ISDN

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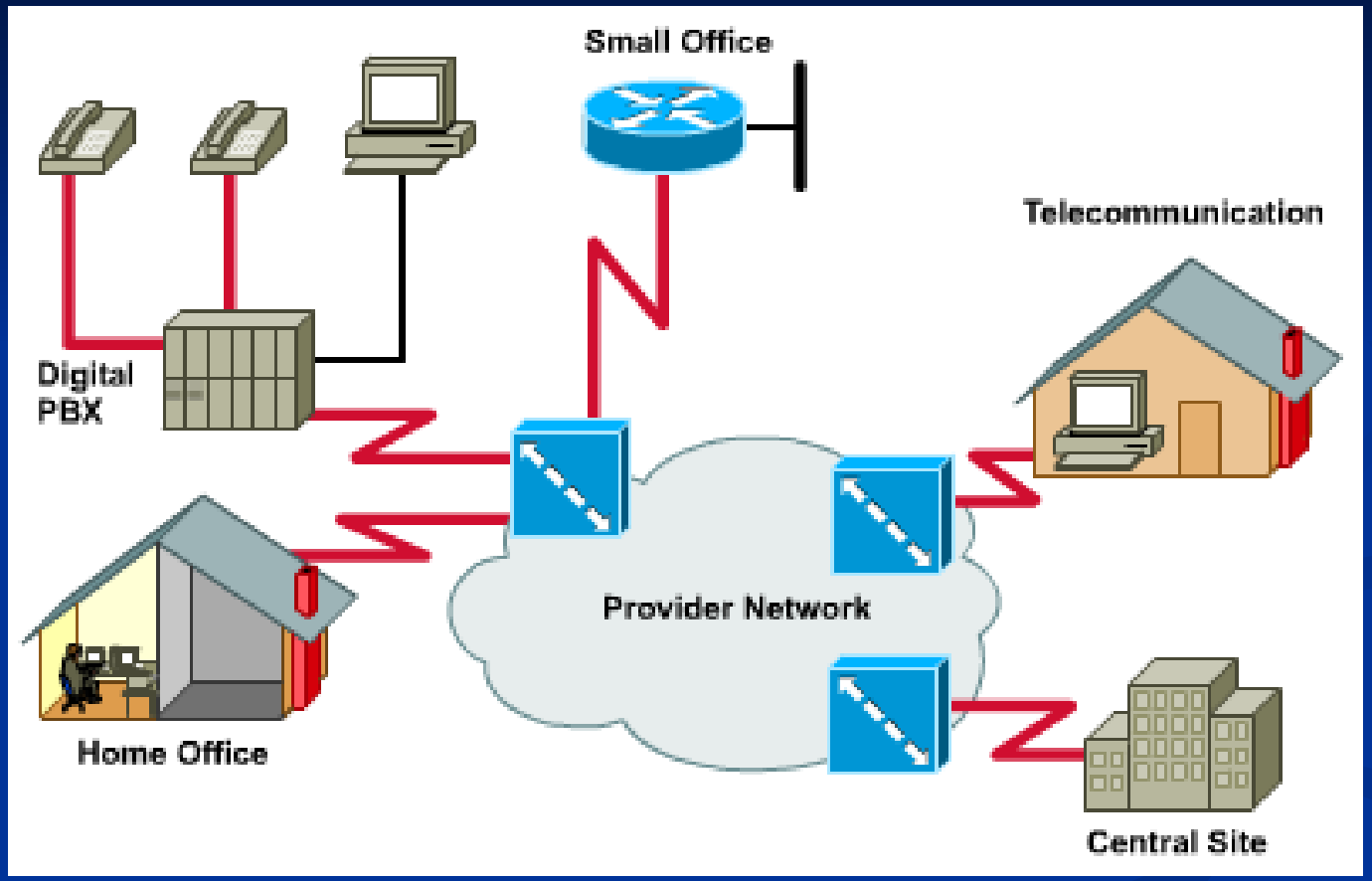
Integrated Services Digital Network

- Circuit-switched digital network
  - connection setup and termination required
  - user pays for connection time
  - addressing of subscriber devices according to E.164
- Transparent circuits 64kbps (full duplex)
  - Optimized for digital voice transfer
    - 4kHz*2=8ksamples * 8b/sample = 64 kbps
  - Can carry traffic of any telecommunication service, i.e. ISDN "integrates" multiple services on the same infrastructure
  - New service can be added purely by subscriber device software modification
    - and possibly extending signalling protocol options

ISDN usage



ISDN uses original (POTS) subscriber lines

ISDN advantages over analog lines

- Higher speeds
  - cheaper than leased lines
- Quicker connection setup
- Voice & Data Simultaneously

ISDN Channels

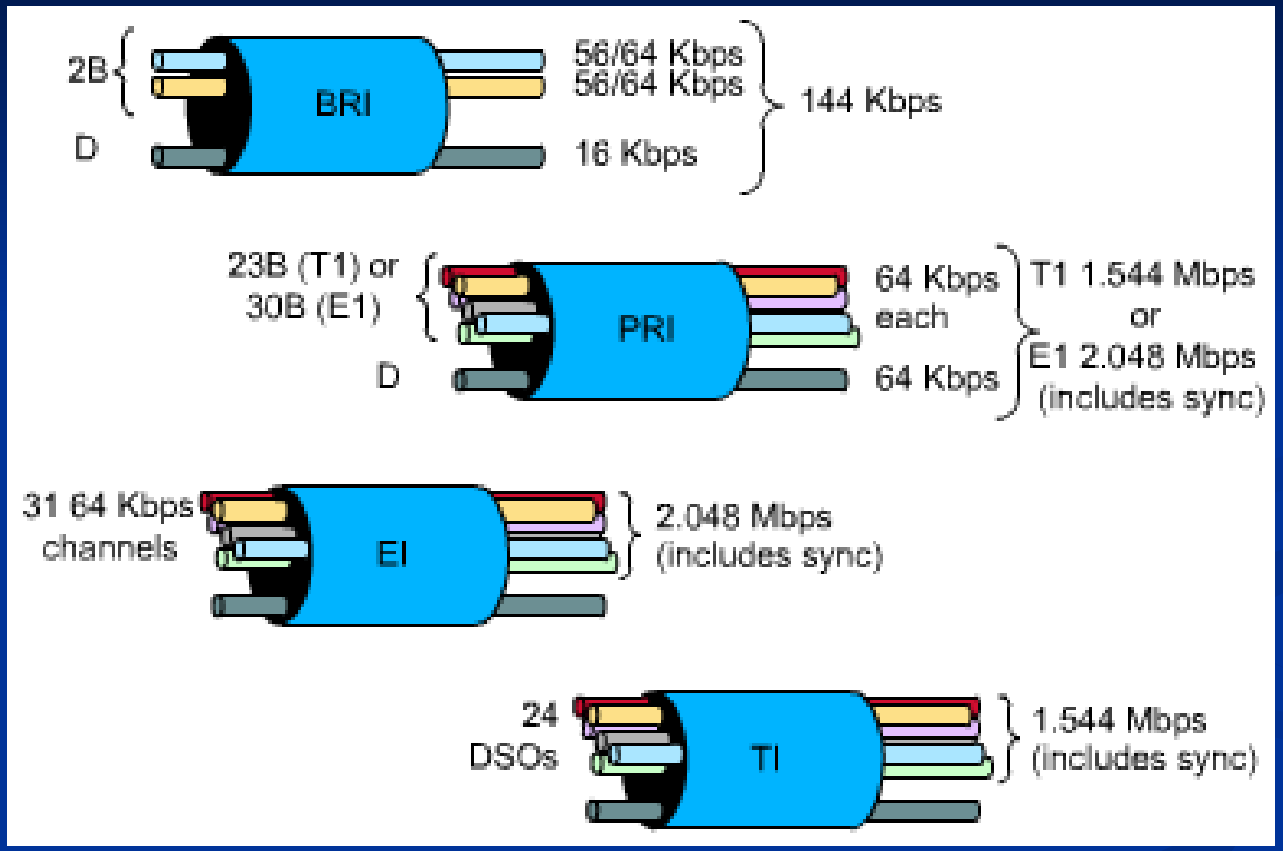
- B (bearer) – transparent bit stream 64kbps
  - between local and remote subscriber device
- D – signalling
  - between subscriber device and central office
  - transfers signalling messages
    - Layer 2: LAPD
    - Layer 3: Digital Subscriber Signalling System no. 1
  - may provide low-speed packet mode channel
    - if supported by operator

ISDN subscriber line interfaces

Fully digital transmission

- Basic Rate Interface (BRI)
  - 2B+D (16kbps)
  - TDM + echo cancellation (both directions on 2-wire line)
  - NT converts one pair (2 wires) to two pairs (4 wires)
    - NT separates directions and resolves D-channel access conflicts (bus)
    - NT sometimes integrated in PBX
- Primary Rate Interface (PRI)
  - 30B+D (64kbps) / 23B+D
  - used to connect PBX, ISP
  - physically E1/T1 line (PDH hierarchy line)

ISDN channels vs. E1/T1 lines



DS0 = 64 kbps

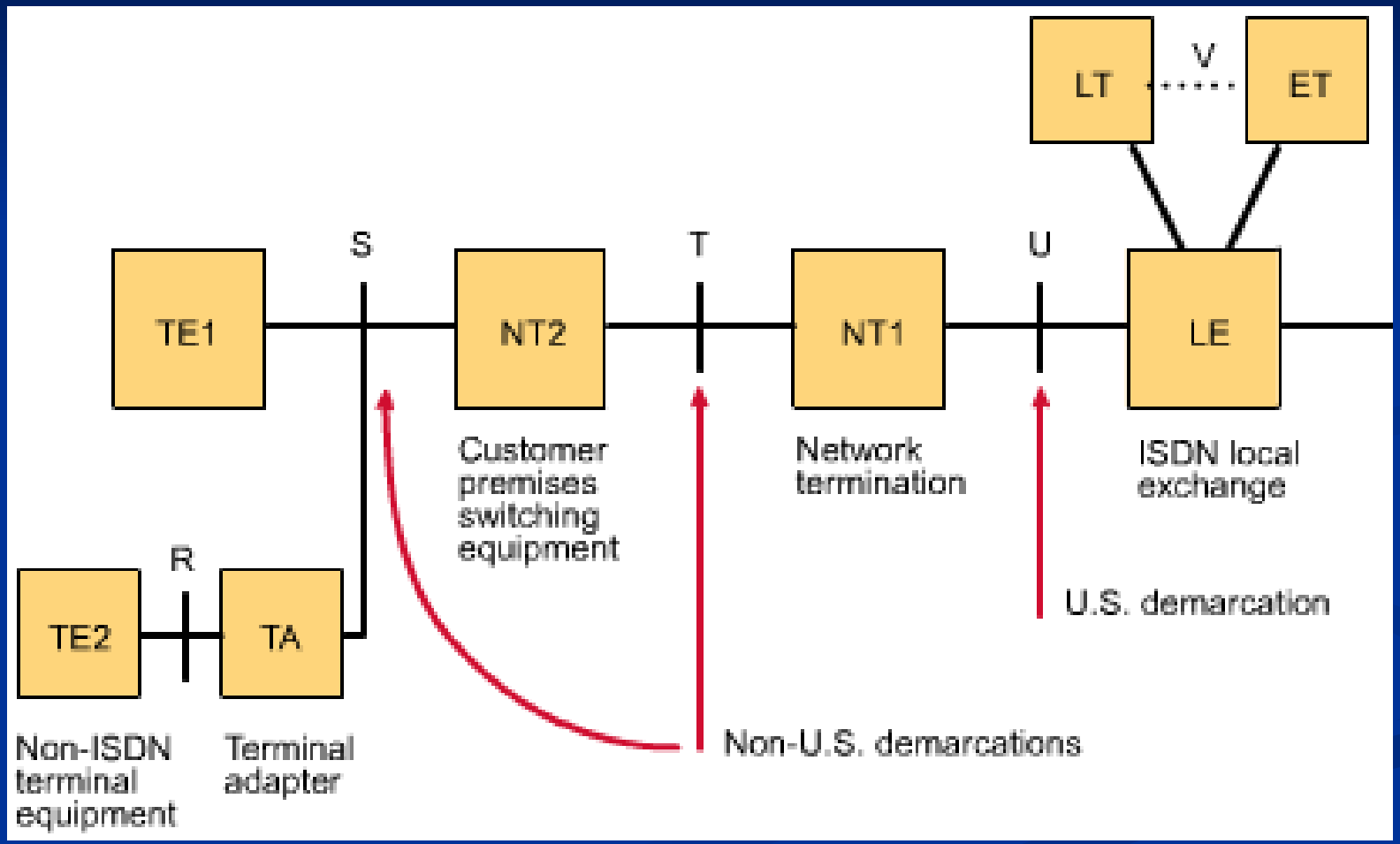
ISDN ITU-T standards

- I – series - Concepts and interfaces
  - I.430, I.431: BRI interface
- E – series - Telephone network
  - E.164 - International ISDN addressing
- Q – series - Switching and signaling
  - Q.921- Link Access Procedures on the D channel (LAPD)
  - Q.931 – Digital Subscriber Signalling System #1 (DSS1)

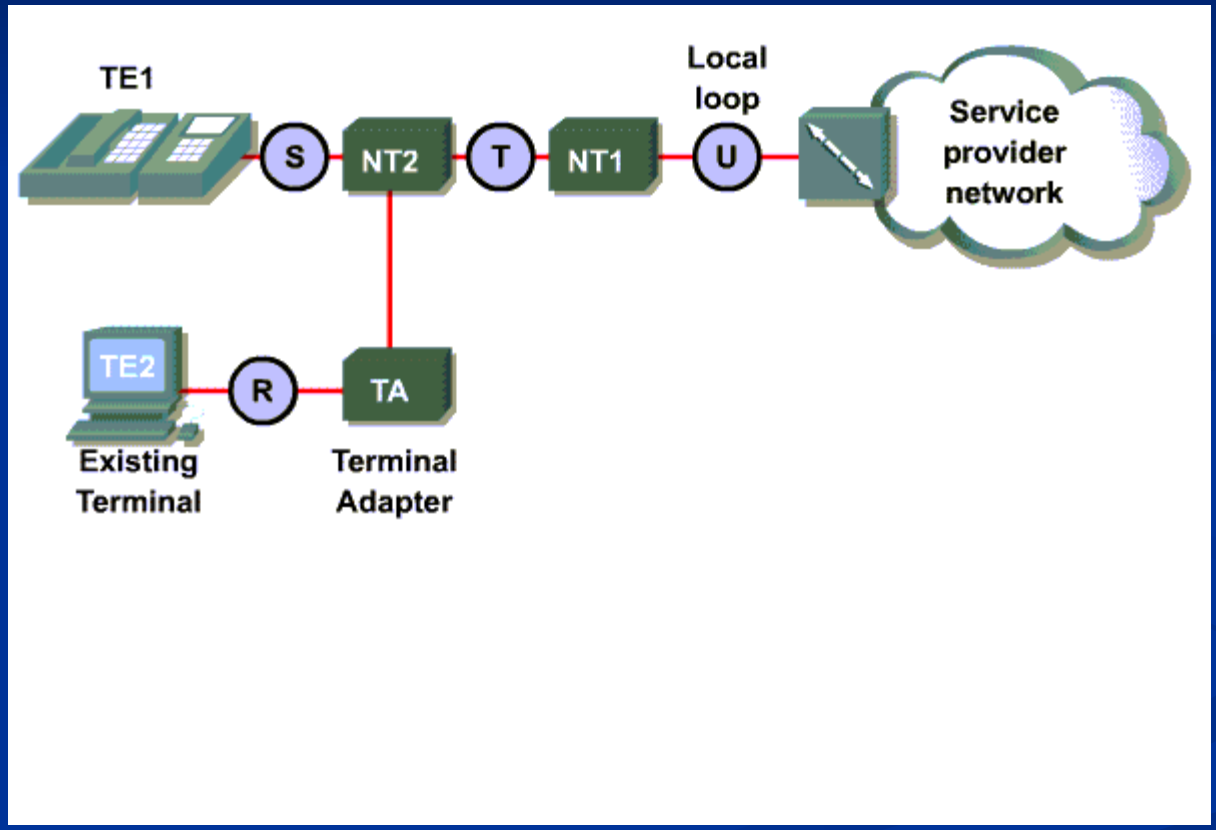
Basic Rate Interface (BRI)

2B+D

BRI Functional Groups & Reference Points



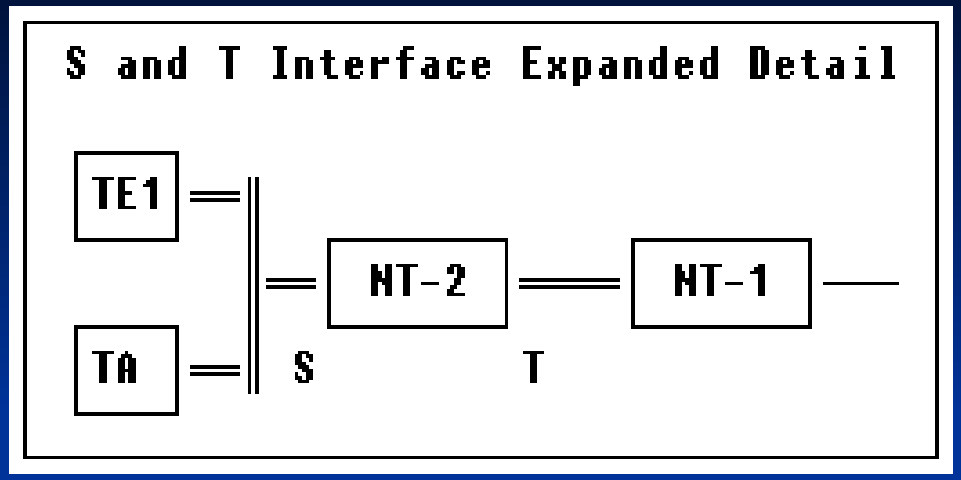
Reference points – practical view

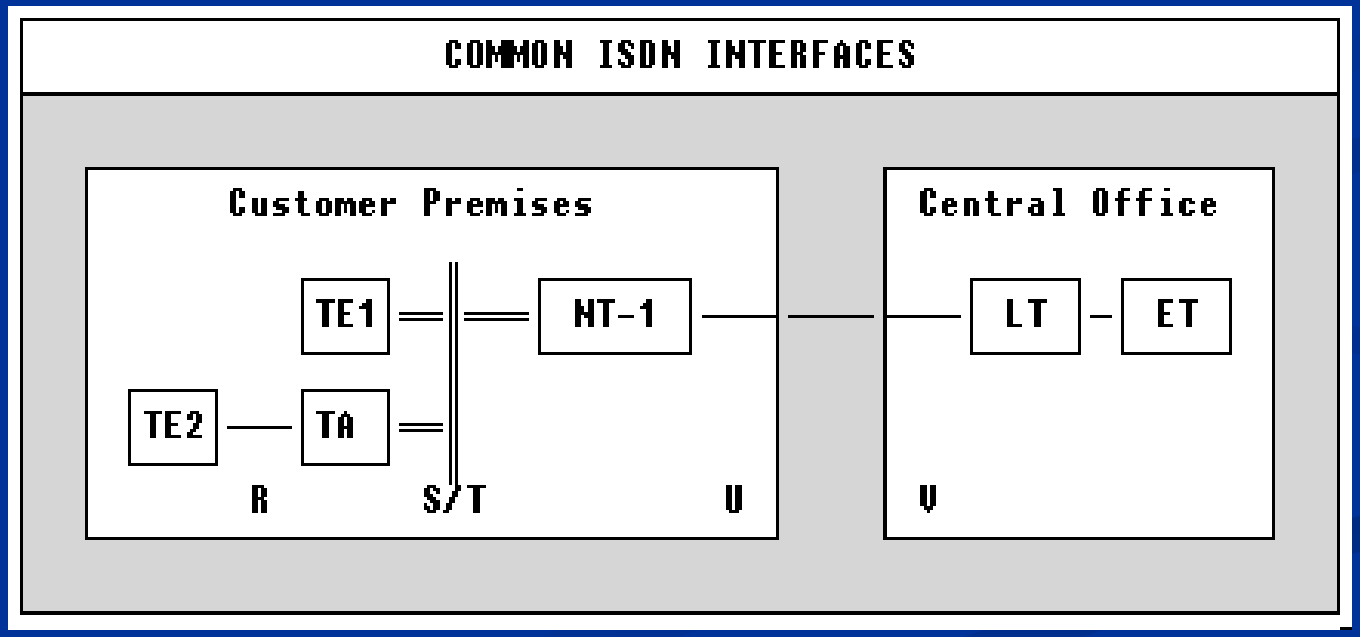


S, T and U reference points

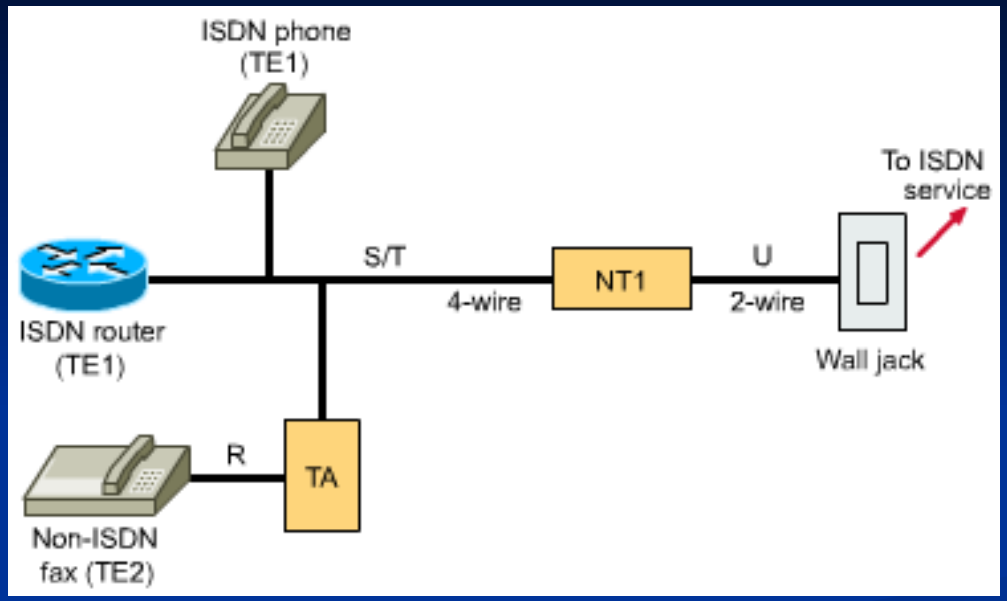
- S - between the TE1/TA and the NT2
- T - between the customer site switching equipment (NT2) and the local loop termination (NT1)
- U - various standards
  - depending on Central office manufacturer
  - I.431/ANSI T1.601

Separated and combined S/T interface





Combined S/T interface



- ITU-T I.430 (S,T,S/T)
- without NT2 (PBX) at customer site, we refer to combined S/T reference point
  - NT2 is a switching or concentrating device with ISDN at both sides
- NT1 device sometimes integrated into central office ports (S0)

Line codes

- S/T: Modified Alternate Mark Inversion (MAMI)
  - ITU Recommendation I.460
  - delimits frames using code rules violation
    - 2 violations in every frame
- U: proprietary, most often 2B1Q

ISDN subscriber device types

Device	Device Type	Device Function
TE1	Terminal Equipment 1	Designates a device with a native ISDN interface, such as an ISDN router or ISDN telephone.
TE2	Terminal Equipment 2	Designates a non-ISDN device, such as a workstation or router, that requires a TA to connect to an ISDN service provider.
TA	Terminal Adapter	Converts EIA/TIA-232, V.35, and other signals into BRI signals.
NT2	Network Termination 2	The point at which all ISDN lines at a customer site are aggregated and switched using a customer switching device.
NT1	Network Termination 1	Controls the physical and electrical termination of the ISDN at the customer's premises. Converts the four-wire BRI signals into two-wire signals used by the ISDN digital line.

ISDN subscriber devices – practical view

- ISDN phone
- ISDN modem
  - external async modem with AT command set
  - ISDN PC card
- Router
  - equipped with BRI/PRI module
- Terminal Adapter + non-ISDN device
  - e.g. POTS phone or router with RS-232 interface
- …

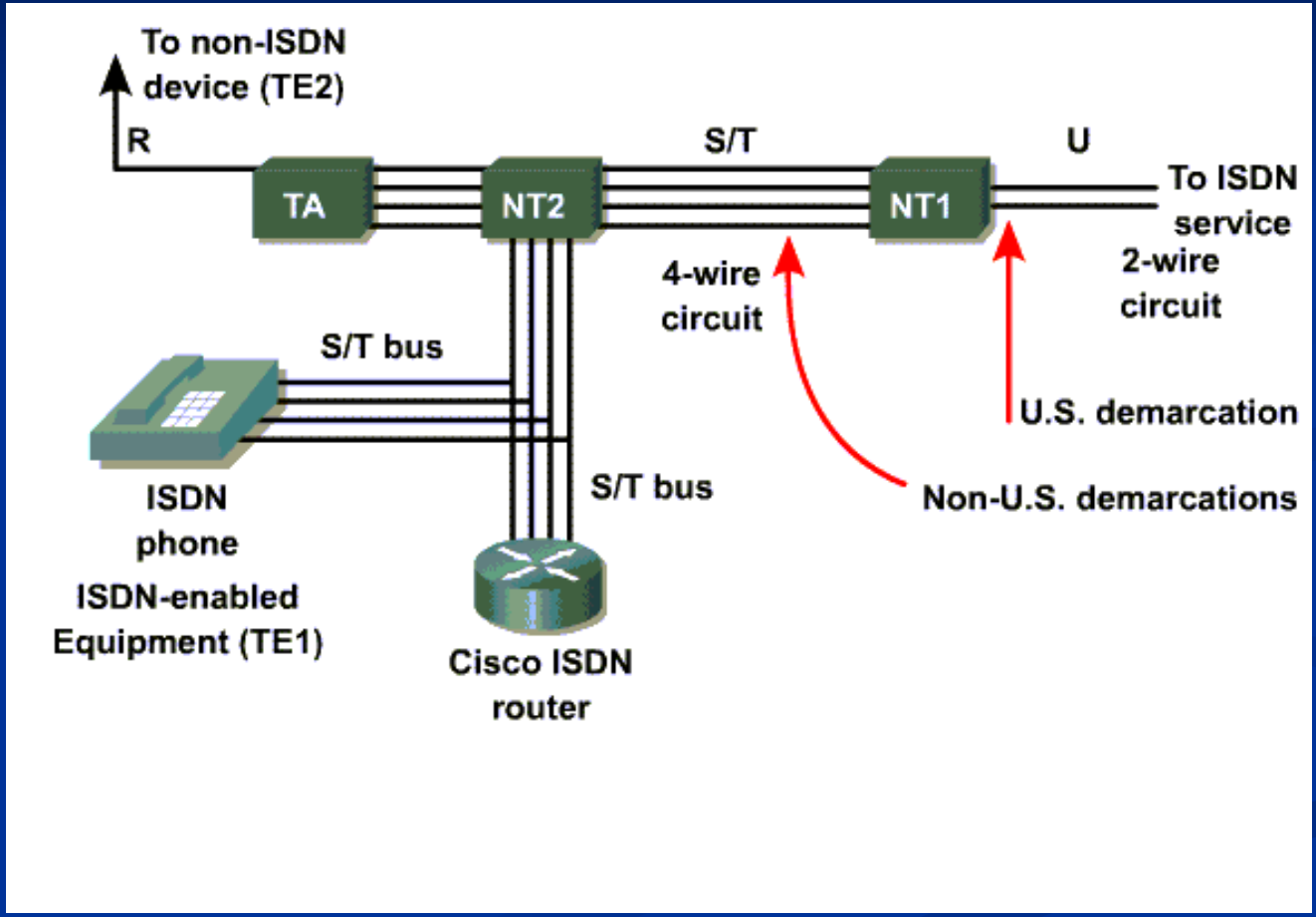
NT1 functions

- Converts 2-wire to 4-wire line
  - separates directions
- Converts frame format between U and S/T interfaces
- Echoes (outgoing) D bits into (incoming) E bits to support D-channel collision resolving

BRI configuration options

- Point-to-Point – one subscriber device up to 1 km from NT1
- Passive Bus - up to 8 subscriber devices in parallel on S/T bus
  - all share 2 B-channels
  - subscriber devices 100-200 m from the NT1
  - TX and RX pairs of subscriber devices connected together using bus lines, terminated with 100ohm resistors
  - every device can have it's own telephone number
    - Multiple Subscriber Number (MSN) option
- Extended Passive Bus – up to 8 subscriber devices up to 500 m from NT1
  - all devices placed at last 50 meters
  - signal propagation delay has to be similar for each subscriber device to ensure proper operation of D-channel access arbitration method

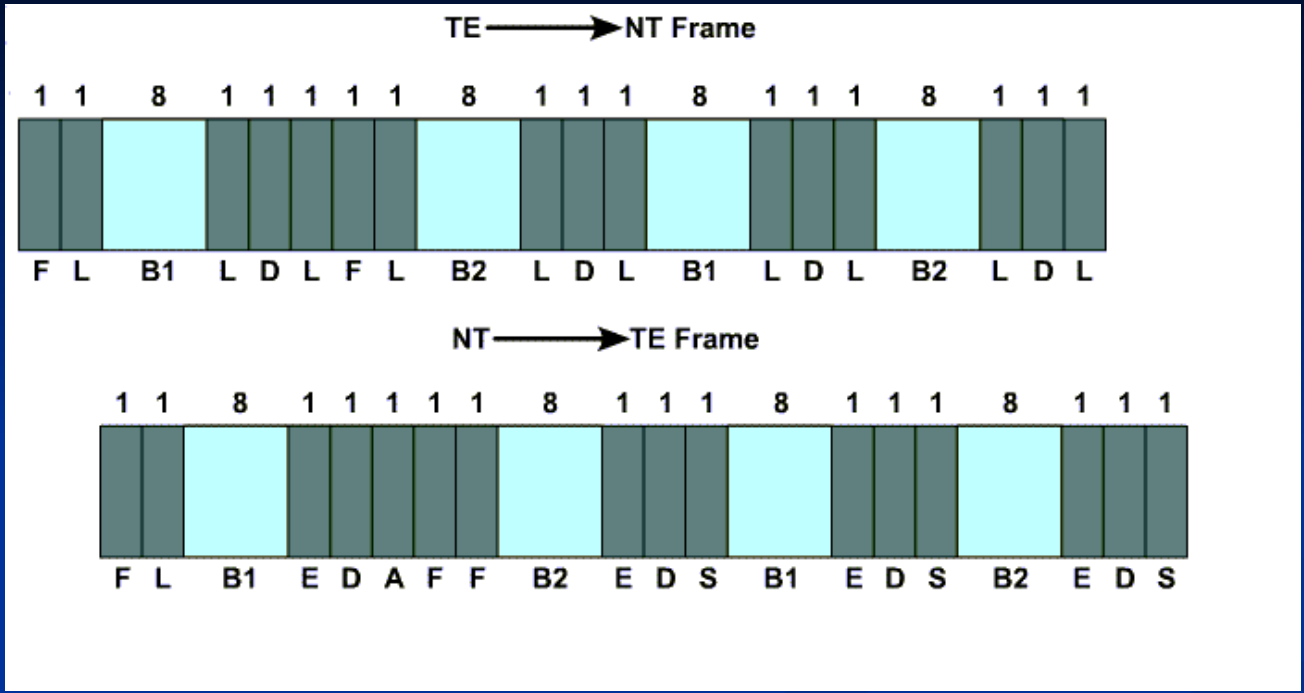
ISDN BRI bus



S/T interface physical frame

- TDM used to multiplex 2B + D channels
- Different format of outbound and inbound frames
- Inbound frame delayed 2 bit intervals after (corresponding) outbound frame
  - used for CSMA/CR (Collision Recognition) D-channel access method

S/T interface frame structure



- B1,B2 – bearer channel bits (payload)
- D – D-channel bits
- F – framing bits
- L – DC compensation bits
- E - echo bits (echoed D-bits from outbound frames)
- S – Spare (not used)
- A - Activation bit – set to 1 if subscriber line in synchronization

BRI S/T interface transfer rate

- Frames are 2*125 us (2*1/8000 s) long
- B channel transmits 8 bits each 125 us (1/8000 s)
- One 250-us frame has to carry 2*8bit of both channels
  - 2 times * 8 bits/sample * 2 channels =32bits
- 16 kb/s D-channel: 4 bits every 250 us
  - 4 bits 4000-times per second = 16000 bps
- 12 bits overhead

Total frame length 32+4+12=48 bits, repeats four time per second

=> frame physical transfer rate is 192 kb/s

BRI line activation

1. TE sends 01111110 (i.e. the HDLC 7E flag)
2. NT sends frames with the A bit set to 0 meaning “not activated”
3. The TE synchronizes on line code violations
4. NT synchronizes on the line code violations and sets the A bit to 1 indicating that layer 1 is up

Powering of user devices

- NT generates 48V DC voltage between TX and RX pair (4W)
  - NT powered from customer side supply
- In case of customer site power outage DC voltage generated by central office (0.4 W)
  - allows emergency calls (commonly voice service)
    - Some subscriber device is set to accept emergency voltage supply
  - NT device able to bridge power voltage from CO
  - Emergency voltage has opposite polarity relative to voltage generated by NT itself
- Subscriber devices can have their own voltage supply or rely on NT-supplied voltage
- In case of NT integrated into CO, voltage supply can be switched on/off on per-port basis

U interface

- 2-wire ordinary subscriber line
- No standard in Europe
  - most often 160 kbps full-duplex using 2B1Q
    - 4 voltage levels, each represents one 2-bit combination
- 2*64 kbps (B) + 16 kbps (D) + 16 kbps (sync+framing) in each direction
- Full-duplex implementation options
  - echo cancellation
  - directions alternated using TDM
    - pause required after change to let signal from opposite direction dismiss

D-channel access method (1)

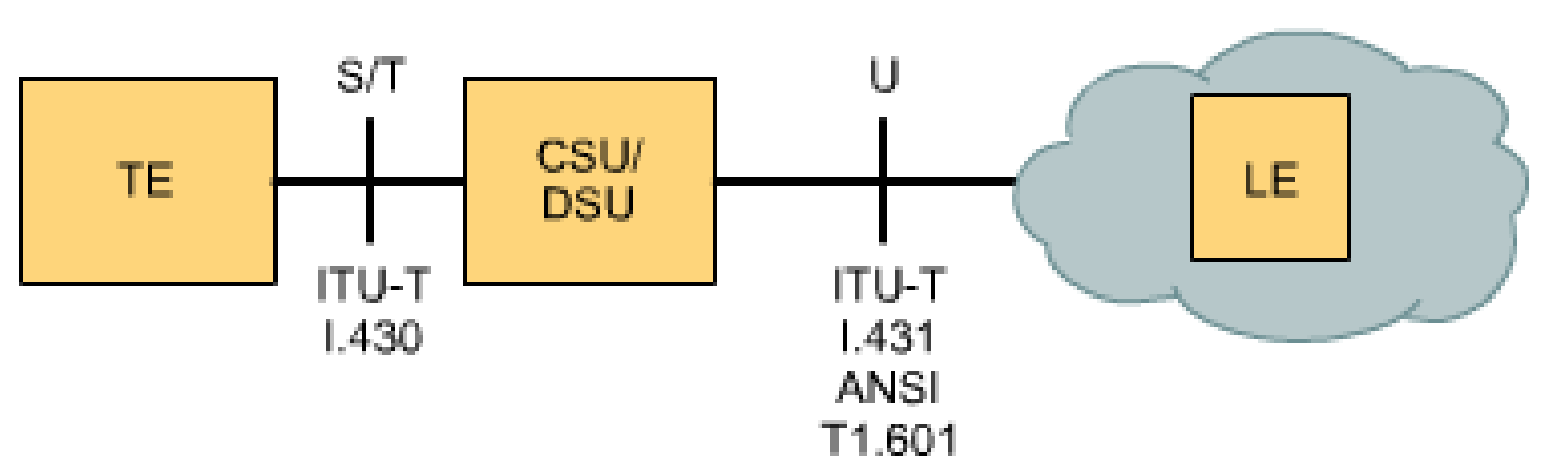
- On BRI bus configuration, up to 8 subscriber devices have to share common D channel
- Device cannot listen for D-channel traffic
  - transmitter and receiver not on the same pair
  - what device hears is D-channel from NT, not from peer subscriber device
- Solution: NT copies D bits of outgoing frames into E bits of incoming frames
  - this is why incoming frames are little delayed after outgoing frames

D-channel access method (2)

- if a device wants to occupy (outgoing) D channel, it has to hear period of "silence" on reflected E-bits
  - silence means sequence of 1s
- also solves priorities for D-channel access
  - less privileged device must detect longer period of silence
  - voice commonly preferred over data
  - after device finishes transmission, it's priority is lowered for a while to deny it to monopolize D-channel
- during transmission to the D-channel, subscriber device has to listen for corresponding E bits to be able to detect collision

Primary Rate Interface (PRI)

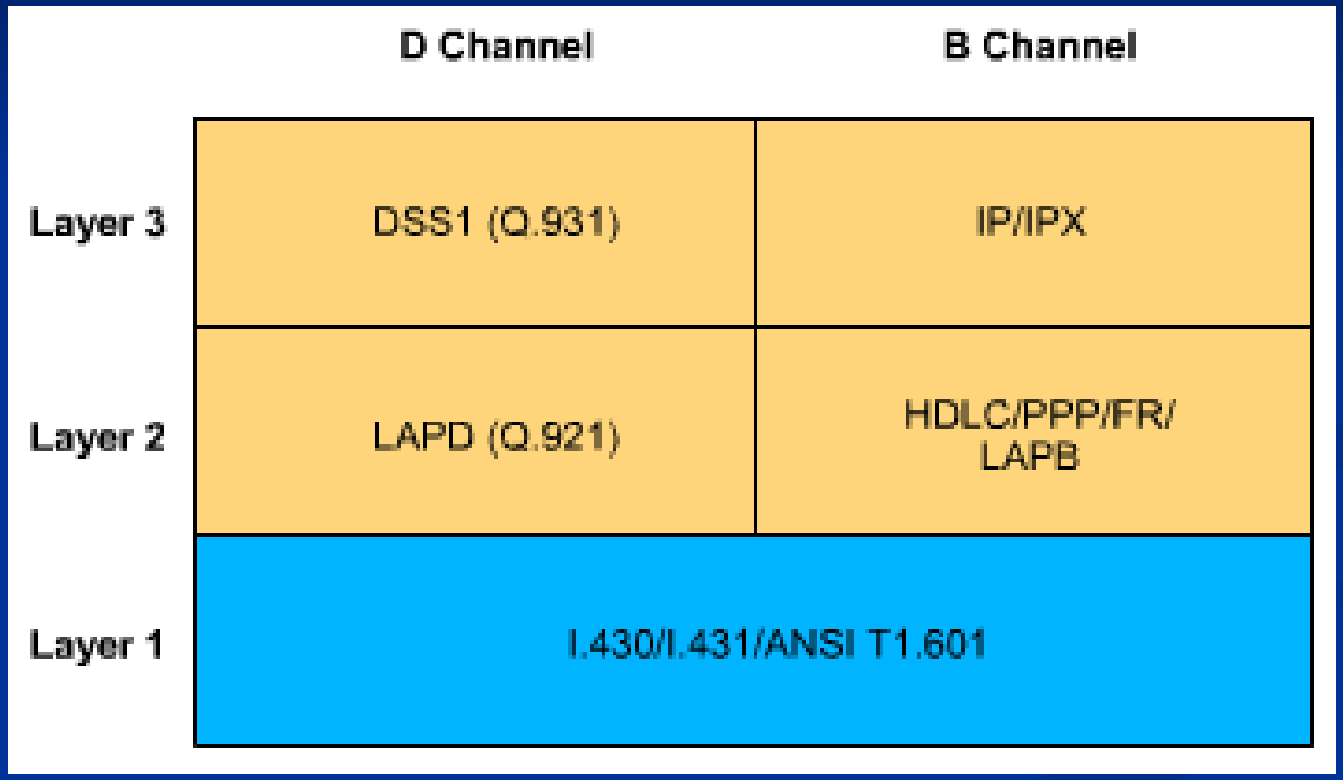
PRI - Reference Points



PRI physical interface

- defined in I.431 (corresponds to E1/T1 physical layer)
  - E1 (Europe): 30B (64 kbps), D (64 kbps, timeslot 16), 64 kbps framing and sync (timeslot 0)
    - (30*64000+64000+64000=2048 Mbps)
  - T1 (USA): 23B (64 kbps), D (64kbps, timeslot 23), 8 kbps framing and sync
    - (23*64000+1*64000+8000=1,544 Mbps)
    - B-channels limited to 56 kbps if Channel-associated signalling used
- 4-wire (or 2-fiber or coax) circuit from central office
  - always point-to-point, CSU/DSU at customer side
- connects PBX or router with PRI interface
- D-channel carries signalling for all B channels

D and B channel layers

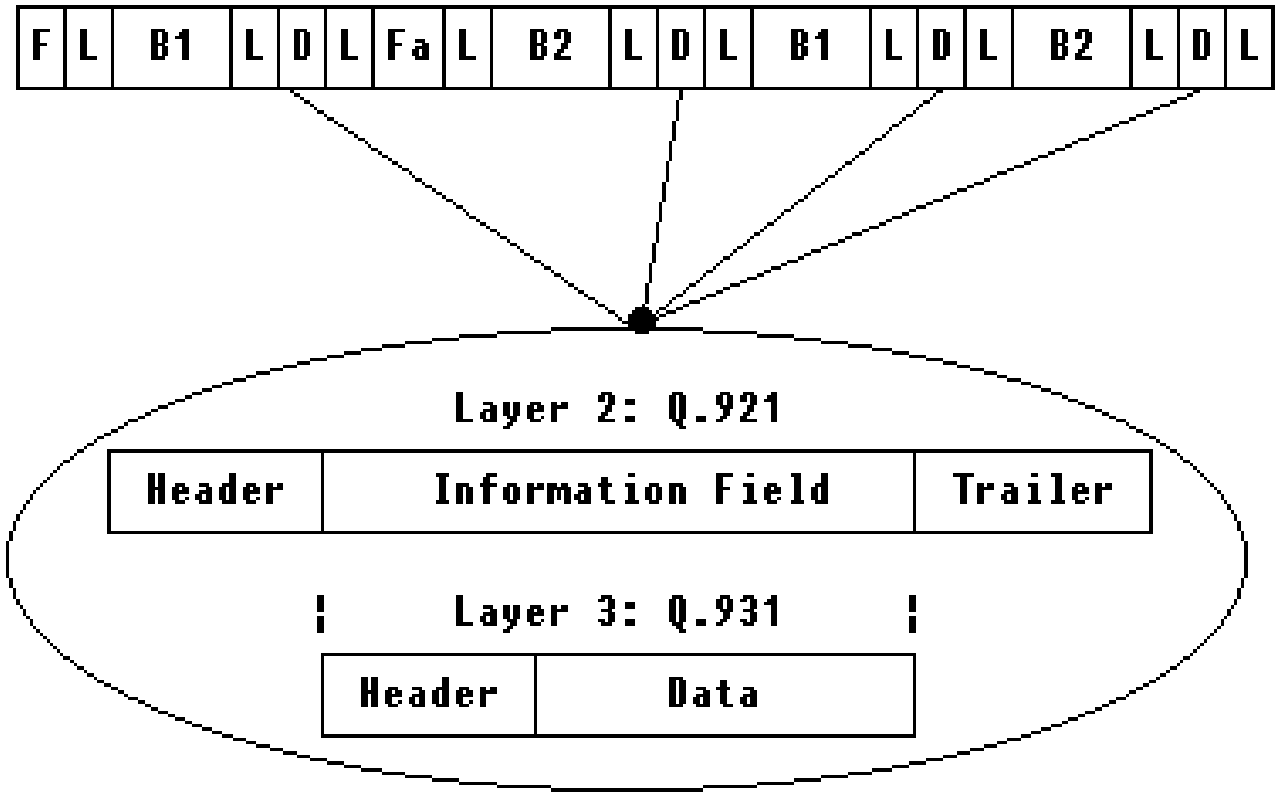


Link layer of B-channel

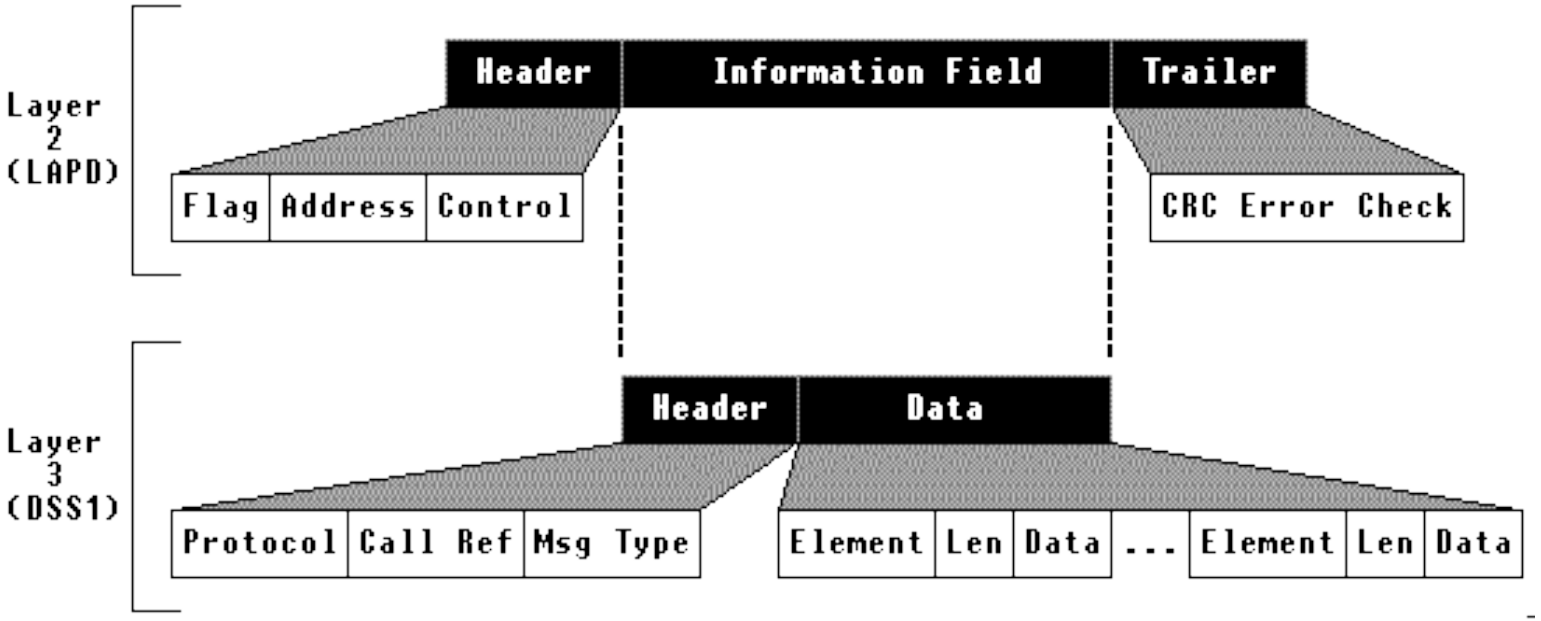
- ISDN circuit provides transparent full duplex 64kbps bit stream
- ISDN does not require any specific data format on B channel
- Subscriber data-service devices need to delimit frames in incoming bit stream
- Any link-layer protocol for synchronous serial lines can be applied
  - Typically PPP, HDLC

D channel

Encapsulation on D-channel



D-channel frames (OSI RM L2/L3)



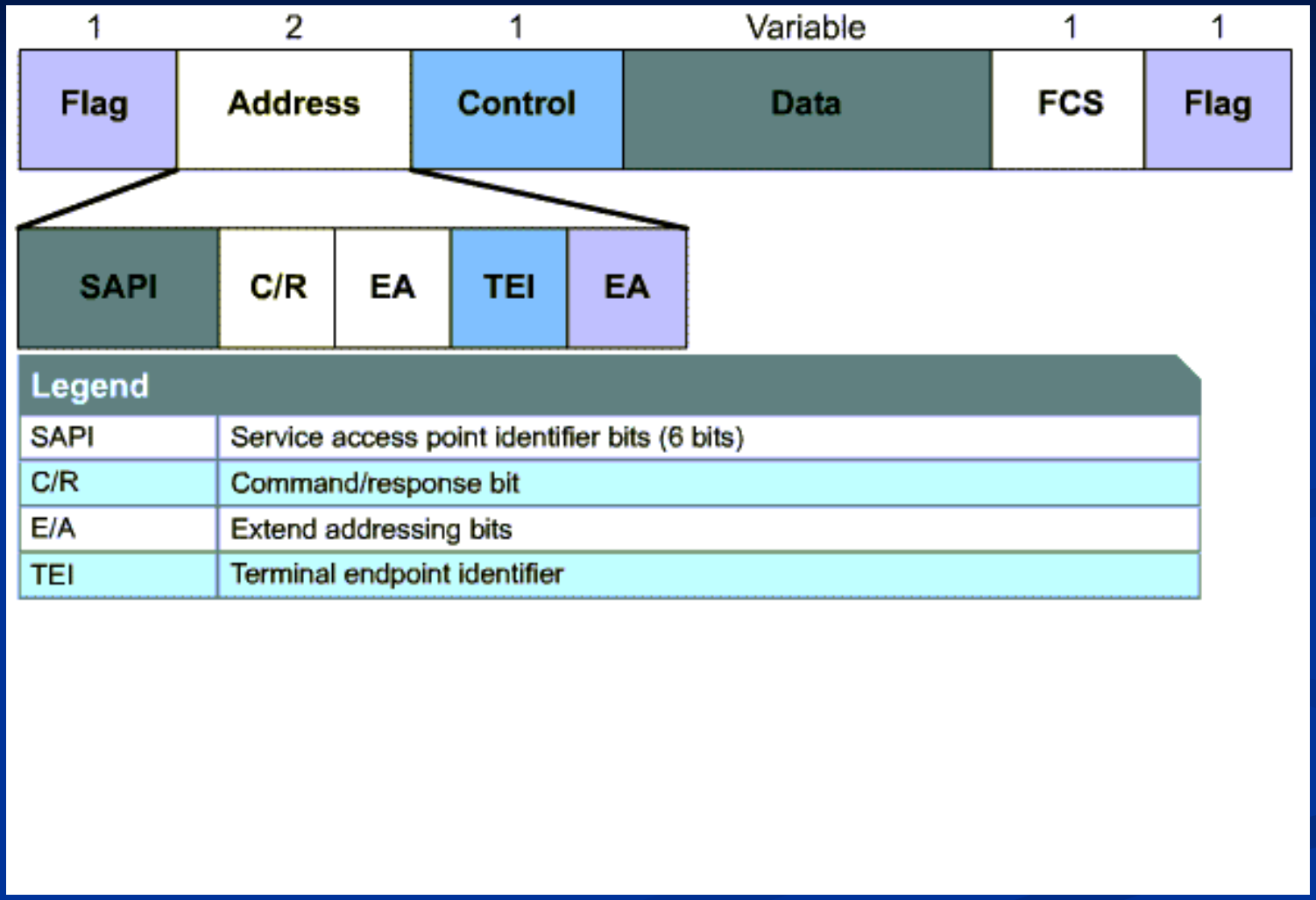
Link Access Procedure D-channel (LAPD)

- Defined in Q.921
- Layer 2 protocol similar to HDLC Balanced mode (LAPB)
- Provides reliable transfer of signalling messages (layer 3)
- Frames delimited by flag (+ bit stuffing)

LAPD addressing

- **TEI (Terminal Identifier)**
  - identifies user devices on S/T bus
  - can be assigned statically on device installation (0-63)
  - central office assigns dynamically if requested (64-126)
  - TEI 127: broadcast
- **SAPI (Service Access Point Identifier)**
  - Specifies upper-layer protocol
    - Signalling
    - User-data – if provided by operator
  - SAPI 63: Layer management (TEI assignment)
  - SAPI 0: signalling (DSS1)

LAPD frame



Legend	
SAPI	Service access point identifier bits (6 bits)
C/R	Command/response bit
E/A	Extend addressing bits
TEI	Terminal endpoint identifier

DSS1 - Digital Subscriber Signalling System No.1

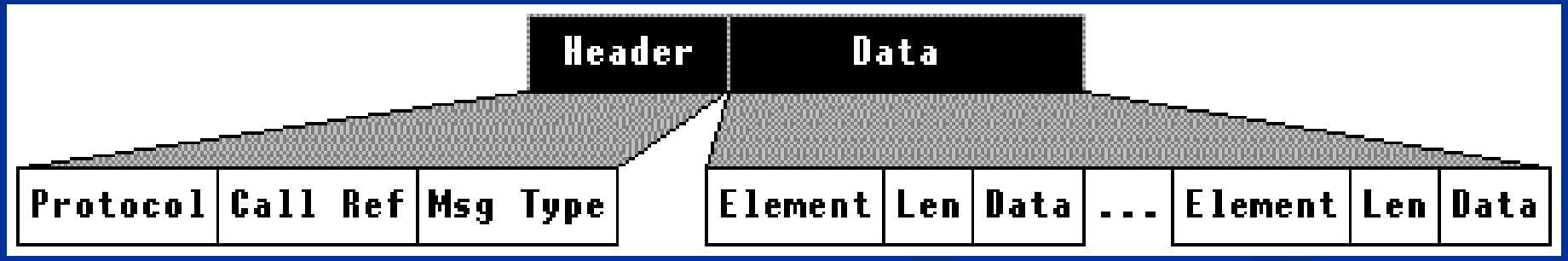
- Defined in Q.931
- Commands/indications for central office and user devices
- DSS1 messages carried in LAPD frames

Note:
DSS1 used for signalling on subscriber line only. In provider network, Signalling System no. 7 (SS7) is used.

Subscriber device identification

- Numbering plan
- E.164 specifies telephone number structure

DSS1 message format



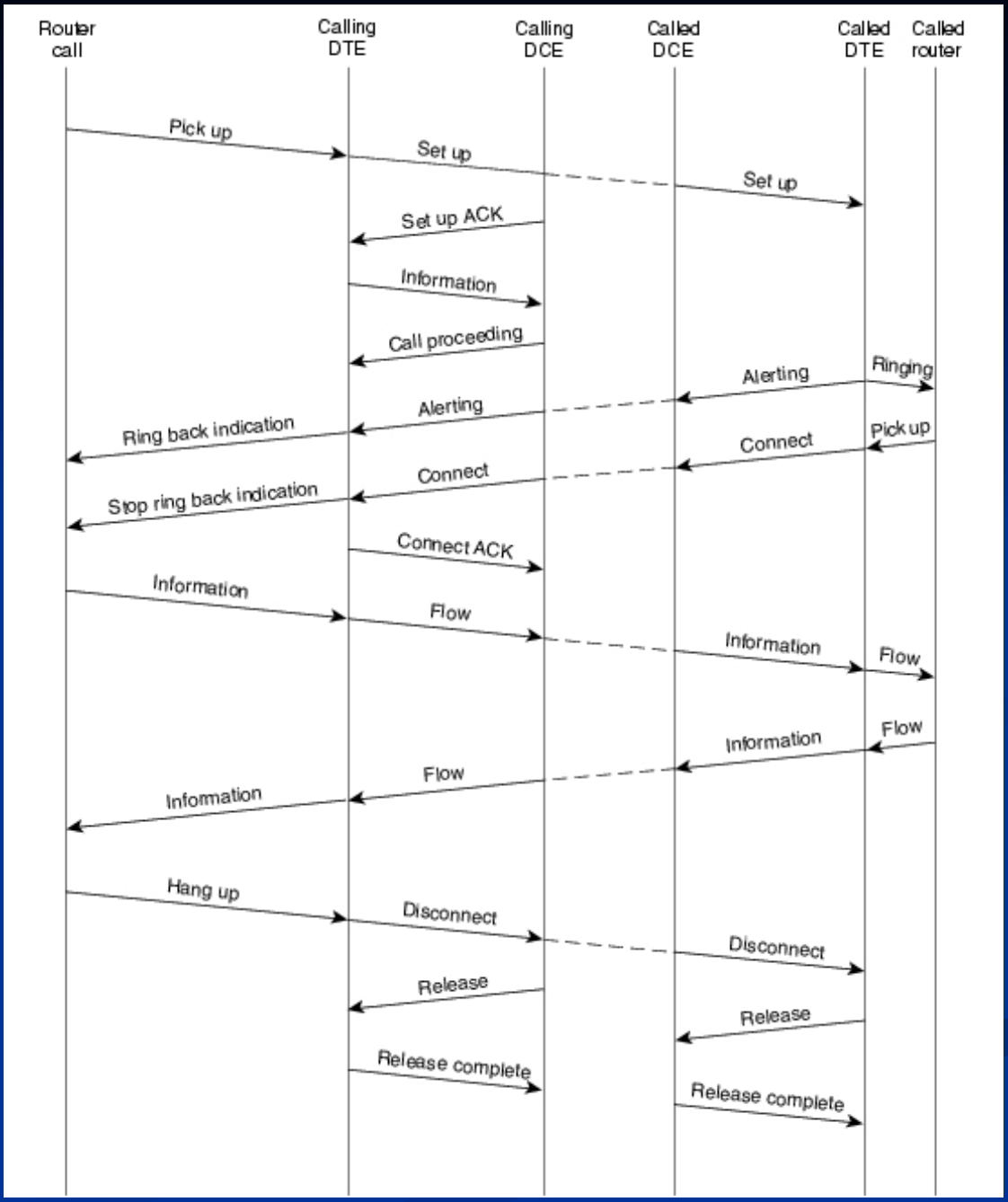
DSS1 messages

000	Call Establishment	
	00001	Alerting
	00010	Call Proceding
	00111	Connect
	01111	Connect ACK
	00011	Progress
	00101	Setup
	01101	Setup ACK
001	Call Information	
	00110	Resume
	01110	Resume ACK
	00010	Resume REJ
	00101	Suspend
	01101	Suspend ACK
	00001	Suspend REJ
	00000	User Information
010	Call Clearing	
	00101	Disconnect
	01101	Release
	11010	Release Complete
	00110	Restart
	01110	Restart ACK
011	Miscellaneous	
	00000	Segment
	11001	Congestion Control
	11011	Information
	00010	Facility
	01110	Notify
	11101	Status
	10101	Status Enquiry

Information element (IE) examples

- **Bearer Capability**
  - identifies transport requirements of the requested B-Channel
- **Cause**
  - identifies reason for call disconnect
- **Calling Party Number** (identifies caller)
- **Calling Party Number Subaddress**
- **Called Party Number**
- **Called Party Number Subaddress**
- …

Typical DSSS1 message interchange



Usage of ISDN for data transfer

Pros and cons of data transfer using ISDN

- ISDN uses dial-up (temporary) circuits
  - payment for connection time
  - useful for short-term data transfer
  - typical usage: backup lines, intermittent data transfers
- Short connection setup time
  - less than 1 sec (Europe)
  - circuit can be established just when there are data to transmit and released just after the transfer end
    - connection setup with classical modems takes tens of seconds

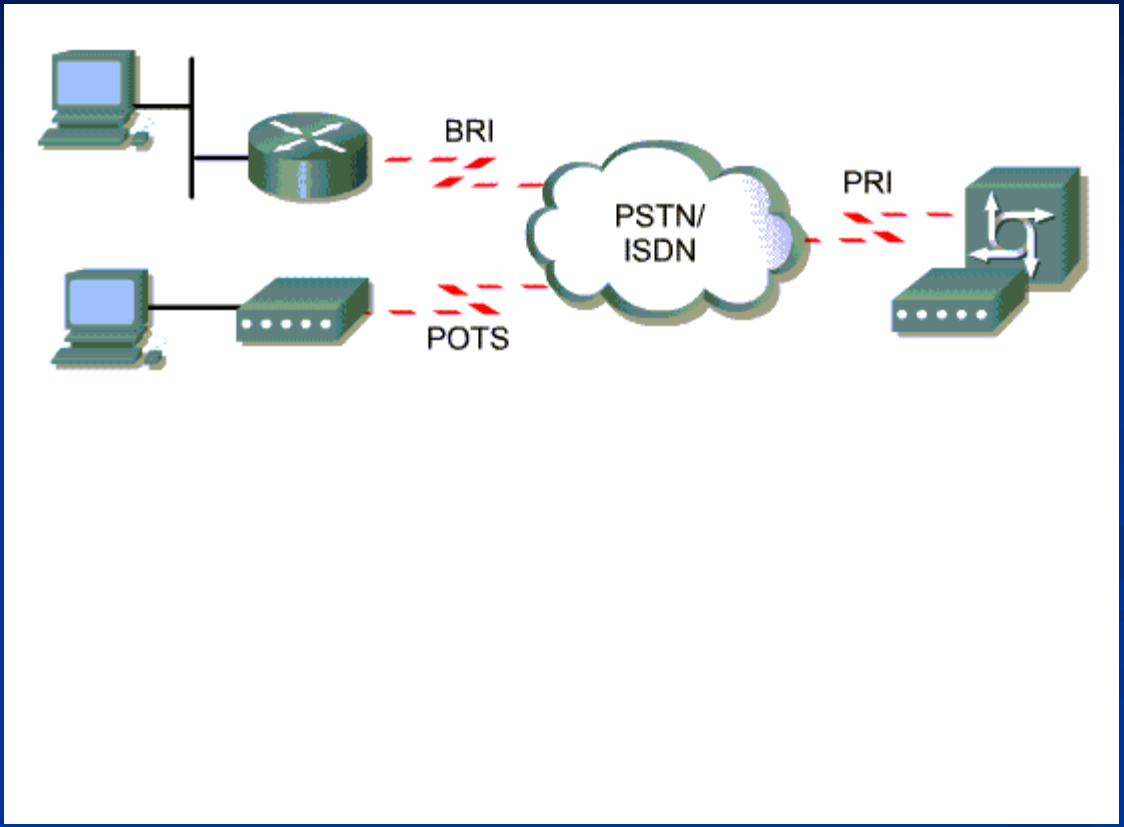
Typical ISDN data transfer usage

- Dial-in access to corporate intranets and Internet (via ISP)
  - PRI at provider site, BRI at customer site
  - replacement of POTS
- Interconnection of distant LANs for short-term data transfer („dial-on-demand“)
  - many LANs connected with BRI
  - PRI in headquarters, BRI at branch offices
- Backup lines
- Low-bandwidth packet transfer (D-channel, X.25)
  - alarm systems, remote monitoring & control systems
  - if supported by telco operator

Remote access using ISDN

- Client commonly connected using modem with BRI
- B-channel typically utilizes PPP
  - authentization, callback, compression, …
- Simultaneous data and voice transfer
  - (multiple B channels)
- Transfer rate may be increased by bundling of multiple B-channels on demand

Typical PRI usage



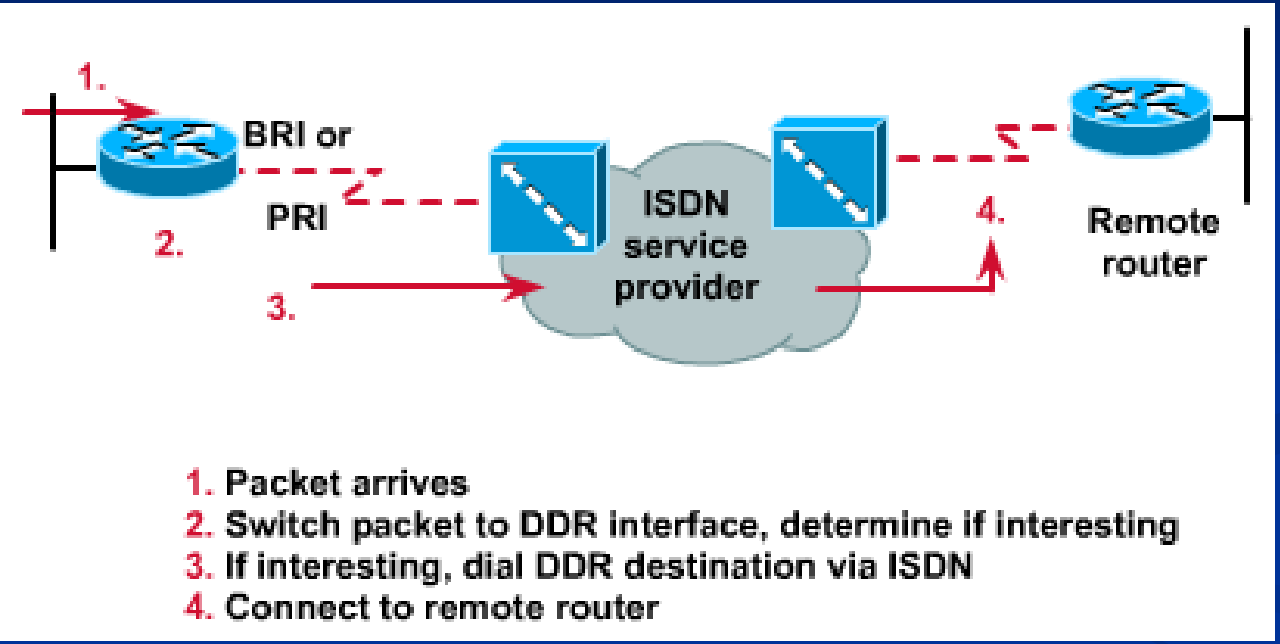
- Connects PBX or ISP/headquarters router

Dial-in from analog modem

- Analog incoming call identified in SETUP message
- ISP router needs to pass incoming data (digitalized by ISDN) into internal modem

Routing in circuit-switching environment

Dial on Demand Routing (DDR)



ISDN routing options and guidelines

- Avoid dynamic routing protocols on dialup circuits if possible
  - use static and default routes instead
- Dynamic routing protocol updates/hellos would maintain dialup line always active
  - if dynamic routing applied, use passive interfaces
- Even inactive line has to be reported as functional into dynamic routing protocol
  - Cisco: BRI interface always up (spoofing) from routing protocol's point of view
  - Define static route to network reachable via ISDN line and redistribute it into dynamic routing protocol
- Usage of Link State protocols problematic
  - require full-time connectivity and checks it using Hello protocol
- Distance Vector protocols more suitable
  - if modified for "Snapshot routing"

Snapshot routing (Cisco)

- Modification of Distance Vector protocols exchanging routing tables periodically
- Defines “active” and “quiet” period
- Routing tables (updates) exchanged only during active period, in quiet period routing tables frozen regardless to expiration timers
  - during quiet period, router silently ingores outage of routing updates
- Connection active only during active period
  - if no other data needs to be passed

Backup routes

- Backup routes may by configured as static routes with low preference (adminstrative distance)
- "Floating static routes"
  - if there exists another (primary) route, backup routes not used because of low administrative distance
  - "float up" if (primary) route with better administrative distance fails and disappears from routing table

ISDN router configuration

- Select ISDN switch (central office) type
  - Europe: basic-net3
- Assign IP address to ISDN interface(s)
- Install routes to supported destinations
  - Next hop at opposite side of ISDN line
- Install next-hop IP address to ISDN number mapping
  - configure authentication
- Specify interesting traffic that triggers call
  - and resets idle timeout
- (configure optional features)
  - Idle timeout
  - Fast idle timeout
  - Multilink thresholds

Devices for ISDN data transfer applications

ISDN modem options (BRI)

- external ISDN modem
  - (implements extended AT command set)
- internal ISDN modem ("ISDN card“)
  - passive/active (HW compression support)
- Often integrated with router (Ethernet)
- Usage:
  PC applications for data transfer, telephony, fax, teleconferencing, …

Router-to-ISDN connection options

- Czech Republic: S/T interface
  - U interface release planned
- USA: U (most often) or S/T interface
- If router lacks ISDN module, TA can be used
- ISDN switch type has to be specified and supported by router's OS
  - Incompatibilities and variations of D-channel protocol
  - Euro-ISDN standard in most European countries (including Czech)

Data transfer security

- Authentication and encryption implemented in subscriber devices (modem, router)
- Router-to-router lines commonly implement mutual authentication using PPP and CHAP/PAP.
- ISDN-level check of calling-party number ("caller-ID screening")
  - Caller-ID contained in Q.931 SETUP message

ISDN vs. xDSL

- ISDN provides lower speeds, connection-oriented
  - DSL provides full-time access
- (cheaper)
- ISDN can be almost everywhere
  - distances from CO, bad subscriber pairs, …
- Can be combined together
  - (using FDM and right splitter)

Useful ISDN links

- http://telecom.tbi.net/isdn.htm
  (BRI/PRI line codes, framing, D-channel operation, ISDN device types and reference points)
- http://www.cisco.com/univercd/cc/td/doc/cisi

  ISDN short overview
- http://www.rhyshaden.com/isdn.htm