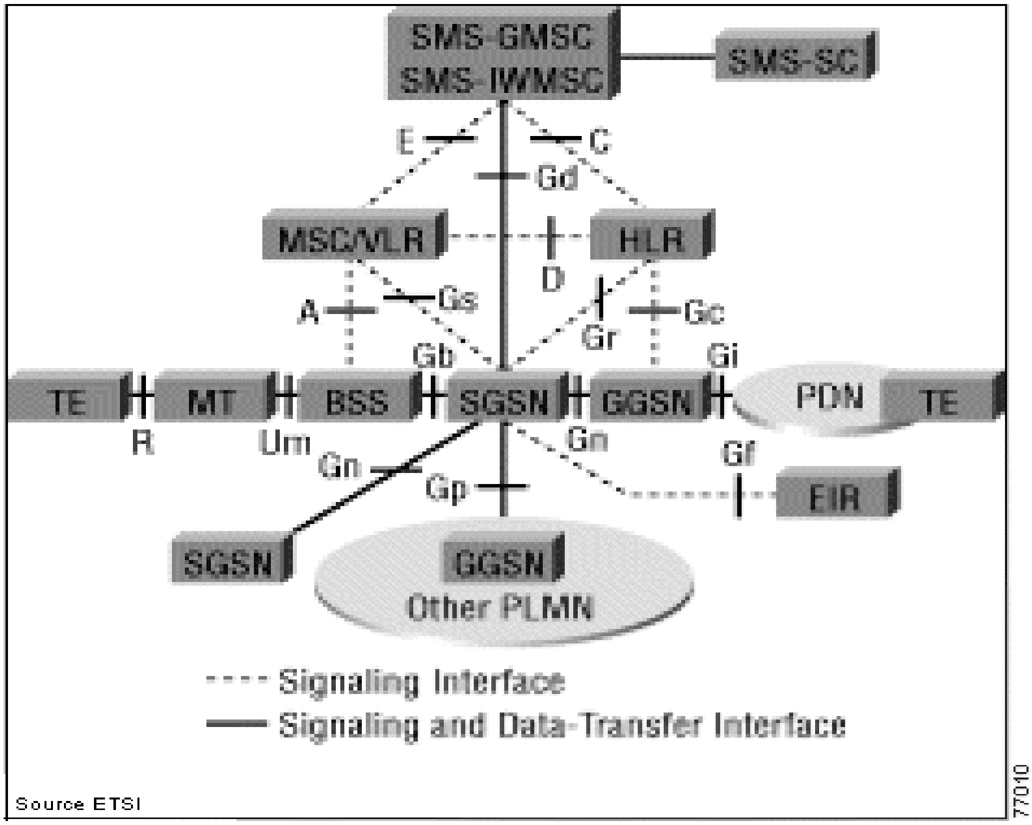
GPRS Architecture

GPRS is a data network that overlays a second-generation GSM network. This data overlay network provides packet data transport at rates from 9.6 to 171 kbps. Additionally, multiple users can share the same air-interface resources simultaneously.

GPRS attempts to reuse the existing GSM network elements as much as possible, but to effectively build a packet-based mobile cellular network, some new network elements, interfaces, and protocols for handling packet traffic are required. Therefore, GPRS requires modifications to numerous network elements as summarized in Table 2-1 and shown in Figure 2-3.

Table 2-1 GPRS Network Elements GSM Network Element	**Modification or Upgrade Required for GPRS.**
Terminal Equipment (TE)	New terminal equipment is required to access GPRS services. These new terminals will be backward compatible with GSM for voice calls.
BTS	A software upgrade is required in the existing base transceiver site.
BSC	The base station controller (BSC) requires a software upgrade and the installation of new hardware called the packet control unit (PCU). The PCU directs the data traffic to the GPRS network and can be a separate hardware element associated with the BSC.
GPRS Support Nodes (GSNs)	The deployment of GPRS requires the installation of new core network elements called the serving GPRS support node (SGSN) and gateway GPRS support node (GGSN).
Databases (HLR, VLR, etc.)	All the databases involved in the network will require software upgrades to handle the new call models and functions introduced by GPRS.

Figure 2-3 GPRS Reference Architecture



GPRS Subscriber Terminals

New terminals are required because existing GSM phones do not handle the enhanced air interface or packet data. A variety of terminals can exist, including a high-speed version of current phones to support high-speed data access, a new PDA device with an embedded GSM phone, and PC cards for laptop computers. These terminals are backward compatible for making voice calls using GSM.

GPRS Base Station Subsystem

Each BSC requires the installation of one or more PCUs and a software upgrade. The PCU provides a physical and logical data interface to the base station subsystem (BSS) for packet data traffic. The BTS can also require a software upgrade but typically does not require hardware enhancements.

When either voice or data traffic is originated at the subscriber terminal, it is transported over the air interface to the BTS, and from the BTS to the BSC in the same way as a standard GSM call. However, at the output of the BSC, the traffic is separated; voice is sent to the mobile switching center (MSC) per standard GSM, and data is sent to a new device called the SGSN via the PCU over a Frame Relay interface.

GPRS Support Nodes

In the core network, the existing MSCs are based on circuit-switched central-office technology and cannot handle packet traffic. Two new components, called GPRS support nodes (GSNs), are added:

- Serving GPRS support node (SGSN)
- Gateway GPRS support node (GGSN)

Serving GPRS Support Node

The SGSN delivers packets to mobile stations (MSs) within its service area. SGSNs send queries to home location registers (HLRs) to obtain profile data of GPRS subscribers. SGSNs detect new GPRS MSs in a given service area, process registration of new mobile subscribers, and keep records of their locations inside a predefined area. The SGSN performs mobility management functions such as handing off a roaming subscriber from the equipment in one cell to the equipment in another. The SGSN is connected to the base station subsystem through a Frame Relay connection to the PCU in the BSC.

Gateway GPRS Support Node

GGSNs are used as interfaces to external IP networks such as the public Internet, other mobile service providers' GPRS services, or enterprise intranets. GGSNs maintain routing information that is necessary to tunnel the protocol data units (PDUs) to the SGSNs that service particular MSs. Other functions include network and subscriber screening and address mapping. One or more GGSNs can be provided to support multiple SGSNs. More detailed descriptions of the SGSN and GGSN are provided in a later section.

GPRS Terminals

The term *terminal equipment* is generally used to refer to the variety of mobile phones and mobile stations that can be used in a GPRS environment. The equipment is defined by terminal classes and types. Cisco's gateway GPRS serving node (GGSN) and data network components interoperate with GPRS terminals that meet the GPRS standards.

Three classes of GPRS terminals are provided: Class A, Class B, or Class C.

Class A Terminals

Class A terminals support GPRS and other GSM services (such as SMS and voice) simultaneously. This support includes simultaneous attach, activation, monitor, and traffic. Class A terminals can make or receive calls on two services simultaneously. In the presence of circuit-switched services, GPRS virtual circuits are held (i.e., placed on hold) instead of being cleared.

Class B Terminals

Class B terminals can monitor GSM and GPRS channels simultaneously but can support only one of these services at a time. Therefore, a Class B terminal can support simultaneous attach, activation, and monitor, but not simultaneous traffic. As with Class A, the GPRS virtual circuits are not disconnected when circuit-switched traffic is present. Instead, they are switched to busy mode. Users can make or receive calls on either a packet or a switched call type sequentially, but not simultaneously.

Class C Terminals

Class C terminals support only sequential attach. The user must select which service to connect to. Therefore, a Class C terminal can make or receive calls from only the manually selected (or default) service. The service that is not selected is unreachable. The GPRS specifications state that support of SMS is optional for Class C terminals.

GPRS Device Types

In addition to the three terminal classes, each handset has a unique form (housing design). Some of the forms are similar to current mobile wireless devices, while others will evolve to use the enhanced data capabilities of GPRS.

The earliest available type is closely related to the current mobile phone. These are available in the standard form with a numeric keypad and a relatively small display.

PC cards are credit card-sized hardware devices that connect through a serial cable to the bottom of a mobile phone. Data cards for GPRS phones enable laptops and other devices with PC card slots to be connected to mobile GPRS-capable phones. Card phones provide functions similar to those offered by PC cards without requiring a separate phone. These devices may require an ear piece and microphone to support voice services.

Smart phones are mobile phones with built-in voice, nonvoice, and Web-browsing services. Smart phones integrate mobile computing and mobile communications into a single terminal. They come in various form factors, which may include a keyboard or an icon drive screen.

The increase in machine-to-machine communications has led to the adoption of application-specific devices. These *black-box* devices lack a display, keypad, and voice accessories of a standard phone. Communication is accomplished through a serial cable. Applications such as meter reading utilize such black-box devices.

Personal digital assistants (PDAs), such as the Palm Pilot series or Handspring Visor, and handheld communications devices are data-centric devices that are adding mobile wireless access. These devices can either connect with a GPRS-capable mobile phone via a serial cable or integrate GPRS capability. Access can be gained via a PC card or a serial cable to a GPRS-capable phone.

Data Routing

One of the main requirements in the GPRS network is the routing of data packets to and from a mobile user. The requirement can be divided into two areas: data packet routing and mobility management.

Data Packet Routing

The main functions of the GGSN involve interaction with the external data network. The GGSN updates the location directory using routing information supplied by the SGSNs about the location of an MS. It routes the external data network protocol packet encapsulated over the GPRS backbone to the SGSN currently serving the MS. It also decapsulates and forwards external data network packets to the appropriate data network and collects charging data that is forwarded to a charging gateway (CG).

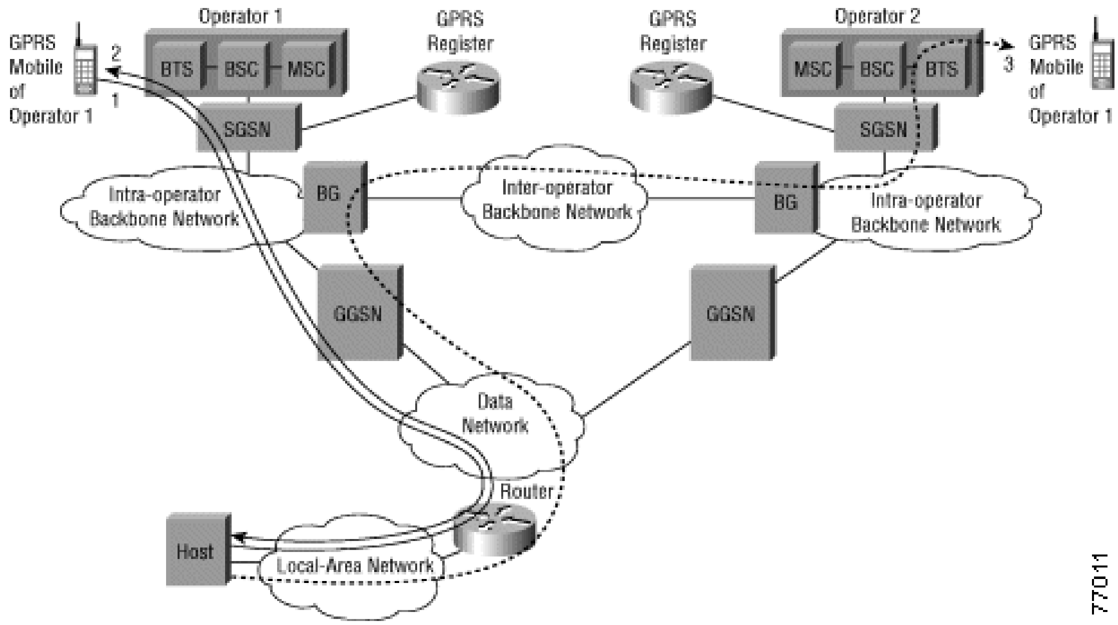
In Figure 2-4, three routing schemes are illustrated:

- Mobile-originated message (path 1)—This path begins at the GPRS mobile and ends at the Host
- Network-initiated message when the MS is in its home network (path 2)—This path begins at the Host and ends at the GPRS mobile
- Network-initiated message when the MS roams to another GPRS network (path 3)—This path is indicated by the dotted line

In these examples, the operator's GPRS network consists of multiple GSNs (with a gateway and serving functionality) and an intra-operator backbone network.

GPRS operators allow roaming through an inter-operator backbone network. The GPRS operators connect to the inter-operator network through a border gateway (BG), which can provide the necessary interworking and routing protocols (for example, border gateway protocol [BGP]). In the future, GPRS operators might implement quality of service (QoS) mechanisms over the inter-operator network to ensure service-level agreements (SLAs). The main benefits of the architecture are its flexibility, scalability, interoperability, and roaming attributes.

Figure 2-4 Routing of Data Packets between a Fixed Host and a GPRS MS



The GPRS network encapsulates all data network protocols into its own encapsulation protocol called the GPRS tunneling protocol (GTP). The GTP ensures security in the backbone network and simplifies the routing mechanism and the delivery of data over the GPRS network.

Mobility Management

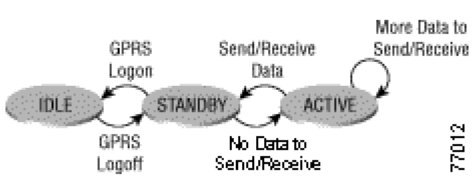
The operation of the GPRS is partly independent of the GSM network. However, some procedures share the network elements with current GSM functions to increase efficiency and to make optimum use of free GSM resources (such as unallocated time slots).

An MS has three states in the GPRS system (Figure 2-5):

- Active
- Standby
- Idle

The three-state model is unique to packet radio; GSM uses a two-state model (idle or active).

Figure 2-5 GPRS States in a Mobile Station



Active State

Data is transmitted between an MS and the GPRS network only when the MS is in the active state. In the active state, the SGSN knows the cell location of the MS.

Packet transmission to an active MS is initiated by packet paging to notify the MS of an incoming data packet. The data transmission proceeds immediately after packet paging through the channel indicated by the paging message. The purpose of the paging message is to simplify the process of receiving packets. The MS listens to only the paging messages instead of to all the data packets in the downlink channels. This reduces battery usage significantly.

When an MS has a packet to transmit, it must access the uplink channel (i.e., the channel to the packet data network where services reside). The uplink channel is shared by a number of MSs, and its use is allocated by a BSS. The MS requests use of the channel in a random access message. The BSS allocates an unused channel to the MS and sends an access grant message in reply to the random access message. The description of the channel (one or multiple time slots) is included in the access grant message. The data is transmitted on the reserved channels.

Standby State

In the standby state, only the routing area of the MS is known. (The routing area can consist of one or more cells within a GSM location area).

When the SGSN sends a packet to an MS that is in the standby state, the MS must be paged. Because the SGSN knows the routing area of the MS, a packet paging message is sent to the routing area. On receiving the packet paging message, the MS relays its cell location to the SGSN to establish the active state.

The main reason for the standby state is to reduce the load in the GPRS network caused by cell-based routing update messages and to conserve the MS battery. When an MS is in the standby state, the SGSN is informed of only routing area changes. By defining the size of the routing area, the operator can control the number of routing update messages.

Idle State

In the idle state, the MS does not have a logical GPRS context activated or any packet-switched public data network (PSPDN) addresses allocated. In this state, the MS can receive only those multicast messages that can be received by any GPRS MS. Because the GPRS network infrastructure does not know the location of the MS, it is not possible to send messages to the MS from external data networks.

Routing Updates

When an MS that is in an active or a standby state moves from one routing area to another within the service area of one SGSN, it must perform a routing update. The routing area information in the SGSN is updated, and the success of the procedure is indicated in the response message.

A cell-based routing update procedure is invoked when an active MS enters a new cell. The MS sends a short message containing the identity of the MS and its new location through GPRS channels to its current SGSN. This procedure is used only when the MS is in the active state.

The inter-SGSN routing update is the most complicated routing update. The MS changes from one SGSN area to another, and it must establish a new connection to a new SGSN. This means creating a new logical link context between the MS and the new SGSN and informing the GGSN about the new location of the MS.

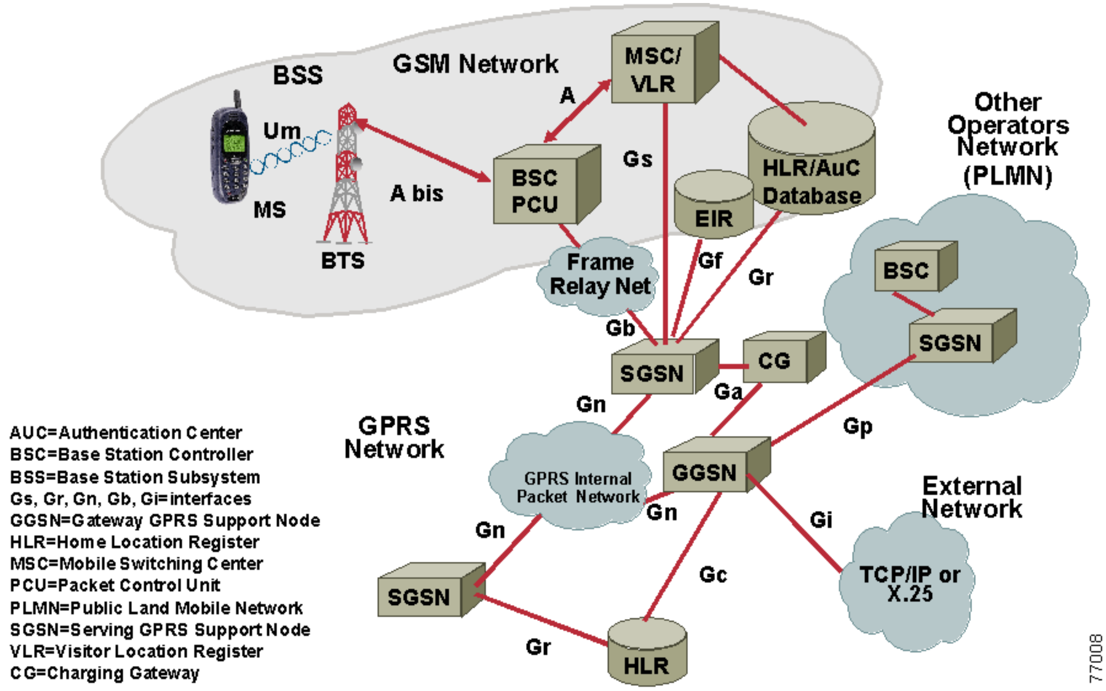
GPRS Interfaces

The GPRS architecture consists of signaling interfaces with various protocols that control and support the transmission of packets across the networks and to the mobile stations. The interfaces in a GPRS network are:

- Ga—Interface between GSN nodes (GGSN, SGSN) and charging gateway (CG)
- Gb—Interface between SGSN and BSS (PCU); normally uses Frame Relay
- Gc—Interface between GGSN and HLR
- Gi—Interface between GPRS (GGSN) and an external packet data network (PDN)
- Gn—Interface between two GSN nodes, i.e., GGSN and SGSN; this connects into the intra-network backbone, for example, an Ethernet network
- Gp—Interface between two GSN nodes in different PLMNs; this is via border gateways and is an inter-PLMN network backbone
- Gr—Interface between SGSN and HLR
- Gs—Interface between SGSN and the MSC/VLR
- Gf—Interface between SGSN and EIR

Figure 2-6 shows these interfaces.

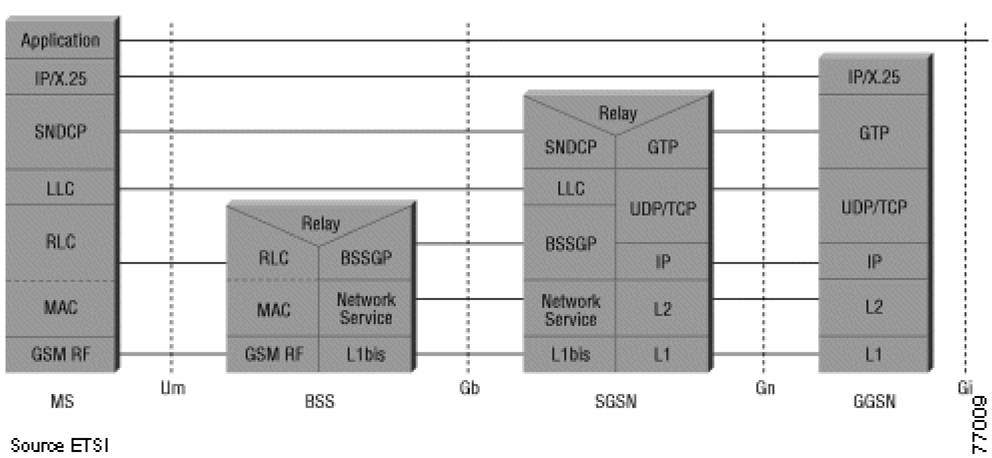
Figure 2-6 GPRS Interfaces



GPRS Protocol Stacks

Figure 2-7 shows the GPRS protocol stack and end-to-end message flows from the MS to the GGSN. The protocol between the SGSN and GGSN using the Gn interface is GTP. This is a Layer 3 tunneling protocol similar to L2TP.

Figure 2-7 GPRS Network Protocol Stack



Although Figure 2-7 defines the Gn and Gi interface as IP, the underlying protocols are not specified, providing flexibility with the physical medium. The GGSN software runs on a Cisco 7206VXR hardware platform, which provides a wide range of supported

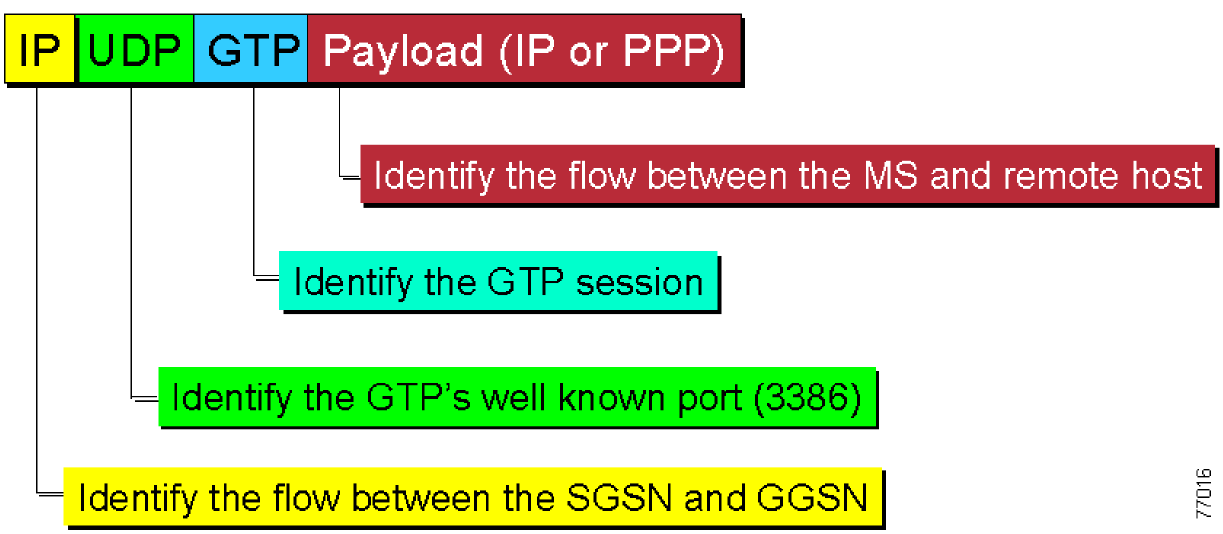
physical interfaces and a high port density. The GGSN software uses a virtual template interface, which is a logical interface within the router and does not depend on the physical medium directly. A list of supported physical interfaces for the 7206VXR can be found at this URL:
http://www.cisco.com/univercd/cc/td/doc/product/core/7200vx/portadpt/index.htm .

The most common physical interface used with GPRS is Fast Ethernet. This interface provides high bandwidth, low cost, and universal connectivity to other vendor equipment. For the Gi interface, common interfaces are Serial, E1/T1 or Ethernet. Running over the physical WAN interfaces can be a wide range of protocols including Frame Relay, ISDN, and HDLC.

GPRS Tunneling Protocol

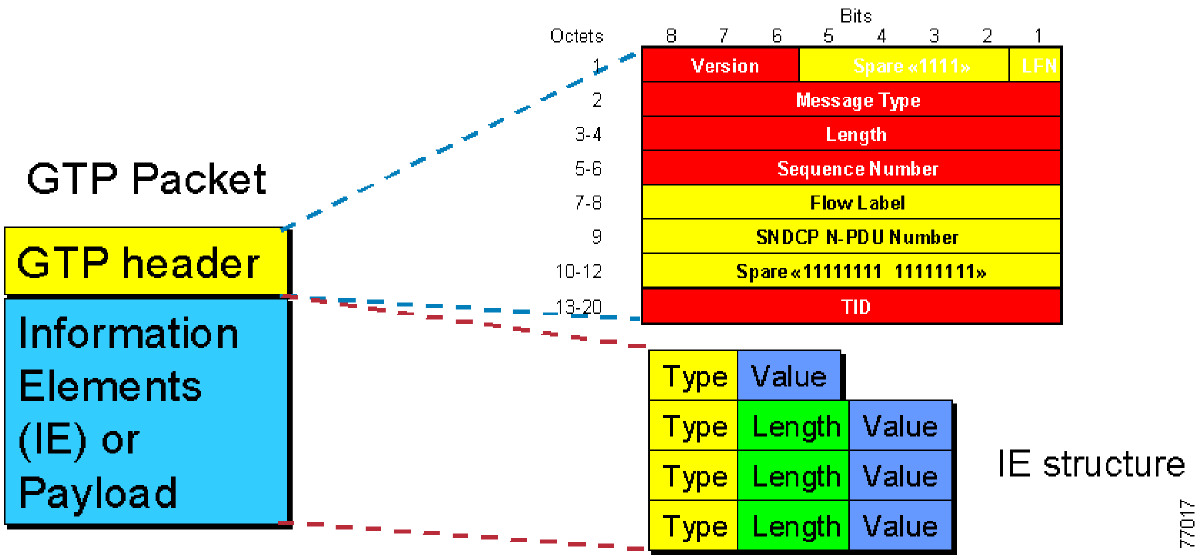
The GTP tunneling protocol is a Layer 3 tunneling protocol. The IP header identifies a session flow between the GGSN and SGSN. The UDP header identifies the GTP application protocol (Port 3386). The GTP header identifies the GTP tunnel session. The payload identifies the session flow between the mobile station and the remote host. See Figure 2-8.

Figure 2-8 GPRS Tunneling Protocol



The GTP packet structure, like any other packet, typically has a fixed-size header and other information called payload or information elements. Currently, bits 1-5 of Octet 1 and Octets 7-12 are not in use. TID is the tunnel ID that identifies a tunnel session. The length field of GTP is different from the length field of IP. In IP, the length includes the header; in GTP, length indicates only the GTP payload. See Figure 2-9.

Figure 2-9 GTP Packet Structure



GPRS Access Modes

The GPRS access modes specify whether or not the GGSN requests user authentication at the access point to a PDN (Public Data Network). The available options are:

- Transparent—No security authorization/authentication is requested by the GGSN
- Non-transparent—GGSN acts as a proxy for authenticating

The GPRS transparent and non-transparent modes relate only to PDP type IPv4.

Transparent Mode

Transparent access pertains to a GPRS PLMN that is not involved in subscriber access authorization and authentication. Access to PDN-related security procedures are *transparent* to GSNs.

In transparent access mode, the MS is given an address belonging to the operator or any other domain's addressing space. The address is given either at subscription as a static address or at PDP context activation as a dynamic address. The dynamic address is allocated from a Dynamic Host Configuration Protocol (DHCP) server in the GPRS network. Any user authentication is done within the GPRS network. No RADIUS authentication is performed; only IMSI-based authentication (from the subscriber identity module in the handset) is done.

Non-transparent Mode

Non-transparent access to an intranet/ISP means that the PLMN plays a role in the intranet/ISP authentication of the MS. Non-transparent access uses the Password Authentication Protocol (PAP) or Challenge Handshake Authentication Protocol (CHAP) message issued by the mobile terminal and piggy-backed in the GTP PDP context activation message. This message is used to build a RADIUS request toward the RADIUS server associated with the access point name (APN).

GPRS Access Point Name

The GPRS standards define a network identity called an access point name (APN). An APN identifies a PDN that is accessible from a GGSN node in a GPRS network (e.g., www.Cisco.com). To configure an APN, the operator configures three elements on the GSN node:

- Access point—Defines an APN and its associated access characteristics, including security (RADIUS), dynamic address allocation (DHCP), and DNS services
- Access point list—Defines a logical interface that is associated with the virtual template
- Access group—Defines whether access is permitted between the PDN and the MS

The Cisco GGSN is based on the routing technology, Cisco IOS. It integrates GPRS with already deployed IP services, like virtual private data networks (VPDNs) and voice over IP (VoIP).

The mobile VPN application is the first service targetted for business subscribers that mobile operators are offering when launching GPRS networks. In GPRS, the selection of the VPN can be based on the same parameters that are used in VPDN applications:

- Dialed number identification service (DNIS), i.e., the called number
- Domain, e.g., user@domain
- Mobile station IDSN (MSISDN) number, i.e, the calling number

In GPRS, only the APN is used to select the target network.The Cisco GGSN supports VPN selection based on the APN.