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The Technology of Long Distance Service

OVERVIEW OF THE PUBLIC NETWORK

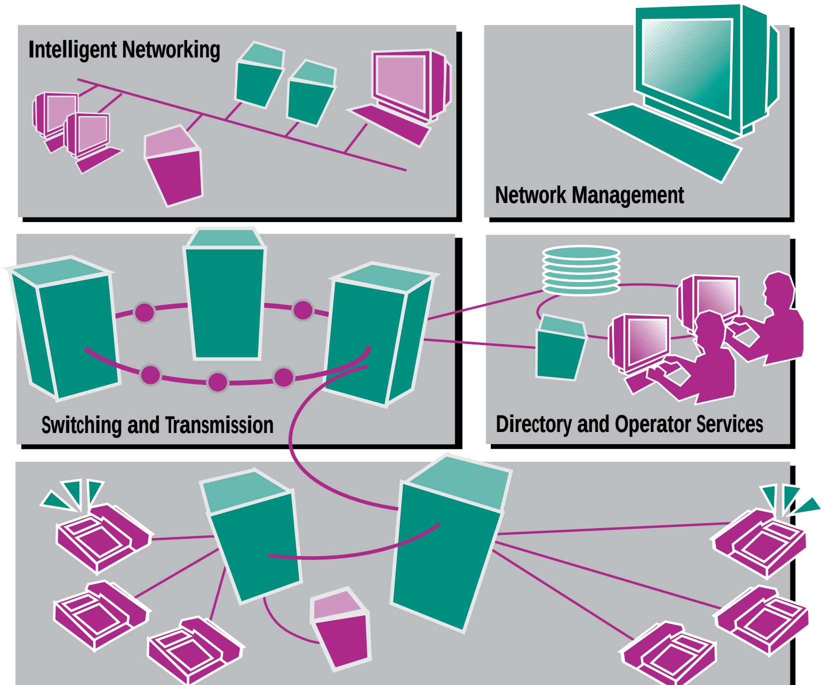
North American long distance subscribers expect to be able to pick up a phone anywhere, place a call anywhere else in the country, charge the call to a designated account or the called party, and get operator assistance at any time. In the last 10 years, they have also come to expect easy, seamless ways to send data and video traffic to long distance destinations just as easily.

The public network that has evolved to meet this expectation is one of the largest and most sophisticated networks in existence. This section describes the technology of this network and how it is applied to provide long distance service.

The Network Building Blocks

The public network is made up of access lines, switching systems, transmission systems, and, increasingly, of external databases that supplement the "intelligence" of the switching system to perform sophisticated routing, screening, and other tasks.

- **Access lines** carry traffic to and from subscribers. Access lines can be physical connections such as twisted copper wire pairs, optical fiber, or coaxial cable, or they can be built on wireless technologies. This part of the network is often referred to as the "local loop."
- The **switching system** at the central office makes the connections for each call, routing incoming voice and data calls to their destinations.
- **Transmission systems** interconnect switching systems by copper wire, coaxial cable, optical fiber cable, or microwave radio transmission. This inter-office facility is often called the "transport network." Transmission systems also carry traffic in volume from large customers, such as business computers and centrex systems, to the switch.
- An **operator services center** supports attendant backing for long distance services, plus new revenue-generating call agent services.
- A fully integrated **SS7 system** supports "intelligent" services such as 800 number translations and virtual private networking.



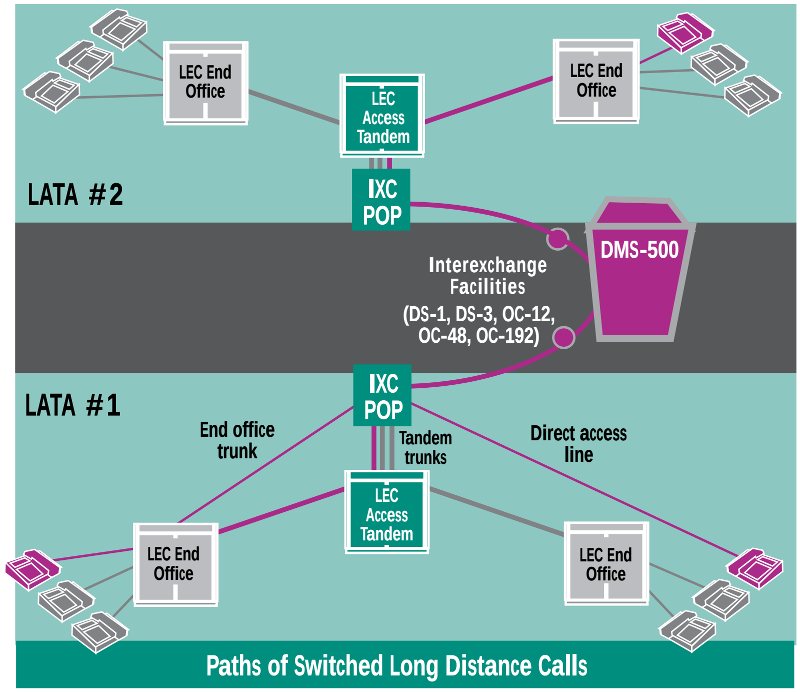
Building Blocks of the Complete Long Distance Network

The domain of the long distance provider includes all these elements—access, switching, transmission, operator services platform, and SS7 capabilities.

On the access side, the long distance provider must procure access to local subscriber loops by connecting to the LEC (local exchange carrier) network at the DS-1 or DS-3 level at point of presence locations (POPs), the meetpoint between the local and interexchange networks. The long distance provider can also own or lease special access lines directly to customers, such as DS-0, DS-1, or DS-3 dedicated access lines (DALs).

On the transmission side, the long distance provider will generally own or lease DS-1 and DS-3 digital facilities between its switches and points of presence (POPs). For long haul applications, or those for which survivability is paramount, transmission systems may be configured in “self-healing” fiber-optic rings that automatically redirect traffic away from failed or degraded facililities, without interrupting service.

The heart of the long distance network is a switching system capable of receiving toll traffic from end-offices and routing it to appropriate destination switches. Ideally, this switch supports a wide range of revenue-generating services and offers an integrated platform for operator services and SS7 signaling as well.



The operator services center—which houses operators, operator workstations, and the processors to support their functions—may be located at the toll tandem switching center or hundreds of miles away. The most significant trend in operator services in the '90s is the increasing automation of routine tasks, such as collecting listing and locality information for directory assistance calls. Automating mechanical, repetitive tasks reduces the cost of providing operator services and frees operators for the tasks that really require human logic and intervention.

The SS7 network consists of switches with Intelligent Network (IN) software that enable the network to generate inquiries to an external database, transfer the inquiries to the appopriate database, find out how to process the call, and return the instructions to the originating switch. The SS7 network is the foundation for meeting U.S. regulatory requirements for 800 number services, which require that the switch query an 800-number database to determine how to route the call.

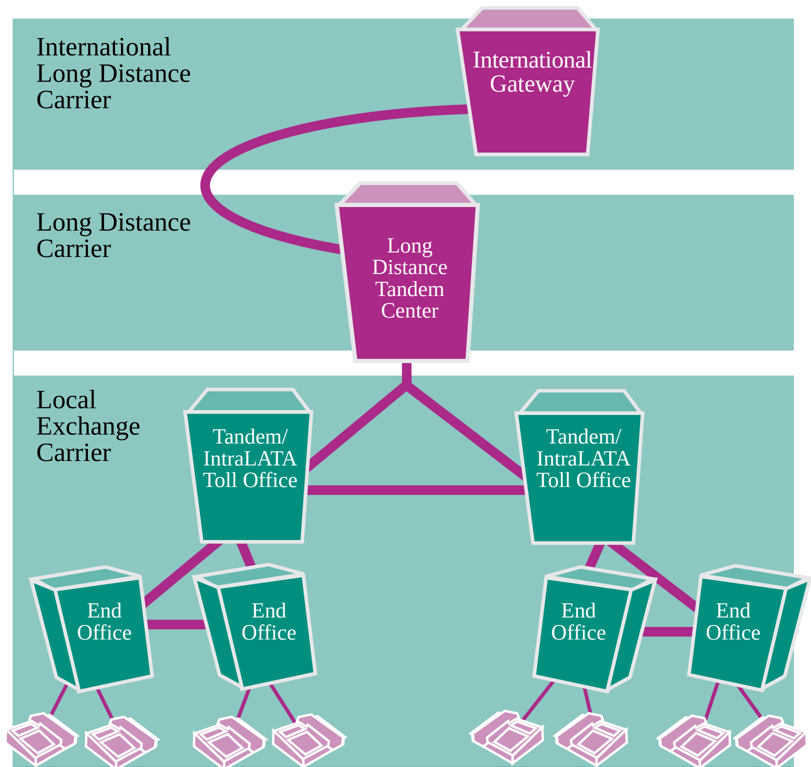
Access, transmission, switching, operator services, and IN technologies are described later in this chapter.

The Conceptual Switching Hierarchy

The traditional public network hierarchy includes several levels of switching systems.

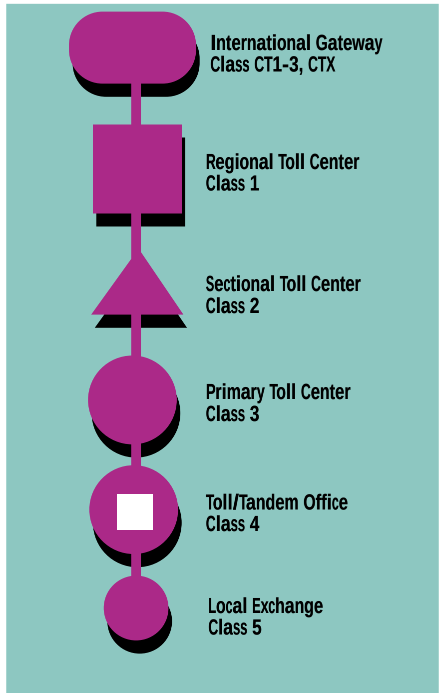
- The access line from the telephone or data user is connected through the local loop to a local exchange switch, referred to as an **end office** or a "Class 5 end office." The Nortel DMS-100 switching system, for example, is an end office switch because it connects to subscriber loops.

- End offices are linked to **tandem offices** that switch traffic between central offices—and to toll offices that carry long distance calls. Traffic is carried from one office to another on trunks, which can carry traffic for many calls. The Nortel DMS-200 switch, for example, is a tandem office switch that supports up to 60,000 trunks between switches. Tandems that are toll centers (toll/tandem centers) have telephone operators and long-distance billing equipment. The DMS-250 and DMS-500 switches are Nortel's platform for long-distance switching and operator services.
- **International gateways** provide connectivity to networks around the world. The DMS-300 switch is Nortel's international gateway, supporting up to 45,000 trunks and able to interconnect with the networks and signaling systems of any country.



Sample Network Hierarchy

In the North American classification system, the end office is a Class 5 office, and classes 1 through 4 were designated as toll centers—each level serving a larger geographic area than the level below it. Long distance calls entering the network through the caller's end office would climb the switching hierarchy in search of an idle circuit. If the most direct route was busy, the call moved up the hierarchy to the next level switching center, and the next, until a path was found to complete the call.



Historical Network Hierarchy

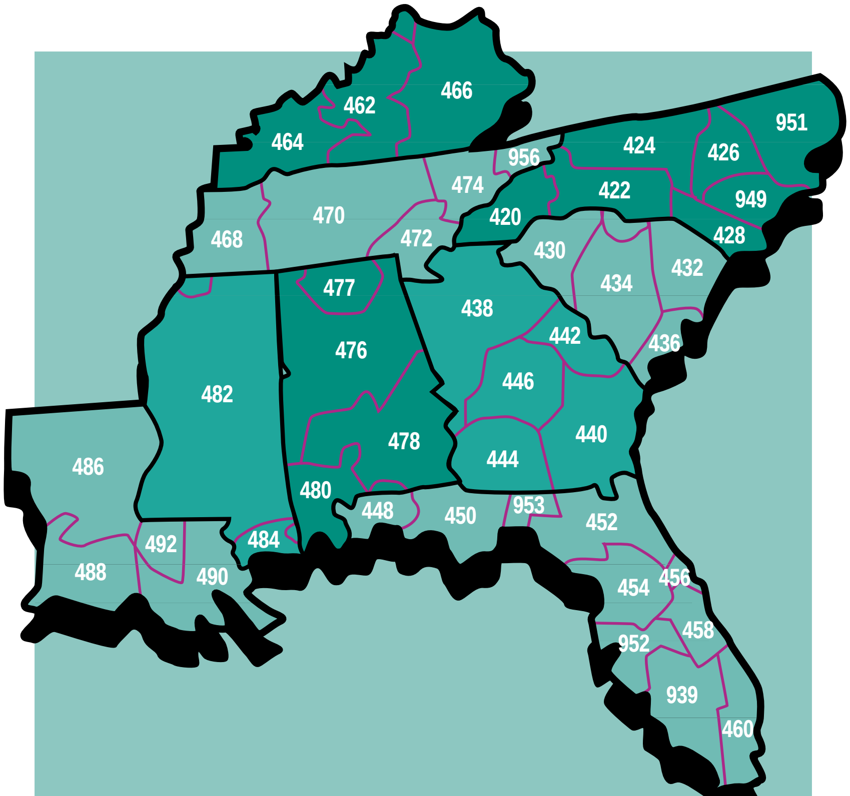
Over the years, the distinction between classes has blurred as switching systems become more versatile. For example, a DMS-100/200 switch performs the functions of both an end office and a local toll office. A DMS-500 switch is a local (end office) and long distance (tandem) switch all in one, with support for operator services.

KEY CONCEPTS OF LONG DISTANCE

What is Local and What is Long Distance?

The 1982 Modified Final Judgment—which broke up the AT&T monopoly and created the seven Regional Bell Operating Companies—also defined the boundaries between local and long-distance services. The MFJ established a series of Local Access and Transport Areas (LATAs) that divided the geography of the United States into a series of local service areas.

Calls that originate and terminate in the same LATA can be carried by a local exchange carrier, such as BellSouth, NYNEX, or Ameritech. Local calls can also be carried by independent operating companies and alternative network providers, which were not constrained by the MFJ rulings. Calls that cross LATA boundaries are typically carried by interexchange carriers, such as AT&T, MCI, Sprint, or WorldCom (formerly WilTel). However, many states allow interexchange carriers to also carry toll calls within a LATA—and are applying equal access principles to IntraLATA calls as well. Regulatory reforms on the horizon would spread this trend to all states,



Sample LATA Map (South East Region)

Traditionally, the NPA used only 0 or 1 as the second (middle) digit, allowing 144 assignable NPAs—not enough to meet the needs of a growing population. A new numbering scheme mandated by the FCC and implemented in 1995 permits any number from 0 to 9 to appear in the middle of the NPA. This change alone produced another 640 possible digit combinations, but required changes in switching systems to be able to recognize digits other than 0 or 1 in the middle of the area code.

Equal Access

Under the terms of the MFJ, interexchange carriers are entitled to establish points of presence (POPs) in each LATA so that calls originating in that LATA can be routed into the IXC network for transport across LATA boundaries. The Regional Bell Operating Companies and GTE must provide interexchange carriers with “equal access”—equal in type, quality, and price—to any of their respective local switches. This provision is designed to ensure that subscribers served by RBOCs or GTE can easily access the long distance carriers of their choice. (Equal access was mandated in Canada in July 1994.)

Although the MFJ does not apply to other service providers, in March 1985 the Federal Communications Commission (FCC) ordered that, if an IXC other than AT&T requests it, an independent service provider has three years to provide exchange access services that are equal in all respects to that offered to AT&T. If the independent can demonstrate unfeasibility, it may apply to the FCC for a waiver with a three-year time limit.

To accomplish equal access, each long distance carrier is assigned a carrier identification code (CIC) of five to seven digits. Subscribers can dial these digits with each long distance call (this method is called “casual access”), or can pre-subscribe to a particular carrier and the switch software can add the CIC to dialed digits for each call.

The switch software to perform this task may be located at the end office (which is then known as an equal access end office, or EAEO), or at an access tandem switch.

Numbering Plans

In order for calls to reach their proper destinations, subscribers must have telephone numbers that are both unique and recognizable by all the switches in the public network. This is accomplished globally under guidelines of the ITU-TSS (International Telecommunications Union—Telecommunications Standards Sector, formerly known as CCITT), the pre-eminent international telecommunications standards organization. In the U.S. and Canada, the numbering process—the North American Numbering Plan (NANP)—is implemented under the auspices of the North American Numbering Plan Administration (NANPA), a private group overseen by the FCC. The assigned number consists of four parts:

- **Country code**—to designate the international designation
- **Three-digit area code**—known in the industry as NPA (numbering plan area) code, to identify the area of the country
- **Three-digit central office code**—known in the industry as NXX code, to designate the switch to which the subscriber is connected
- **Four digits**—to designate the individual subscriber line

Nationwide Caller ID

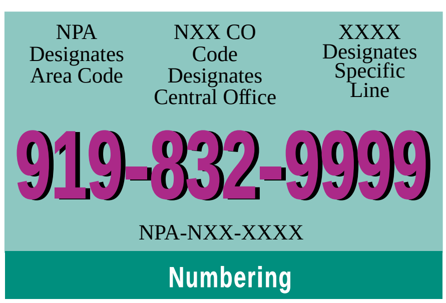
In December 1995 an FCC ruling took effect that requires long distance companies to give local phone companies the data needed to identify callers' numbers on long distance calls, where technologically feasible.

The FCC also manded a free, simple, and consistent method of blocking and unblocking the delivery of caller ID on a per-line or per-call basis.

This ruling is expected to stimulate growth in the high-margin caller ID market by about 75 percent annually for the next few years, reaching an estimated $400 million by the end of 1997 in the U.S. alone.

Central office codes are issued to local telephone service providers according to the procedure spelled out in *Central Office Code Assignment Guidelines* document (ICCF 93-0729-010), available through the Industry Carriers Compatibility Forum (ICCF).

In addition to the full public dialing plan, business users who get their telephone features through the digital switch can establish abbreviated dialing plans to simplify internal calling. Software in the switch or intelligent peripherals translates this abbreviated dialing plan into the full digit string for switching.



Numbering

Inter-Office Trunk Signaling

Connections between switches generally use one of the following industry standard signaling protocols:

Feature Group A is actually a line-side interface to a carrier, used by older switches. This method of inter-office signaling generates industry standard billing records but does not send automatic number identification (ANI) to the called party's switch.

Feature Group B signaling is used for trunk connections between local exchange carrier end office switches and interLATA carriers—or international carriers. The caller dials a special number or access code to reach the long distance carrier of choice. This is the signaling protocol used when the call originates with an end office that is not equipped for equal access.

Feature Group C is the traditional AT&T toll service interface, which includes automatic number identification (ANI) of the calling party, answer supervision, and disconnect supervision.

Feature Group D is the interoffice signaling protocol associated with equal access. With FGD signaling, callers do not have to dial any special digits to place long distance calls with the carrier of their choice. They just dial 1 plus the 10-digit number to place a call on the carrier they have pre-selected. (Interexchange switches that are equipped with 15-digit international dialing can also automatically collect, translate, and route international phone numbers up to 15 digits in length.)

Common Channel Signaling No. 7 (CCS7) is a signaling protocol adopted for intelligent networking, in which signaling information for a number of trunks is transmitted on a separate link. CCS7 signaling, often referred to as SS7, is the basis for 800-number database translations, calling card validation, and other advanced services.

Interfaces between local exchange carrier and interexchange carrier switches almost exclusively rely on Feature Group D signaling. This is the only protocol to support true Common Channel Signaling System No. 7 (CCS7) and Intelligent Network (IN) functions between the local and interexchange carriers.

Interfaces between the long distance carrier and customers—such as a dedicated access line to a customer PBX—are generally not Feature Group signaling but rather line-side signaling or ISDN Primary Rate Interface (PRI) interface.

THE ANATOMY OF A LONG DISTANCE CALL

In days before divestiture of AT&T, a long distance call originating on an AT&T line was carried all the way to its destination by AT&T—whether across the street or across the country. Today, long distance calls travel through a carefully managed series of hand-offs . . . from access provider to switching provider to transmission provider—which may or may not be the same company—across any combination of leased or owned facilities. There are many variants on the progression of a long distance call; we'll look at the following examples here:

- Intrastate voice call placed from a regular residential phone line
- Interstate voice call placed on a WATS line from a business
- Interstate data transmission on a Dedicated Access Line (DAL)
- Incoming call to a toll-free 800 number
- Call from a pay phone and charged to an account with a calling card

How the Network Processes a Simple Long Distance Voice Call

"Hi Mom. Happy Mother's Day." "Guess what! Your grandson scored the winning run!" When families and businesses are dispersed all over the country, we depend on ubiquitous, easy-to-access long distance service to stay in touch and conduct business. The typical MTS (Message Telecommunications Service) long distance phone call traverses a complex and sophisticated network path in a series of steps that is all but invisible to the caller and called party.

Here's the progression of a typical MTS long distance call.

❶ **Off-hook.** The caller picks up the phone, which signals an "off-hook" condition to the end-office switch and causes the delivery of dial-tone to the caller's phone. The phone line is the same one the household or business uses for local phone calls.

❷ **Dialing.** The caller dials the number as "1" plus the area code plus the seven-digit number. The "1" up front tells the switch that this is a toll or interexchange call. The next three digits (numbering plan area, or NPA) tell the switch the area code to which the call is directed. The next three digits (NXX) indicate the central office of the called party, and the last four digits identify the telephone (station) of the called party.

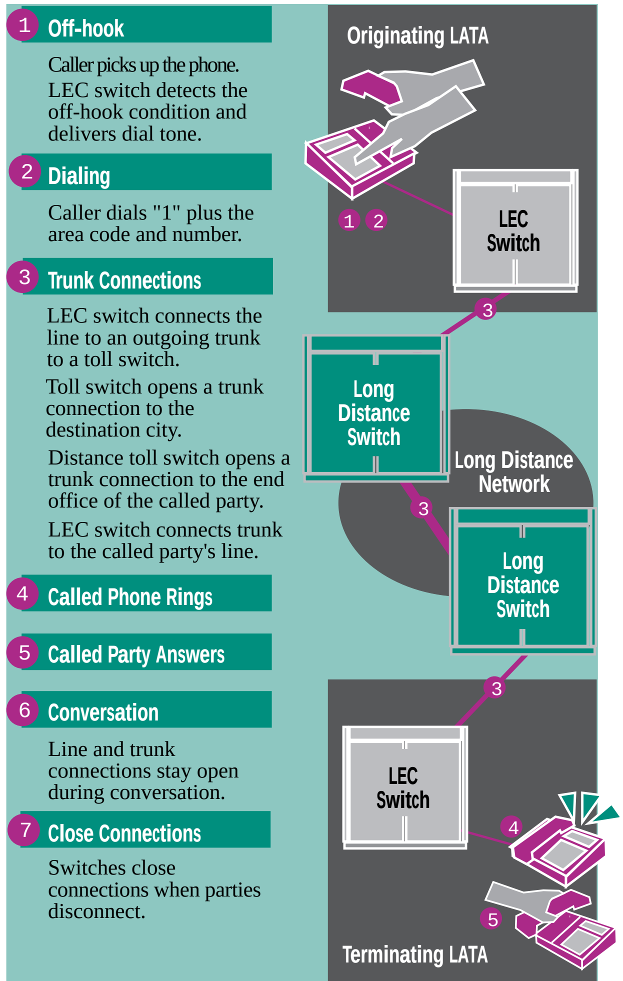
❸ **Trunk Connections.** With the information gathered from the dialed digits, the originating central office connects the subscriber line to an outgoing trunk to a toll switch in the same city—perhaps in the same central office. This toll switch opens a four-wire "toll quality" trunk connection to the toll switch in the destination city. The originating number and the dialed digits, known at this stage as Automatic Number Identification (ANI), are sent to the toll switch through this trunk connection. The toll switch in the distant city opens a trunk connection to the terminating end office, which connects the incoming trunk to the called party's line.

❹ **Called Phone Rings.** A ringing circuit in the terminating central office switch sends alternate current (AC) to the called party's phone to produce two seconds of ringing and four seconds of silence. Where the technology is in place to support calling name/number delivery, this information will be displayed to the called party.

❺ **Called Party Answers.** When the called party picks up the phone, the ringing circuit is removed and an answer supervision signal—a 2600 Hz tone or SS7 signal—is sent over the incoming trunk to the interexchange switch. The interexchange switch passes answering supervision to the local exchange carrier's central office and billing data recording begins. Without this signal, the originating switch would have no way of knowing if the call had been answered, and would bill for non-completed calls.

❻ **Conversation.** The line and trunk connections remain open as long as both parties are off-hook. The participating exchanges maintain records of call duration in order to prepare billing records.

❼ **Close Connections.** When the caller hangs up the phone, the originating central office returns the loop to the idle state and passes a disconnect supervision signal over the outgoing trunk to the interexchange switch. The originating interexchange switch passes the disconnect signal to the billing system and the terminating interexchange office—and from there to the terminating end office, which monitors the called party for disconnect and returns the loop to the idle state.



A Simple Long Distance Call—Switched Access

How the Network Processes a WATS Call

WATS lines are dedicated to incoming or outgoing long distance service of a particular type. They are used by businesses to aggregate long distance calls onto one service and reduce long distance charges.

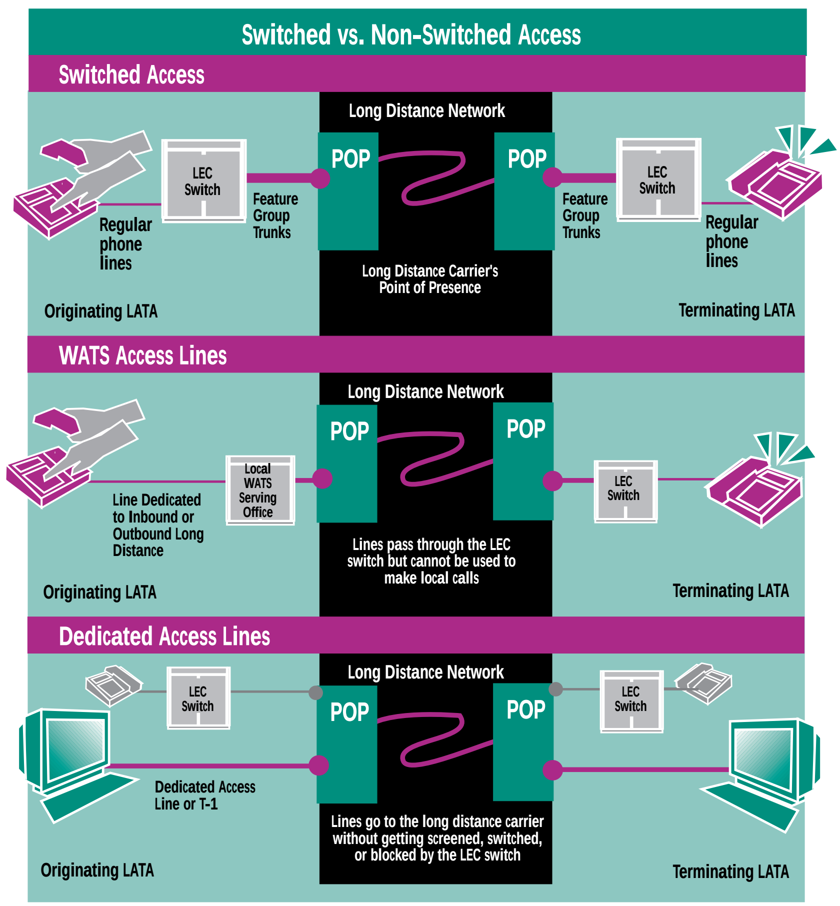
When placing a WATS call, the caller lifts the receiver and selects the company's WATS line on the telephone, either by dialing a special digit or pressing a button for the line. This dedicated line goes directly from the caller's location to the nearest local WATS serving office and is used exclusively for long distance calls. In fact, it cannot complete local calls.

The off-hook indication and dialed digits travel to the local end office switch, which automatically switches them on a Feature Group trunk to the caller's long distance company—along with regular 1+ long distance traffic. From there, the call is handled in the same manner as regular MTS calls described earlier.

The local switch can screen the dialed digits to determine if the call is eligible for completion, block the call if it is not eligible for completion, time the duration of the call, and record this information for billing purposes. For interstate WATS, the local WATS serving office sends billing information to the long distance provider, which sends the bill to the customer.

How the Network Processes a Dedicated Access Line Call

Unlike WATS calls, which are switched through the local end office switch, Dedicated Access Lines (DALs) go directly from the subscriber's location (usually an office) to the long distance provider. The local telephone provider often provides the lines, but it doesn't see what digits are dialed and doesn't do any switching, screening, or blocking. Traffic on the DAL line is just automatically forwarded to a direct connection port on the long distance company's switch. From there, the call process is the same as for regular long distance calls.



How the Network Processes an 800 Number Call

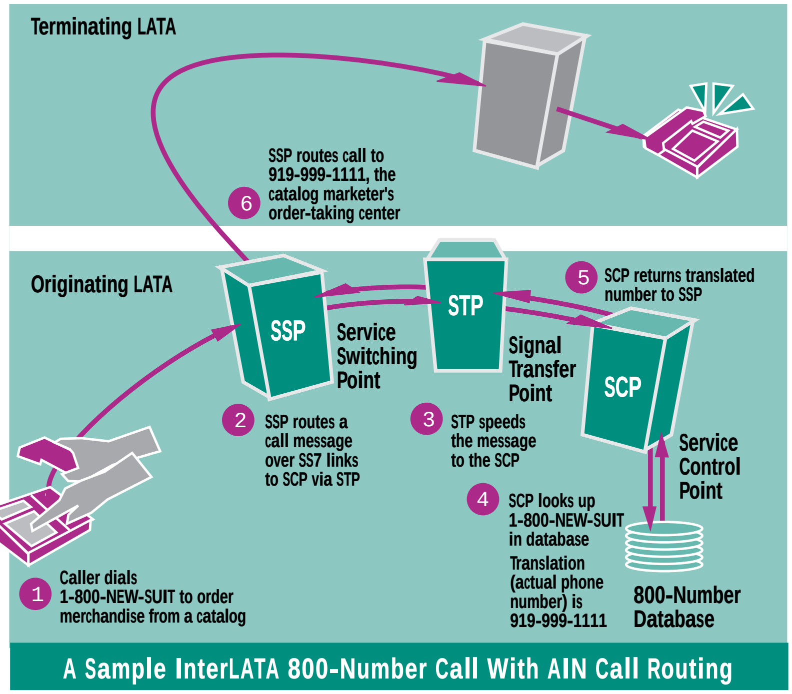
Traditionally, translations for 800 calls were done at the local office or tandem, where incoming calls were screened on the digits 8-0-0 and the NXX prefix. Translation tables in the switch identified the interexchange carrier that “owned” the number, and the call was routed appropriately. A 1993 FCC ruling mandated that the 800 translation take place in an 800 database, rather than in the switch. The database would allow numbers to be screened on all 10 digits. This both dramatically increased the number of possible 800 numbers and allows any number to be easily associated with any 800 service provider.

To ensure acceptable quality of service, the FCC also set stringent limits on the interexchange access delay (IAD) associated with processing the call. By March 1993, 97 percent of all 800 calls had to be passed to the interexchange carrier (IXC) within 5 seconds; by 1995, *all* calls had to be passed to the IXC within 5 seconds, and mean time could not exceed 2.5 seconds.

These standards are directed to Bell Operating Companies and GTE, but they will also inevitably affect independent telephone companies and others that want to expand or retain revenues from originating 800 calls or that want to ensure that their subscribers have an equivalent grade of service.

Today, 800 calls trigger a database inquiry from the end office switch or tandem switch to a large database maintained by Database Service Management, Inc. (DMSI). This database translates 800-number digits into the actual 10-digit phone number of the called party. This number is relayed back to the requesting switch through CCS7 signaling, and the call is completed to the assigned carrier.

Advanced signaling systems make it possible to perform special call routing, blocking, or answering based on where the call originated. For example, in a variant on traditional 800 service, the subscriber (the one with the 800 number) can designate which callers are authorized to use the 800 number service. The network will complete calls from those numbers only.



How the Network Processes a Calling Card Call

Long distance carriers issue calling cards to subscribers, which allow them to place toll calls from away-from-home locations and charge the service to their base account.

1. The caller dials a 1-800 number to access the carrier's calling card platform.

2. The carrier switch answers with a tone. (Steps 1 and 2 do not apply to calls made with some carriers, such as Regional Bell Operating Companies).

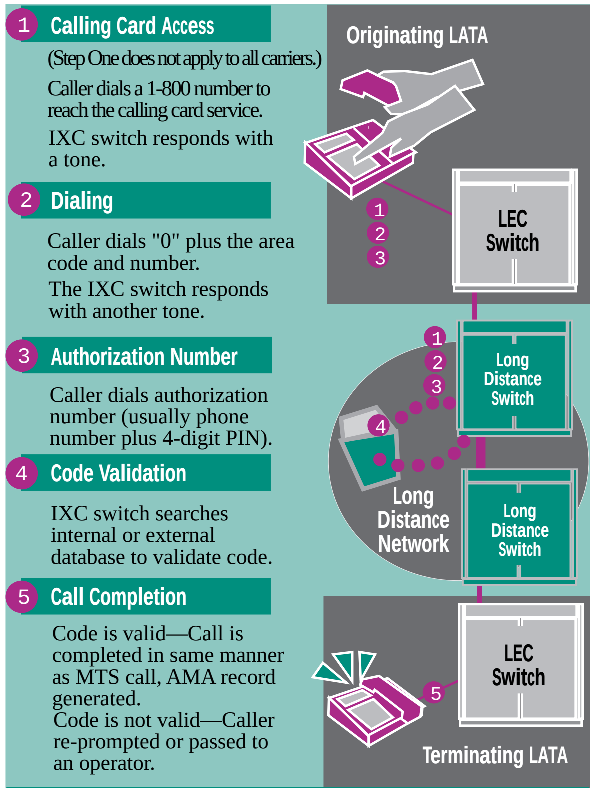
3. The customer dials "0" plus the area code and telephone number of the called party.

4. The carrier switch responds with another tone, signaling the caller to enter a personal authorization code. If no entry is made in a given period of time, an announcement prompts the caller to enter the authorization number.

5. The caller enters an authorization number, typically his or her telephone number plus a four-digit personal identification number, or "PIN."

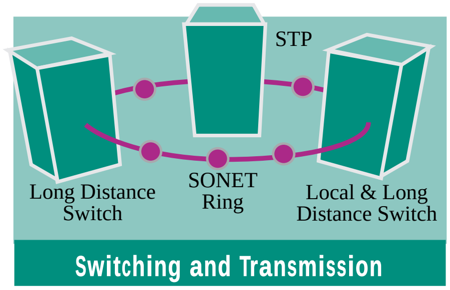
6. The carrier switch searches an internal or external database to validate the authorization code.

   If the code is valid, the switch processes the call and creates the appropriate AMA billing record. If the code is not valid, the caller may be prompted to re-enter the code, or passed to an operator for processing. (An operator also processes calling card calls placed from rotary phones. The caller speaks the authorization number, and the operator performs the database search and completes the call.)



How the Network Processes a Calling Card Call

THE LONG DISTANCE NETWORK—SWITCHING SYSTEMS



In the mid 1970s Nortel—followed shortly by a host of other vendors—began introducing digital technologies into the core of the public switched network. Digital switches fully capitalize on the strength of the computer revolution by routing both voice and data through the switch in the form of 0/1 binary coded information, which can be moved through the switch very quickly.

Because the digital switch was faster, smaller, more able to efficiently handle data, it soon became the standard switching system in North America. A single digital switch typically serves anywhere from under 1000 to well over 100,000 subscribers.

Switch Architecture—The typical digital switch has four essential components:

- The **central processor** controls call processing activities and direct system control functions, system maintenance, and the loading and downloading of software. To ensure reliability, the central processor is generally duplicated in digital switches. Each call is processed simultaneously on both processors; if the “hot” processor should develop a problem, the system automatically shifts to the standby processor, without the caller noticing any interruption of service. State-of-the-art larger digital switches are increasing processing power through additional specialized processors for tasks such as service control point functinality.

- The **switch matrix**, also referred to as the network, handles the actual connection of calls to their destinations. The latest switching moduels, such as the DMS SuperNode Enhanced Network (ENET), can process up to 64,000 channels in a single cabinet and switch wideband data as effortlessly as a voice conversation.

- **Peripheral modules** provide switch interfaces for the range of lines and trunks coming in from the network. The peripherals convert incoming voice and data signals into the digital format used by the switch and perform some low-level call processing tasks.

- The **input/output controller** provides access to the switch for maintenance, billing, routine operations and administration, and loading of software.

By varying the architecture of these components—and the software that defines how they perform—digital switches are created for a wide range of functions—from end-office connection of subscriber loops to international gateways. Long distance services are supplied from any of the following types of switches:

- A **toll/tandem switch** used for toll-center applications within a serving area. Nortel’s DMS-200 switch provides this function, including the world’s most sophisticated operator services.
- A **combination local/toll switch** that combines local and toll switching for large exchanges that can serve both subscriber lines and long-distance circuits within a serving area. Nortel’s DMS-100/200 switch is a combination local/toll switch.
- A **long-distance tandem switch** used exclusively by long distance providers, such as Nortel’s DMS-250 system.
- A **combination local/long distance switch**, such as Nortel’s DMS-500 switch, which combines the functionality of a DMS-100/200 and DMS-250 switch into one system. The DMS-500 switch allows established and entrepreneurial carriers to take advantage of anticipated regulatory change to provide local access services, toll and operator services, and long distance services from a single platform.
- An **international gateway** exchange, such as Nortel’s DMS-300 switch, that can interconnect with the telecommunications networks of virtually any country in the world.

Local Exchange Switch Features

- Residential Features
  - Custom Calling
  - Custom Local Area Signaling Services (CLASS)
- S/DMS BusinessExpress Features
  - Meridian Digital Centrex (MDC)
  - DMS-100 Meridian ACD
  - DataSPAN Frame Relay
  - Switched 56-kbps
  - Dialable Wideband Service (DWS)
  - ISDN Basic Rate Interface (BRI)
  - ISDN Primary Rate Interface (PRI)
  - DIALAN
  - Datapath
- Enterprise Network Features
  - Multilocation Business Group (MBG)
  - Meridian Switched Network
  - Virtual Access to Private Networks (VAPN)
  - Virtual Private Networking (VPN)
- System Features
  - Coin Lines
  - Carrier Identification Code (CIC) Routing
  - LATA Equal Access System (LEAS)
  - CCS7 Signaling (IBN7, ISUP FGD)
  - Equal Access Trunking
- Billing Features
  - Automatic Message Accounting (AMA)
  - Station Message Detail Recording (SMDR)

Interexchange Switch Features

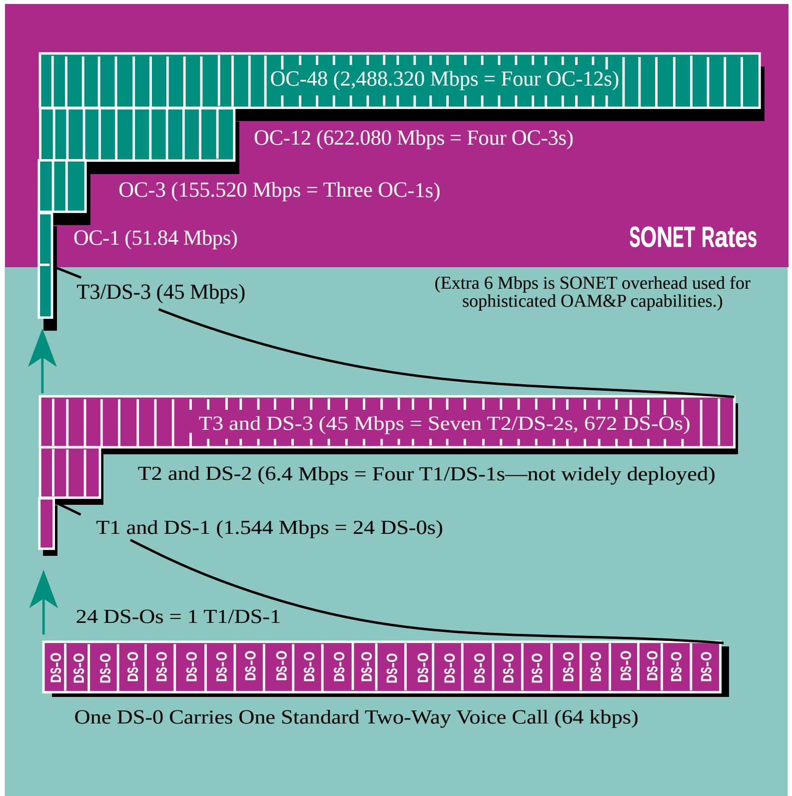
- Dialing Plans
  - Authorization and Account Codes
  - Calling Cards, Personal Identification Numbers
  - International Direct Distance Dialing (IDDD)
  - Virtual Private Network (VPN)
- Enterprise Network and Data Switching
  - Ethernet and X.25 File Transfer
  - Switched 56-kbps
  - Dialable Wideband Service (DWS)
- Interexchange Trunking Features
  - Feature Group A, B, C, D
  - Dedicated Access Line (DAL)
  - Intermachine Trunk (IMT)
  - ISDN PRI
  - CCS7 TCAP
- Intelligent Network Database Services
  - 800/900 Number Service
  - Inswitch Calling Card Database
  - Inswitch N00 Database
- Screening and Routing Features
  - Automatic Number Identification (ANI)
  - Time-of-Day, Class-of-Service
  - Code-Based and Alternate Routing
  - Full 10-Digit Routing
- Billing Features
  - Call Detail Recording (CDR)

Local and Long Distance Switch Can Provide Both Feature Sets

Switch planning, engineering, and maintenance are described in chapter 3, “The Business of Long Distance.”

THE LONG DISTANCE NETWORK—TRANSMISSION SYSTEMS

Transmission facilities connect the long distance provider’s switch with points of presence (POPs) on local exchange carrier’s switches—and to toll/tandem switches or international switches elsewhere in the public network. The most common scenario for a new entrant into the long distance market would be to lease all-digital DS-1 and DS-3 transmission facilities from another IXC to connect its long distance switches to local end office switches.



Transmission Rates—DS-O through OC-48

Long-haul or high-capacity applications, such as transport across the intraLATA network, typically use fiber-optic facilities based on SONET (Synchronous Optical Network) standards. SONET transport network elements offer cost-effective solutions for all types of service transport applications, from long-haul to local distribution. A complete product family will support both a range of optical line rates (OC-3, OC-12, OC-48, and OC-192) and multiple network topologies, including point-to-point, add/drop, optical hub, and bi-directional line-switched ring (BLSR) arrangements. (In Europe, Synchronous Digital Hierarchy [SDH] is the standard for fiber-optic transmission.)

Multivendor interworking

Because SONET provides an industry-wide standard high-speed transport, it ensures that providers can mix and match vendor equipment and interface with other SONET networks.

Reduced hardware costs with multipoint configurations and enhanced bandwidth management

SONET allows providers to build hub, rather than just point-to-point, networks so traffic can be delivered to multiple spurs with the most efficient use of facilities. More efficient bandwidth management also reduces the need for cabling, multiplexers, and cross-connects.

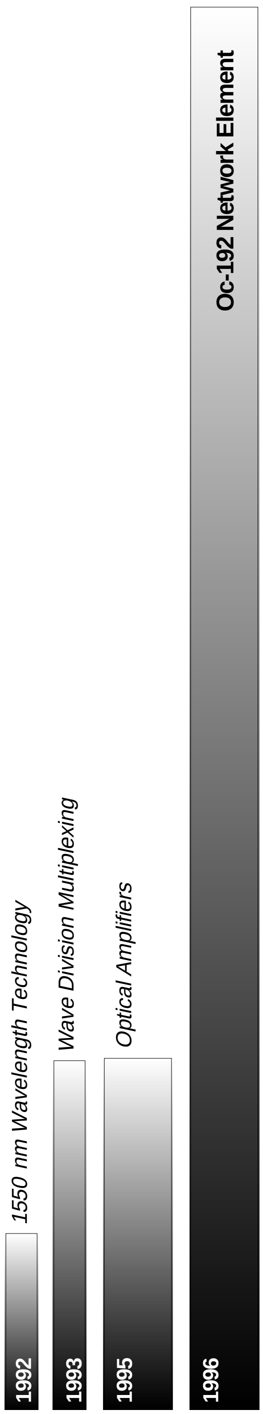
Enhanced OAM&P

Overhead information built into the SONET protocol allows providers to provide centralized operations, administration, maintenance, and provisioning.

New Services

The bandwidth flexibility of the SONET standard enables it to transport new high-speed packet data services, high definition TV, and services built on the asynchronous transfer mode (ATM) standard.

Key SONET Benefits



In addition to supporting a variety of transport scenarios, the long-distance provider has to juggle conflicting issues—how to increase capacity to prepare for the demands of broadband services, while holding the line on costs in an aggressive competitive environment

Ten years ago, industry-watchers forecast an explosion of demand for video teleconferencing, LAN and WAN connectivity, Internet access, telecommuting, medical imaging, distance learning, and other bandwidth-hungry applications. These forecasts proved true, and growth in local and long distance traffic continues at exponential rates. Interexchange carriers have seen their forecasts exceeded three times over in the last five years. Industry-watchers predict that by the year 2000, traffic will be almost *ten times* today's volume.

Already, many long-haul optical fiber routes—which once seemed limitless in capacity—are pushed to the limit with 20 Gb/s of traffic or more. In many cases, laying down new fiber is not an option. In all cases, it is more cost-effective to squeeze more from existing fiber plant than to install more fiber.

Fortunately, technology advances of the last five years have dramatically increased the range and capacity of long distance transmission systems.

1992 ***Extending reach***—In 1992, the introduction of 1550 nm wavelength technology doubled the reach of OC-48 fiber optic systems from 25 miles (40 kilometers) to 50 miles (80 kilometers).

1993 ***Doubling capacity***—In 1993, the introduction of Wave Division Multiplexing (WDM) technology at 1533 nm and 1557 nm wavelengths doubled system capacity while maintaining the 80 kilometer reach.

1995 ***Doubling reach once again while maintaining capacity gains—*** In 1995, the introduction of optical amplifier modules effectively doubled the capacity *and* reach of OC-48 systems—with single spans up to 160 kilometers and supporting the capacity gains of Wave Division Multiplexing as well.

1996 ***Achieving a <u>four-fold</u> increase in capacity—*** The new OC-192 network element provides four times the carrying capacity of OC-48 systems—plus the gains brought by Wave Division Multiplexing and optical amplifiers. The result is an eight-fold increase in bandwidth, compared to a single-channel OC-48 system.

More Traffic on Existing Fiber

Whether fiber is enclosed in a pipeline, installed in a tunnel, buried under the street, or strung along a high-voltage transmission line, long distance providers would clearly prefer to maximize existing fiber resources rather than deploy more fiber. Thus, many interexchange and long haul service providers are now looking for ways to increase the traffic-handling capacity of existing fiber routes—without the expense and delay involved in laying additional fiber cable. This trend can only accelerate in the near future as new and emerging services (such as Asynchronous Transfer Mode and broadband multimedia services) dramatically increase the demand for network bandwidth.

Several cost-effective solutions are available to provide immediate expansion in the traffic carrying capacity of currently installed fiber plant. Among the most important of these are:

No need for a protection channel for every working channel

- ***Protection Channel Sharing*** —A single protection channel can be shared among multiple traffic-carrying channels in a configuration known as "1:N" (where N equals the number of traffic-carrying channels). 1:N configurations conserve fiber pairs by allowing many optical channels to be protected by a single fiber pair; there's no need to reserve an unused fiber for every working channel needing protection.

Use protection bandwidth to transport extra traffic.

- ***Extra Traffic***—In 1:N arrangements, unprotected "extra traffic" can be transported in the shared protection channel. In fact, this additional capacity can be offered to other carriers, providing a significant source of new revenue without a corresponding investment in new fiber plant. Or, the long distance provider can use the extra traffic feature to provide route-diversity for critical services.

Combine two optical signals on a single fiber.

- ***Wave Division Multiplexing***—Optical signals of different wavelengths can be combined in a single fiber, thereby doubling traffic-handling capacity without increasing line rate. The benefits of Wave Division Multiplexing can be combined with 1:N protection for dramatic fiber savings.

Use existing fiber to transport traffic at 10 Gb/s.

- ***OC-192 Line Rate—*** The latest addition to the transport network technology is a 10 Gb/s OC-192 system, which terminates up to 20 Gb/s of tributary bandwidth. Multiple OC-48 systems could be deployed together to support the same capacity, but the OC-192 system offers a key advantage in that more traffic can be pumped through the *existing fiber plant*, forestalling the day when additional fiber has to be installed on long-haul routes. OC-192 technology also affords the network operator a 4:1 network element reduction, and bandwidth management across 192 STS-1 channels.

Extending the Reach of Long Haul Fiber Routes

In the last 15 years, as the price of fiber has dropped, long distance providers have built extensive fiber networks for long-haul applications that once would have relied on microwave technologies. For these fiber routes, providers seek to create the longest spans possible while maintaining signal quality. Traditionally, optical regenerators were required every 25 miles (40 kilometers) to boost the optical signal. New advancements have greatly increased the spans that can be created with fiber signals.

Optical spans up to 100 miles (160 kilometers) without intermediate regenerators

1550 nm Wavelength Technology—In 1992, Nortel introduced 1550 nm wavelength technology for S/DMS TransportNode systems. Because 1550 nm wavelength signals fall within the “low loss” window (1530 to 1560 nm) of optical fiber, this advancement allowed transport systems to reach twice as far without regenerators—up to 50 miles (80 kilometers), instead of the previous limit of 25 miles (40 kilometers).

Optical Amplifiers—With optical amplfiers, optical spans can be created up to 100 miles (160 kilometers), without intermediate regenerators—more than 310 miles (500 kilometers) in "cascade" implementations. By eliminating the need for many intermediate regenerators on long haul routes, optical amplifier technology produces a significant savings in equipment and maintenance costs.

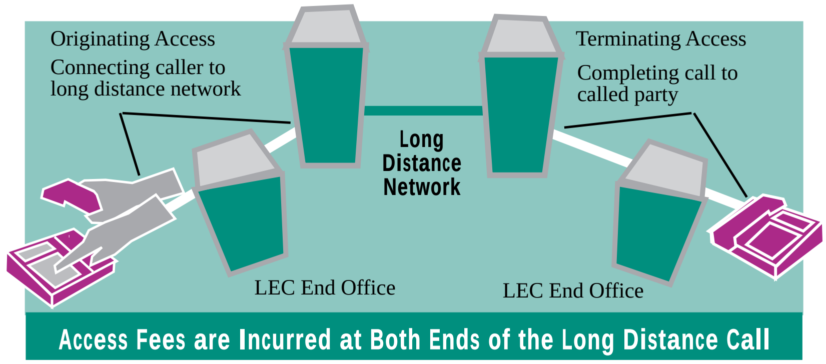
THE LONG DISTANCE NETWORK—ACCESS SYSTEMS

For long distance providers, the access equation includes two key components:

- Securing access to customers through the end office that serves their local loops, to provide long distance services that originate on regular telephone lines
- Providing dedicated access lines (DALs) that allow customers, usually business customers, to connect directly to the long distance company and bypass the local telephone company entirely

Switched Access through the Local Exchange Carrier

Under the terms of the Modified Final Judgment, Regional Bell Operating Companies must provide access to its network to complete long distance calls to and from their customers—equal in type and quality to the access offered to AT&T. In exchange for this service, the LEC receives an access charge. The access fees vary from one LEC to another and from one call type to another. An average long distance call might incur a 3.3 cent access fee on the originating end (to connect the caller to the long distance network) and a 3.5 cent fee on the terminating end (to connect the called party to the long distance network).



Dedicated Access Facilities

Long distance providers can lease, wholesale, or purchase access links directly to a customer to provide long distance services that bypass the local exchange carrier. For example, a dedicated access line could carry traffic directly from a customer's PBX to the long distance carrier's network. In exchange for a monthly fee for the line, the customer receives substantially reduced per-minute rates because there are no LEC access charges to pay.

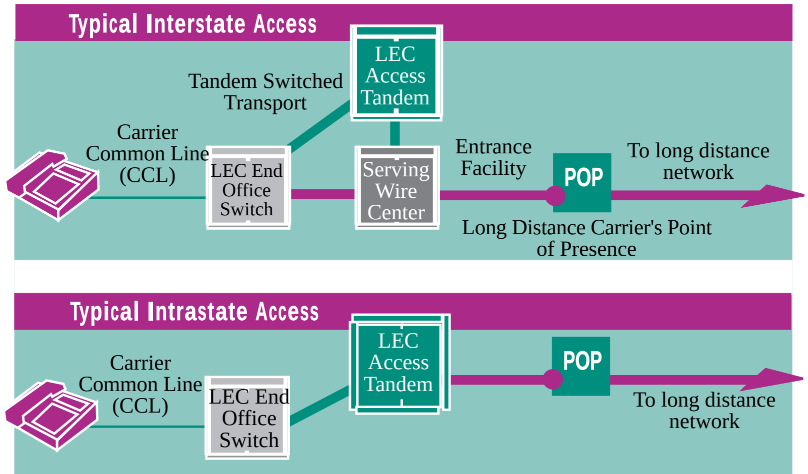
These dedicated access lines tend to be DS-1 or DS-3 connections, but for the example above are more likely to be ISDN Primary Rate Interface (PRI) trunks. The carrier may choose to lease some or all of the access links required to reach the customer—(1) from the customer to the end office, (2) end office to serving wire center or access tandem, and (3) the "entrance facility" from serving wire center to the interexchange carrier's point of presence (POP).

A typical scenario would have the local exchange carrier . . .

(1) Leasing the transport facility from the end office to the serving wire center or access tandem switch (leased from the local exchange carrier or competitive access provider in DS-1 and DS-3 increments, with discounts based on volume and term), and

(2) Leasing or constructing the "entrance" facility between the serving wire center and POP

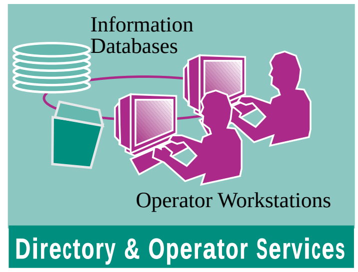
It would not be uncommon for a carrier to implement its own network facilities, end to end, to a large customer—or to lease only until traffic volume justified construction of its own network facilities.



Switched Access—Typical Scenarios

OPERATOR SERVICES PLATFORM

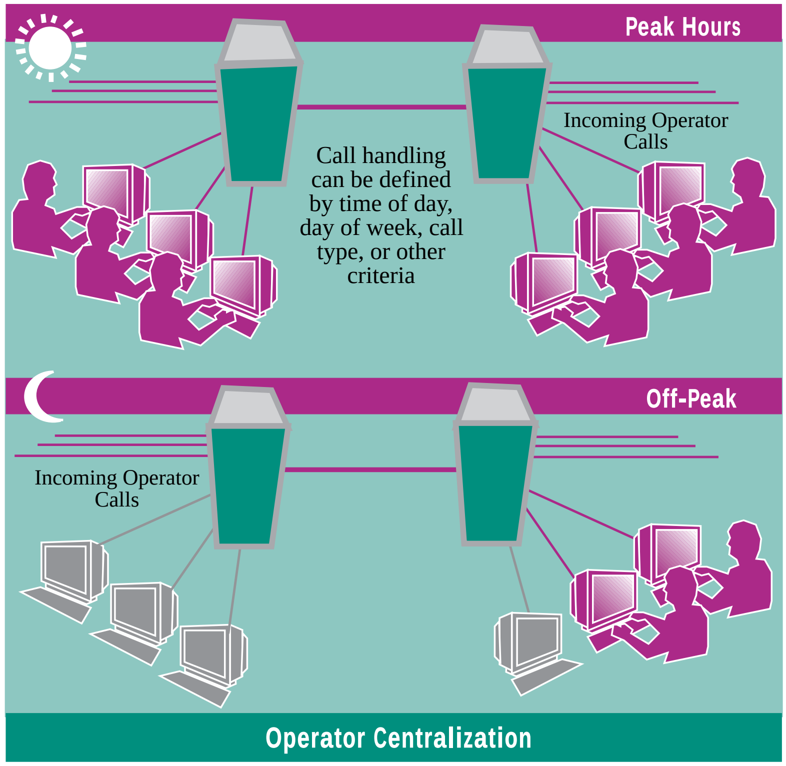
Switching Platform for Operator Services



Operator services are usually provided from the toll/tandem switching platform or a combination local/long distance platform such as Nortel's DMS-500 switch. To support operator services, the switch connects to operator positions, directory assistance systems, intelligent peripherals, operator reference databases, audio processors, and other information systems and databases using proprietary or industry standard protocols.

A state-of-the-art digital switch can support more than 1,000 operator positions defined into dozens operator teams—with productivity statistics maintained and reported for each operator, team, and center.

"Host" and "remote" switches can be defined, permitting the concentration of the operator work force at the convenience of the network provider. A remote performs operator functions, such as automated alternate billing, but sends the call to a host switch when a live attendant is needed. That host can handle operator traffic from up to many remote switches, 1,000 miles or more away. Any one switch can perform as a host or remote—or both—with call-handling determined by the time of day, day of week, call type, or other criteria. The result is unprecedented flexibility in managing operator service resources.

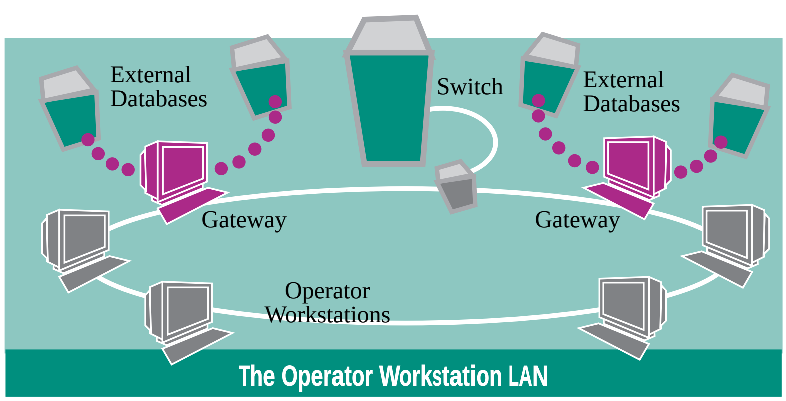


Ideally, the network provider will deploy a calling card and operator services system on a platform that is reusable in local exchange networks—in anticipation of a time when the provider chooses to enter the local market as well—or is permitted by regulatory change to re-integrate local and long distance networks.

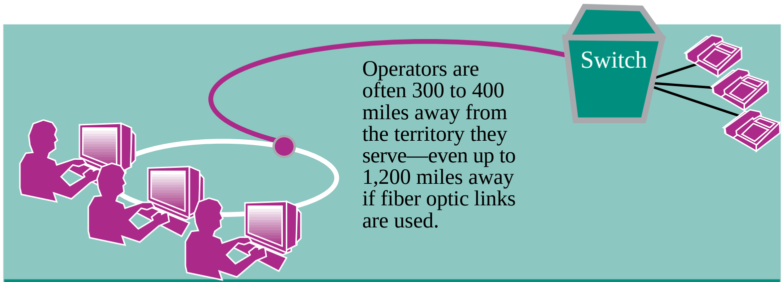
Operator Workstations

Operators sit at computer workstations—often based on industry standard personal computers with custom keyboards. A group of workstations can be connected through a local area network to supervisory workstations and to an interface unit that provides voice and data connections to the switch.

Operator workstations on the LAN can be set up as “gateway” positions, providing connections to directory assistance or intercept systems, or to other external databases.



The operator services center doesn’t have to be in the same building as the switch, or even the same city. It is not uncommon for workstations to be located 300 or 400 miles away. If fiber-optic connections are used, the workstations can be located up to 1,200 miles from the host switch.



Operator Services Can be Remote from the Switch

Workstations can be dedicated to a specific task, such as toll and assistance service, or support multiple services, such as toll and assistance plus directory assistance. New “intelligent” workstations support these traditional services alongside any number of custom applications created by the network provider or a third-party developer.

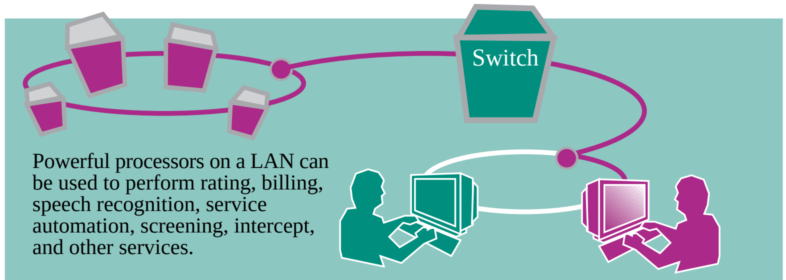
When workstation software has been built on open interfaces and industry standards, network providers can create powerful workstation applications that interact with other elements of the operator services environment.

Intelligent Service Nodes for the Operator Network

As operator services become more sophisticated—and as network providers seek to deploy new services very quickly across a widespread network—off-switch platforms can be advantageous. Some applications are particularly well suited for external, special-purpose processors connected to the switch through a local area network and industry standard communication protocols.

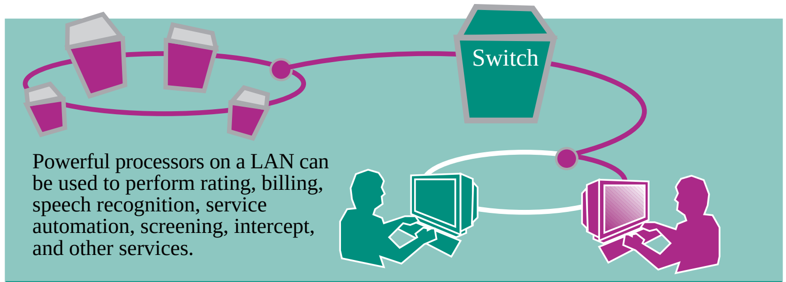
For example, speech recognition capabilities can be deployed on a powerful off-switch processor to recognize callers’ responses to prompts for alternate billing. Similarly, a directory assistance system deployed on an industry-standard UNIX processor can take advantage of speedy RISC (Reduced Instruction Set Computing) processing for powerful directory searches in seconds—without burdening the switch processor. And because this type of directory assistance system uses an off-switch database that is accessed by several switches, database updates only have to be made in one place.

Audio processing, listing services, reference and rating systems, and statistical reporting systems are well suited for off-switch deployment. When processing power isn’t shared with call-processing functions, several gigabits of memory is available to perform tasks quickly. The migration of processing-intensive tasks to off-switch computer processors frees up valuable call processing resources in the switch—and allows the applications to work easily in the multi-vendor environment.



Off-Switch Processors for Directory and Operator Services

INTELLIGENT NETWORKING (IN)



Off-Switch Processors for Directory and Operator Services

Today, most services are resident in the software in each central office switch. While this has allowed providers to deliver a vast array of revenue-generating features, it also means that providers must depend on vendors to develop new features and then must often coordinate the development of these features among the several switch vendors that they buy equipent from. When the features are available, they must then be loaded into each individual switch in the network, a complex task for networks that may contain hundreds of central offices.

As competition intensifies between providers of long distance services, providers are looking for three competitive advantages:

- They want to be able to rapidly develop customize features to differentiate their offering in the marketplace.
- They want to be able to quickly deploy new features throughout their serving areas as cost-effectively as possible.
- They want to put certain processing-intensive or network-based services onto centralized databases that all network switches can access

Intelligent Networking (IN) offers these advantages by placing the intelligence to deliver key features in a centralized network database instead of in each individual switch. Services can be deployed quickly and consistently on a network Service Control Point (SCP), to be accessed by many central office switches. “Triggers” in the software of individual service switching points (SSPs—central office switches with IN software) momentarily interrupt call processing and generate queries to the SCP for instructions on how to process features for individual calls.

IN also provides a standard environment for creating new services. Network providers or third-party developers can create their own new services—or purchase "off-the-shelf" service packages.

A sophisticated “service-creation environment” allows developers to create services in an industry-standard UNIX processing platform using standard C++ programming. Creation of new services can be made even easier by the availability of a graphical user interface and software "building blocks." Developers don't have to build from the ground up; they build from a foundation and framework, with modular components that are easily modified to form new services.

In addition, network providers can now choose from a selection of ready-made IN services for long-distance networks. A standard Long Distance Service Package would likely enable network providers to offer number translations services, such as 800 services and other inbound and outbound screening and translation functions. A single, off-the-shelf service package could also deliver calling card services, Virtual Private Networks, and flexible network access and carrier selection services for business users, telecommuters, and work-at-home employees.

Whether custom-developed or purchased off-the-shelf, IN services are loaded into the SCP, where they can be immediately accessed and used by any SSP in the network.

With IN and service-creation capabilities, providers can mobilize quickly to deploy new revenue-generating services, limited only by imagination and regulatory constraints.

Bellcore's standards for intelligent networking are known in the industry as "Advanced Intelligent Network" or "AIN." Similiarly, unique IN standards have been defined for wireless networks and for markets outside of North America.

Reduces trunking costs

SS7's "out-of-band" signaling frees the trunks carrying actual voice and data traffic to be used to their maximum capacity, significantly reducing the provider's cost for connecting the nework.

Enables profitable feature networking

SS7 protocol carries key information that significantly increases the value of services such as calling number/name and Centrex features by allowing them to work across networks that are served by more than one central office.

Enables marketing differentiation through AIN

SS7 is the signaling infrastructure for Advanced Intelligent Networking (AIN), which draws on network databases to allow providers to quickly develop and deploy customized features that can differentiate their service offerings from their competitors.

Key SS7 Benefits

Key IN Network Elements

- **Service Switching Point (SSP)** is a central office switch enhanced with SS7 messaging links to permit communication with application databases. Triggers in SSP software initiate queries to network SCPs for information to complete call processing.
- **Signaling Transfer Point (STP)** transports messages between SS7 nodes.
- **Service Control Point (SCP)** is the intelligence center in an SS7 network, processing queries for information and sending the response out to the originator.
- **Service Management System (SMS),** the operations support system for IN, provides the mechanism for downloading new features and monitoring the network.

- **Intelligent Peripherals (IPs)** provide the intelligence to drive IN features (as do SCPs), but they are more specialized network elements that, for instance, only control a specialized set of features (voice recognition services, for example), or provide a specialized set of functions to support features (IPs, for instance, may supply the voice prompts for some operator service automation features.)
- **Service Creation Environment (SCE)** is the set of tools and related activities that are used to quickly create new IN services.

A Sample IN Call

IN would, for example, be ideal for developing and delivering a custom service to allow areawide or nationwide chains to advertise one number that would automatically connect callers to the closest outlet. In the example shown here, the callers anywhere in the U.S. dial 1-800-EAT-PIZZa to order from the PiZZaParlor. The SSP (a central office switched equipped with IN software) collects the incoming digits and recognizes this as a call requiring a database translation by the SCP.

The switch routes the dialed digits as a message requesting translation. The SCP receives the message, consults a database of locations and number translations, and translates the digits to a “real” number. The SCP routes the translated number, with billing information, back to the SSP, which sets up the call and bills it to PiZZaParlor.

RELIABILITY AND SURVIVABILITY IN THE PUBLIC NETWORK

Long distance customers expect that their long distance service will be consistently up and running, under any conditions short of the occasional catastrophic natural disaster that destroys the actual facilities that deliver their service. Therefore, the public switched network is built to exacting standards for premium levels of reliability and survivability.

Reliability in Switching Components

The digital switch is designed to have essentially no unplanned downtime (many digital switches, for instance, have traditionally been built to specifications that ensure they are out of service for unplanned purposes no more than a few minutes in a 40-year period.)

This level of reliability is accomplished in the digital switch by having all essential components duplicated. Any given call is simultaneously processed by a primary ("hot") and a standby processor. If the primary component fails, the standby unit takes over the call with no perceptible loss of service. Routine automated diagnostic and maintenance programs in the switch software identify and correct problems before they affect service, and a sophisticated automated system of alarms and logs keep central office staff informed of any troubles with the switching system.

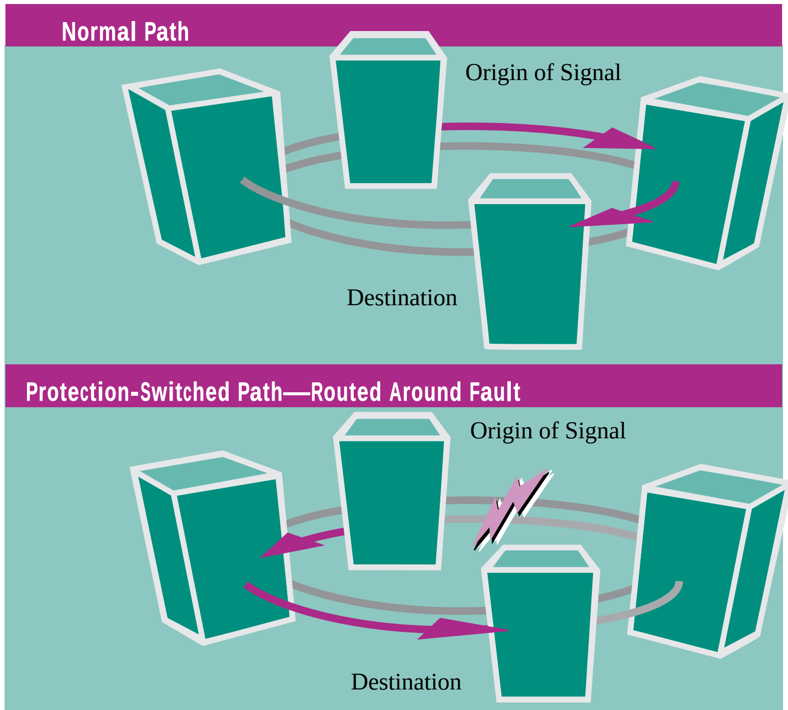
In addition, most large providers provision network-wide operations systems (OSs) that give them a real-time view of all their switching systems. The OS provides a central place to anticipate and preempt problems that might span multiple network nodes.

Reliability in Access and Transmission Systems

The most common enemy of access and transmission networks is the backhoe—the inadvertent cutting of the transmission route. Network providers have traditionally ensured the reliability of their transmission networks by configuring and engineering alternate routes for their traffic. One route—the working path—between City A and City B, for instance, might be placed along a major highway while the alternate route—the protection path—might be placed along a utility right-of-way. Microwave transmission is another widely used way to provide alternate routing.

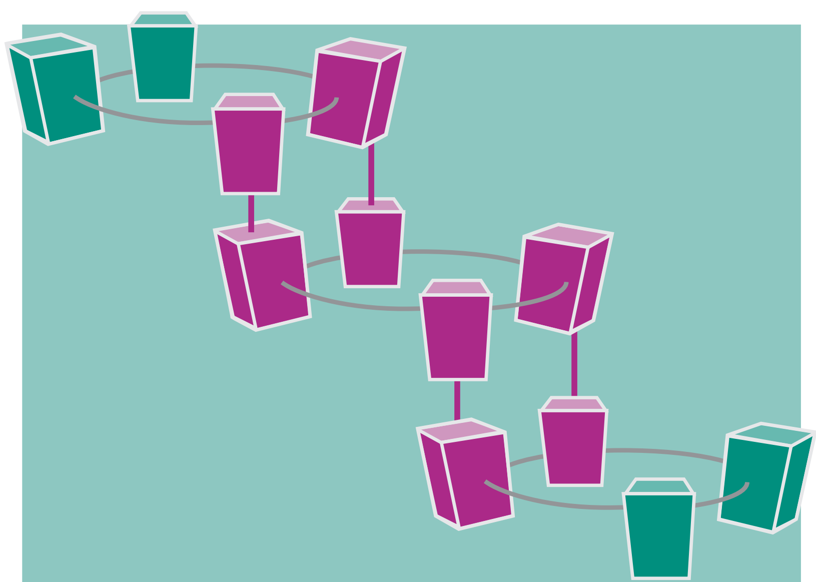
The advent of high-speed fiber-optics—especially when coupled with the SONET standard—has recently made possible dramatic increases in the reliability of transmission networks through self-healing fiber ring technologies.

With a bidirectional line-switched SONET ring, for instance, multiple offices are linked by pairs of fiber rings, each of which is provisioned to normally carry half the traffic on the system. The remaining bandwidth is held in reserve for protection. In the event of a cable cut or degradation of optical signal, the transmission equipment automatically places the affected traffic on the other route and sends it around the ring in the opposite direction, routing around the point of failure. Since the reroute is accomplished in milliseconds, service outages are prevented.



Sample Ring Protection Scheme

By provisioning matched SONET nodes, providers can ensure end-to-end survivability for routes that cross two or more SONET rings—offering continuous service for traffic that originates in a node on one ring and terminates in a node on another ring.



Matched Nodes Protect Paths That Span Multiple Rings

With these capabilities built into access, transmission, and switching systems, long distance providers can offer their customers the industry's highest standard of performance—99.999 percent availability.

Chapter 2 described the technology platform for providing long distance services—with thumbnail descriptions of how to manage that technology for maximum performance. The next chapter describes the business of operating a long distance company.