Electronic Switched Network Reference — Signaling and Transmission Avaya Communication Server 1000

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Contents

Chapter 1: New in this release

The following sections detail what's new in *Avaya Electronic Switched Network Reference - Signaling and Transmission, NN43001-280* for Avaya Communication Server 1000 (Avaya CS 1000) Release 7.6.:

- Features on page 9
- Other changes on page 9

Features

There are no updates to the feature descriptions in this document.

Other changes

See the following sections for information about changes that are not feature-related:

Revision History

March 2013	Standard 06.01. This document is up-issued to support Communication Server 1000 Release 7.6.
January 2012	Standard 05.04. This document is up-issued to support the removal of End of Life (EoL) and Manufactured Discontinued (MD) hardware content and associated diagrams.
August 2011	Standard 05.03. This document is up-issued to support the removal of content for outdated features, hardware, and system types.
November 2010	Standard 05.02. This document is up-issued to support Avaya Communication Server 1000 Release 7.5.
June 2010	Standard 04.01. This document is up-issued to support Avaya Communication Server 1000 Release 7.0.
May 2009	Standard 03.01. This document is up-issued to support Communication Server 1000 Release 6.0.

December 2007	Standard 02.01. Up-issued to support Communication Server 1000 Release 5.5.
June 2007	Standard 01.02. Up-issued to remove the Nortel Networks Confidential statement.
May 2007	Standard 01.01. Issued to support Communication Server 1000 Release 5.0. This document contains information previously contained in the following legacy document, now retired: *Electronic Switched Network: Signaling and Transmission Guidelines (553-3001-180)*. No new content has been added for Communication Server Release 5.0. All references to Communication Server Release 4.5 are applicable to Communication Server 1000 Release 5.0.
August 2005	Standard 3.00. Up-issued to support Communication Server 1000 Release 4.5.
September 2004	Standard 2.00. Up-issued to support Communication Server 1000 Release 4.0.
October 2003	Standard 1.00. This document is new for Succession 3.0. It was created to support a restructuring of the Documentation Library, which resulted in the merging of multiple legacy NTPs. This new document consolidates information previously contained in the following 2 legacy documents, now retired: • *Electronic Switched Network Signaling Guidelines (309-3001-180)* • *Electronic Switched Network Transmission Guidelines (309-3001-181)*

Chapter 2: Customer service

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Navigation

- Getting technical documentation on page 11
- Getting product training on page 11
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- Getting technical support from the Avaya Web site on page 12

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Chapter 3: Introduction

This document is a global document. Contact your system supplier or your Avaya representative to verify that the hardware and software described are supported in your area.

Subject

Note on legacy products and releases

This document contains information about systems, components, and features that are compatible with Communication Server 1000 software. For more information on legacy products and releases, click the Technical Documentation link under Support & Training on the Avaya home page:

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Applicable systems

This document applies to the following systems:

- Avaya Communication Server 1000M Single Group (Avaya CS 1000M SG)
- Avaya Communication Server 1000M Multi Group (Avaya CS 1000M MG)
- Avaya Communication Server 1000E (Avaya CS 1000E)

Intended audience

This document is intended for individuals responsible for the planning, engineering, and administration of a system.

Conventions

Terminology

In this document, the following systems are referred to generically as "system":

- Communication Server 1000M (CS 1000M)
- Communication Server 1000E (CS 1000E)
- Meridian 1

The following systems are referred to generically as "Large System":

- Communication Server 1000M Single Group (CS 1000M SG)
- Communication Server 1000M Multi Group (CS 1000M MG)
- Meridian 1 PBX 61C and CP PIV
- Meridian 1 PBX 81C and CP PIV

Related information

This section lists information sources that relate to this document.

Publications

The following publications are referenced in this document:

- *Avaya Features and Services Fundamentals (NN43001-106)*
- *Avaya Software Input/Output Administration (NN43001-611)*
- *Avaya Software Input/Output Reference - Maintenance (NN43001-711)*

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Chapter 4: Overview

Contents

This section contains information on the following topics:

Private networks

Private networks have three basic elements:

1. telephones
2. a circuit switch
3. transmission facilities

Each telephone connects to a Private Branch Exchange (PBX) circuit switch that establishes connections between the telephones. In a private network, connections between telephones on different switches are established over a transmission facility (such as a trunk) between the pair of switches, or over a tandem connection of transmission facilities and intermediate switches.

To place a call, the end user dials a string of digits that direct the connection to the target telephone. In Tandem TIE Trunk Networks (TTTNs), the dialed digits steer the connection through the network. A string of successive access codes cause facilities to connect in tandem until the switch that connects to the destination telephone is reached. Each time a switch connects a new facility in tandem, it passes the digits onto the connected facility.

In an Avaya Communication Server 1000 (Avaya CS 1000) and Meridian 1 network, the Electronic Switched Network (ESN) node switches collect all digits of the called number and pass the full-called number between switches. The called number is dialed in a Uniform Dialing Plan (UDP) format. Switches connected to ESN nodes may need the dialed numbers in a

Tandem TIE Trunk Network (TTTN) format before switching to UDP format. Similarly, the ESN node may control routing to connected switches by transmitting a sequence of access codes, followed by the called number.

Switches are also provided with trunks to the Public Switched Telephone Network (PSTN). Calls to telephones in the PSTN (and to other switches) can be placed by these trunks. However, trunks between switches (TIE Trunks) are normally provided because the call can be performed at a lower cost.

Switch designations

System circuit switches in a network configuration have designations that depend on the network function. Designations used include the following:

- node switch
- main switch
- satellite switch
- Common Control Switch Arrangement (CCSA) tandem switch

Node switch

A node system equipped with the ESN Network Alternate Route Selection (NARS) software package has full route selection capabilities while other non-node systems have limited route selection capabilities.

Main switch

A main switch has an outgoing trunk route to only one node. This route can be incoming and outgoing, but routes to other nodes must be incoming only to the main circuit switch, since the main circuit switch cannot select between nodes to route network calls. A main circuit switch can have Central Office (CO), Foreign Exchange (FX), and Wide Area Transmission Service (WATS) trunks, as well as TIE Trunks to other switches.

A circuit switch with outgoing trunk routes to more than one node that does not meet the requirements for classification as a node, is classed as a main circuit switch. The outgoing routes can be assigned different access codes, leaving route selection to the end user. Outgoing routes can also be selected by an automatic route selection capability.

Tributary switch

A tributary switch is a circuit switch that has a trunk route to a main circuit switch, but not to a node. A tributary circuit switch can have CO, FX, and WATS trunks, as well as TIE Trunks to other switches.

Satellite switch

The only difference between a satellite and tributary circuit switch is that the satellite switch has neither incoming CO trunks nor attendant service. In this document, satellite and tributary circuit switches are treated the same.

CCSA tandem switch

A Common Control Switching Arrangement (CCSA) tandem switch is the major switching vehicle in a CCSA network. It is intended for very large systems. In a CCSA system, any end user can reach any other global end user by dialing seven digits. The tandem switch performs trunk-to-trunk switching only. Its function is similar to that of an ESN node, except that an ESN node can support telephones in addition to trunk-to-trunk switching. Switches with TIE Trunks to the tandem switch are called main switches. The CCSA network supports a dialing plan similar to the ESN Uniform Dialing Plan (UDP).

The CCSA tandem switch is the interface point between the ESN network and a CCSA network. The two networks can be arranged to function as a single integrated network.

Supervision

Supervision is a binary signal associated with each direction of transmission on a trunk facility. The two states are on-hook and off-hook, similar to the condition of a telephone on-hook (hung up) or off-hook (in use).

Each switch connected to a trunk sends a supervision signal to, and receives a supervision signal from, the connected switch. Thus, the trunk has four supervision states. The trunk is idle when both directions are on-hook. Off-hook is sent when a call is initiated on an idle trunk. This action is called " seizing" the trunk. The distant switch receives the off-hook signal and prepares to receive digits. A momentary off-hook condition returned from the destination switch can occur during call setup, but a steady off-hook is not transmitted until the called telephone answers. This off-hook signal is called "answer supervision." The supervision changes to on-hook when the called telephone hangs up or is disconnected.

When a switch serves as an intermediate (tandem) connection between trunks, it normally sends the supervision signal it receives from each incoming trunk to the connected outgoing trunk. It also monitors for a disconnect signal so the trunks can return to an idle state and wait for new calls.

In some cases, no provisions are made for returning an answer supervision signal from the destination when the called telephone answers. If this occurs, an off-hook signal can be returned from an intermediate switch. This off-hook signal is called "substitute answer supervision." This signal is provided to remove transmission impairments associated with the on-hook condition on some trunk facilities and to distinguish a call that has been blocked from one that might have reached a destination party.

A connection by a PSTN trunk is a typical case where a called telephone answer indication is not returned. The circuit switch that connects the call to the PSTN trunk must be configured to provide an off-hook signal to the incoming trunk after sending digits to the PSTN trunk.

Modes of operation

A circuit switch can operate in one of two modes when routing a call over a TIE Trunk:

- cut-through mode
- senderized mode

The following sections define these two modes.

Cut-through mode

With cut-through mode, a trunk is accessed immediately following an access code. Subsequent digits are forwarded to the trunk as dialed. The telephone end user monitors call progress tones from connected switches. Because of a blocking tone, the end user may be required to pause during dialing to listen for a dial tone, or may be required to abandon the call before completing dialing.

Pure cut-through mode provides the greatest flexibility for providing compatible operation for calls originating at main and tributary switches. The number of digits transmitted to the node can be flexible. The node can prompt for additional digits when required for the authorization code features.

Senderized mode

With senderized mode, all digits of the called number are collected before an outgoing trunk is accessed. The trunk is accessed and digits are transmitted to set up the call. The transmitted digits need not be the same as those dialed, for example, as a result of NARS digit manipulation. The end user does not receive call progress tones until all digits are transmitted.

No tones are provided during dialing other than a locally-generated dial tone following the trunk access code.

Senderized mode limits flexibility. The main circuit switch must be programmed to determine how many digits to collect before forwarding those digits to the node. Usually, no more than 12 digits can be collected and forwarded.

Start dial control

After a TIE Trunk is seized, digits of the dialed number are normally transmitted. The only exception is a manual trunk, which rings a designated telephone when seized. However, most terminating equipment requires a variable time interval to prepare for the reception of digits. This time interval often depends on the switch's call-processing load. Therefore, a fixed delay before sending digits is unreliable.

There are four common ways to handle start dial control:

- immediate start
- delay for dial tone
- wink start
- delay dial

Immediate start

Immediate start applies in those cases where a short fixed delay is required for the switch to receive digits.

Delay for dial tone

A dial tone is provided when the switch is ready to receive digits.

Wink start

A momentary off-hook signal is sent when the terminating equipment is ready to receive digits.

Delay dial

An off-hook signal is sent if the switch is not ready to receive digits. An on-hook signal is sent if the switch is ready to receive digits.

The delay for dial tone is used when an end user controls digit sending, as in a TTTN. Wink start and delay dial are used in registerized digit sending.

Normally, only one start dial control is used. However, on some switches, a dial tone may be combined with any of the other three.

System switches in an ESN network can work with any start dial signal.

Chapter 5: Call setup sequences

Contents

This section contains information on the following topics:

Introduction

The following sections describe call set up sequences between conventional circuit switch equipment and an Electronic Switched Network (ESN) node, with emphasis on signaling compatibility. Calls to the node, between nodes, and from the node are described herein. Several cases are included, based on variations in configuration (cut-through or senderized), tandems, and so on.

A circuit switch without ESN main or ESN node software is treated as a cut-through circuit switch in the following discussion. (A circuit switch with ESN main software is not addressed.)

Calls to the ESN node

Case 1: Calls From a telephone at a cut-through main switch

This case describes a call to the ESN node from a telephone at a cut-through main switch:

1. The user at the main circuit switch goes off-hook, receives a dial tone from the main circuit switch, and then dials the network access code.
2. The main circuit switch seizes a TIE Trunk to the ESN node and provides audio transmission to the caller. This enables the caller to hear subsequent call-progress tones from the node.
3. The node returns a dial tone to the caller when it is ready to receive digits.
4. The user dials the desired number and, if required, the authorization code. The digits transmit to the node as dialed. The node provides an authorization code request tone only if the authorization code is required. If not, routing takes place immediately following the last digit of the called number.
5. The node proceeds to set up the call.

Case 2: Calls From a cut-through non- senderized tributary circuit switch

This case describes a call from a cut-through non-senderized tributary circuit switch to the ESN node by a cut-through non-senderized main circuit switch:

1. The user at the main tributary circuit switch goes off-hook, receives dial tone from the tributary circuit switch, and dials a TIE Trunk access code to access the main circuit switch.
2. The tributary circuit switch seizes a TIE Trunk to the main circuit switch and provides audio transmission. This enables the user to hear tones from the main circuit switch, and dialed digits from the user can pass to the main circuit switch. The main circuit switch normally provides a dial tone to incoming TIE Trunks.
3. After receiving dial tone from the main circuit switch, the user dials the ESN network access code and the desired number. Call set up proceeds as in Case 1, except that the user's dialed digits and the tones from the node pass through both cut-through switches.

Note:

Whenever practical, provide a direct trunk group to the ESN node to avoid using the main circuit switch as a tandem switch.

Case 3: Calls From stations at a senderized main circuit switch

This case describes calls from stations at a senderized main circuit switch to an ESN node:

1. The caller goes off-hook, receives a dial tone, dials the ESN access code, receives a second dial tone from the main circuit switch, and then dials the desired number.
2. The senderized main circuit switch does not seize a TIE Trunk to the node after receiving the access code. Instead, it collects the digits of the called number and then seizes a TIE Trunk to the node. The node does not provide a dial tone.
3. The senderized main circuit switch and the node are mutually arranged to use either a wink start or delay dial signal as a start dial signal to initiate outpulsing.
4. When the main circuit switch receives the appropriate start dial signal, it outpulses the called number to the node and connects the user so that subsequent ringing signals can be heard.

The system authorization code is not supported in this case. The following limitations prohibit the authorization code:

- The senderized main circuit switch cannot provide the authorization code request tone for authorization code digits.
- The senderized main circuit switch cannot register enough digits for the authorization code and the called number.
- It is impractical to forward additional digits after the senderized main circuit switch has outpulsed the called number to the node.

Case 4: Calls From a cut-through tributary circuit switch

This case applies to calls from a cut-through tributary circuit switch to the ESN node by a senderized main circuit switch. This case is similar to calls from a senderized main circuit switch. The user at a cut-through tributary circuit switch dials a TIE Trunk access code to reach the main circuit switch and receives a dial tone from the main circuit switch. From this point on, the call is handled as though it originated at the senderized main circuit switch.

Case 5: Calls From a senderized tributary circuit switch

This case applies to calls from a senderized tributary circuit switch to the ESN node by a cut-through main circuit switch. This is not permitted because of signaling compatibility problems. The tributary cannot provide the proper outpulsing control for routing the call through the main to the node. In this situation, direct trunks must be provided from the tributary circuit switch to the node. By definition, the tributary then becomes a main circuit switch.

Case 6: Calls From main senderized and tributary senderized circuit switches

In this case, both the main circuit switch and tributary circuit switch are senderized. This is also not permitted because of compatibility problems similar to Case 5. Direct trunks must be provided to the node from the tributary circuit switch. The tributary circuit switch thus becomes a main circuit switch.

Call completions

Call completions to the following are handled in a normal manner:

- stations on the node
- stations at other nodes
- Public Switched Telephone Network (PSTN) trunks from the node
- Public Switched Telephone Network (PSTN) trunks from the connected nodes

Using TIE Trunks to the main circuit switch, the node completes calls to the following destinations:

- stations at the main circuit switch
- stations at a tributary circuit switch connected to the main circuit switch
- off-network stations by PSTN trunks terminating on the main circuit switch
- off-network stations by PSTN trunks terminating on the tributary circuit switch

In all cases, call routing to the main is initiated by an off-hook signal sent to the TIE Trunk. The basic sequences for call completion are as follows:

1. To reach a telephone at the main circuit switch, outpulse the Directory Number (DN).
2. To reach a telephone at the tributary circuit switch, outpulse an access code for a TIE Trunk to the tributary, pause if necessary, and outpulse the Directory Number (DN).
3. To reach a PSTN telephone by a Central Office (CO) trunk terminating on the main, outpulse the access code for the CO trunk, followed by the PSTN number.
4. To reach a PSTN telephone by the tributary circuit switch, the node outpulses an access code for the main to tributary TIE Trunk, followed by the access code to the CO trunk, followed by the PSTN number.

Case 1

This case applies to a call from an ESN node to a telephone at either a cut-through or a senderized main circuit switch:

1. The node seizes a TIE Trunk to the main circuit switch and then pauses, waiting for the main circuit switch to receive digits.
2. The node then outpulses the telephone DN digits to the main circuit switch.

Case 2

This case involves a call from an ESN node to a tributary circuit switch by a cut-through main circuit switch. This is similar to Case 1, except the initial digit(s) outpulsed by the node is an access code for a TIE Trunk connecting the main circuit switch to the tributary circuit switch:

1. The node inserts a fixed pause (for a delay for a dial tone) after the access code, unless both main and tributary circuit switches are step-by-step (SXS) switches.
2. The node resumes outpulsing either when the fixed pause interval elapses or a dial tone is detected.
3. The tributary circuit switch resumes outpulsing of the DN.

Case 3

This case involves a call from an ESN node to an off-network telephone by a cut-through main circuit switch:

1. The access code outpulsed by the ESN node is for a CO trunk, instead of TIE Trunk as in Case 2.
2. After the access code is required, there must be a fixed pause or a delay for a dial tone even when both the main circuit switch and the CO are SXS switches.
3. The resumed outpulsing consists of the PSTN number rather than a circuit switch number.

Case 4

This case applies when the main circuit switch is senderized and tandems a call from the node to a tributary circuit switch or CO.

When the main circuit switch is senderized, the beginning of the call setup sequence is the same as in Case 3 on page 27. However, once the node begins outpulsing, it outpulses all digits without pausing. If the main circuit switch can receive DTMF digits, outpulsing should be

DTMF digits regardless of the capability of the tributary circuit switch or CO. The senderized main circuit switch collects the digits, translates, prefixes, and completes the call to the next switch.

Calls to other private networks

Tandem TIE Trunk Networks (TTTN)

Calls to a Tandem TIE Trunk Network (TTTN) are engineered similarly to calls to a main circuit switch with tributaries. The maximum number of switches connected in tandem is five in a TTTN setup. Thus, up to three access codes with pauses may have to be outpulsed. To avoid the requirement for outpulsing a large number of digits, arrange trunks to several switches in the TTTN so no more than two trunks in tandem are required to reach any telephone in the TTTN.

Common control switching arrangement

An ESN node with TIE Trunks to a Common Control Switching Arrangement (CCSA) switch is arranged to outpulse seven digits to the CCSA switch to complete network calls to a telephone in that part of the network. Optionally, the ESN node can outpulse ten digits to complete off-networked calls by the CCSA switch.

Calls from other private networks

An ESN node can function as a TTTN switch for calls from a TTTN. The user in a TTTN dials access codes sequentially to add trunks in tandem.

Calls from a TTTN do not require different engineering than calls from a main circuit switch, other than a Route Data Block option to arrange the incoming trunk for TTTN operation. TTTN operation is currently supported by the system and is not changed for ESN.

Calls from a CCSA switch (see CCSA tandem switch on page 19) can be arranged to terminate on an ESN node or any other switch that is part of the Coordinated Dialing Plan (CDP). Current CCSA trunk options can accommodate this. TIE Trunks from a CCSA switch must be provided to all switches in the ESN network (including those that are part of the CDP) to be accessible from the CCSA switch. An unambiguous numbering plan encompassing both the ESN network and CSSA must be arranged. The ESN node routes calls in the CCSA numbering plan to the CCSA switch.

Requirements for dialing pauses

When outpulsing to the main circuit switch and to a TTTN, ESN nodes are occasionally required to pause at various points in the digit string to allow for trunk access and register attachment. Failure to pause causes missed digits and calls to connect to wrong numbers or to be lost altogether.

ESN software provides for pauses following trunk access codes in the Network Alternate Route Selection (NARS) translation tables. The general rule is that each trunk access code outpulsed must be followed by a pause. However, there are a number of situations where the pause is not required.

In determining whether the pause is required, you must consider the following:

- what type of circuit switch is reached in the dialing
- what piece of equipment is accessed

Important:

IMPORTANT!

Pauses are supported on analog and DTI trunks, but are not supported on ISDN trunks. The asterisk (*) used to introduce a pause is supported only on analog and DTI trunks, but not supported on ISDN trunks. On ISDN trunks, if OPAO feature is enabled, the asterisk (*) is outpulsed as a called party digit.

Pauses are not required in the following situations:

- The access code connects a SXS circuit switch to an SXS circuit switch.
- The access code connects a system circuit switch to any other circuit switch, providing that subsequent pauses are not required.
- The access code is 9 for a CO trunk by a Centrex circuit switch, but not for other CO trunks.
- The access code is for an automatic route selection on any circuit switch.

A potential problem can occur when a trunk access code requiring a pause is made after the call is routed through one or more system switches. While the ESN node need not pause between access codes for routing through the system switches, if it does not pause, a problem occurs where the pause is required.

The connected switches insert the proper delay after the access code before resending digits. However, the time spacing between digits is not maintained. The trailing digits "catch up" with the leading digits. The time delay required after an access code is eliminated. To avoid this problem, the ESN node must insert pauses after each access code for this call routing.

Chapter 6: Transmission considerations

Contents

This section contains information on the following topics:

Echo

All voice connections between telephones require two directions of transmission for conversation to take place. When the signal transmitted in one direction reflects over the other directional path, the caller hears the caller's own voice, with a slight delay.

Depending on the delay, the effect is perceived as sidetone, rain barrel effect, or echo. Two-wire facilities require care in matching impedances to prevent reflections. Four-wire facilities neither generate reflections, nor eliminate reflection in built-up connections, because in most cases, there are 2-wire connections to the telephones.

The objection to echo increases with echo delay. The Via Net Loss (VNL) plan increases loss depending on delay. However, the loss also reduces the received volume. Limits are placed on the amount of loss used to suppress echo. If these limits are exceeded, use echo suppressor devices instead.

Loss

The provision of good transmission requires the following compromises:

- sufficiently low (one-way) loss in each direction to provide satisfactory volume on the call
- minimum contrast in received volumes on different calls
- sufficiently high round-trip losses to ensure adequate performance from the standpoint of suppressing talker echo, noise, and near-singing

The following loss plan has been developed for the Electronic Switched Network (ESN). The network is partitioned into node-to-node connections, node-to-main connections and main-to-satellite or tributary connections. The plan requires that:

- node-to-node trunks have a maximum loss of 3.5 dB
- node-to-node tandem connections have a maximum loss of 4.1 dB
- node-to-main trunks have a maximum loss of 2.5 dB

You can meet these loss objectives by installing echo suppressors and reducing the loss to 0 dB on trunks when the objective loss is exceeded with VNL alone.

Tandem switching

Tandem switching is the networking of telephone switches in a series configuration.

PSTN tandem switching

A PSTN tandem switch is usually collocated with the carrier facilities that serve the switch. You can make tandem connections between trunks terminating at a PSTN tandem switch without significant degradation of transmission performance.

Private network tandem switching

A private network tandem switch is usually located on the end user's premises, remote from the carrier facilities that serve the circuit switch. These carrier facilities are generally located at a telephone company (telco) switching center and connected to the circuit switch by local loop plant (cable). If the telco switching center does not have long-haul carrier facilities, short-haul carrier facilities connect to another telco switching center that has these facilities. Thus, a tandem connection made at the circuit switch can introduce the distortion of two loop plant connections and two carrier facility connections, both avoided in the PSTN tandem connections.

Trunk routing rules

Trunk routing rules define the allowed connections between node, main, tributary, and satellite circuit switches. These routing rules are summarized in Table 1: Trunk routing rules on page 33.

Table 1: Trunk routing rules

To: From:	Node	Main	Tributary	Satellite
Node	Yes (up to 4 links)	Yes (Note 4)	No (Note 3)	No (Note 3)
Main	Yes (one node only)	No (Note 1)	Yes (one main only)	Yes (one main only)
Tributary	No (Note 3)	Yes (one main only)	No (Note 2)	No (Note 2)
Satellite	No (Note 3)	Yes (one main only)	No (Note 2)	No (Note 2)

Note:

Permitted for non-tandem trunks if the connected main circuit switches are part of a coordinated dialing plan. Also, routes of this type already in place when ESN is installed may remain. However, these routes should be eliminated as part of network evolution to support the dialing plan.

Note:

Routes of this type already in place when ESN is installed may remain. These routes should be eliminated as the network evolves.

Note:

This route is permitted by upgrading the tributary or satellite switch to support main switch capabilities.

Note:

One-way routes from nodes to main circuit switches are not restricted.

Gain

For remote network access, one application of private networks is to reduce toll charges on PSTN-to-PSTN calls. The end user in the PSTN makes a local or toll-free call to one of the private network switches and then calls to an off-network destination by either Direct Inward System Access (DISA) or attendant assistance.

The PSTN transmission plan does not support tandems of two or more connections. Such tandems occur when using the private network to make a PSTN-to-PSTN call. The loss can be partially offset by gain.

PSTN-to-PSTN calling over the private network has relatively small usage and savings, so it does not justify a change to the private network transmission plan. Instead, gain is applied on the access trunks, which are used exclusively for incoming calls. The gain is applied independent of the connection established through the private network. Thus, the amount of gain provided is a compromise that optimizes grade of service on the more important connections but possibly degrades service on others.

Gain devices

Gain must be bidirectional between 2-wire interfaces and is provided by devices called repeaters. There are two acceptable types of bidirectional gain devices: fixed-gain and switched-gain. Fixed-gain devices are extremely sensitive to impedance mismatches at the 2-wire interfaces. Such mismatches can cause oscillation. Switched-gain overcomes the oscillation problem, but introduces speech impairments due to the switching action.

Fixed gain

To implement bidirectional fixed gain, add either an amplifier on a 2-wire path or two unidirectional amplifiers in a 4-wire arrangement, interfacing the 2-wire path through hybrids. Both schemes are sensitive to the impedances at the 2-wire interfaces. Adjustable matching networks are required to allow the device to interface a variety of facilities.

The more gain required, the closer the match must be between impedance and interface to prevent oscillation or poor transmission associated with near oscillation. The impedance at the interfaces is partly determined by the impedances of facilities switched into a connection. Ultimately, those impedances limit the practical gain.

Voice-switched gain

The voice-switched gain amplifier avoids stability problems by applying gain dynamically. Only one direction of transmission can have gain at a time. A loss equal to the gain is provided in the opposite transmission direction.

Gain is applied by monitoring for speech and applying gain in the talker-to-listener direction when speech is detected. In the idle mode, a small loss is inserted in both directions. Compensation for impedances is required for the direction sensing circuitry to function properly. Table 2: Comparison of fixed gain and voice-switched gain on page 35 compares fixed gain and voice-switched gain.

Gain with compression

On some connections, signal levels may already be high, and gain may increase the levels above FCC specified limits. Some manufacturers provide compression options to guard against exceeding FCC limits. Speech compression ensures that signal levels do not exceed a specified maximum, generally –9 dBm. When amplified but uncompressed speech levels exceed that level, the gain is dynamically reduced so the output level does not exceed –9 dBm. The –9 dBm limit is specified in FCC requirements.

Gain with compression is possible on both fixed gain and voice-switched gain repeaters and does not change the adjustment procedure. See Table 2: Comparison of fixed gain and voice-switched gain on page 35.

Table 2: Comparison of fixed gain and voice-switched gain

Fixed gain	Voice-switched gain
Does not degrade speech by gain switching action.	May degrade speed.
Must be permanently attached to a trunk and be adjusted for its impedance.	May be switched into connections as required, but is affected somewhat by facility impedance.
Is not sensitive to voice levels.	May require voice activation adjustment to provide required sensitivity.
May oscillate under certain circumstances.	Is "unconditionally" stable.
Is "transparent" to voice-band data and DTMF signaling.	Must be switched out for voice-band data and may impair DTMF signaling.

Recommendation

When the required test equipment is available and the type of facility provided by the telco is known, use fixed gain units for superior performance. Use switched gain units when transmission performance is not critical or when the more complex alignment procedure for fixed gain units cannot be performed.

Adjustment

The gain should be set initially to 6 dB in each transmission direction. This value of gain is a compromise between optimized grade of service and practical considerations of avoiding oscillation and other transmission impairments. Based on experience, you may adjust the gain to greater or less than 6 dB.

Application to trunks

To minimize the effect on the overall transmission plan, install the gain units only on trunks used to access the network primarily over TIE Trunk facilities or to public destinations. Calls originated on-network must be blocked from accessing these trunks.

Arrange one-way incoming Direct Inward System Access (DISA) central office trunk (COT) groups, using ground start trunks. The trunks are used for calling over TIE Trunks and off-network. Calls terminating on the same circuit switch should be placed by the attendant on direct inward dial (DID) trunks, if provided.

When DISA is equipped on DID trunks, do not provide gain units. DID trunks carry traffic both to telephones and DISA, and gain is not desirable for the traffic to telephones. Instead, add a new ground-start CO trunk group and move DISA to that group. Gain units can then be provided on that group.

Chapter 7: Transmission planning

Contents

This section contains information on the following topics:

Planning

The planning of Electronic Switched Networks (ESNs) can be partitioned into five major tasks:

1. assessing current equipment to identify locations of nodes
2. designating existing equipment to remain in place as main, satellite, and tributary circuit switches
3. planning TIE Trunk routes
4. planning network routing
5. planning off-network call routing

Placement of nodes

The first task is to choose locations for node switches. The following transmission factors should be considered:

- Locate the node near a telco toll switching center to minimize the loop plant and short-haul facilities between the node and long-haul facilities.
- Locate the node near the middle of its cluster of main circuit switches so most main-to-node facilities fall in the short-haul category.
- If earth satellite facilities are used extensively, locate nodes near the earth station facilities.

Once the nodes are designated, the remaining circuit switches are designated as main, satellite, or tributary switches. All switches that have direct trunk groups to a node are main circuit switches. Those switches that access a node by the main circuit switch are satellite or tributary switches, depending on whether or not they have incoming Central Office Trunks (COTs).

TIE trunk routes

Each pair of nodes in the network represents a potential TIE Trunk route. Traffic considerations and tariffs determine how many routes are equipped and how many trunks are required for each route. In general, the objectives of lowest cost and best transmission both dictate that the number of tandem trunks required to establish any connection be kept to a minimum. Thus, direct trunk routes should be established wherever practical.

Direct trunk routes represent a radical departure from Tandem TIE Trunk Networks (TTTNs). For TTTNs, routing is usually organized into major trunk route highways with feeder routes. This structure is efficient when alternate routing is not permitted, as with TTTNs, but it is not efficient when alternate routing is supported, as with ESNs. Thus, converting a large TTTN to an ESN can have significant impact on permitted routing.

Network call routing

Plan direct and alternate routes for routing calls so transmission can be evaluated on each route and appropriate controls can be established on individual trunks. Table 3: Route count table (maximum number of node-to-node routes) on page 39 gives the maximum number of node-to-node routes possible in networks of various sizes. The table establishes the upper limits on the number of routes to ensure that no potential route is overlooked.

Table 3: Route count table (maximum number of node-to-node routes)

Nodes	Direct routes	2 trunks in tandem	3 trunks in tandem	4 trunks in tandem
1	0	0	0	0
2	1	0	0	0
3	3	3	0	0
4	6	12	12	0
5	10	30	60	60
6	15	60	180	360
7	21	105	420	1260
8	28	168	840	3360
9	36	252	1512	7560
10	45	360	2520	15,120
11	55	495	3960	27,720
12	66	660	5940	47,520

Note:

Each node has trunks to every other node.
All routes that do not include the same node more than once are valid.

Transmission controls

Transmission controls are established first for each direct trunk route, then for two-trunk tandem routes, then for three-trunk tandem routes, and so on. For each route, an echo suppressor (ES) control or Via Net Loss (VNL) value is specified. (VNL applies to land circuits shorter than 1800 miles [2800 km]; longer land circuits and all satellite circuits require echo suppressor control.)

The required VNL value is determined from the round-trip delay, which depends primarily on the type of facility and distance. Table 4: Loss table for land circuits on page 40 gives approximate VNL values for varying distances (in airline miles), based on the type of facilities typically provided by a telco. The actual distance could be considerably greater, because the actual signal path is less direct. However, the value includes a margin to accommodate average deviation from direct routing.

Table 4: Loss table for land circuits

Distance in miles (km)	VNL (dB)
0–100 (0–160)	
100–400 (160–640)	1.0
400–700 (640–1120)	1.5
700–1000 (1120–1600)	2.0
1000–1300 (1600–2080)	2.5
1300–1600 (2080–2560)	3.0
1600–1800 (2560–2880)	3.5

Note:

Land circuits longer than 1800 miles (2880 km) and all satellite circuits require echo suppressor control.

Two-trunk tandem routes

Wherever two VNL trunks are in tandem, their VNL losses are summed. If the loss exceeds 4.1 dB, you must equip at least one trunk with echo suppressors (ES). Select the higher loss trunk for echo suppression. However, consider the number and types of trunks and keep trunk changes to a minimum. Thus, trunks that appear most frequently in high-loss connections should also be considered prime candidates. Table 5: Transmission control requirements for two-trunk tandem connections on page 40 summarizes this requirement.

Table 5: Transmission control requirements for two-trunk tandem connections

Trunk 1	Trunk 2	Requirement
ES	ES	No action
ES	VNL	No action
VNL	ES	No action
VNL	VNL	If total loss is less than 4.1 dB, no action; otherwise, change trunk 1 to ES or prohibit this connection.

Three-trunk tandem routes

For smaller networks, sort and test all three-trunk tandem routes for proper controls. For larger networks, the number of three-trunk tandem routes actually permitted is small in comparison to the number of possible routes. Therefore, the more efficient approach is to sort out the permitted routes and to consider only them.

For three-trunk tandem routes, ES combinations must be considered, as well as total loss. Whenever a VNL TIE Trunk is connected with ES between two trunks, equip the VNL TIE Trunk with ES to disable intermediate echo suppressors.

Table 6: Transmission control requirements for three-trunk tandem connections on page 41 summarizes the transmission control requirements for three-trunk tandem connections.

Table 6: Transmission control requirements for three-trunk tandem connections

Trunk 1	Trunk 2	Trunk 3	Total loss if less than 4.1 dB	Total loss if greater than 4.1 dB
ES	ES	ES	No action required	No action required
VNL	ES	ES	No action required	No action required
ES	VNL	ES	Prohibit this connection (preferred) or change trunk 2 to ES	
ES	ES	VNL	No action required	No action required
VNL	ES	VNL	No action required	Change trunk 1 or 3 to ES or connection prohibited
ES	VNL	VNL	No action required	Trunk 2 must be ES or connection prohibited
VNL	VNL	ES	No action required	Trunk 2 must be ES or connection prohibited
VNL	VNL	VNL	No action required	One or more must be ES or connection prohibited

Note:

When a trunk is changed to echo suppressor (ES) control, check all combinations in which it appears for routing violations.

Off-network call routing

Call transmission properties largely depend on the type of facilities over which the call transmits (see Table 8: Private network facility requirements on page 43). Because of these properties, certain destinations are disallowed for some types of off-network call routing. These are summarized in Table 7: Permitted off-network call routing on page 42.

Table 7: Permitted off-network call routing

Route off-network call				Destinations permitted			
From	By	By	Station	CO trunk	FEX trunk	WATS trunk	Other common carrier
Node			Yes	Yes	Yes	Yes	Yes
TIE Trunk	Node		Yes	Yes	Yes	Yes	Yes
Node	Main		Yes	Yes	No	No	No
Node	Main	Tributary or satellite	Yes	No	No	No	No
Main	Tributary or satellite		Yes	Yes	Yes	No	No

Note:

Off-network calls to CO or FEX trunks are allowed only within local calling areas.

Network facilities

Private network facilities

You can order private network facilities from the local telco and other common carriers. Although you order facilities on a point-to-point basis, the telco must be informed of the overall planned network, and it generally assists in the design and selection of facilities. The following facilities can be ordered from the telco:

- 2-wire trunks
    - TL 11M/E (E&M Type I signaling)
    - TL 12M/E (E&M Type II signaling)
- 4-wire trunks
    - TL 31M/E (Type I signaling)
    - TL 32M/E (Type II signaling)

Conditioning is the tolerance on frequency response and delay distortion. Several degrees of conditioning beyond basic line quality are available, including: C1, C2, C3, C4, and D1.

Generally, the basic line quality is adequate for voice applications. Conditioning is usually required for voiceband data applications.

Table 8: Private network facility requirements

From	To	Facility required	IPE cards
Node	Node	TL 31M/E interface (4-wire E&M Type 1)	NT8D15
Node	Main	TL 31M/E interface (4-wire E&M Type 1)	NT8D15
Main	Satellite	TL 11M/E or TL 12M/E (2-wire E&M Type 1)	NT8D15

When ordering telco facilities, you must provide the FCC registration number. Different interfaces must be ordered for non-registered equipment. It is acceptable to have registered and non-registered equipment attached to the same facility, as well as to have a TIE Trunk between telco and end-user Private Branch Exchange (PBX) equipment. Facilities ordered from a telco are equipped with VNL loss (0 dB loss if echo suppression is provided). When facilities owned by the end user are used, it is the end user's responsibility to insert the VNL loss into the facility.

PSTN facilities

You must order PSTN facilities from the telephone company. A summary of these facilities is given in Table 9: PSTN facility requirements on page 43. The facilities must be identified as connecting to equipment provided by the end user, and the FCC registration number provided.

The facilities ordered can include:

1. PBX central office trunks
2. PBX foreign exchange trunks to specific foreign exchanges
3. PBX inward WATS trunks
4. PBX outward WATS trunks
5. off-premise stations

In addition, you can order direct trunks to common carrier systems (for example, AT & T, Qwest, or Bell) from these service suppliers. These services provide indirect access to the PSTN.

Table 9: PSTN facility requirements

Service required	Facility required
Local calling area	PBX/CO trunk

Service required	Facility required
Calling area local to a distant exchange	PBX/FEX trunk
Wide calling area within the same state	Intrastate WATS outgoing PBX trunk
Calling area, all bordering states	Interstate WATS outgoing PBX trunk, band 1
Calling area within USA, Canada, bordering states, and beyond	Interstate WATS outgoing PBX trunk, band 2 and higher
Calling to major cities in United States	Non-Bell services such as Sprint or MCI

Chapter 8: Transmission performance

Contents

This section contains information on the following topics:

Voice quality performance

The quality of voice connections over tandem trunks is a function of the composite characteristics of the trunks. Each trunk added to the connection degrades the overall transmission performance. Thus, some limits must be placed on the number of trunks permitted in tandem, as well as on which trunks can be connected.

To maintain adequate voice quality while keeping the routing restrictions from becoming unduly complex, ESN is partitioned into two basic connection categories, each with its own set of requirements. The connection categories are as follows:

- node-to-node
- node-to-main, satellite, or tributary

Node-to-node connections

The restrictions on node-to-node connections are the following:

1. No trunk has a loss exceeding 3.5 dB.
2. No combination of trunks used for a valid connection has a loss exceeding 4.1 dB.
3. Split echo suppressors are provided at each end of each trunk equipped with echo suppressors. Each echo suppressor is enabled or disabled by the switch at its end.
4. Tandem connections of echo suppressor-controlled trunks are permitted, provided the intermediate echo suppressors are disabled. The switch disables the echo suppressors it controls when a direct connection is made between two echo

suppressor-controlled trunks, thus meeting this requirement. Because the intermediate echo suppressor cannot be disabled, planners cannot place a trunk that is not controlled by echo suppressors between trunks that are controlled by echo suppressors.

5. Generally, no more than three TIE Trunks should be connected in tandem. A limit of four is imposed between echo suppressor-controlled trunks. Software is arranged to disable echo suppressors when it tandems a call from an echo suppressor-controlled trunk to another such trunk. This software does not disable echo suppressors on other connections.

Node-to-main, satellite, or tributary connections

Restrictions on these TIE Trunks follow:

1. The node-to-main trunk is normally a land circuit that does not exceed 250 miles (400 km). If this is not the case, the main circuit switch is treated as a node for transmission planning. The transmission planning of the node-to-main TIE Trunk is considered part of node-to-node transmission planning.
2. Volume loss on a node-to-main TIE Trunk, if less than 250 miles, must not exceed 2.5 dB.
3. Loss on main-to-satellite and main-to-tributary trunks must not exceed 2 dB.

Note:

In some cases, the telco can provide only non-VNL trunks, which have a loss exceeding these objectives. If the loss is significantly higher than VNL, the switchable pad must be in the "pad-out" mode for connection to these trunks.

To minimize toll charges, ESN can route calls over private network facilities to PSTN trunks. The PSTN has a designed loss that does not take into account the added loss of extending the call over private network facilities.

ESN, like any other private network, provides lower quality connections than a call routed directly to the PSTN. The amount of degradation must be kept small enough that the connection is acceptable to most end users. This loss is restricted as follows:

1. Off-network long-distance connections must only be established from trunks terminating on nodes. The private network loss added to the PSTN loss is limited to the following:
    a. 4.1 dB for calls originating at node stations
    b. 6.6 dB for calls originating at main stations
2. Off-network local connections can terminate at nodes and main PBXs. For nodes, the loss is the same as above. For mains, the loss is limited to the following:
    a. 6.6 dB for calls originating at node stations

b. 9.1 dB for calls originating at main stations

Voiceband data performance

Voiceband data modems can transmit data between private network switches. General guidelines on the expected performance of various modem types for different ESN connections are provided in Table 10: Performance of modems with automatic adaptive equalizers on page 47 and Table 11: Performance of modems with fixed equalizers on page 48.

These guidelines are based on the documented transmission performance of Bell System private lines and the actual measurement of the system and several metropolitan area private lines. The expected performance is stated in statistical terms only to reflect the wide performance range of actual circuits.

The probability of success in completing a data call is based on an overall average of all Bell System private lines. A particular line or group of lines may be better or worse than the average. The expected performance stated here should be understood only as a probability.

Table 10: Performance of modems with automatic adaptive equalizers on page 47 applies to modems with automatic adaptive equalizers; no significant improvement is expected with C2- or C1-conditioned lines compared with basic-quality private lines. Using D1-conditioned lines (guaranteed lower noise) can improve performance as shown in Table 10: Performance of modems with automatic adaptive equalizers on page 47.

Table 10: Performance of modems with automatic adaptive equalizers on page 47 and Table 11: Performance of modems with fixed equalizers on page 48 specify the expected performance for ESN connections with one, two, and three trunks in tandem. The percentage of successful calls is presented according to modem bit-rate.

For modems without automatic (fixed) equalizers, significant improvement over basic line performance can result from using C1 or C2 conditioning, as shown in Table 11: Performance of modems with fixed equalizers on page 48.

Table 10: Performance of modems with automatic adaptive equalizers

Modem bit rate (probability of success)		
Number of trunks connected in tandem	**Basic C1, C2 conditioning**	**D1 conditioning (4-wire facility)**
1	2400 b/s (80%)	4800 b/s (<80%)
2	2400 b/s (50%)	4800 b/s (50%)
3	Not recommended	2400 b/s (50%)

Table 11: Performance of modems with fixed equalizers

Modem bit rate (probability of success)			
Number of trunks connected in tandem	**Basic conditioning**	**C2 conditioning**	**C3 conditioning**
1	2400 b/s (75%)	2400 b/s (80%)	2400 b/s (90%)
2	2400 b/s (50%)	2400 b/s (60%)	2400 b/s (75%)
3	Not recommended	2400 b/s (50%)	2400 b/s (50%)

Chapter 9: Maintaining transmission performance

Contents

This section contains information on the following topics:

Installation

Maintaining high transmission performance in private networks requires constant attention by network administrators. Experience shows that transmission performance can degrade over time. This degradation can be traced to inadequate maintenance of the facility by the supplier and administrative changes by the supplier in the assignment of equipment to provide TIE Trunk service.

After a TIE Trunk facility is installed, the installer runs a transmission test to verify that the facility meets tariff requirements. Only after the performance has been verified is the facility ready to be turned up for service.

Scheduled maintenance

Scheduled maintenance should be performed at regular intervals whether or not trunk faults are known to exist. Testing should be carried out once a week until it is determined that less frequent testing is adequate.

Corrective maintenance

Follow-up to trouble reports generated by end users or software diagnostics identifies various trunk problems in need of correction.

Transmission testing of TIE Trunks

ESN switches are capable of accessing a quiet termination or a 1020 Hz test tone at a remote ESN switch. These capabilities permit the testing of TIE Trunk transmission performance.

Testing loss

The following test is performed at each end of each TIE Trunk so both directions of transmission are checked:

1. From the maintenance terminal, load the trunk test program and access the remote test tone for the trunk to be tested.
2. Connect a transmission level meter to the "facility in" access jacks of the trunk under test. Measure the level of the 1020 Hz test tone.

The permitted level requirements, based on a switched-in pad mode at the far-end switch, are given in Table 12: Transmission level requirements on page 50.

Table 12: Transmission level requirements

Trunk design loss (dB)	Minimum (dBm)	Maximum (dBm)
0	–17.5	–11.5
0.5	–18	–12
1.0	–18.5	–12.5
1.0	–19	–13
2.0	–19.5	–13.5
2.5	–20	–14
3.0	–20.5	–14.5
3.5	–21	–15

If the requirements in Table 12: Transmission level requirements on page 50 are not met, isolate the fault to the trunk facility or equipment. Use the following test to aid in this isolation. Perform the test at each end of the facility:

1. From the maintenance terminal, load the trunk test program and access the local test tone.
2. Connect a transmission level meter to the "equipment" out jack of the suspect trunk. Measure the level and compare to the minimum and maximum levels required for the trunk card used.

If the second requirement is not met at any facility end, perform corrective maintenance and repeat the test. If the requirement is met at both facility ends, the facility supplier should perform corrective maintenance.

Testing noise

Use Testing noise on page 51 at each end of each TIE Trunk so both directions of transmission are checked.

Testing noise

1. From the maintenance terminal, load the trunk test program and access the remote quiet termination for the trunk to be tested.
2. Connect a noise meter to the "facility in" access jacks of the trunk under test. The noise requirements are given in Table 13: Transmission noise requirements on page 51.

Note:

If the requirements in Table 13: Transmission noise requirements on page 51 are not met, use Isolating the fault to the trunk facility or equipment on page 52 to isolate the fault to the trunk facility or equipment.

Table 13: Transmission noise requirements

Distance in miles (km)	Maintenance (dBrnC)	Immediate action (dBrnC)
0–15 (0–24)	28	36
16–50 (26–80)	28	36
51–100 (82–160)	29	36
101–200 (162–320)	31	36
201–400 (322–640)	33	40
401–1000 (642–1600)	35	40
1001–1500 (1602–2400)	36	40

Distance in miles (km)	Maintenance (dBrnC)	Immediate action (dBrnC)
1501–2500 (2402–4000)	39	44
2501–4000 (4002–6400)	41	46

Note:

Trunks with a noise measurement in the maintenance range may be left in service. Trunks with a noise measurement in the immediate action range should be immediately removed from service. In either case, initiate maintenance action promptly.

If the requirements in Table 13: Transmission noise requirements on page 51 are not met, use Isolating the fault to the trunk facility or equipment on page 52 to isolate the fault to the trunk facility or equipment. Perform this procedure at each end of the facility.

Isolating the fault to the trunk facility or equipment

1. From the maintenance terminal, load the trunk test program and access the local quiet termination.
2. Connect a noise meter to the "facility out" jack of the suspect trunk. The requirement is that the noise not exceed 23 dBrnC.

   If the requirement is not met at either or both facility ends, perform corrective maintenance on the appropriate switch and repeat the test. If the requirement is met at both facility ends, the facility supplier should perform corrective maintenance.

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