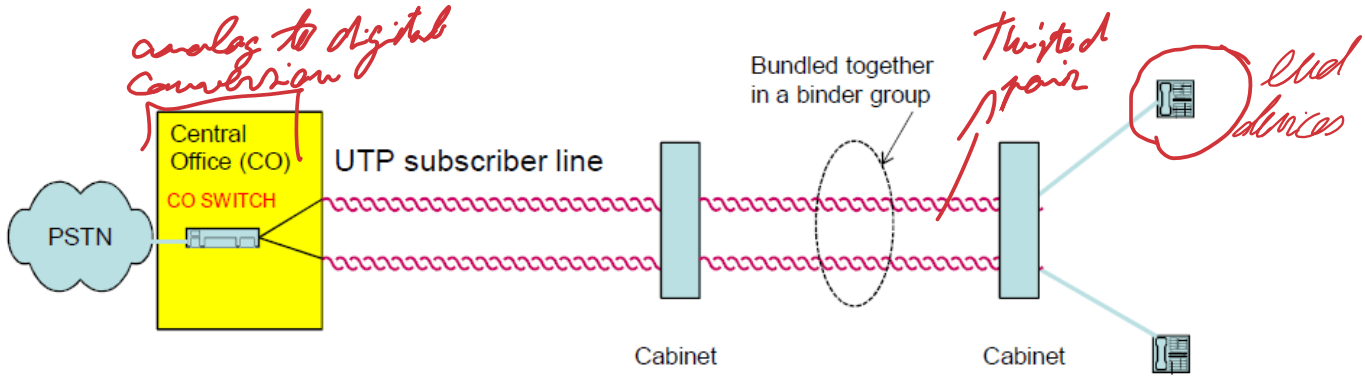
5. xDSL Family

Is a family of technologies that provide digital data transmission over the wires of a local telephone network.

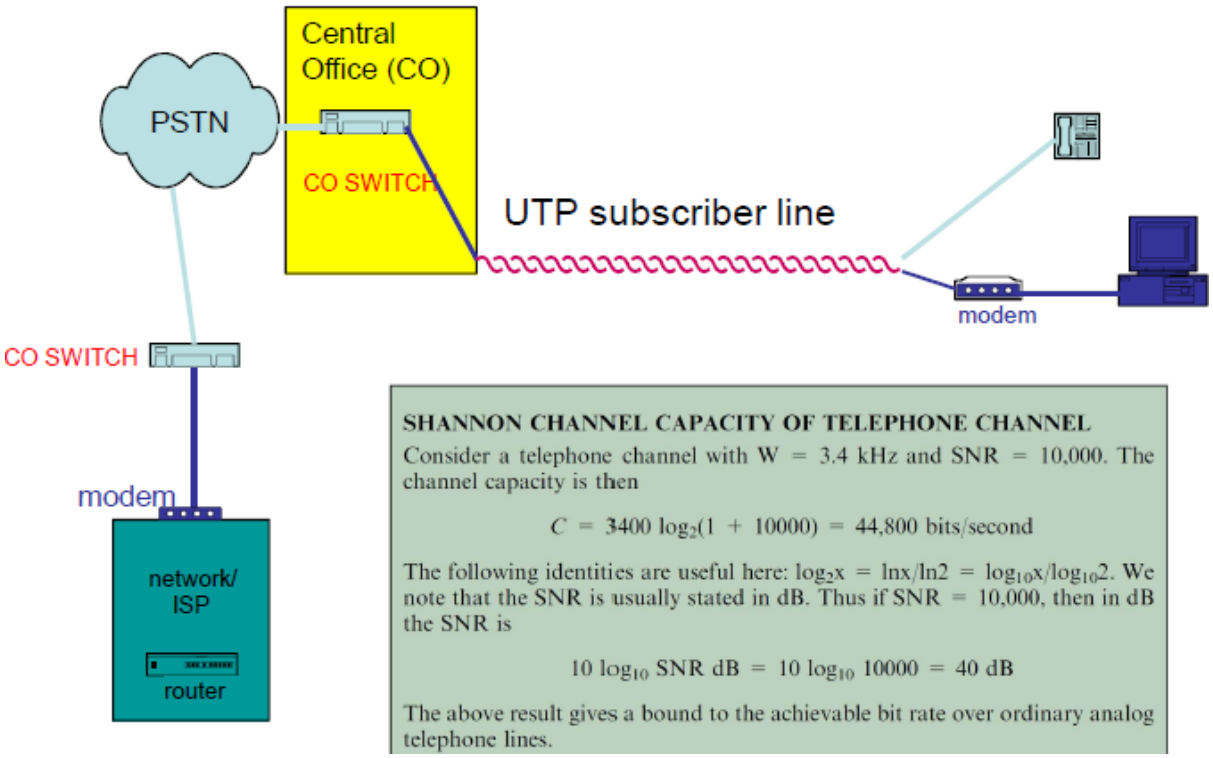
- Why?

Growing requests, presence of copper wires worldwide.

ISDN DSL was initiated in 80s (160 kbit/s) then arose asymmetry interest (more download). For ADSL placed wideband digital signal above the existing baseband analog voice signal.



Analog modems



SHANNON CHANNEL CAPACITY OF TELEPHONE CHANNEL

Consider a telephone channel with W = 3.4 kHz and SNR = 10,000. The channel capacity is then

$$C = 3400 \log_2(1 + 10000) = 44{,}800 \text{ bits/second}$$

The following identities are useful here: $\log_2 x = \ln x / \ln 2 = \log_{10} x / \log_{10} 2$. We note that the SNR is usually stated in dB. Thus if SNR = 10,000, then in dB the SNR is

$$10 \log_{10} \text{SNR dB} = 10 \log_{10} 10000 = 40 \text{ dB}$$

The above result gives a bound to the achievable bit rate over ordinary analog telephone lines.

5.1 HDSL (High Data Rate DSL)

Most widely deployed

Provide leased-line T1 service

2B1Q (2 binary, 1 quaternary)

Used in cellular networks

Drawbacks: no analog voice, crosstalk for symmetric

5.2 ADSL (Asymmetric DSL)

Born for distribution of video on demand (failed)

Every local loop is exclusive for the subscriber, with no contention

Volume of data flow is greater in one direction than the other

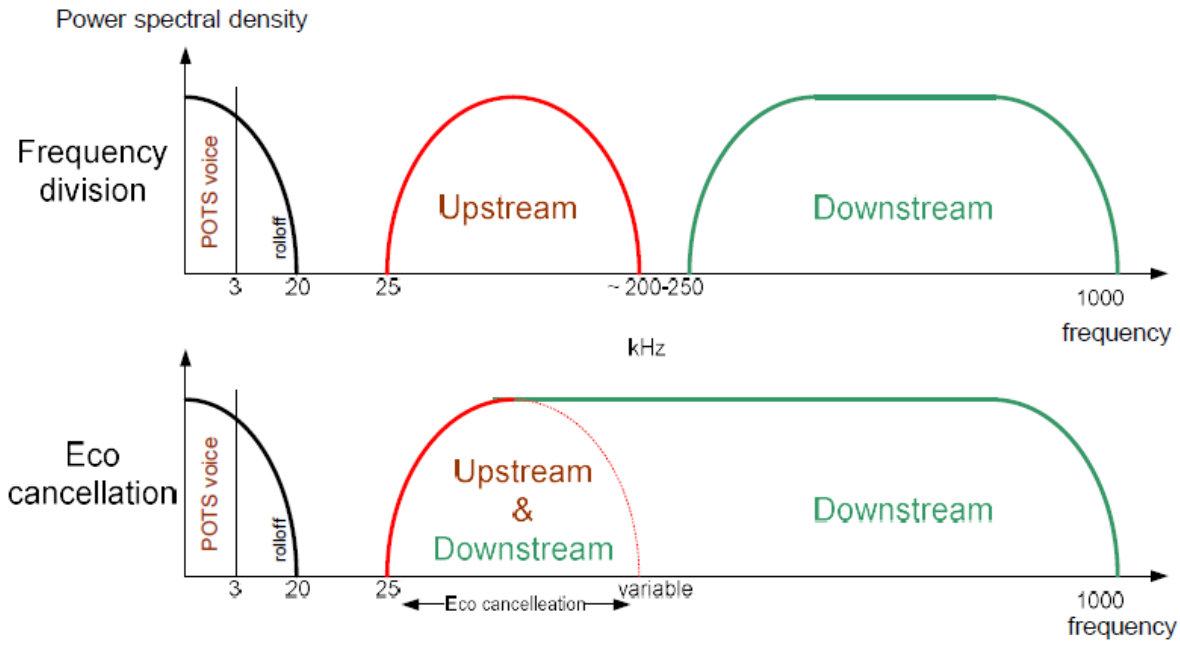
Providers market ADSL for consumers to connect in passive mode

Speed: from 8 Mbit/s to 24 Mbit/s

5.2.1 Frequency bands

Two separated band:

- upstream to communicate with CO (25.875 kHz to 138 kHz)
- downstream from CO to user (138 kHz to 1104 kHz)



Eco cancellation: cancel the return of what has been sent

5.2.2 Cross-talks

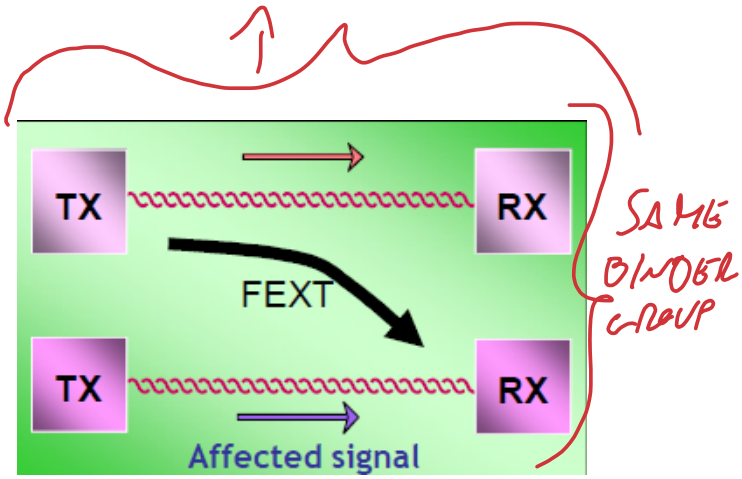
Two kinds depending on power spectral density, number of wires and overlapping of bandwidths:

Exist only if we have high frequency at the same time

1. **FEXT (far-end cross-talk)**

between opposite sides of the cable, signals travel the entire length of the channel. Signal on other pairs can create interferences;

to reduce: less than a dozen of twisted pairs.

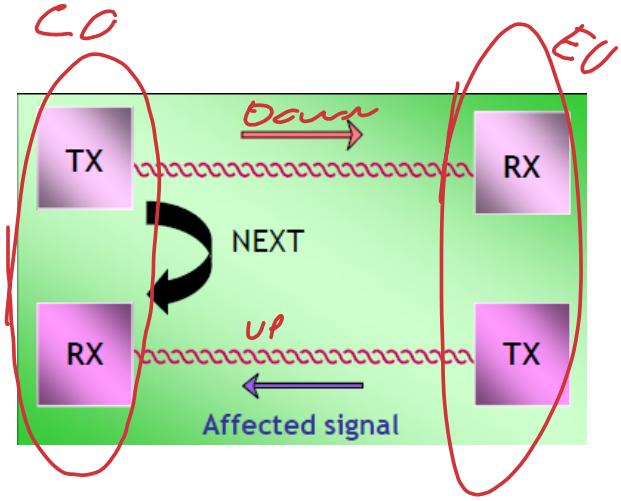


2. **NEXT (near-end cross-talk)**

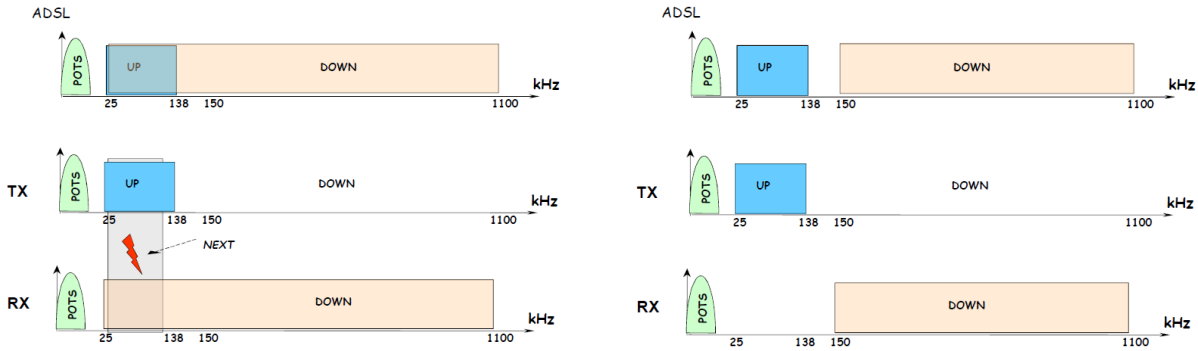
between transmitter and receiver on the same side of the cable.

Receiver's signal are softer than transmitter's one, so can found interference.

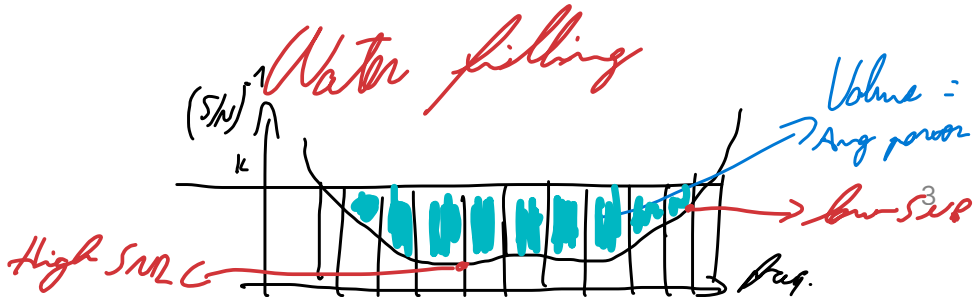
NEXT is a reason of the frequency division.



It is necessary to install frequency filters to avoid interferences



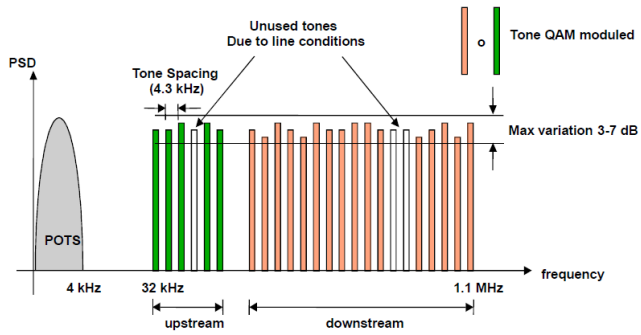
5.2.3 Modulations



- CAP (Carrier-less Amplitude/Phase modulation)

Is a version of QAM; incoming data modulates a single carrier that is then transmitted down a telephone line (carrier itself is suppressed).

- DMT (Discrete Multi-Tone): 256 QAM64 sub-bands of 4.3125 kHz (total 1024 MHz)



Principle: divide ADSL bandwidth in very small subchannels, carriers used in the centre to transmit data independently in each subcarrier.

DMT can dynamically adapt the data rate to the line conditions:
- Maximum upstream: 1.5 Mbit/s
- Maximum bandwidth: 14.9 Mbit/s

Spectral efficiency
Depends on SNR

- **CAP and DMT**

CAP requires Adaptive equalizer since noise varies

DMT has speed advantage over CAP

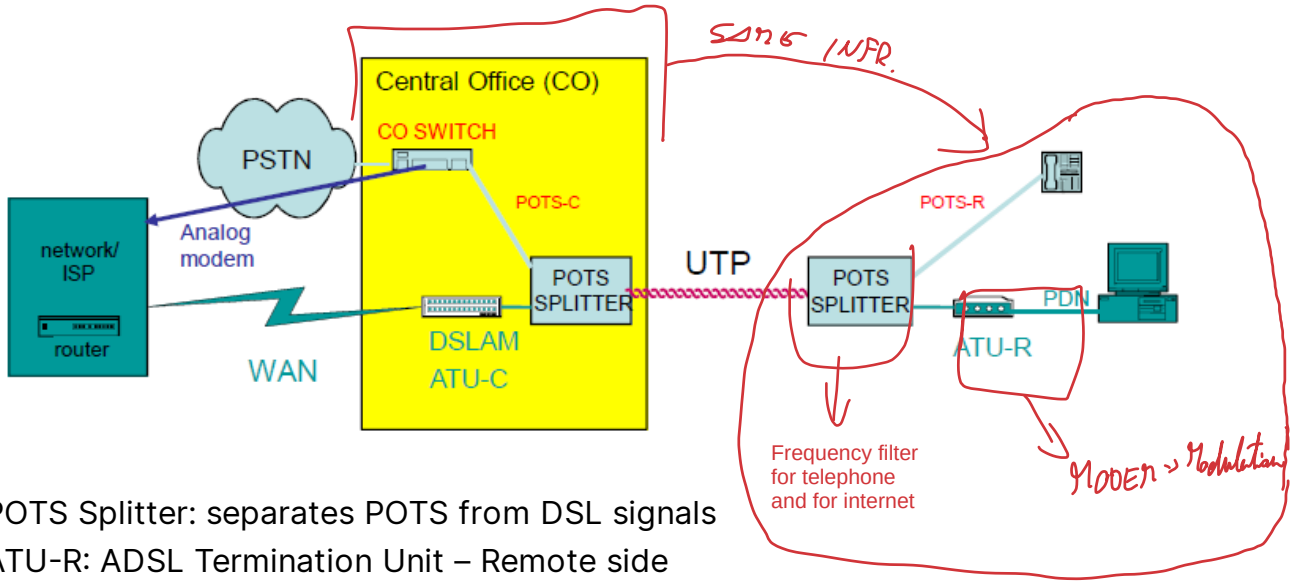
	CAP	DMT
Power consumption	Lower, fewer gates	Higher peak/average, but will likely narrow gap
Forward carriers	1	256
Return carriers	1	32
Increment	320 Kb	32 Kb
Adaptive equalizers	Needed	None
Licensing	Globespan	Many sources
Standardization	In process	ITU and ANSI
Key competitors	Globespan, Paradyne, Westell	Conexant, Cisco, Alcatel, Amati (now Texas Instruments), Westell, Efficient Networks

5.2.4 ADSL Architecture

• Content providers transmit information to the CO over the A9 interface (not shown) and the A4 interface.

• ATU-C: ADSL Transmission Unit – CO

– Embedded in a line card, One ATU-C per subscriber

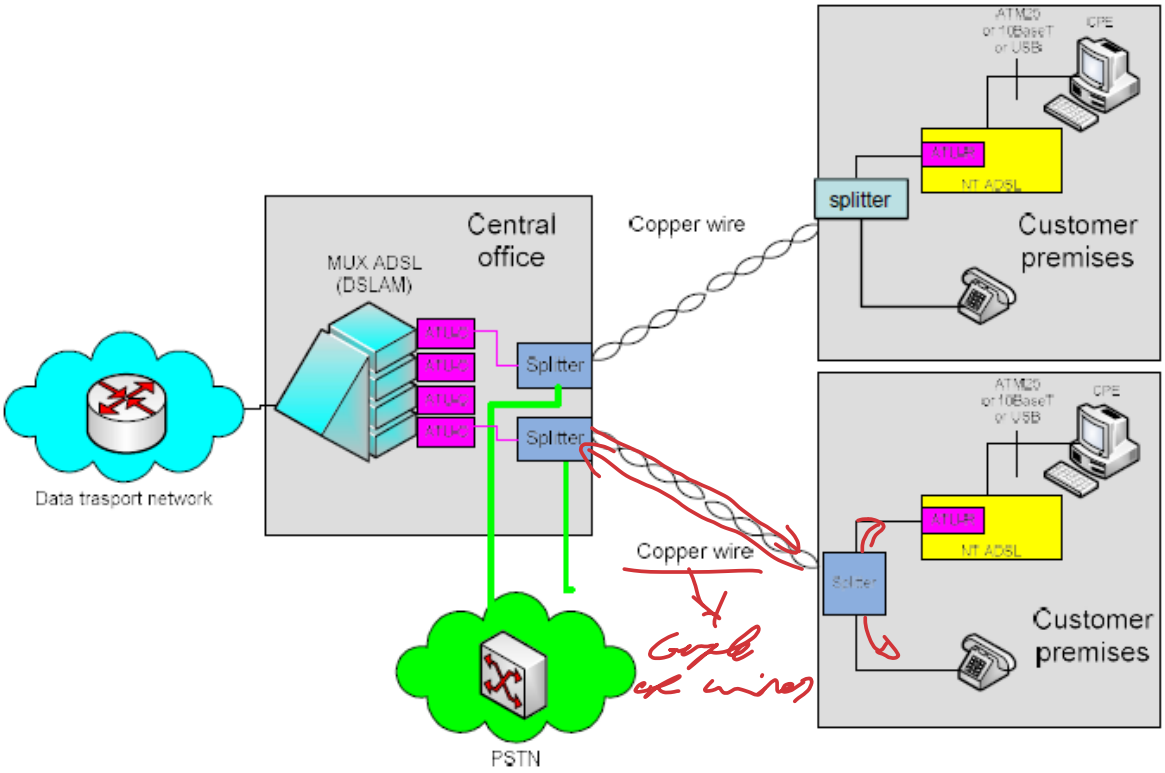


POTS Splitter: separates POTS from DSL signals

ATU-R: ADSL Termination Unit – Remote side

ATU-C: ADSL Termination Unit Central office side

DSLAM: DSL Access Multiplexer



Two services: transparent access to legacy voice service, high-speed

Frequencies above the voice band are for high-speed data service to get to the ATU-R

-ATU-R: ADSL Transmission Unit – Remote: Supports shared-home topology
-ATU-C: ADSL Transmission Unit – Central: ATU-C and ATU-R engage in negotiations between the home and the CO; Keep management statistics, such as SNR, packet counts.
-POTS splitter (PS): A low-pass/high-pass filter

- **ATU-C & R operations:**

1. physical layer
2. frequency allocation
3. echo cancellation
4. Rate adaption

-DSL Access Multiplexer (DSLAM)

House ATU-Cs

mux e demux traffic

negotiate line speed

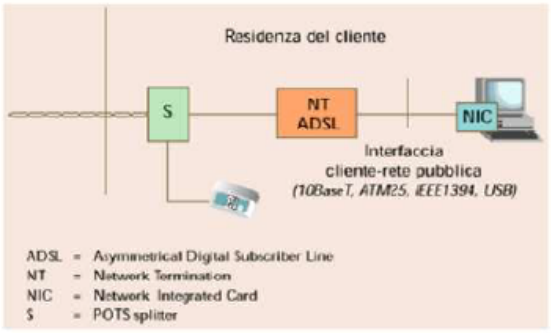
management platform

located in CO

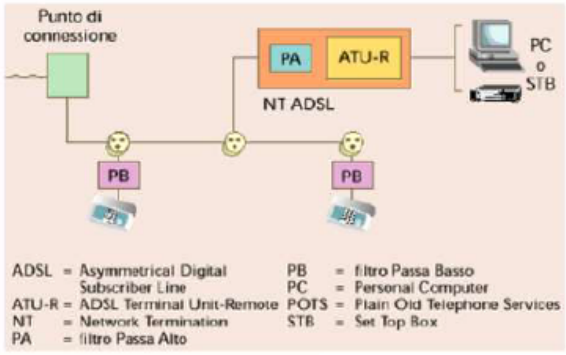
-Splitter

Separates POTS from DSL; works as a multiband filter

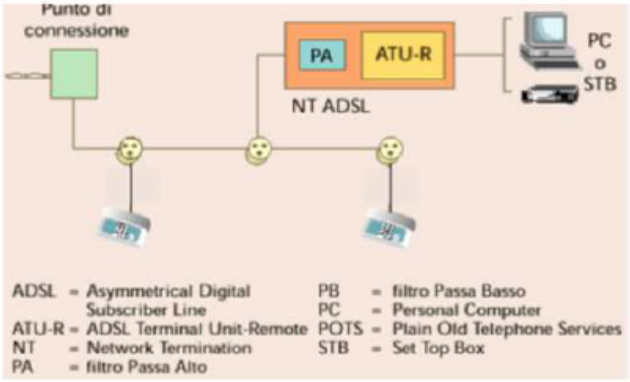
- Splittered



- Distributed splitters

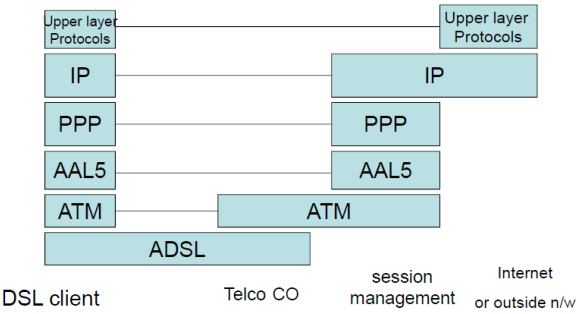


Splitterless (g.lite)

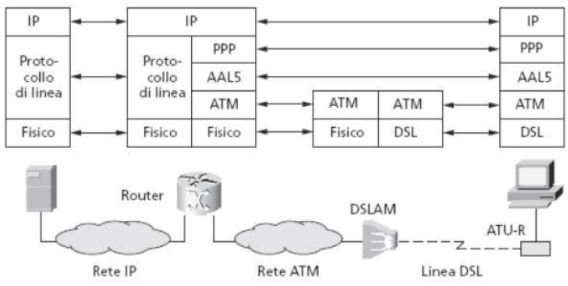


47

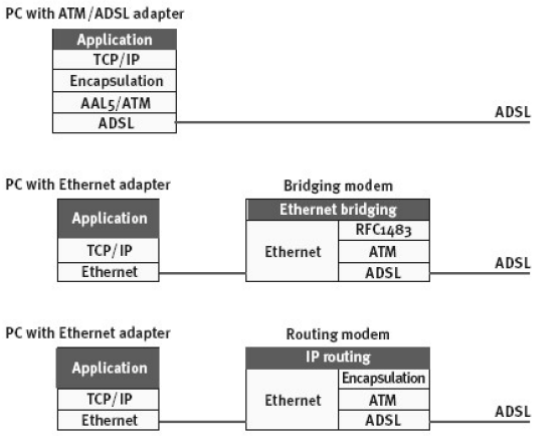
ADSL Protocol Architecture



ADSL Architecture – network side



ADSL Architecture – user side



5.2.5 ADSL Principles of Operation

1. Bit rate negotiation
2. Autoconfiguration

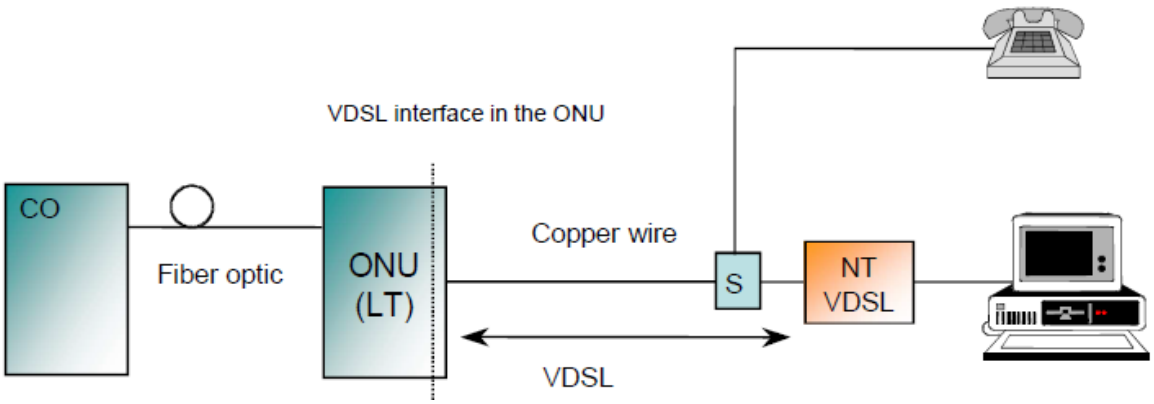
Benefits of rate adaption: increase with good phone wire, cover greater distances

5.3 VDSL (Very high data rate DSL)

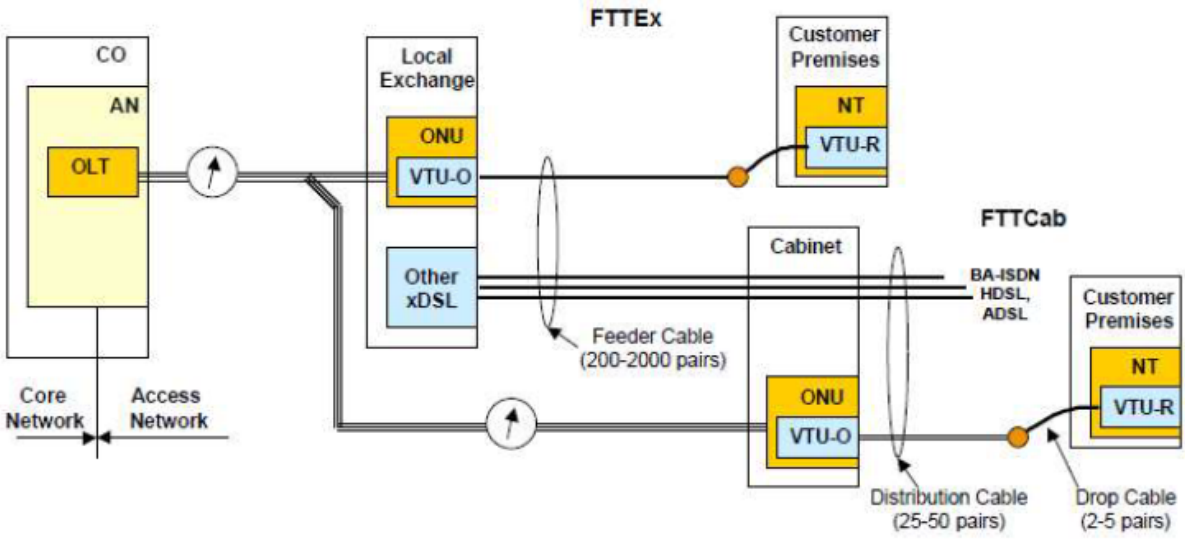
VDSL pushes to the limit what can be transmitted over 24-gauge copper pairs.

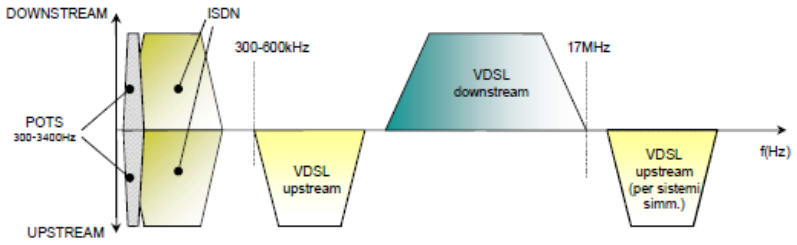
Key for speed: decrease distances.

Architecture

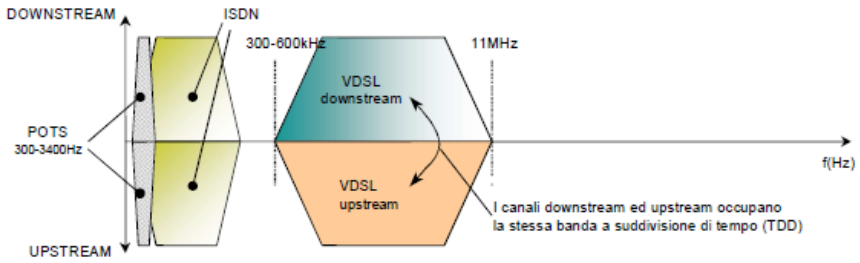


ONU: Optical Network Unit
S: POTS splitter
NT VDSL: Network termination VDSL





FDD solution



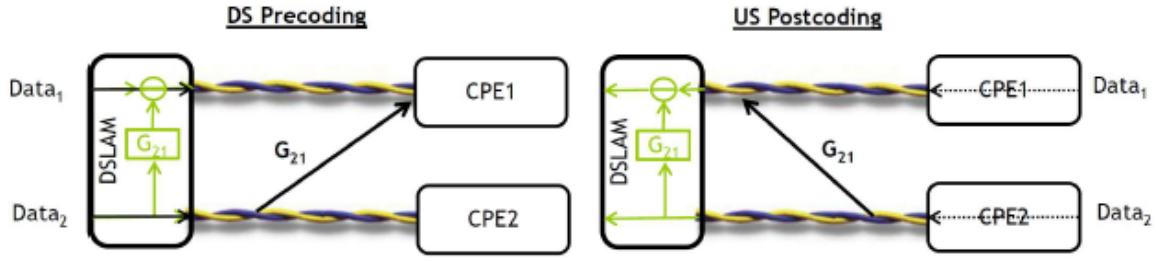
TDD solution

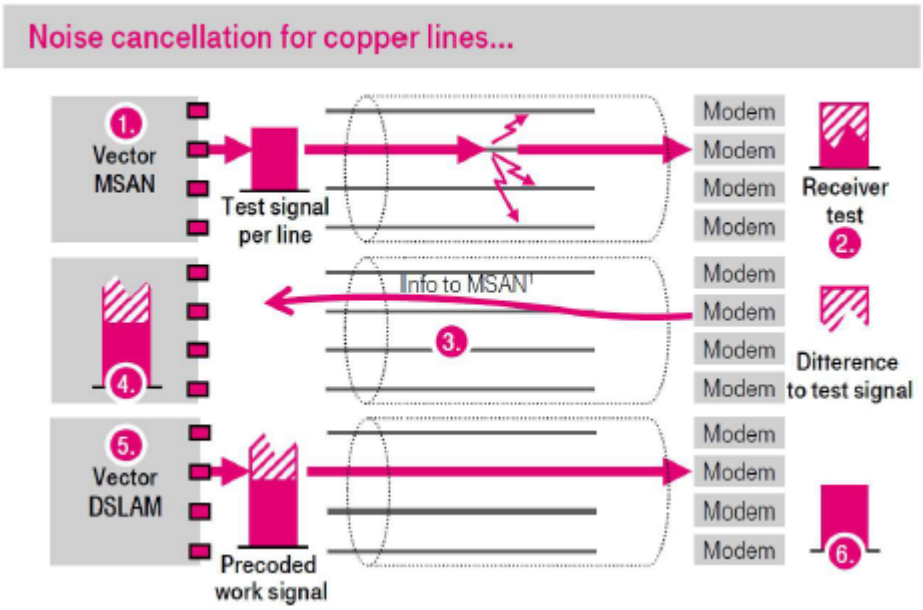
	Modulation Scheme	Downstream Bit Rate	Upstream Bit Rate	POTS Support	Comments
ISDN	2B1Q	64 Kbps, 128 Kbps	64 Kbps, 128 Kbps	No	ANSI T1.601 Uses 4B3Q coding in some European countries
IDSL	2B1Q	128 Kbps	128 Kbps	No	Uses ISDN TA
HDSL	2B1Q	Up to 2 Mbps	Up to 2 Mbps	No	Uses four wires; current T1 service
HDSL-2	PAM-16	2 Mbps	2 Mbps	No	Uses two wires; not rate-adaptable
SDSL (ETSI)	2B1Q	2 Mbps	2 Mbps	Yes	Uses two wires; rate adaptable
G.Lite	DMT	2 Mbps	512 Kbps	Yes	ITU G.992.2
ADSL	CAP	1.5 Mbps to 6 Mbps	64 Kbps to 800 Kbps	Yes	Mostly Paradyne
ADSL	DMT	1.5 Mbps to 7 Mbps	64 Kbps to 800 Kbps	Yes	ANSI T1.413
Multiple Virtual Line (MVL)	CAP	768 Kbps	768 Kbps	Yes	Paradyne
One Megabit Modem	QAM	1 Mbps	320 Kbps	Yes	Proprietary to Northern Telecom; resides in Nortel loop carrier system
VDSL	QAM/CAP DMT	12.96 Mbps to 51.84 Mbps	1.5 Mbps to 3 Mbps	Yes	Range of 300 meters for top speeds; ANSI T1.E1.4, ETSI and ITU Study Group 15

5.3.1 VDSL Vectoring

Crosstalk cancelling by injecting an "anti signal" on each crosstalk-impaired line

- Requires full synchro, calculation of the "anti-signals", crosstalk estimating mechanism





5.4 Point to Point Protocol

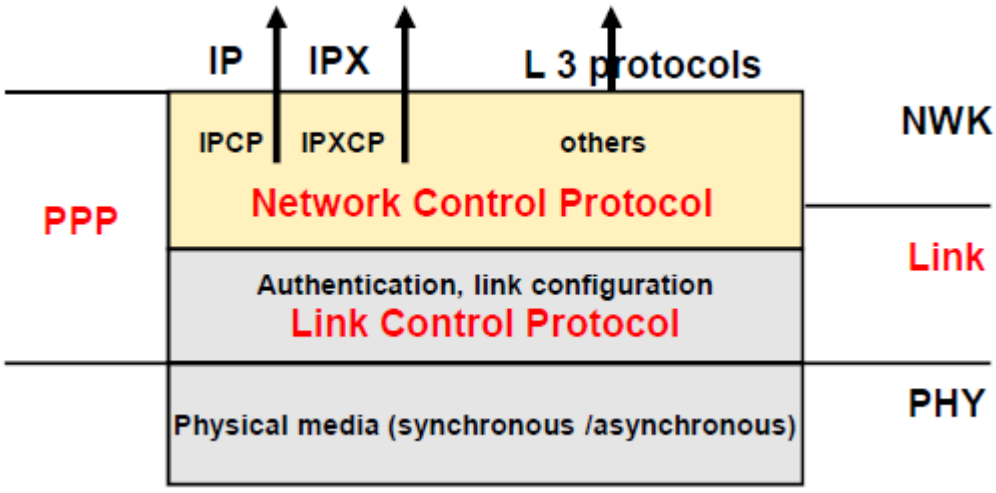
Designed for transporting packets between two peers;

Provides Link Control Protocol (LCP) that negotiates the connection of PPP link and the encapsulation format, authentication and quality monitoring

Key feature: connect directly to CO + authentication, authorization, automatic configuration.

In Europe PPP is encapsulated inside ATM cells (PPPoA)

5.4.1 Protocol architecture

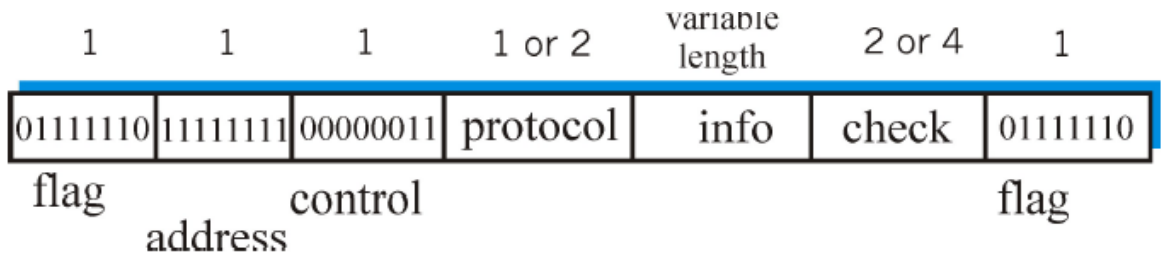


LCP: Establishment, control and termination of the link

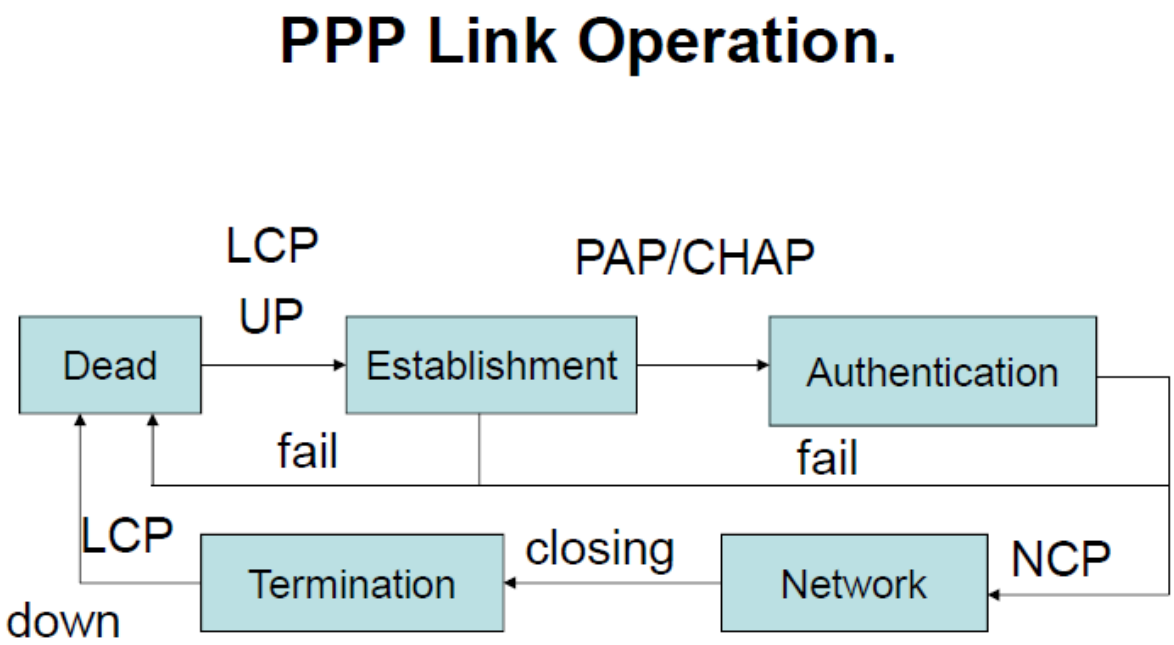
NCP: configure network layers

5.4.2 Encapsulation

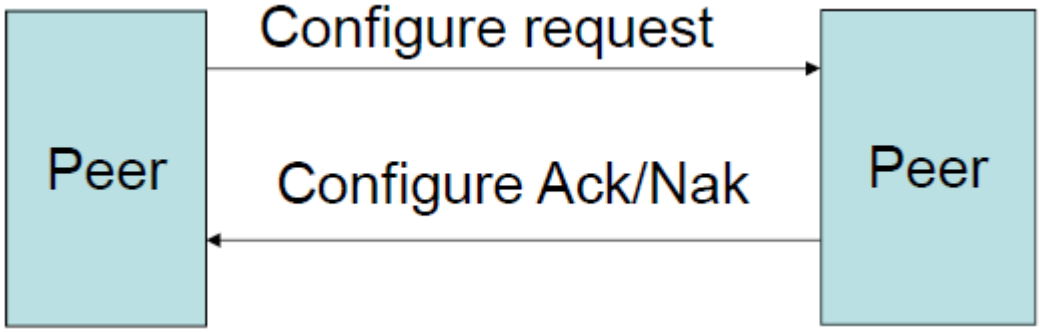
The protocol field identifies the datagram encapsulated in info field (max 1500 octets)



5.4.3 Link



Link Establishment Process

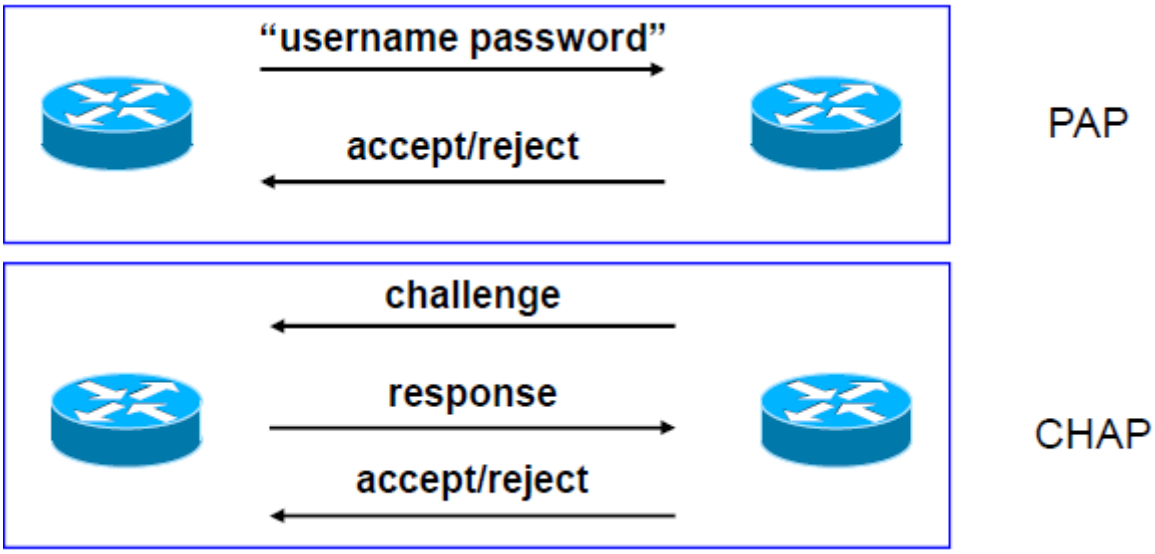


1. send configure-request message
2. request is responded with configure-ack if accepted
3. configure-Nak if not accepted and suggests an acceptable negotiation.

5.4.4 Authentication

Uses Password Authentication Protocol (PAP) or Challenge Handshake Authentication Protocol (CHAP).

CHAP uses a one-way hashing algorithm and is more secure than PAP



Some References

http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/adsl.htm

http://www.adsl.com

Book: Balaji Kumar, Padmanand Warrier "XDSL Architecture", Publisher: ***McGraw-Hill*** Companies (October 25, 1999)

BooK: Maurice Gagnaire "Broadband Local Loops for High-Speed Internet Access" (Artech House Telecommunications Library) (2003)

An Overview of G.993.5 Vectoring https://www.broadband-forum.org/download/MR-257_Issue-2.pdf