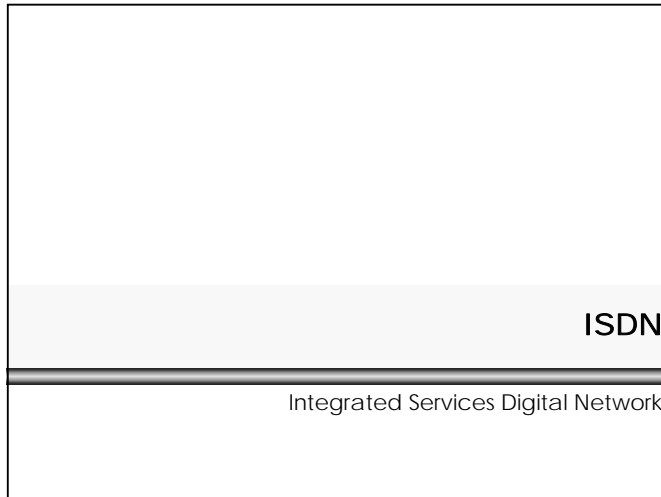


L11 - ISDN



Agenda

- ISDN Introduction
- ISDN Terminology
- ISDN Physical Layer (I.430, BRI)
- ISDN Physical Layer (I.431, PRI)
- ISDN Data Link Layer (Q.921)
- ISDN Network Layer (Q.931)
- ISDN Telco Aspects

L11 - ISDN

Overview

- **Integrated Services Digital Network (ISDN)**
- **based on digital telephone network**
 - all-digital interface at subscriber outlet
 - able to handle data communications directly
- **dial-up digital end-to-end connections**
 - offers transport of voice, video and data
- **standardized user-to-network interface**
- **implementation of a circuit switching network**
 - synchronous TDM
 - constant delay and constant capacity

Some ISDN Facts

- **First major user-visible upgrade to the worldwide public switched telephone network**
 - new features seen on the phone
- **Technology of the '80s**
 - Concept dates back to early '70s
- **First real specification in mid '80s**
 - Real deployment in the mid '90s
- **64 kbps channel is the fundamental building block**
 - to carry digital PCM voice
- **Narrowband (N-) ISDN versus Broadband (B)-ISDN (ATM)**

L11 - ISDN

ISDN Services

- **three types defined by ITU-T**
 - bearer services
 - transport of information in real time
 - circuit mode
 - 64 kbps, unrestricted, 8 kHz structured (transparent data)
 - » without any alteration of bits and no restriction on the bit pattern
 - 64 kbps, 8 kHz structured, usable for speech information transfer
 - » bit integrity not guaranteed, processing techniques to achieve high quality reproduction of transmitted voice signal
 - 64 kbps, 8 kHz structured, usable for 3.1 kHz audio transfer
 - 2 x 64 kbps, unrestricted, 8 kHz structured
 - 384 kbps, unrestricted, 8 kHz structured
 - 1536 kbps, unrestricted, 8 kHz structured
 - 1920 kbps, unrestricted, 8 kHz structured
 - packet mode
 - virtual call circuit, permanent virtual circuit, user signaling

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ISDN Services

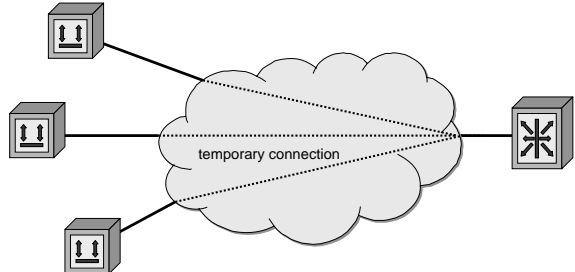
- **three types defined by ITU-T (cont.)**
 - teleservices
 - combine transportation function with information-processing function
 - e.g. telephony, teletex, telefax, videotex, telex, teleconference, video telephony
 - supplementary services
 - can be used to enhance bearer- or teleservices
 - reverse charging
 - closed user group (VPN)
 - line hunting
 - call forwarding, threeparty service
 - calling-line-identification
 - multiple subscriber number (MSN)
 - subaddressing
 - etc.

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Dial-up Connection

- **needs connection establishment**
- **during connection time, a transparent channel with full nominal bandwidth is available**



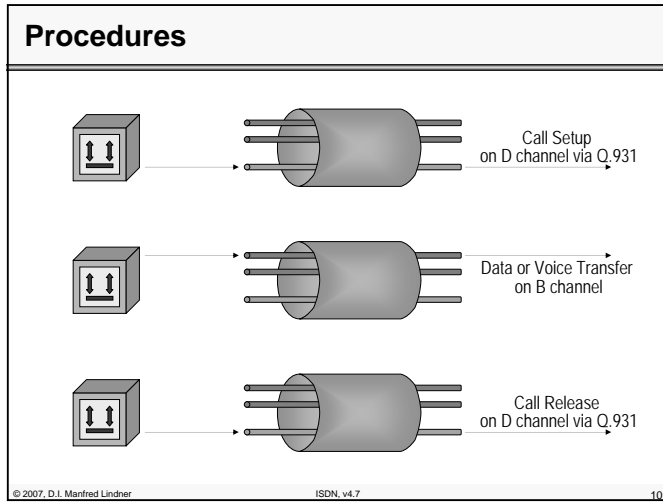
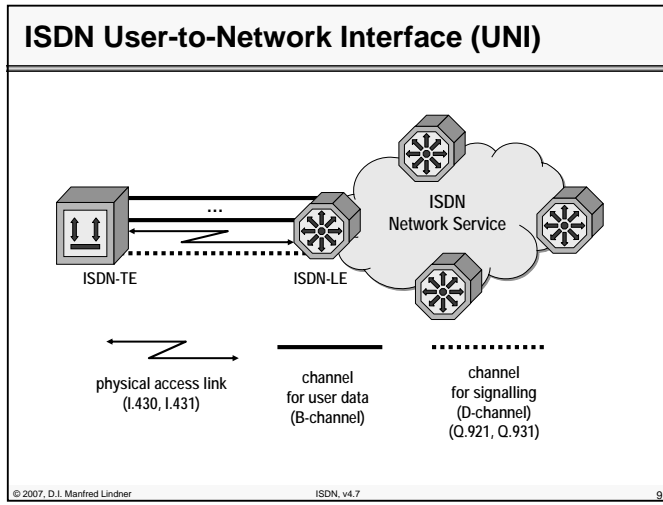
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User-to-Network Interface

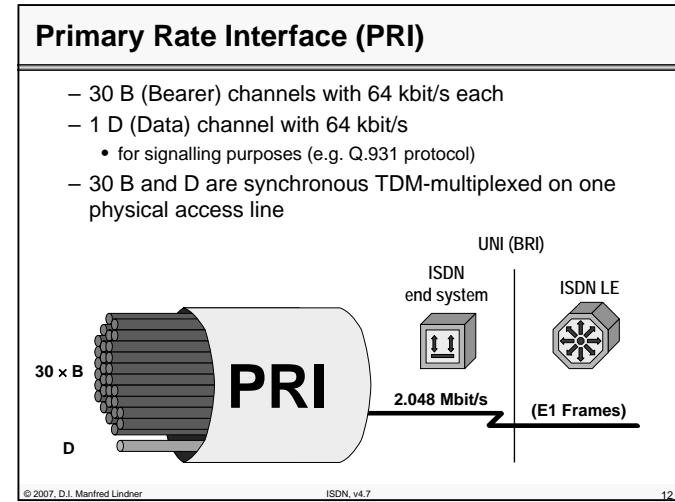
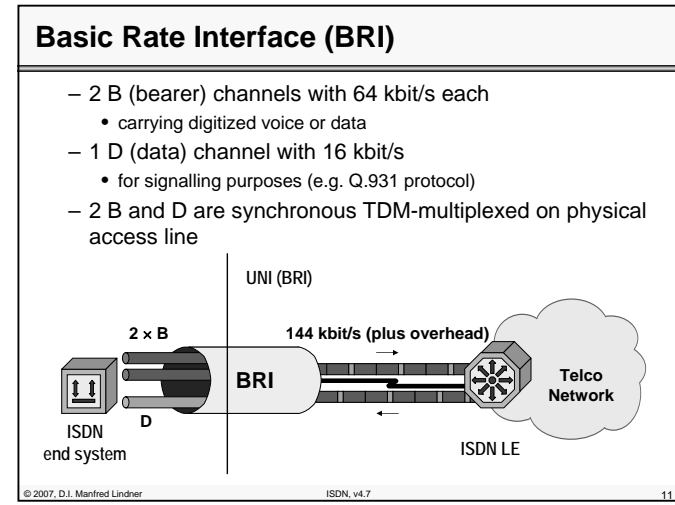
- **basic building blocks are**
 - digital voice channels
 - 64 kbps, derived from PCM voice coding
 - 8000 samples per second, digitized with 8 bits
 - B-channel
 - signaling channel
 - out-band signaling
 - used to set up a connection
 - D-channel
- **two types interfaces**
 - basic rate interface (BRI)
 - primary rate interface (PRI)

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L11 - ISDN



L11 - ISDN



L11 - ISDN

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ISDN Terminology

- **ISDN standards define**
 - reference configuration to characterize ISDN interfaces
- **reference configuration consists of**
 - functional groupings
 - are a set of capabilities needed in an ISDN user-access interface
 - specific functions may be performed by multiple pieces of hardware or software equipment
 - examples: TE, TA, NT
 - reference points
 - divide functional groupings
 - corresponds to a physical interface between pieces of ISDN equipment
 - examples: R, S, T, U

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L11 - ISDN

Terminal Equipment (TE)

- **TE1**
 - native ISDN terminal
 - connects to ISDN using a 2 pair twisted pair cable
 - used time division multiplexing to provide three channels
 - two bearer channels (2B) and one data channel (D)
 - B channels can be used independently
 - D channel carries control and signaling information
 - supports user data transmission in certain cases
 - layer 1 - 7 protocol handling
- **TE2**
 - non-native ISDN terminal
 - connects to ISDN via a terminal adapter (TA)

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Network Termination Equipment (NT)

- **network termination (NT)**
 - TA and TE1 devices are connected to either an NT1 or an NT2 device
- **NT1**
 - is responsible for physical layer functions such as
 - terminates transmission line from the ISDN local exchange to the customers premises
 - signal conversion (4 wire subscriber interface to the conventional 2 wire local loop) and interface termination
 - transmission signaling and timing (bit-synchronization)
 - possible multiplexing of B and D channels at layer level 1
 - possible provision for power to TE's
 - ISDN "modem"

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Network Termination Equipment (NT)

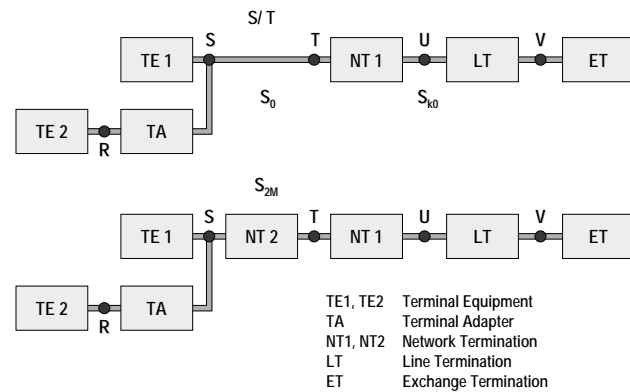
- **NT1 (cont.)**
 - can be used as simple customer premises device
 - NT2 function is equal null, BRI only
 - up to eight TE1 can be connected to NT1 (bus structure)
 - combined S/T reference point
- **NT2**
 - performs concentration services
 - multiplexing, switching of several TE's onto one ISDN network access line (e.g. PBX with PRI)
 - protocol handling for layer 2 and 3
 - termination of layer 1 functions
 - end-user equipment interface
 - advanced customer premises device

L11 - ISDN

ISDN Channels

- **basic channels requested by TE**
 - one or two B channels, 64 or 128 kbps
- **special channels for applications requiring higher speed - called H channels**
- **only available on primary rate interface**
- **H0 channel**
 - 6 B channels, 384 kbps
- **H11 channel**
 - 24 B channels, 1536 kbps
- **H12 channel**
 - 30 B channels, 1920 kbps

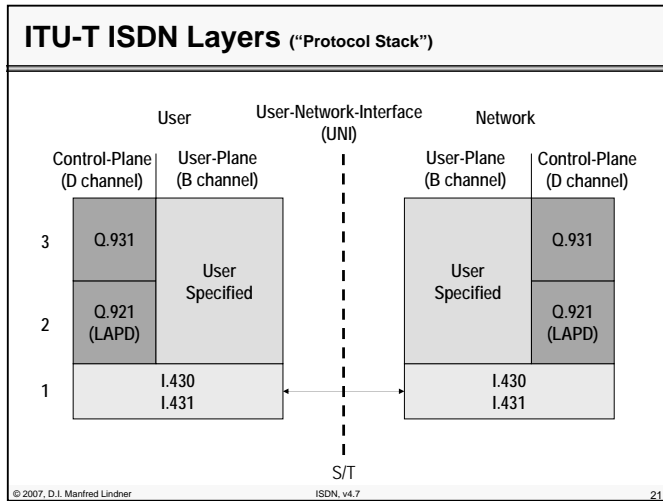
Functional Groups and Reference Points



ITU-T ISDN Standards Overview

- **I.100 Series**
 - General Structure
- **I.200 Series**
 - Service Capabilities
- **I.300 Series**
 - Overall Network Aspects and Functions
- **I.400 Series**
 - User-Network Interfaces
- **I.500**
 - Internetworking Interfaces
- **I.600**
 - Maintenance Principles

L11 - ISDN



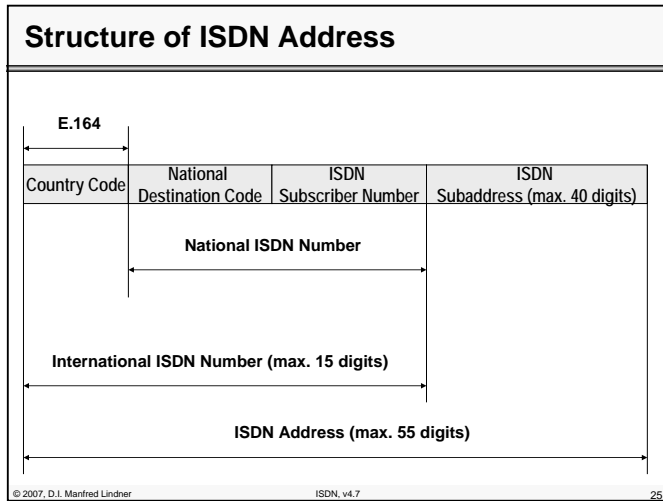
- ### ITU-T ISDN Standards
- **I.430**
 - basic user-network interface layer 1 specification
 - BRI Basic Rate Interface
 - **I.431**
 - primary rate user-network interface layer 1 specification
 - Primary Rate Interface
 - **Q.920 (I.440)**
 - user-network interface data link layer - general aspects
 - **Q.921 (I.441)**
 - user-network interface data link layer specification
 - LAPD
- The diagram is labeled with "© 2007, D.I. Manfred Lindner" and "ISDN, v4.7" and has a page number "22" in the bottom right corner.

L11 - ISDN

- ### ITU-T ISDN Standards
- **Q.930 (I.450)**
 - user- network interface layer 3 - general aspects
 - **Q.931 (I.451)**
 - user- network interface layer 3 specification
 - call control
- The diagram is labeled with "© 2007, D.I. Manfred Lindner" and "ISDN, v4.7" and has a page number "23" in the bottom right corner.

- ### ISDN Addressing
- **ISDN Number**
 - contains sufficient information for the network to route a call
 - typically corresponds to the subscriber attachment point (reference point T)
 - T can have multiple ISDN numbers
 - **ISDN Address**
 - may needed at the subscriber site to distribute a call to the appropriate party
 - typically corresponds to an individual terminal TE (reference point S)
 - ISDN Subaddress
- The diagram is labeled with "© 2007, D.I. Manfred Lindner" and "ISDN, v4.7" and has a page number "24" in the bottom right corner.

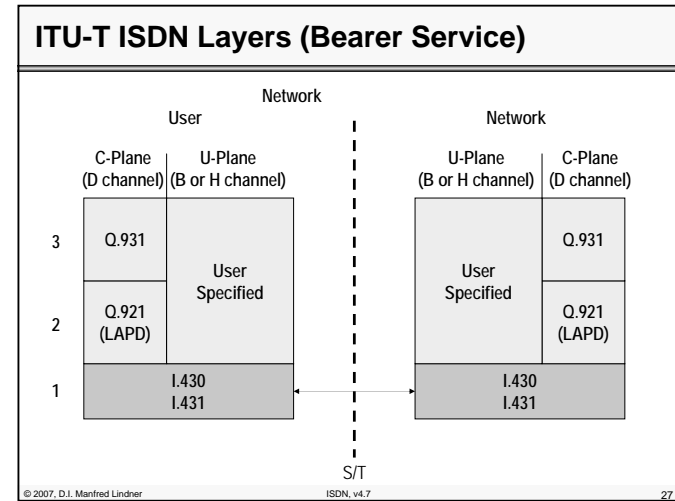
L11 - ISDN



Agenda

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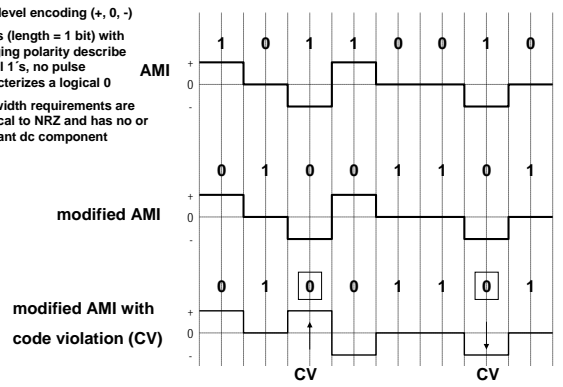
BRI (I.430)

- **basic rate interface (S₀/T interface)**
 - four wires with terminating resistor (100 ohm)
 - RJ45 connector with 8 leads
 - 2 transmit + 2 receive with power source 1 via phantom circuit
 - 4 optional power feeds for power source 2 and 3
 - modified AMI code (zero causes alternate pulses)
 - positive or negative pulse of 750mV + -10%
 - bitstuffing prevent long sequences of ones on D-channel
 - frame synchronization based on code violations
 - frame of 48 bit is transmitted in a period of 250 usec
 - 192 kbps total speed
 - 2 B channels at 64 kbps, 1 D channel at 16 kbps
 - 48 kbps for framing, DC balancing and D-channel mirroring
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AMI Code and Code Violation

three level encoding (+, 0, -)
 pulses (length = 1 bit) with
 changing polarity describe
 logical 1's, no pulse
 characterizes a logical 0
 bandwidth requirements are
 identical to NRZ and has no or
 constant dc component



BRI (I.430)

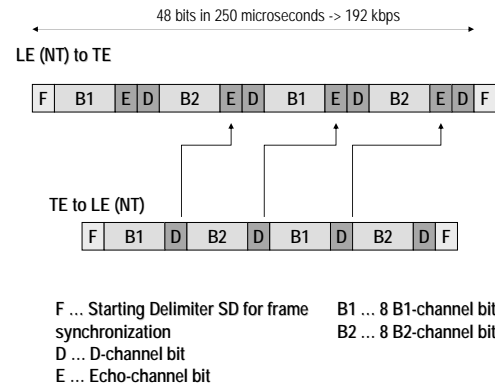
• basic rate interface (cont.)

- allows either a point-to-point or multipoint configuration
- point-to-point
 - maximum distance between TE and NT is 1000 meters
- for multipoint, physical connection is a passive bus
 - up to eight TE's can share a bus
 - maximum distance between TE and NT is 200 meters (short bus) or 500 meters (extended bus)
- multipoint operation
 - B channels are dynamically assigned to TE's for exclusive usage only
 - D channel must be shared by all TE's in order to request usage of a B channel
 - contention mode on D channel

L11 - ISDN

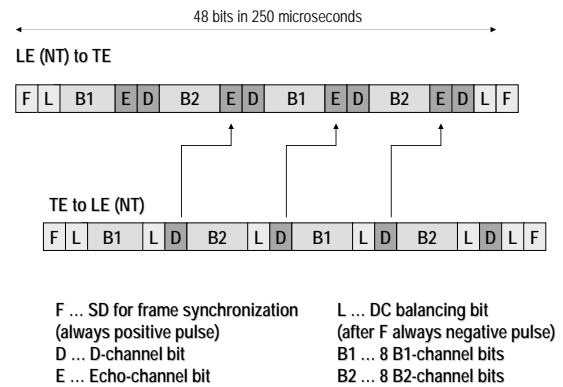
Simplified Frame Structure I.430

1

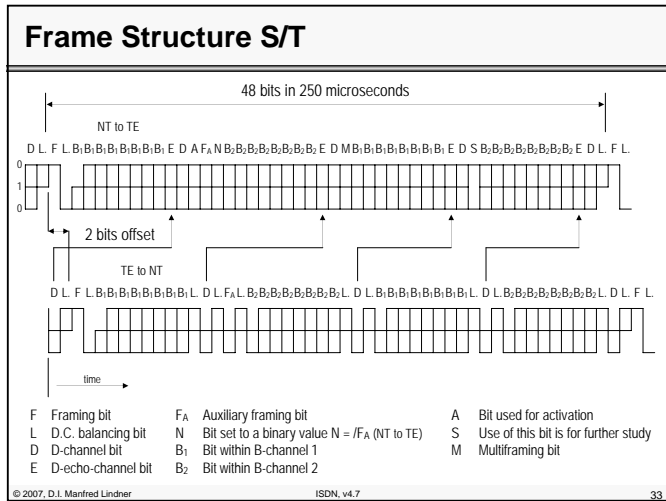


Simplified Frame Structure I.430

2

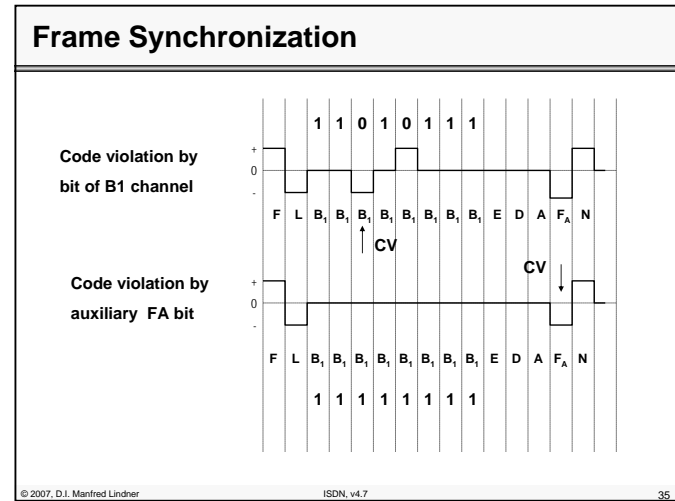


L11 - ISDN



- ### Frame Synchronization, DC Balancing
- **F (+) followed by L(-) marks start of frame**
 - **to detect F in the bit stream code violations are used**
 - normally alternate pulses (+, -) used for zeros
 - **general rule:**
 - first zero to be transmitted after F/L violates coding
 - **in case of all ones in B channels FA performs code violation**
 - auxiliary framing bit
 - FA always set to 0; N = inverse FA = 1
 - **L bits are used to guarantee DC balance**
 - from NT to TE only one L bit is necessary
 - from TE to NT every part of the frame (B₁, B₂ and D) is balanced by individual L bits
 - reason: every part of the frame (B₁, B₂, D) may be sent by a different TE hence every TE must balance its own part
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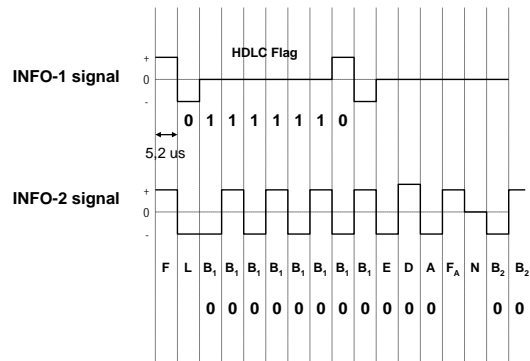
L11 - ISDN



- ### Activation of TE1 <-> NT
- **Done in several phases using so called special signals**
 - no signal on the physical line indicates silent state
 - state S0, INFO-0 signal
 - INFO-1 signal
 - TE1 -> NT1 clock indication using own unsynchronized 192kbit/s
 - INFO-2 signal
 - NT1 -> TE1 provides clock signal 192kbit/s derived from network clock for TE1 clock synchronization
 - INFO-3 signal
 - TE1 -> NT1 synchronized clock and B/D bits ready
 - INFO-4 signal
 - NT1 -> B/D bits ready and Activation bit A = 1
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Activation Signals INFO-1, INFO-2



D - Channel Access Control

- **D - channel**
 - must be shared by different TEs in a multipoint configuration
 - control of access to D channel is necessary
- **control is done via E - bits**
 - TEs use D - bits for transmission to NT
 - E contains echo (sent by NT) of D bit received by NT
 - note:
 - encoding gives transmitted zeros higher priority than ones (zeros produce signal changes (pulses) but ones do not)
 - if TEs send at the same time on D channel, only TE with the most zeros transmitted will see its message on E again

L11 - ISDN

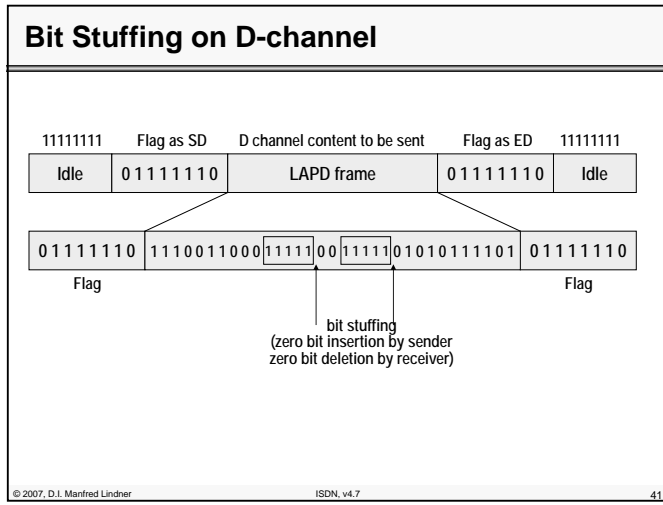
D - Channel Access Control

- **before TE can use D channel**
 - at least eight ones (no signal activity) in sequence must be received (carrier sense, monitor state)
- **when TE starts transmitting on D channel**
 - E bits are used for comparison transmitted information with received information
 - if unequal (collision detect) TE will stop transmission (collision resolution) and will listen for next eight ones in sequence

D - Channel Access Control

- **once the D channel was successfully occupied**
 - bitstuffing will prevent sequence of eight ones for the rest of the message and TE can finish its transmission without disturbance
- **to give other TEs fair chance to access the D channel**
 - TE must release D channel after message was sent
 - TE waits then for a sequence of nine ones before access is tried again
 - this allows other waiting TEs access to the D channel
 - round-robin among all TEs in worst case

L11 - ISDN



- ### Terminal Endpoint Identifier
- **D - channel**
 - will be shared by different TEs in a multipoint configuration
 - identification of TEs is necessary
 - **each terminal equipment TE must have a unique identifier**
 - called terminal end point identifier (TEI)
 - on outgoing frames, the TEI identifies the source terminal
 - on incoming frames, network uses the TEI to address the receiving terminal
 - TEI assignment is part of layer 2 procedures
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- ### PRI (I.431)
- **primary rate interface**
 - allows point-to-point configuration only
 - based on E1 or T1 specifications
 - E1 (HDB3 encoding)
 - 2.048 Mbps total speed
 - timeslot 0 used for synchronization
 - timeslot 16 used for D channel information
 - timeslots 1-15 and 17-31 for 30 B-channels
 - T1 (B8ZS encoding, ESF format)
 - 1.544 Mbps total speed
 - timeslot 24 used for D channel information
 - timeslots 1-23 for 23 B-channels
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Agenda

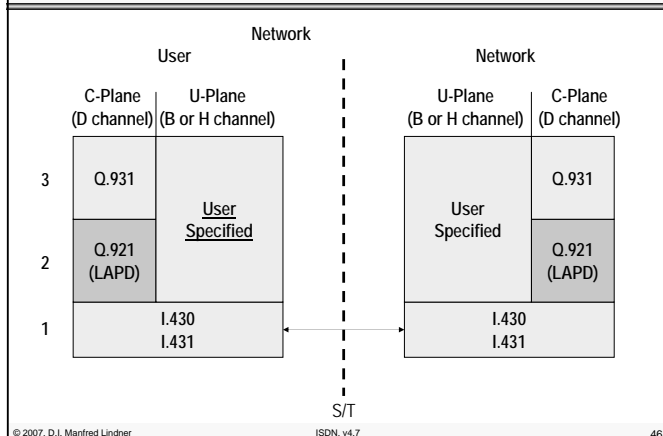
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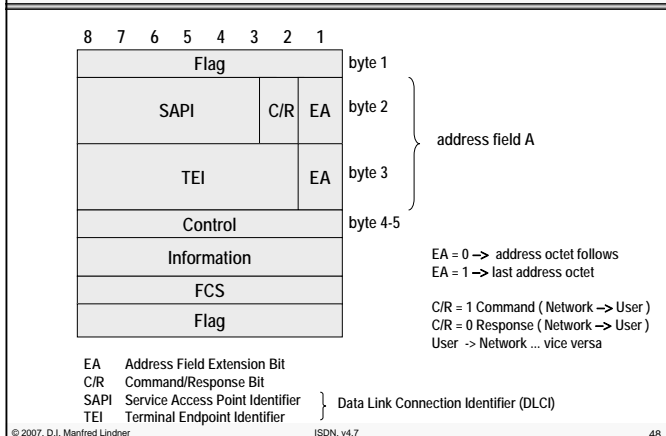
ISDN Data Link Layer

- **only used on the D channel**
- **uses LAPD**
 - Link Access Procedure D-Channel
 - based on HDLC ABM mode
 - 2 byte address field
 - may use extended sequence numbering (0-127)
- **ISDN level 3 signaling**
 - travels in the information field of the LAPD I-frame
- **LAPD may also be used to support user traffic**
 - D channel is not fully utilized by signaling messages
 - e.g. X.25 over D-channel

ITU-T ISDN Layers (Bearer Service)



LAPD Frame Format



L11 - ISDN

SAPI and TEI

- **SAPI - Service Access Point Identifier**
 - identifies the entity where data link layer services are provided to the layer above
 - examples
 - 0 signaling information (s-type)
 - 16 packet data (p-type)
 - 63 management information
- **TEI - Terminal Endpoint Identifier**
 - identifies an endpoint within a service access point
 - possible values
 - 0 - 127

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Frame Types (Control Field)

- **information transfer frames (I frames)**
- **supervisory frames (S frames)**
 - RR (Receive Ready)
 - RNR (Receive Not Ready)
 - REJ (Reject)
- **unnumbered frames (U frames)**
 - SABME (Set Asynchronous Balanced Mode Extended)
 - DM (Disconnected Mode)
 - UI (Unnumbered Information)
 - DISC (Disconnect)
 - UA (Unnumbered Acknowledgment)
 - FRMR (Frame Reject)

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TEI Management

- **before a LAPD connection can be established**
 - either a TEI value is assigned automatically between TE and network
 - TEI value range 64-126
 - TEI assignment procedure
 - or a preconfigured value may be used
 - TEI value range 0-63
 - TEI verification procedure for checking duplicates
- **TEI = 127**
 - broadcasting, means all
- **on PRI**
 - TEI always 0

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TEI Management Messages

- **always UI frames with SAPI = 63 and TEI 127**
- **information field of UI contains**
 - reference indicator (RI)
 - correlation of request and responses
 - action indicator (AI)
 - contains TEI number to be requested, assigned or checked
 - AI = 127 asks for assignment of any TEI or checks all TEs
 - message type
 - user to network (TE to NT)
 - ID_Request, ID_Check Response, ID_Verify
 - network to user (NT to TE)
 - ID_Assigned, ID_Denied, ID_Check Request (ri always 0), ID_Remove (ri always 0)

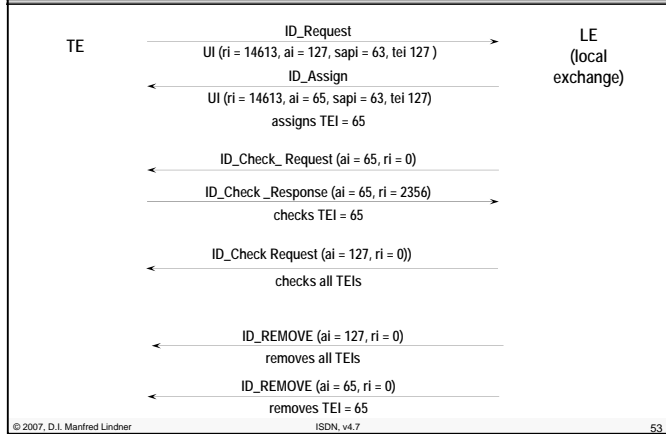
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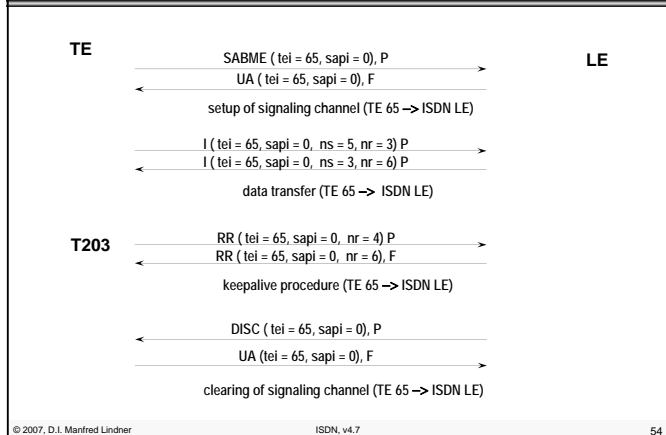
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TEI Assignment, Checking, Removal



Signaling Channel Active

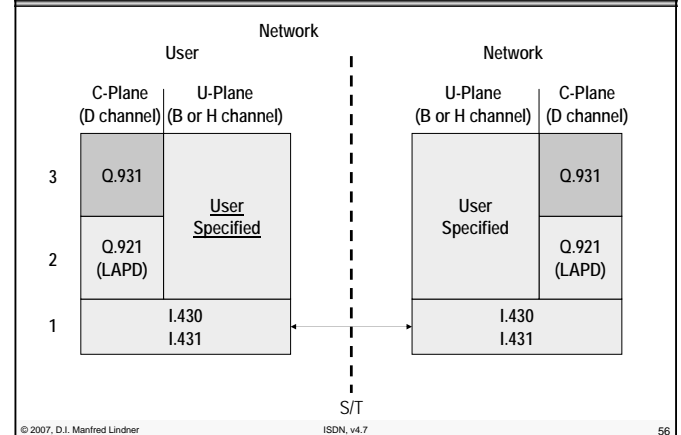


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ITU-T ISDN Layers (Bearer Service)



L11 - ISDN

ISDN Network Layer

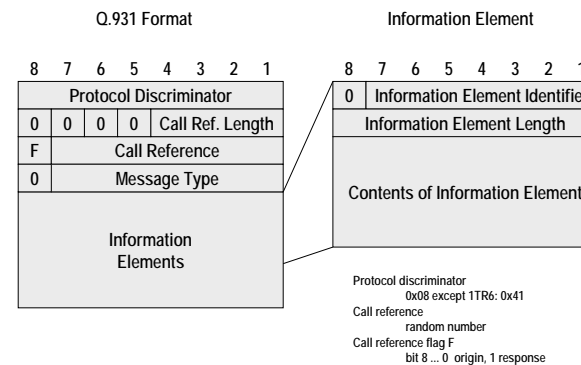
- **not used on B channels**
- **Q.931 is used on D channels for call control**
 - used between TE and local ISDN switch
 - not used end-to-end
- **Signaling System 7 (SS#7) is used inside the network**
- **several flavors exist on the market**
 - be careful to select the correct version of the protocol

ISDN Switch Types

- **PRI**
 - 4ESS, 5ESS, DMS-100 (USA)
 - primary-net5 (Euro ISDN)
 - NTT (Japan)
 - TS014
- **BRI**
 - 5ESS, DMS-100, NT1 (USA)
 - NTT (Japan)
 - basic 1TR6 (Germany)
 - VN2, VN3 (France)
 - basic-net3 (Euro ISDN)
 - TS013 (Australia)

L11 - ISDN

Q.931 Protocol Format



Q.931 Messages Types for Circuit Mode Connection

1

- Call Establishment Phase
 - **SETUP** (global, both: NT or TE)
 - initiates call establishment
 - **SETUP ACKnowledge** (local, both)
 - indicates that call establishment has been started but requests more information (e.g. dial numbers)
 - **ALERTing** (global, both)
 - indicates that user alerting has begun
 - **CALL PROCeeding** (local, both)
 - indicates that call establishment has been initiated
 - **CONNect** (global, both)
 - indicates call acceptance by called TE
 - **CONNect ACKnowledge** (local, both)
 - indicates that user has been awarded the call
 - **PROGress** (global, both)
 - reports progress of a call

L11 - ISDN

Q.931 Messages Types for Circuit Mode Connection 2

- Call Information Phase
 - SUSPend (local, TE -> NT)
 - requests suspension of a call
 - SUSPend ACKnowledge (local, NT -> TE)
 - call has been suspended
 - SUSPend REJect (local, NT -> TE)
 - indicates failure of requested call suspension
 - RESume (local, TE -> NT)
 - requests resumption of previously suspended call
 - RESume ACKnowledge (local, NT -> TE)
 - indicates requested call has been reestablished
 - RESume REJect (local, NT -> TE)
 - indicates failure to resume suspended call

Q.931 Messages Types for Circuit Mode Connection 3

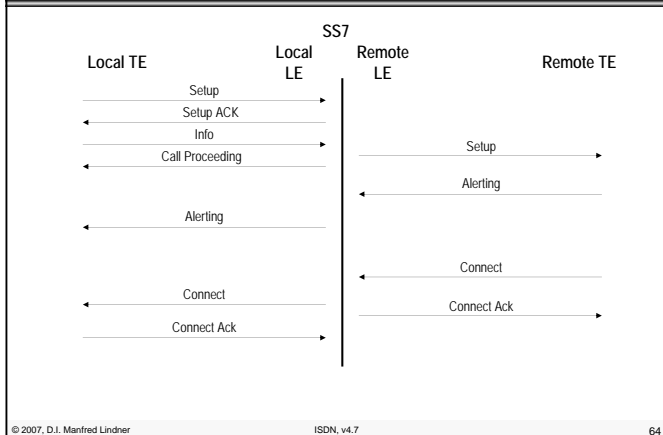
- Call Clearing
 - DISConnect (global, both: NT or TE)
 - sent by user to request connection clearing; sent by network to indicate connection clearing
 - RELease (local, both)
 - indicates intent to release a channel and call reference
 - RELease COMplete (local, both)
 - indicates release of a channel and call reference

L11 - ISDN

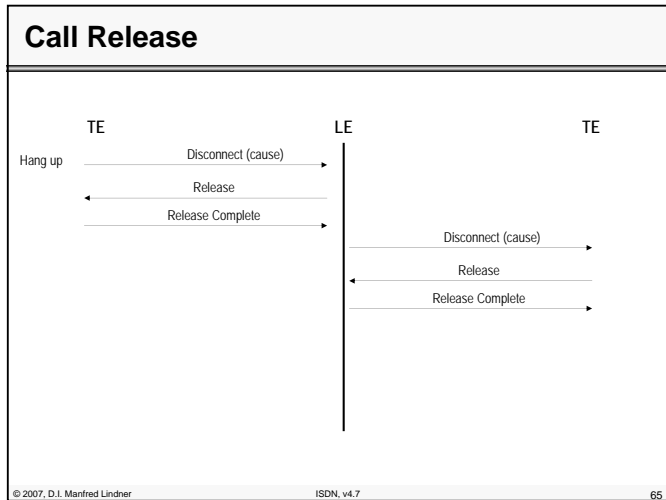
Q.931 Messages Types for Circuit Mode Connection 4

- Miscellaneous
 - INFOrmation (local, both)
 - provides additional information
 - NOTIFY (both)
 - indicates information pertaining a call
 - STATUS ENQuiry (local, both)
 - solicits a status message
 - STATUS (local, both)
 - answer to enquiry message or error report at any time

Call Establishment



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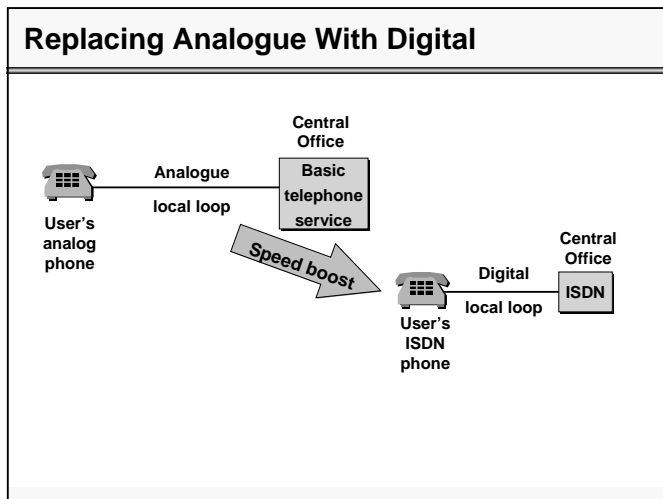
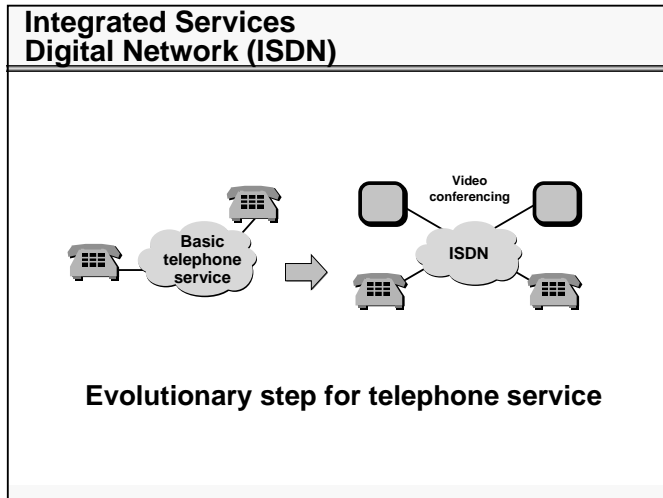
- ### Some Information Elements
- 0x04 Bearer Capability
 - 0x08 Cause (reason codes for call disconnect)
 - 0x18 Channel Identification
 - 0x1E Progress Indicator
 - 0x6C Calling Party Number
 - 0x6D Calling Party Subaddress
 - 0x70 Called Party Number
 - 0x71 Called Party Subaddress
 - 0x7C Low-Layer Compatibility
 - 0x7D High-Layer Compatibility
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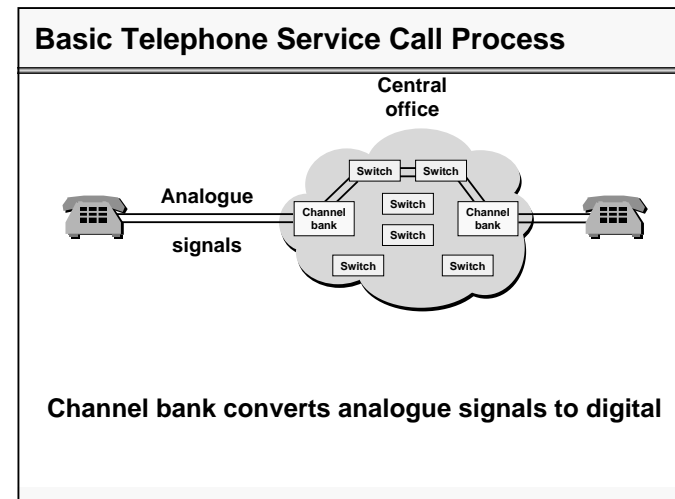
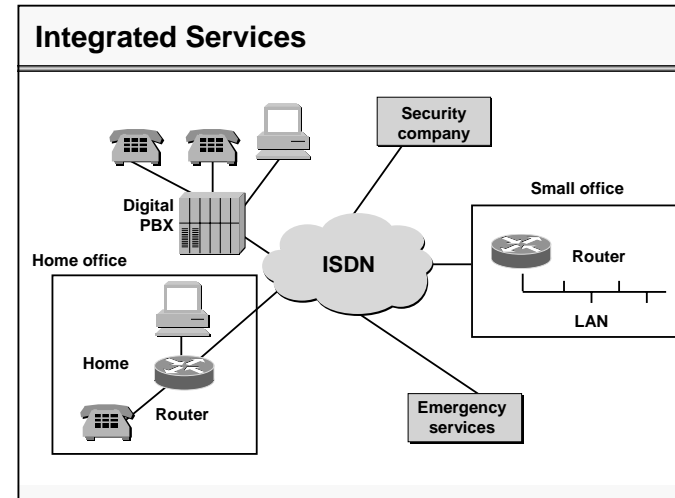
- ### IEs of Setup Message
- **Bearer Capability (BC) IE**
 - Voice/data call/fax
 - speed (64/56)
 - transfer mode (packet/circuit)
 - user info L2 (I.441/X.25 L2)
 - user info L3 (I.451/X.25 L3)
 - **Calling-Party number IE**
 - who is calling you
 - may not be delivered
 - **Channel Identification IE**
 - defines which B-channel is used
 - **Called-Party number IE**
 - whom are you calling
 - **different switch types will have variations of the information elements**
 - **Keypad IE**
 - can be used instead of called-party number
 - **High-Layer Compatibility IE**
 - used with the BC to check compatibility
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- ### Agenda
- **ISDN Introduction**
 - **ISDN Terminology**
 - **ISDN Physical Layer (I.430, BRI)**
 - **ISDN Physical Layer (I.431, PRI)**
 - **ISDN Data Link Layer (Q.921)**
 - **ISDN Network Layer (Q.931)**
 - **ISDN Telco Aspects**
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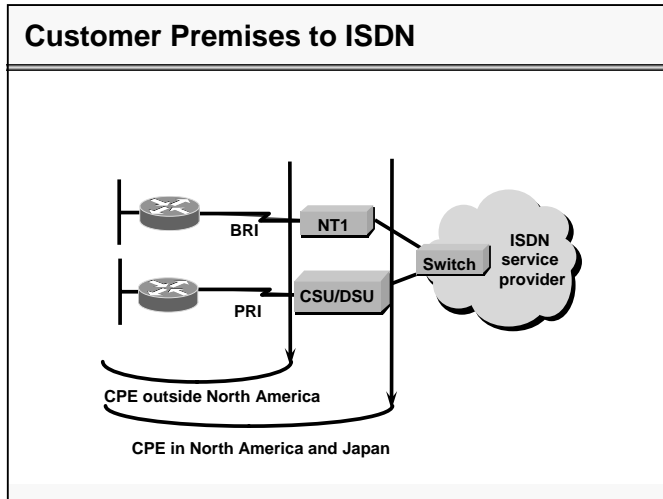
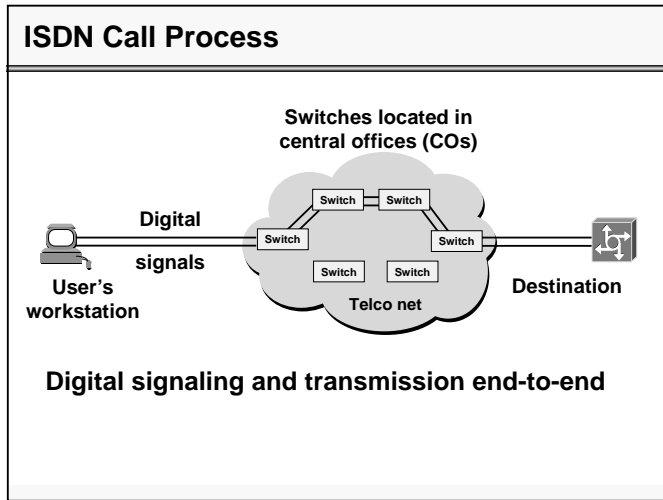
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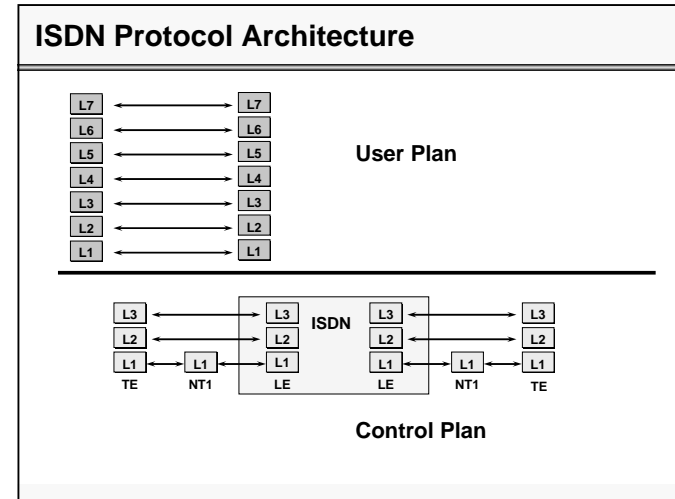


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ISDN Concept

- **full protocol stack for all 7 layers**
 - might be used a standalone solution for subscriber services
 - however, because of delays and interoperability problems in implementations it has not become the dominant solution as it was expected some time ago...
- **however, Layers 1-3 might be used to establish a transparent bit stream connection between two end-points**
 - this might be treated as a physical link layer by other overlay networks, such as IP
 - same technologies can be used for data link as with leased-lines or analog dial-up connections

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