassembly of the compressed data to the maximum length of the LLC-PDU
- Negotiation of the control parameters (XID) between SNDCP entities.

LLC (logical link control) protocol provides a highly reliable, ciphered logical link between the SGSN and the mobile phone. The LLC uses both acknowledged and unacknowledged modes of frame transmission, depending on a user's negotiated quality of service. This protocol also manages frame re-transmission, buffering, and information length based on the negotiated QoS delay class.

BSSGP (base station system GPRS protocol) routes information between the SGSN and the BSS. This protocol conveys QoS information but does not carry out any form of error correction. Its primary function is to provide radio-related information for use by the radio link control (RLC) and medium access control (MAC) functions on the air interface.

The LLC layer uses the services of the BSSGP for data transfer. The relay function at the BSS transfers LLC frames between the RLC/MAC layer and the BSSGP layer. The BSSGP sends information to the network services layers to determine the transfer destination:

- **BVCI (BSSGP virtual connection identifier)** is sent to the network services layers for routing signaling and data information to the correct peer functional entities. Each BVCI between two peer entities is unique.
- **LSP (link selection parameter)** is used in conjunction with the BVCI to aid in selecting a physical link for the load-sharing process.
- **NSEI (network service entity identifier)** used at the BSS and the SGSN provides the network management functionality required for operation of the Gb interface. The NSEI together with the BVCI uniquely identifies a BSSGP virtual connection.

NS (network service) layer uses frame relay across the Gb interface and could be a point-to-point connection between the SGSN and the BSS or a frame relay network. The NS layer uses a DLCI (data link connection identifier) look-up table to indicate the routing path between the SGSN and the BSS. The initial value of the DLCI field is derived from the BVCI, NSEI, and LSP supplied by the BSSGP layer. This value changes as the frame passes through the frame relay network and reaches its final destination.

The following are Um interface protocols:

RLC (radio link control) is responsible for a number of functions:

- Transferring LLC-PDUs between the LLC layer and the MAC function
- Segmentation of LLC-PDUs into RLC data blocks and re-assembly of RLC data blocks to fit into TDMA frame blocks
- Segmentation and re-assembly of RLC/MAC control messages into RLC/MAC control blocks
- Backward error correction for selective transmission of RLC data blocks.

The RLC segmentation function is a process of taking one or more LLC-PDUs and dividing them into smaller RLC blocks. The LLC-PDUs are known collectively as a temporary block flow (TBF) and are allocated the resources of one or more packet data channels (PDCH). The TBF is temporary and is maintained only for the duration of the data transfer. Each TBF is assigned a temporary flow identity (TFI) by the network.

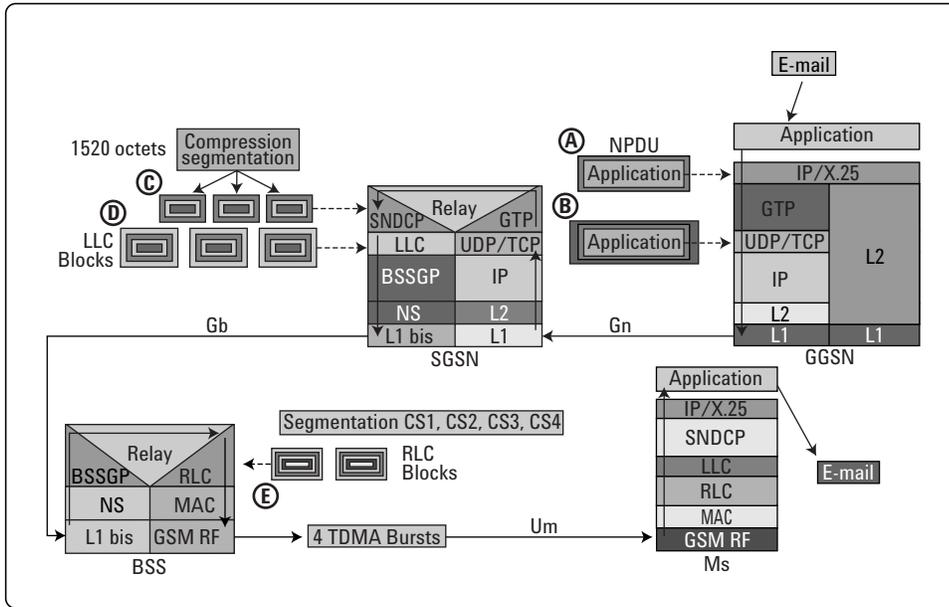
The RLC data blocks consist of an RLC header, an RLC data unit, and spare bits. The RLC data block along with a MAC header may be encoded using one of four defined coding schemes. The coding scheme is critical in deciding the segmentation process.

MAC (medium access control) controls the access signaling across the air interface, including the management of shared transmission resources (assignment of the radio block to multiple users on the same timeslot). MAC achieves these functionalities by placing a header in front of the RLC header in the RLC/MAC data and control blocks. The MAC header contains several elements, some of which are direction-specific, referring to the downlink or uplink.

The key parameters of MAC header are:

- Uplink status flag (USF), is sent in all downlink RLC/MAC blocks and indicates the owner or use of the next uplink radio block on the same timeslot.
- Relative reserved block period (RRBP), identifies a single uplink block in which the mobile phone will transmit control information.
- Payload type (PT), the type of data (control block or data block) contained in the remainder of the RLC/MAC block.
- Countdown value (CV), is sent by the mobile to allow the network to calculate the number of RLC data blocks remaining in the current uplink TBF.

Figure 5. GPRS data packet transfer



Transmitting the packet data units

Having defined the different GPRS protocol layers, we can now look at how packet data units (PDUs) are transmitted from one end of the GPRS network to the other. Let's take the example of a packet destined for a mobile phone.

A short e-mail is sent from a computer in your office (shown in the upper right-hand corner of the diagram above) to your friend's GPRS mobile phone in a taxi (shown in the lower right-hand corner). The data has to travel from the Internet to the GGSN, then to the SGSN, to the BSS, and finally to the MS (in this case, the GPRS mobile phone). The application layer (that is, the e-mail from the computer) generates an IP datagram and sends it across the external data communication (IP or X.25) network to a GGSN. When the IP datagram arrives at the GGSN, it is called an N-PDU (network packet data unit), and it will be addressed to a particular IMSI or IP address. Note, that as the data is passed down the GGSN protocol stack, headers are added at each layer. While many successive headers are added in this manner, the diagram highlights only a few examples for simplicity. Pay particular attention to the reference letters in the diagram (A - E). The subsequent headers are denoted by adding rectangular layers to the original application data. For example, at reference A in the diagram, an IP header is added to the application data in the IP/X.25 layer, as the data is passed from the PC onto the IP network.

The N-PDU is passed over to the GTP, which adds a GTP header that differentiates the N-PDU from a GTP message. After GTP header encapsulation, the N-PDU moves to the UDP/TCP protocol layer. This layer inserts its own header—either UDP or TCP, based on QoS class—which contains the source and destination port addresses, routing information, and (in the case of TCP) flow control. (Refer to B in the diagram.)

Now the N-PDU is forwarded to the IP layer, which adds the addresses of the source and final destination GSN (SGSN for this case). Depending on the N-PDU's length and the IP layer's maximum transmission unit (MTU), fragmentation of the PDU may be required.

Finally the N-PDU with all the added headers is transported over the physical layer of the Gn interface to the SGSN.

Transmission at the SGSN

At the SGSN, the headers are removed and the N-PDU is relayed to the SNDCP. This protocol layer will compress (optionally) and segment the packet in order to meet the MTU requirement of 1520 octets for transmission over the frame-relay network services (NS) layer on the Gb interface. Then the SNDCP will first classify the N-PDU as either a connection-oriented SN-DATA PDU or a connectionless SN-UNITDATA PDU. Finally it will add an SNDCP header containing compression and segmentation information and send the PDU to the LLC layer below. (Refer to C in the diagram on page 12.)

The primary function of the LLC layer, as discussed earlier, is to provide a highly reliable logical connection between the SGSN and the mobile phone. The LLC layer here behaves like the LAPD and LAPDm layers of the GSM Abis and Um interfaces. The layer encapsulates the SN-DATA or SN-UNITDATA PDU in an LLC frame with its own header. The LLC frame containing the SN-PDU now can be called the LLC block. The LLC header adds control information (used for acknowledged-mode frame transfer), frame check sequence, and SAPI values. The SAPI in this case refers to the service associated with the LLC frame for this PDP session. The services for this frame could be mobility management (MM) or user data levels 1 through 5 (levels of QoS parameters such as delay, re-transmission, and buffer size). These levels of service are decided in the QoS negotiation process. (Refer to D in the diagram on page 12.)

The BSSGP layer below the LLC layer now provides some routing information to the NS layer to route the LLC block over the frame relay physical layer. The BSSGP also adds a header to the LLC block, which contains some essential information for the RLC/MAC layers of the air interface regarding the block's transmission including parameters such as priority, TLLI (temporary logical link identifier), etc.

Transmission at the BSS

The data is sent over the physical layer connection between the SGSN and BSS. Next the BSSGP at the BSS sends all of this information to the radio link control (RLC). The most important job of the RLC layer is segmentation of LLC blocks into smaller RLC blocks. A group of LLC blocks, which has been segmented into smaller blocks, is known as a TBF (temporary block flow). Each TBF is allocated resources on the air interface on one of more packet data traffic channels (PDTCH). As noted earlier, the TBF is temporary and maintained only for the duration of the data transfer. The TBF is assigned a TFI (temporary flow identity), and the RLC layer adds a header to the data blocks containing the TFI, RLC block sequence number, last block indication, TLLI, and other information. The RLC header includes direction (downlink/uplink) information as well. (Refer to E in the diagram on page 12.)

One determination that must be made is the "size" of information inside the RLC data blocks (in other words, the size of the segments of the LLC blocks converted into RLC blocks). The LLC data block segment size will depend on the coding scheme used on the air interface. There are four coding schemes defined for GPRS: CS1, CS2, CS3, and CS4, which contain maximum data of 22, 32, 38, and 52 octets correspondingly. The selection of coding scheme depends upon trade-off between desired throughput and reliability. We will talk more about these coding schemes later.

Transmission over the air interface

After the RLC segmentation and header insertions, the RLC blocks are transmitted over the air interface.

It is interesting to note that there is one more layer before the physical radio interface—the MAC (medium access control). This layer controls the access signaling, including assignment of uplink and downlink blocks. It adds its own header, which is monitored by the mobile phones. We'll discuss this more in a later section on packet data transfer operations.

The data is transmitted over the air interface to the mobile phone (MS) via the physical layer (GSM RF). The data then moves up the MS protocol stack where the headers are stripped off at each successive layer. Finally, the original e-mail message is received at the application layer by the mobile user.

Section 4: GPRS identities

Before further discussion of GPRS operations and the air interface, we'll define some common identities associated with GPRS.

IMSI (international mobile subscriber identity) which is associated with a SIM (subscriber identity module) card is the same for GPRS and GSM service. Even a SIM for a GPRS-only subscription will have an IMSI.

P-TMSI (packet temporary mobile subscriber identity)
We are familiar with the concept of TMSI in GSM, which is used to maintain the identity confidentiality of the IMSI. The TMSI is allocated to the GSM mobile by the VLR on a GSM attach and location update. A Packet-TMSI is similar to the TMSI but is assigned by the SGSN when the mobile phone performs a GPRS attach. The P-TMSI is also used by the mobile to derive another identity, the TLLI.

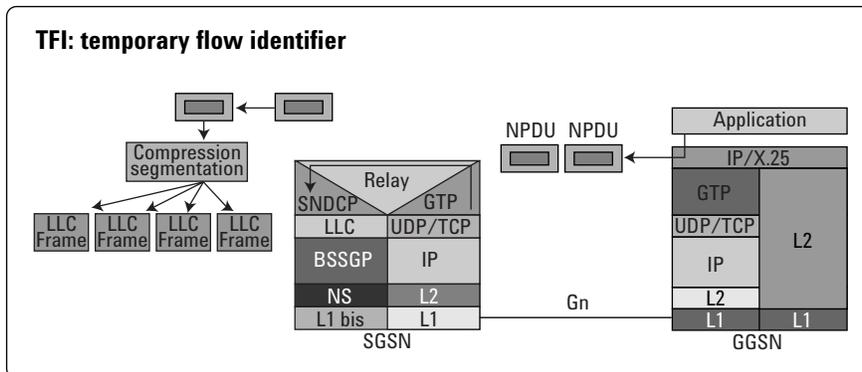
TLLI (temporary logical link identifier)

The TLLI is an identity used (along with NSAPI discussed earlier) during a PDP session to identify the mobile phone on the Um and Gb interface. While the NSAPI is used at the SMDCP layer, TLLI is used at the RLC/MAC layer on the Um interface and in the BSSGP layer on the Gb interface.

TLLI can be derived from one of the following four sources:

- Local TLLI, which is derived using the P-TMSI from the SGSN. It is valid only in the routing area associated with the P-TMSI.
- Foreign TLLI, which is derived from a P-TMSI allocated in a different routing area.
- Random TLLI, which is selected randomly by the mobile phone and is used when the mobile does not have a valid P-TMSI available or when the mobile originates an anonymous access.
- Auxiliary TLLI, which is selected by the SGSN and is used by the SGSN and mobile to unambiguously identify an anonymous access MM (mobility management) and PDP context.

Figure 6. GPRS identities



TBF (temporary block flow)

The physical connection between the MS and the BSS for the duration of the link of packet data transfer is called the temporary block flow (TBF). The most important job of the RLC layer is segmentation. As described earlier, the RLC layer takes one or more LLC blocks and segments them into smaller RLC blocks. These LLC blocks together are known as a TBF (temporary block flow). Thus, a TBF is a physical connection used by the two radio resource entities to support the unidirectional transfer of LLC PDUs on packet data physical channels. All of the LLC frames that have been segmented for one NPDU (network packet data unit) form one TBF on the logical link on the air interface. Each TBF is allocated resources on the air interface on one or more packet data traffic channels (PDTCH). The TBF is temporary and is maintained only for the duration of the data transfer. The TBF is “open” during the data transfer and “closed” when the transfer is discontinued.

TFI (temporary flow identifier)

Each TBF is assigned a TFI (temporary flow identity), which is allocated to a mobile for both uplink and downlink packet transfer. This TFI is unique among concurrent TBFs in one direction and is used in place of the MS identity at the RLC/MAC layer. The same TFI value can be assigned to concurrent TBFs in the opposite direction. A resource assignment message containing the TFI precedes the transfer to or from the MS of the LLC frames belonging to one TBF. To address the peer RLC entities, the same TFI is included in every RLC header belonging to the TBF as well as in the control message associated with the LLC frame transfer (for example, acknowledgments). Since a TFI comprises a five bit field, values from 0 to 31 are possible.

USF (uplink status flag)

The USF, which is transmitted in the RLC/MAC header of the downlink RLC block, tells the mobile which uplink resources to use. Multiple users can be multiplexed on the same timeslot, transmitting only when the USF indicates their turn. The mobile monitors the USFs on the allocated PDCHs and transmits radio blocks on those that currently bear the USF value reserved for MS usage.

RAI (routing area identity)

A subset of a location area, the RAI is a unique identity similar to the LAI (location area identity). When a mobile moves from one routing area to another, it performs routing area updates via the SGSN. An SGSN may control one or more routing areas. Since a GGSN can have links to several SGSNs, the SGSN in which the mobile currently resides must be identified so that packets can be routed correctly. For this reason the mobile performs the routing area update when it enters a new routing area, and if that area belongs to a different SGSN, a new RAI for the MS is sent to the HLR (home location register) for communicating with the GGSN. If a PDP session is active, then PDP update information also is sent. The routing area identity consists of the MCC (mobile country code), the MNC (mobile network code), the LAC (location area code), and the RAC (routing area code).

Section 5: GPRS air interface

Now we turn our attention to the GPRS air interface. It is important to note that GPRS uses the existing GSM resources—spectrum, channels (200 kHz), and timeslots. GPRS users will share the same TDMA frame with GSM voice users, thus increasing capacity requirements. To a certain extent, GPRS takes care of increased capacity demand by multiplexing multiple users on the same physical channels (timeslots). Additionally, the GPRS air interface will dynamically allocate resources (timeslots) for voice and PDCH (packet data channels). Certain physical channels will be configured for packet data use, but can be re-configured for voice if needed.

GPRS must allocate resources for signaling and traffic control. Since GPRS has its own set of parameters for network access and call control, it needs separate channels for broadcast common control functions (such as paging, random access, and access grant) and associated traffic (similar to SACCH). Some of the signaling channels can be multiplexed with the GSM channels by using different possible channel configurations.

Before describing the options for allocating resources, let's first review some of the terminology. The diagram illustrates that the GSM or GPRS frames consist of eight timeslots. Timeslot 0 is reserved for the GSM BCH (broadcast channel). The CS (circuit switched) timeslots are used for GSM voice or circuit-switched data calls. The PBCH (packet broadcast channel) and p-data (packet data) are used for GPRS channels.

Two options are available for establishing GPRS air interface channels, (illustrated in the figure below):

Option 1 uses the GSM signaling resources but establishes separate packet data channels for traffic control. Traffic channels can be fixed or dynamic.

Option 2 separates the GPRS resources entirely from those of GSM. There are several possible configurations with this option. A PBCH can be used to carry GPRS-BCH information, common control channels, GPRS packet data channels, and traffic-associated channels. If the packet data channels are not carried by the PBCH or if additional PDCH resources are required, separate timeslots can be configured.

Packet data channels can use any timeslot other than the BCH (timeslot 0). The mobile will synchronize with the GSM BCH first. Since the PBCH does not use Timeslot 0, the mobiles must use the GSM camp ON process to camp on to the BCH. A BCH "system information type 13" message (which identifies it as a GPRS network) then notifies the mobiles of the PBCH.

Figure 7. GPRS air interface channelization

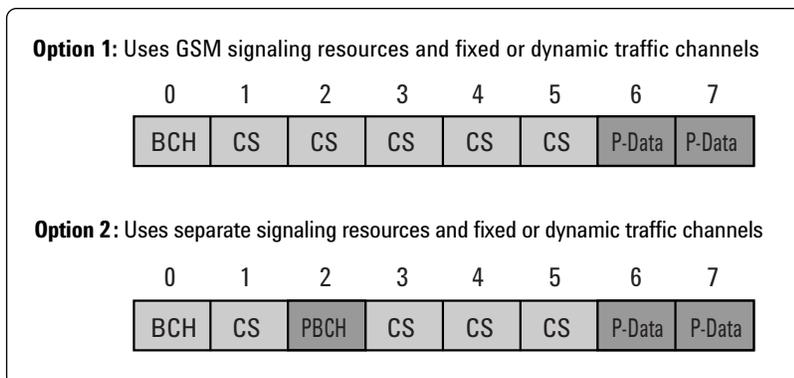
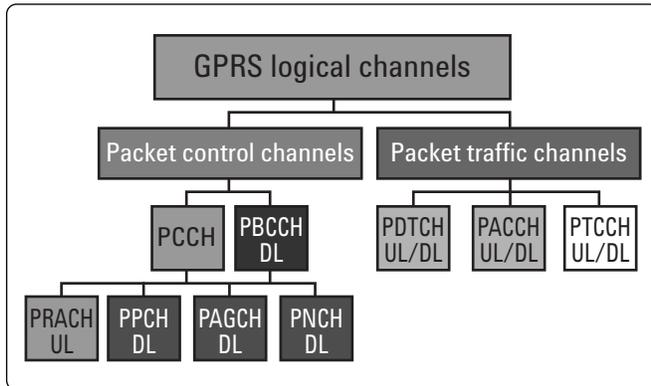


Figure 8. GPRS logical channels



GPRS logical channels

Logical channels are pre-defined functions supported by frames within a physical channel. GPRS physical channels generally carry two types of information: control signaling for establishing and maintaining a GPRS service, and user data traffic. Hence, GPRS logical channels can be classified as **packet control channels** and **packet traffic channels**.

GPRS packet control channels are further divided into common control functionalities and broadcast control functions, in a manner similar to GSM.

PCCCH (packet common control channel) is a set of logical channels used for common signaling between the mobile station and the base station.

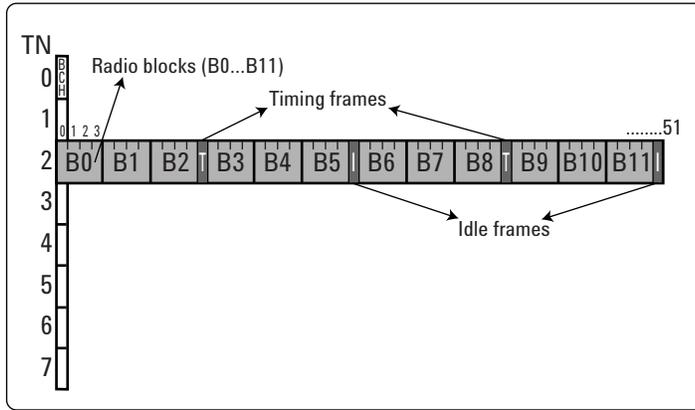
- PRACH (packet random access channel) is used only in uplink to initiate uplink transfer.
- PPCH (Packet Paging Channel) is used to page a mobile prior to downlink packet transfer. The PPCH is used for paging both circuit-switched and GPRS services, depending on the network operation modes and the class of mobile. (Class A or B will support this functionality).
- PAGCH (packet access grant channel) is used in the packet transfer establishment phase to send resource assignment messages to a mobile prior to packet transfer. Additional resource assignment messages are also sent on a PCCH if the mobile is already involved in packet transfer.
- PNCH (packet notification channel) is used to send a point-to-multipoint multicast notification to a group of mobiles prior to point-to-multipoint multicast packet transfer.

PBCCH (packet broadcast control channel) is used to broadcast packet data system information to all GPRS mobiles in a cell. The PBCCH might not be present for certain channel combinations, in which case the BCCH will be used to broadcast packet system information.

PTCH (packet traffic channel) consists of the following sub-channels associated with traffic:

- PDTCH (packet data traffic channel) is allocated for data transfer. It is dedicated temporarily to one or a group of mobiles for multicast applications. One mobile may use multiple PDTCHs in parallel for packet data transfer during multislot operation.
- PACCH (packet associated control channel) is used to convey signaling information related to a given mobile—for example, power control, packet acknowledgments, or resource reassignments. One PACCH is associated with one or several PDTCHs concurrently assigned to a mobile.
- PTCCH (packet timing advance control channel) is used in the uplink for transmission of random access burst. It allows the timing advance required by the mobile in the packet transfer mode to be estimated. In the downlink, the PTCCH can be used to update the timing advance to multiple mobiles.

Figure 9. Mapping of logical channels to physical channels



Mapping logical channels to physical channels

We have defined several logical channels for GPRS. These channels do not necessarily require separate physical resources. The logical channels are mapped over physical channels using the technique of “multiframing.” A multiframe is a set of some fixed number of TDMA frames that are together assigned a functionality.

This section describes how radio link control (RLC) blocks are generated using multiframes. The diagram shows a single TDMA frame for GPRS consisting of eight timeslots (0 – 7) on the vertical axis. These frames repeat, as indicated by the example in timeslot 2 (TN 2 – timeslot number 2). For GPRS we define a multiframe of 52 frames. Each timeslot 2 from frames 0-51 is combined to form the multiframe shown. The multiframe is divided into 12 blocks, numbered 0-11; each made up of four TDMA frames. These blocks are sometimes referred to as radio blocks, and they are assigned certain logical channel functions. The 12 radio blocks account for 48 of the TDMA frames in the multiframe. Of the remaining four frames, two single-burst frames are used for the timing channel and two are kept idle for neighbor-cell BSIC decode and interference measurements for power control.

ETSI defines three combinations of logical channels that can be mapped onto a single physical channel using the 52-frame multiframe.

The first combination allows all categories of logical channels to be mapped on to one physical channel. Since there are only 12 blocks for logical channels on a multiframe, this option will definitely reduce the number of channels available for each category.

The second combination allows all channels other than PBCCH to be mapped on to a physical channel. This increases the capacity of the PCCCH and PDTCH. But this option can be used only if the PBCCH (or BCCH) exists on some other physical channel—for example, in a configuration that uses the GSM BCCH.

The last combination is a traffic-and-dedicated-signaling-only combination, which excludes the PBCCH and PCCH. This combination provides more PDTCHs on one physical channel and can be used only if the PBCCH/PCCH exist on some other channels or the GSM BCCH/CCCH can be used.

The master-slave concept can be used in some instances in which one physical channel is configured as the master and carries all logical channel types (the first combination), and other physical channels are configured as “slaves” and used for data transfer only (the third combination). When data transfer demand is low, these other physical channels could be used for circuit-switched services.

Coordination of GSM and GPRS functions

There are certain functions that are common to GSM and GPRS. These include paging, location updates, and attach/detach.

Paging is a critical function that must be coordinated between GSM and GPRS. To do this, the network will operate in one of three modes. This operation mode is broadcast on the system information message and will be the same within a routing area.

Network operation mode 1

In this mode the mobile phone monitors only one paging channel during the GPRS attach. The network sends the circuit-switched paging either on a GPRS paging channel or on the GSM CCCH (common control channel) paging channel (depending on channel combinations). In order to send circuit-switched paging on the GPRS paging channel, the Gs interface must be present.

Network operation mode 2

The CCCH paging channel is used for both circuit-switched and GPRS paging. Hence the mobile has to monitor only the CCCH paging channel.

Network operation mode 3

In this mode the mobile monitors both the CCCH and the GPRS paging channel (PPCH). The mobile will receive circuit-switched pages on the CCCH and GPRS pages on a PPCH. In order to monitor both paging channels, the mobile must be Class A or Class B.

Attach and location updates also depend on network operation modes and class of mobile. The network operation mode is part of the broadcast system information transmitted to the mobiles, and it should be the same for each cell within a routing area. Upon receiving this information, the mobile determines whether to perform a GPRS attach, an IMSI attach, or both. This determination depends not only on the network mode, but also on the class of mobile, which specifies whether or not the mobile can perform simultaneous attach or detach.

In Network Operation Mode 1 with a mobile that is IMSI- and GPRS-attached, combined routing area/location area updates must be performed. In network operation modes 2 or 3, a mobile that can be GPRS- and IMSI-attached must perform a routing area update and either access the circuit-switched control channel for circuit-switched operation or, if circuit-switched operation is not required, perform a detach.

Multi-slot configurations

A multi-slot configuration consists of multiple circuit- or packet-switched channels together with their associated control channels, all allocated to the same mobile phone. The multi-slot configuration occupies up to 8 physical channels, with different timeslot numbers (TNs) but the same frequency parameters and the same training sequence.

A mobile may be allocated several PDTCH/Us (packet traffic data channel/uplink) or PDTCH/Ds (packet traffic data channel/downlink) for a mobile-originated or a mobile-terminated communication, respectively. In this context, allocation refers to the list of PDCHs that can dynamically carry the PDTCHs for that specific mobile. The PACCH may be mapped onto any of the allocated PDCHs. If there are m timeslots allocated for reception and n timeslots allocated for transmission, there shall be $\text{Min}(m, n)$ reception and transmission timeslots with the same TN.

Multi-slot configuration depends on the type of mobiles:

- Type 1 mobiles do not transmit and receive simultaneously. Hence their multi-slot usage is limited by the time required to do neighbor cell measurements.
- Type 2 mobiles can transmit and receive simultaneously and hence support more slots.

There are 29 multi-slot classes defined, each with specific parameters. Key parameters for multi-slot configuration are the following:

- **Tx**, the number of simultaneous timeslots on which a mobile can transmit
- **Rx**, the number of simultaneous timeslots on which MS can receive
- **Sum**, the total number of timeslots that can be used in the uplink and downlink. For example, the expression **TX =3 and Rx=3, Sum = 4** means that a mobile of this class can receive on three timeslots and transmit on one only; receive on two and transmit on two; or receive on one and transmit on three. In any case, the total number of timeslots cannot be greater than four.
- **Tn**, the minimum number of timeslots required to measure adjacent channels for a particular class of mobile. This parameter will impose limitations on the type of mobile for a particular class.

Figure 10. MS multislot class

| Multislot class | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|-----------------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Rx timeslots | 1 | 2 | 2 | 3 | 2 | 3 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 5 | 6 | 7 | 8 | 6 | 6 | 6 | 6 | 6 | 8 | 8 | 8 | 8 | 8 | 8 |
| Tx timeslots | 1 | 1 | 2 | 1 | 2 | 2 | 3 | 1 | 2 | 2 | 3 | 4 | 3 | 4 | 5 | 6 | 7 | 8 | 2 | 3 | 4 | 4 | 6 | 2 | 3 | 4 | 4 | 6 | 8 |
| Sum | 2 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 5 | NA |
| Tn | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 1 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

The table above lists the 29 multi-slot classes. Classes 2, 8, and 12 will be preferred most in the early stages of GPRS rollout.

Classes 13 to 29 will be supported by Type 2 mobiles only.

RF power control

RF power control is used to minimize the transmit power required by the mobile or BSS while still maintaining the quality of the radio links. By minimizing the transmit power levels, interference among co-channel users can be reduced.

For circuit-switched services, the mobile is commanded by the base station to change its power level. The base station directs this process with the help of the uplink Rx level and Rx quality measurements. For GPRS, however, the process is controlled by the mobile, since transmission is not continuous.

The mobile calculates the output power (in dBm) to be used on each uplink PDCH. The output power of any channel has to be the minimum required to maintain the quality of service, with exception of the maximum power transmitted on the access bursts.

Output power is calculated by the mobile using specific power-control parameters set by the network, which are dependent on the maximum allowed power in the cell, the mobile's power class, and the signal strength of the receiver.

To measure the minimum uplink output power of a mobile,

$$P_{ch} = \min (\tau_0 - \tau_{ch} - (\alpha * (C + 48)), P_{max}$$

This formula attempts to measure the most accurate receive signal level. The value of C is the receive signal level at the mobile, calculated using the difference in the received power from the BTS in the downlink power control relative to the PBCCH. The C calculation here is simplified; in practice, C is the running average measurement with some associated multi-frame parameters obtained from the system information messages.

τ_{ch} is sent to the mobile in the RLC control message. The network can modify this parameter at any time in 31 steps of 2 dB each. The parameter is modified dynamically with the help of some BTS measurements. The most important element of the τ_{ch} calculation and therefore of the value available to the mobile is the interference power measurement. The BTS will measure power in the idle frames (of the 52-frame GPRS multi-frame) and apply a weight to the measurements using alpha (0 to 1, in steps of 0.1 dB).

τ_{ch} plays an important role in controlling the power output of the mobile, since with this measurement the power control becomes quality control. If we remove τ_{ch} , the mobile station's power calculation will be based on the received signal level only.

$\tau_0 = 39$ dBm for GSM 900 or 36 dBm for GSM 1800
 P_{max} = maximum output power allowed in the cell.

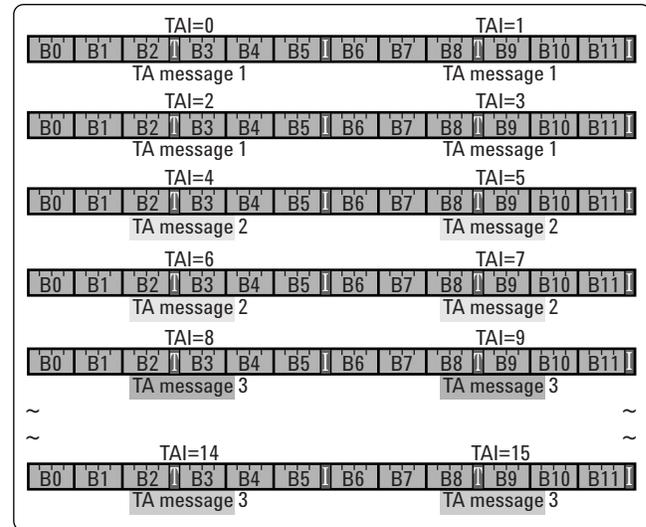
GPRS-mode timing advance

The main difference between circuit-switched transmission and packet-switched transmission is that packet-switched transmission is not continuous. During circuit-switched operation, when the mobile is transmitting continuously, the BTS can easily derive the delay relative to previous timing values. This would be very difficult in packet-switched applications, since the mobile will be transmitting on assigned radio blocks only and the interval between two blocks could be significant. To avoid inter-timeslot interference and other possible impairments, GPRS deploys a new technique for achieving correct burst timing.

This technique, called timing advance, is carried out in two parts:

- **Initial timing advance** is made, in a manner similar to circuit switching, whereby the initial delay is measured by the PRACH/RACH reception at the base station using the extended guard period of 88 bits.
- **Continuous timing advance** follows the initial timing advance and is carried out on a continuous basis using the PTCCH (packet timing advance control channels) logical channels on the 52 frame multi-frame. There are two PTCCH channels in one multi-frame. We create a group of eight multi-frames (for timing advance operation purposes only), which gives us a 16 PTCCH logical channel. Each of the PTCCHs is now considered a sub-channel and given an index value TAI (timing advance index) from 0 -15. The mobile is given a TAI value in the assignment message. With this TAI, the mobile will transmit an access burst in every sub-channel occurrence assigned (once in eight multi-frames). The base station will capture this burst and calculate the access delay and the new timing advance value. The new timing advance value will be returned to the mobile in the TA message sent in the downlink PTCCH channel. A signaling message needs four bursts, and so one TA message will occur in four bursts. A TA message will contain the TA values associated with all 16 TAI values.

Figure 11. GPRS mode timing advance

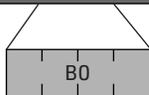


The example above illustrates the timing advance process. We have eight frames, with each PTCCH assigned an index value from TAI=0 to TAI=15. A mobile assigned TAI=5 will transmit the access burst in the third multi-frame, second PTCCH frame in this set of eight frames. The corresponding response with the updated timing advance value will be received in the TA message 3. This same TA value will be repeated in all TA messages until in the next set of eight multi-frames the mobile sends a new access burst in the TAI=5 subchannel.

Using this process, the mobile thus updates its position (access delay) once in every eight GPRS multi-frames (approximately every 2 seconds) and receives updates in the same intervals.

Figure 12. Coding schemes for coding data on radio blocks

| Coding scheme | RLC data and header | RLC/MAC header and data | Data rate-kbps | USF | BCS | Tail bits | Total raw bits | Coding | Puncturing | Encoded bits |
|---------------|---------------------|-------------------------|----------------|-----|-----|-----------|----------------|-----------|------------|--------------|
| 1 | 22 octets | 181 bits | 9.05 | 3 | 40 | 4 | 228 | Half rate | No | 456 |
| 2 | 32 octets | 268 bits | 13.4 | 6 | 16 | 4 | 294 | Half rate | 132 | 456 |
| 3 | 38 octets | 312 bits | 15.6 | 6 | 16 | 4 | 338 | Half rate | 220 | 456 |
| 4 | 52 octets | 428 bits | 21.4 | 12 | 16 | 0 | 456 | No | No | 456 |



Coding data on radio blocks

Having defined some common RF processes and operations, we turn again to the information being sent on the air interface. Earlier we discussed briefly the coding on the radio interface. The radio interface limits the maximum data transfer rate. One TDMA burst can carry up to 114 bits of information; therefore, each radio block of four bursts can carry only 456 bits of information. The information carried in those bits is the user data and coding. Coding provides error detection and error correction, and it is essential for managing the impairments on the air interface.

The common process used in GSM coding is the insertion of CRC bits and convolutional encoding. GPRS uses the same mechanisms, but provides four options for coding the data in different ways, see figure above. Coding scheme 1 has the highest level of protection and therefore the least number of errors. The disadvantage is that it provides the slowest throughput. Each successive coding scheme (2, 3, and 4) compromises the level of coding in some way and thus increases the probability of errors. On the other hand, a higher coding scheme number (4 is the highest coding scheme number) increases the data throughput. The table above illustrates the process. As we move to higher coding

schemes, we reduce the number of CRC bits and thus the probability of detecting bad frames. We also remove some of the protection bits (a process called “puncturing”). Now if the radio interface is poor, we will suffer more from errors.

The coding scheme and number of timeslots partially determine the theoretical data rate. For example, if eight timeslots and coding scheme 4 are used, a theoretical data rate of 171.2 kbps would result (21.4 kbps x 8 timeslots). However, due to practical considerations including air interface impairments and availability of GPRS phones supporting more than 3-4 timeslots, this theoretical data rate is not achievable under normal operating conditions.

Coding schemes can be assigned in several ways—first in the initial channel assignment process, and later by “toggling” using the control bits on the burst.

It’s important to remember that although coding schemes play a major role in optimizing throughput on the air interface, ultimately it is the air interface quality that governs the results. Coding schemes 1 and 2 will be common in the early GPRS network installations.

Section 6: Packet data transfer operations

In this final section we examine some of the procedures associated with packet data transfer. This is important because the concepts described here will provide valuable background information for RF engineers who are required to troubleshoot GPRS data network problems using the layer 3 message protocol decoding capability of commercial drive test tools from vendors such as Agilent Technologies.

As we have already seen, to initiate a packet transfer a GPRS mobile first must attach itself to the GPRS network, and then perform a GPRS-specific process known as PDP context activation. The PDP context assigns an IP address to the mobile (if it has no static address). Then the mobile can access the network, request resources, send data, go into standby mode if no data is being transmitted, and repeat the process over again.

Uplink packet data transfer

A mobile phone needs to request resources from the BSS (base station subsystem). The mobile phone initiates a data transfer by making a packet channel request (PRACH or RACH). The network responds on PAGCH (packet access grant channel) or AGCH respectively. It is possible to use a one- or two-phase packet access method.

In one-phase access, the network responds to a packet channel request with the packet uplink assignment, reserving resources on one or more PDCHs for uplink transfer of a number of radio blocks. The resource reservation is made in accordance with the resources requested in the packet channel request.

- Using RACH, the packet channel request has only two cause values for denoting GPRS. These can be used to request either limited resources or two-phase access.
- Using PRACH, the packet channel request may contain enough information (multi-slot class, number of blocks required, etc.) about the requested resources for the network to assign uplink resources on one or several PDCHs via the packet uplink assignment message.

The mobile or the network can initiate a two-phase access request. The mobile can request two-phase access in a packet channel request message. The network may respond with an order to send a packet resource request or with an order to continue with the one-phase access procedure.

The packet resource request message contains a complete description of the resources requested for the uplink transfer. The mobile may indicate the medium access method (radio access capabilities, reason for request, current receive signal level, interference level in all timeslots) preferred for the TBF. The network responds with a packet uplink assignment reserving resources for the uplink transfer and defining the actual data transfer parameters. If the network does not respond to the packet channel request within a pre-defined time period, the mobile tries again after a random back-off time.

Figure 13. Uplink data transfer

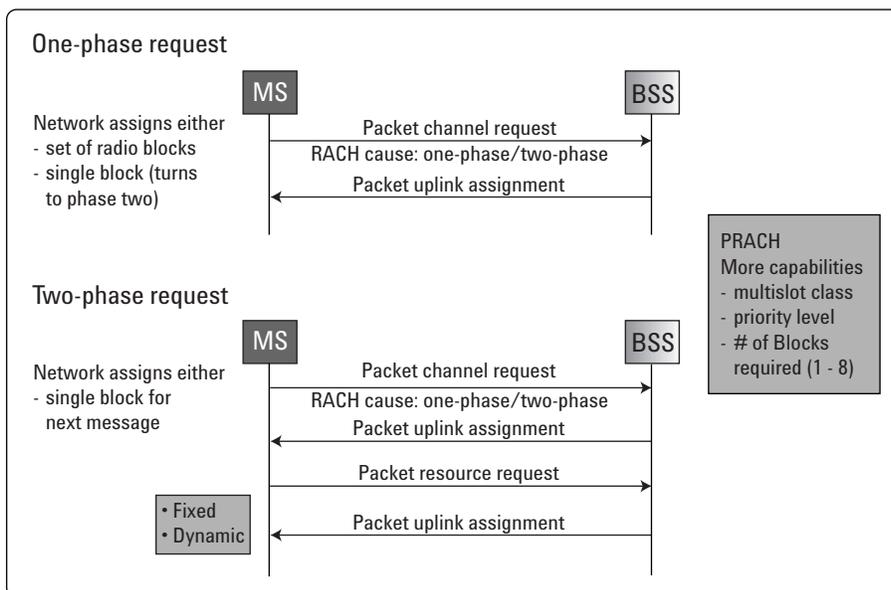
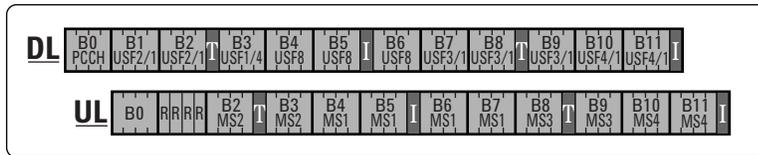


Figure 14. Uplink data transfer - dynamic radio block allocation



Dynamic radio block allocation

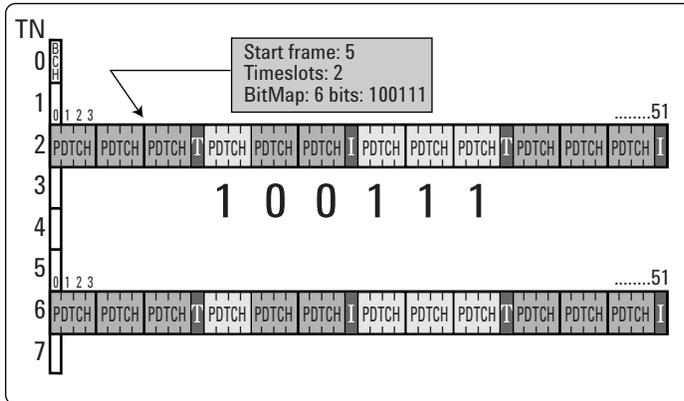
The next step in the packet data transfer process is radio block allocation. Dynamic and fixed allocation types are used. We will begin with dynamic allocation.

How does a mobile know in which RLC block to transmit? The process by which the mobile is told of the availability of resources for uplink transmission on a block-by-block basis is known as dynamic allocation.

The network sends a packet uplink assignment message to the mobile with the list of assigned PDCHs (timeslot and carrier) and corresponding uplink status flag (USF) values. Also, a unique TFI is allocated which is thereafter included in each RLC data and control block related to that temporary block flow. The mobile monitors the USFs on the allocated PDCHs and transmits the radio blocks on those channels that bear the USF value reserved for that mobile's use.

The USF is a 3-bit MAC header. It assigns either one radio block or four radio blocks at a time to the mobile. Therefore when the mobile detects the USF on a downlink, it transmits either a single RLC/MAC block or a sequence of four blocks. The mobile includes in the uplink block transmission the number of blocks remaining in the temporary block flow. The network will continue to assign radio blocks to the mobile until the mobile indicates that it has no more blocks to transmit.

Figure 15. Uplink data transfer – fixed allocation



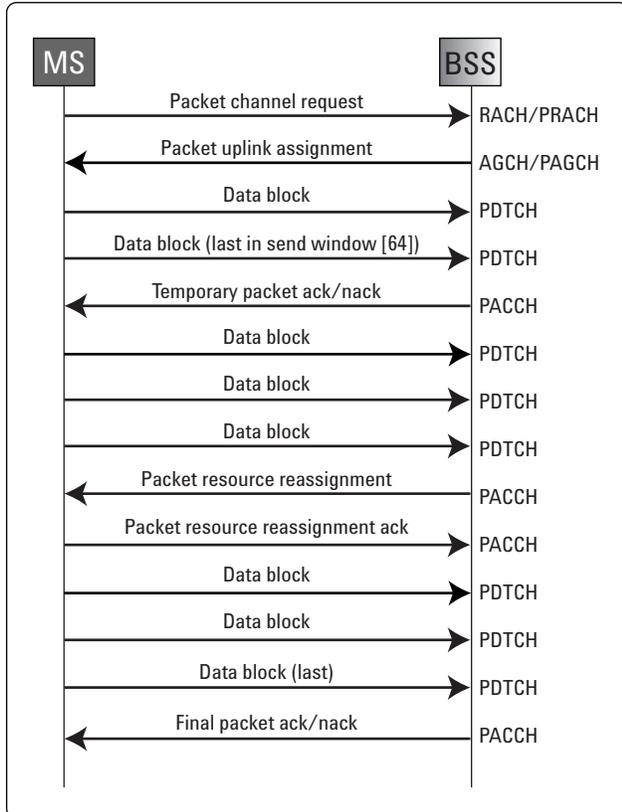
Fixed radio block allocation

In addition to dynamic allocation of resources for block transmission, the option exists for fixed allocation. With this method, the network in the packet uplink assignment message assigns all of the blocks requested by the mobile in the packet resource request message. This resource assignment will include the frequency parameter, timeslots, a bit map of 1 to 127 bits, and a start frame number. When the mobile receives this information, it will begin transmitting the uplink data in the corresponding blocks, beginning with the start frame number and using the information in the bit map (0 = a block not assigned; 1 = an assigned block).

The example shows an assignment of two timeslots (TN 2 and 6), a starting frame of 5 (relative to where it was received), and a bit map of 100111 (refer to highlighted blocks).

Transferring RLC data blocks

Figure 16. Uplink data transfer



RLC data blocks are transferred using a process called acknowledged RLC/MAC mode. This process is controlled by a selective ARQ mechanism and by the numbering of the RLC data blocks within a temporary block flow. The transfer process between the mobile and the base station is shown in the diagram. An understanding of this process will provide useful background information to help RF engineers troubleshoot network problems using the layer 3 messaging decode functions found in drive test tools such as those from Agilent. Let's start with the uplink data transfer. The sending side (either the mobile or the network) transmits blocks within a window, and the receiving side sends a packet uplink ack/nack (acknowledged/ not acknowledged) or packet downlink ack/nack message as needed. Every such message acknowledges all correctly received RLC data blocks up to an indicated block sequence number (BSN), thus "moving" the beginning of the sending window on the sending side.

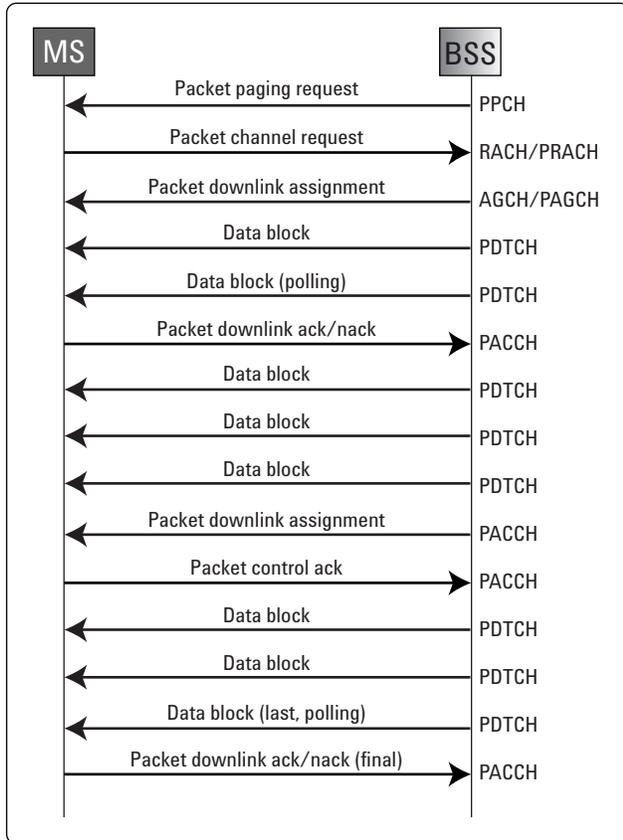
The packet ack/nack message contains a bit map of the RLC block sequence numbers, with each bit representing the received status of the data block (0 = nack or not acknowledged; 1 = ack or acknowledged). The message also provides the starting absolute BSN value for the bit map. For example, if RLC data blocks with BSN numbers 21 through 26 have been sent by the mobile and blocks 24 and 25 are corrupted, when the network sends the ack/nack message, it will indicate which blocks were received and which were not. The bit map will appear as "111001," beginning with a "1" acknowledging BSN 21 and including a "0" each for BSNs 24 and 25.

The ack/nack message can be sent in any of the assigned blocks, and the RLC/MAC header will indicate that this is a control message. A mobile has a transmit window of only 64 blocks, and if it doesn't receive an ack/nack message within this window, it will notify the network in the next available block that the window is stalled. The mobile also sends a "countdown value" (of 0 - 15) in the uplink RLC data block header to inform the network how many RLC data blocks remain in the current uplink TBF. Once the countdown value reaches 0, the network can send the final ack/nack message.

After the mobile sends the last data block with a countdown value of 0, it starts a timer. When the timer expires after 5 seconds, the mobile considers the current assignment of resources invalid.

Downlink packet data transfer

Figure 17. Downlink data transfer



Now let's see how the downlink data transfer works. The network initiates transmission of a packet to a mobile in the ready state using a packet downlink assignment message. If an uplink packet transfer is already in progress, the packet downlink assignment message can be transmitted on a PACCH. Otherwise, it can be sent on a PCCCH or a CCCH. The packet downlink assignment message conveys information to the mobile about the timeslots, the frequency parameters, timing advance, power control, TFI, and starting TDMA frame number.

The network sends the RLC/MAC blocks belonging to a temporary block flow (TBF) on the assigned downlink channels. Generally more than one mobile is multiplexed on the PDCHs at any given time, and each mobile needs a way to identify its own TBF. This is done with the TFI in the RLC header. As defined earlier, the TFI is a unique identity associated with a TBF in one direction on one set of PDCHs. The MAC header identifies the RLC block as a control/data block, and the TFI in the RLC header identifies the mobile to which the block belongs.

The MAC header in the downlink RLC blocks contains a bit for polling the mobile. It uses an information field such as relative reserved block period (RRBP) to inform the mobile of the relative frame number (and thus the radio block) after which the mobile has to send the packet downlink ack/nack message. There is also a final block indicator (FBI) bit in the downlink RLC header that flags the final RLC data block and initiates the release of resources process. On receiving this final ack/nack message from the mobile, the network starts a timer (value not defined in the GPRS specifications), and when this timer expires, the TFI and all resource assignments to the mobile are released.

It is possible for the network to change a current downlink assignment by using a packet downlink assignment message or a packet timeslot reconfigure message, which in turn has to be acknowledged by the mobile in a reserved radio block on the uplink.

Cell reselection

The final data transfer process that we will consider is cell reselection. This is useful for understanding how a mobile will hand over a call from cell to cell as the mobile moves through the wireless network.

In GSM, cell reselection is an idle-mode procedure in which no dedicated resources are assigned to the mobile. Instead the process is accomplished by C1 and C2 calculations.

In GPRS, cell reselection is done in packet transfer mode as well as in idle mode. GPRS also uses the C1 calculation, which is called the path loss criterion, and settable parameters such as the receive level minimum, access power, and classmark. These parameters used to calculate C1 are now GPRS-specific.

Optionally GPRS systems can use the C31 calculation, known as the signal level criterion. This calculation provides additional fixed and temporary offsets to C1 for hierarchical cell structures and it is used to prioritize cells for GPRS reselection. That is, if all cells in a network are not GPRS cells, it is preferable to force the GPRS mobiles to attach to a GPRS cell. The C31 calculations enable the process.

In order to further differentiate cells that have the same priority, GPRS can use the C32 calculations known as the cell ranking criterion parameter.

The network may control its cell-reselection and request measurement reports from the mobile. The request is indicated by the parameter `network_control_order`, which has three possible values defined as the following:

- NC0, which is the normal mobile station control mode. In this mode the mobile performs autonomous cell reselection using C1, C31, and C32.
- NC1, which is a mobile station control mode with measurement reports. In this mode the mobile sends measurement reports to the network and performs autonomous cell reselection using C1, C31, and C32.
- NC2, which is a network control mode. In this mode, the mobile sends measurement reports to the network but does not perform autonomous reselection. Instead the GPRS network does the packet resource reassignments.

Summary

GPRS technology adds packet-switching capability to GSM that opens the door for new Internet-based services and other high-speed data applications. However, GPRS also adds new protocols and complexity to the network. An understanding of the technology and the changes it brings will be vital for successful deployment of GPRS and a full realization of the benefits it brings to the mobile network.

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