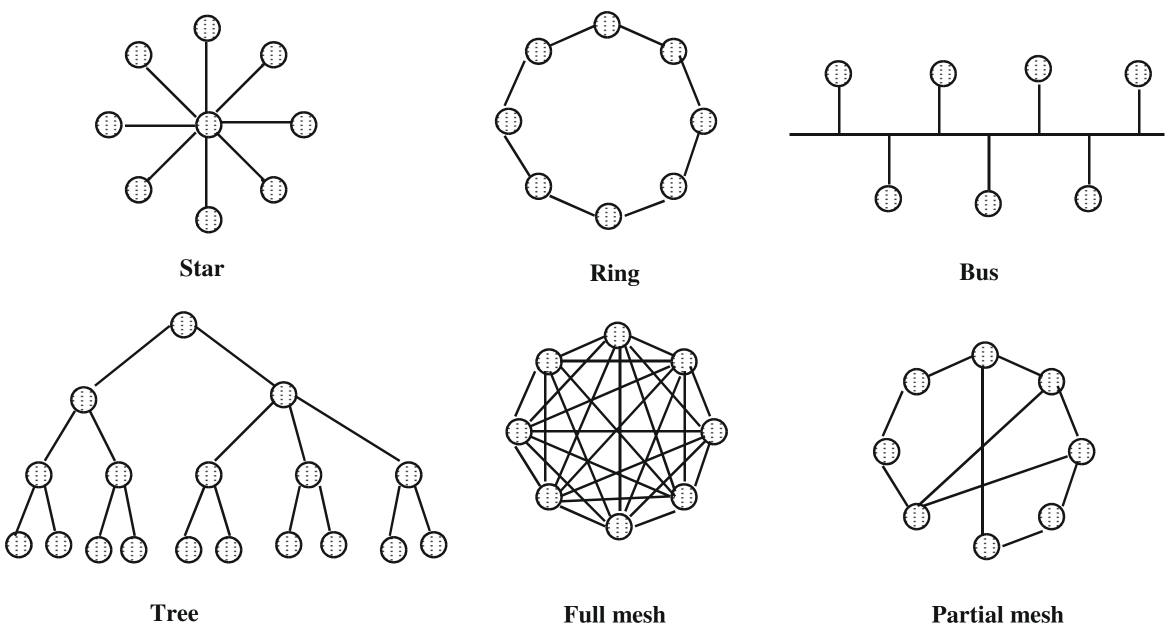
2.4 Physical Media

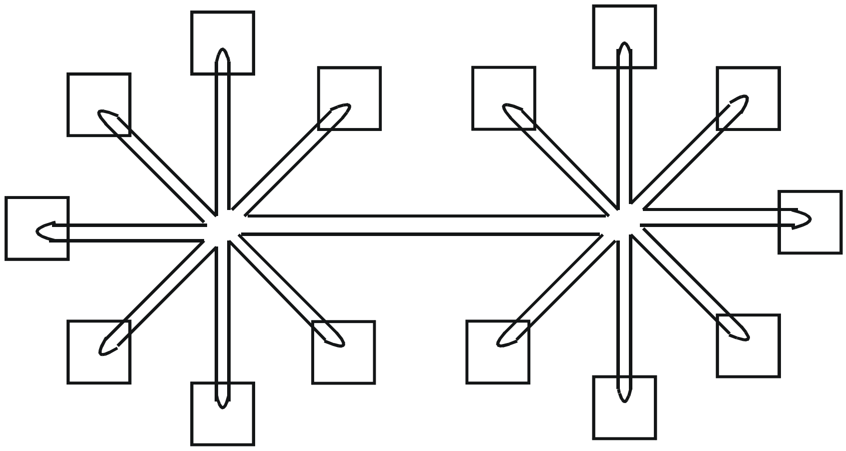
- Network topologies
- Copper cable
  - twisted pair cable
  - cat-5 cable
  - coaxial cable
- Fiber optic cable
- Radio links
  - Satellite communication
  - GSM and UMTS
  - Wireless LAN (802.11)
  - BlueTooth

Network Topologies



Structured Wiring

Possibility of ring wiring: logical ring, physical star



Logical Ring

Physical Star

Twisted Pair Cable

Unshielded twisted pair (UTP)

Two copper wires, twisted to reduce the influences of noise, therefore called "**twisted pair**". This is the classical telephone wiring. Small physical dimension, small bending radius, inexpensive.

Shielded twisted pair (STP)

Two copper wires, twisted, shielded with a surrounding copper mesh. Less susceptible to inductive (electrical, magnetic) interference from the outside. Larger diameter than "unshielded twisted pair", larger bending radius, more expensive.

Cat-5 Cable

Short for Category 5, a network cable that consists of four twisted pairs of copper wire terminated by RJ45 connectors. Cat-5 cabling supports frequencies up to 100 MHz and speeds up to 1,000 Mbit/s. It can be used for ATM, token ring, 1000Base-T, 100Base-T, and 10Base-T networking.

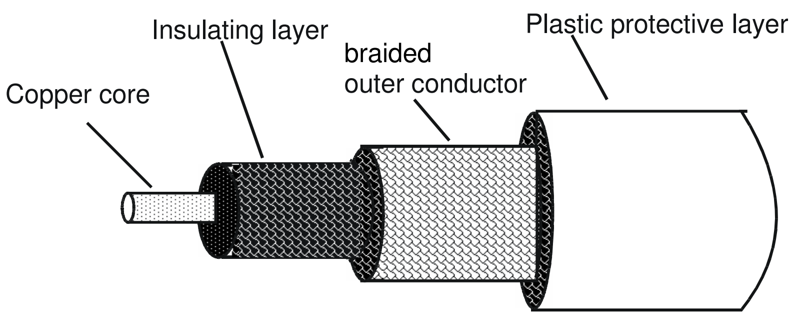
Computers hooked up to LANs are usually connected using Cat-5 cables.

Cat-5 is based on the EIA/TIA 568 Commercial Building Telecommunications Wiring Standard developed by the Electronics Industries Association.

Coaxial Cable

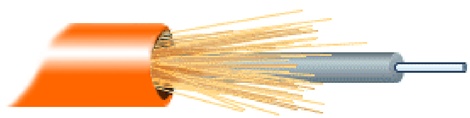
Example: The "classical" bus cable of the original Ethernet standard

- 50 Ohm coaxial cable
- Maximum of cable length: 500 m
- Maximum of 100 transceivers (stations connected) per segment
- Maximum of four repeaters between any transmitter and receiver
- The distance between the connections must be a multiple of 2,5 m.
- Data rate: 10 Mbit/s



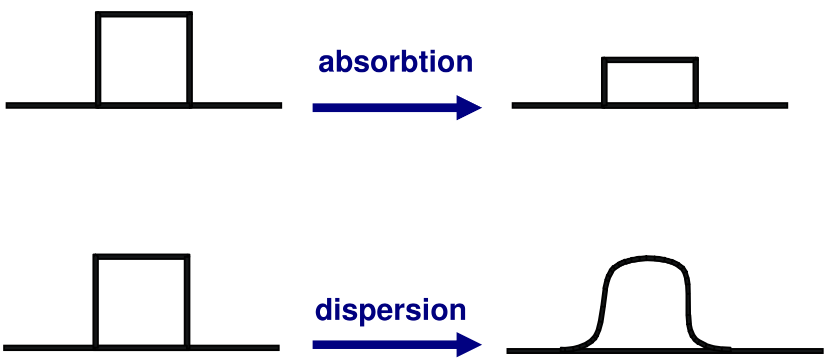
Fiber Optic Cable (1)

- Very high data rates!
- Theoretical limit: 300 TeraHz
- Practical limit: approx.10 GigaHz
- Transmitter and receiver can be semiconductor elements.



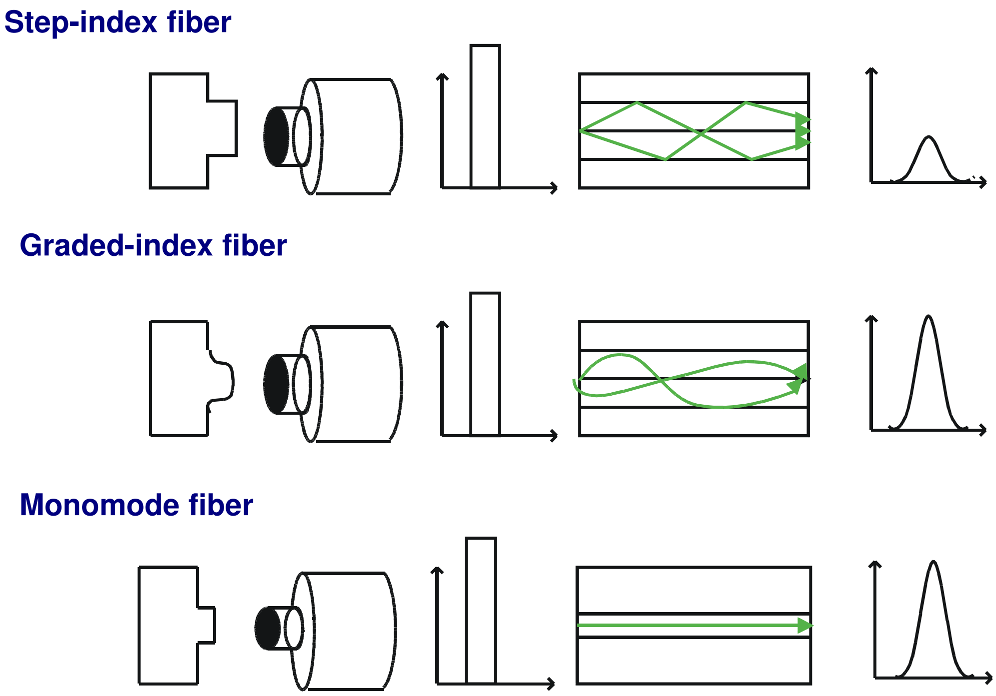
Fiber Optic Cable (2)

Factors limiting the transmission speed

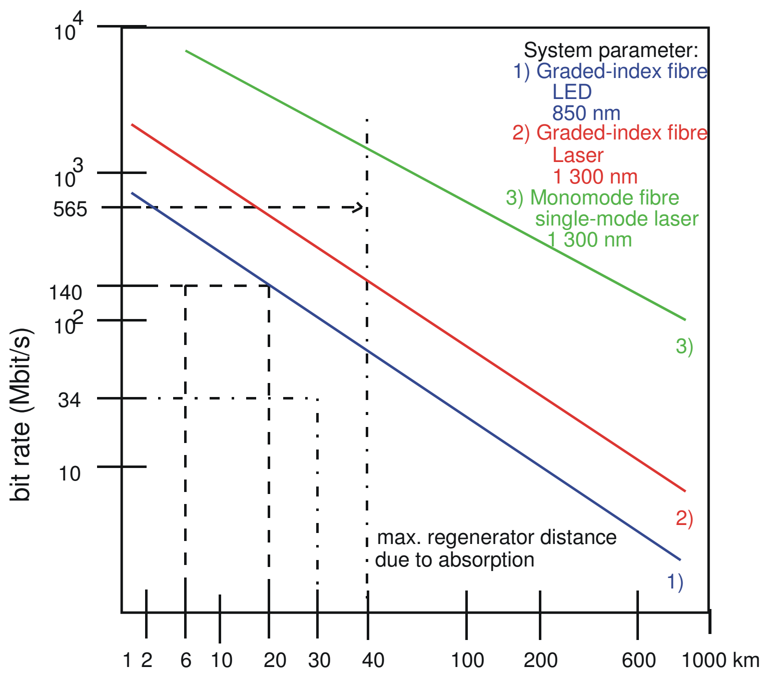


Connections are difficult: the diameter is only 5 μ - 50 μ.

Technology of Fiber Optic Cables



Optical Fiber



Satellite Communication

Properties

- High bandwidth
- Broadcast topology (security problems)
- Long delay
  - For earth stations with fixed antennas the satellite must be on a geosynchronous orbit.
  - This means an elevation of 36,000 km.
  - This results in a delay of 270 ms (to the satellite and back).
  - This long delay affects the protocols of the higher layers!

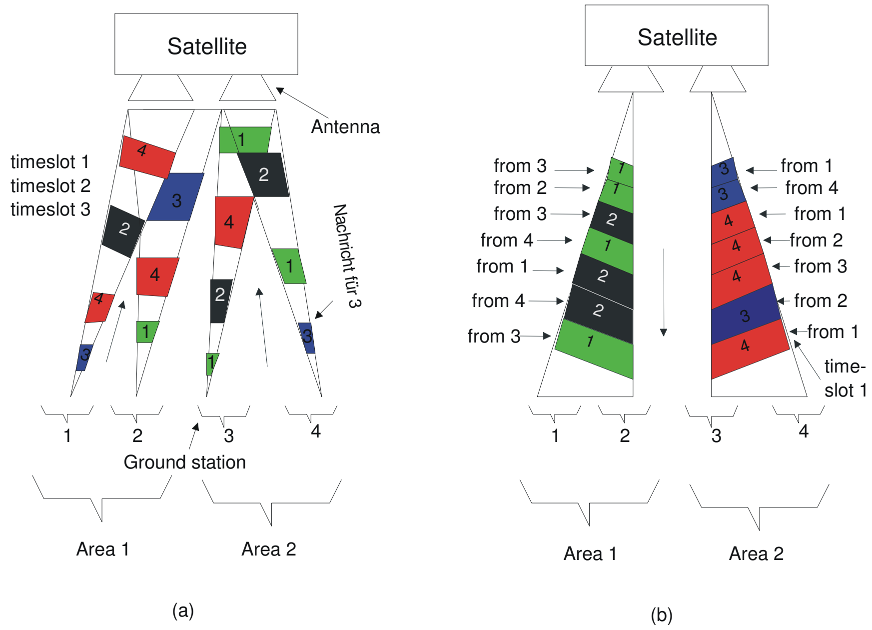
Example: INTELSAT

- 794 simplex PCM chanels, 64 kbit/s each, in addition a signalling channel with 128 kbit/s
- Multiplexing with FDM
- One pair of simplex channels always forms a duplex channel since the main usage is telephony.

Satellite Networks

- Like bus and ring networks, satellite networks are broadcast networks.
- The satellite is a passive repeater and amplifier station. The signals from the sending earth station are mapped to another frequency and sent out again.
- In satellite networks the problem of channel assignment is difficult due to the long delays. For example, with a token mechanism the channel would be unused for 270 ms for each tolen passing).

Satellite Example



Within one transmission area time division multiplexing (TDM) is used.

GSM and UMTS

- Digital cellular telephone communication is standardized at an international level (e.g., GSM and UMTS for Europe).
- The main usage is for telephony.
- In GSM the bandwidth for data communication is very low. (9,6 kbit/s in the original GSM standard).
  - The digital bandwidth depends on the width of the carrier channel.
  - Because of frequency multiplexing within a cell the channels must be narrow-band.
- More data applications are expected for UMTS.

Wireless LANs

- Quick and wide acceptance of **wireless LANs** after the publication of the IEEE standards 802.11b and 802.11g
- Bandwidth on the wireless link: 11 Mbit/s for 802.11b, 54 Mbit/s for 802.11g
- The Access Point (base station) is usually attached to the wired network (LAN) of the enterprise.
- 802.11b has become a low-cost technology and is very widely deployed.
- Note: Weak encryption features in the standard and careless users cause serious security problems.

Bluetooth

Bluetooth was designed for the connection of peripheral devices to a computer.

The number of devices in a segment is very limited.

Note: Bluetooth and WLAN operate in the same (free) frequency range (2.4 GHz) and are not compatible!

2.5 Examples: V.24, ADSL

Example 1: V.24, the serial interface of a PC

Domain (from CCITT Recommendation V.24): "This recommendation refers to interface lines between data terminal equipment (DTE) and data communications equipment (DCE), called feeder lines, for transmission of binary data, control and step timing signals. This recommendation extends also to both sides of separate intermediate mechanisms, which can be inserted between the mechanisms of these two categories."

Mechanical characteristics

The mechanical characteristics of the interface are defined in the standards ISO 2110 (25-25-pin connector) or ISO 4902 (37-pin and 9-pin connector).

Electrical characteristics

The electrical characteristics of the interface lines are treated in separate recommendations.

Functional Characteristics of V.24

1	2	3	4	5	6	7	8	9
102	Ground	x						
102a	DTE- Back conductor	x						
102b	DCE- Back conductor	x						
102c	Common back conductor							
103	Transmit data			x				
104	Receive data		x					
105	switch on transmitting unit					x		
106	Ready-to-transmit state				x			
107	Ready status				x			
108/1	turn on channel					x		
108/2	DTE* ready for use					x		
109	Received signal level				x			
110	Receive quality				x			
111	switch on high transmission rate (DTE*)					x		
112	switch on high transmission rate (DCE*)				x			
113	Transmission signal element timing (DTE*)							x
114	Transmission signal element timing (DCE*)						x	

1= No. of the interface line	6= Control from DCE**
2= name of the interface line	7= Control toward DCE**
3= Ground	8= Signal element timing from DCE**
4= Data from DCE**	9= Signal element timing towards DCE**
5= Data toward DCE**	

Example 2: ADSL

ADSL (Asymmetric Digital Subscriber Line) and the related techniques HDSL, SDSL and VDSL transfer very high bit rates (up to 8 Mbit/s) over unshielded twisted pair cables (telephone wires).

Why is the ADSL technology economically interesting?

- Over 700 million installed telephone lines installed world-wide
- 96% of them with copper cables
- Over 50% of the entire investment of a telephone infrastructure goes into cabling!

=> ADSL is a very cost-effective solution, since copper cable capacity is already installed and can be used.

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* Für die Überlassung seines Foliensatzes über ADSL danke ich Herrn Mathias Gabrysch, NEC C&C Research Labs, Heidelberg

xDSL - High Data Rates on Copper Cables

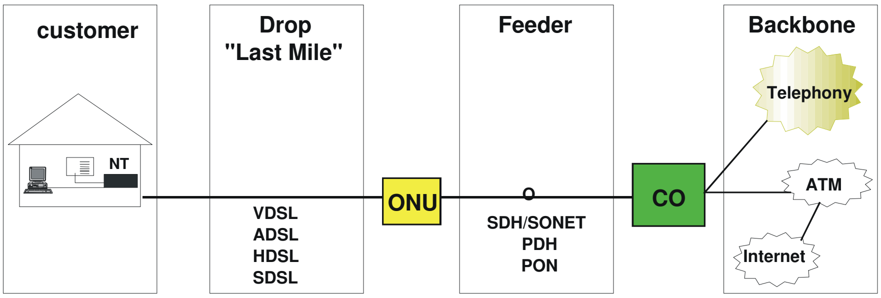
How are such high data rates possible?

The signal of a classical modem has to cross the entire telephone network form one end to the other. Thus it has to limit its modulation range to the **speech frequency range** of 300 - 3400 Hz.

In contrast the x-DSL signal runs over a plain copper cable, between exactly two line terminators.

In practice, the length and quality characteristics of the copper cables can vary widely, which poses quite an engineering challenge. Typically a fre-quency range of 0 - 1.1 MHz is used for modulation.

Broadband Feeder Networks



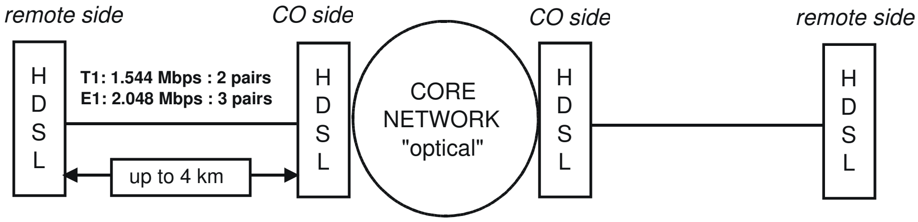
Feeder scenarios

- Fiber to the Building (FttB)
- Fiber to the Curb (FttC)
- Fiber to the eXchange (FttX)

ONU = Optional Network Unit

CO = Switching centre („central office“)

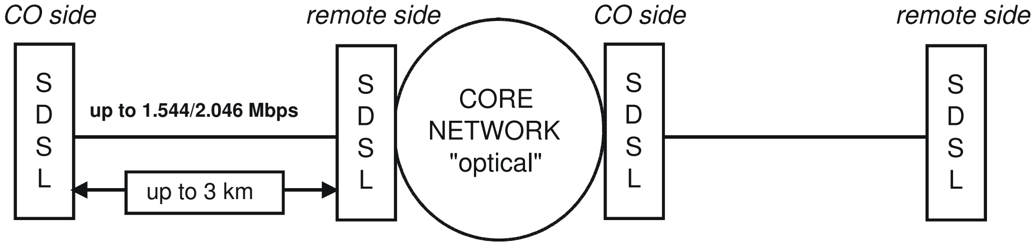
HDSL – High Data Rate Digital Subscriber Line



High, symmetric bit rates over several parallel copper cables

- Initially designed as a cost effective technique for telecoms to realize T1 or E1 (1.5 Mbit/s or 2 Mbit/s) over two to three two-wire copper cables.
- Based on 2B1Q (QAM, Quadrature Amplitude Modulation, 2 bits per baud) or CAP modulation techniques (a digital variant of QAM)
- No simultaneous telephone service on the cable
- Typical use: T1 or E1 to buildings that do not have a fiber-optical connection

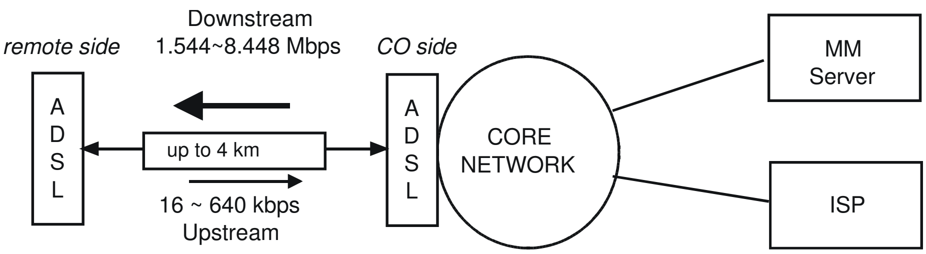
SDSL – Symmetric Digital Subscriber Line



„SINGLE LINE“ version of HDSL (only one twisted pair)

- symmetric bit rates
- based on 2B1Q (QAM), CAP or DMT modulation techniques
- telephone service and T1/E1 available simultaneously
- typical use: same as HDSL

ADSL – Asymmetric Digital Subscriber Line

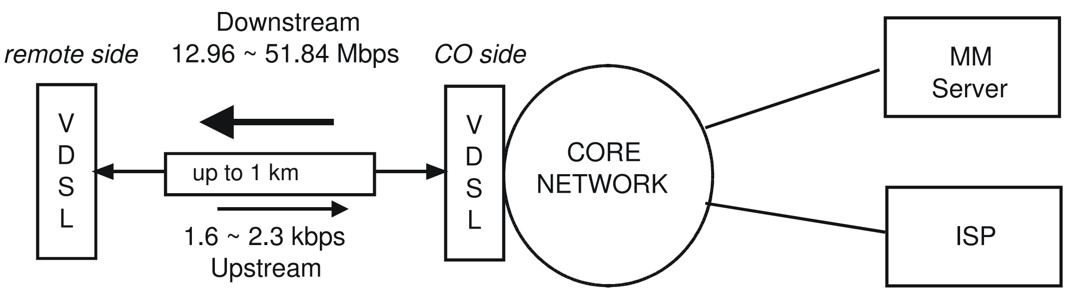


- Duplex transmission with asymmetric data rates over an unshielded twisted pair cable (two wires)
- The achievable data rate depends on the distance and quality of the wires. **The adaptation takes place automatically**.
- Based on CAP or DMT modulation techniques
- Telephone service and ADSL data service are available simultaneously.
- Typical use: fast data transmission for private homes, Internet access for private homes, remote acess to company LANs

ADSL: Why Asymmetric?

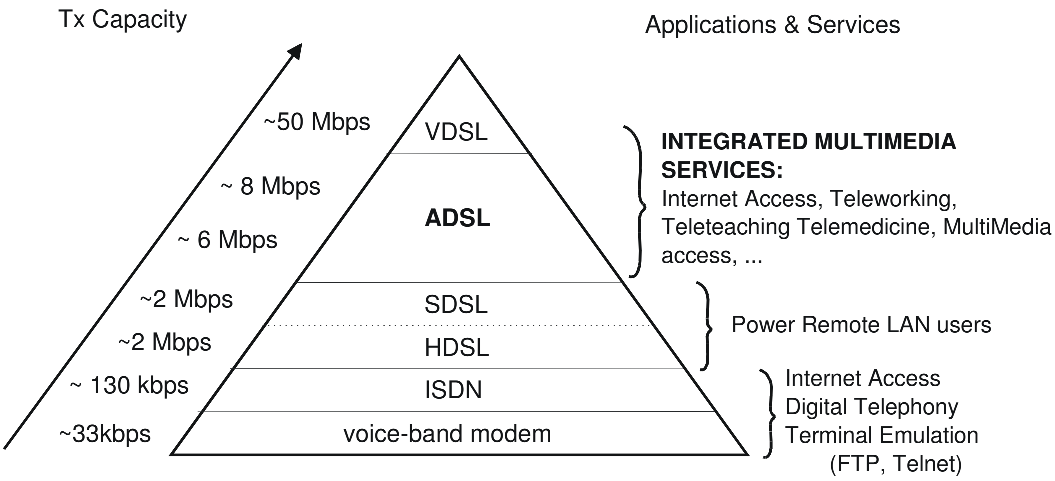
- The cable topology is a tree.
- The “upstream" signals merge in large numbers at the switching centers which causes significant crosstalk by induction, in a place where the signals are already weak due to absorption. On the other hand the "downstream" signals run away from each other, to distant modems, so that cross modulation has much less effect. As a consequence, much higher bit rates can be realized in the "downstream" direction.

VDSL – Very High Data Rate Digital Subscriber Line

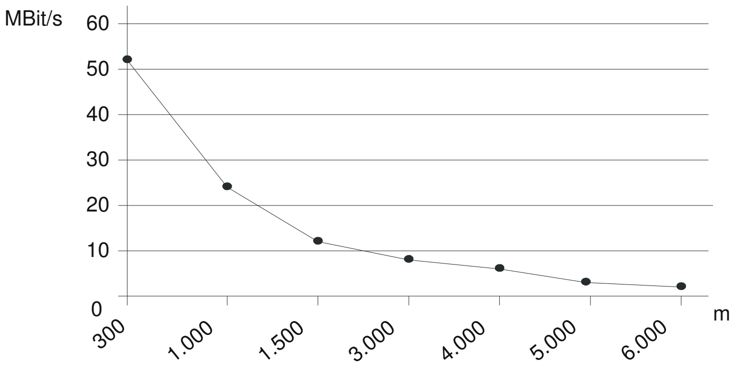


- Duplex transmission with asymmetric or symmetric data rates over a twisted-pair line
- Higher data rates than ADSL, but shorter cable lengths
- Telephone service, ISDN and data transmission simultaneously
- Typical use: next generation of the services provided by ADSL
- no standards yet, currently in discussion and testing

Overview of the xDSL Techniques



Speed vs. Distance in xDSL



Copper factors

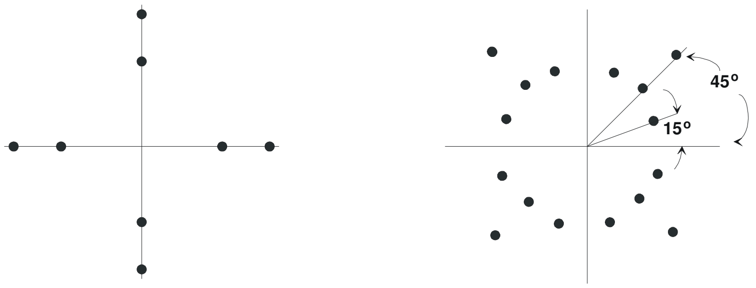
- Absorption is frequency-dependent
- phase shift is frequency-dependent
- cross modulation

Other factors

- impulse noise
- antenna effect for radio frequencies
- white noise (“thermal noise“)

Modulation Techniques for ADSL

Basis: QAM (Quadrature Amplitude Modulation). This is a combination of amplitude and phase modulation. Each "data point" in the diagram corresponds to an encoded bit combination.

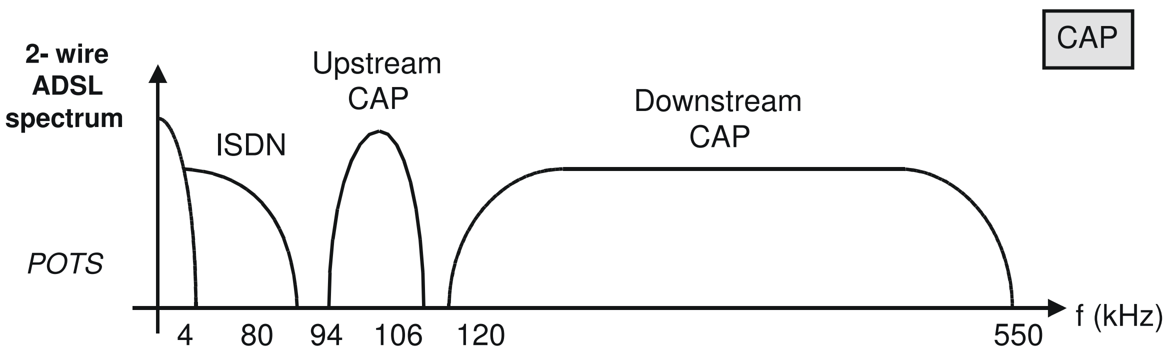


(a) (b)

a) 2 amplitudes, 4 rapid phase change angles, 8 data points, thus 3 bits transmitted per baud. Used in V.32 modems.

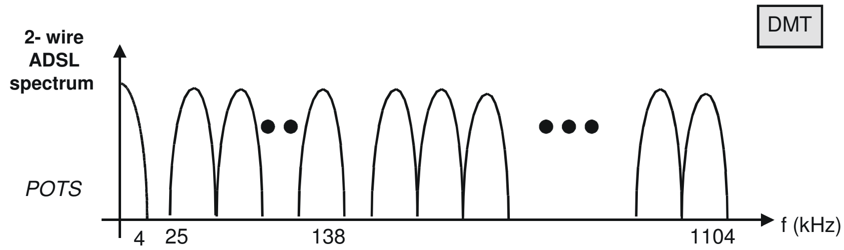
b) 16 data points, thus 4 bits per baud (used in V.32 modems for 9600 bit/s at 2400 baud)

CAP - Carrierless Amplitude/Phase Modulation



- a variant of the quadrature amplitude modulation
- computation of the combined signal by a digital signal processor
- use of one carrier frequency only
- telephone service and ISDN lie below the CAP frequency spectrum

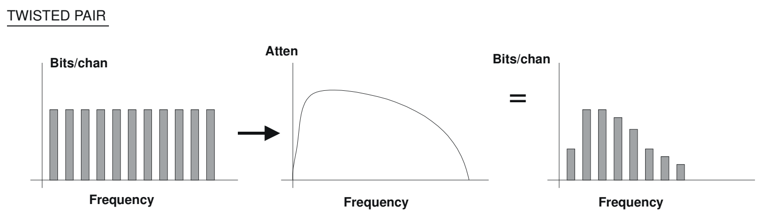
DMT - Discrete Multitone Modulation

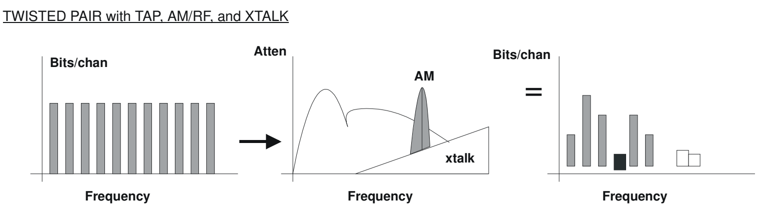


- Basically a frequency multiplexing (FDM) with separate bit rate adaptation per carrier frequency
- Frequency spectrum: the range from 26 kHz to 1.1 MHz is subdivided into 256 subcarrier frequencies, each 4 kHz wide
- Each channel transmits up to 60 kbit/s.
- The telephone service and/or ISDN service lie below the DMT frequencies for data transmission. A "splitter" at both ends of the line adds it in resp. filters it out.
- ADSL is an ANSI standard (T1.413), now also a European ETSI standard.

Automatic Bit Rate Adaptation With DMT

DMT adapts to every line condition





With ADSL the bit rate is adapted dynamically to the length and the quality of the transmission wire. With DMT the modems continuously measure the transmission quality of **each individual channel** (each carrier frequency) and adapt the bit rate in accordance with those current characteristics.