Switching techniques

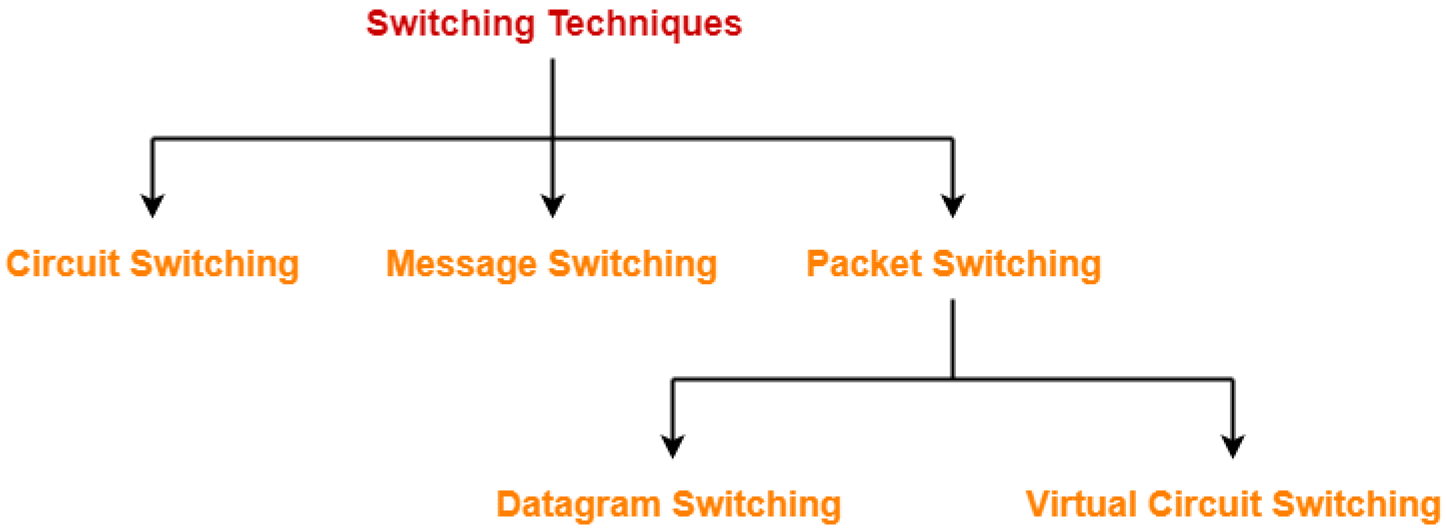
Traditionally the telephonic system is based on circuit switching; is the main infrastructure for communications (computer) networks => the switching term remains.

Switching techniques used in information transfer are:

-circuit switching

-message switching

-packet switching



Circuit switching

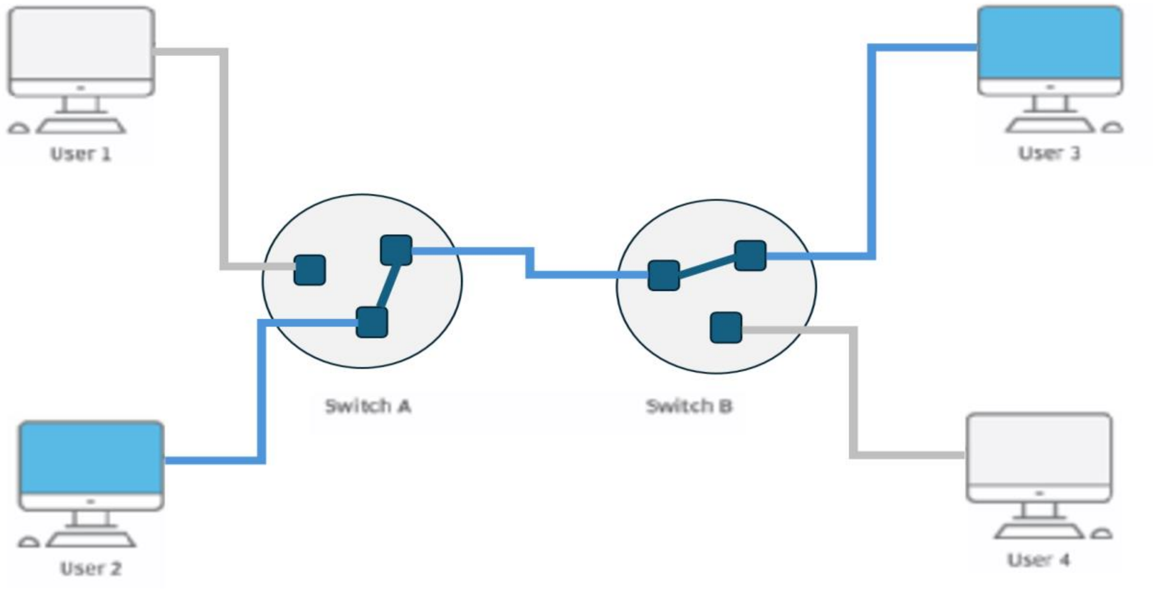
Physical path between communicating parts, achieved using circuit switching –switches (relays)-in the networks nodes.

Three phase communication:

-circuit establishment (setup), establish a (optimum) path between parts; both parts agree communication

-effective data transmission (signal transfer), on this route

-circuit release (disconnection); initiative of one part.



Circuit switching

Drawbacks:

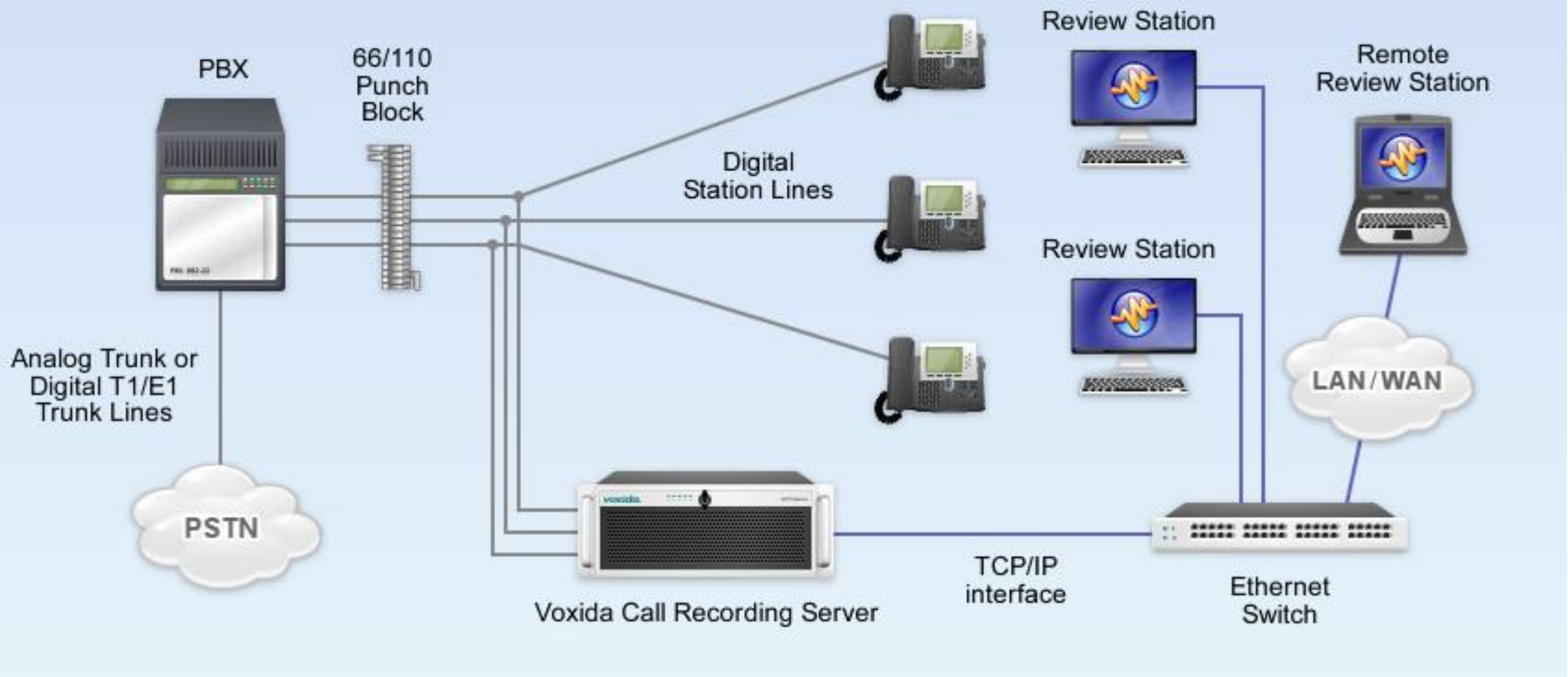
-not efficient due to existence of the first phase (it will exist even if there's no data transfer)

-need for covering bandwidth allocation

-important amount of cabling

-no buffers in switches for transmission equalization

Today use of digital **PBX** (Private Branch Exchange)



First circuit-switching: space-division switching (separated signal paths – divided in space): crossbar matrix of I/O full duplex lines

An improvement: multiple-stage switches

Today all telephony: digital time-division techniques (synchronous TDM)

Signaling in digital telephony:

-inchannel

  -in-band: signals using the same band as the voice channel (as payload)

  -out-band: (voice signals do not use whole 4kHz bandwidth)

-common channel – a common signal channel for a number of voice channels

Signaling may use the same (or not) path as the payload (associated/nonassociated modes)

What's signaling? **Signal = control** Examples:

  -connection setup request = off-hook signal from telephone to switch

  -connection setup acknowledge = dial tone

  -destination address = pulse or tone dialing

  -destination busy = busy tone

  -destination available = ringing tone

Other signaling functions: transmission of: dialed number between switches, information about a call not completed, about billing, diagnose and failure isolation

Message switching

Data transfer using **messages** (independent data units, with diff. lengths but similar structures). Types: control and data (embedding control)

Need for addressing (source & destination of message)

Communications nodes are not physical switches, but computing systems (with memory and processing units).

Philosophy is: message *store & forward* .

Not more dedicated communications path; established in an optimum way (cost, network status) by nodes (using routing tables).

Advantages:

-improvement in efficiency (path multiplexing)

-introduces message priority

-equilibrated transmissions.

Drawbacks:

-messages are too long, memory waste and difficult error recovery

Packet switching

Combines the advantages of previous methods. The **packet** has similar message structure but a lower length, up to 1000octets.

Two methods:

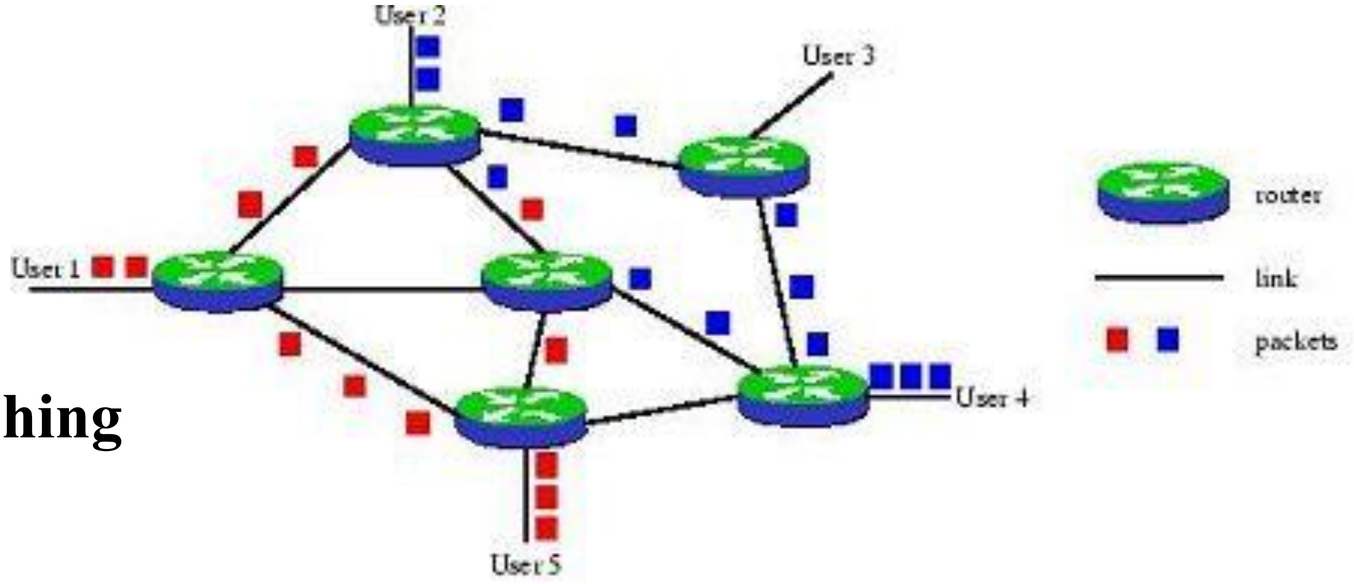
-use of **datagrams** (close to message switching)-more speedy and flexible method

    -use or not of transmission acknowledgments (ACK)

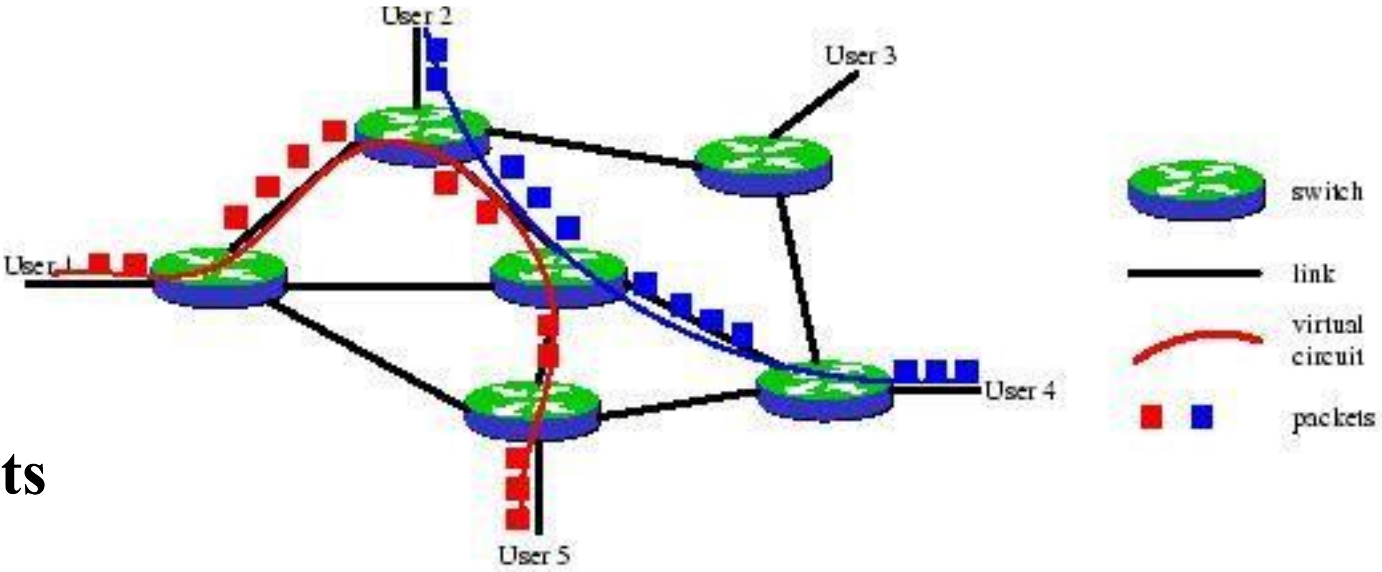
-use of **virtual circuits** (close to circuit switching)-use of the three phases (connection request, data transfer, disconnect) for a logical connection activation; use of special control packets for that. Also embedding of control information (piggybacking).

A logical connection may be implemented with more different physical connections.

Datagram switching



Virtual circuits



Routing in packet-switching networks

Circuit switching vs. Packet switching

Most of WANs based on circuit or packet switching

Circuit switching designed for voice

- Resources dedicated to a particular call
- Much of the time a data connection is idle
- Data rate is fixed
  - Both ends must operate at the same rate

Packet switching - Basic Operation

Data transmitted in small packets

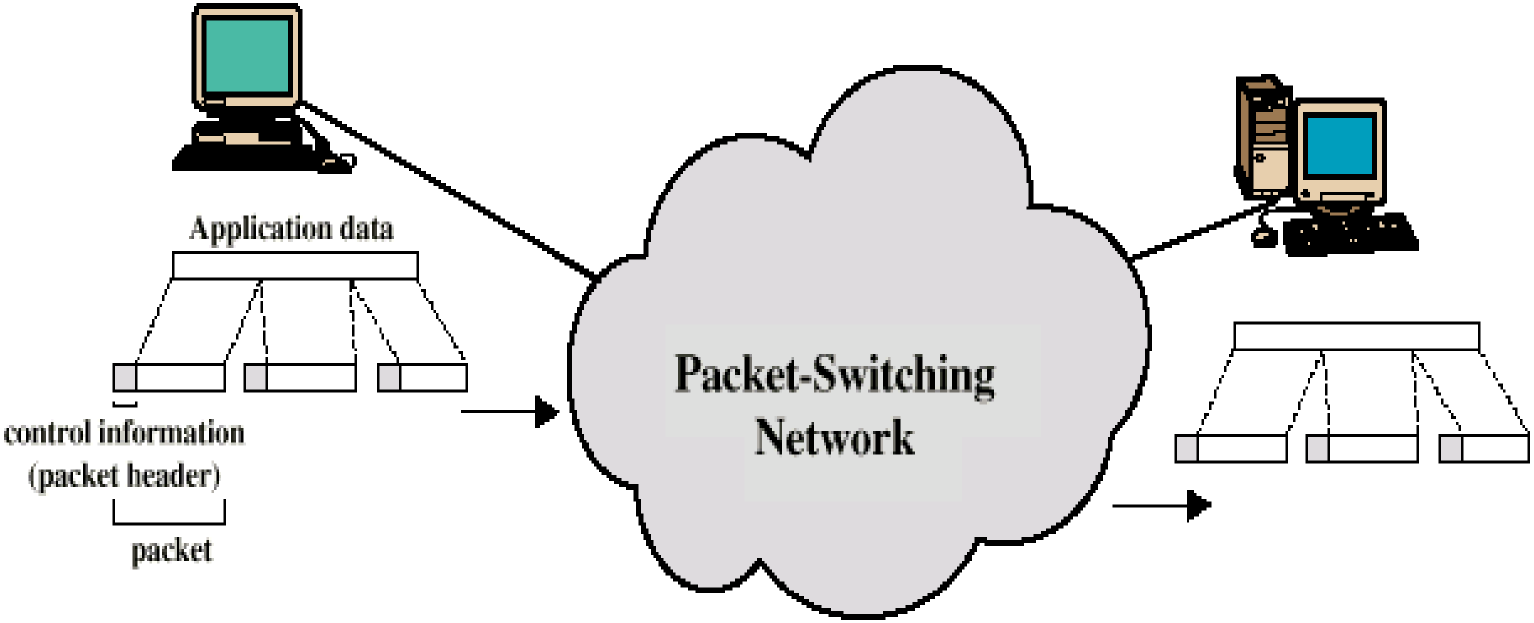
- Typically 1000 octets
- Longer messages split into series of packets
- Each packet contains a portion of user data plus some control info

Use of **Control info**

- Routing (addressing) info

Packets are received, stored briefly (buffered) and past on to the next node

- Store and forward



Advantages of packet switching

- Line efficiency
  - Single node to node link can be shared by many packets over time
  - Packets queued and transmitted as fast as possible
- Data rate conversion
  - Each station connects to the local node at its own speed
  - Nodes buffer data if required to equalize rates
- Packets are accepted even when network is busy
  - Delivery may slow down
- Priorities can be used

Packet Switching Technique

- Station breaks long message into packets
- Packets sent one at a time to the network
- Packets handled in two ways: **Datagram** or **Virtual circuit**

Virtual Circuits v Datagram

Virtual circuits

- Network can provide sequencing and error control
- Packets are forwarded more quickly
    - No routing decisions to make
- Less reliable
    - Loss of a node looses all circuits through that node

Datagram

- No call setup phase
    - Better if few packets
- More flexible
    - Routing can be used to avoid congested parts of the network
- Use of variant with acknowledgements

Routing

Complex, crucial aspect of packet switched networks

Characteristics required

- Correctness
- Simplicity
- Robustness
- Stability
- Fairness
- Optimality
- Efficiency

Performance Criteria

Used for selection of route

Minimum hop

Least cost algorithms (shortest path)

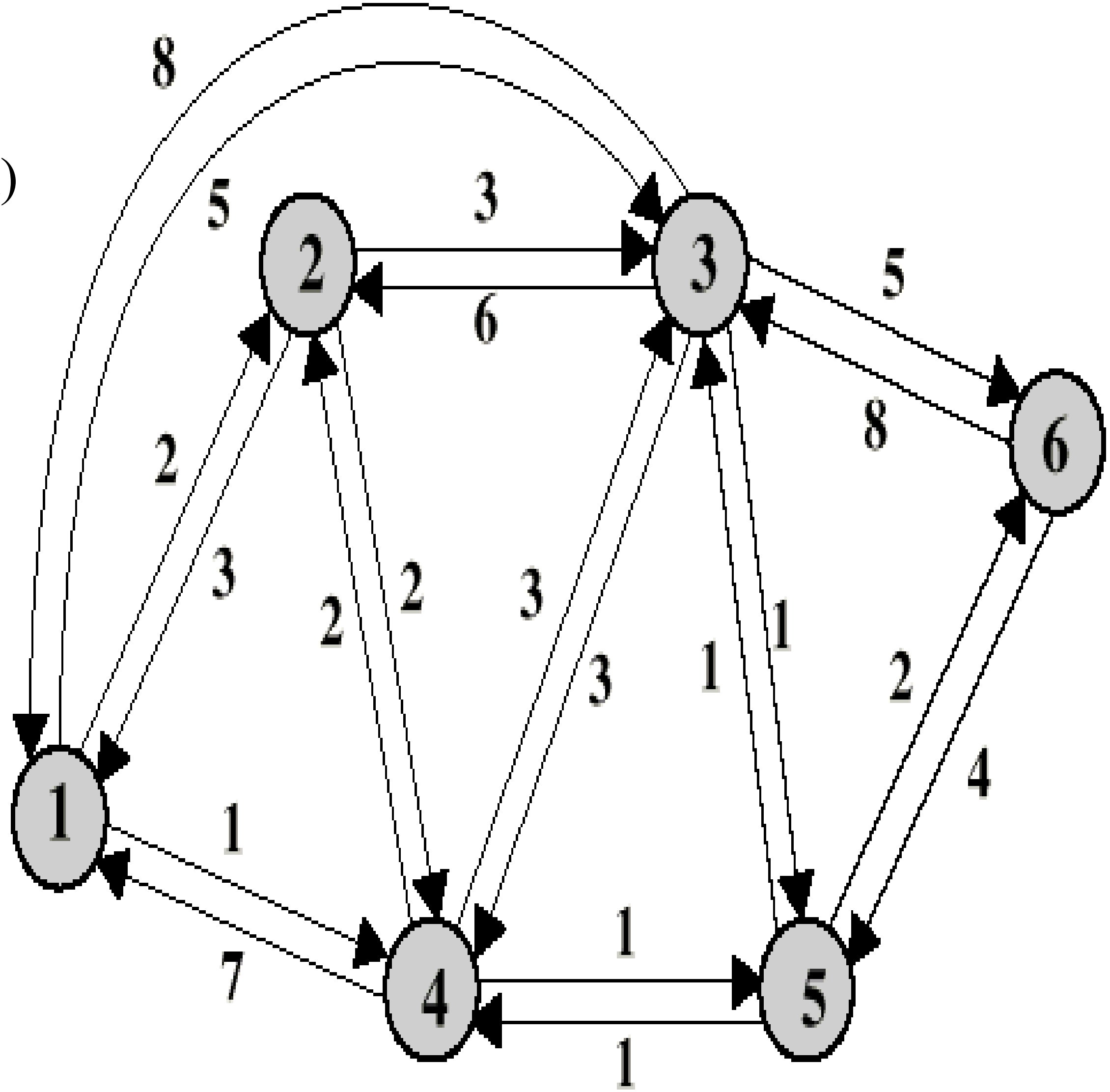
Dijkstra's Algorithm

Implemented in link state packet

routing algorithms

Bellman-Ford algorithm

Used by distance vector based



Routing: Decision Time and Place

Time

On packet or virtual circuit basis

Place

Distributed routing

Made by each node

Centralized routing

Source-based routing

Network Information Source and Update Timing

Routing decisions usually based on knowledge of network (not always)

Distributed routing

Nodes use local knowledge

May collect info from adjacent nodes

May collect info from all nodes on a potential route

Central routing

Collect info from all nodes

Update timing

When is network info held by nodes updated

Fixed - never updated

Adaptive - regular updates

Routing Strategies

Fixed

Flooding

Random

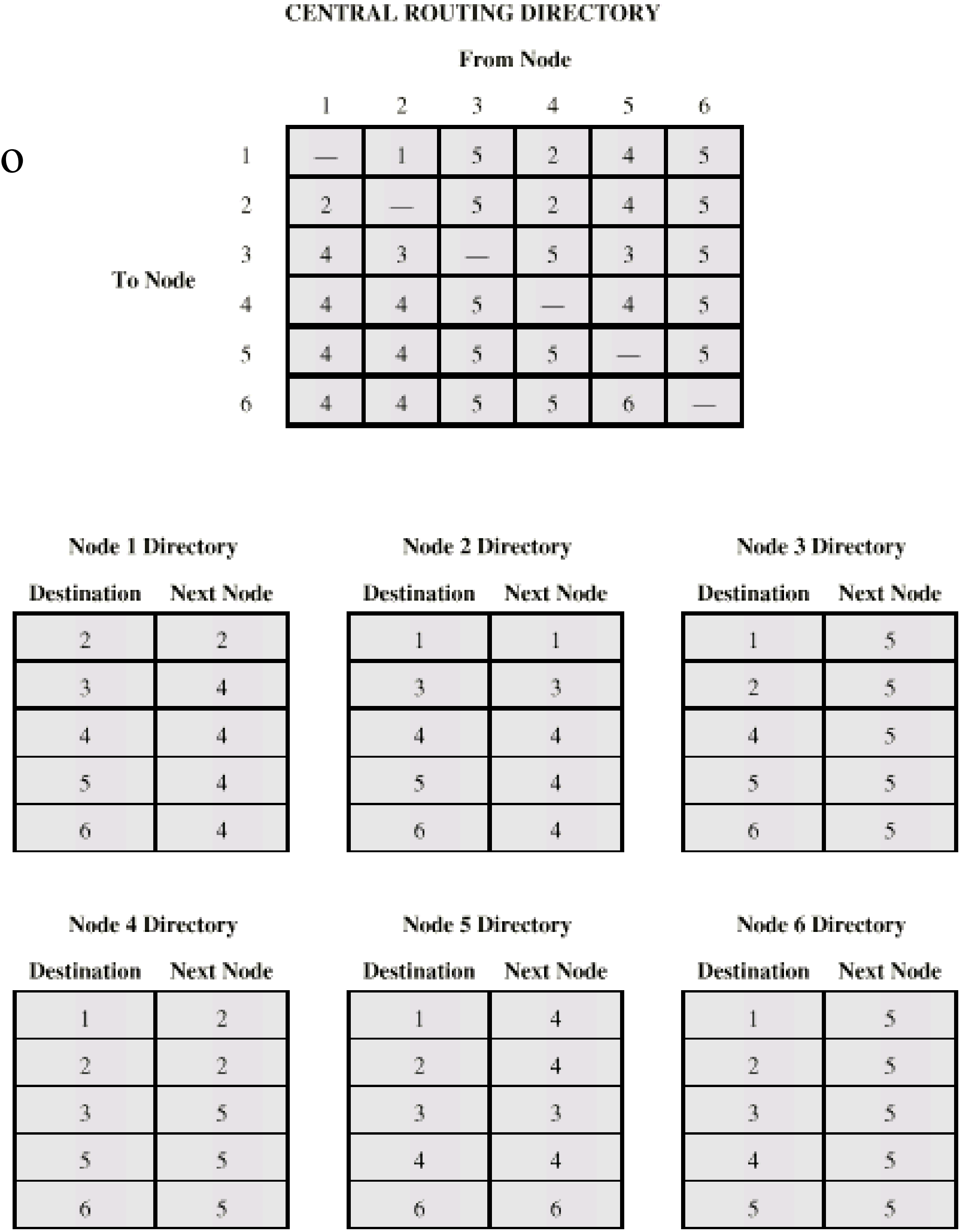
Adaptive

Fixed Routing

Single permanent route for each source to destination pair

Determine routes using a *least cost algorithm*

Route fixed, at least until a change in network topology



CENTRAL ROUTING DIRECTORY

		From Node					
		1	2	3	4	5	6
To Node	1	—	1	5	2	4	5
	2	2	—	5	2	4	5
	3	4	3	—	5	3	5
	4	4	4	5	—	4	5
	5	4	4	5	5	—	5
	6	4	4	5	5	6	—

Node 1 Directory

Destination	Next Node
2	2
3	4
4	4
5	4
6	4

Node 2 Directory

Destination	Next Node
1	1
3	3
4	4
5	4
6	4

Node 3 Directory

Destination	Next Node
1	5
2	5
4	5
5	5
6	5

Node 4 Directory

Destination	Next Node
1	2
2	2
3	5
5	5
6	5

Node 5 Directory

Destination	Next Node
1	4
2	4
3	3
4	4
6	6

Node 6 Directory

Destination	Next Node
1	5
2	5
3	5
4	5
5	5

Flooding

No network info required

Packet sent by node to every neighbor

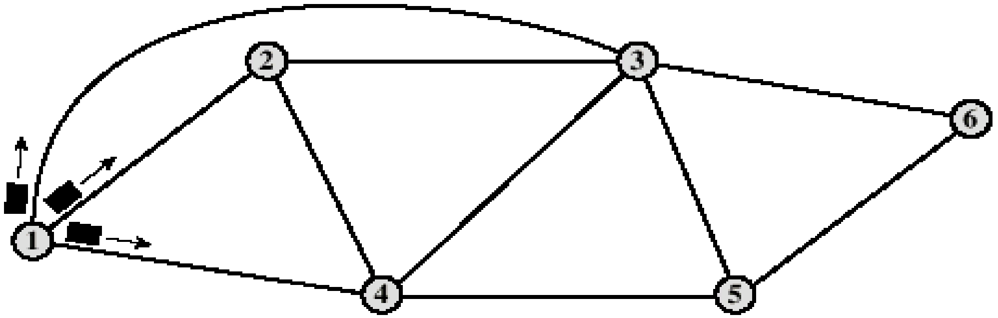
Incoming packets retransmitted on every link except incoming link

Eventually a number of copies will arrive at destination

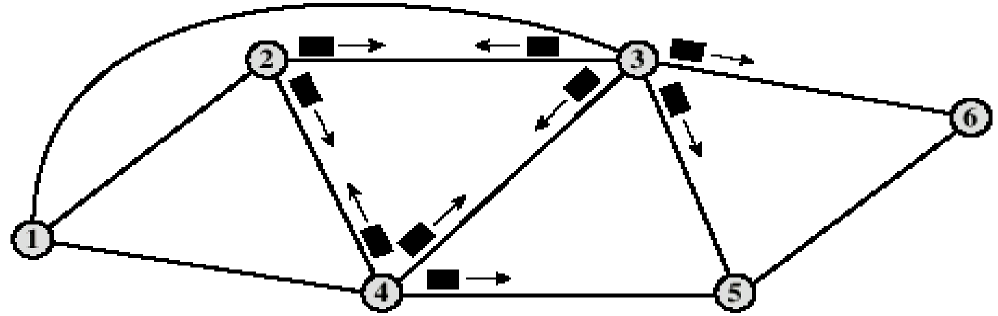
Each packet is uniquely numbered so duplicates can be discarded

Nodes can remember packets already forwarded to keep network load in bounds

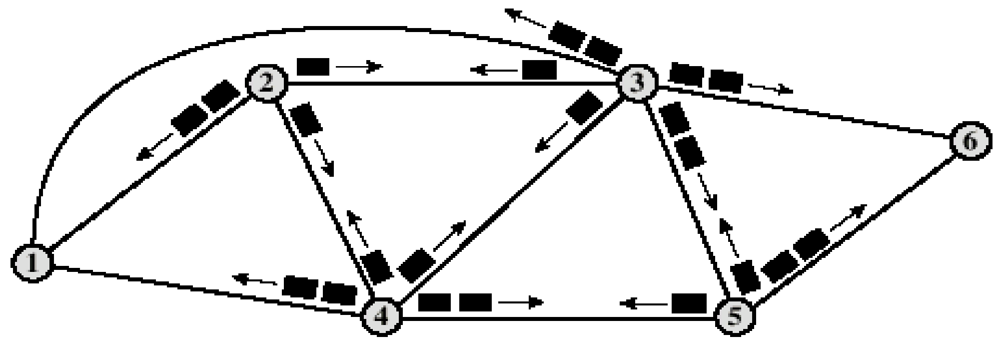
Can include a hop count in packets



(a) First hop

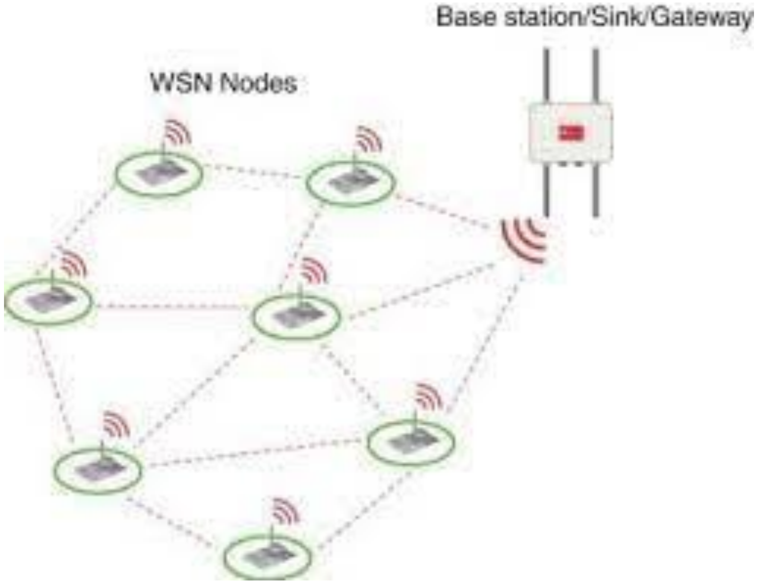


(b) Second hop



(c) Third hop

Properties of Flooding



All possible routes are tried

- Very robust

At least one packet will have taken minimum hop count route

- Can be used to set up virtual circuit

All nodes are visited

- Useful to distribute information (e.g. routing)

Random Routing

Node selects one outgoing path for retransmission of incoming packet

Selection can be random or round robin

Can select outgoing path based on probability calculation

No network info needed

Route is typically not least cost nor minimum hop

Adaptive Routing

Used by almost all packet switching networks

Routing decisions change as conditions on the network change

- Failure
- Congestion

Requires info about network

Decisions more complex

Tradeoff between quality of network info and overhead

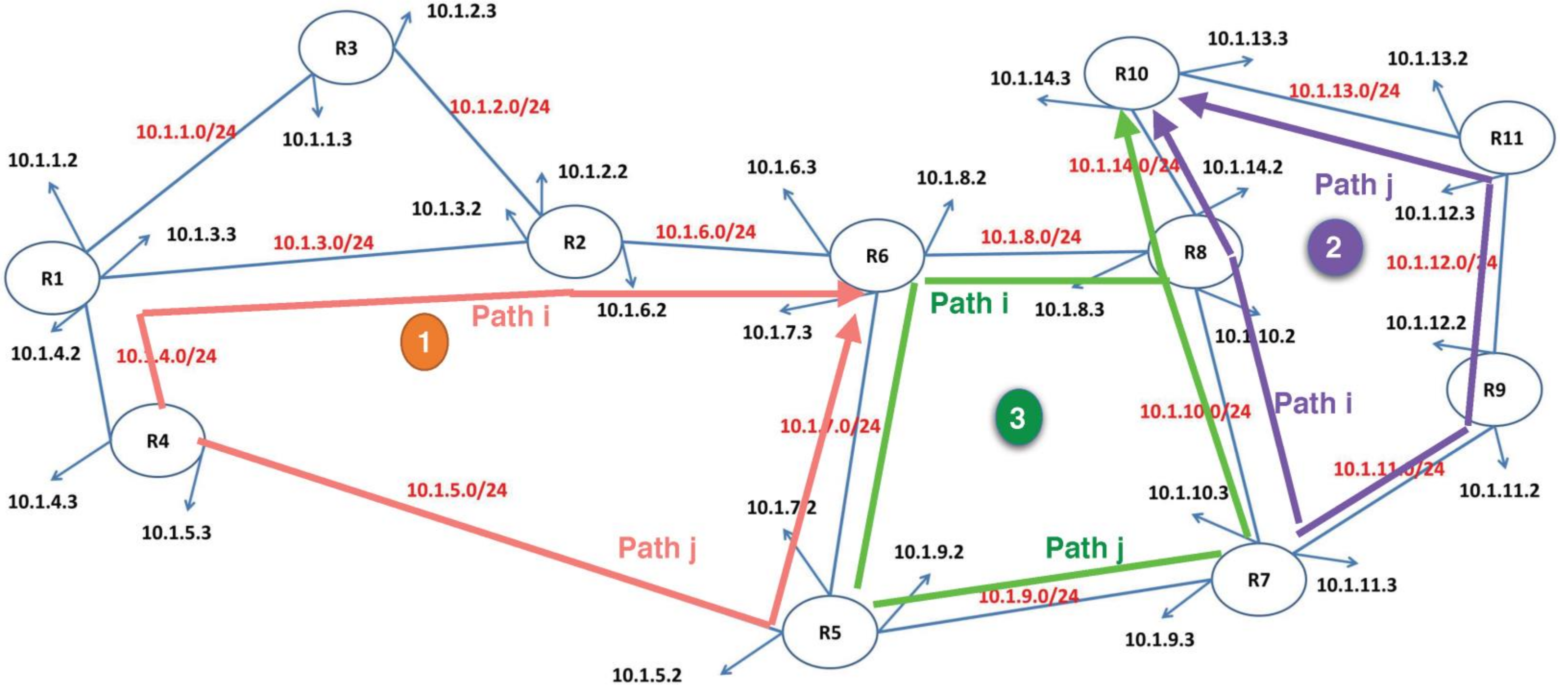
Advantages

Improved performance

Aid congestion control

Complex system

- May not realize theoretical benefits



Classification

Based on information sources for network state

- **Local** (isolated)
  - Route to outgoing link with shortest queue
  - Can include bias for each destination
  - Rarely used - do not make use of easily available info
- **Adjacent** nodes – select information based on the neighbour's experience (network delays or outages)
- **All** nodes – used for source based routing

Access to Data & Computer Networks – Physical Level

- **Terminology**
- **Serial Interface**
- **Cable Modems**
- **DSL technologies**

ISP (Internet Service Provider)

- An Internet service provider company that provides other companies or individuals with access to, or presence on, the Internet
- Individual hosts and LANs are connected to an (ISP) through a point of presence (POP).

POP (Point of Presence)

- An Internet access provider may operate several POPs distributed throughout its area of operation and represents a collection of telecommunications equipment

CPE (Customer Premises Equipment)

- is the communications equipment located onsite with the host (example: modem)

Local loop" or "last mile

- the infrastructure between a provider's installation and the site where the host is Located

NAP (Network Access Point)

- a physical facility that provides the infrastructure to move data between connected networks; serve to tie the ISPs together; ISP also connect using peering arrangements and interconnections within geographic regions

CO (Central Office)

- the place where telephone companies terminate customer lines and locate switching equipment to interconnect those lines with other networks

Common connections for SOHO (small office home office) LANs

Cable - offered by cable television service providers, where data signal is carried on television cable;

- high bandwidth, always on connection

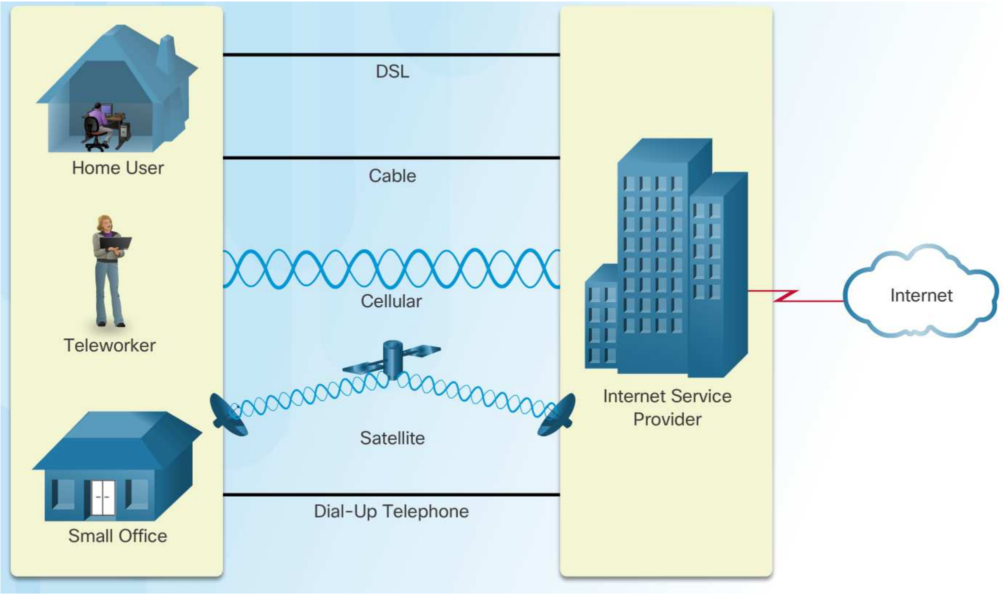
DSL – on telephone lines (usually ADSL)

- high bandwidth, always on connection

Cellular - using cell phone network; performance limited by phone and cell tower the capabilities.

Satellite – using satellite dishes
- requires a clear line of sight to the satellite.

Dial-up Telephone - inexpensive option using phone line and modems.
- low bandwidth not recommended for large data transfer.



Cisco CCNA1

Serial Interface

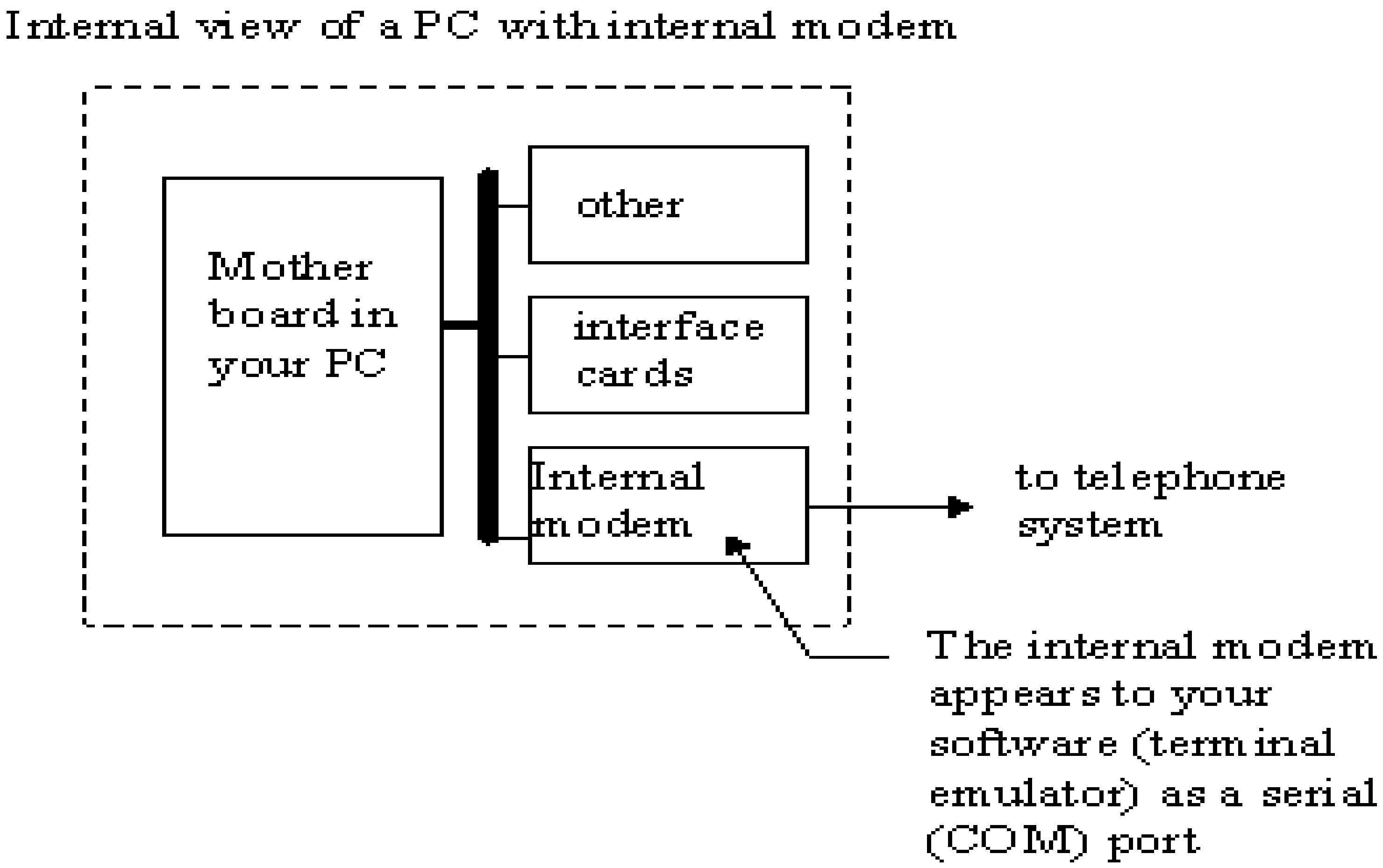
Serial Transmission – all bits (of an octet) are transmitted (received) on a single line
Parallel Transmission – each bit (of an octet) uses a line

Data processing devices (or Data Terminal Equipment, **DTE**, like computers, terminals, printers) do not (usually) include data transmission facilities, are stand alone equipment.
Need for an interface, called Data Circuit terminating Equipment (**DCE,** e.g. modem, NIC –Network Interface Card)

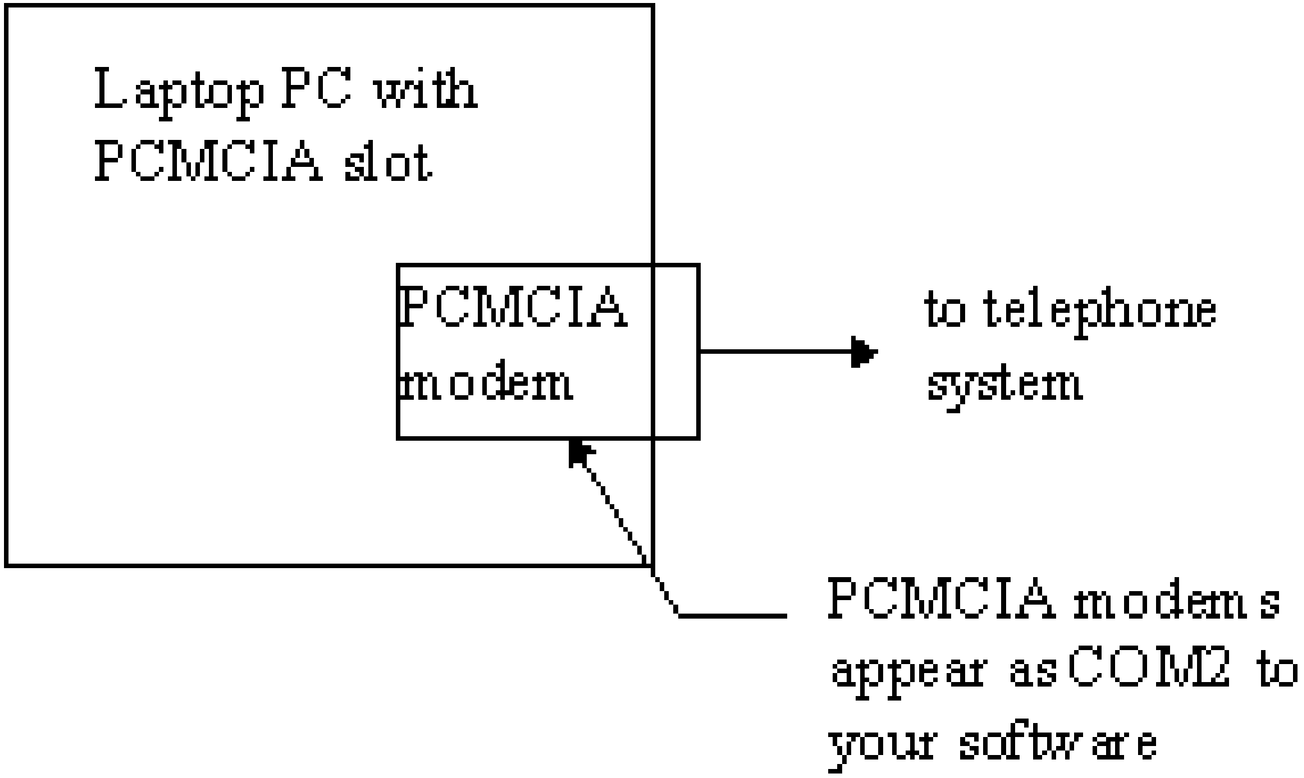
First data transmissions used the telephonic system, a normal phone and a modem, so a **dial-up line** (line established by circuit switching); takes time, unsafe =>
Use of **leased lines**, but are expensive!

Digital telephony – all signals and equipment are digital => big digital telecommunication networks, with high speed and great reliability
Still remains (yet) analog the **local loop**, connecting the subscriber to Telecom office
All DTEs use for connecting to telephone line (either analog or digital) the **serial interface**, so for the PCs the COM ports will be used.

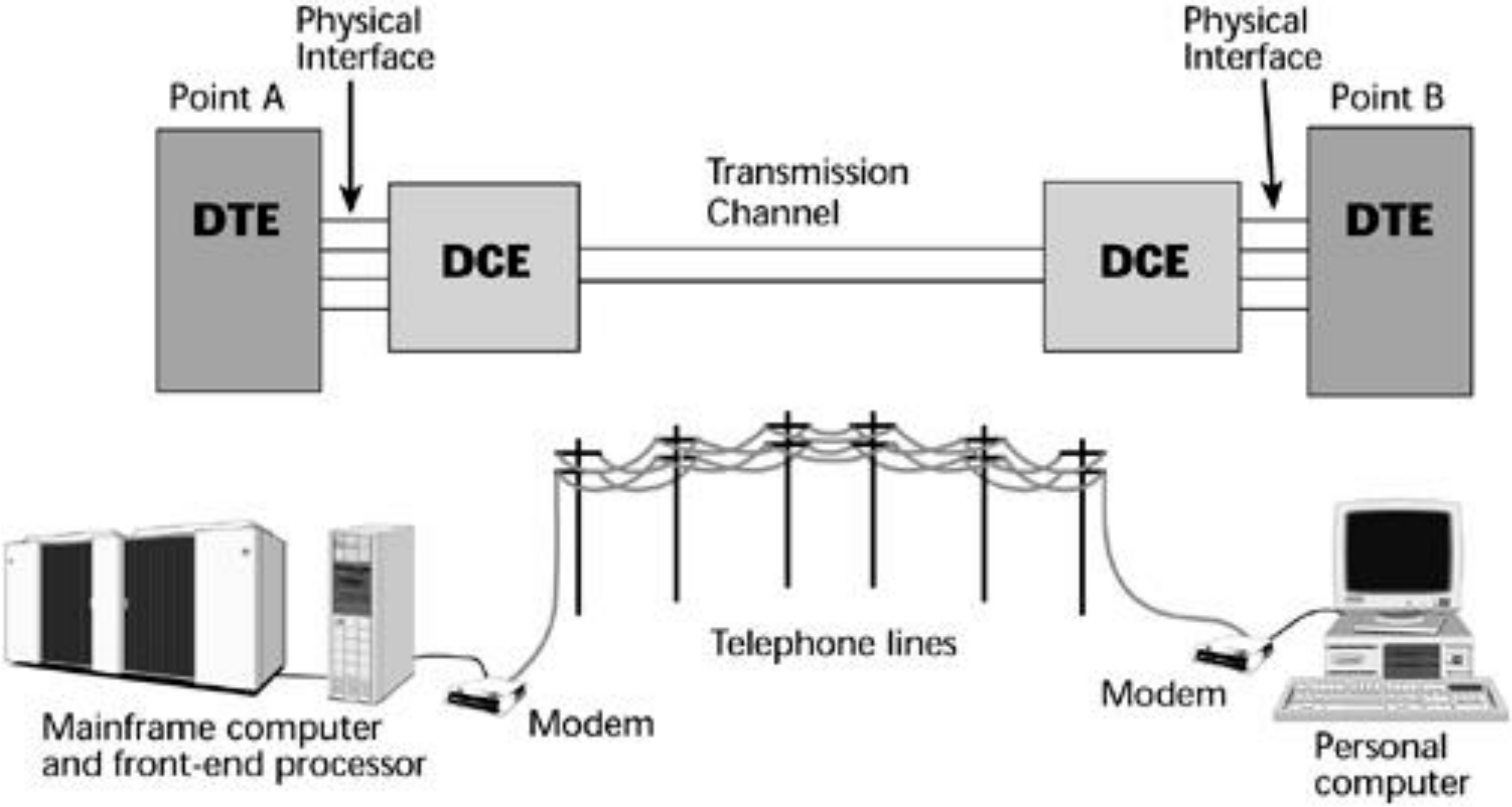
For PCs the modem may be external or internal, today's internal.



For your Laptop with interface adapter PCMCIA slot:



- In OSI terminology, communications interface act where data processing terminals (computers, hosts, terminals, printers) connect to the transmission system, i.e. where is the ‘end system to the network’ (data-circuit terminating equipment).
- Communications interface contains : DTE, DCE & interchange circuits.



Physical layer protocols describe this interface, in many aspects:

-electrical (voltages, currents, encoding techniques)

-electromechanical (connectors, pins location)

-functional (what circuits belongs to what pins & what signals on them mean: data, control, timing, grounding)

-procedural aspects (sequence of events, ex.: protocol of using the standard for answering calls…)

Physical aspects of connecting a DTE to a DCE – object of many standards:

EIA RS 232 (RS 232-D, from 1986, now RS 232-E, from 1991)

equivalent to ITU-T/CCITT V.24; V28 & ISO 2110

RS-449, followed by RS-530

Useful link for all kind of serial interfaces: www.arcelect.com

RS232 Serial Interface

Basics

-initial variant 232C, followed by D & E variants, improving performances and maintaining compatibility

-governs interface of DTE (computer) to DCE (modem)

-serial connection, up to 20kbaud over 15-16 m maximum (RS232C); further, data speed improved to 50kbps (versions D & E)

-originally developed for dumb terminals to modems

-good noise immunity

-handshaking not used consistently

-very cheap, single asynchronous chip

-unbalanced interface for control & data (common reference ground)

-wiring isn't set up to connect two DTEs together => use of null modem to cross several wires

-initial asynchronous, now providing synchronous capabilities

Electrical Specifications

Logic data representation by voltage transitions of min. 6V (both for data and control)

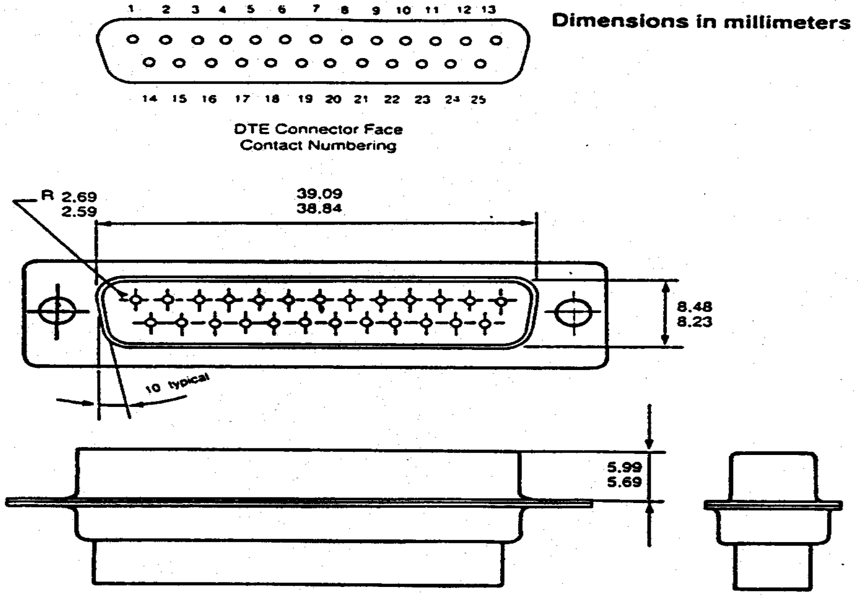
off = 0 (+3 to +15V) **on = 1 (-3 to –15V)**

Mechanical Specifications

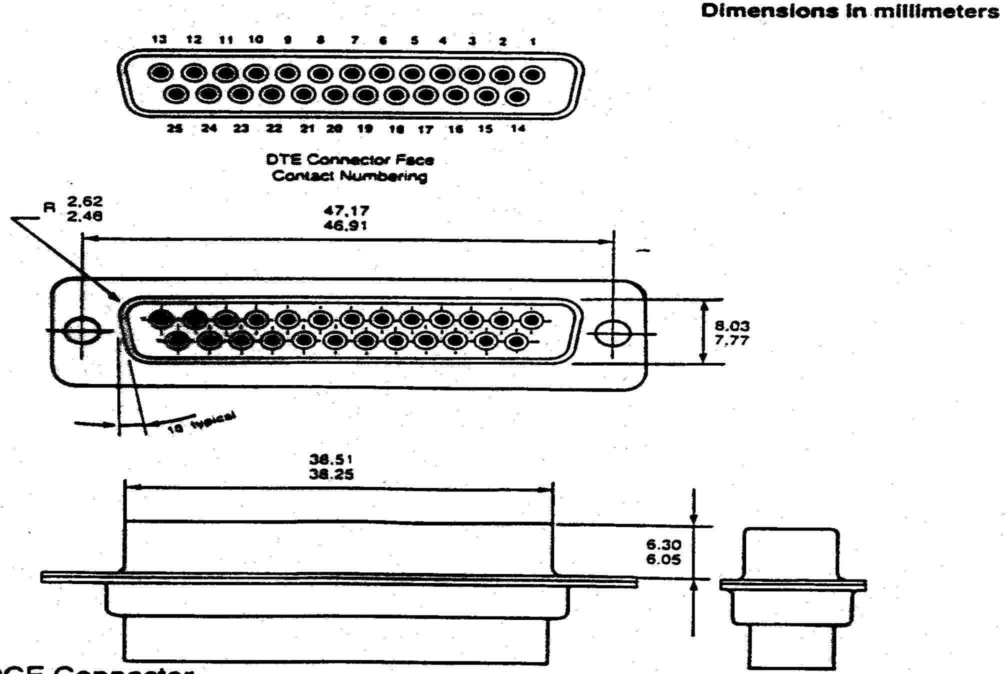
-connector male/female with 25 pins, ‘D’ shape, one 12 pins row, other with 13pins

-male connector on DTE, female connector on DCE

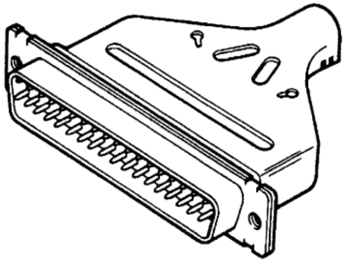
-mechanical specifications include: total connector’s width, distance between successive pins, between pins rows, etc.

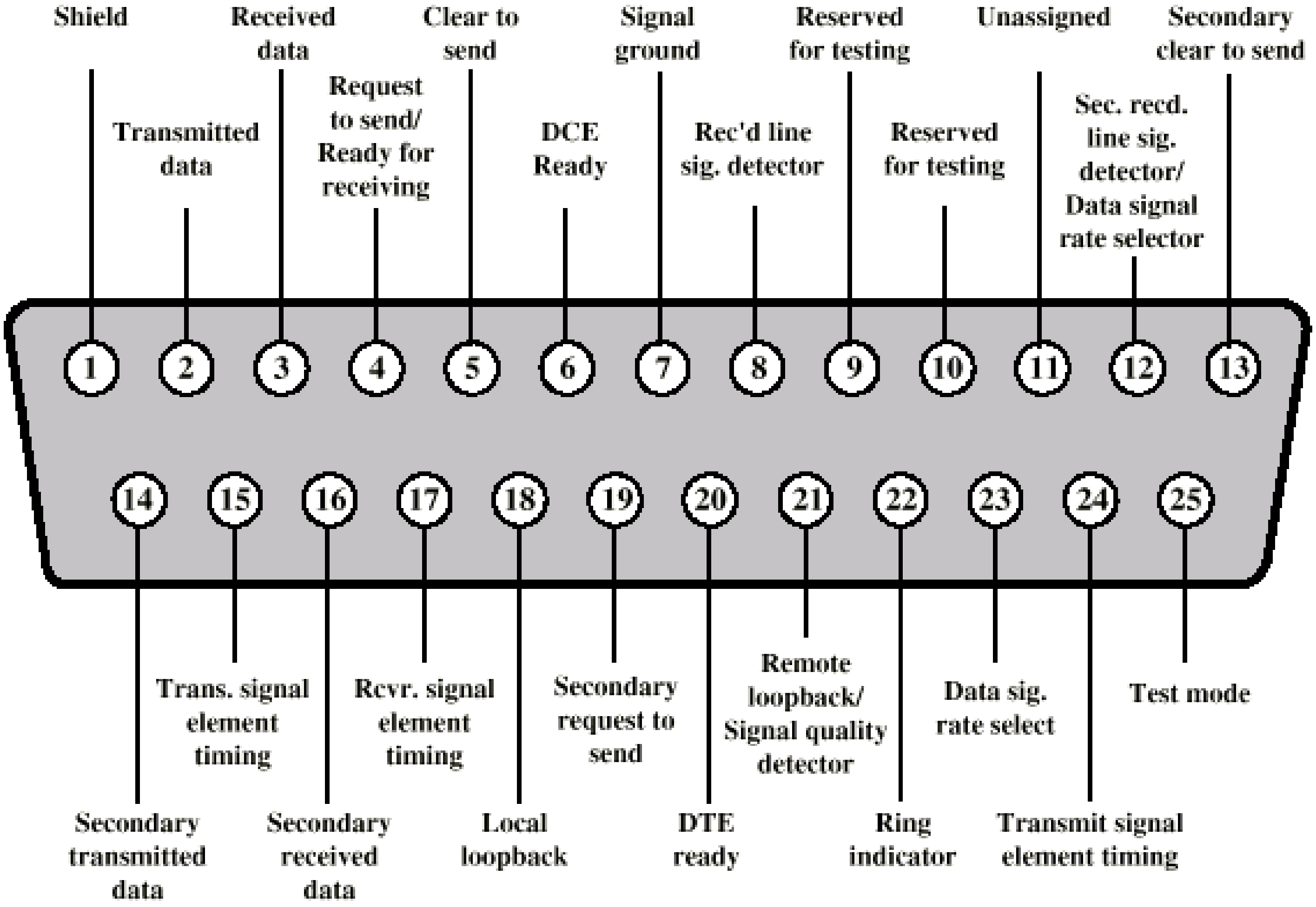


DTE Connector

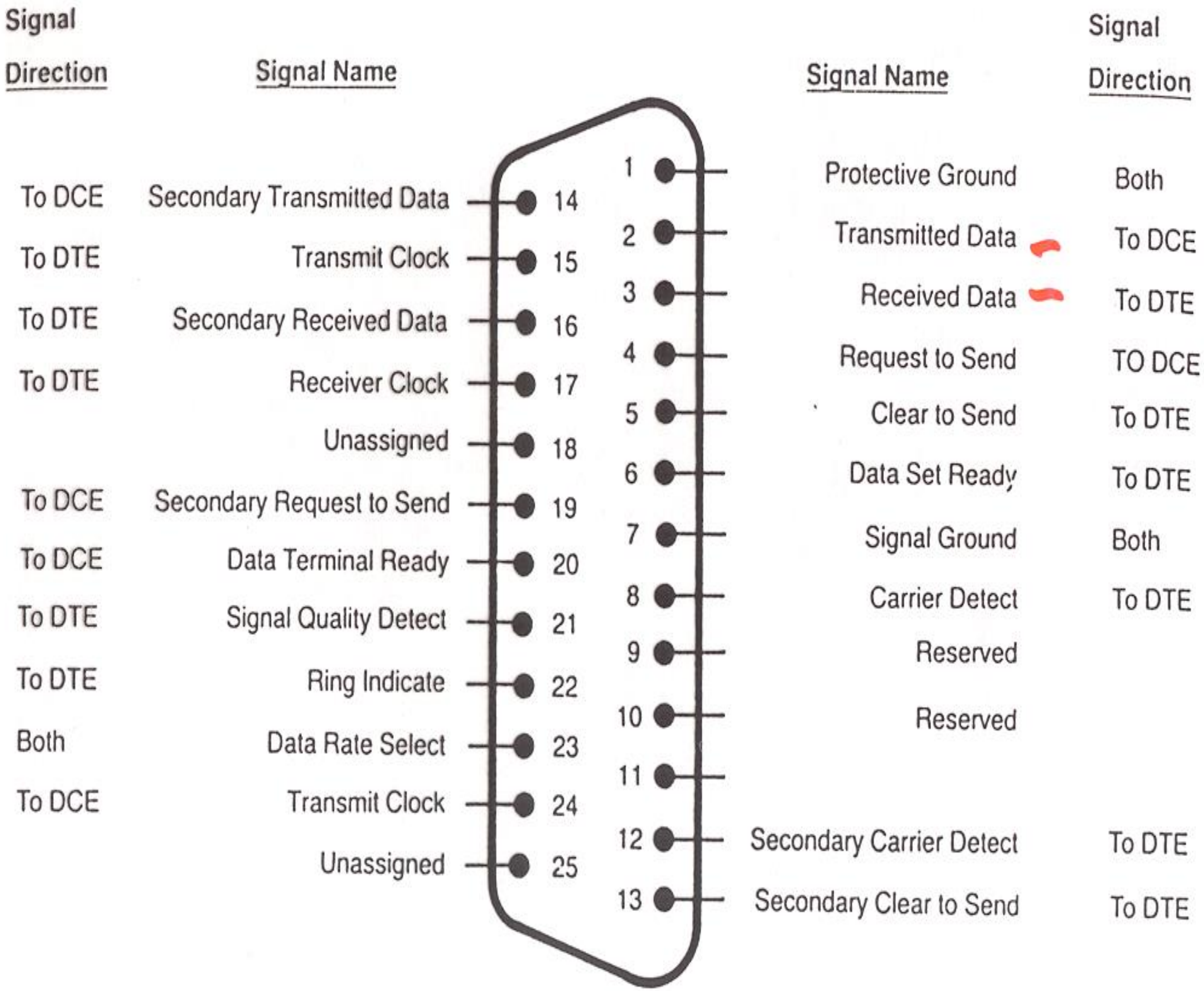


DCE Connector





Pin Assignments for V.24/EIA-232 (DTE Connector Face)



Signal Direction	Signal Name	
To DCE	Secondary Transmitted Data	14
To DTE	Transmit Clock	15
To DTE	Secondary Received Data	16
To DTE	Receiver Clock	17
	Unassigned	18
To DCE	Secondary Request to Send	19
To DCE	Data Terminal Ready	20
To DTE	Signal Quality Detect	21
To DTE	Ring Indicate	22
Both	Data Rate Select	23
To DCE	Transmit Clock	24
	Unassigned	25

	Signal Name	Signal Direction
1	Protective Ground	Both
2	Transmitted Data	To DCE
3	Received Data	To DTE
4	Request to Send	TO DCE
5	Clear to Send	To DTE
6	Data Set Ready	To DTE
7	Signal Ground	Both
8	Carrier Detect	To DTE
9	Reserved	
10	Reserved	
11		
12	Secondary Carrier Detect	To DTE
13	Secondary Clear to Send	To DTE

Functional Specifications

Functional Specifications

Define which circuits connect to each of the 25 pins (see previous slide)

9 typically used pins:

20: *Data Terminal Ready* (DTE to DCE): tells that DTE is powered up and ready
6: *Data Set Ready* (DCE to DTE): tells DTE that DCE is powered up and ready
8: *Carrier Detect* (DCE to DTE): tells DTE that it detects a carrier on the line
4: *Request to Send* (DTE to DCE): tells DCE it wants to send data (usually for half duplex)
5: *Clear to Send* (DCE to DTE): tells DTE that it can accept data, usually for half duplex
2: *Transmit* (DTE to DCE): sends data to DCE for it to transmit
3: *Receive* (DCE to DTE): sends received data to DTE
1: *Protective ground* (for safety)
7: *Signal Ground/Common Return* (reference voltage for detecting signal levels)

Some PCs use 9 pins connectors; pin assignment is shown in the following table.

Procedural Specifications

Gives the communication rules or how's the understanding between DTE – DCE, and between pairs.
Sample example: an asynchronous private line modem:

When turned-on and ready, modem (DCE) asserts *Data Set Ready*

When DTE ready to send data, it asserts *Request to Send*

Also inhibits receive mode in half duplex

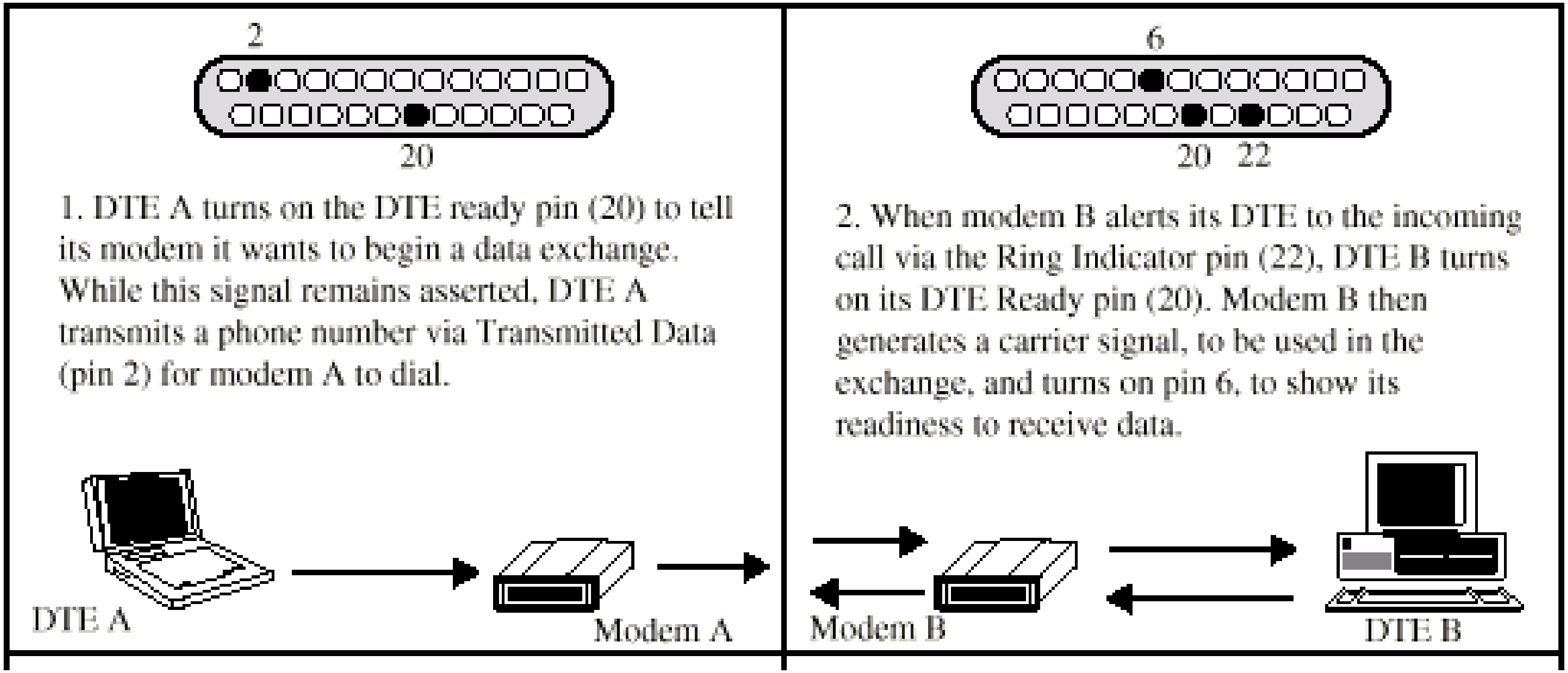
Modem responds when ready by asserting *Clear to Send*

DTE sends data

When data arrives, local modem asserts *Receive* Line Signal Detector and delivers data

9 pin	**Signal**	**25 pins**
1	Carrier Detect	8
2	Received Data	3
3	Transmitted Data	2
4	Data Terminal Ready	20
5	Signal Ground	7
6	Data Set Ready	6
7	Request To Send	4
8	Clear To Send	5
9	Ring Indicator	22

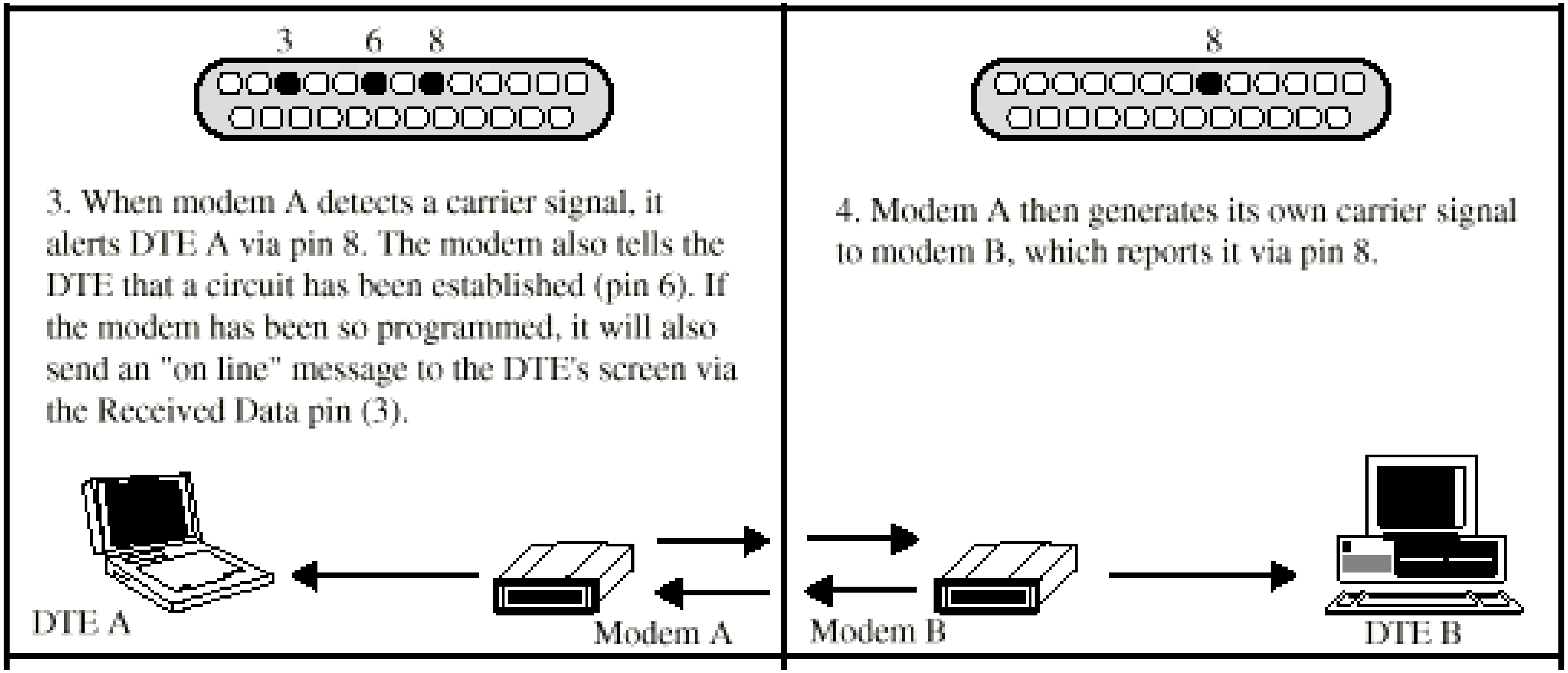
Dial Up Operation



1. DTE A turns on the DTE ready pin (20) to tell its modem it wants to begin a data exchange. While this signal remains asserted, DTE A transmits a phone number via Transmitted Data (pin 2) for modem A to dial.

2. When modem B alerts its DTE to the incoming call via the Ring Indicator pin (22), DTE B turns on its DTE Ready pin (20). Modem B then generates a carrier signal, to be used in the exchange, and turns on pin 6, to show its readiness to receive data.

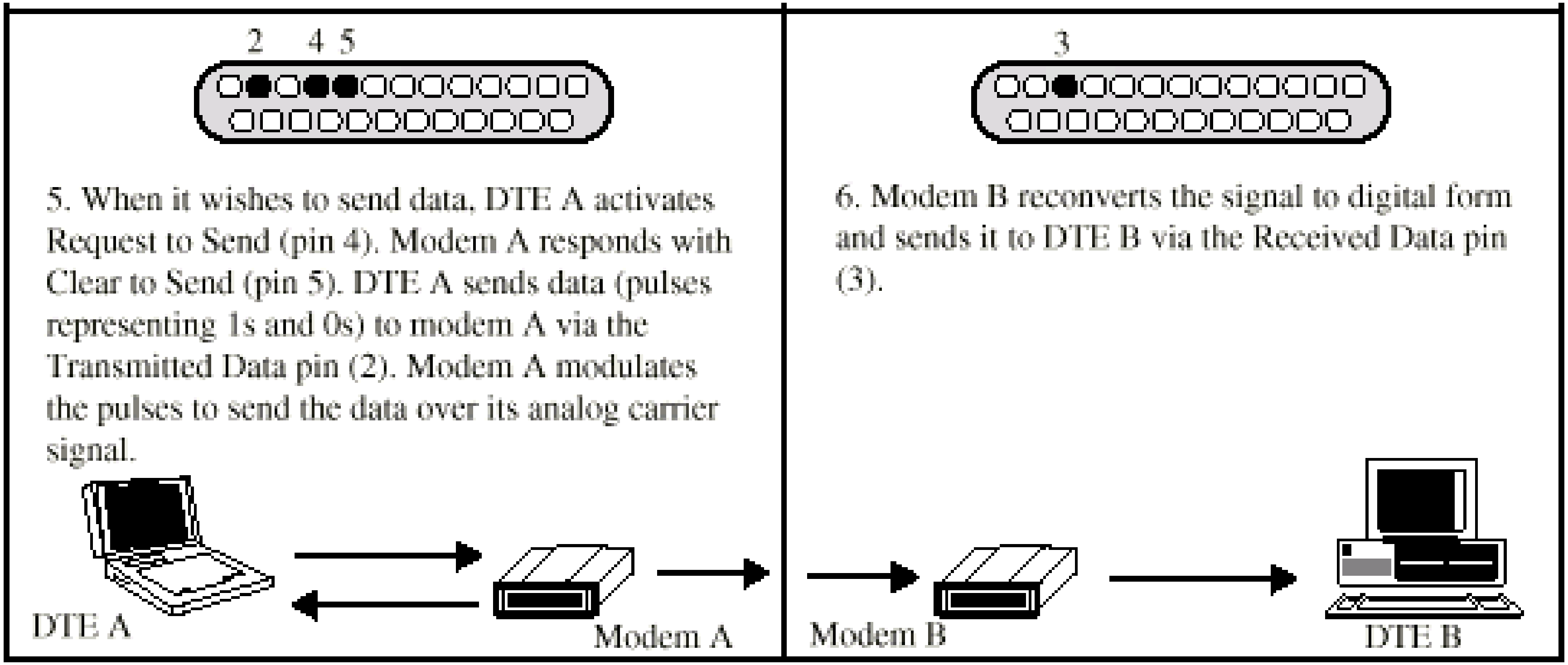
Dial Up Operation – cont.



3. When modem A detects a carrier signal, it alerts DTE A via pin 8. The modem also tells the DTE that a circuit has been established (pin 6). If the modem has been so programmed, it will also send an "on line" message to the DTE's screen via the Received Data pin (3).

4. Modem A then generates its own carrier signal to modem B, which reports it via pin 8.

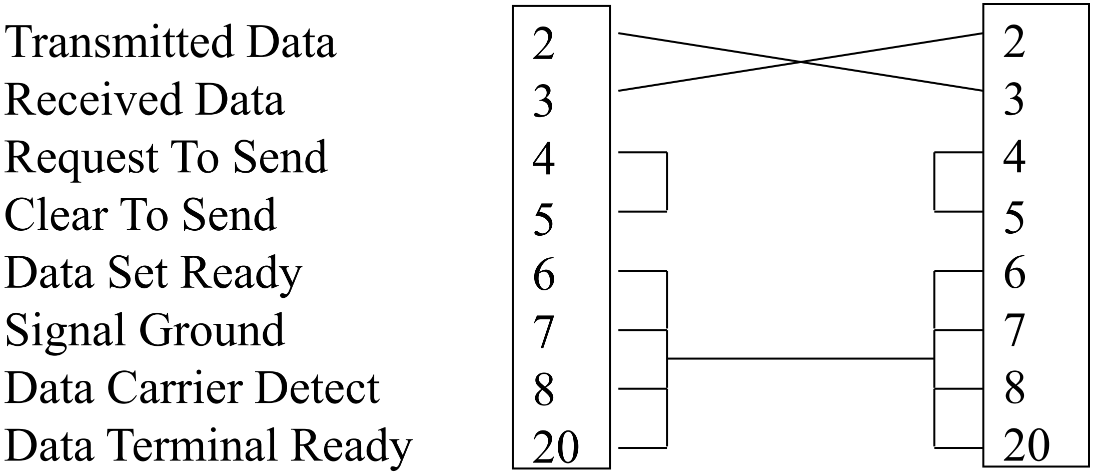
Dial Up Operation –cont.



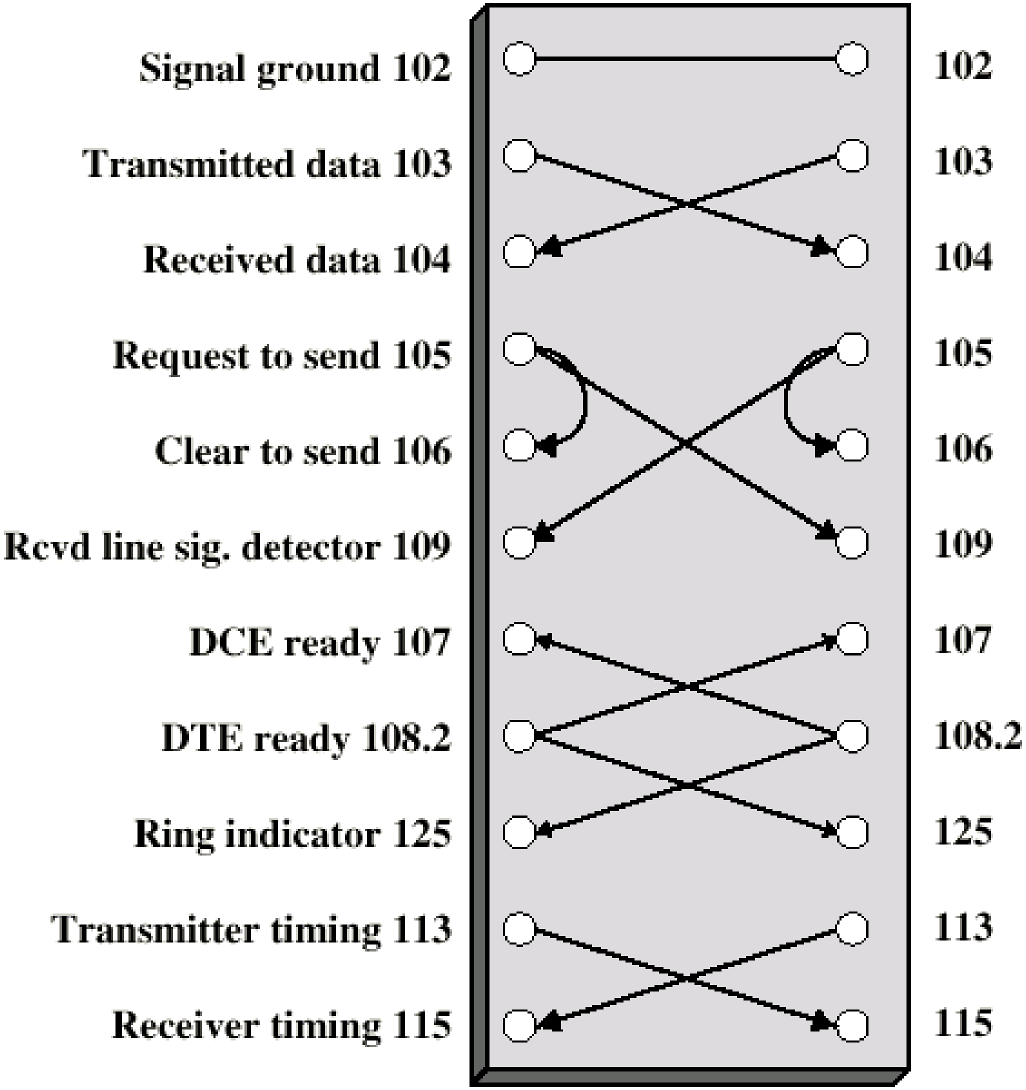
5. When it wishes to send data, DTE A activates Request to Send (pin 4). Modem A responds with Clear to Send (pin 5). DTE A sends data (pulses representing 1s and 0s) to modem A via the Transmitted Data pin (2). Modem A modulates the pulses to send the data over its analog carrier signal.

6. Modem B reconverts the signal to digital form and sends it to DTE B via the Received Data pin (3).

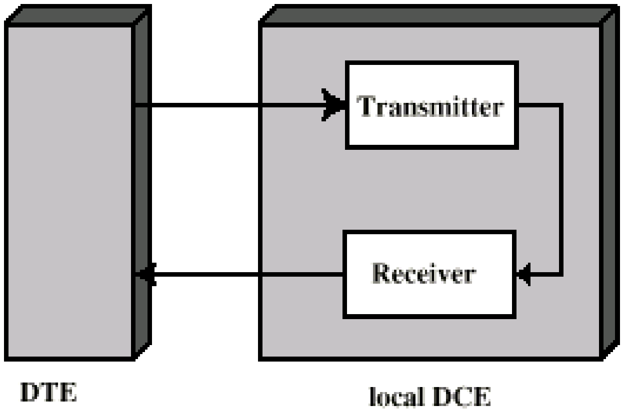
The wiring isn't set up to connect two DTEs together => use of **null modem** to cross several wires. Simplest case, the 3 wires short cable null modem, with the following architecture:



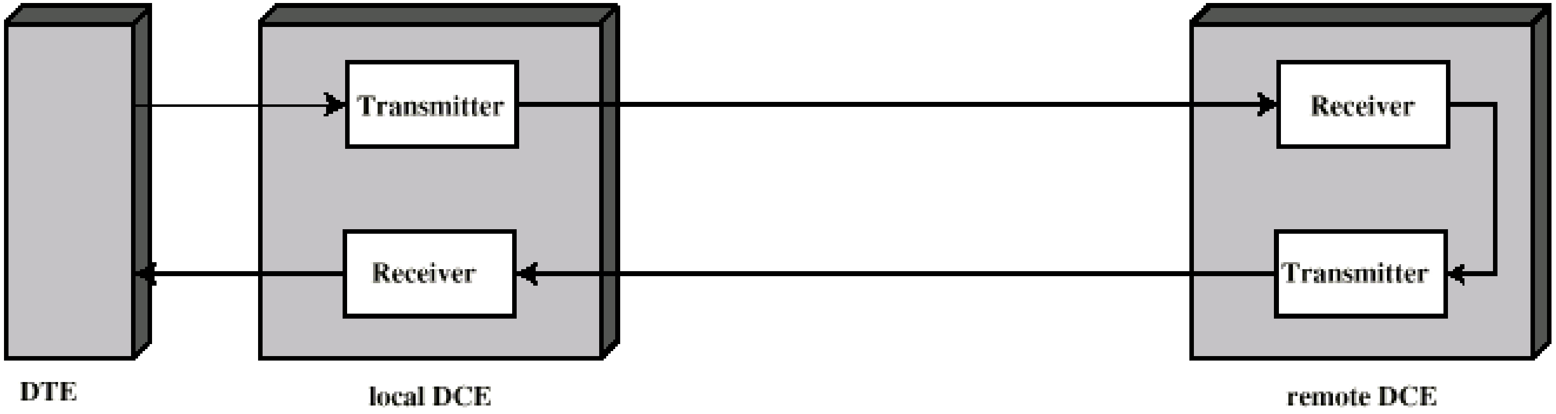
Other example of null modem, with more wires, same effect!



For testing the serial interface (COM port), two simple tests:



(a) Local loopback Testing



(b) Remote loopback Testing

RS 449 Standard

Dates from ’80s, improving the RS-232 standard, overcoming the defects.

Offers backward compatibility – very important, due to RS-232 huge usage => RS-232 can be emulated by changing various connections.

Consists in fact of three standards:

Basic RS-449, giving mechanical, functional & procedural interfaces

Electric interface given by two standards:

RS-423A, similar with RS-232, using **unbalanced** transmission (an unique return path for all signals)

RS-422A, assigns to each signal its own grounding (or, other, for each signal is provided individual return path, isolated from other grounds); so defines a **balanced** transmission.

Gives greater DTE control over DCE, but still not exist autodialing.

Mechanical connectors: 37 pins + an additional 9 pins, if secondary channel used.

Provides synchronous & asynchronous transmissions

Offers 10Mbps for a distance of max. 12m, and 100kbps for hundreds of meters, when using RS-422A, and 3kbps @ 100m or 30kbps @ 10m length, for RS-423A.

Circuit description follows; remark that there are new circuits, like those used for testing!

Future developments: **RS-530**, using balanced transmission, speed up to 2Mbps.

Mnemonics	**Circuit Description**	**Mnemonics**	**Circuit Description**
SG	Signal Ground	SC	Send Common
RC	Receive Common	IS	Terminal in Service
IC	Incoming Call	TR	Terminal Ready
DM	Data Mode	SD	Send Data
RD	Receive Data	TT	Terminal Timing
ST	Send Timing	RT	Receive Timing
RS	Request to Send	CS	Clear to Send
RR	Receiver Ready	SQ	Signal Quality
NS	New Signal	SF	Select Frequency
SR	Signaling Rate Selector	SI	Signaling Rate Indicator
SSD	Secondary Send Data	SRD	Secondary Receive Data
SRS	Secondary Request to Send	SCS	Secondary Clear to Send
SRR	Secondary Receiver Ready	LL	Local Loopback
RL	Remote Loopback	TM	Test Mode
SS	Select Standby	SB	Standby Indicator

X21 Digital interface

CCITT standard for direct digital connections to the digital telephone network.

Uses only 8 signal lines, on a 15 pin connector, allowing use of 2 channels (A, B)

Data rate fro 9600bps up to 64kbps

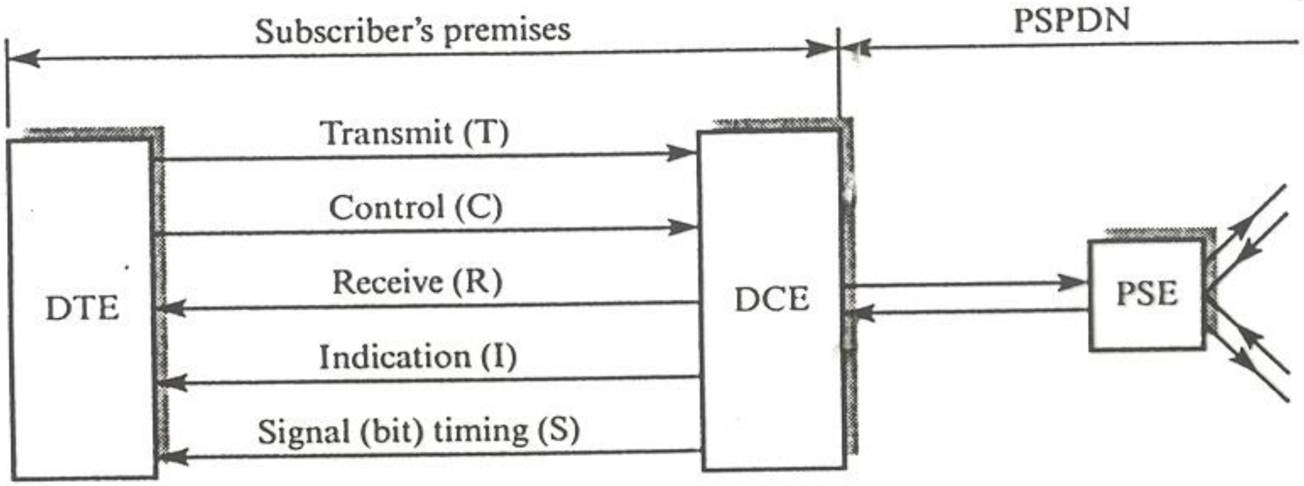
Use of more logic, instead of more signals (RS-449)

Allows bit and byte synchronization

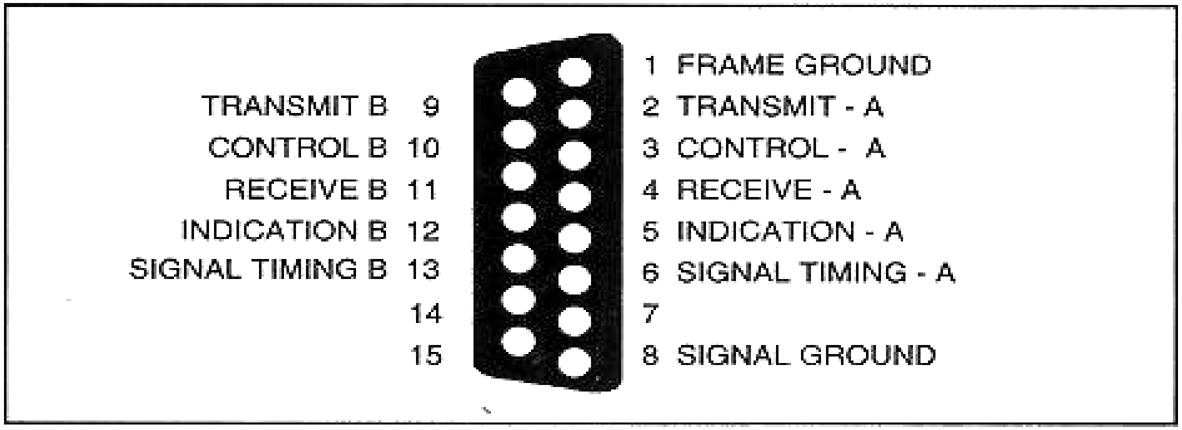
X21bis standard allows analog signalling (is a subset of RS-232D), developed for backward compatibility (use of analog telephone networks)

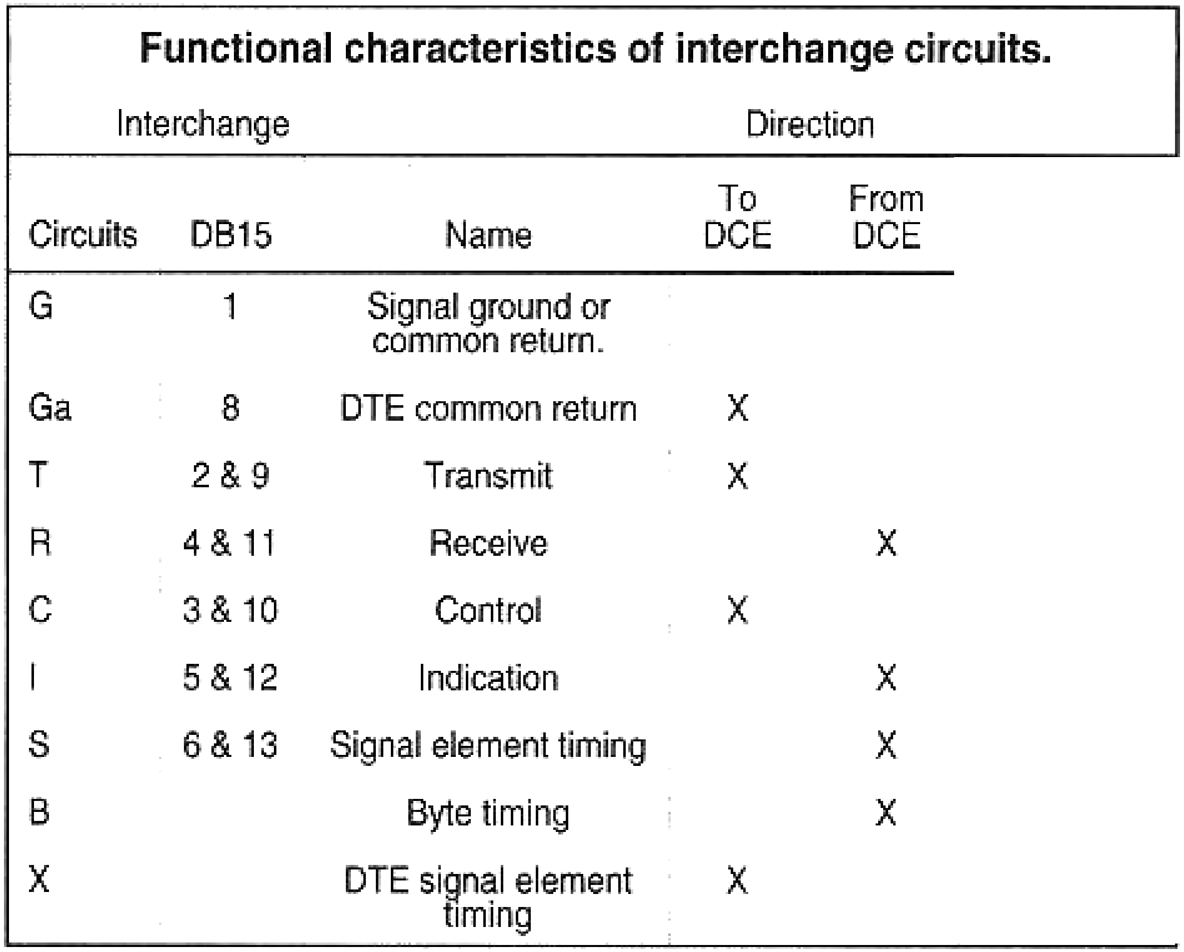
DCE provides a full-duplex, bit-serial, synchronous transmission path between the DTE and the local PSE.

Trend continued with 8-pins physical connector for **ISDN** (Integrated Services Digital Network)



Pin assignment and functional characteristics:





Functional characteristics of interchange circuits.

Interchange			Direction	
Circuits	DB15	Name	To DCE	From DCE
G	1	Signal ground or common return.		
Ga	8	DTE common return	X	
T	2 & 9	Transmit	X	
R	4 & 11	Receive		X
C	3 & 10	Control	X	
I	5 & 12	Indication		X
S	6 & 13	Signal element timing		X
B		Byte timing		X
X		DTE signal element timing	X	

Signal Specification

Signal Ground (G): protective ground (earth).

DTE Common Return (Guard) – for the unbalanced mode, gives reference ground for receivers in the DCE interface

Transmit (T) - carry data and control from the DTE to the DCE

Receive (R) - from DCE, indicates to the DTE the type of data

Indication (I) –controlled by DTE, indicates to the DCE the meaning of the data sent on the transmit circuit

Byte Timing (B) - provides the DTE with 8-bit byte element timing

Signal Element Timing (S) - provides the DTE or DCE with timing information for sampling the Receive line or Transmit line

Control line (C) – to DCE circuit, for extra control of DTE over DCE.

ISDN Physical Interface

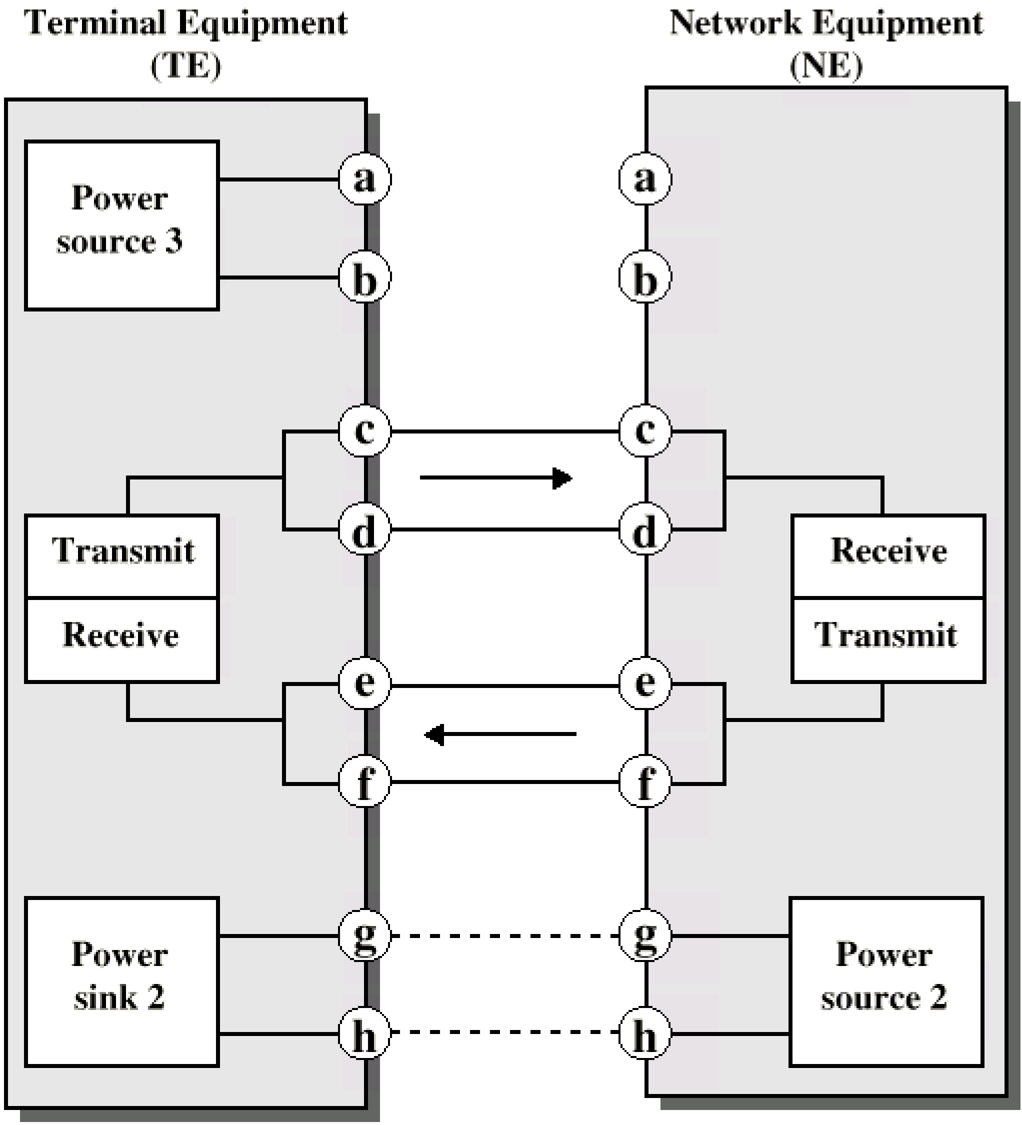
Further evolution of X21 was the specification of the ISDN physical connection

Connection between **terminal equipment** TE (c.f. DTE) and **network terminating equipment** NE (c.f. DCE)

ISO 8877

Cables terminate in matching connectors with 8 contacts

Transmit/receive lines carry both data and control



ISDN Electrical Specification

Balanced transmission

- Signals carried on a channel made by two conductors, e.g. twisted pair
- Signals (as currents) travel down one conductor and up the other (return way)
- Differential signaling, as binary value depends on the voltage difference between lines (value depends on direction of voltage); usual differences under 1V => low power circuitry
- Tolerates more noise and generates less then unbalanced transmissions, because noise affects both lines, not their voltage difference
- (Unbalanced, e.g. RS-232, uses single signal line and a (common) ground)
- Data encoding depends on the data rate
  - Basic rate 192kbps uses pseudoternary
  - Primary rate uses alternative mark inversion (AMI) and B8ZS or HDB3

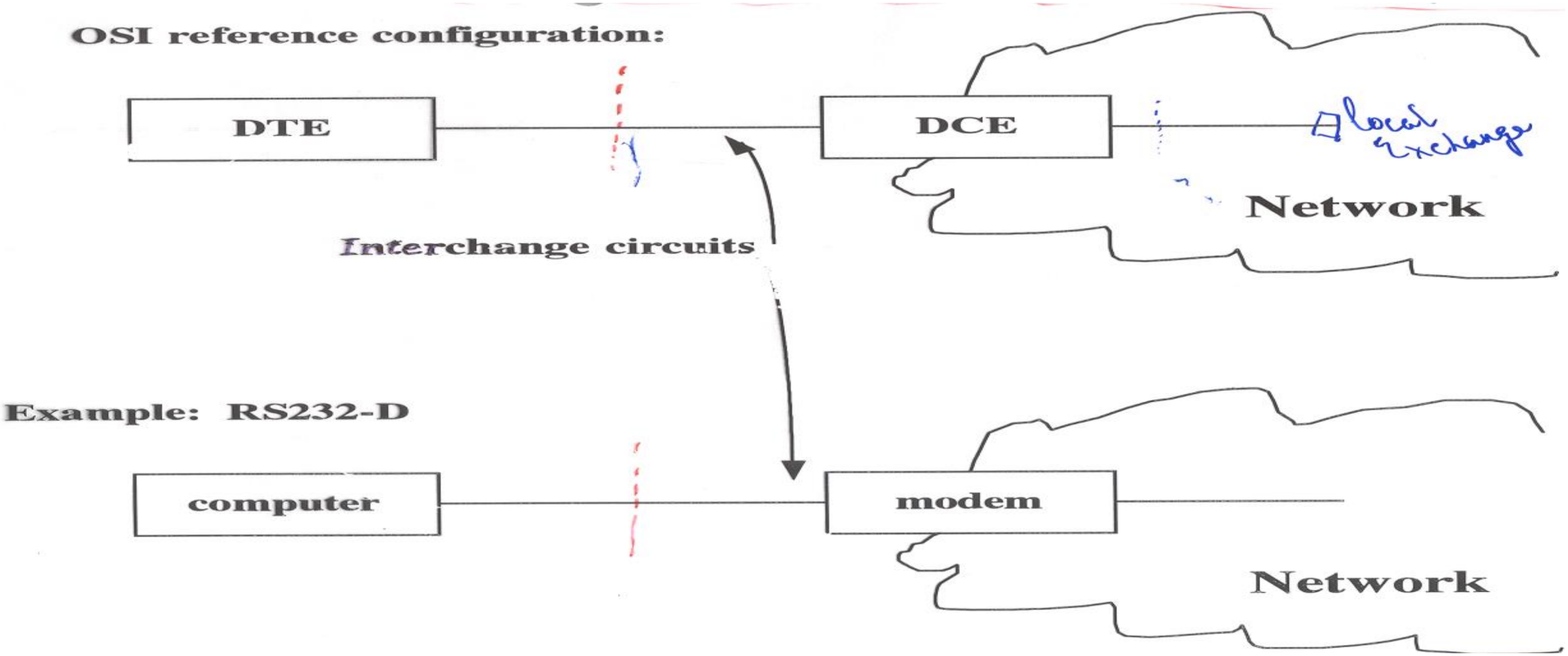
Modem

Standard modem definition:

The **modem** is the interface between a DTE (like a PC) that generates digital signals, and the telephone system that carries analog signals.

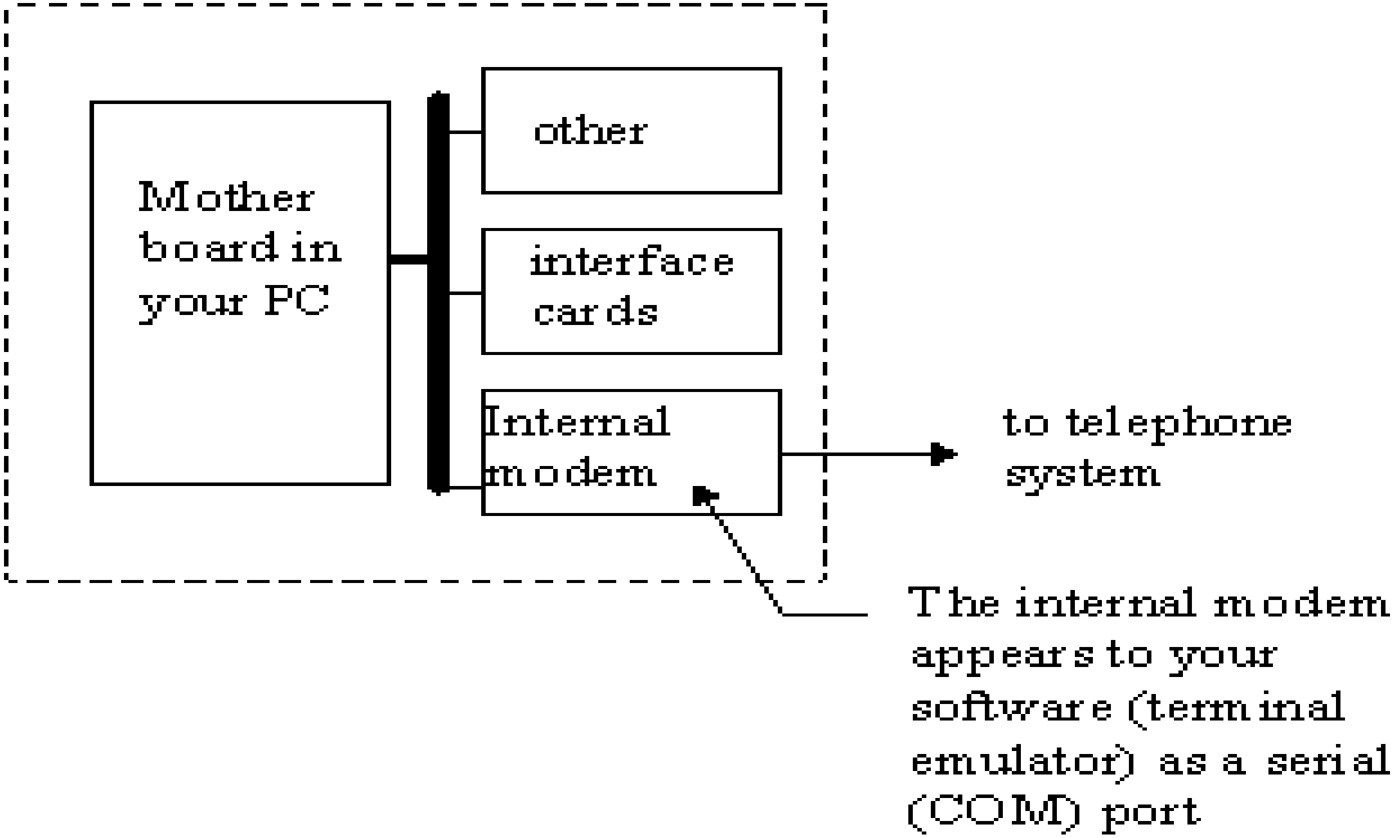
Modems encode digital signals onto analog signals by modulating an analog signal by changing the phase, frequency or amplitude of the signal, to represent 1s and 0s. The method of modulation defines the *modem standard*.

The modem receives signals from the interchange circuits, respecting the serial interface standards.

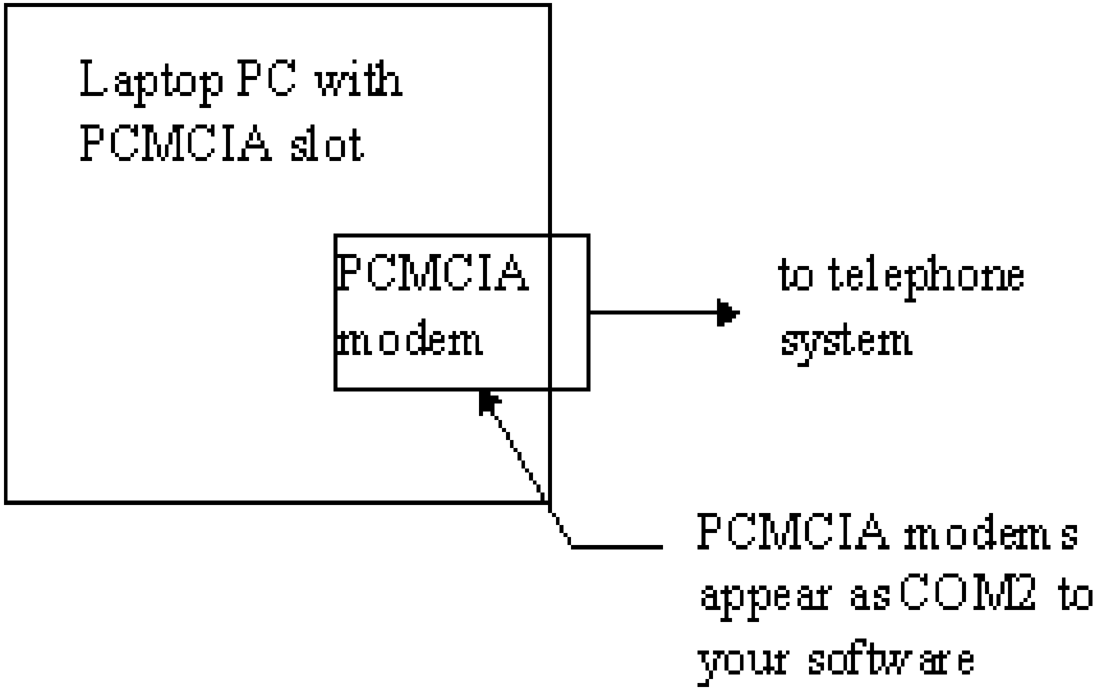


For PCs the modem may be *external* or *internal*, today’s mostly internal.
Even if using an internal modem, these serial interface’s signals are generated by the serial interface in the modem and are recognized by the terminal emulation software.

Internal view of a PC with internal modem



For your Laptop with interface adapter PCMCIA slot the modem appears like:



A PCMCIA modem being inserted into a laptop computer. Attached to the card is an adaptor which connects the card to a standard RJ-11 telephone line

Modem standards issued by:

-Bell standards (old standards), ITU-T (former CCITT) recommendations, concerning modulation and coding techniques

-EIA/TIA, ITU-T for interfaces

Categories of modems: (see table on next slide)

-**operating speed** –low, medium & high speed

-**implemented standard**

-type of transmission (asynchronous, synchronous)

-type of modulation (FSK, PSK, QAM)

-**type of telephonic lines** (dial-up or leased)

-**complexity** (traditional or smart)

-other modems (ISDN modems, coax cable modems, LAN modems, wireless and cellular modems)

Data rate	**Standard Body**	**Line Type**	**Modulation Technique**	**Transmission Type**	**Duplex Full/Half**
300	Bell 103, CCITT V21	Dial-up	FSK	Asynchronous	Half+Full
600	CCITT V22	Dial-up/leased	PSK	Asynchronous	Half+Full
1200	Bell 202, CCITT V22	Dial-up/leased	PSK	Asynch/Synch	Half+Full
2400	CCITT V22bis	Leased	QAM	Asynchronous	Half+Full
4800	CCITT V27	Leased	PSK	Synchronous	Half+Full
9600	Bell 209, CCITT V32	Dial-up/leased	QAM	Asynch/Synch	Half+Full
14400	CCITT V32bis	Dial-up/leased	QAM	Asynch/Synch	Half+Full
33600	CCITT V34	Dial-up/leased	PSK	Asynch/Synch	Full
56600	CCITT V90	Dial-up/leased	QAM	Asynchronous	Full

Low speed modems

First modem operated at 300 Bauds, cf. to Bell 103A standard (repeated by CCITT V21).

A modem could be (vis-a-vis a transmission):

-transmission originate

-transmission answer

Used 2 audio frequencies, one for sending and one for receiving.

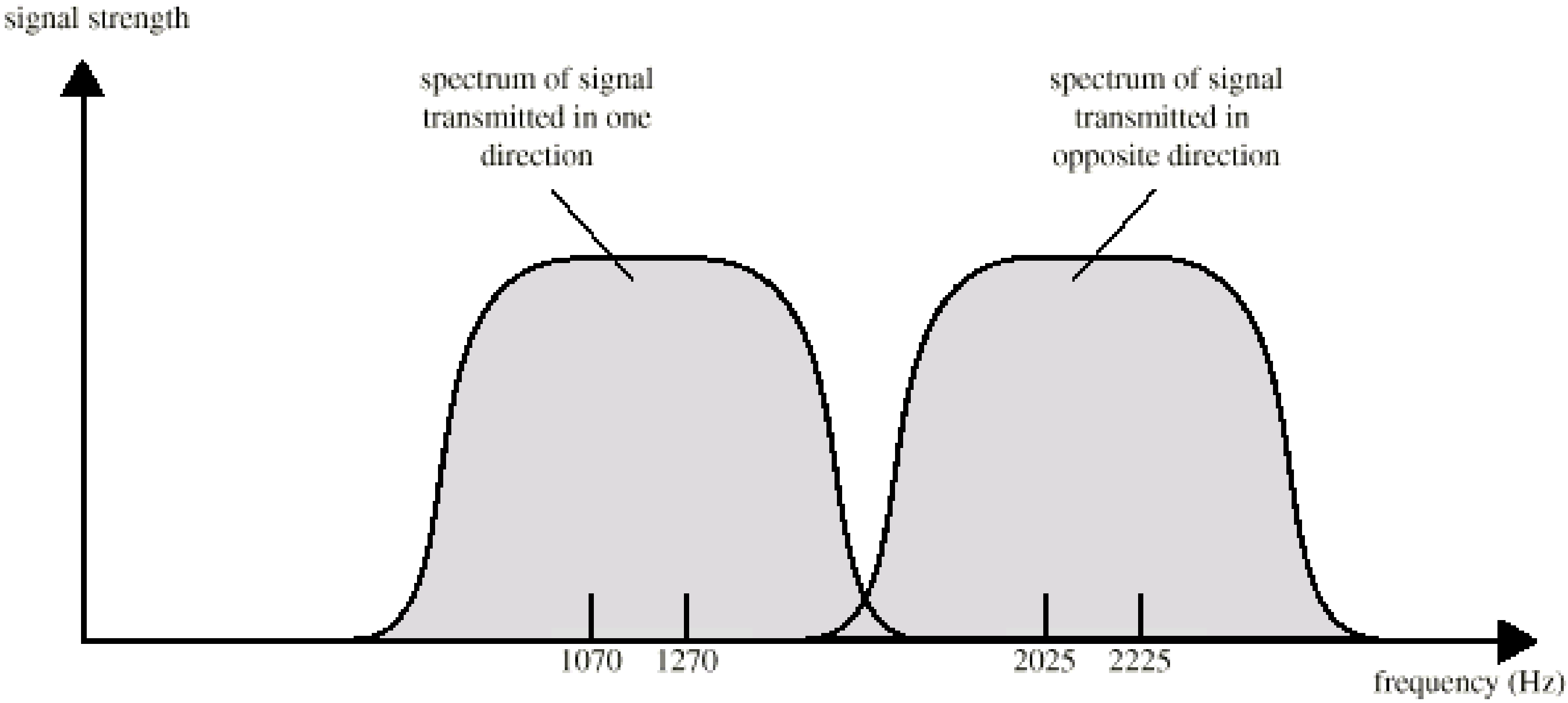
Ex. For Bell 103:

1070-1270 Hz being the frequency band for originate modem data transmission and receiving band for the answering modem

2025-2225 Hz, reception band for originate modem and emission band for answering modem.

For CCITT V21 the similar frequency bands are 980-1180 Hz and 1650-1850Hz respectively.

For this low speed ‘old’ modem, the interface signal set comprises the following signals: RTS, CTS, DSR, DTR, DCD, RI (see RS232 signal table).



Full-Duplex FSK Transmission on a Voice-Grade Line

Smartmodems (Hayes compatible)

Cf. RS232-C data and control lines are separated. Smartmodems ‘understand’ commands and status information using characters, so no more signal separation..

Modem Commands (Hayes-compatible modem)

These are commands (character strings) that the terminal emulator can send to the modem to instruct it to perform operations, such as automatic dial. Interface signal set comprises only the lines Tx (Transmit), Rx (Receive), and ground.

The modem is in one of the states:

-receive command from DTE

-on-line

-hang-up, or carrier-wait.

General format of the command:

AT *command*

Where *command* is a letter, followed (eventually) by a parameter.

The following are examples of a few of the AT (attention) commands:

ATDT n: Dial phone number <n>, using touch tone
ATDP n: Dial using pulse
ATH: Hangup
ATH1: Pick up the phone line

Introduction to:
ISDN Modem

ISDN (Integrated Services Digital Network), offers services on a full digital network.

ISDN modems, known as **TA** (Terminal Adapters).

An ISDN line is split in channels (see table):

B (Bearer) channel – carries (PCM coded digital) voice + data up to 64kbps

D (data signaling) channel – carries control for B channels; speed 16kbps or 64kbps

Usually B and D channels use separate paths, speeding up the transmissions

H (High speed) channel – data transport at speeds of Mbps

ITU-T defines two types of services:

BRI (Basic Rate Interface), operating at 192kbps, contains 2 B channels and one D channel at 16kbps (2B + D16)

PRI (Primary Rate Interface), signalling at 64kbps and operating at 1.544Mbps in US (23B + D64), or 2.048Mbps in Europe (30B + D64)

Channel	Bit Rate	Interface
B	64kbps	Basic access
H0	384kbps	Primary rate access
H11	1536kbps	Primary rate access
H12	1920kbps	Primary rate access
D16	16kbps	Basic access
D64	64kbps	Primary rate access

Use of H channels instead of B (see table for more details):

Interface	**Bit Rate**	**Interface Structure**
Basic access	192 kbps	2B+D16
Primary rate access	1544 kbps	23B+D64 3H0+D64
	2048 kbps	30B+D64 5H0+D64 H12+D64

TA has similar functions as a normal modem, plus those for adapting the variable data rate of the DTE to the constant B channel data rate. Also transforms analog voice or fax data into digital. The commands for a TA have similar structure as for the smart Hayes modem (AT … commands).

A little bit more about the physical level of ISDN:

ISDN: First important change from analog to digital telephony, from circuit switching telephony to packet switching based

Digital data exchanged between subscriber (user) and network terminal equipment (NTE) is Full Duplex => Separate physical line for each direction

Pseudoternary coding scheme: 1=no voltage, 0=positive or negative 750mV +/-10%

Basic rate: data rate of 192kbps, i.e. one 48 bit-long frame every 250 μs; **Basic access** uses synchronous TDM two 64kbps B channels and one 16kbps D channel (2B+D16) => This gives 144kbps multiplexed over 192kbps => Remaining capacity used for framing and synchronization.

Use of LAP-D frames (see the following data link protocol HDLC)

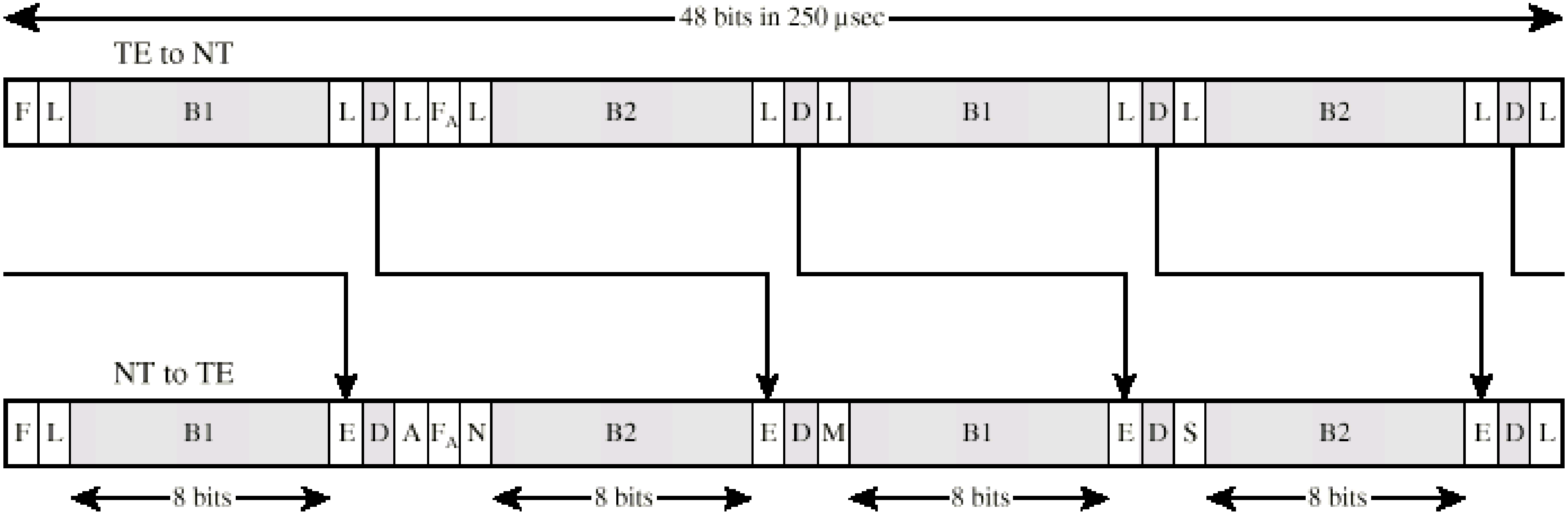
Two kind of frames: from/to subscriber to/from Terminal Equipment. Structure:

From 48 bit: 16bit for each of B channels and 4 bit for D channel.

F –framing bit (positive pulse, followed by a negative one L, for dc balance

F_A – auxiliary framing; E: D-echo channel bit (retransmission by NTE of the most received D bit; A: activation bit for NTE (allows low power-consumption mode)

ISDN LAP-D Frame Structure (basic access)

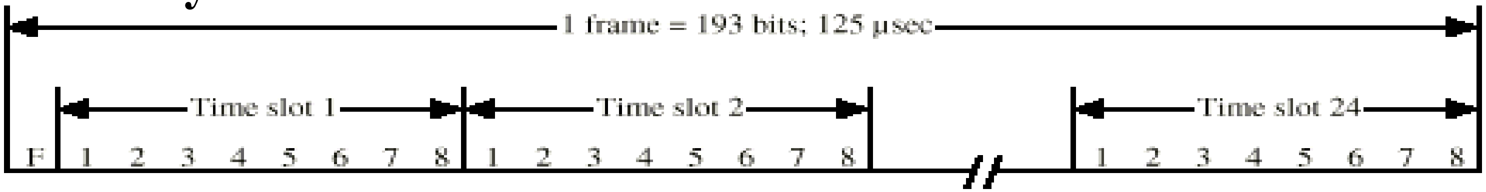


F = Framing bit
L = DC balancing bit
E = D-echo channel bit
A = Activation bit
F_A = Auxiliary framing bit
N = Set to opposite of F_A
M = Multiframing bit

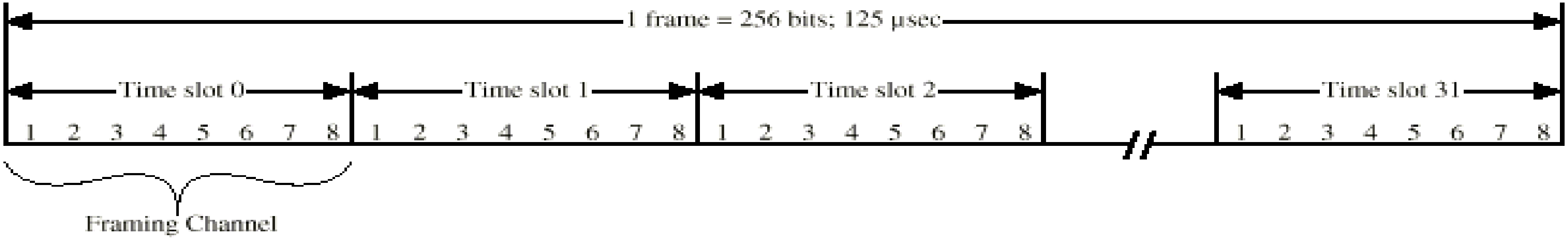
B1 = B channel bits (16 per frame)
B2 = B channel bits (16 per frame)
D = D channel bits (4 per frame)
S = Spare bits

Primary ISDN Interface: synchronous TDM of multiple channels, allows point-to-point configurations; 2 data rates defined:
DS-1 of 1.544Mbps, based on T1 trame: 24*8data bit + 1 framing, every 125 µs; 8000 frames/sec => each channel supports 64kbps; implements 23B+D64; data encoding using AMI (alternate mark inversion) – B8ZS(bipolar-8 zeros substitution)
E1 trame, at 2.048Mbps for 30B+D64; one 256 bit frame every 125µs, 8000 frames/sec each channel supports 64kbps; first time slot for framing and synchronization; data coded sing AMI – HDB3(high density bipolar 3zeros)

Primary ISDN Frame Formats



(a) Interface at 1.544 Mbps



(b) Interface at 2.048 Mbps

B-ISDN (Broadband ISDN)

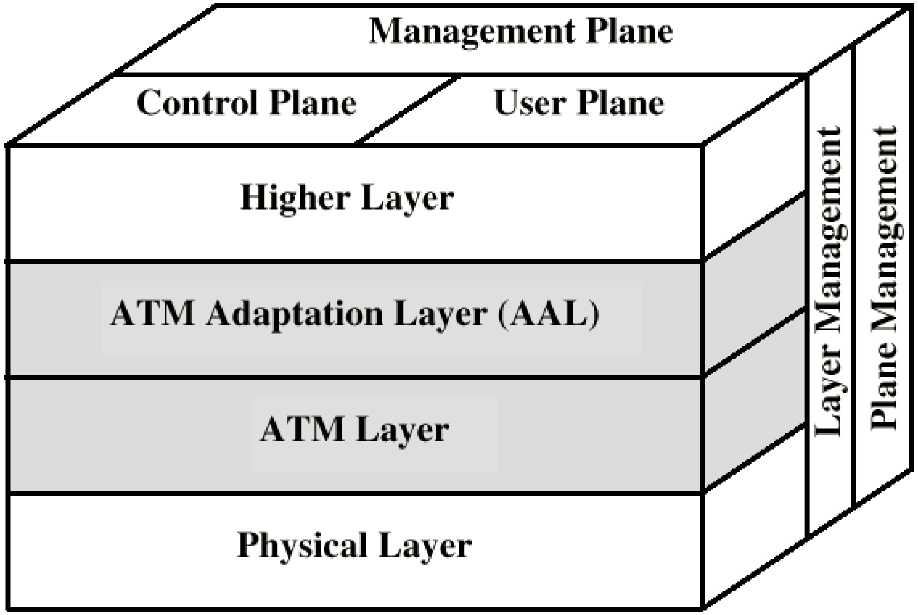
N-ISDN (Narrow – ISDN) deal with 64kbps channels (type B); with H type channels (actual H channel offers tens of Mbps) => development of B-ISDN, offering a transport of packets (cells) at a rate beginning with 155Mbps.

Transfer mode implementing B-ISDN (dealing with transmission and switching aspects) is the **ATM** (Asynchronous Transfer Mode).

The ATM transport unit is the **cell**, small packet of 53bytes, 5 octets for control and 48 bytes payload.

The protocol hierarchy of ATM is depicted below:

At the Physical level, the ATM technology is based on SONET and SDH standards.



Cable Modems

Devices allowing high-speed access to the Internet via a cable television network. Even similar with voice-band modems, more than 500 times faster. Voiceband modems operate up to 56kbps, cable modems deliver 30-40Mbps of data on a 6MHz TV channel

In a cable network:

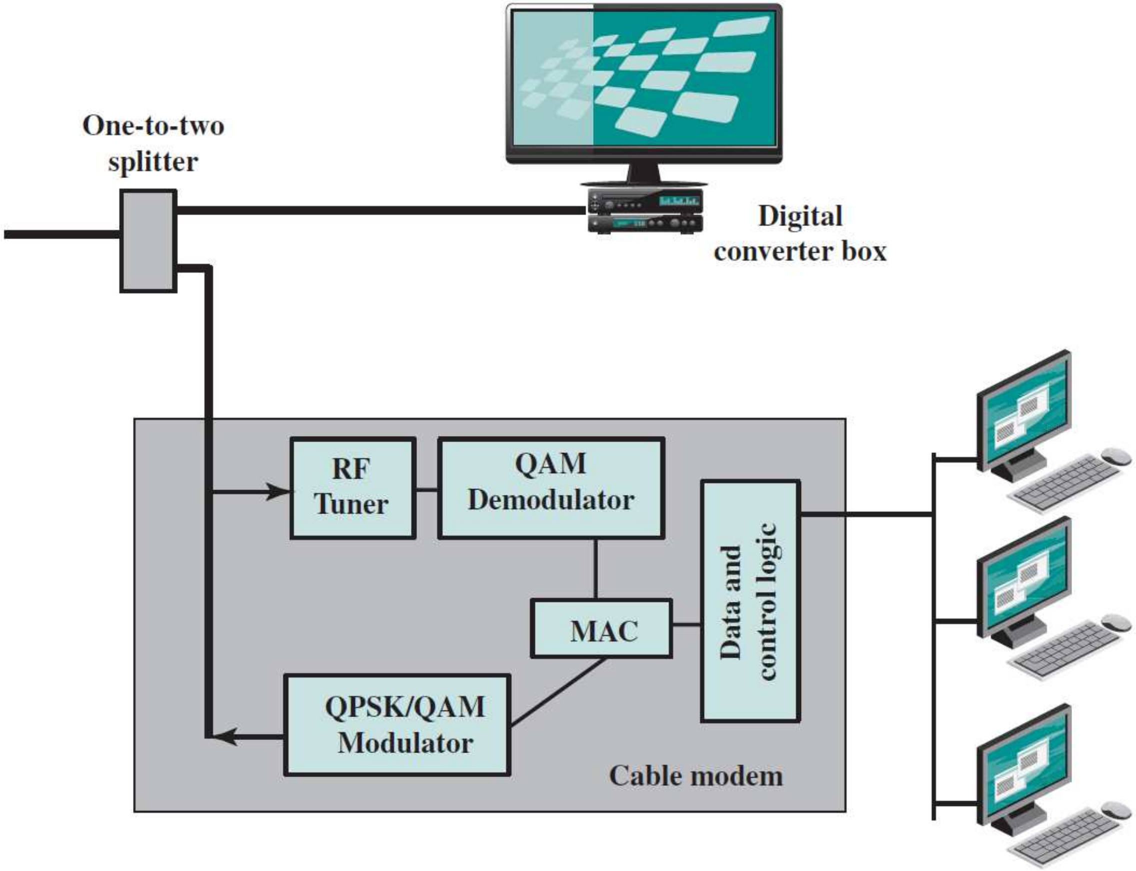
-data from the network to the user: **downstream**

-data from the user to the network: **upstream**

Downstream and upstream bandwidths may be configured after application (domestic user-low upstream bandwidth, business office may require a higher upstream band)

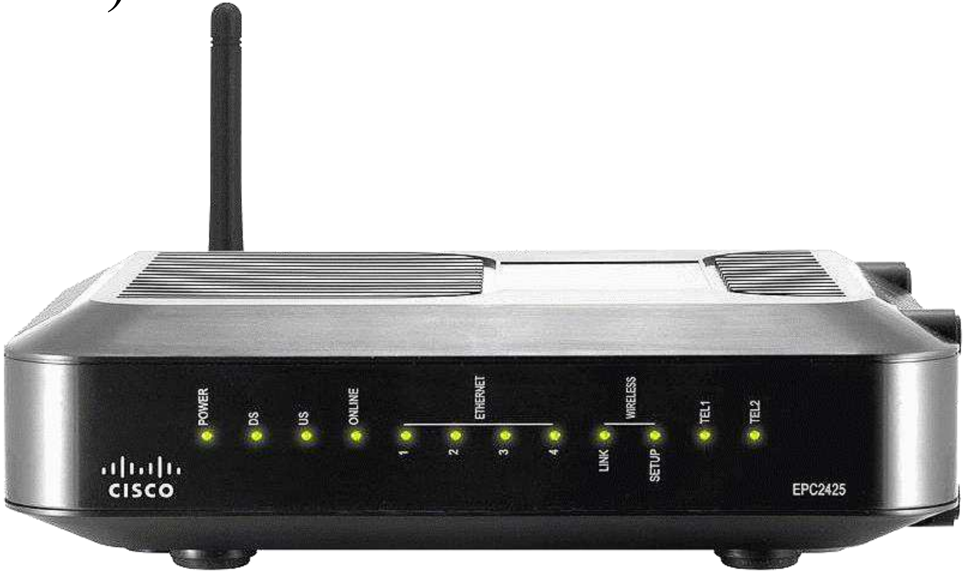
Simple layout:

-one-to-two splitter for transmitting TV services to set top box, and for transmitting data through cable modem to the computer

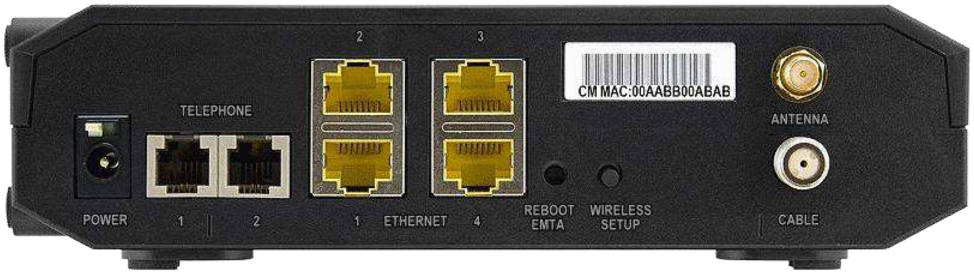


At the other end of the cable there is the head-end, may be a CATV provider or an ISP (Internet Service Provider), let’s say a **head-end point-of-presence**, allowing, by use of a multiplexed network interface, the access to the Internet.

- User-to-network data (upstream): 5–40 MHz
- Television delivery (downstream): 50–550 MHz
- Network to user data (downstream): 550–750 MHz

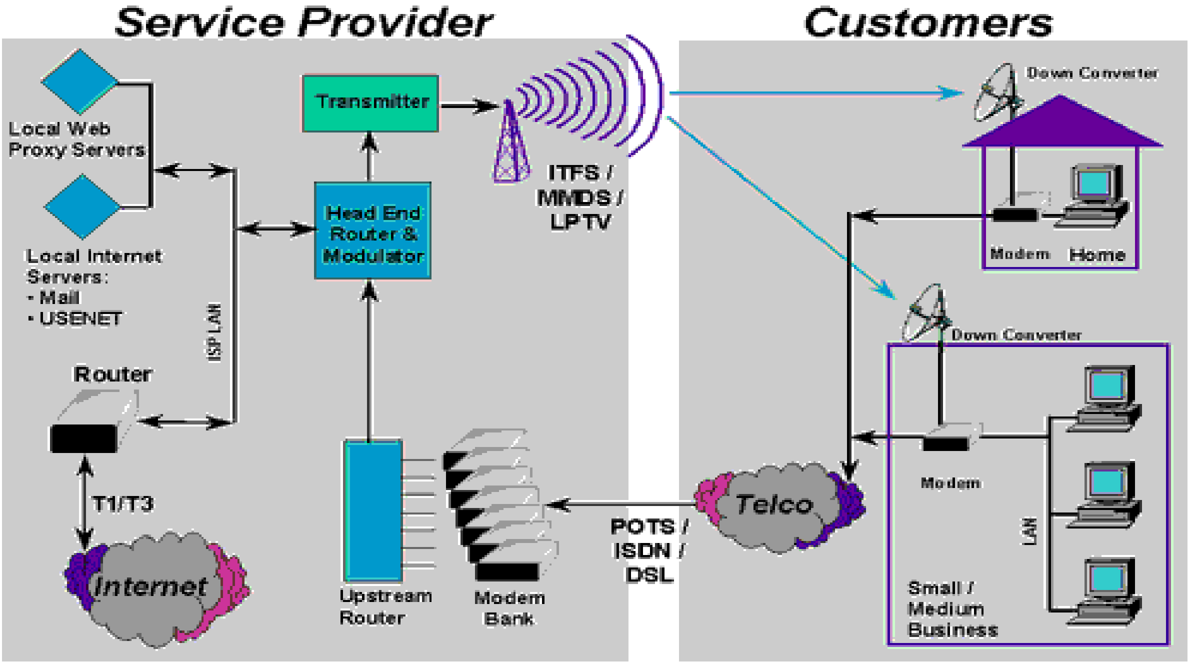


The front of a cable modem showing its various indicators.

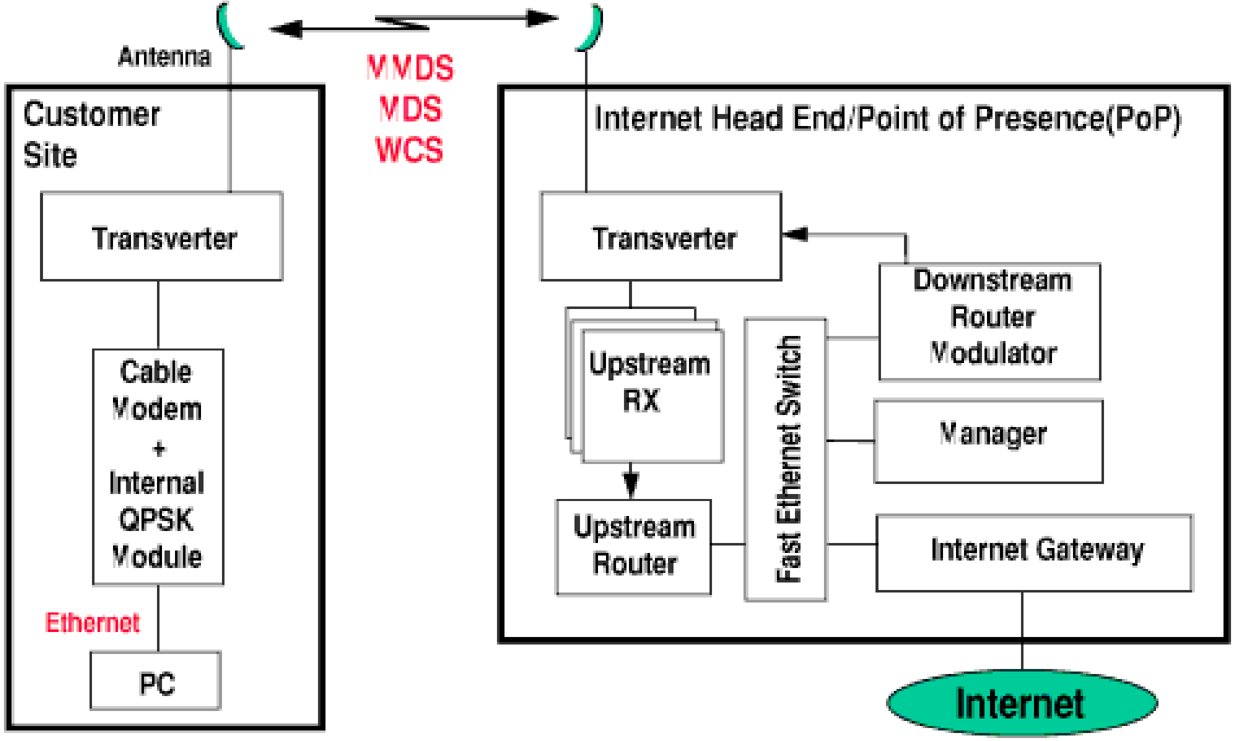


The back of a cable modem with standard coaxial television cable connector, telephone jacks and Ethernet jacks - connects the modem to a computer.

Other application with the downstream offered by CATV and upstream by cable modems.



Other application, with the use of the QPSK Signal from a Cable Modem and use of a transverter, for full wireless communications using CATC antennas.



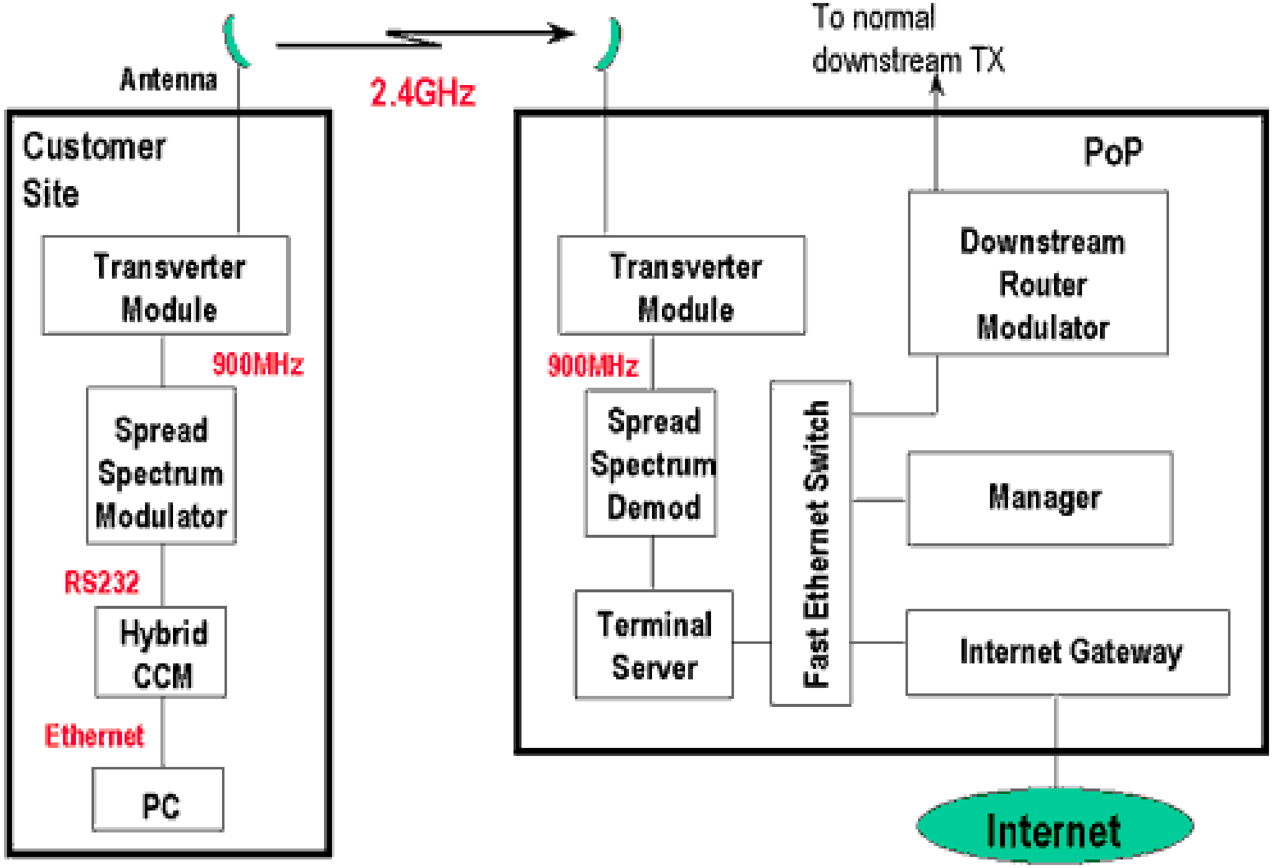
Wireless modems

Many kinds of wireless modems:

-RF modem for a wireless network (use of ISM bands)

-cellular modem for cellular communications, attached to the phone

Example: use the ISM Band for Wireless Return 900 MHz/2.4 GHz:

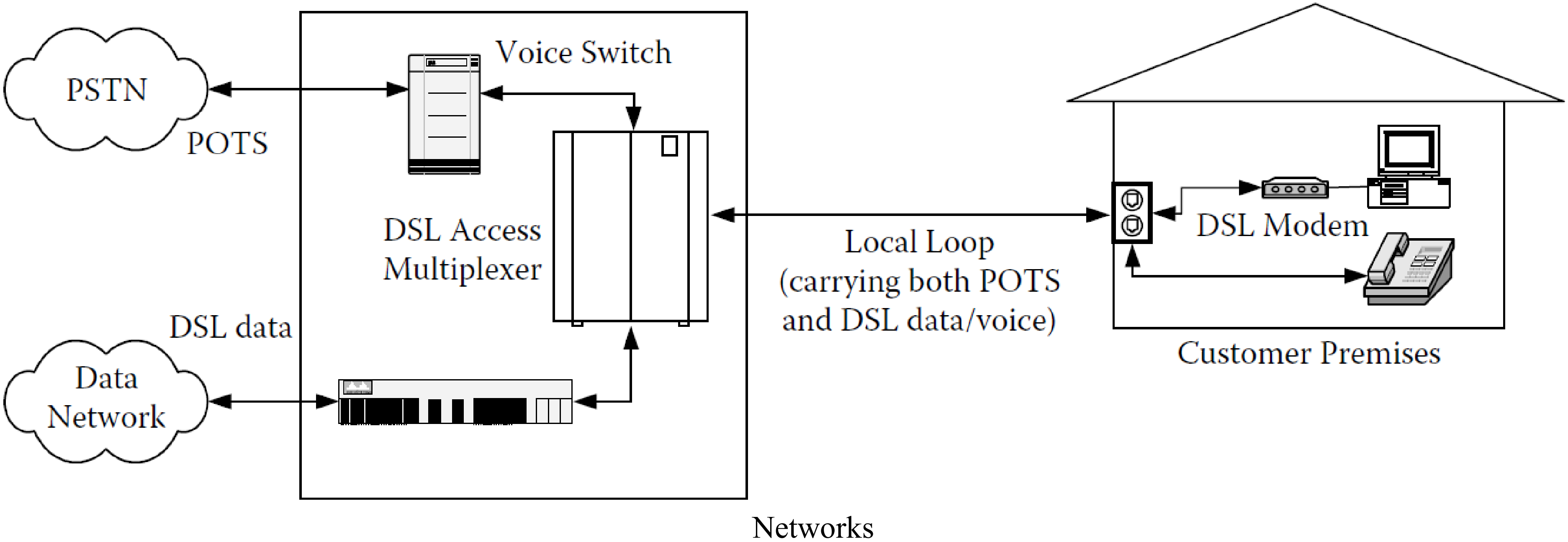


DSL (Digital Subscriber Line)

Link between subscriber and network (local loop); tens of millions installed; Reinstall?

⇒need for exploiting the existing base of TP wired structure; initially designed for voice-grade analog transmissions with 4kHz bandwidth, TP may carry data using signals over a spectrum of more than 1MHz => use of modems for digital high rate data transmissions, using currently installed twisted pair cable.

- DSL refers to the analog local loop between each customer premises and its local central office, and a DSL modem is required at each end of the loop



ADSL (Asymmetric Digital Subscriber Line)

ADSL initially designed for video-on-demand, now appropriate for high-speed Internet access.

Asymmetric because, from the user point, there is greater capacity downstream (from service provider to customer) than upstream.

ADSL uses FDM for managing the 1MHz bandwidth:

-Lowest 25kHz for voice (Plain Old Telephone Service): 0 to 4kHz for voice, rest for guard, avoiding interference with other channels

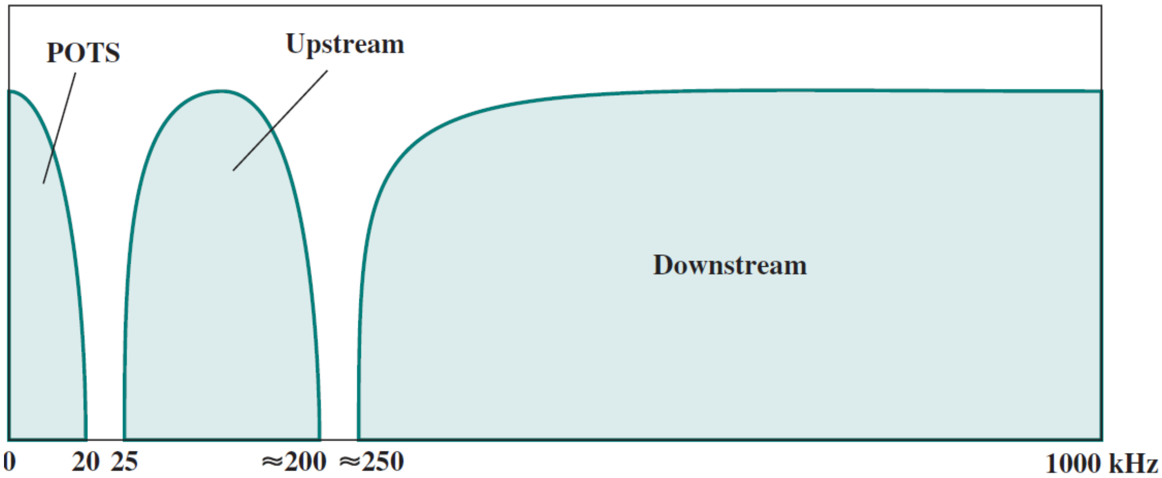
-Use echo cancellation or FDM to give (to allocate) two bands: one for upstream , one for downstream

-Use FDM within each of two bands.

Supports loop length in the range of 5.5km.

Echo Cancellation

Signal processing technique, allowing digital transmissions in both directions on a single line simultaneously. The transmitter must subtract the echo of its own transmission from the incoming signal, to recover the signal sent by the other side.

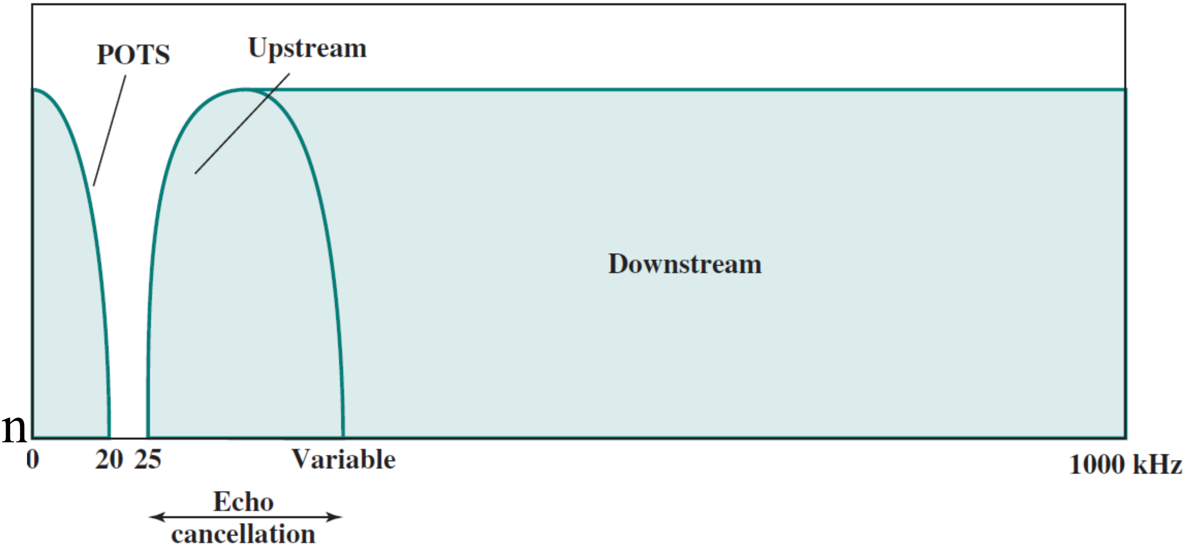


(a) Frequency-division multiplexing

Advantages:

-more flexibility for upstream bandwidth changes, simply extending the area of overlap

-downstream bandwidth in the good part of the spectrum (not so many HFs) => a lower attenuation



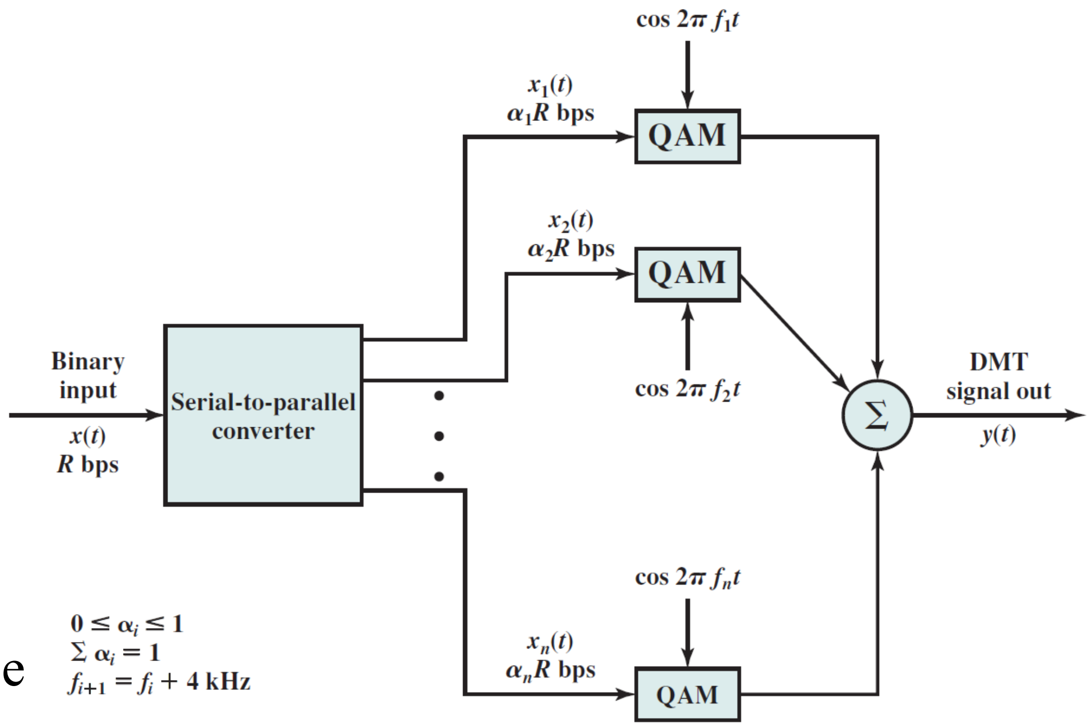
(b) Echo cancellation

DMT (Discrete Multitone)

DMT modem allows multiple carrier signals at different frequencies;

-upstream and downstream bandwidths are split in a number of 4kHz sub-channels, transmitting a number of bits on each channel.

Initially modem send test signal on each subchannel, and then use those subchannels with better signal to noise ratio.



If used 256 downstream subchannels at 4kHz, carring data at 60kbps, will result a data rate of 15.36Mbps. Transmission impairments bring this down to 1.5Mbps to 9Mbps.

Use of **QAM (Quadrature Amplitude Modulation)** – analog signaling technique, a combination of AM and PM. May assign different number of bits/transmitted signal.

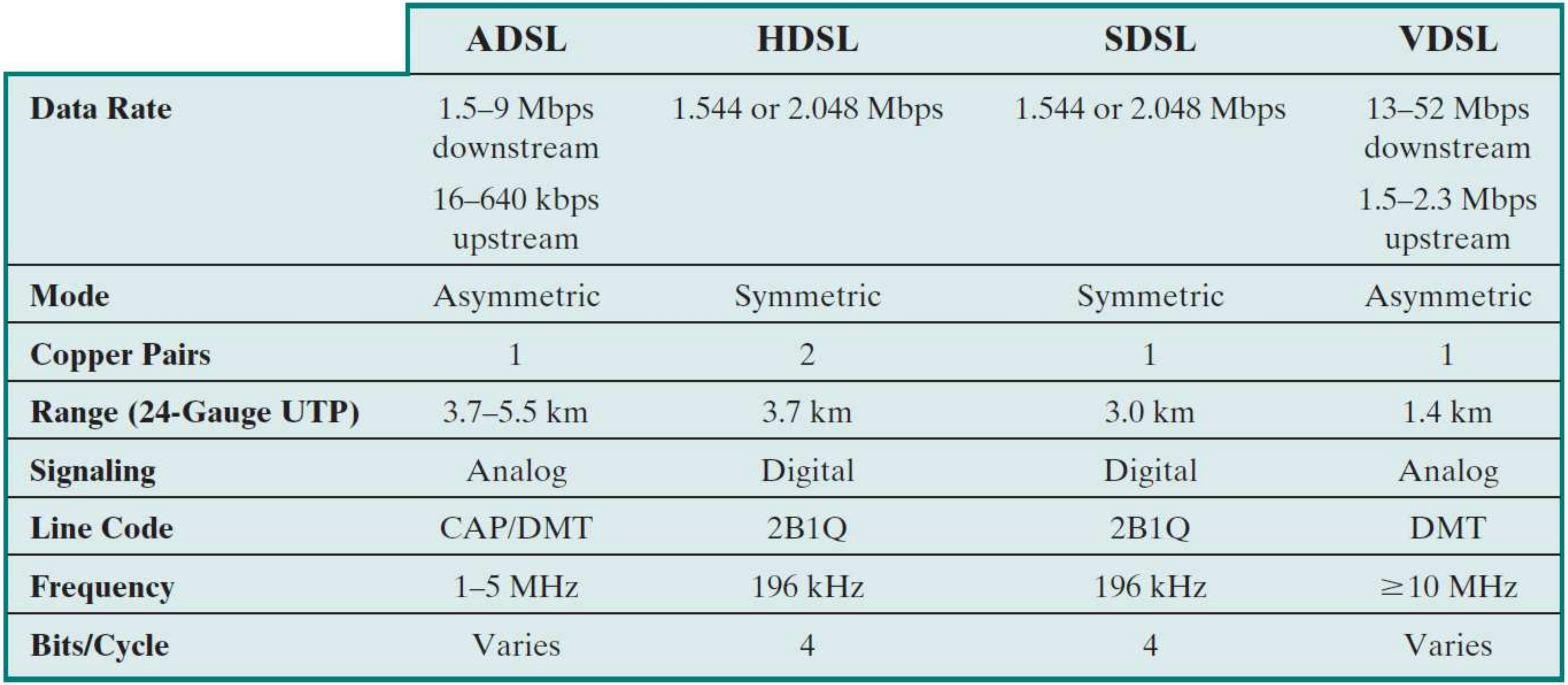
Sample example: data string is split in two sub-strings. One sub-string modulates the carrier, the other modulates the carrier shifted with 90º. The composed QAM signal is the sum: s(t) = d1(t)cos 2πft + d2(t)sin 2πft. => signal has 4 states, for coding 2 bits.

xDSL – recent schemes for high-data speed transmissions on ADSL

High data rate DSL

Single line DSL

Very high data rate DSL



	ADSL	HDSL	SDSL	VDSL
Data Rate	1.5–9 Mbps downstream 16–640 kbps upstream	1.544 or 2.048 Mbps	1.544 or 2.048 Mbps	13–52 Mbps downstream 1.5–2.3 Mbps upstream
Mode	Asymmetric	Symmetric	Symmetric	Asymmetric
Copper Pairs	1	2	1	1
Range (24-Gauge UTP)	3.7–5.5 km	3.7 km	3.0 km	1.4 km
Signaling	Analog	Digital	Digital	Analog
Line Code	CAP/DMT	2B1Q	2B1Q	DMT
Frequency	1–5 MHz	196 kHz	196 kHz	≥10 MHz
Bits/Cycle	Varies	4	4	Varies

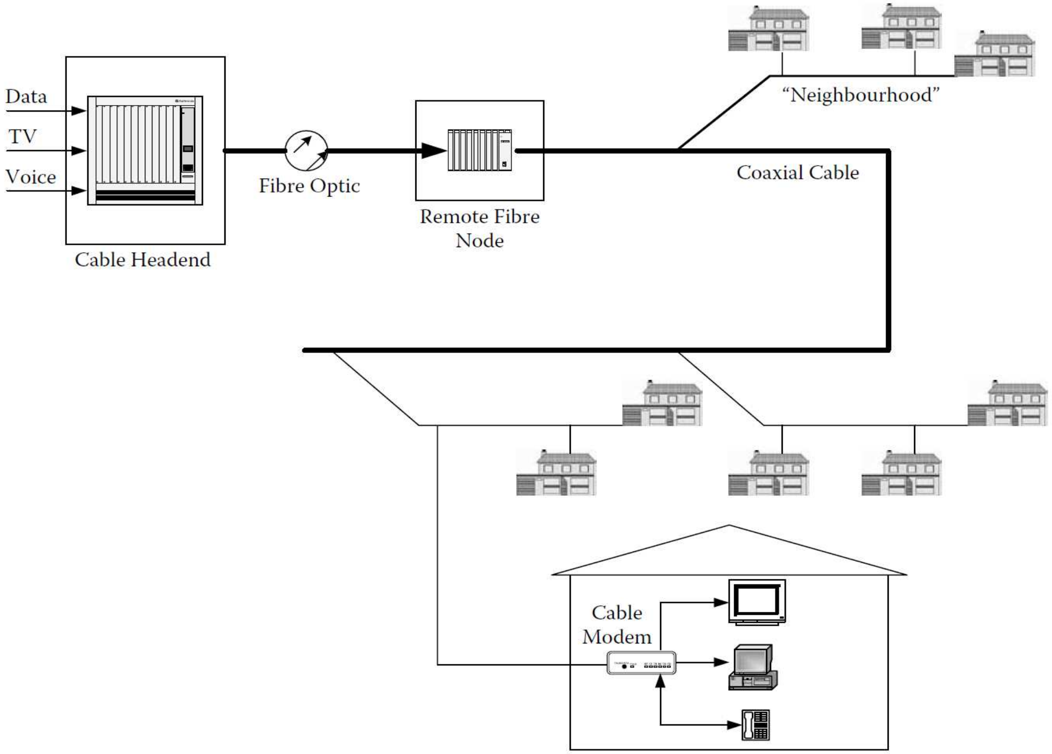
Alternative Broadband Access Technologies

Fiber-to-the-home (FTTH)

- common solution: using passive optical network (PON)
- a single transceiver in the CO serving multiple customers
- splitters and couplers to distribute the service among the different subscribers

Cable

- hybrid fiber-coax (HFC)
- fiber-optic cable carrying signals between the cable headend and fiber nodes in the network, from which existing coaxial cable is used to cover the "last mile" to the subscribers' premises.



Alternative Broadband Access Technologies

Wireless

- wireless local loop with the advantage that it doesn’t need the installation of a transmission medium
- higher frequencies systems: 20 to 40 GHz, sometimes requiring line-of-sight (LOS) availability
- Lower frequency systems: 2,4GHz– 5GHz, with non-LOS transmission

BPL (Broadband over Power Line)

- use of the electric power supply network for the transmission of broadband data

Example: *IEEE 1901-2010 (IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications)*

- high-speed (>100 Mbps at the physical layer) communication
- transmission frequencies below 100 MHz
- BPL devices used for the first-mile/last-mile connection (<1500 m to the premise) and BPL devices used in buildings for local area networks (LANs) and other data distribution (<100 m between devices).