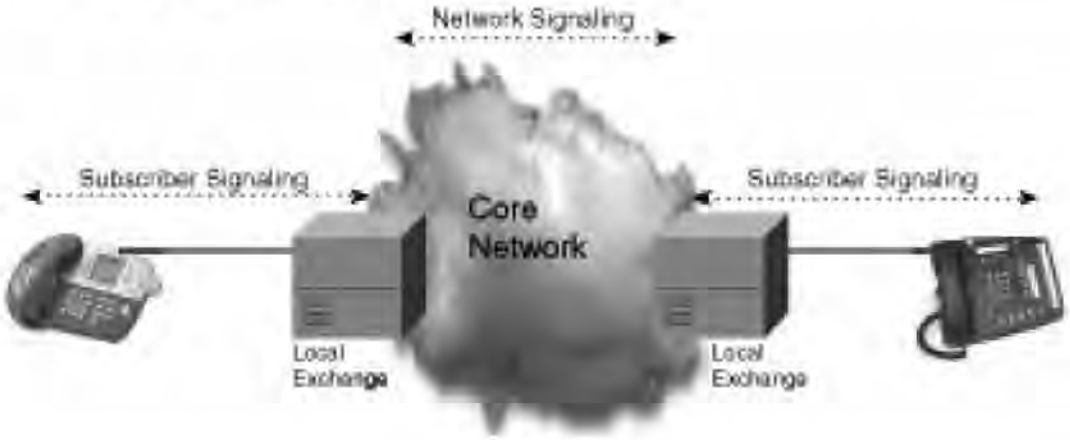
Network Signaling

As previously described, network signaling takes place between nodes in the core network. This is generally from the local switch, through the core network, and to the destination local switch—in other words, between the calling and the called party switch.

Figure 1-3 shows where subscriber and network signaling occur in the PSTN.

Figure 1-3 *Subscriber and Network Signaling*



For obvious reasons, the signaling system employed on the local loop (between the subscriber and the local switch) differs from that which is used in the core network. The subscriber must only generate a limited number of signals: on or off hook, called party digits, and possibly a few commands for supplementary services. In comparison, a modern core network must perform very complex signaling, such as those to support database driven services like Local Number Portability (LNP), credit or calling card validation, and cellular roaming. Therefore, subscriber signaling systems are simple compared to modern network signaling systems.

Network signaling was previously implemented using *Channel Associated Signaling (CAS)* techniques and systems. However, for the past two decades, it has been replaced with *Common Channel Signaling (CCS)* systems. Apart from a rare trace of Signaling System No. 6 (SS6) signaling, System No. 7 (SS7) is almost the exclusive CSS system; thus, CCS can almost be taken to refer exclusively to the use of SS7. The remaining sections of this chapter discuss CAS and CCS methods.

Channel Associated Signaling

The key feature that distinguishes Channel Associated Signaling (CAS) from CCS is the deterministic relationship between the call-control signals and the bearers (voice circuits) they control in CAS systems. In other words, a dedicated fixed signaling capacity is set aside for each and every trunk in a fixed, pre-determined way.

Channel Associated Signaling (CAS) is often still used for international signaling; national systems in richer nations almost exclusively use Common Channel Signaling (CCS). CCS is replacing CAS on international interfaces.

CAS can be implemented using the following related systems:

- Bell Systems MF, R2, R1, and C5.
- Single-frequency (SF) in-band and out-of-band signaling
- Robbed bit signaling

The following sections discuss these methods in context with the type of signal, either address or supervisory.

Address Signals

Multifrequency systems, such as the Bell System MF, R2, R1, and C5, are all types of address signals used by CAS.

Multifrequency

The CAS system can be used on either analog Frequency Division Multiplexed (FDM) or digital Time Division Multiplexed (TDM) trunks. MF is used to signal the address digits between the switches.

Multifrequency (MF) signaling can still be found in traces within the United States, and it is still often found on international interfaces. On international interfaces outside of North America, MF is still used via the CCITT System 5 (C5) implementation. C5 is quite similar to Bell MF and was developed jointly by Bell Laboratories and the British Post Office [102]. R2 is the MF system that was deployed outside North America and is still used in less developed nations. R2 was developed by CEPT (which later became ETSI; see Chapter 2) and was previously known as Multifrequency Compelled (MFC) signaling. The CCITT later defined an international version; see Chapter 2 for additional information regarding the international version [102].

MF simultaneously sends two frequencies, from a choice of six, to convey an address signal. The switch indicates to the switch on the other end of a trunk that it wishes to transmit address digits by sending the KP (start pulsing) signal, and indicates the end of address digits by sending the ST (end pulsing) signal. The timing of MF signals is a nominal 60 ms, except for KP, which has a nominal duration of 100 ms. A nominal 60 ms should be between digits.

Table 1-3 shows the tone combinations for Bell System MF, R1, and C5. R2 tone combinations are not shown.

Table 1-3 *Tones Used to Create MF Signals*

Digit	Frequencies					
	700	900	1100	1300	1500	1700
1	+	+				
2	+		+			
3		+	+			
4	+			+		
5		+		+		
6			+	+		
7	+				+	
8		+			+	
9			+		+	
0				+	+	
KP			+			+
ST					+	+
11 (*)	+					+
12 (*)		+				+
KP2 (*)				+		+

* = Used only on CCITT System 5 (C5) for international calling.

As stated, many international trunks still use C5. Signal KP2 indicates that the number is an international number; by inference, KP indicates that the number is a national number. International operators also use codes 11 and 12. More details on C5 are available in ITU-T Q.152. Supervision signals for MF systems are performed on FDM trunks by the use of Single Frequency (SF), which we describe in the following section.

For circuit supervision, both Bell System MF and R1 use Single Frequency (SF) on FDM trunks and employ robbed bit signaling on TDM controlled trunks. C5 uses a different set of MF tones for supervisory signaling.

Supervisory Signals

Single frequency systems, robbed bit signaling, and digital signaling are all types of *supervisory signals* used by CAS.

Single Frequency(SF)

Single Frequency (SF) was used for supervisory signaling in analog CAS-based systems. North America used a frequency of 2600 Hz (1600 Hz was previously used), and Great Britain used 2280 Hz (as defined in British Telecom's SSAC15 signaling specification). When in an on-hook state, the tone is present; when in an off-hook state, the tone is dropped.

NOTE Supervisory signals operate similarly to those used in access signaling; however, they signal the trunk state between two switches rather than the intention to place or terminate a call. Supervisory signals are also known as line signals.

Table 1-4 details the tone transitions Bell System MF and R1 use to indicate the supervision signals. C5 uses a combination of both one and two in-band signaling tones, which are not presented here.

Table 1-4 *Bell System MF and R1 Supervision Signaling*

Direction	Signal Type	Transition
Forward	Seizure	On-hook to off-hook
Forward	Clear-forward	Off-hook to on-hook
Backward	Answer	On-hook to off-hook
Backward	Clear-back	Off-hook to on-hook
Backward	Proceed-to-send (wink)	Off-hook pulse, 120–290 ms

As with the MF address signaling, SF is sent switch to switch. A trunk is initially on-hook at both ends. One of the switches sends a forward off-hook (seizure) to reserve a trunk. The receiving switch indicates that it is ready to receive address digits, (after connecting a digit received by the line by sending a wink signal. When the originating switch receives the wink signal, it transmits the digits of the called party number. When a call is answered, the called parties switch sends an off-hook signal (answer). During the conversation phase, both ends at each trunk are off-hook. If the calling a party clears the call, it sends a clear-forward signal; likewise, when the called party hangs up, it sends a clear-backward signal.

SF uses an *in-band* tone. In-band systems send the signaling information within the user's voice frequency range (300 Hz to 3400 Hz). A major problem with in-band supervisory signaling, however, is its susceptibility to fraud. The hacker quarterly magazine "2600" was named for the infamous 2600 Hz tone, which could be used by the public to trick the phone system into giving out free calls. The subscriber could send supervisory tone sequences down his telephone's mouthpiece using a handheld tone generator. This enabled the subscriber to instruct switches and, in doing so, illegally place free telephone calls.

The other major problem with in-band signaling is its contention with user traffic (speech). Because they share the same frequency bandwidth, only signaling or user traffic can be present at any one time. Therefore, in-band signaling is restricted to setting up and clearing calls down only because signaling is not possible once a call is in progress.

Subscriber Line Signaling

A regular subscriber line (that is analog) still uses in-band access signaling. For example, DTMF is used to signal the dialed digits and the frequencies used are within the voice band (see Table 1-1). You can prove that DTMF uses in-band signaling by using a device, such as a computer, to generate the tones for each digit (with correct pauses). Simply play the tones from the computer speaker down the mouthpiece of a touch-tone telephone. This allows you to dial a number without using the telephone keypad. Because the signaling is sent down the mouthpiece, you can be certain that it traveled within the user's voice frequency range.

FDM analog systems nearly always reserve up to 4000 Hz for each circuit, but only use 300–3400 Hz for speech; therefore, signaling is sent above the 3400 Hz (and below 4000 Hz). This is known as out-of-band signaling and is used in R2 for supervisory signaling. Unlike with in-band signaling, no contention exists between user traffic and signaling. North America uses a frequency of 3700 Hz, and CCITT (international) uses 3825 Hz. Table 1-5 details the tone transitions that indicate the supervision signals used in R2 and R1.

Table 1-5 *R2 Supervision Signaling*

Direction	Signal Type	Transition
Forward	Seizure	Tone-on to tone-off
Forward	Clear-forward	Tone-off to tone-on
Backward	Answer	Tone-on to tone-off
Backward	Clear-back	Tone-off to tone-on
Backward	Release-guard	450 ms tone-off pulse
Backward	Blocking	Tone-on to tone-off

R2 does not use a proceed-to-send signal; instead, it includes a blocking signal to stop the circuit that is being seized while maintenance work is performed on the trunk. The release guard signal indicates that the trunk has been released after a clear-forward signaling, thereby indicating that the trunk can be used for another call.

Digital

Supervisory signaling can be performed for R2 on digital TDM trunks. On an E1 facility, timeslot 16 is set aside for supervisory signaling bits (TS16). These bits are arranged in a multiframe structure so that specific bits in the multiframe's specific frames represent the signaling information for a given TDM audio channel. See Chapter 5, "The Public Switched Telephone Network (PSTN)," for explanation of facilities and timeslots.

Limitations of CAS

We discuss the general disadvantages of CAS for the purpose of reinforcing the concepts and principles we have introduced thus far. CAS has a number of limitations, including:

- Susceptibility to fraud
- Limited signaling states
- Poor resource usage/allocation

The following sections discuss these limitations in more detail.

Susceptibility to Fraud

CAS employing in-band supervisory signaling is extremely susceptible to fraud because the subscriber can generate these signals by simply using a tone generator down a handset mouthpiece. This type of device is known as a *blue box*; from the beginning of the 1970s, it could be purchased as a small, handheld keypad. Blue box software was available for the personal computer by the beginning of the 1980s.

Limited Signaling Information

CAS is limited by the amount of information that can be signaled using the voice channel. Because only a small portion of the voice band is used for signaling, often CAS cannot meet the requirements of today's modern networks, which require much higher bandwidth signaling.

Inefficient Use of Resources

CAS systems are inefficient because they require either continuous signaling or, in the case of digital CAS, at regular intervals even without new signals.

In addition, there is contention between voice and signaling with in-band CAS. As a result, signaling is limited to call set-up and release phases only. This means that signaling cannot take place during the call connection phase, severely imposing technological limits on the system's complexity and usefulness.

Common Channel Signaling (CCS)

CCS refers to the situation in which the signaling capacity is provided in a common pool, with the capacity being used as and when necessary. The signaling channel can usually carry signaling information for thousands of traffic circuits.

In North America, signaling can be placed on its own T1 carrier even though it only takes up one timeslot. This means that two physical networks, "speech" and "signaling," can have different routings. (Please refer to Chapter 5 for a description of carriers and timeslots.) Alternatively, the signaling might exist on a carrier with other user traffic, depending on the network operator.

Outside of North America, the signaling is placed in its own timeslot on an E1 (that is, logically rather than physically separated). The other timeslots on E1 are for user traffic—apart from TS0, which is used for synchronization. E1 systems tend to use the TS16 timeslot for signaling; some core network equipment ignores TS16, expecting it to be used for signaling traffic because it has historically been the timeslot for digital CAS signaling.

The only CCS systems that have been implemented to date are Signaling Systems No. 6 and No. 7 (SS6 and SS7). The ITU for the international network originally standardized SS6, but they saw limited deployment. AT&T nationalized SS6 for the North American network and called it Common Channel Interoffice Signaling (CCIS) No. 6. SS6 saw a limited deployment after the mid-1970s because it had far less bandwidth and a much smaller packet size than SS7. In addition, its evolutionary potential was severely limited because it was not a layered protocol architecture.

CCS systems are packet-based, transferring over 200 bytes in a single SS7 packet, as opposed to a few bits allocated to act as indicators in digital CAS. The signaling information is transferred by means of *messages*, which is a block of information that is divided into fields that define a certain parameter or further sub-field. The signaling system's specifications (Recommendations and Standards) define the structure of a message, including its fields and parameters.

Because CCS is packet-based and there is not a rigid tie between the signaling and the circuits it controls, it can operate in two distinct ways. These two distinct ways are circuit-related signaling and non-circuit-related signaling.

Circuit-Related Signaling

Circuit-related signaling refers to the original functionality of signaling, which is to establish, supervise, and release trunks. In other words, it is used to set up, manage, and clear down basic telephone service calls. Circuit-related signaling remains the most common mode of signaling. As it is with CAS, signaling capacity is not pre-allocated for each traffic circuit. Rather, it is allocated as it is required. Each signaling message is related to a traffic circuit. Because no dedicated relationship exists between the circuits and the signaling, it is necessary to identify the traffic circuit to which a particular signal message refers. This is achieved by including a circuit reference field in each signaling message.

Non-Circuit-Related Signaling

Non-circuit-related signaling refers to signaling that is not related to the establishment, supervision, and release of trunks. Due to the advent of supplementary services and the need for database communication in cellular networks and Intelligent Networks, for example, signaling is no longer exclusively for simply setting up, managing, and clearing down traffic circuits. Non-circuit-related signaling allows the transfer of information that is not related to a particular circuit, typically for the purpose of transmitting both the query and response to and from telecommunication databases. Non-circuit-related signaling provides a means for transferring data freely between network entities without the constraint of being related to the control of traffic circuits.

Common Channel Signaling Modes

A signaling mode refers to the relationship between the traffic and the signaling path. Because CCS does not employ a fixed, deterministic relationship between the traffic circuits and the signaling, there is a great deal of scope for the two to have differing relationships to each other. These differing relationships are known as *signaling modes*.

There are three types of CCS signaling modes:

- Associated
- Quasi-associated
- Non-associated

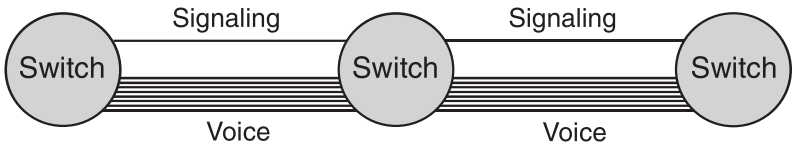
SS7 runs in associated or quasi-associated mode, but not in non-associated mode. Associated and quasi-associated signaling modes ensure sequential delivery, while non-associated does not. SS7 does not run in non-associated mode because it does not have procedures for reordering out-of-sequence messages.

Associated Signaling

In *associated* mode, both the signaling and the corresponding user traffic take the same route through the network. Networks that employ only associated mode are easier to design

and maintain; however, they are less economic, except in small-sized networks. Associated mode requires every network switch to have signaling links to every other interconnected switch (this is known as a fully meshed network design). Usually a minimum of two signaling links are employed for redundancy, even though the switched traffic between two interconnected switches might not justify such expensive provisioning. Associated signaling mode is the common means of implementation outside of North America. Figure 1-4 illustrates the associated concept.

Figure 1-4 *Associated Mode*

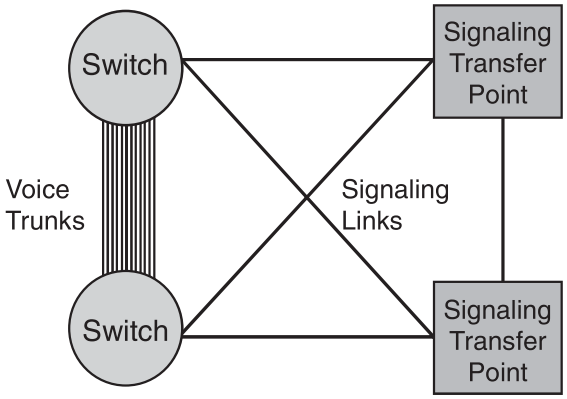


Quasi-Associated Signaling

In *quasi-associated* mode, signaling follows a different route than the switched traffic to which it refers, requiring the signaling to traverse at least one intermediate node. Quasi-associated networks tend to make better use of the signaling links; however, it also tends to create a more complex network in which failures have more potential to be catastrophic.

Quasi-associated signaling can be the most economical way of signaling for lightly loaded routes because it avoids the need for direct links. The signaling is routed through one or more intermediate nodes. Signaling packets arrive in sequence using quasi-associated signaling because the path is fixed for a given call (or database transaction) at the start of a call (or transaction). Figure 1-5 shows the quasi-associated signaling mode, which is the common means of implementation within North America.

Figure 1-5 *Quasi-Associated Mode*



Non-Associated Signaling

Because the path is not fixed at a given point in time in *non-associated* mode, the signaling has many possible routes through the network for a given call or transaction. Therefore, the packets might arrive out of sequence because different routes might have been traversed.

SS7 does not run in non-associated mode because no procedures exist for reordering out-of-sequence messages. Associated and quasi-associated signaling modes assure sequential delivery, while non-associated signaling does not. Quasi-associated mode is a limited case of non-associated mode, in which the relative path is fixed.

Summary

CCS has evolved to address the limitations of the CAS signaling method. CCS has the following advantages over CAS:

- Much faster call set-up time
- Greater flexibility
- Capacity to evolve
- More cost effective than CAS
- Greater call control

Most CCS calls can be set up in half the time it takes to set up CAS calls. CCS achieves greater call control because no contention exists between signaling and user traffic as it does with in-band CAS. Because the subscriber cannot generate particular signals intended for inter-switch (core network) signaling, CCS offers a greater degree of protection against fraud than analog CAS methods.

CCS has the following disadvantages in comparison to CAS:

- CCS links can be a single point of failure—a single link can control thousands of voice circuits, so if a link fails and no alternative routes are found, thousands of calls could be lost.
- There is no inherent testing of speech path by call set-up signaling, so elaborate Continuity Test procedures are required.

CHAPTER 3

The Role of SS7

The purpose of this chapter is to introduce Signaling System No. 7 (SS7/C7) and give the reader an indication of how it affects the lives of nearly two billion people globally. The chapter begins by providing a brief introduction to the major services that SS7/C7 provides and explains how the protocol has been and will continue to be a key enabler of new telecommunication services. It concludes with an explanation of why SS7/C7 is a cornerstone of convergence.

SS7/C7 is the protocol suite that is employed globally, across telecommunications networks, to provide signaling; it is also a private, "behind the scenes," packet-switched network, as well as a service platform. Being a signaling protocol, it provides the mechanisms to allow the telecommunication network elements to exchange control information.

AT&T developed SS7/C7 in 1975, and the *International Telegraph and Telephone Consultative Committee* (CCITT) [109] adopted it in 1980 as a worldwide standard. For more information on the standards bodies, see Chapter 2, "Standards." Over the past quarter of a century, SS7 has undergone a number of revisions and has been continually enhanced to support services that are taken for granted on a daily basis.

SS7/C7 is the key enabler of the public switched telephone network (PSTN), the integrated services digital network (ISDN), intelligent networks (INs), and public land mobile networks (PLMNs).

Each time you place and release a telephone call that extends beyond the local exchange, SS7/C7 signaling takes place to set up and reserve the dedicated network resources (trunk) for the call. At the end of the call, SS7/C7 takes action to return the resources to the network for future allocation.

TIP Calls placed between subscribers who are connected to the same switch do not require the use of SS7/C7. These are known as intraoffice, intraexchange, or line-to-line calls.

Each time a cellular phone is powered up, SS7/C7-based transactions identify, authenticate, and register the subscriber. Before a cellular call can be made, further transactions check

that the cellular phone is not stolen (network dependent option) and qualify permission to place the call (for example, the subscriber may be barred from International usage). In addition, the SS7/C7 network tracks the cellular subscriber to allow call delivery, as well as to allow a call that is already in progress to remain connected, even when the subscriber is mobile.

Although the average person typically uses SS7/C7 several times a day, it is largely unheard of by the general public because it is a "behind the scenes" private network—in stark contrast to IP. Another reason for its great transparency is its extreme reliability and resilience. For example, SS7/C7 equipment must make carrier grade quality standards—that is, 99.999 percent availability. The three prime ways it achieves an industry renowned robustness is by having a protocol that ensures reliable message delivery, self-healing capabilities, and an over-engineered physical network.

Typically, the links that comprise the network operate with a 20–40 percent loading and have full redundancy of network elements. SS7/C7 might well be the most robust and reliable network in existence.

SS7/C7 is possibly the most important element from a *quality of service* (QoS) perspective, as perceived by the subscriber.

NOTE Here QoS refers to the quality of services as perceived by the subscriber. It should not be confused with QoS as it relates specifically to packet networks.

QoS is quickly becoming a key in differentiating between service providers. Customers are changing service providers at an increasing pace for QoS reasons, such as poor coverage, delays, dropped calls, incorrect billing, and other service-related impairments and faults. SS7/C7 impairments nearly always impact a subscriber's QoS directly. A complete loss of signaling means a complete network outage, be it a cellular or fixed-line network. Even a wrongly-provisioned screening rule at a SS7/C7 node in a cellular network can prohibit subscribers from roaming internationally or sending text messages. A loss of one signaling link could potentially bring down thousands of calls. For this reason, the SS7/C7 network has been designed to be extremely robust and resilient.

Impact of SS7 Network Failure

The critical nature of the SS7 network and the potential impact of failures was demonstrated in January 1990 when a failure in the SS7 software of an AT&T switching node rippled through over 100 switching nodes. The failure caused a nine-hour outage, affecting an estimated 60,000 people and costing in excess of 60 million dollars in lost revenue as estimated by AT&T.

Signaling System No. 7-Based Services

In addition to setting up and releasing calls, SS7/C7 is the workhorse behind a number of telecommunication services, including:

- Telephone-marketing numbers such as toll-free and freephone
- Televoting (mass calling)
- Single Directory Number
- *Enhanced 911* (E911)—used in the United States
- Supplementary services
- Custom local area signaling services (CLASS)
- Calling name (CNAM)
- Line information database (LIDB)
- Local number portability (LNP)
- Cellular network mobility management and roaming
  - Short Message Service (SMS)
  - *Enhanced Messaging Service* (EMS)—Ringtone, logo, and cellular game delivery
- Local exchange carrier (LEC) provisioned private virtual networks (PVNs)
- Do-not-call enforcement

The following sections describe these telecommunications services.

Telephone-Marketing Numbers

The most commonly used telephone-marketing numbers are *toll-free* calling numbers (800 calling), known as *freephone* (0800) in the United Kingdom. Because the call is free for the caller, these numbers can be used to win more business by increasing customer response. Telephone-marketing numbers also provide premium rate lines in which the subscriber is charged at a premium in exchange for desired content. Examples of such services include adult services and accurate road reports.

Another popular telephone-marketing number is *local call*, with which a call is charged as a local call even though the distance might be national. In recent years in the United Kingdom, marketing numbers that scarcely alter the call cost have been a popular means of masking geographical location. These numbers allow for a separation between the actual number and the advertised number.

Televoting

Televoting is a mass calling service that provides an easy method of surveying the public on any imaginable subject. The host (for example, a deejay at a radio station) presents specific questions and the caller uses a telephone keypad to select a choice; the caller's action adds to the vote for that particular choice. The conversation phase is usually limited to a simple, automated "thank you for…" phrase. Televoting can also be used in many other areas, such as responding to fundraising pleas and telephone-based competitions. A single night of televoting might result in 15 million calls [110]. Televoting services represent some of the most demanding—as well as lucrative—call scenarios in today's telephone networks. Revenue generation in this area is likely to grow as customers shift more toward an "interactive" experience, on par with convergence.

Single Directory Number

Another service that uses SS7/C7 and has been deployed in recent years is the single directory number, which allows a company with multiple offices or store locations to have a single directory number. After analyzing the calling party's number, the switch directs the call to a local branch or store.

Enhanced 911

E911, which is being deployed across some states in the United States, utilizes SS7 to transmit the number of the calling party, look up the corresponding address of the subscriber in a database, and transmit the information to the emergency dispatch operator to enable a faster response to emergencies. E911 might also provide other significant location information, such as the location of the nearest fire hydrant, and potentially the caller's key medical details. The *Federal Communications Commission* (FCC) also has a cellular 911 program in progress; in addition to providing the caller's telephone number, this program sends the geographical location of the antenna to which the caller is connected. Enhancement proposals are already underway to obtain more precise location information.

Supplementary Services

Supplementary services provide the subscribers with more than *plain old telephony service* (POTS), without requiring them to change their telephone handsets or access technology. Well-known supplementary services include three-way calling, *calling number display* (CND), call-waiting, and call forwarding. Note that the exact names of these services might differ, depending on the country and the operator.

Recently, supplementary services have been helpful in increasing operators' revenues since revenues against call minutes have been on the decline. Usually the subscriber must pay a fixed monthly or quarterly fee for a supplementary service.

Custom Local Area Signaling Services (CLASS)

Custom local area signaling services (CLASS) are an extension of supplementary services that employ the use of SS7 signaling between exchanges within a local geographical area. Information provided over SS7 links, such as the calling party number or the state of a subscriber line, enable more advanced services to be offered by service providers. A few examples of CLASS services include:

- **Call block**—Stops pre-specified calling party numbers from calling.
- **Distinctive ringing**—Provides a distinct ringing signal when an incoming call originates from a number on a predefined list. This feature is particularly beneficial to households with teenagers.
- **Priority ringing**—Provides a distinct ring when a call originates from a pre-specified numbers. If the called subscriber is busy and has *call waiting,* the subscriber receives a special tone indicating that a number on the priority list is calling.
- **Call completion to busy subscriber (CCBS)**—If a subscriber who has CCBS calls a party who is engaged in another call, the subscriber can activate CCBS with a single key or sequence. When activated, CCBS causes the calling party's phone to ring when the called party becomes available; when the calling party answers, the called party's phone automatically rings again. This feature saves the calling party from continuously attempting to place a call to a party is still unavailable.

Note that the exact names of these services might differ, depending on the country and the operator. In addition, the term "CLASS" is not used outside of North America.

Calling Name (CNAM)

Calling name (CNAM) is an increasingly popular database-driven service that is only available in the United States at this time. With this service, the called party receives the name of the person calling in addition to their number. The called party must have a compatible display box or telephone handset to use this service. The CNAM information is typically stored in regional telecommunications databases. SS7/C7 queries the database for the name based on the number and delivers the information to the called party's local switch.

Line Information Database (LIDB)

Line information database (LIDB) is a multipurpose database that stores valuable information about individual subscribers to provide feature-based services (it is only available in the United States at this time). Such information might include the subscriber's profile, name and address, and billing validation data. The name and address information can be used to power CNAM, for example. The billing validation data is used to support alternate billing services such as calling card, collect, and third number billing. Alternate billing services allow subscribers to bill calls to an account that is not necessarily associated with the originating line. For example, it can be used to validate a subscriber's calling card number that is stored in the LIDB, designating this as the means of payment. SS7/C7 is responsible for the real-time database query/response that is necessary to validate the calling card before progressing to the call setup phase.

Local Number Portability (LNP)

Local number portability (LNP) provides the option for subscribers to retain their telephone number when changing their telephone service. There are three phases of number portability:

- Service Provider Portability
- Service Portability
- Location Portability

The various phases of LNP are discussed in more detail in Chapter 11, "Intelligent Networks."

The FCC mandated this feature for fixed-line carriers in the United States as part of the Telecommunications Act of 1996; later that same year, the act was also clarified to cover cellular carriers.

LNP is primarily aimed at stimulating competition among providers by removing the personal inconvenience of changing phone numbers when changing service providers. For example, many businesses and individuals spend relatively large sums of money to print their phone numbers on business cards, letterheads, and other correspondence items. Without LNP, people would have to reprint and redistribute these materials more often. This contributes to the inconvenience and detracts from the profitability of changing the telephone number, thereby making changing providers far more prohibitive.

Since telephone networks route calls based on service provider and geographic numbering plan information, SS7/C7 must figure out where the ported number's new terminating switch is by performing additional signaling before setting the call up. This step should add only a second to the call overhead setup; however, it is a technically challenging network change because it complicates the process by which SS7/C7 establishes a call behind the scenes. This process is further discussed in Chapter 8, "ISDN User Part (ISUP)."

2nd and 3rd Generation Cellular Networks

Cellular networks use SS7/C7 for the same reasons they use fixed line networks, but they place much higher signaling demands on the network because of subscriber mobility. All cellular networks, from 2G (GSM, ANSI-41, and even PDC, which is used in Japan) to 3G (UMTS and cdma2000), use SS7/C7 for call delivery, supplementary services, roaming, mobility management, prepaid, and subscriber authentication. For more information, see Chapter 13, "GSM and ANSI-41 Mobile Application Part (MAP)."

Short Message Service (SMS)

Short Message Service (SMS) forms part of the GSM specifications and allows two-way transmission of alphanumeric text between GSM subscribers. Although it is just now catching on in North America, SMS has been an unexpected and huge revenue source for operators around the world. Originally, SMS messages could be no longer than 160 alphanumeric characters. Many handsets now offer concatenated SMS, which allows users to send and receive messages up to 459 characters (this uses EMS described below). Cellular operators usually use SMS to alert the subscribers that they have voice mail, or to educate them on how to use network services when they have roamed onto another network. Third party companies offer the additional delivery services of sending SMS-to-fax, fax-to-SMS, SMS-to-e-mail, e-mail-to-SMS, SMS-to-web, web-to-SMS, and SMS notifications of the arrival of new e-mail.

Some European (Spain, Ireland, and Germany, for example) and Asian countries (the Philippines, for example) are rolling out fixed-line SMS, which allows users to send SMS through their fixed phone line to cell phones and vice versa, as well as to other fixed-line SMS-enabled phones, fax machines, e-mail, and specialized web pages. Thus far, each European rollout has also offered SMS-to-voice mail. If a caller sends a text message to a subscriber without fixed-line SMS facility, the SMS is speech-synthesized to the subscriber's and their voice mailbox. Fixed-line SMS requires compatible phones, which are becoming readily available.

SMS is carried on the SS7/C7 network, and it makes use of SS7/C7 for the required signaling procedures. For more information, see Chapter 13, "GSM and ANSI-41 Mobile Application Part (MAP)."

Enhanced Messaging Service (EMS)

Enhanced Messaging Service (*EMS*) adds new functionality to the SMS service in the form of pictures, animations, sound, and formatted text. EMS uses existing SMS infrastructure and consists largely of header changes made to a standard SMS message. Since EMS is simply an enhanced SMS service, it uses the SS7/C7 network in the same way; the SS7/C7 network carries it, and it uses SS7/C7 for the required signaling procedures.

EMS allows users to obtain new ring tones, screensavers, pictures, and animations for their cell phones either by swapping with friends or purchasing them online.

Operators have recently begun using EMS for downloading games (from classics like Asteroids, to newer games like Prince of Persia), which can be purchased from operator web sites.

Private Virtual Networks

Although the *private virtual networks* concept is not new, SS7/C7 makes it possible for a *Local exchange carrier* (LEC) to offer the service. The customer receives PVNs, which are exactly like leased (private) lines except that the network does not allocate dedicated physical resources. Instead, SS7/C7 signaling (and a connected database) monitors the "private customer" line. The customer has all the features of a leased-line service as well as additional features, such as the ability to request extra services ad hoc and to tailor the service to choose the cheapest *inter-exchange carrier* (IC), depending on the time of day, day or week, or distance between the two parties.

Do-Not-Call Enforcement

In the United States, federal and state laws have already mandated do-not-call lists [108] in over half the states, and all states are expected to follow suit. These laws restrict organizations (typically telemarketers) from cold-calling individuals. To comply with these laws, SS7 can be used to query state and federal do-not-call lists (which are stored on a database) each time a telemarketer makes an outbound call. If the number is on a do-not-call list, the call is automatically blocked and an appropriate announcement is played to the marketer.

Signaling System No. 7: The Key to Convergence

Telecommunications network operators can realize increased investment returns by marrying existing SS7/C7 and intelligent networking infrastructures with Internet and other data-centric technologies. SS7/C7 is a key protocol for bridging the telecom and datacom worlds.

The following sections describe the exemplar hybrid network services that SS7/C7 enable:

- Internet Call Waiting
- Internet Calling Name Services
- Click-to-Dial Applications
- Web-Browser-Based Telecommunication Services
- WLAN "Hotspot" Billing
- Location-Based Games

Internet Call Waiting and Internet Calling Name Services

Internet call waiting is a software solution that alerts online Internet users with a call-waiting message on their computer screens when a telephone call enters the same phone line they use for their Internet service. The user can then send the call to voice mail, accept the call, or reject it.

Some providers linking it to CNAM, as mentioned in Calling Name (CNAM), have enhanced the Internet call-waiting service. This service is known as Internet calling name service, and it provides the calling party's name and number.

Click-to-Dial Applications

Click-to-dial applications are another SS7-IP growth area. An example of a click-to-dial application is the ability to click a person's telephone number in an email signature to place a call. These types of services are particularly beneficial to subscribers because they do not require them to change their equipment or access technologies; a POTS and a traditional handset are the only requirements.

Web-Browser-Based of Telecommunication Services

Over the coming decade, we are likely to witness an increase in web based telecommunications services. An example is customer self-provisioning via the Internet, a practice that has been in the marketplace for some time and is likely to increase in both complexity and usage. A customer can already assign himself a premium or toll-free "number for life" via the Internet. The customer can subsequently use a Web interface to change the destination number it points to at will, so that during the day it points to the customer's office phone, and in the evening it points to the customer's cell phone, and so forth.

Another example is the "call me" service, which allows a customer to navigate a Web page to arrange a callback from a department, rather than navigating interactive voice response (IVR) systems through the use of voice prompts and a touch-tone phone.

The potential extends far beyond traditional telecommunications services, to the point where the distinction between Web and telecommunications services is blurred. An example of such an enabling technology is Voice Extensible Markup Language (VoiceXML), which extends Web applications to telephones and shields application authors from low-level, platform-specific *interactive voice response* (IVR) and call control details.

The marriage is not only between SS7/C7, the Internet, and fixed-line networks—it also extends to cellular networks. Plans are underway to put the location-based information and signaling found in cellular networks into hybrid use. For example, Web-based messenger services could access cellular network *home location registers* (HLRs) to enable a user to locate a friend or relative in terms of real-time geographic location.

WLAN "Hotspot" Billing

SS7/C7 has recently begun playing a role in the marriage of wireless (WLANs) and cellular networks. A subscriber can use a cellular subscriber identity module (SIM) card for authentication and billing purposes from a WLAN hotspot. For example, if a subscriber is at a café with WLAN facilities (typically wi-fi), the subscriber can request permission to use the service via a laptop screen. This request triggers a short cellular call to authenticate the subscriber (using SS7/C7 signaling). The usage is then conveniently billed to the subscriber's cellular phone bill.

NOTE A SIM is used in 2nd generation cellular networks based on GSM, and on 2.5/3G networks as defined by 3GPP. A SIM contains the subscriber's identity so that the subscriber can change cellular equipment freely by simply changing the SIM card over to the new device. This means that the subscriber can plug the SIM into a new cellular handset and the number "transfers" to that handset, along with the billing.

Location-Based Games

SS7/C7 is not only used to deliver games to cell phones, but it also plays a role in the creation of a new genre of location-based games and entertainment. Cellular games incorporate the player's location using SS7/C7 to provide mobility information a dedicated web site as a central point. Some of the games that are emerging at the time of this writing are using global positioning system (GPS), WLAN support, and built-in instant messaging capabilities (to help tease your opponents) to blend higher location accuracy.

Summary

This chapter has shown that, although it is transparent, SS7/C7 plays a role in the lives of virtually every individual in developed countries. It is also the key to new, revenue-generating services and is crucial to the QoS as perceived by subscribers—both of which lie at the very heart of success in a fiercely competitive telecommunications market. Furthermore SS7/C7 is a common thread that ties fixed-line, cellular, and IP networks together, and it is a key enabler for the convergence of the telecommunications and data communications industries.

CHAPTER 4

SS7 Network Architecture and Protocols Introduction

The *International Telecommunication Union (ITU)* is the international governing body for Signaling System No. 7. More specifically, it is governed by the Telecommunication Standardization Sector of the ITU (ITU-TS or ITU-T for short). Formerly it was governed by the ITU's Consultative Committee for International Telegraph and Telephone (CCITT) subcommittee until that was disbanded in 1992 as part of a process to speed up the production of recommendations (as well as other organization changes). See Chapter 2, "Standards," for more information on standards-making bodies.

Signaling System No. 7 is more commonly known by the acronyms SS7 and C7. Strictly speaking, the term C7 (or, less commonly, CCS7) refers to the international Signaling System No. 7 network protocols specified by the ITU-T recommendations as well as national or regional variants defined within the framework provided by the ITU-T. The term C7 originates from the former title found on the specifications—CCITT Signaling System No. 7. The term SS7 tends to specifically refer to the North American regional standards produced by Telcordia (formerly known as Bell Communications Research or Bellcore) and the American National Standards Institute (ANSI). The North American standards themselves are based on the ITU-T recommendations but have been tailored outside the provided framework. The differences between ITU and Telcordia/ANSI are largely subtle at the lower layers. Interaction between ANSI and ITU-T networks is made challenging by different implementations of higher-layer protocols and procedures.

For the purpose of this book, we will use the term SS7 to refer generically to any Signaling System No. 7 protocol, regardless of its origin or demographics. An overview of SS7 by the ITU-T can be found in recommendation Q.700 [111], and a similar overview of SS7 by ANSI can be found in T1.110 [112].

Chapter 3, "The Role of SS7," provides a comprehensive list of the functions and services afforded by SS7. These can be summarized as follows:

- Setting up and tearing down circuit-switched connections, such as telephone calls made over both cellular and fixed-line.
- Advanced network features such as those offered by supplementary services (calling name/number presentation, Automatic Callback, and so on).
- Mobility management in cellular networks, which permits subscribers to move geographically while remaining attached to the network, even while an active call is in place. This is the central function of a cellular network.
- *Short Message Service (SMS)* and *Enhanced Messaging Service (EMS)*, where SS7 is used not only for signaling but also for content transport of alphanumeric text.
- Support for *Intelligent Network (IN)* services such as toll-free (800) calling.
- Support for ISDN.
- *Local Number Portability (LNP)* to allow subscribers to change their service, service provider, and location without needing to change their telephone number.

After reading the preceding chapters, you know that signaling serves the requirements of the telecommunications service being delivered; it is not an end in itself. Signaling enables services within the network.

This chapter makes you familiar with the SS7 network, protocols, fundamental concepts, and terminology so that the topics covered in the rest of the book will be more accessible if you're unfamiliar with the subject. This chapter begins with a brief description of pre-SS7 systems and SS7 history. The chapter then presents the protocol stack, showing how SS7 protocols fit together. It concludes with a discussion of the relevant protocols.

Pre-SS7 Systems

The following are the main systems that preceded SS7:

- CCITT R1 (regional 1) was deployed only on a national level. R1 is a *Channel Associated Signaling (CAS)* system that was employed in the U.S. and Japan. It uses multifrequency (MF) tones for signaling. It is no longer in general operation, although some remnants might remain in the network.
- CCITT R2 (regional 2) was deployed only on a national level. R2 is a CAS system that was employed in Europe and most other countries. It used *Multifrequency Compelled (MFC)* for signaling; it compelled the receiver to acknowledge a pair of tones before sending the next pair. It is no longer in general operation, although some remnants might remain in the network.

- Signaling systems that have been deployed for both national and international (between international switches) signaling have progressed from CCITT #5 (C5) to CCITT #6 (C6) and finally to CCITT #7 (C7):
  - C5 (CCITT Signaling System No. 5) is a CAS system standardized in 1964 that has found widespread use in international signaling. It is still in use today on a number of international interfaces. National implementations are now scarce, except in less-developed regions of the world, such as Africa, which makes extensive use of the protocol. C5 can be used in both analog and digital environments. In an analog setting, it uses tones for signaling. In a digital setting, a digital representation of the tone is sent instead (a pulse code modulation [PCM] sample).
  - C6 (CCITT Signaling System No. 6), also called SS6, was the first system to employ *Common Channel Signaling* (CCS). It was standardized in 1972. (CAS and CCS are explained in Chapter 1, "The Evolution of Signaling.") C6 was a pre-OSI model and as such had a monolithic structure as opposed to a layered one. C6 was a precursor to C7 and included the use of data links to carry signaling in the form of packets. It had error correction/detection mechanisms. It employed a common signaling channel to control a large number of speech circuits, and it had self-governing network management procedures. C6 had a number of advantages over C5, including improvements in post-dial delay and the ability to reject calls with a cause code. The use of locally mapped cause codes allowed international callers to hear announcements in their own language. Although C6 was designed for the international network, it was not as widely deployed as C5. However, it was nationalized for the U.S. network and was deployed quite extensively under the name *Common Channel Interoffice Signaling System* 6 *(CCIS6)* in the AT&T network. C6 was introduced into the Bell system in the U.S. in 1976, and soon after, Canada. All deployments have now been replaced by SS7.

The next section provides a brief history of SS7.

History of SS7

The first specification (called a *recommendation* by the CCITT/ITU-T) of CCITT Signaling System No. 7 was published in 1980 in the form of the CCITT *yellow book* recommendations. After the yellow book recommendations, CCITT recommendations were approved at the end of a four-year study period. They were published in a colored book representing that study period.

Table 4-1 provides an evolutionary time line of CCITT/ITU-T SS7.

Table 4-1 *CCITT/ITU-T SS7 Timeline*

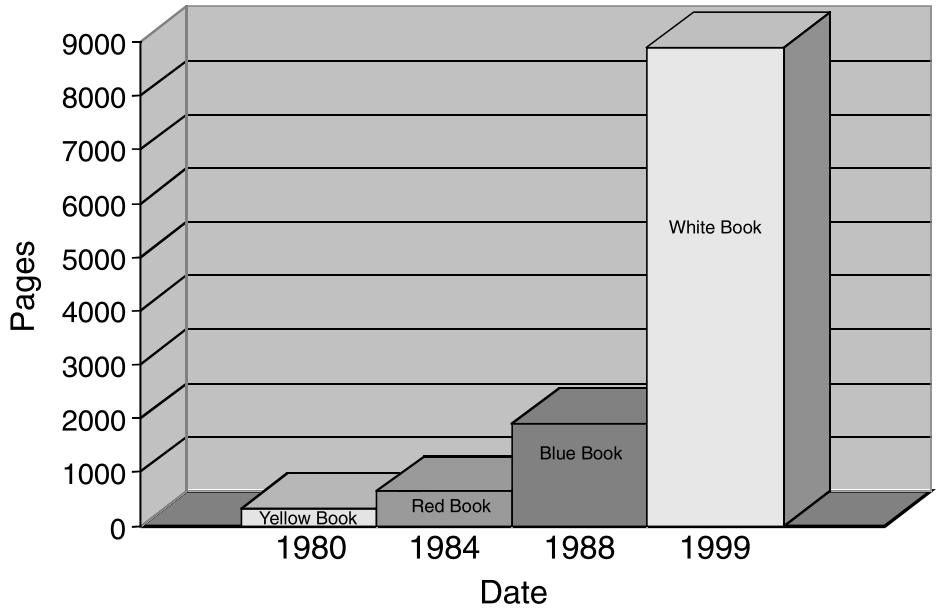
Year	Publication	Protocols Revised or Added
1980	CCITT Yellow Book	MTP2, MTP3, and TUP, first publication.
1984	CCITT Red Book	MTP2, MTP3, and TUP revised. SCCP and ISUP added.
1988	CCITT Blue Book	MTP2, MTP3, TUP, and ISUP revised. ISUP supplementary services and TCAP added.
1992	ITU-T Q.767	International ISUP, first publication.
1993	ITU-T "White Book 93"	ISUP revised.
1996	ITU-T "White Book 96"	MTP3 revised.
1997	ITU-T "White Book 97"	ISUP revised.
1999	ITU-T "White Book 99"	ISUP revised.

Under the CCITT publishing mechanism, the color referred to a published set of recommendations—that is, all protocols were published at the same time. The printed matter had the appropriate colored cover, and the published title contained the color name. When the ITU-T took over from the CCITT, it produced single booklets for each protocol instead of producing en bloc publications as had been the case under the supervision of the CCITT. Under the new mechanism, the color scheme was dropped. As a result, the ITU-T publications came to be known as "White Book" editions, because no color was specified, and the resulting publications had white covers. Because these publications do not refer to a color, you have to qualify the term "White Book" with the year of publication.

As Table 4-1 shows, when SS7 was first published, the protocol stack consisted of only the Message Transfer Part 2 (MTP2), Message Transfer Part 3 (MTP3), and Telephony User Part (TUP) protocols. On first publication, these were still somewhat immature. It was not until the later Red and Blue book editions that the protocol was considered mature. Since then, the SS7 protocols have been enhanced, and new protocols have been added as required.

Figure 4-1 shows how many pages the ITU-T SS7 specifications contained in each year. In 1980, there were a total of 320 pages, in 1984 a total of 641 pages, in 1988 a total of 1900 pages, and in 1999 approximately 9000 pages.

Figure 4-1 *How Many Pages the ITU C7 Specifications Covered Based on Year (Source: ITU [Modified])*



The following section introduces the SS7 network architecture.

SS7 Network Architecture

SS7 can employ different types of signaling network structures. The choice between these different structures can be influenced by factors such as administrative aspects and the structure of the telecommunication network to be served by the signaling system.

The worldwide signaling network has two functionally independent levels:

- International
- National

This structure makes possible a clear division of responsibility for signaling network management. It also lets numbering plans of SS7 nodes belonging to the international network and the different national networks be independent of one another.

SS7 network nodes are called signaling points (SPs). Each SP is addressed by an integer called a point code (PC). The international network uses a 14-bit PC. The national networks also use a 14-bit PC—except North America and China, which use an incompatible 24-bit PC, and Japan, which uses a 16-bit PC. The national PC is unique only within a particular

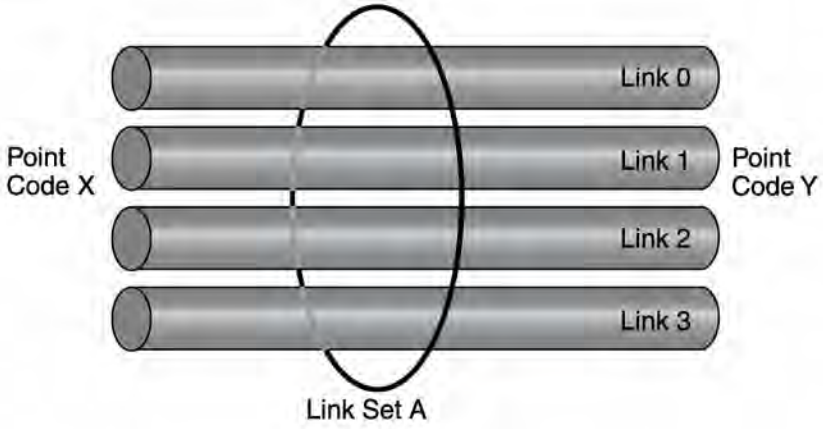
operator's national network. International PCs are unique only within the international network. Other operator networks (if they exist) within a country also could have the same PC and also might share the same PC as that used on the international network. Therefore, additional routing information is provided so that the PC can be interpreted correctly—that is, as an international network, as its own national network, or as another operator's national network. The structure of point codes is described in Chapter 7, "Message Transfer Part 3 (MTP3)."

Signaling Links and Linksets

SPs are connected to each other by signaling links over which signaling takes place. The bandwidth of a signaling link is normally 64 kilobits per second (kbps). Because of legacy reasons, however, some links in North America might have an effective rate of 56 kbps. In recent years, high-speed links have been introduced that use an entire 1.544 Mbps T1 carrier for signaling. Links are typically engineered to carry only 25 to 40 percent of their capacity so that in case of a failure, one link can carry the load of two.

To provide more bandwidth and/or for redundancy, up to 16 links between two SPs can be used. Links between two SPs are logically grouped for administrative and load-sharing reasons. A logical group of links between two SP is called a *linkset*. Figure 4-2 shows four links in a linkset.

Figure 4-2 *Four Links in a Linkset Between SPs*



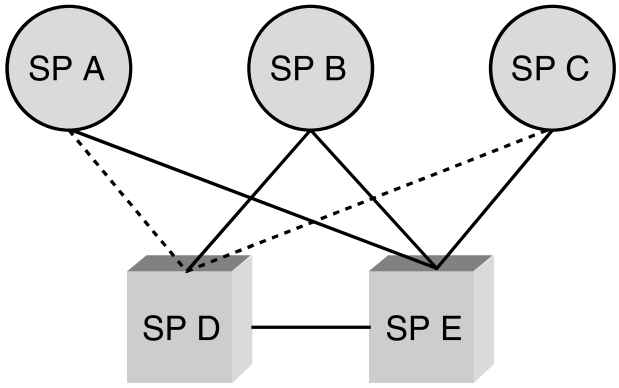
A number of linksets that may be used to reach a particular destination can be grouped logically to form a *combined linkset*. For each combined linkset that an individual linkset is a member of, it may be assigned different priority levels relative to other linksets in each combined linkset.

A group of links within a linkset that have the same characteristics (data rate, terrestrial/satellite, and so on) are called a *link group*. Normally the links in a linkset have the same characteristics, so the term *link group* can be synonymous with *linkset*.

Routes and Routesets

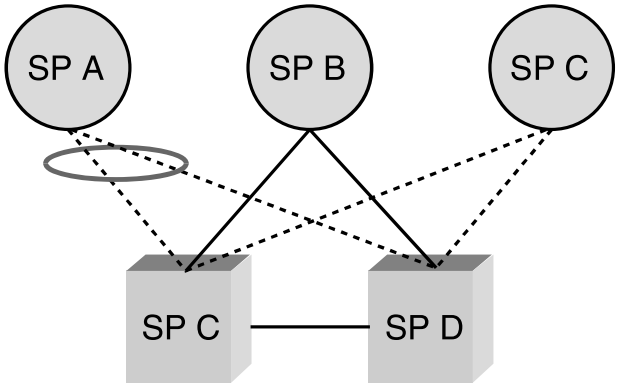
SS7 routes are statically provisioned at each SP. There are no mechanisms for route discovery. A *route* is defined as a preprovisioned path between source and destination for a particular relation. Figure 4-3 shows a route from SP A to SP C.

Figure 4-3 *Route from SP A to SP C*



All the preprovisioned routes to a particular SP destination are called the *routeset*. Figure 4-4 shows a routeset for SSP C consisting of two routes.

Figure 4-4 *Routeset from SP A to SP C*



The following section discusses the SP types.

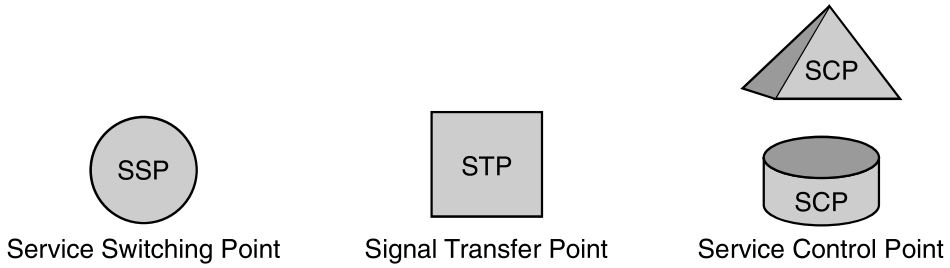
Node Types

There are three different types of SP (that is, SS7 node):

- Signal Transfer Point
- Service Switching Point
- Service Control Point

Figure 4-5 graphically represents these nodes.

Figure 4-5 *SS7 Node Types*



The SPs differ in the functions that they perform, as described in the following sections.

Signal Transfer Point

A Signal Transfer Point (STP) is responsible for the transfer of SS7 messages between other SS7 nodes, acting somewhat like a router in an IP network.

An STP is neither the ultimate source nor the destination for most signaling messages. Generally, messages are received on one signaling link and are transferred out another. The only messages that are not simply transferred are related to network management and global title translation. These two functions are discussed more in Chapters 7 and 9. STPs route each incoming message to an outgoing signaling link based on routing information contained in the SS7 message. Specifically, this is the information found in the MTP3 routing label, as described in Chapter 7.

Additionally, standalone STPs often can screen SS7 messages, acting as a firewall. Such usage is described in Chapter 15, “SS7/C7 Security and Monitoring.”

An STP can exist in one of two forms:

- Standalone STP
- Integrated STP (SP with STP)

Standalone STPs are normally deployed in “mated” pairs for the purposes of redundancy. Under normal operation, the mated pair shares the load. If one of the STPs fails or isolation occurs because of signaling link failure, the other STP takes the full load until the problem with its mate has been rectified.

Integrated STPs combine the functionality of an SSP and an STP. They are both the source and destination for MTP user traffic. They also can transfer incoming messages to other nodes.

Service Switching Point

A Service Switching Point (SSP) is a voice switch that incorporates SS7 functionality. It processes voice-band traffic (voice, fax, modem, and so forth) and performs SS7 signaling. All switches with SS7 functionality are considered SSPs regardless of whether they are local switches (known in North America as an end office) or tandem switches.

An SSP can originate and terminate messages, but it cannot transfer them. If a message is received with a point code that does not match the point code of the receiving SSP, the message is discarded.

Service Control Point

A Service Control Point (SCP) acts as an interface between telecommunications databases and the SS7 network. Telephone companies and other telecommunication service providers employ a number of databases that can be queried for service data for the provision of services. Typically the request (commonly called a query) originates at an SSP. A popular example is freephone calling (known as toll-free in North America). The SCP provides the routing number (translates the toll-free number to a routable number) to the SSP to allow the call to be completed. For more information, see Chapter 11, "Intelligent Networks (IN)."

SCPs form the means to provide the core functionality of cellular networks, which is subscriber mobility. Certain cellular databases (called registers) are used to keep track of the subscriber's location so that incoming calls may be delivered. Other telecommunication databases include those used for calling card validation (access card, credit card), calling name display (CNAM), and LNP.

SCPs used for large revenue-generating services are usually deployed in pairs and are geographically separated for redundancy. Unless there is a failure, the load is typically shared between two *mated* SCPs. If failure occurs in one of the SCPs, the other one should be able to take the load of both until normal operation resumes.

Queries/responses are normally routed through the mated pair of STPs that services that particular SCP, particularly in North America.

See Chapters 10, "Transaction Capabilities Application Part (TCAP)," and 11, "Intelligent Networks (IN)," for more information on the use of SCPs within both fixed-line and cellular networks. See Chapters 12, "Cellular Networks," and 13, "GSM and ANSI-41 Mobile Application Part (MAP)," for specific information on the use of SCPs within cellular networks.

The following section introduces the concept of link types.

Link Types

Signaling links can be referenced differently depending on where they are in the network. Although different references can be used, you should understand that the link's physical characteristics remain the same. The references to link types A through E are applicable only where standalone STPs are present, so the references are more applicable to the North American market.

Six different link references exist:

- Access links (A links)
- Crossover links (C links)
- Bridge links (B links)
- Diagonal links (D links)
- Extended links (E links)
- Fully associated links (F links)

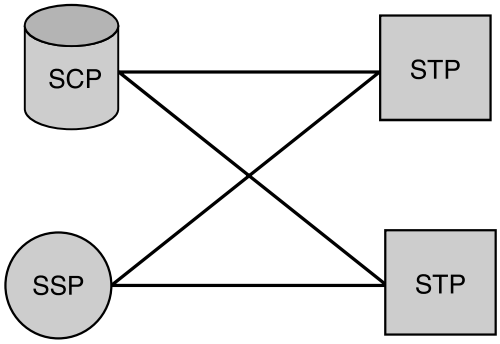
The following sections cover each link reference in more detail.

NOTE In the figures in the sections covering the different link references, dotted lines represent the actual link being discussed, and solid lines add network infrastructure to provide necessary context for the discussion.

Access Links (A Links)

Access links (A links), shown in Figure 4-6, provide access to the network. They connect "outer" SPs (SSPs or SCPs) to the STP backbone. A links connect SSPs and SCPs to their serving STP or STP mated pair.

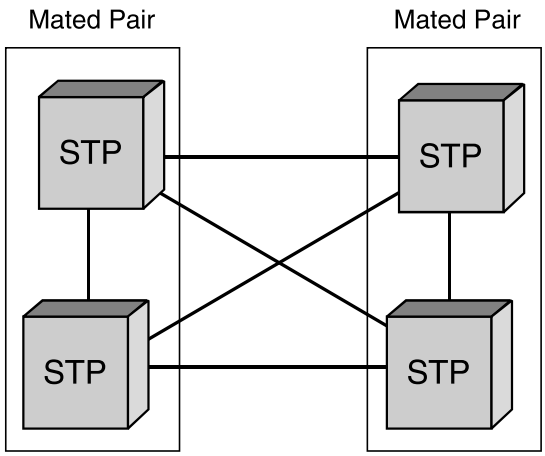
Figure 4-6 *A Links*



Cross Links (C Links)

Cross links (C links), shown in Figure 4-7, are used to connect two STPs to form a mated pair—that is, a pair linked such that if one fails, the other takes the load of both.

Figure 4-7 *C Links*



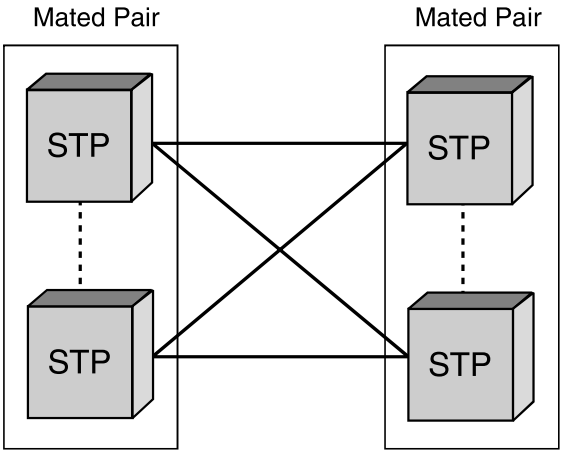
C links are used to carry MTP user traffic only when no other route is available to reach an intended destination. Under normal conditions, they are used only to carry network management messages.

Bridge Links (B Links)

Bridge links (B links) are used to connect mated pairs of STPs to each other across different regions within a network at the same hierarchical level. These links help form the backbone of the SS7 network. B links are normally deployed in link quad configuration between mated pairs for redundancy.

Figure 4-8 shows two sets of mated pairs of B links.

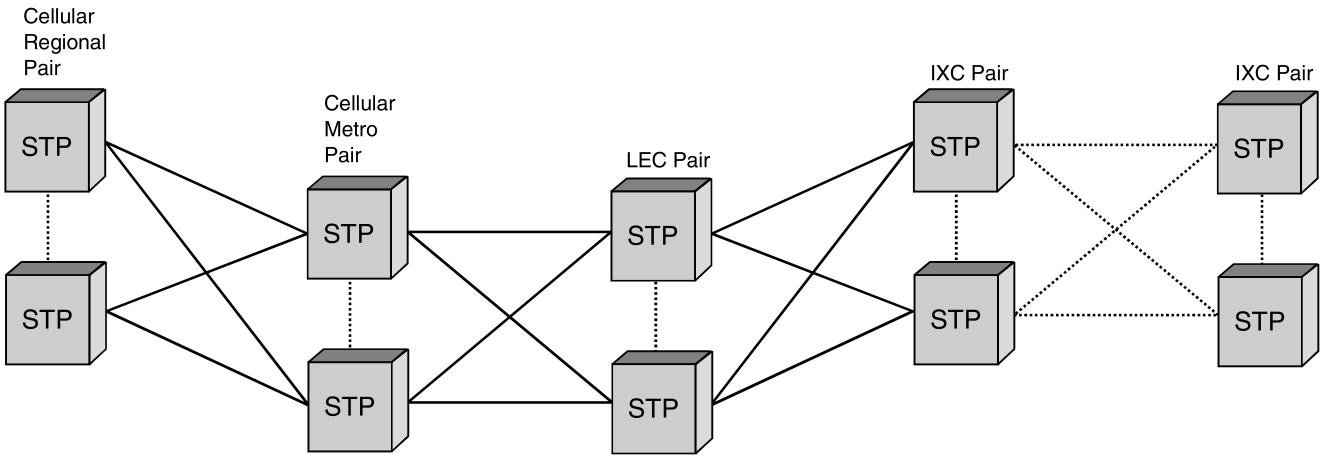
Figure 4-8 *B Links*



Diagonal Links (D Links)

Diagonal links (D links), shown in Figure 4-9, are the same as B links in that they connect mated STP pairs.

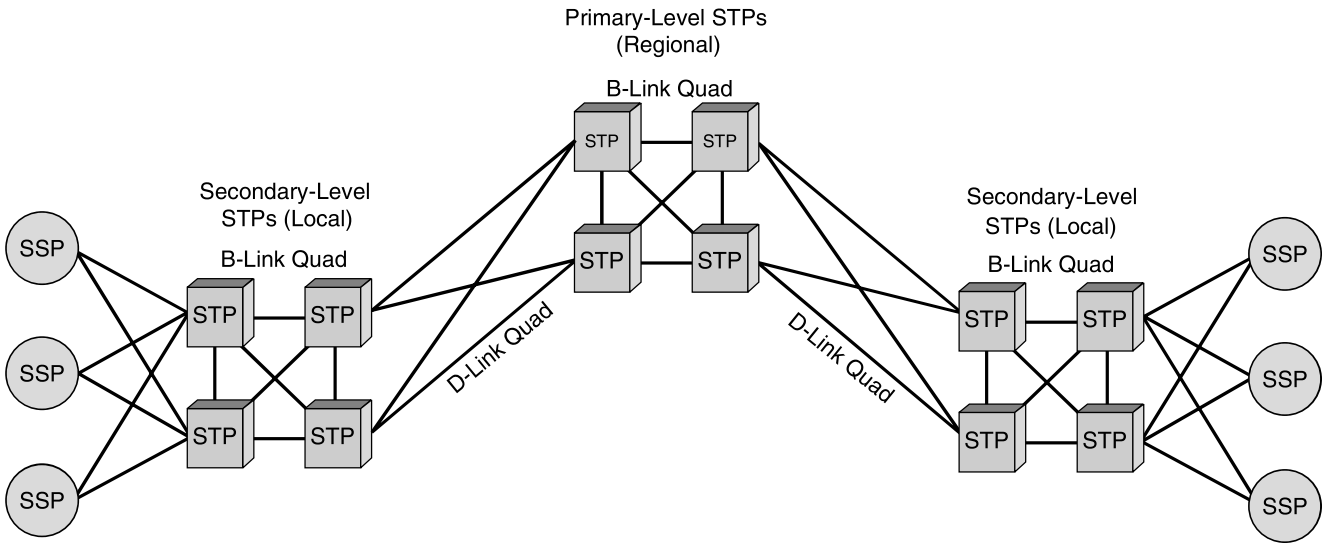
Figure 4-9 *D Links*



The difference is that they connect mated STP pairs that belong to different hierarchical levels or to different networks altogether. For example, they may connect an interexchange carrier (IXC) STP pair to a local exchange carrier (LEC) STP pair or a cellular regional STP pair to a cellular metro STP pair.

As mentioned, B and D links differ in that D links refer specifically to links that are used either between different networks and/or hierarchical levels, as shown in Figure 4-10.

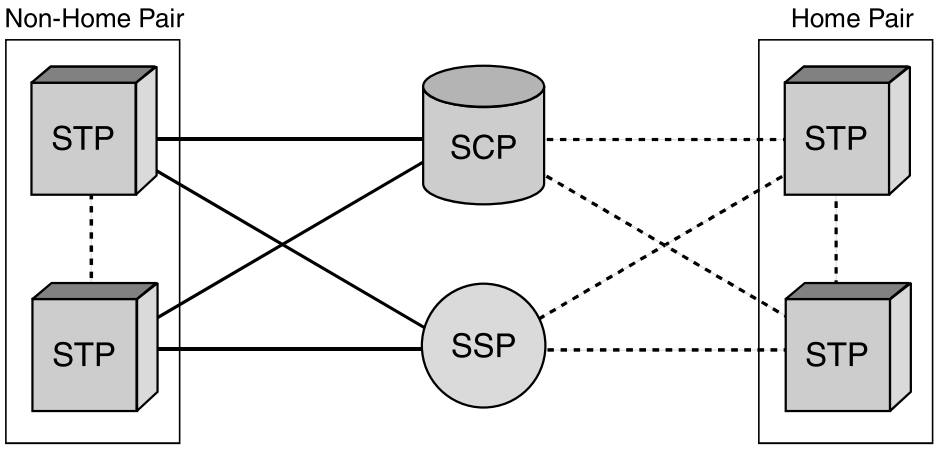
Figure 4-10 *Existence of an STP Backbone and STP Hierarchy*



Extended Links (E Links)

Extended links (E links), shown in Figure 4-11, connect SSPs and SCPs to an STP pair, as with A links, except that the pair they connect to is not the normal home pair. Instead, E links connect to a nonhome STP pair. They are also called alternate access (AA) links. E links are used to provide additional reliability or, in some cases, to offload signaling traffic from the home STP pair in high-traffic corridors. For example, an SSP serving national government agencies or emergency services might use E links to provide additional alternate routing because of the criticality of service.

Figure 4-11 *E Links*

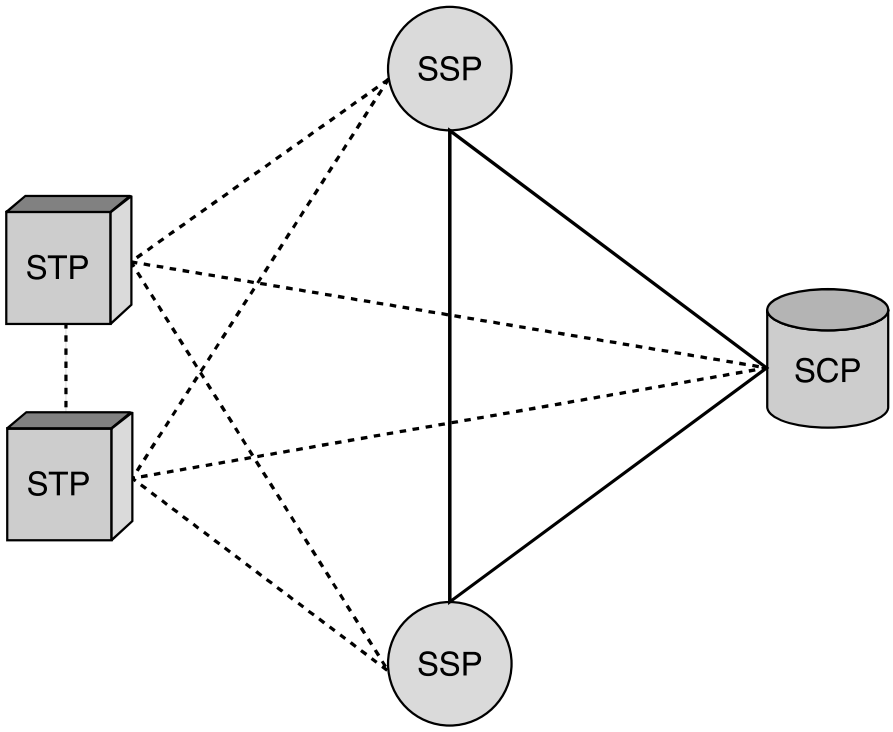


Fully-Associated Links (F Links)

Fully-associated links (F links), shown in Figure 4-12, are used to connect network SSPs and/or SCPs directly to each other without using STPs. The most common application of this type of link is in metropolitan areas. F links can establish direct connectivity between all switches in the area for trunk signaling and Custom Local Area Signaling Service (CLASS), or to their corresponding SCPs.

Figure 4-13 shows an SS7 network segment. In reality, there would be several factors more SSPs than STPs.

Figure 4-12 *F Links*

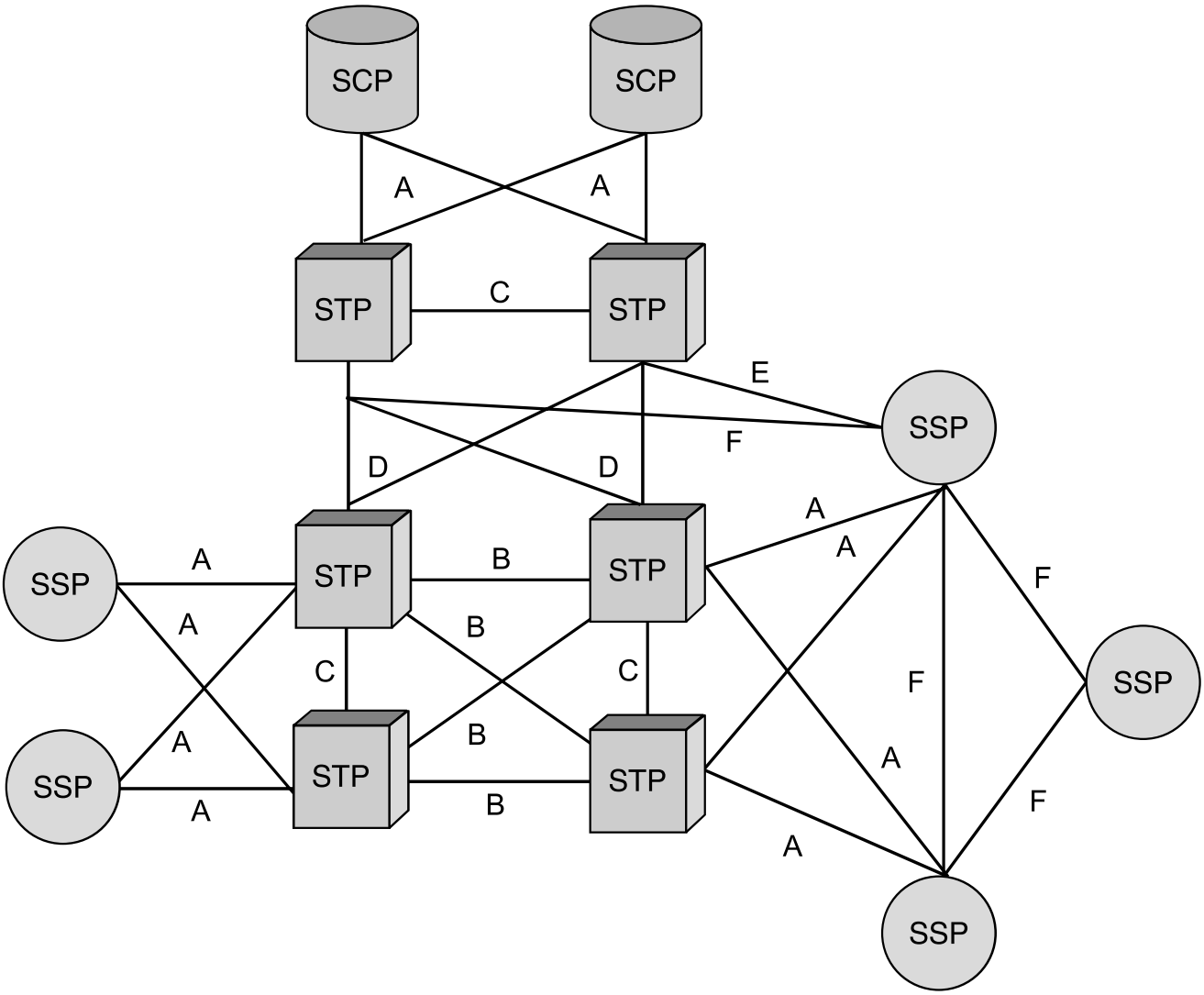


Signaling Modes

The signaling relationship that exists between two communicating SS7 nodes is called the signaling mode. The two modes of signaling are associated signaling and quasi-associated signaling. When the destination of an SS7 message is directly connected by a linkset, the *associated* signaling mode is being used. In other words, the source and destination nodes are directly connected by a single linkset. When the message must pass over two or more linksets and through an intermediate node, the *quasi-associated* mode of signaling is being used.

It's easier to understand the signaling mode if you examine the relationship of the point codes between the source and destination node. When using the associated mode of signaling, the Destination Point Code (DPC) of a message being sent matches the PC of the node at the far end of the linkset, usually referred to as the far-end PC or adjacent PC. When quasi-associated signaling is used, the DPC does not match the PC at the far end of the connected linkset. Quasi-associated signaling requires the use of an STP as the intermediate node because an SSP cannot transfer messages.

Figure 4-13 *SS7 Network Segment*

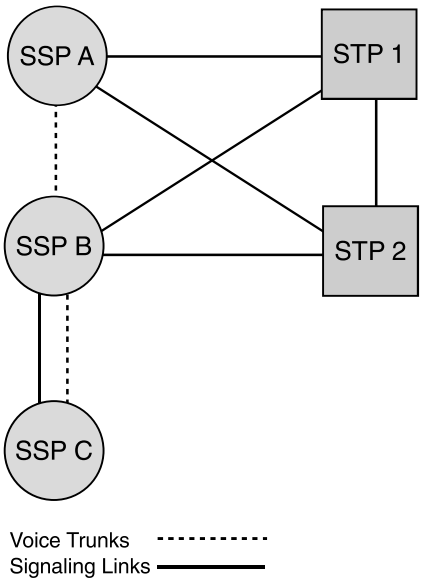


In Figure 4-14, the signaling relationships between each of the nodes are as follows:

- SSP A to SSP B uses quasi-associated signaling.
- SSP B to SSP C uses associated signaling.
- STP 1 and STP 2 use associated signaling to SSP A, SSP B, and each other.

As you can see from Figure 4-14, associated signaling is used between nodes that are directly connected by a single linkset, and quasi-associated signaling is used when an intermediate node is used. Notice that SSP C is only connected to SSP B using an F link. It is not connected to any other SS7 nodes in the figure.

Figure 4-14 *SS7 Signaling Modes*



When discussing the signaling mode in relation to the voice trunks shown between the SSPs, the signaling and voice trunks follow the same path when associated signaling is used. They take separate paths when quasi-associated signaling is used. You can see from Figure 4-14 that the signaling between SSP B and SSP C follows the same path (associated mode) as the voice trunks, while the signaling between SSP A and SSP B does not follow the same path as the voice trunks.

Signaling Network Structure

Standalone STPs are prevalent in North America because they are used in this region to form the backbone of the SS7 network. Attached to this backbone are the SSPs and SCPs. Each SSP and SCP is assigned a "home pair" of STPs that it is directly connected to. The network of STPs can be considered an overlay onto the telecommunications network—a packet-switched data communications network that acts as the nervous system of the telecommunications network. Figure 4-15 shows a typical example of how SSPs are interconnected with the STP network in North America.

STPs are not as common outside North America. Standalone STPs typically are used only between network operators and/or for applications involving the transfer of noncircuit-related signaling. In these regions, most SSPs have direct signaling link connections to other SSPs to which they have direct trunk connections. Figure 4-16 shows an example of this type of network with most SSPs directly connected by signaling links.

Figure 4-15 *Typical Example of North American SSP Interconnections*

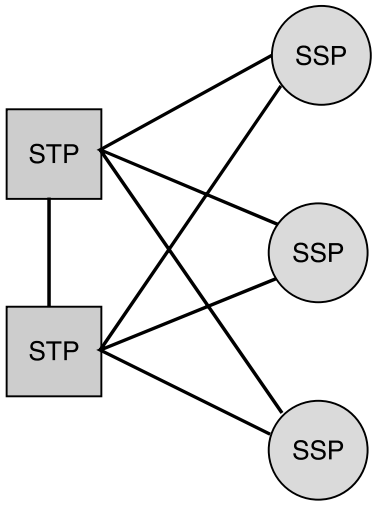
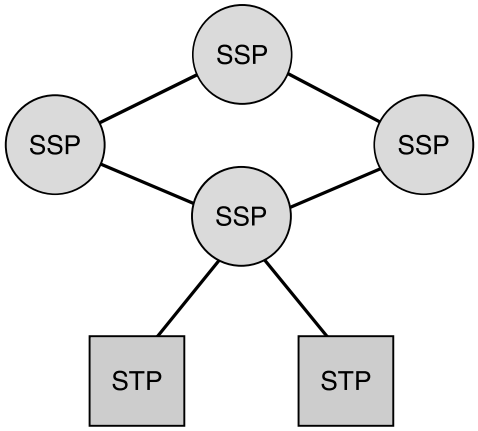


Figure 4-16 *Typical Example of SSP Interconnections in Most Areas Outside North America*



SSPs often have indirect physical connections to STPs, made through other SSPs in the network. These are usually implemented as nailed-up connections, such as through a Digital Access Cross-Connect System or other means of establishing a semipermanent connection. Logically, these SSPs are directly connected to the STP. The signaling link occupies a digital time slot on the same physical medium as the circuit-switched traffic. The SSPs that provide physical interconnection between other SSPs and an STP do not "transfer" messages as an STP function. They only provide physical connectivity of the signaling links between T1/E1 carriers to reach the STP. Figure 4-17 shows an example of a network with no STP connection, direct connections, and nondirect connections. SSP 1 is directly connected to an STP pair. SSP 4 uses direct signaling links to SSP 2 and SSP 3,