7.1 INTRODUCTION TO MOBILE WIRELESS DATA NETWORKS

The growth of the Internet and its daily use by the average person coupled with the public's desire for anytime, anywhere voice and data communications has been the driving force behind the growth and development of mobile wireless data networks. If one plots the number of Internet Web sites or Internet users versus time, the resulting upward curve is closely matched only by the growth in the number of worldwide wireless cellular subscribers. If desired, the reader may view any number of the previously listed Web sites (i.e., GSM, UMTS, CDMA forums or industry collaborations) that provide impressive, near real-time running totals of existing subscribers to a particular air interface technology and maps of worldwide deployment and coverage areas with detailed information about the service providers, frequency bands used, technology used, and so on. Most cellular industry predictions of future system expansion and total numbers of wireless subscribers are heavily optimistic, with double-digit growth predicted for at least this decade.

What is not so certain, however, are the predictions concerning

Overview of the Packet Data Network

A short review of the packet data network is appropriate at this time. Essentially, the packet data network consists of an interconnection of numerous data networks, both public and private, that use packet switching to deliver data to a final destination. The network is set up to deliver data packets through the use of header information appended to the beginning of the data. The packet header typically includes such information as the destination address, the sender's address, and other overhead information necessary for the successful and perhaps necessary timely delivery of the data contained in the packet. Some of this overhead information might also be appended to the end of the packet (thus encapsulating the data). Within the packet data network there are nodes (routers) that connect to other routers and eventually to other packet networks and so on and so forth. The function of these routers is to inspect the packet header destination information and forward or switch individual packets on to the correct router output interconnection as they make their way toward their final destinations (hence the term *connectionless switching*). Numerous types of packet data networks exist, both public and private. As technology has evolved, various protocols (review Chapter 1 and its coverage of the OSI model) have been developed to facilitate the transmission of data over networks utilizing different types of physical media, providing different and ever increasing data rates, dealing with various quality of service (QoS) issues, using different error handling techniques, and interconnecting with other possibly different networks. Furthermore, depending upon the physical scope of the data network (i.e., LAN, MAN, or WAN) many sophisticated transport technologies (Ethernet, ATM, SONET, frame relay, X.25, T-carrier, xDSL, etc.) exist today.

Interestingly, the almost universal use of transport control protocol/ internet protocol (TCP/IP) makes the packet data network transparent to the user and basically hides the network hardware from view. At this point, most consider the packet data network and the Internet one in the same. The wireless packet data network is an extension of the Internet that provides the end user mobility with Internet connectivity in a WAN environment somewhat similar to the untethered environment offered by a wireless LAN.

CDPD

As mentioned before, CDPD was created to provide bursty packet data delivery over the AMPS system. It is able to perform this data service by defining a specific network architecture, a set of protocols, and having a radio interface that is compatible with the AMPS technology. CDPD works by sharing AMPS spectrum (and later on, NA-TDMA spectrum) for both data and voice services. It uses idle time on the AMPS channels to transmit data packets and dedicated spectrum from an NA-TDMA system. It should be pointed out that CDPD can also be overlaid on a CDMA network. The CDPD network architecture is depicted by Figure 7–1.

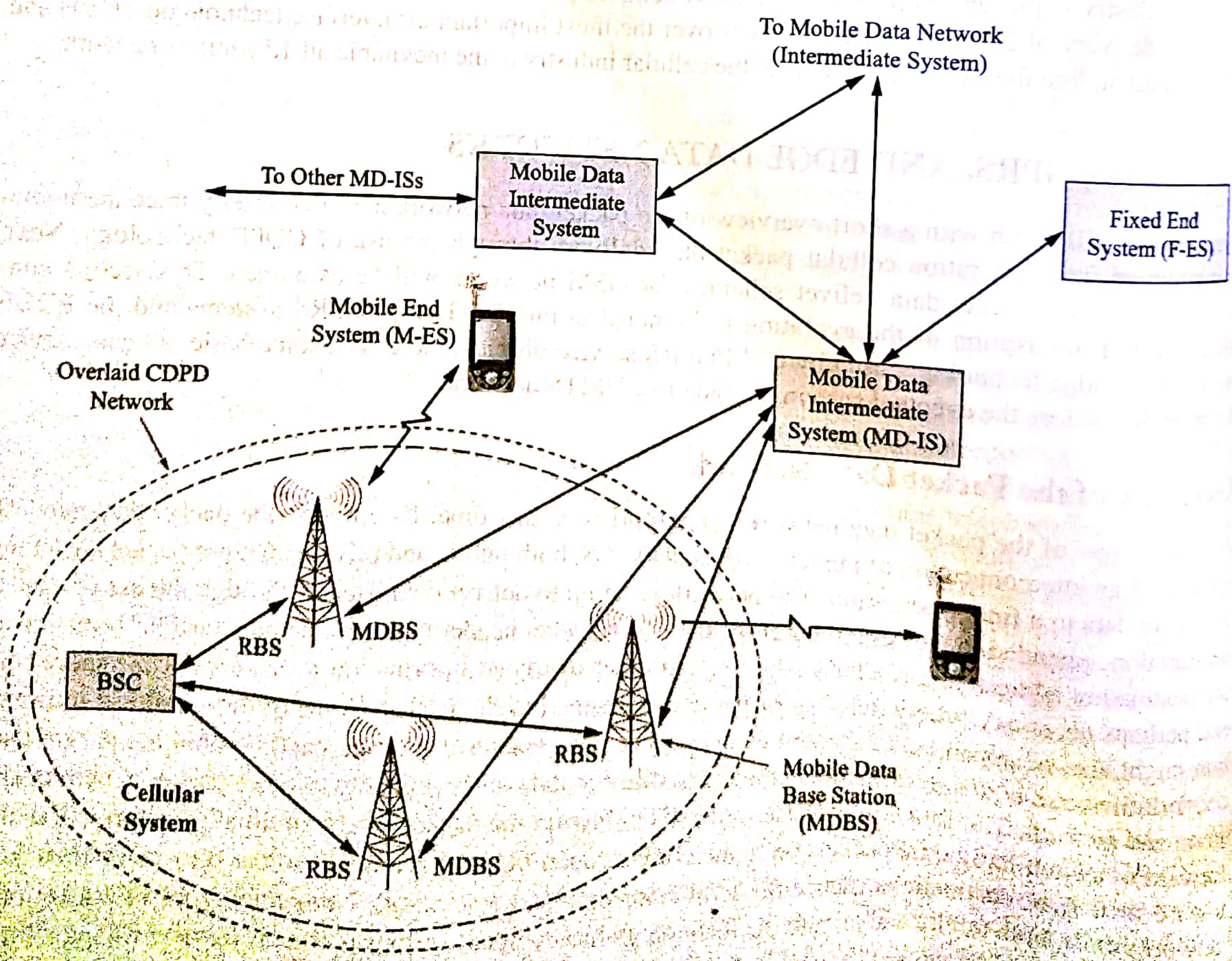

Figure 7–1 Typical CDPD network architecture.

... network elements that ...

As shown by Figure 7–1, the CDPD network consists of several network elements that provide the functionality necessary for system operation. The basic CDPD network elements are the intermediate systems, the mobile data intermediate system, and the mobile data base stations. The intermediate systems act as gateways between the CDPD network and other packet data networks. Essentially, they are routers that form the CDPD network backbone and provide the necessary connections to other external networks. The mobile data intermediate system provides the interface between the fixed CDPD network and the mobile user of the network. This network element provides the end user with mobility within the system and performs similar functions as the HLR and the VLR in a cellular network. The mobile data base stations provide the radio interface to the end users of the network. Every cell that supports CDPD delivery contains a base station supporting CDPD operation. Lastly, the CDPD standard specifies two types of end terminal devices, the user mobile end system (M-ES) and a fixed end system (F-ES). The M-ES might be a credit card verification unit installed in a taxi cab, a wirelessly enabled PDA, or some other form of handheld. Since the CDPD system is able to be colocated with the host AMPS system (and other later cellular systems) and share both the antenna and the site, CDPD was viewed as a cost-effective solution to packet data service early on in the evolution of cellular technology.

For proper CDPD operation, the CDPD wireless network must overlay the host AMPS network. This is accomplished through one of several possible scenarios involving the two networks. The AMPS system can dedicate one or more of its available traffic channels for CDPD service. This will certainly provide superior-quality CDPD service; however, if there is not a great deal of CDPD traffic it might compromise the AMPS service. Another possible arrangement is to have shared channels for CDPD and voice traffic with voice calls having the highest priority. In this case, the CDPD network detects unused or idle voice channels and allocates them to packet data calls as needed. If the AMPS system needs the channel for a voice call, it will be relinquished by the CDPD network. The CDPD network will continue the data call if it can detect another idle voice channel within the system and transfer the call to it before the expiration of a system timer. In this case, the performance of the CDPD network depends upon the amount of voice traffic on the AMPS network. A third option is to dedicate a number of the AMPS channels as voice only and then share a number of channels for both voice and data traffic. This option guarantees a certain level of AMPS performance at the expense of the CDPD network. For colocated operation with host NA-TDMA or CDMA networks, the CDPD network usually requires a dedicated allocation of spectrum.

The operation of a CDPD wireless network is very similar to typical wireless cellular system operation. For an M-ES-originated packet data call, the mobile device must acquire a CDPD channel. Depending upon the system setup, either a dedicated CDPD channel will be specified and programmed into the M-ES's memory or the mobile device will need to perform what is known as channel sniffing to find a CDPD-enabled channel. Once a CDPD channel has been acquired by the M-ES it will perform a registration and authentication process with the CDPD network. The CDPD network's versions of the HLR and VLR (located in the mobile data intermediate system) will be updated with the mobile device's present location and required routing information. Once these operations are complete, the M-ES may commence sending and receiving packets over the radio link that has been setup. For an M-ES-terminated packet data call the process is somewhat different. Each MD-IS broadcasts identification information about itself over the forward CDPD radio link. If the M-ES moves from its home MD-IS serving area into a new MD-IS serving area, it will register with the system and hence provide its present location within the system to the network. Packet data destined for the M-ES will be routed to the new serving area and be broadcast over the forward link. All M-ESs within the radio coverage area will receive the data packets, but only M-ESs with valid network identifiers are able to decode them.

GPRS

When the second-generation GSM standards were developed, the digital-based GSM system was designed to be an integrated wireless voice-data service network that offered defined data services. Phase 1 of GSM deployment defined both teleservices and bearer services that included short message service, teletex, FAX, both asynchronous and synchronous data, and synchronous packet data delivery albeit at low data rates by today's standards (9600 bps maximum). Phase 2 of the GSM specifications added enhanced circuit data throughput rates, and Phase 2+ of the standards have addressed the evolution to higher packet data transfer rates. Phase 2+ calls for GSM support for high-speed circuit-switched data (HSCSD), the ability to transfer small data packets over radio interface signaling channels, general packet radio service (GPRS), and enhanced data rate for global evolution (EDGE). This section will discuss GPRS in more detail and the next section will discuss EDGE technology.

GPRS *Networks*

Although GSM wireless networks have the vast majority of cellular subscribers worldwide, extensive GSM networks have only recently been introduced into the United States. Nationwide GSM/GPRS networks are being rapidly built out by several service providers in the PCS bands (1900 MHz) while other service providers have systems operating at 850 MHz. In a related development, NA-TDMA service providers have deployed GSM/GPRS systems to provide high-speed packet data services to complement their legacy voice service systems (requires a dual-mode handset). The overlay of these new GSM/GPRS systems will gradually reduce the spectrum available for NA-TDMA systems and eventually these service providers will migrate totally to GSM/GPRS/EDGE wireless networks. As always, economics will dictate the speed at which these events happen. However, the process has been set into motion and there appears to be a worldwide commitment by the wireless industry to deploy true 3G service-capable networks during the middle of this decade. The conversion to GSM by the NA-TDMA operators affords them a clearer migration path to 3G than they previously had.

Figure 7–2 shows a typical GSM/GPRS network. The GPRS network runs in concert with a GSM wireless network. A typical GPRS public land mobile network (PLMN) allows a mobile user to roam within the geographical coverage area of the GSM/GPRS system and provides continuous, moderate-speed, wireless packet data service. In the case of a mobile subscriber moving about the system, the GSM PLMN keeps track of the subscriber's location and aids the GPRS PLMN in routing the incoming data packets to the correct serving cell.

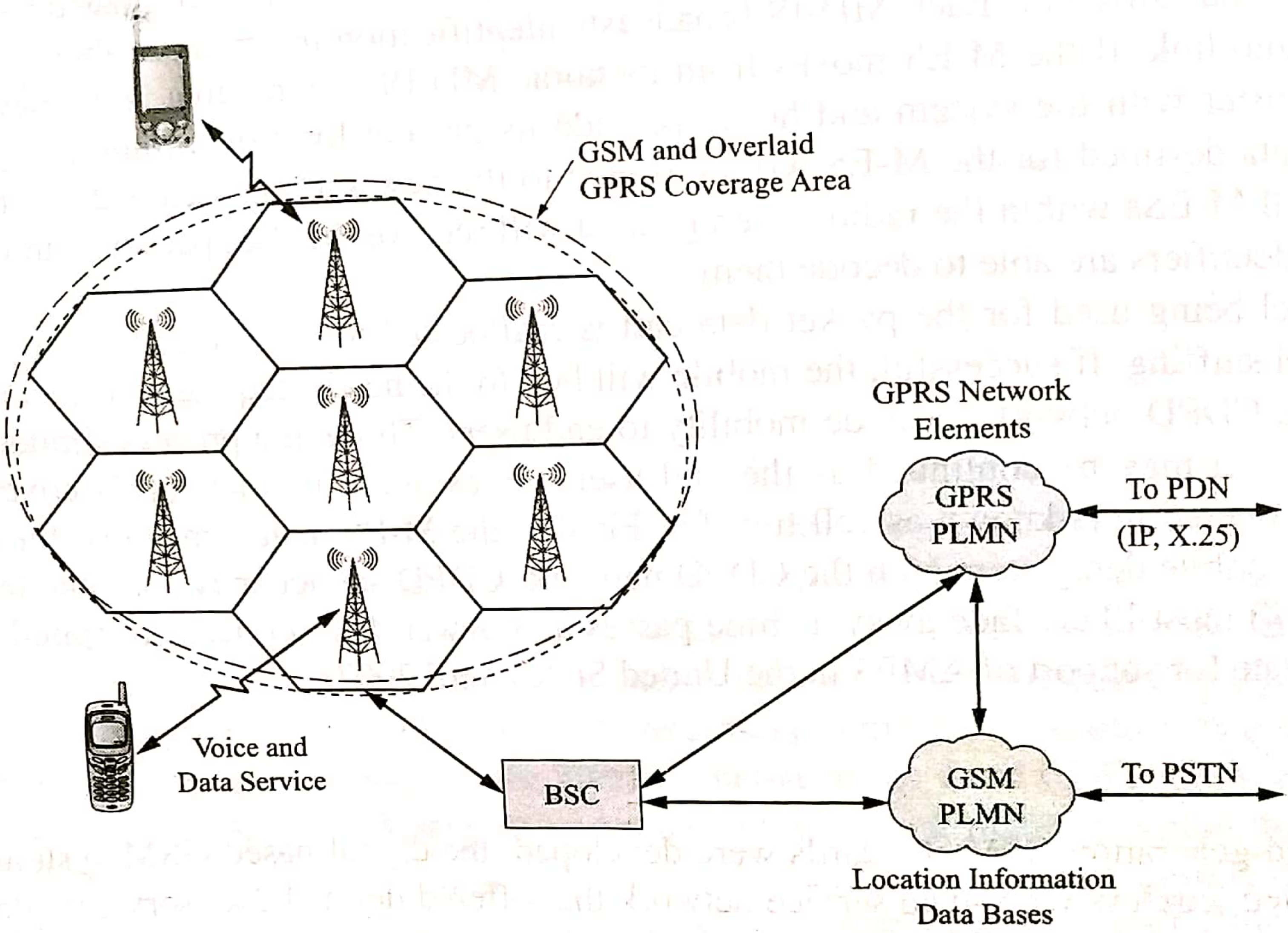

Figure 7–2 Typical GSM/GPRS network.

The GPRS PLMN uses the GSM air interface to provide packet data service to the subscriber and the fixed portion of the network interfaces with the public data network using standard packet data protocols. Network layer protocols like X.25 and IP (Internet protocol) are supported and therefore the end user is able to access Internet Web sites and private enterprise servers via the GPRS PLMN. The GPRS user can also receive voice services via the GSM PLMN. Depending upon the mobile's capabilities, these services may be accessed either one at a time or simultaneously.

The GPRS standard supports many different and useful features: roaming between different GPRS networks, several different connection topologies (point-to-point, point-to-multipoint, etc.), SMS service over packet data channels, different quality of service (QoS) levels, different modes of addressing (e.g., static, dynamic, multiple simultaneous), and security and confidentiality through a GSM-based system of authentication, sophisticated encryption, and a packet temporary mobile subscriber identity (P-TMSI).

GPRS Network Details

A GPRS PLMN is made up of several network elements and various communications links that interface these elements to one another. The GSM standards specify a GPRS network reference model with these network elements and signaling interfaces and their interconnection to the standard GSM network elements. Figure 7–3 depicts the components of a GPRS network and the GPRS logic architecture with some of the signaling interfaces labeled. The key new network elements in the GPRS PLMN are the **GPRS support nodes** (GSNs) of which there are two types. There is a gateway GPRS support node (GGSN) that serves as the gateway between the GPRS network and other packet data networks, and the serving GPRS support node (SGSN) that controls GPRS service in a coverage area. The GGSN is also responsible for routing data to the correct SGSN. All of the GSNs within a GPRS PLMN are interconnected by an IP backbone and perform routing functions specific to the GPRS PLMN.

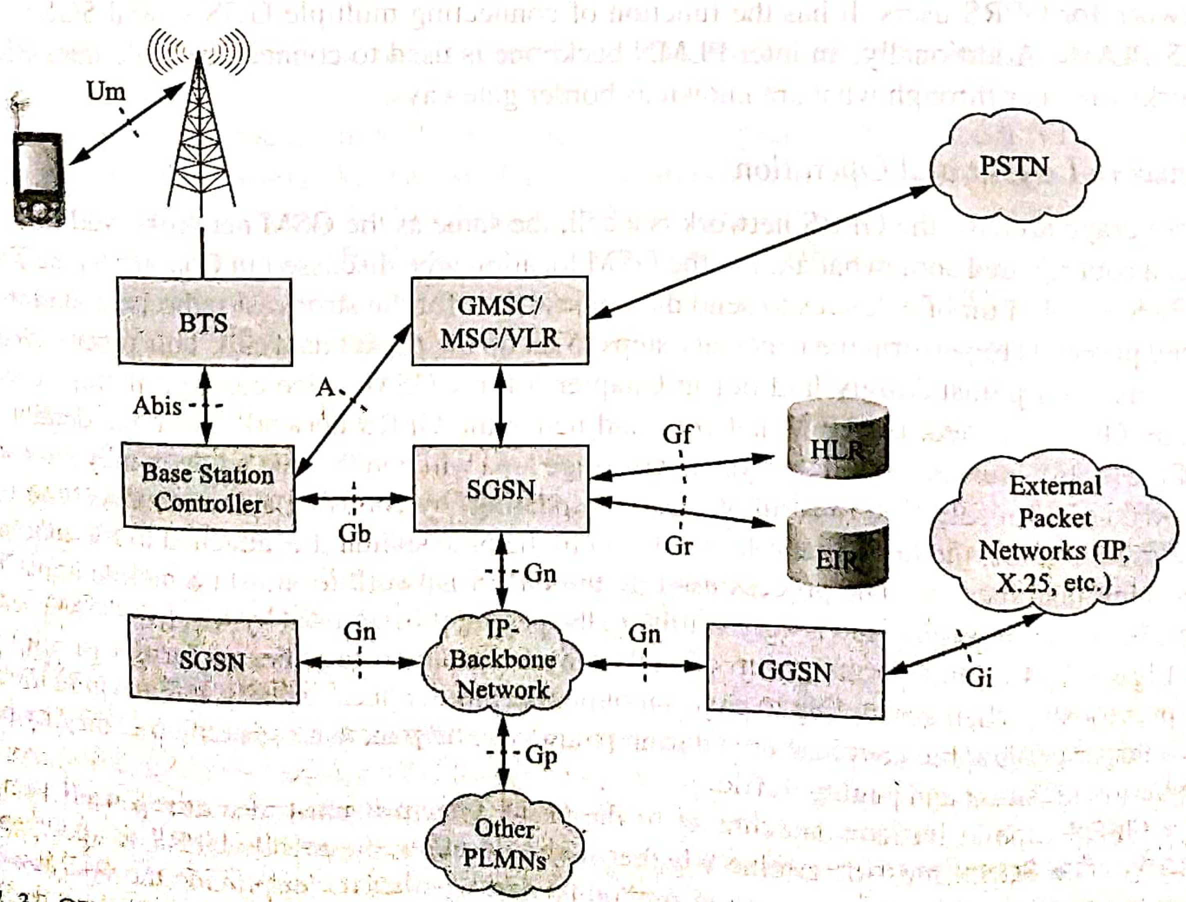

Figure 7–3 GPRS network components.

GPRS Network Elements The gateway GSN serves as the access point to the packet data networks supported by the GPRS PLMN. The primary function of the GGSN is to route packets from the packet data networks to the GSM mobile station. When a mobile station attaches to the GSM network and activates its packet data address, the mobile becomes registered with the GGSN. The GGSN's routing table is updated with the correct serving GSN (SGSN), indicating the mobile's point of attachment. The GGSN also is tasked with performing mobile station address management and activation functions. That is, if the mobile needs a packet data address, the GGSN will provide it and also activate the mobile's address in its routing table. The serving GSN node basically provides a point of attachment to the GPRS mobiles. The SGSN is responsible for the delivery of packets to and from the mobile. To perform this function correctly, the SGSN must be aware of the location of the mobiles attached to it (akin to the function of a VLR). Furthermore, the SGSN is tasked with performing GPRS system security functions (authentication, encryption, etc.), which are performed in conjunction with the HLR of the host GSM system. Both the GGSN and the SGSN are linked to the GSM PLMN and therefore have access to the network elements of the GSM system (MSC/VLR, SMS-GMSC, HLR, etc.), which facilities the performance of their operations. The SGSN is normally connected to the base station system by Frame Relay or some other high speed data transport technology. The SGSN may provide service to multiple base stations thus providing coverage to a group of cells. Lastly, the functionality of the SGSN and the GGSN may be physically combined into a single SGSN/GGSN unit by a wireless equipment vendor.

Within a GPRS PLMN, both the GSM base station subsystem and the mobile stations must be able to cope with GPRS data. The GSM HLR already has the responsibility of keeping track of the mobile subscriber's location within the GSM network and hence within the GPRS network. Therefore, in support of GPRS service, the HLR manages GPRS subscription data that includes mobile roaming privileges, details of QoS-level privileges, and the mobile's static IP or other packet data address information. Other network elements within the GPRS network include an intra-PLMN backbone (high-speed data network). This is a private network for GPRS users. It has the function of connecting multiple GGSNs and SGSNs within the same GPRS PLMN. Additionally, an inter-PLMN backbone is used to connect multiple intra-PLMN backbone networks together through what are known as border gateways.

GPRS Network Layout and Operation

GPRS Packet Data Transfers

Assuming that a GPRS-enabled mobile has attached to the GPRS network and activated an IP address, it is now ready to begin transferring packet data. Packet data transfers between the GGSN and the GPRS mobile take place using a technique known as "tunneling." In this context, tunneling is the process of encapsulating a data packet so that it may be routed through the GPRS PLMN IP backbone network eliminating the problem of protocol interworking. An example of this process should help the reader understand this technique. Data packets for a certain IP address arrive from the public data network at the GGSN that anchors the IP address. At the GGSN, the data packets are given new headers. Inside the GPRS PLMN IP network,

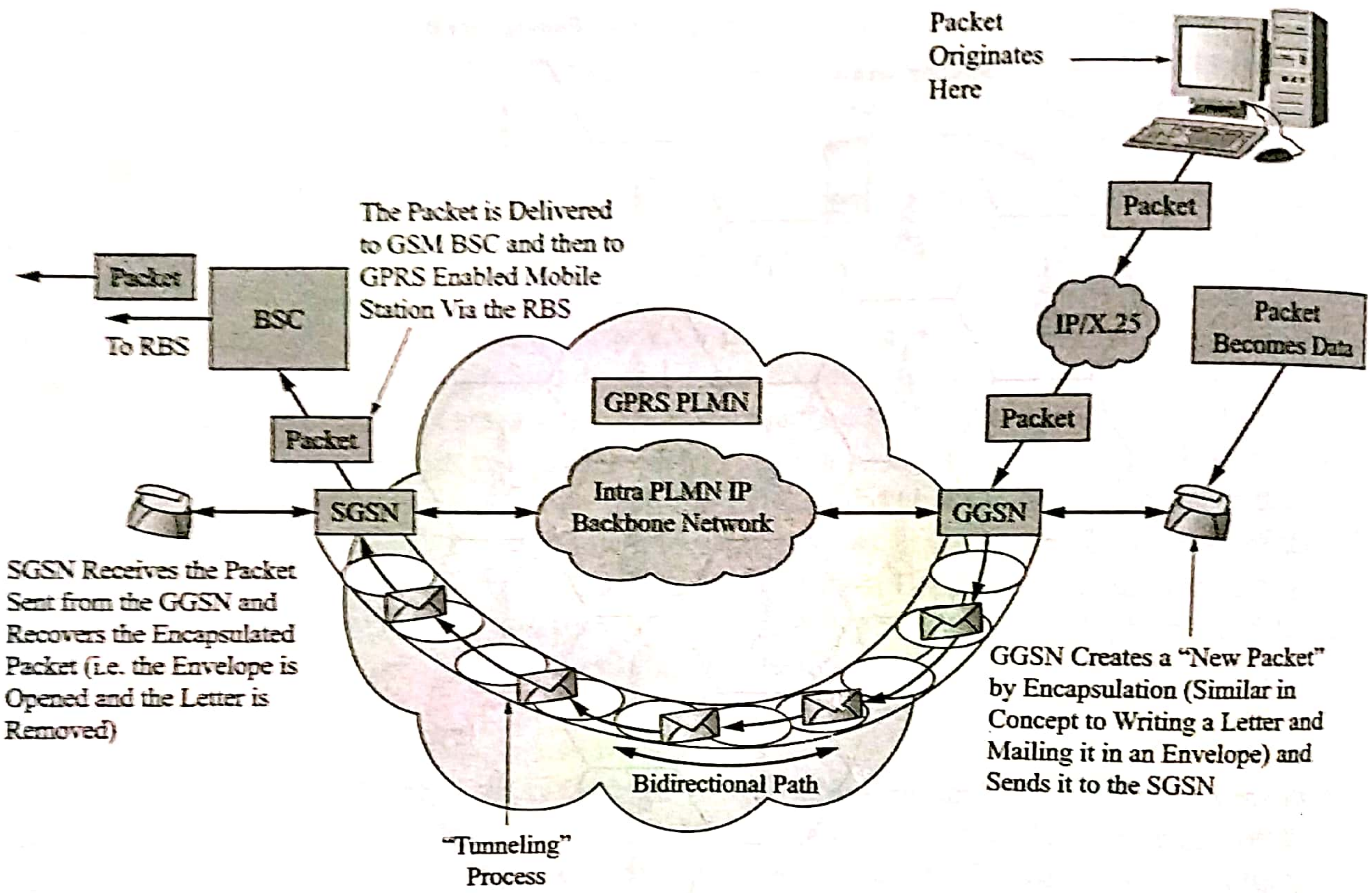

Figure 7–5 GPRS data transfer via tunneling.

these packets are routed based on the new header while the original packet is transported as the data. Once through the network, the new header is stripped of the packet and the data packet is now routed based on the original header. Likewise, packets sent from the GPRS mobile to the public data network must be sent from the SGSN to the GGSN in the same fashion. See Figure 7–5 for a depiction of this process. This use of tunneling within the GPRS network solves the mobility problem and hides the fact that the GPRS mobile is in fact a mobile station.

GPRS Protocol Reference Model