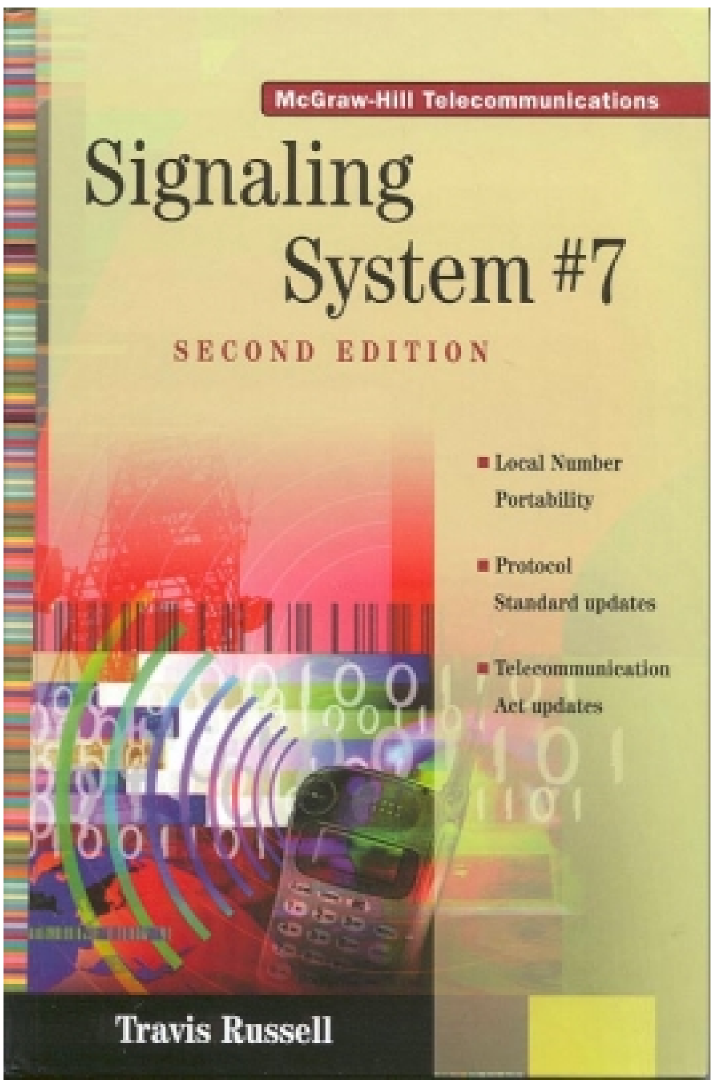
FURTHER READING:

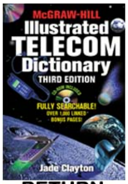
As a preview for further reading, the following reference has been provided from the pages of the book below:

Title: Signaling System #7 Second Edition
Author: Travis Russell
Publisher: McGraw-Hill

ISBN: 0070580324



DC signaling



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As mentioned previously, DC signaling relies on direct current to signal distant offices. This is a very limited signaling method, because of the minimum number of states that can be represented by voltages and current. When a subscriber lifts the receiver of a phone, current is allowed to flow through the phone and back to the central office. Current detectors on the line cards in the central office switching equipment detect the current and provide the subscriber with a dialtone.

Other types of trunks use similar techniques. E&M signaling is another form of DC signaling. These trunks use a separate pair of wires for signaling. The two wires are labeled as E and M, or “ear” and “mouth.” These, of course, are not what the letters really stand for, but this designation is often used to describe their function.

The M lead is used to send 248 V DC or ground to the distant switch (implementation dependent). The M lead of one switch must be connected to the E lead of the distant switch. When the distant switch detects current on its E lead, it closes a relay contact and allows the current to flow back to the sending switch through its M lead.

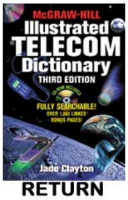
When the sending switch detects the current flow on its E lead, the connection is considered established and transmission can begin on the separate voice pairs. This type of trunk is often used between two PBXs, and is often referred to as tie lines.

In-band signaling

In-band signaling is used when DC signaling is not possible, for example, in tandem offices. In-band signaling uses tones in place of DC current. These tones may be Single Frequency (SF) tones, Multi-Frequency (MF) tones, or Dual-Tone Multi-Frequency (DTMF). The tones are transmitted with the voice. Because these tones must be transmitted over the same facility as the voice, they must be within the voice band (0 to 4 kHz). There is the possibility of false signaling when voice frequencies duplicate signaling tones. The tones are designed for minimal occurrence of this, but this is not 100 percent fault tolerant. Signal delays and other mechanisms are used to prevent the possibility of voice frequencies from imitating SF signals.

Single Frequency (SF) signaling is used for interoffice trunks. Two possible states exist: on-hook (idle line) or off-hook (busy line). To maintain a connection, no tone is sent while the circuit is up. When either party hangs up, a disconnect is signaled to all interconnecting offices by sending a tone (2.6 kHz) over the circuit. Detectors at each end of the circuits detect the tone and drop the circuit.

SF signaling has become the most popular of all the in-band methods, and the most widely used of all signaling methods. SF is still in use today in some parts of the telephone network. However, as deployment of the SS7 network spreads, SF is no longer needed.



Multi-Frequency (MF) is much like Dual Tone Multi-Frequency (DTMF), and is used to send dialed digits through the telephone network to the destination end office. Because voice transmission is blocked until a connection to the called party is established, there is no need for mechanisms that prevent the possibility of voice imitating signaling tones.

MF is also an interoffice signaling method used to send the dialed digits from the originating office to the destination office.

Out-of-band signaling

Out-of-band signaling has not shared the popularity and widespread usage of SF signaling. Out-of-band signaling was designed for analog carrier systems, which do not use the full 4-kHz bandwidth of the voice circuit. These carriers use up to 3.5 kHz, and can send tones in the 3.7-kHz band without worrying about false signaling. Out-of-band signaling is an analog technology, and is of no advantage today.

Digital signaling

As digital trunks became more popular, signaling methods evolved that greatly enhanced the reliability of the network. One technique used in digital trunks (such as DS1) is the use of signaling bits. A signaling bit can be inserted into the digital voice bit stream, without sacrificing voice quality. One bit is "robbed" out of designated frames and dedicated to signaling (robbed-bit signaling). The digitized voice does not suffer from this technique since the loss of one bit does not alter the voice signal enough to be detectable by the human ear.

Because of its digital nature, digital signaling is much more cost effective than Single Frequency (SF). SF requires expensive tone equipment both for sending and detection, whereas digital signaling can be detected by any digital device loaded in the switching equipment and can create any kind of signaling information. This has fueled the efforts to make carriers digital rather than analog.

Digital signaling has another fundamental difference. It does not use messages as SS7 and other message-based protocols do. This limits the type of signaling it can provide.

Common channel signaling

As discussed earlier, Common Channel Signaling (CCS) uses a digital facility, but places the signaling information in a time slot or *channel* separate from the voice and data it is related to. This allows signaling information to be consolidated and sent through its own network apart from the voice network. It is this method that is used in ISDN and SS7 today.

In addition, this method of signaling is capable of sending and receiving messages, supporting an unlimited number of signaling values. Even information retrieved from a remote database can be transferred from one entity to another using CCS.

Introduction to Telephony

The telecommunications industry has undergone many organizational changes as well as service changes. With the current trend to merge data communications with telephony, many new professionals have entered the industry without the opportunity to learn the nuances of the industry and its players.

This section provides a fundamental outline of the telephony industry and its players. Of major importance is understanding how the telephone network is structured, and how it has evolved over the years.

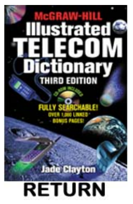
Bell System hierarchy

The Bell System network really can be divided into two distinct functions: signaling and switching. The signaling network is the SS7 network. The switching network is the portion used for the transfer of data and voice from one subscriber to another, through the telephone service providers' network.

There exists a hierarchy within the switching network, to ensure efficient use of trunk facilities and to provide alternate circuits in the event of failures or congestion. Before the divestiture of the Bell System in 1984, the hierarchy was much different than today. The hierarchy provided five levels of switching offices, with the class five office being the end office or local office (Fig. 1.1).

The class five office was capable of connecting to other end offices within its calling area, but relied on the class four office to connect to offices outside of its calling area. The calling area was not defined by area codes, but was a geographical service area drawn by the Bell System. Service access areas have since been reallocated as *Local Access Transport Areas* (LATAs) by the Justice Department as a result of the Bell System divestiture.

The class four office allowed the Bell System to aggregate its facilities and used high-capacity trunks to interconnect to other class four offices. In this way, the class five office did not require high-capacity facilities and handed off the bulk of its calls to the class four office. This also prevented the necessity for the class five office to have trunks to every other class five office in the service area. The class four office was also known as the toll center.



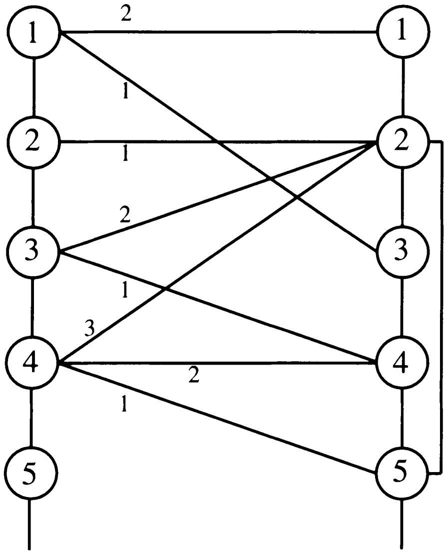


Figure 1.1 This figure illustrates the Bell System Switching Hierarchy prior to the divestiture of the Bell System. The priority of the routes is indicated by the numbers.

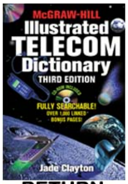
As seen in Fig. 1.1, the class four office provided two paths for a telephone connection. The interconnection of these various offices depended mostly on distance. There were many occurrences of class five offices connecting directly to class one offices.

The toll office searched its trunks for an available trunk as low in the hierarchy as possible. If one was not available, it would search for a trunk to a primary center in the destination calling area. If there were no available trunks to the primary center, then the last choice would be an overflow trunk to its own primary center.

The class three office, or primary center, was part of the toll network. This office connected to class two offices, or sectional offices, but also provided a path to other class three offices and class four offices. This office served as an overflow switching center in the event that other routes lower in the hierarchy were not available.

The class two office was also known as the sectional center, and provided access to the regional center. Only two routes were available at this level, one to its peer in the destination calling area and one to the regional switching center, or class one office.

The class one office was known as the regional center, and was used for toll calls. The regional center also provided access to the long distance network. A typical toll call required an average of three trunks. The maximum number of trunks allowed in a connection was nine.



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Postdivestiture switching hierarchy. In the mid-1980s, technology allowed many of the functions just described to be combined. As switching equipment was improved, systems were given the capability to act as local switches, tandems, and even toll switches. In addition to better routing functionality, these switches were also given the ability to record billing records and perform alternate routing in the event of congestion or failures.

The new hierarchy consists of fewer levels, consolidating many of the functions of the previous hierarchy into two layers. Long distance access is accomplished through a Point-of-Presence (POP) office. The long distance carrier will also have its own multilevel hierarchy, which may be several layers as well.

After divestiture of the Bell System, the calling areas were also redefined and changed to Local Access Transport Areas (LATAs). Within each LATA is a simple hierarchy, with three levels. With newer advanced switching equipment, many of the functions once found in the higher layers of the hierarchy can now be combined and located in the end office (Fig. 1.2).

Local Access Transport Areas (LATAs)

After divestiture, the telephone companies' service areas (or *exchanges,* as they were sometimes called) were redrawn by the Justice Department so that telephone companies would have evenly divided

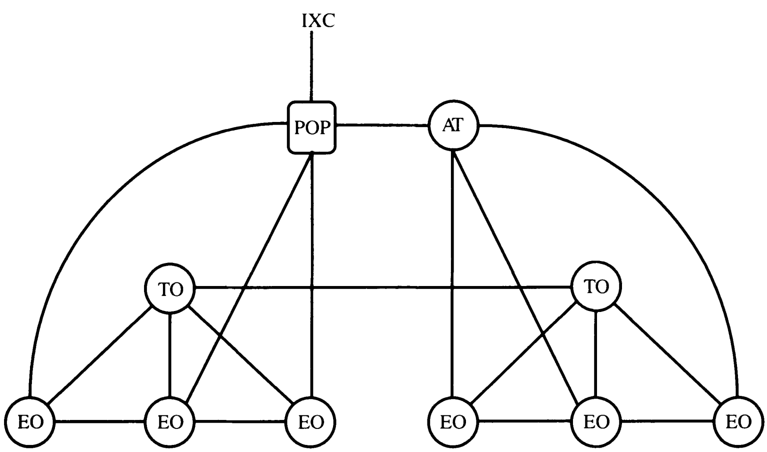
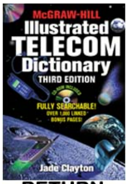


Figure 1.2 This figure illustrates a much flatter switching hierarchy, used after the divestiture of the Bell System.



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service areas with equal revenue potential. These areas, called Local Access Transport Areas (LATAs), were divided according to census information regarding the demographics of each LATA. Each Regional Bell Operating Company (RBOC) and each independent telephone company received a service area that would provide it a fair and equal market. There were originally 146 LATAs, but as changes take place in the networks, the number of LATAs is growing.

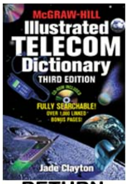
Other considerations had to be made regarding LATAs. Telephone companies already had a significant amount of equipment and capital invested in the previous service areas, which meant reassigning service areas could have a major financial impact. The service areas were divided into LATAs, which are much smaller than the original service areas defined by the telephone companies themselves. Each telephone company could have more than one LATA for which it provides service. This allowed telephone companies to maintain their original investment, but forced them to divide areas into smaller chunks.

The difference was made between LATAs. The local operating companies and independents were not allowed to carry traffic from one LATA to another. Instead, they were required to use a long distance carrier such as AT&T or MCI to provide them that service. This ensured that the local telephone companies did not interfere with long distance competition, and provided the long distance companies a fair and profitable boundary for which they could compete with other carriers.

In the mid-1980s, the telephone companies were forced to provide the long distance carriers equal access into the telephone network. This was accomplished in the current switching hierarchy by establishing a point-of-presence (POP), which serves as an interface to all interexchange carriers into the LATA. Every LATA must have one POP. The telephone companies collected access fees from the long distance carriers for this interface into their network, to offset the cost of equipment and ensure a revenue stream from long distance traffic.

The local telephone companies further divided each LATA into a *local market* and a *toll market.* The toll market is within the LATA but considered by the telephone company as a long distance call, because of the distance from one city to another or the distance between central offices handling the call. These toll calls are currently very expensive, and have recently been open for competition. These are the only long distance calls local telephone companies are allowed to provide. Many states have allowed long distance carriers to compete in this market, opening up the LATA to competition.

In 1996, the government approved the Telecommunications Act of 1996. This piece of legislation has changed the face of the telecommunications industry in many ways, and impacts both users of the telephone network and the telephone companies themselves. One part of this legislation allows long distance companies to provide local telephone service in their markets. They must pass specific criteria defined by the Telecommunications Act before the FCC can grant them permission to provide local service. This reverses the legislation put into place by Judge Green when divestiture of the Bell System reshaped the nation's telephone industry and limited long distance companies from offering local service.



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At the same time, the Telecommunications Act of 1996 also allows local telephone companies to offer long distance (interLATA) service in their market areas. They must demonstrate that they have allowed competition in their market areas, and pass criteria set in the Telecom-munications Act before offering such service. The result of this sweeping new legislation is yet to be seen, but many anticipate local telephone companies will partner and merge with long distance companies taking advantage of one another's markets.

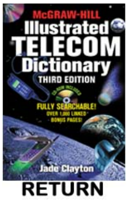
There are over 300 LATAs presently defined throughout the United States. Throughout these LATAs are hundreds of telephone companies competing for revenues. Many of the smaller independent companies are investing capital to get connected to the SS7 network so that they can offer the same types of advanced calling features the larger service providers offer. These independent companies have joined forces forming telephone associations across the nation. This allows them to represent their industry in standards committees, and voice their concerns to the government as a collective body rather than a lone voice. These associations also pool their resources and build their own networks using monies from the member companies to pay for the cost of the network. This is how many small independent companies are getting involved in SS7.

Hierarchy of the synchronization network

All digital networks rely on timing mechanisms to maintain integrity of the data transmission. Since all digital transmission is multiplexed and based on time division, accurate timing is critical. This is especially true when DSO links are used in SS7. DSO links must have accurate timing sources in order for them to synchronize and carry signaling traffic.

Digital facilities must have reliable, accurate clock sources to determine proper bit timing. These clocks must be synchronized with the same source, and are deployed throughout the telephone network. To maintain timing in the telephone network, a separate synchronization network has been defined (Fig. 1.3).

The source for a clock signal is referred to as the *Primary Reference Source* (PRS). These clock sources reside in the various regions of the telephone network. They are highly accurate clocks, usually cesium beam or rubidium-based clocks. These clocks must be resynchronized and continuously verified using a universal time source. Loran-C and the Global Positioning System (GPS) are currently used by many companies to check



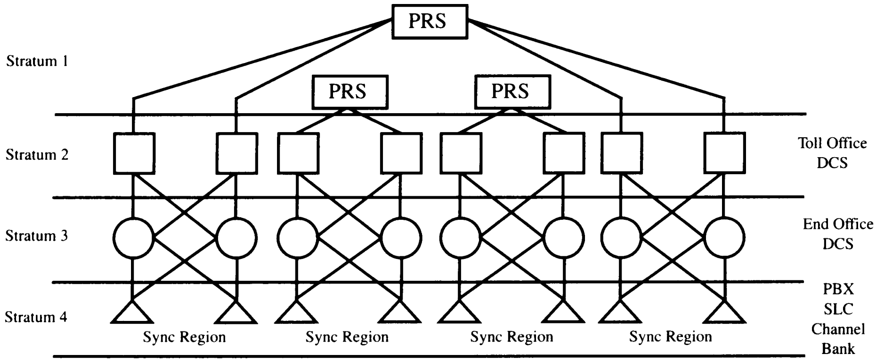


Figure 1.3 To maintain synchronized timing throughout the digital network, the Bell System Operating Companies (BOCs) use this timing network.

the accuracy of their clocks. The distribution of clock signals is implemented at different levels, referred to as *strata*. The highest stratum obtainable is stratum 1, which is the primary clock source.

Clock signals are distributed in a primary/secondary relationship to all other levels. This means that central office switching equipment at stratum 2 distributes its clock signal to equipment at stratum 3.

The PRS distributes clocking signals to toll offices. The toll office is considered stratum 2, and must redistribute the clock to end offices within its LATA. Each LATA must have at least one stratum 2 clock. Whenever a clock is redistributed, it loses some accuracy. Yet the clock signal is accurate enough to operate throughout the network reliably, despite the loss of accuracy. End offices are considered stratum 3.

The end office will distribute clock signals to other users of digital transmission facilities, such as private branch exchanges (PBXs) and channel banks. These are considered to be at stratum 4. In some cases, devices at this level can redistribute the clock signal to other adjunct equipment. These devices are considered to be at the lowest level of the hierarchy, stratum 5.

Within a central office, clocks are distributed through a *building integrated timing system* (BITS). BITS is a distribution system for clock signals, and is distributed throughout the office to switching equipment in that office. BITS is critical to the proper operation of DS0A links in the SS7 network. Failure of this clock signal will result in the failure of the signaling links.

Digital signaling hierarchy

The telephone network also has a digital hierarchy for all digital transmission facilities. This digital hierarchy is a means for expressing the

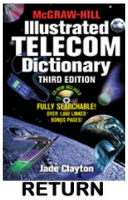


TABLE 1.1 North American Hierarchy

Digital signal destination	Bandwidth	Channels (DSOs)	Carrier designation
DS0	64 kbps	1 channel	None
DS1	1.544 Mbps	24 channels	T-1
DS1C	3.152 Mbps	48 channels	T-1c
DS2	6.312 Mbps	96 channels	T-2
DS3	44.736 Mbps	672 channels	T-3
DS4	274.176 Mbps	4032 channels	T-4

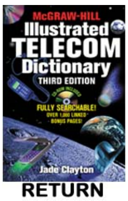
capacity of these various facilities. Typically, the highest level of the hierarchy is an aggregate of the levels below it. Thus, the lowest digital signal in the hierarchy is multiplied to establish the next level, which is multiplied to obtain the next level, and so forth. Table 1.1 illustrates the correlations between levels in the hierarchy.

The SS7 network uses DS0s for signaling links. This is a 56- or 64-kbps data link, capable of sending voice or data. The DS0 in the United States is always 56 kbps, because the telephone company uses 8 kbps for control information. This control information is used by the transmission equipment to maintain the integrity of the data link. Some studies have been under way regarding the use of 64 kbps, but the multiplexers used throughout the telephone network today do not support 64-kbps links.

In order for equipment to use the DS0, special digital interfaces that are capable of sending and receiving signals at this level must be installed. If a DS1 is used, a device called a *channel bank* must be used as the interface. The channel bank divides the 24 time slots of the DS1 into 24 separate DS0s, which can then be distributed to their proper destinations. Other types of multiplexers/demultiplexers exist that perform the same task, depending on the location in the network.

Currently, only the DS0 level is supported in the SS7 network. This is currently under study, however, as new high-speed networks are deployed. *Asynchronous Transfer Mode* (ATM) and *Broadband ISDN* (BISDN) may require signaling speeds beyond that of DS0. As ATM is deployed in the public networks, signaling traffic will migrate to these new facilities. The current digital facilities will be replaced and the signaling network will become integrated with the new broadband network. The first step is to support DS1 speeds over an ATM interface. This is currently under development and will be deployed in many networks by the end of 1999. ANSI and ITU-TS are currently studying the use of DS1 in the SS7 network.

As seen in Table 1.1, the DS1 facility provides a total bandwidth of 1.544 Mbps. This should be more than adequate for almost any signal-



ing requirements. The impact on the existing network will require new hardware as well as software upgrades. The SS7 protocol will undergo many changes to support these new high-speed data links.

The digital hierarchy is quickly being replaced with a newer and faster technology. Fiber optics is quickly replacing copper facilities throughout the telephone network. Fiber optics has the capability to transmit at much higher data rates than copper, and is critical to the success of technologies such as broadband and ATM.

Synchronous Optical NETwork (SONET) is currently found in telephone company networks worldwide and has become the transmission medium of choice. SONET provides data rates up to 2.4 Gbps, and will support broadband ISDN and ATM. SONET is also being used to link local area networks (LANs) through the Public Switched Telephone Network (PSTN).

As seen in Table 1.2, SONET is also divided into different levels of service, each level being an aggregate of the levels below it. There are two designations used for these levels: the electrical signal itself and the optical signal. They are terms used for different reasons. Electrical signals are directly related to the optical signals and, therefore, can almost be used synonymously in most discussions. In this book, we will always refer to the optical signal.

When compared to the digital signal hierarchy, there is a stark difference (Table 1.3). Even at the lowest level of the optical hierarchy, 28 DS1s can be supported on one facility. This represents a significant cost savings to telephone companies. At OC-1, 672 time slots are supported for voice, data, or even signaling.

A single SONET facility is not dedicated entirely to one application. One channel may be used for signaling, while the remainder carry voice, data, and video. This practice allows telephone companies to use existing transmission facilities between offices, rather than deploying a special link just for SS7.

TABLE 1.2 SONET Digital Hierarchy

Electrical signal	Optical signal	Data rate (Mbps)	ITU designation
STS-1	OC-1	51.84	
STS-3	OC-3	155.52	STM-1
STS-9	OC-9	466.56	STM-3
STS-12	OC-12	622.08	STM-4
STS-18	OC-18	933.12	STM-6
STS-24	OC-24	1244.16	STM-8
STS-36	OC-36	1866.24	STM-12
STS-48	OC-48	2488.32	STM-16

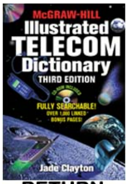


TABLE 1.3 Optical and Digital Compared

Digital signal	Optical signal
DS0 (64 Kbps)	OC-1 (51.84 Mbps)
DS1 (1.544 Mbps)	OC-3 (155.52 Mbps)
DS1C (3.152 Mbps)	OC-9 (466.56 Mbps)
DS2 (6.312 Mbps)	OC-12 (622.08 Mbps)
DS3 (44.736 Mbps)	OC-18 (933.12 Mbps)
DS4 (274.176 Mbps)	OC-24 (1244.16 Mbps)
	OC-36 (1866.24 Mbps)
	OC-48 (2488.32 Mbps)

Current Trends in Telecommunications Technology

Today's telecommunications industry has changed dramatically. Data communications and voice networking have been merged to provide a variety of services that leave even the most educated somewhat confused and baffled. These services all revolve around the backbone of the new Intelligent Network (IN), SS7.

Because of SS7, these new technologies can be supported in the Public Switched Telephone Network (PSTN) rather than having to have a separate network for each type of service (as previously done to support packet switching in the '70s and '80s). In fact, all data and voice communications will be simplified to the point that the subscriber does nothing but dial a number and get connected. The signaling network will handle the rest.

The goal of the telephone network is to provide seamless service to all subscribers, regardless of the information being sent through the network. As previously discussed, the IN will provide this capability. But before the IN is fully deployed, there are many different pieces that must first be put into place.

The telephone network of today will not support the types of services that subscribers are asking for. If there is a need for high-speed data, a special circuit must be installed from the customer premises to the other end of the circuit. If video is to be transmitted through the telephone network, special high-capacity circuits must be installed from the studio through the telephone network to another high-capacity circuit at the transmitter.

The ultimate goal is to provide one network capable of transferring all kinds of information regardless of the bandwidth necessary and sending it through the network just as if placing a telephone call. To support this level of service, the network must be changed.