7.3 GPRS NETWORK ARCHITECTURE

GPRS uses the GSM architecture for voice. In order to offer packet data services through GPRS, a new class of network nodes need to be introduced as an upgrade to the existing GSM network.

These network nodes are called GPRS support nodes (GSN). GPRS support nodes are responsible for the delivery and routing of data packets between the mobile stations and the external packet data networks (PDN). There are two types of support nodes, viz., SGSN (Serving GSN) and GGSN (Gateway GSN). Figure 7.1 depicts GPRS system components for data services.

Serving GPRS Support Node (SGSN): A serving GPRS support node (SGSN) is at the same hierarchical level as the MSC. Whatever functions MSC does for voice, SGSN does the same for packet data. SGSN's tasks include packet switching, routing and transfer, mobility management (attach/detach and location management), logical link management, and authentication and charging functions. SGSN processes registration of new mobile subscribers and keeps a record of their location inside a given service area. The location register of the SGSN stores location information (e.g., current cell, current VLR) and user profiles of all GPRS users registered with this SGSN. SGSN sends queries to Home Location Register (HLR) to obtain profile data of GPRS subscribers. The SGSN is connected to the base station system with Frame Relay.

Gateway GPRS Support Node (GGSN): A gateway GPRS support node (GGSN) acts as an interface between the GPRS backbone network and the external packet data networks. GGSN's function is similar to that of a router in a LAN. GGSN maintains routing information that is necessary to tunnel the Protocol Data Units (PDUs) to the SGSNs that service particular mobile stations. It converts the GPRS packets coming from the SGSN into the appropriate packet data protocol (PDP) format for the data networks like Internet or X.25. PDP sends these packets out on the corresponding packet data network. In the other direction, PDP receives incoming data packets from data networks and converts them to the GSM address of the destination user. The readdressed packets are sent to the responsible SGSN. For this purpose, the GGSN stores the current SGSN address of the user and his or her profile in its location register. The GGSN also performs authentication and charging functions related to data transfer.

7.3.1 GPRS Network Enhancements

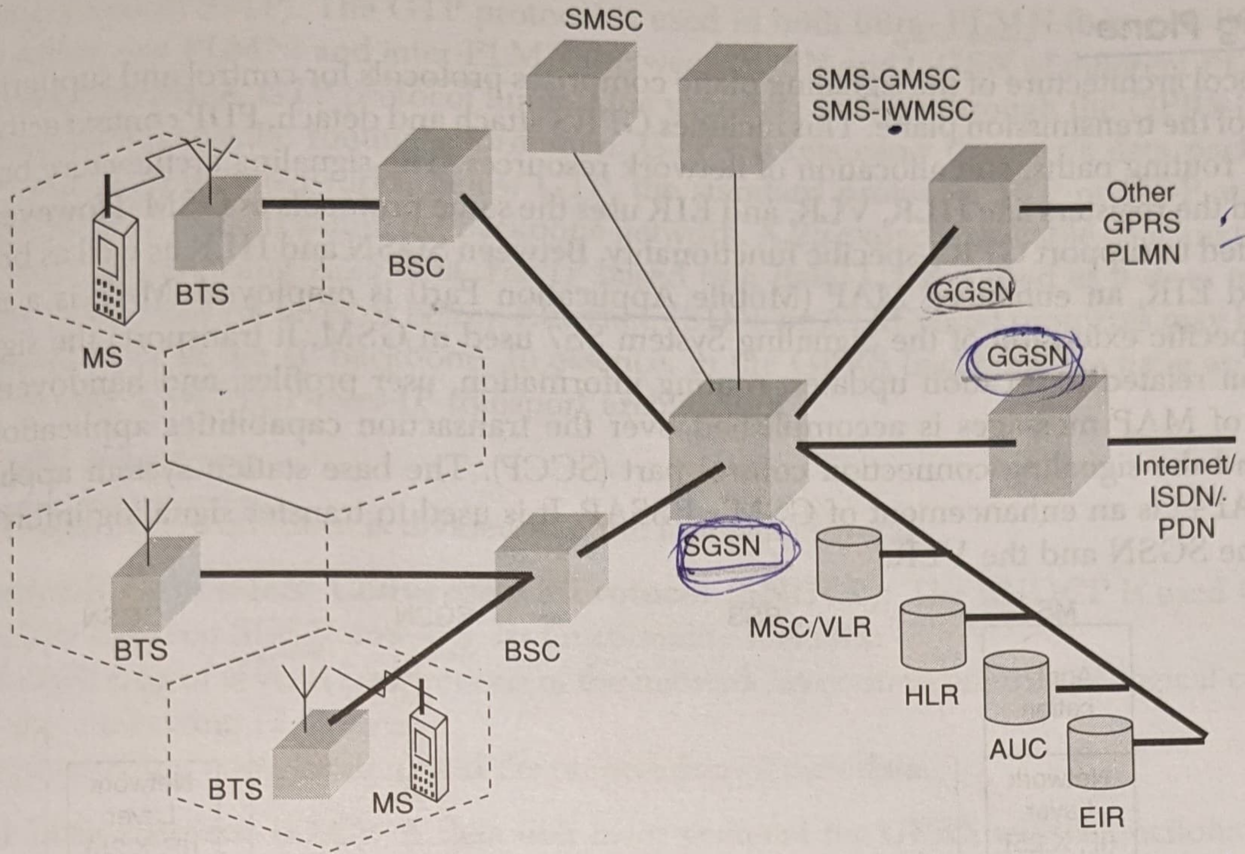
In addition to the new GPRS components (SGSN and GGSN), some existing GSM network elements must also be enhanced in order to support packet data. These are:

Base Station System (BSS): BSS system needs enhancement to recognize and send packet data. This includes BTS upgrade to allow transportation of user data to the SGSN. Also, the BTS needs to be upgraded to support packet data transportation between the BTS and the MS (Mobile Station) over the radio.

Home Location Register (HLR): HLR needs enhancement to register GPRS user profiles and respond to queries originating from GSNs regarding these profiles.

Mobile Station (MS): The mobile station or the mobile phone for GPRS is different from that of GSM.

SMS Nodes: SMS-GMSCs and SMS-IWMSCs are upgraded to support SMS transmission via the SGSN. Optionally, the MSC/VLR can be enhanced for more efficient coordination of GPRS and non-GPRS services and functionality.



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AUC	Authentication Centre	MS	Mobile Station
BSC	Base Station Controller	MSC	Mobile Switching Centre
BTS	Base Transceiver Station	PDN	Packet Data Network
EIR	Equipment Identity Register	PLMN	Public Land Mobile Network
GGSN	Gateway GPRS Support Node	SMSC	Short Message Service Centre
GPRS	General Packet Radio Service	SMS-GMSC	SMS Gateway MSC
HLR	Home Location Register	SMS-IWMSC	SMS Inter-Working MSC
ISDN	Integrated System Digital Network	SGSN	Serving GPRS Support Node

Figure 7.1 GPRS System Architecture

7.5 DATA SERVICES IN GPRS

A wide range of corporate and consumer applications are enabled by GPRS services. A user is likely to use either of the two modes of the GPRS network. These are *Application mode* or *Tunneling mode.*

Application mode: In this mode the user will be using the GPRS mobile phone to access the applications running on the phone itself. The phone here acts as the end user device. All GPRS phones have WAP browser as an embedded application. This browser allows browsing of WAP sites. Some GPRS devices support mobile execution environment (MExE classmark 3). These devices support development of client application that can run on the device. The device operating execution environments supported are Symbian and J2ME. Applications can be developed in C/C++ or Java.

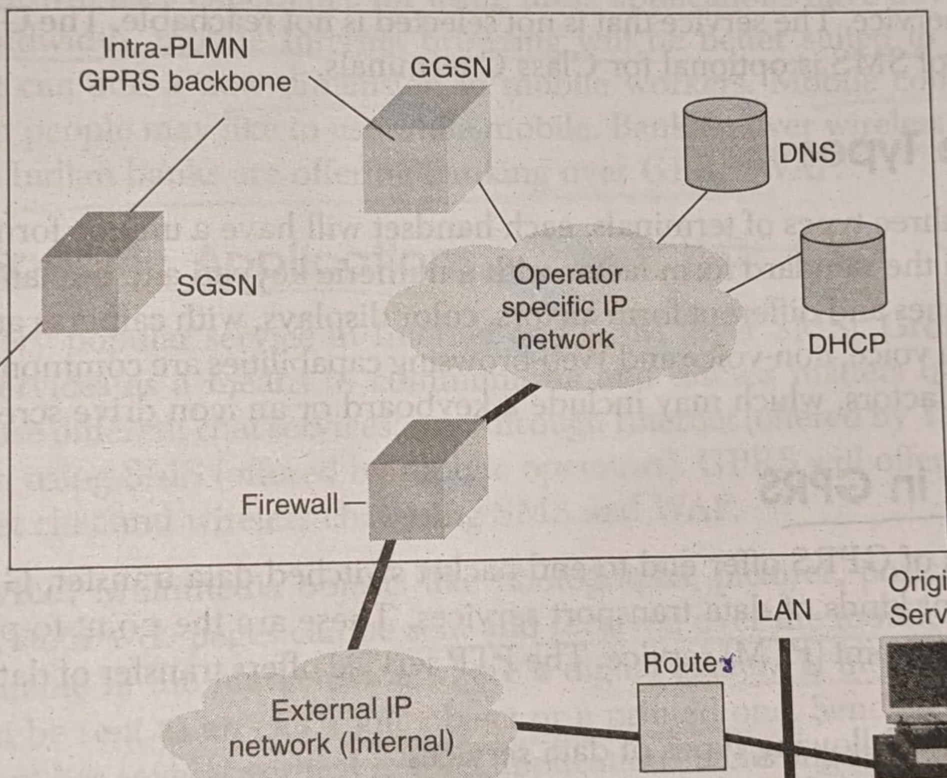


Figure 7.5 Example of a GPRS–Internet Connection

Tunneling mode: This mode is for mobile computing where the user will use the GPRS interface as an access to the network. The end user device will be a large footprint device like laptop computer or small footprint device like PDAs. The mobile phone will be connected to the device and used as a modem to access the wireless data network. For these devices, access can be gained via a PC Card (PCMCI) or via a serial cable to a GPRS capable phone. These "black-box" devices do not have display, keypad and voice accessories of a standard phone.

7.6 APPLICATIONS FOR GPRS * Imp

In this section we describe some applications which need higher data bandwidth and are suitable for GPRS.

7.6.1 Generic Applications

There are many applications suitable for GPRS. Many of them are of generic type, some of them are specific to GPRS. Generic applications are applications like information services, Internet access, email, Web Browsing, which are very useful while mobile. These are generic mass market applications offering content like sports scores, weather, flight information, news headlines, prayer reminders, lottery results, jokes, horoscopes, traffic information and so on. Using Circuit Switched Data (CSD as in GSM), user experience for using these applications have never been enduring. Due to higher bandwidth, mobile Internet browsing will be better suited to GPRS. Access to corporate Intranet can add a new dimension to mobile workers. Mobile commerce is another generic application people may like to use while mobile. Banking over wireless is another generic application. Some Indian banks are offering banking over GPRS/WAP.

7.6.2 GPRS-Specific Applications

CMVPJUVL

Chat: Chat is a very popular service in Internet and GSM (over SMS). Groups of like-minded people use chat services as a means to communicate and discuss matters of common interest. Generally people use different chat services; one, through Internet (offered by Yahoo, ICQ, Google, etc.) and the other, using SMS (offered by mobile operators). GPRS will offer ubiquitous chat by integrating Internet chat and wireless chat using SMS and WAP.

Multimedia Service: Multimedia objects like photographs, pictures, postcards, greeting cards and presentations, static web pages can be sent and received over the mobile network. There are many phones available in the marketplace where a digital camera is integrated with the phone. These pictures can be sent as an electronic object or a printed one. Sending moving images in a mobile environment has several vertical market applications including monitoring parking lots or building sites for intruders or thieves. This can also be used by law enforcement agents, journalists, and insurance agents for sending images of accident site. Doctors can use these applications to send pictures of patients from a health center for expert help.

Virtual Private Network: GPRS network can be used to offer VPN services. Many Bank ATM machines use VSAT (Very Small Aperture Terminal) to connect the ATM system with the banks server. As the bandwidth in GPRS is higher, many banks in India are migrating from VSAT to GPRS-based networks. This is expected to reduce the transaction time by about 25%.

Personal Information Management: Personal diary, address book, appointments, engagements, etc. are very useful for a mobile individual. Some of these are kept in the phone, some in the organizer and some in the Intranet. Using J2ME and WTAI (Wireless Telephony Application Interface), the address book, the diary of the phone can be integrated with the diary at the home office. GPRS and other bearer technology will help achieve this.

Job Sheet Dispatch: GPRS can be used to assign and communicate job sheets from office-based staff to mobile field staff. Customers typically telephone a call center whose staff takes the call and categorize it. Those calls requiring a visit by field sales or service representative can then be escalated to those mobile workers. Job dispatch applications can optionally be combined with vehicle positioning applications so that the nearest available suitable personnel can be deployed to serve a customer.

Unified Messaging: Unified messaging uses a single mailbox for all messages, including voice mail, fax, e-mail, SMS, MMS, and pager messages. With the various mailboxes in one place, unified messaging systems then allow for a variety of access methods to recover messages of different types. Some will use text-to-voice systems to read e-mail and, less commonly, faxes over a normal phone line, while most will allow the interrogation of the contents of the various mailboxes through data access, such as the Internet. Others may be configured to alert the user on the terminal type of their choice when messages are received.

Vehicle Positioning: This application integrates GPS (Global Positioning System) that tell people where they are. GPS is a free-to-use global network of 24 satellites run by the US Department of Defense. Anyone with a GPS receiver can receive their satellite position and thereby find out where they are. Vehicle-positioning applications can be used to deliver several services including remote vehicle diagnostics, ad hoc stolen vehicle tracking and new rental car fleet tariffs. In India this application is becoming popular in logistics industry.

Location-based Services and Telematics: Location-based services provide the ability to link push or pull information services with a user's location. Examples include hotel and restaurant finders, roadside assistance, and city-specific news and information. All systems developed for Intelligent Transportation System (ITS) are built around GPRS and GPS technology. Location can be determined either through GPS or cell identification from the operator. This technology also has vertical applications such as workforce management and vehicle tracking.

7.8 BILLING AND CHARGING IN GPRS ✱

There is a saying in the wireless business community, "Data sells, voice pays." Tariffing of data in wireless network has always been a challenge. For voice networks tariffs are generally based on distance and time. This in other words means that users pay more for long distance calls. They also pay more if they keep the circuit busy by talking for a longer period of time. In a voice system, charging is the fundamental part of the architecture. On the other hand, data services have evolved from research and education without any concept of charging. In packet network keeping the circuit busy does not have any meaning. Also, charging a customer by the distance traversed by a packet does not make any sense. Many times due to congestions packets traverse much longer distance than the optimum distance.

7.8.1 Tariffing

The main challenge for a network operator is to integrate these two models and charge the customer. Decisions on charging for GPRS by packet or simply a flat monthly fee are contentious but need to be made. Charging different packets at different rates can make things complicated for the user, whilst flat rates favor heavy users more than occasional ones. It is believed that the optimal GPRS pricing model be based on two variables, time and packet. Network operators levy a nominal per packet charge during peak times plus a flat rate. There will be no per packet charge during non-peak times. Time and packet-related charging will encourage applications such as remote monitoring, social network and chat to use GPRS at night when spare network capacity is available. Simultaneously, a nominal per packet charge during the day will help to allocate scarce radio resources, and charge radio heavy applications such as file and image transfer more than applications with lower data intensity. It has the advantage of automatically adjusting customer charging according to their application usage.

7.8.2 Billing

GPRS is essentially a packet switching overlay on a circuit switching network. The GPRS specifications stipulate that the minimum charging information that must be collected:

- Destination and source addresses.
- Usage of radio interface.
- Usage of external packet data networks.
- Usage of the packet data protocol addresses.
- Usage of general GPRS resources and location of the mobile station.

Since GPRS networks break the information to be communicated down into packets, at a minimum, a GPRS network needs to be able to count packets to charging customers for the volume of packets they send and receive. Today's billing systems have difficulties in handling the charging process for today's data services. It is unlikely that circuit switched billing systems will be able to process a large number of new variables created by GPRS.

GPRS call records are generated in the GPRS Service Nodes. The incumbent billing systems are often not able to handle real time Call Detail Record flows. As such, an intermediary charging platform is a good idea to perform billing mediation by collecting the charging information from the GPRS nodes and preparing it for submission to the billing system. Packet counts are passed to a Charging Gateway that generates Call Detail Records that are sent to the billing system.

The billing of the services can be based on the transmitted data volume, the type of service, and the chosen QoS profile. It may well be the case that the cost of measuring packets is greater than their value. The implication is that there will not be a per packet charge since there may be too many packets to warrant counting and charging for. For example, a single traffic monitoring application can generate tens of thousands of packets per day. Thus the charging gateway function is more a policing function than a charging function since network operators are likely to tariff certain amounts of GPRS traffic at a flat rate and then need to monitor whether these allocations are far exceeded. The billing of roaming GPRS subscribers from one network to another is still a challenge.

In GPRS architecture, the Charging Gateway Functionality (CGF) provides a mechanism to transfer charging information from the SGSN and GGSN nodes to the network operator's chosen Billing Systems (BS). The Charging Gateway concept enables an operator to have just one logical interface between the CGF and the BS. Details of the GPRS charging function can be found in 3GPP TS 12.15 standards.

9.2 SPREAD-SPECTRUM TECHNOLOGY

In a conventional transmission system, the information is modulated with a carrier signal and then transmitted through a medium. When transmitted, all the power of the signal is transmitted centered around a particular frequency. This frequency represents a specific channel and generally has a very narrow band. In spread-spectrum we spread the transmission power over the complete band as shown in Figure 9.1.

In spread-spectrum the transmission signal bandwidth is much higher than the information bandwidth. There are numerous ways to cause a carrier to spread; however, all spread-spectrum systems can be viewed as two steps modulation processes. First, the data to be transmitted is modulated. Second, the carrier is modulated by the spreading code, causing it to spread out over a large bandwidth. Different spreading techniques are:

- **Direct Sequence (DS):** DS spread spectrum is typically used to transmit digital information. A common practice in DS systems is to mix the digital information stream with a pseudo random code.

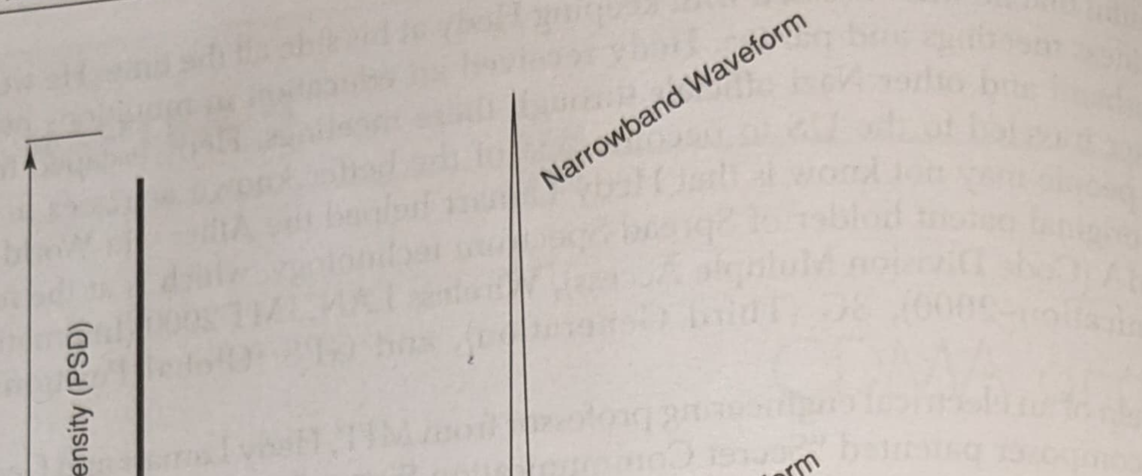


Figure 9.1 Narrow Band and Spread Spectrum

- **Frequency Hopping (FH):** Frequency hopping is a form of spreading in which the center frequency of a conventional carrier is altered many times within a fixed time period (like one second) in accordance with a pseudo-random list of channels.
- **Chirp:** The third spreading method employs a carrier that is swept over a range of frequencies. This method is called chirp spread spectrum and finds its primary application in ranging and radar systems.
- **Time Hopping:** The last spreading method is called time hopping. In a timehopped signal, the carrier is on-off keyed by the pseudo-noise (PN) sequence resulting in a very low duty cycle. The speed of keying determines the amount of signal spreading.
- **Hybrid System:** A hybrid system combines the best points of two or more spread-spectrum systems. The performance of a hybrid system is usually better than can be obtained with a single spread-spectrum technique for the same cost. The most common hybrids combine both frequency-hopping and direct-sequence techniques.

Amateurs and business community are currently authorized to use only two spreading techniques. These are frequency hopping and direct sequence techniques. Rest of the Spread-Spectrum technologies are classified and used by military and space sciences.

9.3.2 IS-95 Architecture

& Compare c GSM architecture

The Key to the North American systems is the use of a common reference model from the cellular standards group TR-45. Different network entities within IS-95 are very similar to the network elements within a GSM network.

cdmaOne or IS-95 uses CDMA for its radio or last mile communication. Other than the radio interface, the rest of the network and especially the core are very similar to GSM.

The main elements of IS-95 (Fig. 9.5) reference model are:

- *Mobile Station (MS)*: This is the mobile phone unit with the user. The MS terminates the radio path on the user side and enables the user to gain access to services from the network. The MS can be a stand-alone device. It can have other devices (e.g., personal computers, fax machines) connected to it where it works as a pass through.
- *Base Station (BS)*: The BS terminates the radio path and connects to the mobile switching center (MSC). BS is a system between the MS and the MSC. The BS is segmented into the BTS and BSC.
  - ❑ Base Transceiver Station (BTS): BTS consists of one or more transceivers placed at a single location and terminates the radio path on the network side.
  - ❑ Base Station Controller (BSC): The BSC is the control and management system for one or more BTSs. The BSC exchanges messages with both the BTS and the MSC. Some signaling messages may pass through BSC transparently.

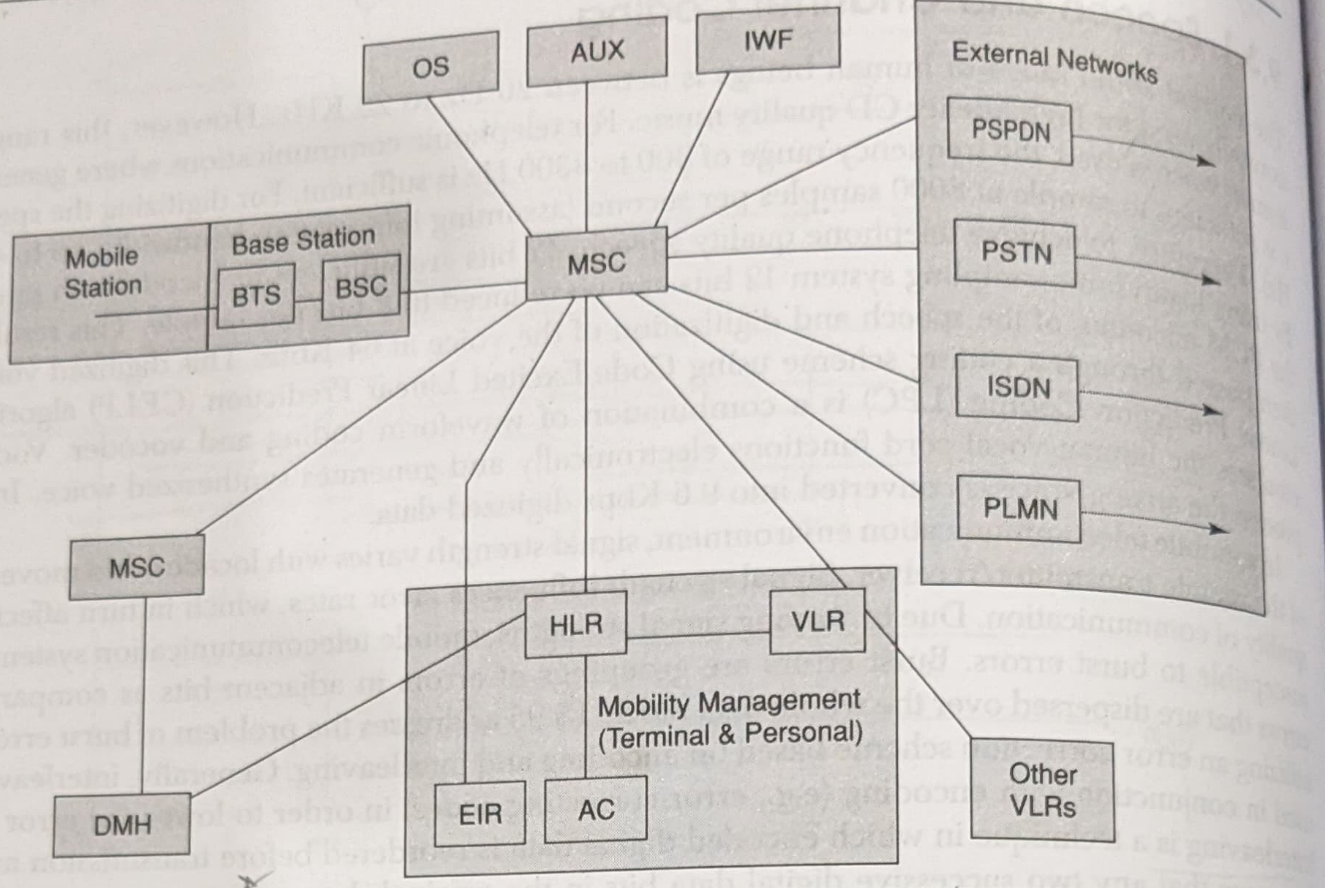


Figure 9.5 The IS-95 Architecture Model

- *Mobile Switching Center (MSC)*: This is the main switching center equivalent to the telephone exchange in a fixed network. The MSC is an automatic system that interfaces the user traffic from the wireless network with the wireline network or other wireless networks. The MSC does one or more of the following functions:
  - Anchor MSC: First MSC providing radio contact to a call
  - Border MSC: An MSC controlling BTSs adjacent to the location of the mobile station
  - Candidate MSC: An MSC that could possibly accept a call or a handoff
  - Originating MSC: The MSC directing an incoming call towards a mobile station
  - Remote MSC: The MSC at the other end of an intersystem trunk
  - Serving MSC: The MSC currently providing service to a call
  - Tandem MSC: An MSC providing only trunk connections for a call in which a handoff has occurred
  - Target MSC: The MSC selected for a handoff
  - Visited MSC: The MSC providing service to the mobile station
- *Home Location Register (HLR)*: HLR is the functional unit that manages mobile subscribers by maintaining all subscriber-related information. The HLR may be collocated with an MSC as an integral part of the MSC or may be independent of the MSC. One HLR can serve multiple MSCs or an HLR may be distributed over multiple locations.
- *Data Message Handler (DMH)*: The DMH is responsible for collating the billing data.

- *Visited Location Register (VLR)*: VLR is linked to one or more MSCs and is the functional unit that dynamically stores subscriber information obtained from the subscriber's HLR data. When a roaming MS enters a new service area covered by the MSC, the MSC informs the associated VLR about the MS by querying the HLR after the MS goes through a registration procedure. VLR can be considered as cache whereas HLR is similar to a persistent storage.
- *Authentication Center (AC)*: The AC manages the authentication associated with individual subscriber. The AC may be located within an HLR or MSC or may be located independent of both.
- *Equipment Identity Register (EIR)*: The EIR provides information about the mobile device for record purposes. The EIR may be located with the MSC or may be located independent of it.
- *Operations System (OS)*: The OS is responsible for overall management of the wireless network.
- *Interworking Function (IWF)*: The IWF enables the MSC to communicate with other networks.
- *External Networks*: These are other communication networks and can be a Public Switched Telephone Networks (PSTN), an Integrated Services Digital Network (ISDN), a Public Land Mobile Network (PLMN) or a Public Switched Packet Data Network (PSPDN).

and counter claims, it is generally believed that CDMA has high potential to address some of the difficult challenges of the past quite effectively. These are described in Table 9.1.

8 #

Table 9.1 GSM versus 3G

Functions	*GSM*	*IS-95*
Frequency	900 MHz; 1800 MHz (DCS180); 1900 MHz (PCS 1900)	800 MHz; 1900 MHz
Channel bandwidth	Total 25 MHz bandwidth with 200 KHz per channels, 8 timeslots per channel with frequency hopping	Total 12 MHz with 1.25 MHz for the spread spectrum
Voice codec	13 Kbits/second	8 Kbits/sec or 13 Kbps
Data bit rate	9.6 Kbits/second and expandable	9.6 Kbits
Short message service	160 characters of text Supports	120 characters
SIM card	Yes	No
Multipath	Causes interference and destruction to service	Used as an advantage
Radio interface	TDMA	CDMA
Handoff	Hard Handover (handoff)	Soft Handoff (handover)
System Capacity	Fixed and limited	Flexible and higher than GSM
Economics	Expensive	Due to many technological advantages, dimension of investment per subscriber is expected to be lower than GSM

9.5 WIRELESS DATA

Data transmission over wireless networks like CDMA or GSM is always a challenge. Typically raw channel data error rates for cellular transmission are 10^{-2}. This means that one in every 100 bits has an error. This is an error rate, which can be tolerated for voice transmission. This is because; our perception of hearing cannot detect it. Even if our ear is sometime able to detect it, our mind is able to correct it from the context. This error rate of 10^{-2} is too high for data transmission. An acceptable BER (Bit Error Rate) for data transmission is 10^{-6}. This means that one bit in a million can be tolerated as an error. In order to achieve this high level of reliability, it requires a design of effective error correction code and Automatic Repeat Request (ARQ). The CDMA protocol stack (Fig. 9.8) for data and facsimile has the following layers.

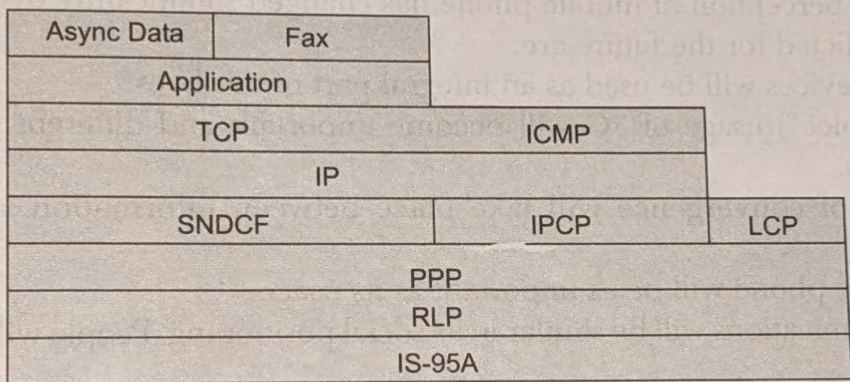
Application Interface Layer: This layer includes an application interface between the data source in the mobile station and the transport layer. The application interface provides functions like modem control, AT (Attention) command processing, data compression, etc.

Transport Layer: The transport layer for CDMA asynchronous data and fax is based on TCP. TCP has been modified for IS-95.

Network Layer: The network layer for CDMA asynchronous data and fax services is based on IP. The standard IP protocol has been enhanced for IS-95.

Sub-network Dependent Convergence Function: The SNDCF performs header compression on the header of the transport and network layers. Mobile station supports Van Jacobson TCP/IP header compression algorithm. Negotiation of the parameters for header compression is carried out using IPCP (Internet Protocol Control Protocol). The SNDCF sublayer accepts the network layer datagram packets from the network layer, performs header compression and passes that datagram to the PPP (Point to Point Protocol) layer. In the reverse operation, it receives network layer datagrams with compressed header from the PPP layer and passes it to the network layer.

Data Link Layer: This layer uses PPP. The PPP Link Control Protocol (LCP) is used for initial link establishment and for the negotiation of optional link capabilities.



ICMP : Internet Control Message Protocol
IP : Internet Protocol
IPCP : Internet Protocol Control Protocol
LCP : Link Control Protocol
PPP : Point-to-Point Protocol
RLP : Radio Link Protocol
SNDCF : Subnetwork Dependent Convergence Function
TCP : Transmission Control Protocol

Figure 9.8 CDMA Data Protocol Stack

Internet Protocol Control Protocol Sublayer: This sublayer supports negotiation of the IP address and IP compression protocol parameters. In general, a mobile station does not have a permanent IP address. Therefore, the IP address needs to be negotiated and obtained from the network. IPCP does this job of leasing an IP address when the transport connection is established. The IP address is discarded when the connection is closed. This is similar to obtaining the IP address from a DHCP (Dynamic Host Configuration Protocol) server in a LAN environment.

Radio Link Protocol Layer: This layer provides octet stream service over the air. This service is responsible for reducing the error rate over the forward and reverse channels. There is no direct