N-ISDN

"It still does nothing"

Why ISDN?

- During the century, Telcos
  - Created telephony networks
  - Created separate digital data networks
- Today: Demand for various different services
  - Voice, fast signaling, data applications, realtime applications, videostreaming and videoconferences, music, Fax, ...

Why has ISDN been invented and what is its basic idea? Originally there were two types of Telco networks: one for voice and one for data. Since both traffic types are totally different in behavior it was reasonable to implement two different technologies. Basically, synchronous techniques were used for voice and asynchronous protocols (X.25) were used for data.

Later additional traffic types appeared, such as voice and video streaming, various realtime applications, and so on. Today we call these traffic types "services".

The inventors of ISDN proposed one single network to transport all these services in order to reduce complexity, increase maintainability, improve scalability—and basically to safe money.

What it is...

- Integrated Services Digital Network
- ISDN is the digital unification of the telecommunication networks for different services
- ISDN ensures world wide interoperability
- All-digital interfaces at subscriber outlet
- This module describes N-ISDN (!)
  - Narrowband ISDN (the "normal" ISDN)

N-ISDN means **Narrowband-ISDN**, but you can also think of "Normal-ISDN". The planning of ISDN began already in 1976, but real-world applications became available only with the mid-80's. Also Frame-Relay is regarded as part of the ISDN family, because it can be transported upon the physical layer of ISDN, which we will discuss soon.

Technical Overview

- ISDN provides standardized UNI
  - Basic Rate Interface (BRI)
  - Primary Rate Interface (PRI)
- Synchronous and deterministic multiplexing
  - Constant delays
  - Constant bandwidth
- Dynamic connection establishment
  - User initiated
  - Temporarily

ISDN specifies only a User to Network Interface (**UNI**)—quite similar than X.25 and Frame Relay. But the main difference is that ISDN relies on deterministic, synchronized multiplexing.

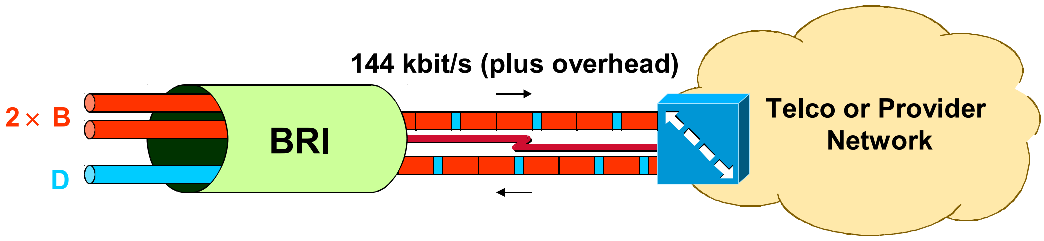
Two data rates were defined: The **Basic Rate Interface (BRI)** and the **Primary Rate Interface (PRI).** Both are explained on the next pages in more detail.

Synchronous and deterministic multiplexing provides constant delays and bandwidth. Therefore, a user can able to put any type of traffic upon this layer—it works fully **transparent**!

The connections are established dynamically by a signaling protocol. The user dials a number and a temporary connection is created. The signaling protocol is the famous "**Q.931**". It is explained later but you should try to memorize it even by now.

Basic Rate Interface (BRI)

- 2 Bearer (B) channels with 64 kbit/s each
- 1 Data (D) channel with 16 kbit/s
  - For outband signaling purposes (mainly)



The picture above describes the BRI which might be installed in every household. The BRI specifies three channels: 2 Bearer (B) channels providing 64 kbit/s each and one signaling or Data (D) channel, providing only 16 kbit/s.

The dedicated timeslot for the Data (D) channel assures a reliable outband signaling. In many cases the D channel is also used for other data traffic, for example X.25 packets.

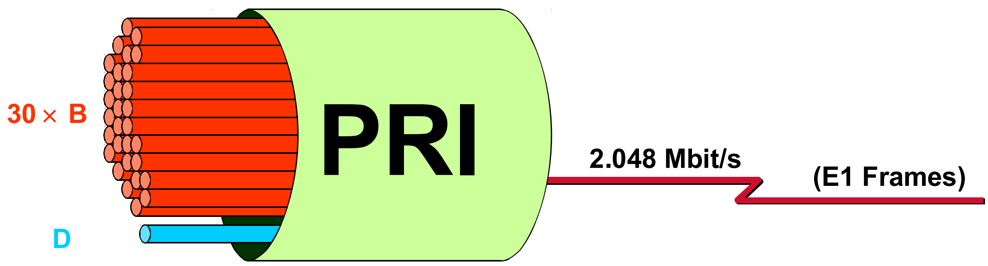
The total bandwidth of all three channels is 64+64+16=144 kbit/s, not regarding the overhead information.

Note that the ISDN link is terminated at the switch of the Telco or provider network. This termination is discussed in greater detail soon.

Unlike a normal telephone connection, an ISDN connection can have more than one telephone number - each of these is called an **MSN** (Multiple Subscriber Number).

Primary Rate Interface (PRI)

- 30 Bearer (B) channels with 64 kbit/s each (USA: 23 B)
- 1 Data (D) channel with 64 kbit/s
  - For outband signaling purposes (mainly)



The PRI also contains B and D channels, but now there are 30 B channels and also the D channel has the same bandwidth of 64 kbit/s. These 31 channels plus an additional synchronization channel result in a total data rate of 2,048 Mbit/s, which is transported over a so-called E1 frame.

Note: In USA and Japan the ISDN PRI offers a data rate of 1.544 Mbit/s.

ISDN Services

- CCITT defined three services
  - Bearer services (Circuit or Packet)
  - Teleservices (Telephony, Telefax, ...)
  - Supplementary services
    - Reverse charging
    - Hunt groups
    - etc...

The CCITT (today known as ITU-T) defined three services for ISDN..

Bearer services define transport of information in real time without alteration of the content of the message. Both circuit mode and packet mode (virtual call and permanent virtual circuit) is supported.

Teleservices combine transportation function with information-processing functions, e.g. telephony, teletex, telefax, videotex, and telex.

Supplementary services can be used to enhance bearer or teleservices. Examples for supplementary services are reverse charging, closed user group, line hunting, call forwarding, calling-line-identification, multiple subscriber number (MSN), and subaddressing.

Functional Groups

- Terminal Equipment (TE)
  - TE1 is the native ISDN user device (phone, PC-card, ...)
  - TE2 is a non-ISDN user device (Analog telephone, modem, ...)
- Network Termination (NT)
  - NT1 connects TEs with ISDN
  - NT2 provides concentration and supplemental services (PBX)
- Terminal Adapter (TA)
  - TA connects TE2 with NT1 or NT2

Several "functional groups" have been specified to differentiate technical capabilities. An end device is called a "Terminal Equipment" (TE).

A TE1 is a true ISDN device such as an ISDN telephone.

A TE2 is any non-ISDN device that can be attached to the ISDN interface via a Terminal Adapter (TA).

A NT1 connects the 4 wire TE1 to the 2 wire ISDN link to the Telco switch, also known as Local Exchange (LE).

A NT2 is an optional device that provides concentration of multiple local premises phone lines and connection to the LE. This device is also called a Private Branch Exchange (PBX) and might provide a lot of additional services, depending on the vendor.

Reference Points

- Logical interfaces between functional groups
  - **R** connects PSTN equipment with TA
  - **S** connects TEs with NT2
  - **T** connects NT2 with NT1
  - **U** connects NT1 with Exchange Termination (ET)

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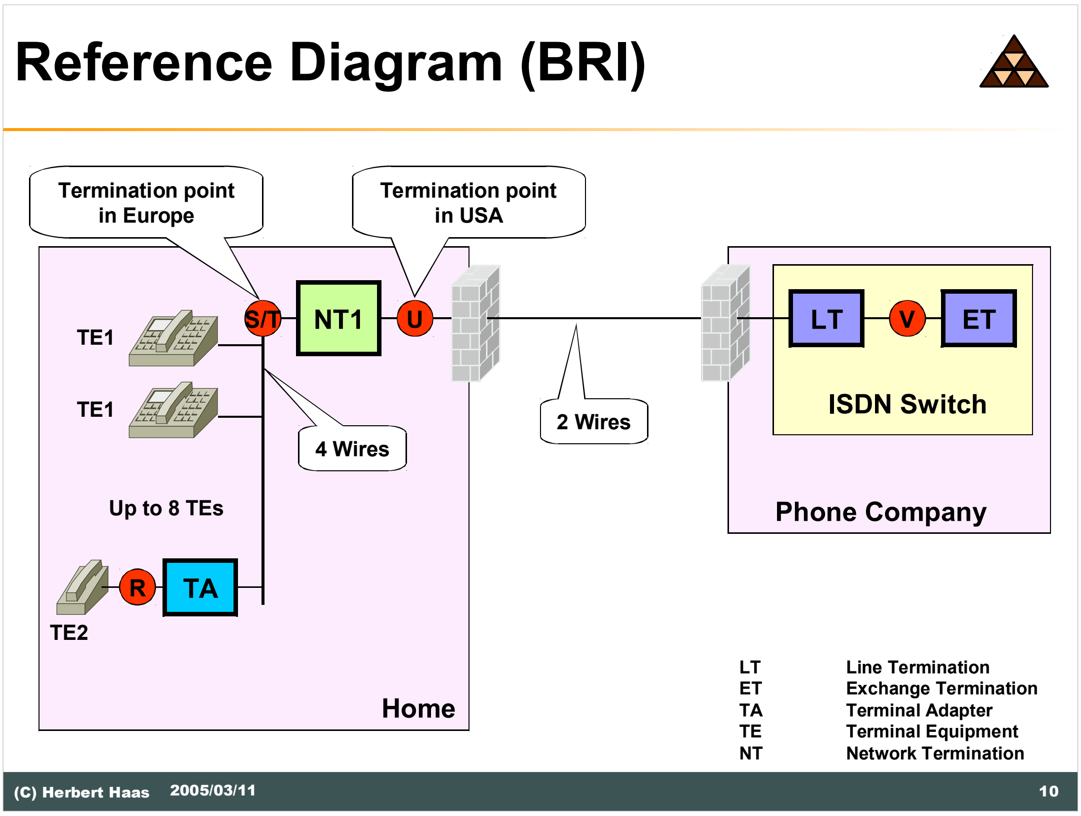
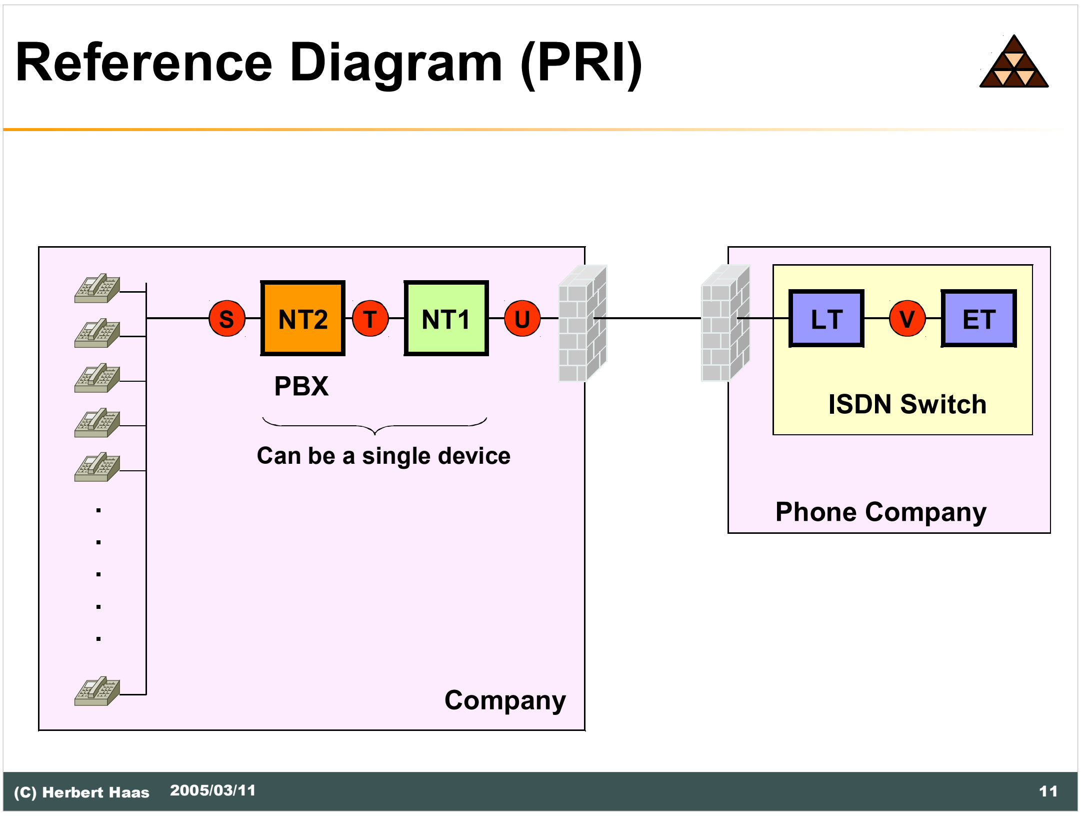
Besides the Functional Groups, also "Reference Points" had been specified. Reference Points identify logical interfaces between the previously mentioned Funtional Groups.



A TE2 is for example a plain old telephone (POT) or an analog modem. The R interface is typically a EIA/TIA-232-C, V.24, or V.35.

Basically, the NT1 converts the U to S/T interface: 2 wires to 4 wires, different coding scheme, different bit-rates (160 to 192 bit/s). Furthermore the NT1 cares for synchronisation, multiplexing of B and D channels, and optional power provision for TEs. Some people just call it ISDN-modem. Never say that.



The picture above shows the principle of a PRI installation, using a PBX (NT2) which terminates all local telephones. Note that these telephones are not necessarily ISDN compliant telephones. Rather vendor proprietary technologies are used here.

U-Interface

- Recommendation G.961
  - 160 kbit/s (remaining capacity used for framing and synchronization)
- Either echo cancellation or time compression (ping-pong)
- 2B1Q (ANSI T1.601)
  - -2.5 V, -0.833 V, +0.833 V, +2.5 V
  - Requires half the BW of NRZ
  - Plus scrambling for synchronization and uniform PSD distribution

The U-interface is defined in CCITT "Recommendation G.961" and specifies a 160 kbit/s transmission method over two wires. Bidirectional communication is provided either by echo cancellation or "ping-pong" transmission, i. e. alternating sending and receiving of both sides within short time periods.

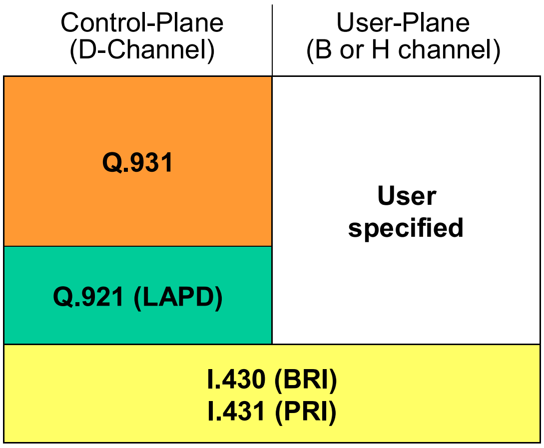
"Two Binary One Quaternary" (2B1Q) digital coding is used on this interface.

ISDN Channels

- TEs just require one D and 1 or 2 B channels
- High-speed PRI applications can be connected with so-called H-channels
  - H0 (6B = 384 kbit/s)
  - H11 (24B = 1536 kbit/s)
  - H12 (30B = 1920 kbit/s)

H channels are bundles of B channels to obtain a higher data rate.

Layers



The diagram above shows the ISDN layer model. There is one common physical layer, which is either I.430 (the BRI) or I.431 (the PRI). Note the vertical separation above the common physical layer—a clear sign of outband signaling!

On the left side the signaling protocol Q.931 can be identified in this diagram. This "Control Plane" protocol carries the dial numbers and is itself carried by Q.921, a HDLC variant providing a reliable delivery of data between two adjacent interfaces—between TE and LE.

On the right side the "User Plane" is specified as an open interface. That is, the user can put any service directly upon the synchronous physical layer.

Additional Standards

- Q.920 (I.440)
  - Layer 2 UNI general aspects
- Q.921 (I.441)
  - Layer 2 UNI specification and LAPD
- Q.930 (I.450)
  - Layer 3 UNI general aspects
- Q.931 (I.451)
  - Layer 3 UNI specification and call control procedures

Just for your interest—and to provide a complete description—the most important standards are listed as summary.

I.430 S/T-Bus

- S/T interface is implemented as bus
  - Point-to-point
    - Maximum distance between TE and NT is 1km (!)
    - Requires a PBX
  - Multipoint
    - Up to 8 TEs can share the bus
    - Maximum distance between TE and NT is 200 meters (short bus) or 500 meters (extended bus)

An ISDN interface can be configured either in multipoint mode or in point-to-point mode.

The point-to-point mode is the normal connection mode for business ISDN users. The user can attach only one single devices to the ISDN connection which will have to handle all calls (typically a PBX will be used).

The ISDN provider will assign a range of numbers to the ISDN connection. Any call within this number range will be sent to the user. The ISDN provider will leave assignment of the last digits of the telephone number to the ISDN user. This setup usually allows for additional features, but is also more expensive.

Multipoint Configuration

- D channel is shared by all TEs
  - To request usage of B channels
  - Contention mode
- B channels are dynamically assigned to TEs
  - Exclusive usage only (!)

The multipoint configuration is typically used for private users. Here the D channel is shared by up to 8 TEs. The D channel is used similarly as an Ethernet bus medium—contention takes place! The winner gets a B channel for communication. This B channel is dynamically assigned but immediately released when the call is terminated.

S/T Bus Details

- **192 kbit/s=**
  144 kbit/s (2B+D) ***+ 48 kbit/s for Framing, D-echoing, and DC balancing***
- **48 bit frames every 250 μs**
  - **Modified AMI code (zero-modulation)**
  - **Bit-stuffing**
  - **Synchronization through code violation**

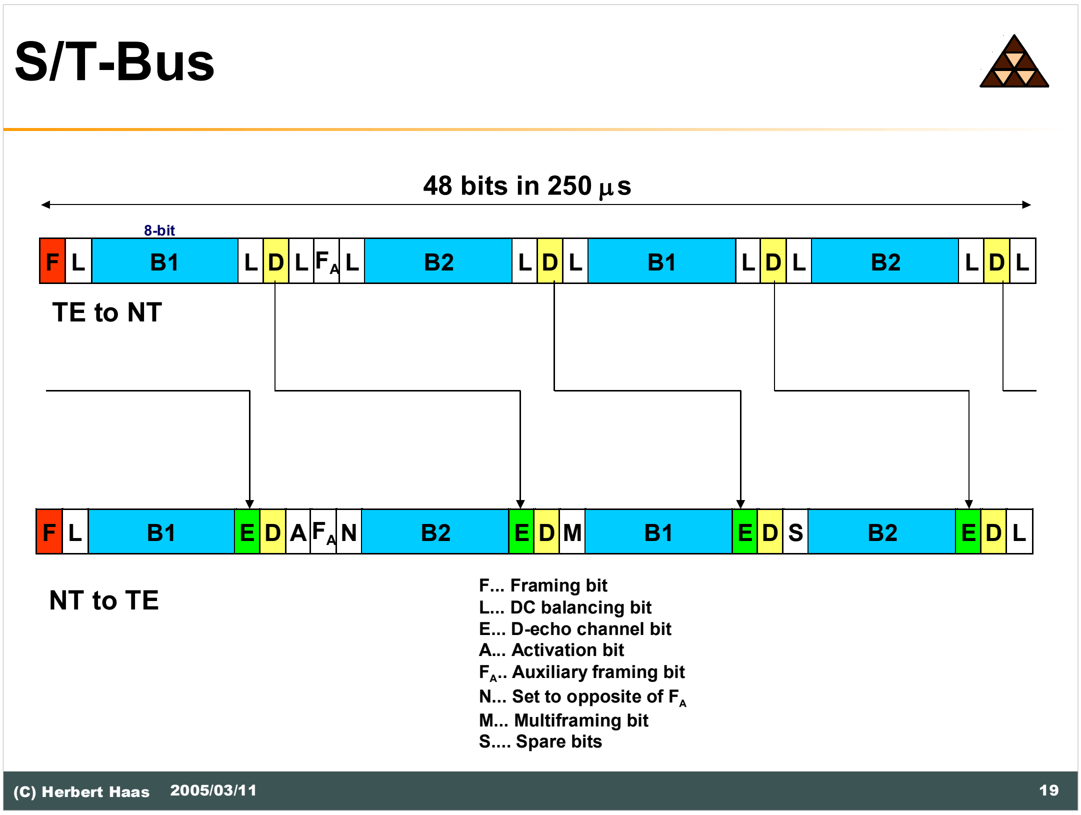
Two B channels and one D channel plus 48 kbit/s overhead results in a sum of 192 kbit/s. This data rate is actually provided by a BRI. The overhead is necessary for framing, bus arbitration, and DC balancing. This details can be seen on the next page.

Electrical details:

RJ-45 Connectors with 8 pins

- 2 TX
- 2 RX
- 4 optional power feeds

100 Ω termination impedance



F (+) followed by L(-) marks start of frame. To prevent F in the bit stream, code violations are used (normally alternate pulses (+, -) used for zeroes)

General rule: first logical zero to be transmitted uses a code violation symbol.

In case of "all-ones", the F_A performs code violation. The auxiliary framing bit F_A is always set to 0; N = is always inverse of F_A (=1 here).

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.

D – Channel Access Control (1)

- **Before TE may use D channel: Carrier Sense**
  - **At least eight ones (no signal activity) in sequence must be received**
- **Then TE may transmit on D channel: Collision Detection**
  - **If E bits unequal D bits TE will stop transmission and wait for next eight ones in sequences**

In multipoint mode the S7T bus is used in contention mode similar to Ethernet. Before a TE may use the D channel it must listen whether some TE is sending —"carrier sense" is performed. Here at least eight "1" must be received in sequence. Since the inverse AMI coding is used this means that nobody is currently sending.

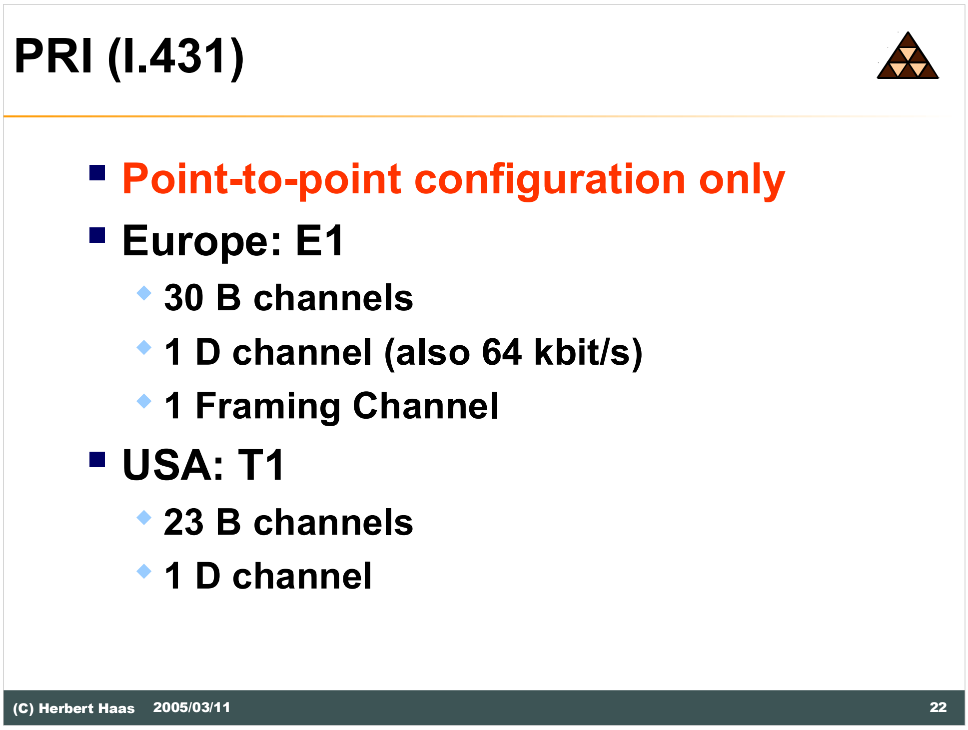
Then the TE may transmit data (e. g. a Q.931 packet within a Q.921 frame) on the D channel. But during sending, this station must perform collision detection by observing the echo bits which reflect all sent bits back from the NT.

D – Channel Access Control (2)

- When using D channel
  - Bit stuffing prevents sequence of eight ones for the rest of the message
- Fairness
  - TE must release D channel after message was sent
  - Next time, this TE must wait for a sequence of nine ones

Of course measures must be implemented to avoid eight ones during sending—another TE might assume that the S/T bus is empty! Thus bit stuffing is performed in such cases (inserting a zero).

Furthermore, if a TE succeeded recently this TE must wait for **nine** ones before grabbing the D channel. This method assures fairness among the TEs.



The T1 frame synchronization is achieved using a single bit at the beginning of the frame. Both E1 and T1 are explained in another module (Telco Backbones).

LAPD (Q.921)

- **Link Access Procedure D-Channel**
  - **Based on HDLC ABM mode**
  - **2 byte address field (SAPI + TEI)**
  - **Optionally extended sequence numbering (0-127)**
- **Carries Q.931 packets**
- **May also be used to carry user traffic**
  - **For example X.25 packets**

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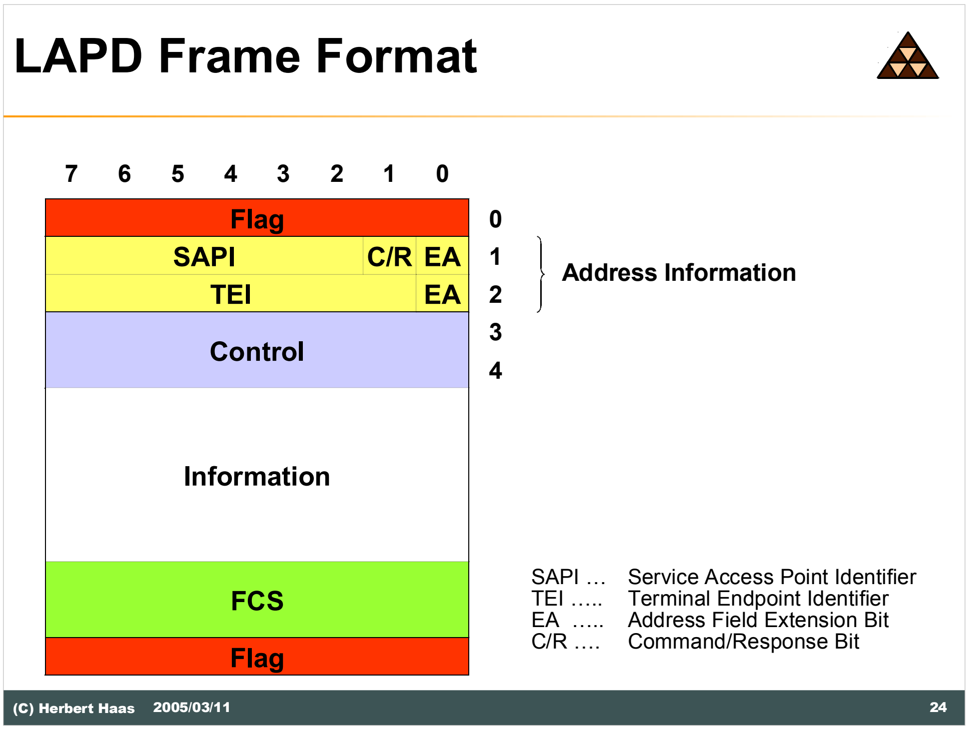
Note that the D channel is empty in most of the time because its only needed when establishing or closing a connection. Because of this, many providers allow to send user data over the D channel, using for example X.25. Of course this is no free service, because the provider network has to transport this data, so users have to pay for it.



The picture above shows the Q.921 or LAPD frame format. The Service Access Point Identifier (SAPI) and the Terminal Endpoint Identifier (TEI) are described next.

FYI: The SAPI and TEI is also called **Data Link Connection Identifier** (DLCI, like in Frame Relay).

TEI

- When TE occupies D channel, the ET (switch) assigns a Terminal Endpoint Identifier (TEI) to it
- LAPD frames carry TEI
  - To identify source (TE → ET)
  - To identify destination (ET → TE)
- Possible values: 0-127

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A switch (LE) would not really know which TE is currently actice and has grabbed the D channel. Therefore a Terminal Endpoint Identifier (TEI) is assigned to the TEs. The LAPD frames carry the TEI which can be compared to an Ethernet MAC address while the telephone number is similar to an IP address in this context.

TEI Management

- **TEIs are either assigned automatically**
  - **By switch (ET)**
  - **TEI value range 64-126**
- **Or preconfigured**
  - **Checking for duplicates necessary**
  - **TEI value range 0-63**
- **TEI = 127 reserved for broadcasting**

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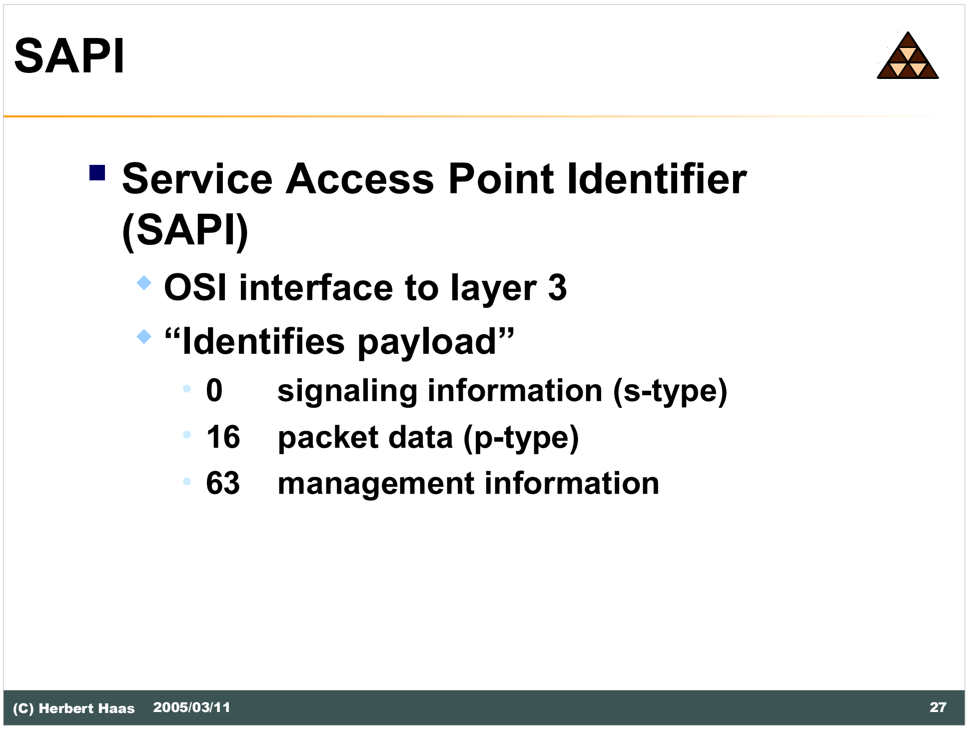
Note that the TEI is not used for primary rate interfaces (PRI) because PRI do not support multipoint connections. Here the TEI is always set to zero.

The local switching station, or with an internal S0 the PBX, automatically or permanently assigns each end device a Terminal End Identifier (TEI). This simply allows the addressing of the D channels. TEIs have the following values: 0-63 = permanent TEIs (e.g. 0 is used for point to point connections) 64-126 = automatically assigned 127 = broadcast to all devices (e.g. an incoming call) .



Additionally a Service Access Point Identifier (SAPI) is needed to identify the content of this LAPD frame. Each SAPI number identifies a layer 3 service. For example Q.931 services might be addressed or the SAPI might also indicate that the LAPD payload is a X.25 data frame.

TEI Management Messages

- UI frames with SAPI = 63 and TEI 127
- Information field contains
  - Reference indicator (RI) to correlate request and responses
  - Action indicator (AI) to specify TEI in question
  - Message type

Also management messages are identifed by a special SAPI (63), combined with a TEI of 127, which addresses **all** TEs (broadcast). These management messages are used to assign TEIs to the TEs.

Examples for message types are:

ID_Request, ID_Check Response, ID_Verify (TE to NT) and

ID_Assigned, ID_Denied, ID_Check Request, ID_Remove (NT to TE)

Q.931

- Carries signaling information
  - Call control
  - E. g. dial number and ring information
  - Terminated by ET
- ET is real 7-layer gateway
  - Translates Q.931 into Signaling System 7 (SS#7)
- Country-dependent versions (!)

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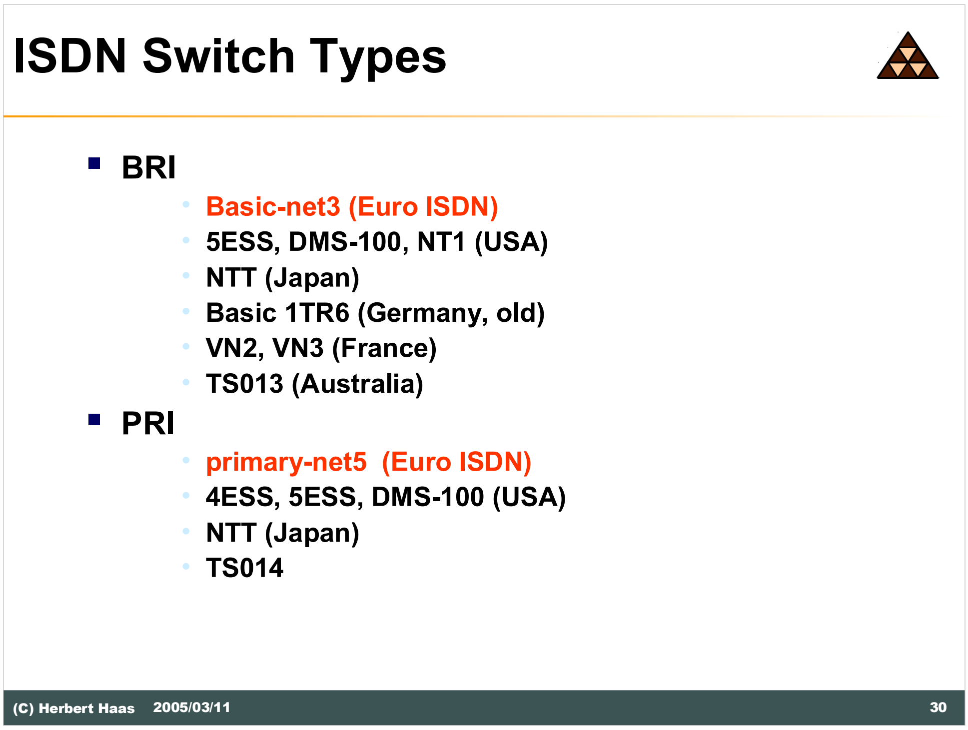
Q.931 is a signaling protocol used by N-ISDN and also (slightly enhanced) by B-ISDN. Using Q.931 the dial number is forwarded to the Telco switch, which terminates the D channels and puts all signaling information on top of another signaling protocol. Typically SS#7 is used in most Telco networks.

FYI: Some special features

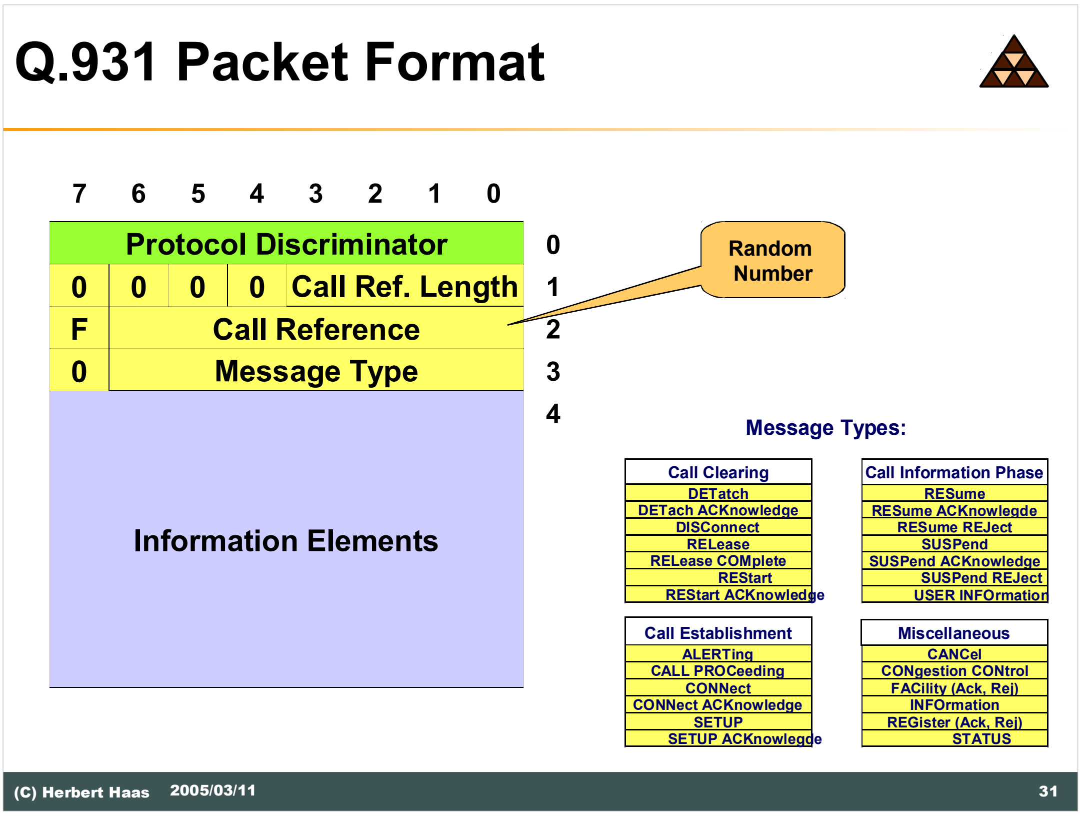
CLIP (Calling Line Identification Presentation) can be offered by the ISDN provider. When you call somebody, then your telephone number will be transmitted to the other phone. The opposite of CLIP is CLIR: one can (from call to call) restrict the identification of one's own caller ID to the other party.

COLP (Connected Line Identification Presentation) can also be offered by the ISDN provider. COLP provides an extended dialing protocol. You will receive feedback from your telecommunication company who picked up your outgoing call. Normally, you will get the same number as you dialed beforehand; however, with call diversion this could also be a different number.



When configuring the ISDN devices it is very important to know about the switch (LE) type because there are many flavors.

The list above presents the most important ISDN BRI and PRI interface variants.



The Q.931 packet format is given in the picture above only to provide a consistent ISDN overview here. It is not necessary to memorize this structure in detail.

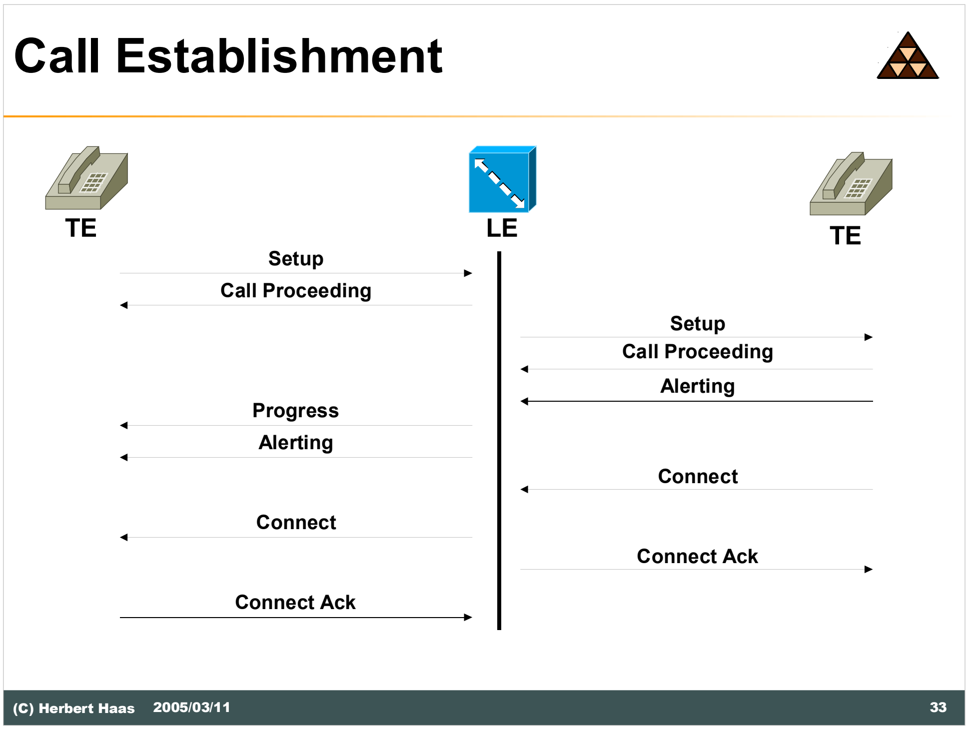
However it should be noticed that the actual information is carried in so-called "**Information Elements**" (IE). Several Q.931 messages are listed in the right hand side of the packet. Each message type is identified in the equivalent field in the header and supports a specific set of IEs.

The protocol discriminator is set to 0x08 (except 1TR6: 0x41).

Information Elements Examples

0x04	Bearer Capability (eg. 0x8890 .. dig. 64kb/s Circuit)
0x08	Cause (reason codes for call disconnect)
0x18	Channel Identification
0x1E	Progress Indicator (check for 56kb/s connection)
0x2C	Keypad
0x6C	Calling Party Number
0x6D	Calling Party Sub address
0x70	Called Party Number
0x71	Called Party Subaddress
0x7C	Low-Layer Compatibility
0x7D	High-Layer Compatibility

In order to get a practical understanding of how Q.931 works, the table above shows some examples of important Information Elements. The left column shows the Information Element Identifier which is used at the beginning of each IE in order to identify this IE. The IE structure is not shown in this chapter.



<u>**Examples for Setup Information Elements are:**</u>

Bearer Capability 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)

Channel Identification IE

Defines which B-channel is used

Called-Party number IE

Whom are you calling

Calling-Party number IE

Who is calling you (does not need to be delivered)

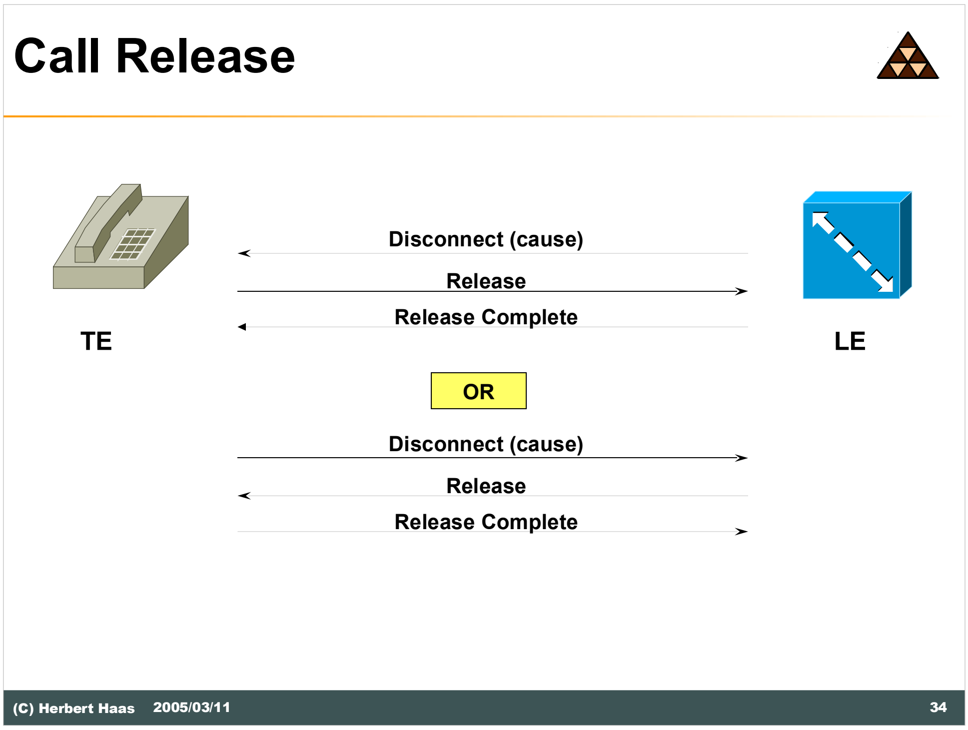
Keypad IE

Can be used instead of called-party number

High-Layer Compatibility IE

Used with the BC to check compatibility

Note: IEs vary among switch types (!)



At the end of this chapter we release the ISDN call with the messages shown above.

Summary

- Dynamical circuit switching
- BRI (2B+D) and PRI (30B+D)
  - Bearer channels (B)
  - Signaling channel (D)
- Q.921 (LAPD) and Q.931 on D channel
- Reference points (R, S, T, U)
- Function Groups
  - TE1, TE2, TA, NT1, NT2, ET

Quiz

- What voltage might be supplied for power supply?
- The U interface is full-duplex but there are only two wires...? How does it work?