02 - Infastructure xDLS

02_Infrastructures_XDSL.pdf

xDSL family

DSL is a famility os technologies that provided digital data transmission over the wires of a local telephone network (ADSL, SDSL, VDSL).

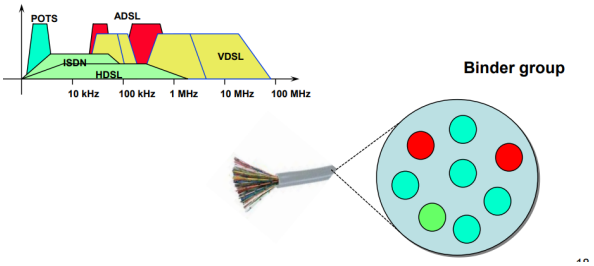
Different versione of DSL vary for speed and distance, symmetry, support for POTS (Plain Ordinary Telephone Service), etc

- HDSL (High Data Rate DSL): most widely deployed form of DSL, use in cellular telephone buildouts

    - no predisposition for analog voice and has crosstalsk in both end → can't do voice call
- ADSL (Asymmetric DSL): mainly for residential use. it provide for passive transmission of analog voice service. With ADSL the exchange of data is greater in one direction than the other one. Due to that it make it perfect for "downloading" so using for web navigation, streaming etc
    - Standard ADSL can deliver up to 8 Mbit/s to customers over 2km with a twisted pair copper wait. Latest standar instead (ADSL2+) can od it up to 24Mbit/s depending by the distance of central office

Crosstalk: in italian "diafonia" which is the phenomena when there is noise due to two close cables.

In the picture we can see that wires sharing same cable intefere eachother



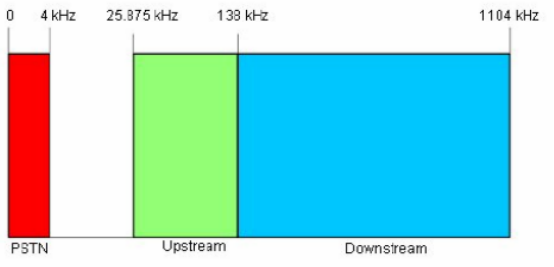
High frequency are associated to higher speed and precision but lower wave lenght. Natural obstacles can be a problem

Low frequency are associated to lower speed but higher wave lenght. Natural obstacles should not be a big problem

ADSL

ADSL use two separate frequency band where for upstream (client to central office) and downstream (central office to client).

PSTN (Public Switched Telehpone Network) its the traditional telephone network used for voice communication (only for tradional voice call)



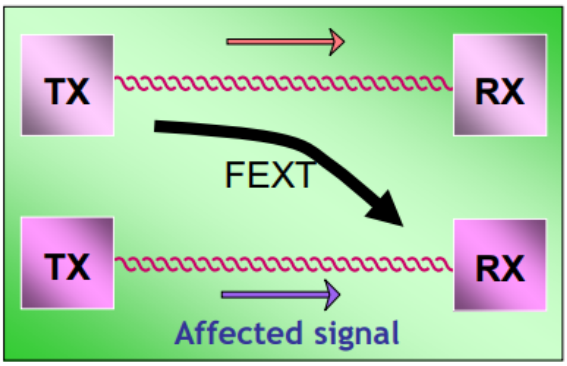
Cross-talks

Cross-talks: interference between one cable to another one

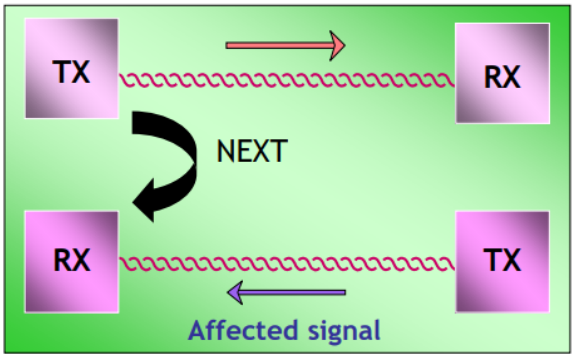
Exist two kind of cross-talks affecting ADSL: Far-End cross-talk (FEXT) and Near-End cross-talk (NEXT) which depend on the power of spectral density of transmitted signal, number of twisted pair in the same cable, overlapping bandwidth of the useful signal nad the inferring ones.

This phenomenon usually increase with frequency.

FEXT is the cross-talk between transmitted and a reciver placed on opposite side of cable. Which short cable this phenomenon is not too strong and to reduce this type of noise, a cable usually doesn't contain more thant a dozen twisted pair of wires



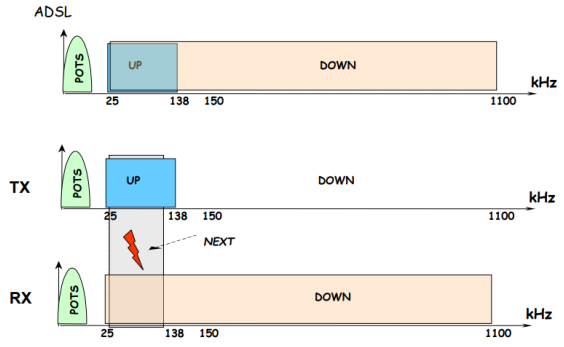
NEXT is the cross-talk between transmitted and receiver placed on the same side of the cable. Receiver's signal are softer than transmitter one because they come from far (the signal encounter interference along its voyage on the cable). This type of cross-talks is one of the reason for the division in upstream and downstream in ADSL. Infact with upstream and downstream overlap, they already created a NEXT, so separing it can attenuate this cross-talks

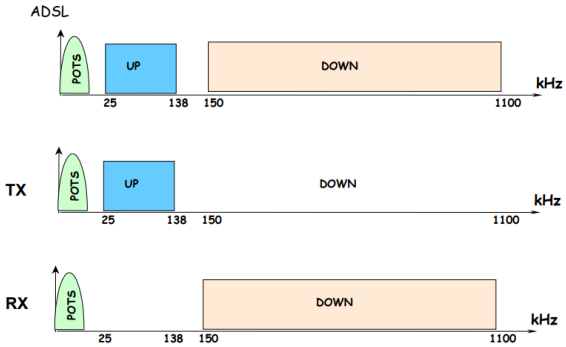


Filtering: splitters

Splitters are filters for frequency and they are used to avoid intereference between services (e.g. voice and ADSL service).

When transmission signals (TX) and reception signals (RX) overlap tit is the verified phenomen of eco, or simply intereference, which is called NEXT in this case because two signal mix and disturb eachother





To eliminate this disturbance it is used “eco cancellation” techniques in which reveal part of the overlapped signal and remoed it resulting on a more clear communication

ADSL: Modulations

> 💡 Modulation: it is the way in which a signal is incorporated in a carrier signal (segnale portante). Think to the radio in which it demodule from a 101.1 Mhz frequence to retreive information which have been incoporated on carrier signal.

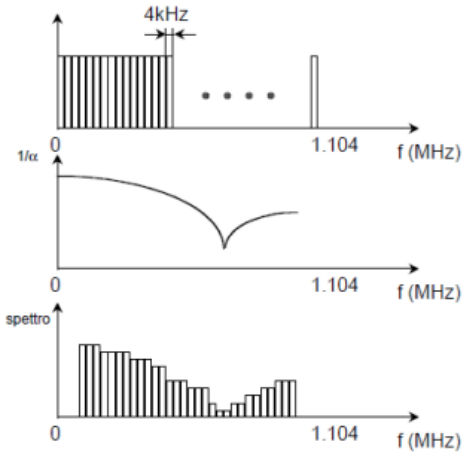
Modulation CAP (Carrier-less Amplitude/Phase)

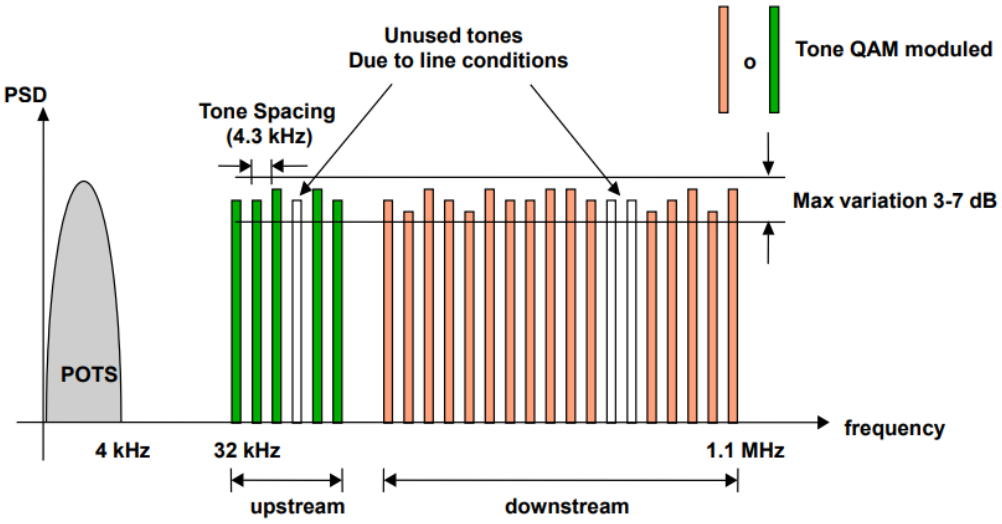
Modulation CAP (Carrier-less Amplitude/Phase) it is a version of QAM in which incoming data modulate on a single carrier later transmitted down a telephone line. The carrier is suppressed before transmission (since contain no information, from here carrier-less) so in the end its only transmitted a residual of modulated signal

Modulation DMT (Discrete Multi-Tone, multicarrier):

Modulation DMT (Discrete Multi-Tone, multicarrier) it is a modulation techniques in which a TX channel in subchannels and every of them is have a part of the original signal. Discrete carrier (tones) are used in the center of each data subchannels.

Given a signal, it can be splitted along all subchannel. We can notice that the total signal is a curve, but if we look ony one piece of this signal, we can fit the piece into a subchannel approximating it to a flat one



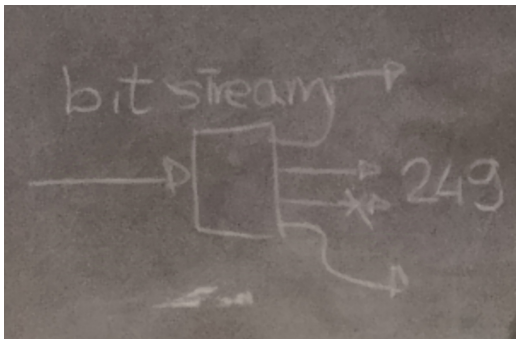


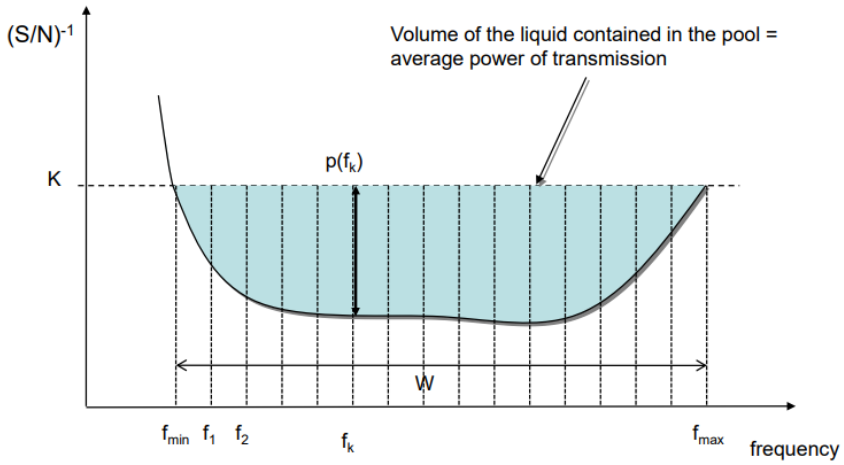
This modulation allow flexibility, infact each subchannel is modulated individually (optimization reason) and whenever a channeld have some interference, it can be ingnored for signal reconstruction. Furthemore it adapt dynamically to data rate of the line.

- theoretical maxium upstream bandwidth
  - $25 \text{ channels} \times 15 \text{ bit/s/Hz/channel} \times 4KHz = 1.5 \ Mbit/s$
- theoretical maxium downstream bandwidth

- $249 \text{ channels} \times 15 \text{ bit/s/Hz/channel} \times 4KHz = 14.9\ Mbit/s$

To measure the signal power of each subcarrier, we can consider “water filling” algorithm (runned by modem which is the TX) where more $p(f_k)$ is depth (so low noise), more volume there is so there is more power in channel k. The DMT algorithm will optimize the transmission based of the noise of each channels to distrubute informations.

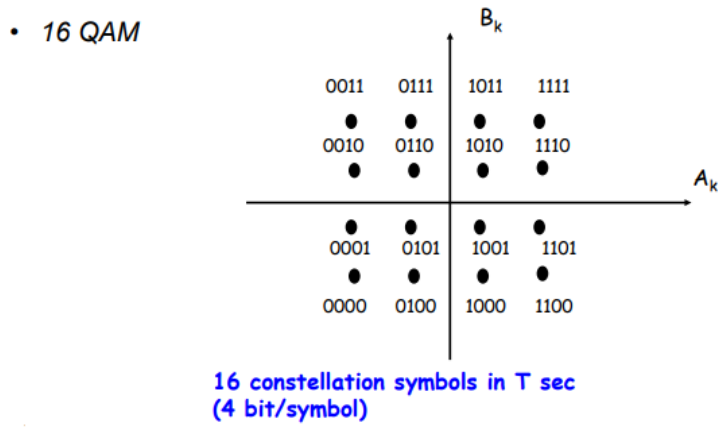




based on depth $p(f_k)$ we can deduce the number of bit per simbol to associate to the QAM costellation used in each subchannels.

Remember that

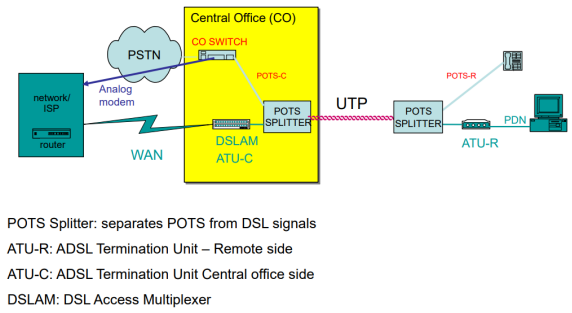
- simbol: are the unit for transmission. number of bit used for transmission
- costellation: it is a graphic representation of all simbols that can be transmitted which a specified QAM modulation

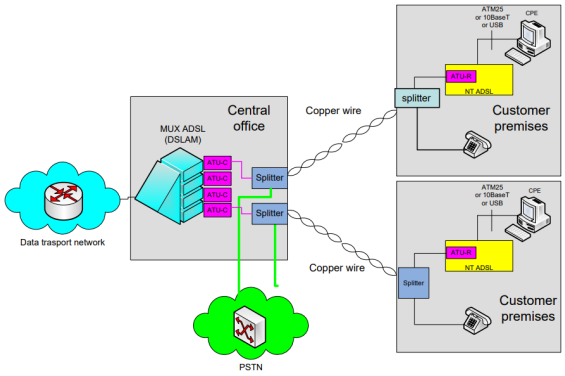


In the end:

- CAP need an adaptive equalizer since noise may vary significanlty
- DMT is faster

ADSL: Architecture





On the right we have a reference model architecture for ADSL, on the left there is a more detailed information about end-to-end.

Some components are:

- Splitters: device used to support the splitting of the signal between users and telephone

- DSLAM: perform multiplexing and send data toward internet

Mainly ADSL offer:

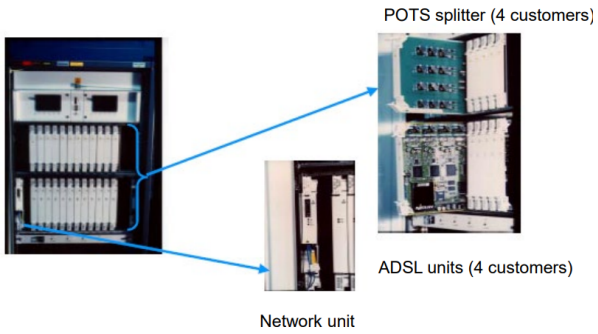
- high-speed digital service
- voice service: transpace acces to legacy voice service. POTS splitters used in home shunt frequencies belowe 3400 Hz to POTS wiring while the one avoce voce voice band are for high-speed data service to get to te ATU-R

ADSL Transmission unit (modem):

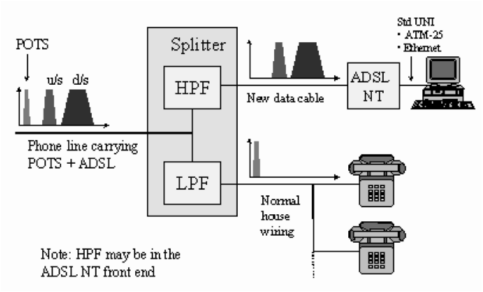
- ATU-R: remote. Supports a multidrop or shared-home topology (modem on house)
- ATU-C: central. Keep managemente statistics such as SNR at phisical layer, packet count in network layer, receive software update (modem on CO)
- POTS splitter (PS): low-pass/high-pass filter
- DSL Access Multiplexer (DSLAM): it is house of a set of ATU-C interfacens, multiplex and demultiplex traffic, negotiate line speed and it is used as a central management plattform. This device is present in CO (Central Office), remote terminal, etc...

Both ATU-R/C engage un physical layer negotiations between home and CO (Central Office) and they can be considered modem. Futhermore their bandwidth is divided in POTS service (belowe 3400 Hz), upstream (25-200 kHz), downstream (25/250-1000 kHz) and perform echo cancellation and rate adaption

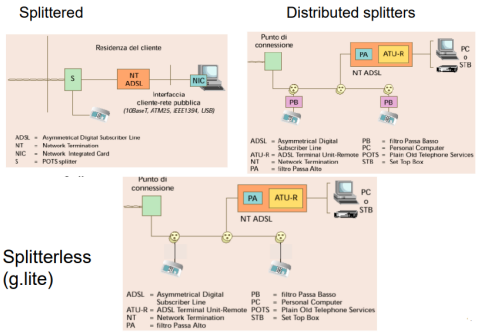
CO elements



In-home configuration



Splitter are filters which separate frequences between POTS and DSL, otherwise they would interfere. They are phisical device which phisically separate lines in different exits for cable (e.g. one for phone, one for model DSL)0



With ADSL we can cover grates distances for service provider and have higher bit rate for customers with food phone wire but there are some challenges like what algorithmo to use and how synchronize information. Furthemore must set a price for a bandwidth.

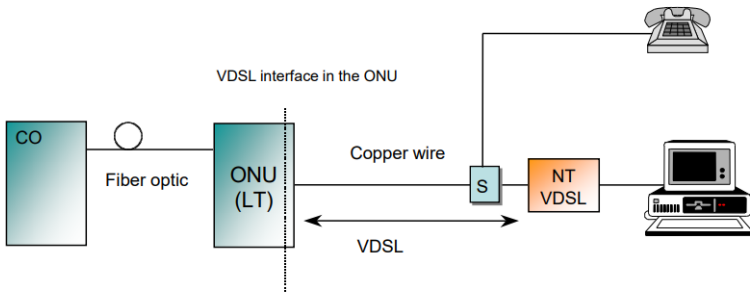
VDSL

VDSL: what is it

VDSL is an high-speed version of DSL and it can be transmitted over 24-gause copper pair: they key is to have shortest possible length of copper wirte to maximize bit rate

Service options:

	Upstream	Downstream	Distance
–	12.96 Mbps	12.96 Mbps	1000 m
–	2 Mbps	25.92 Mbps	1000 m
–	25.84 Mbps	25.92 Mbps	300 m
–	2 Mbps	51.84 Mbps/STS-1	300 m



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

VDSL has less copper and more optic fiber resulting in an higher bit rate becuase CO result to ONU (cabinet).

We have in CO also the Optical Line Terminal (OLT) which transmitt signal in optical domain.

VDSL Vectoring

VDSL Vectoring is a technique of cross-talk cancelling and it solve this problem by injecting an anti-crosstalk signal on every line affected by it: to work correctly it require that all lines are syncronized, all data samples are shared between all line and a good system of cross-talk estimation mechanism.

Do detect interference, I have a test signal which is flat, and the receiver check is is flat when it arrive to him. In this way the receiver understand the amount of

interference and sent a powerful signal (anti-signal)to overcome this interference.

Steps:

1. Genration of test signal: it is performed by Multi-Service Access Node (MSAN).
2. Reception of test signal and analize it: modem compute difference between test signal and received one, later MSAN receive this information on interference of back-signal.
3. Send information to Digital Subscriber Line Access (DSLAM): MSAN compute information of noise and give it to DSLAM and a way that it create a new signal which incorporate information to cancell interference.
4. Send new signal: this new signal (precoded) is later transmitted to users

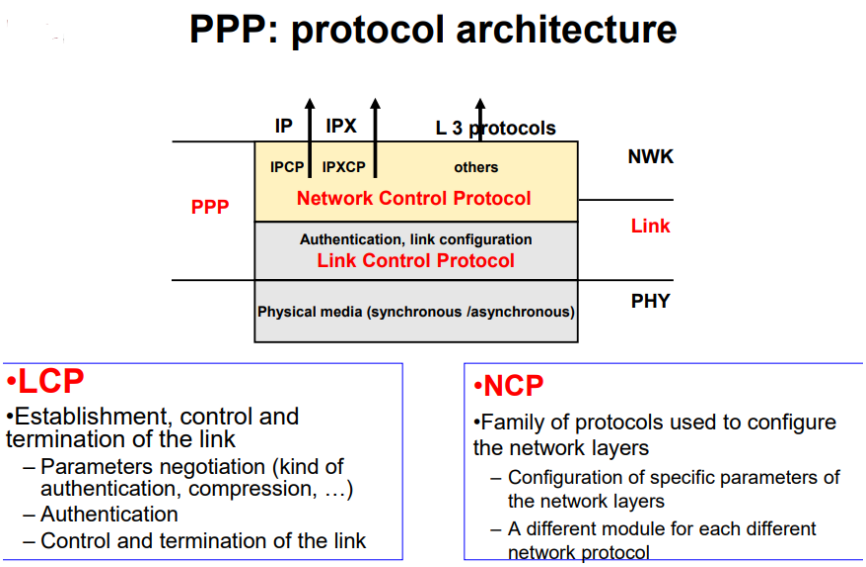
Point to Point Protocol

PPP summary

PPP (Point to Point Protocol) is a protocol used to establish a direct connection between two node on the network (e.g. between pc and an ISP, internet service provider), it is the secondo level layer in OSI model (link layer): it is designed for transport packets and the encapsulation and it is able to do multiplexing so it can handle different transport protocol.

PPP provided a Link Control Protocol (LCP) which negotiate to establish the connection, furthermore this one negotiates the option for encapsulation format, authetication and link quality monitoring.

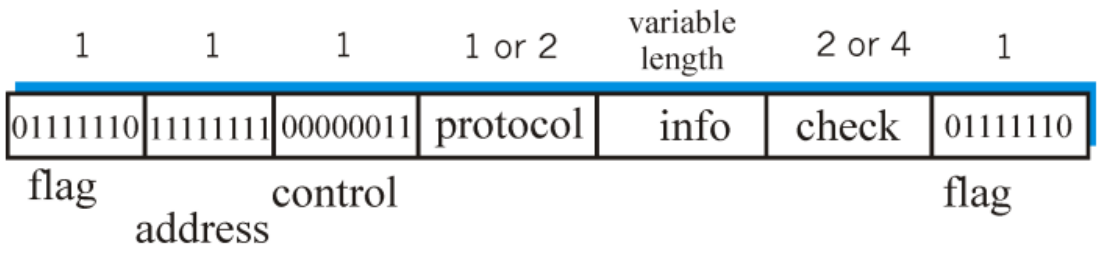
PPP is used together with ADSL to connect user to the CO of its ISP and its important function are authentication, authorization, automatic configuration of network interfaces and DHCP support



Network Control protocol (NPC) work as an adaptation layer.

PPP Encapsulation

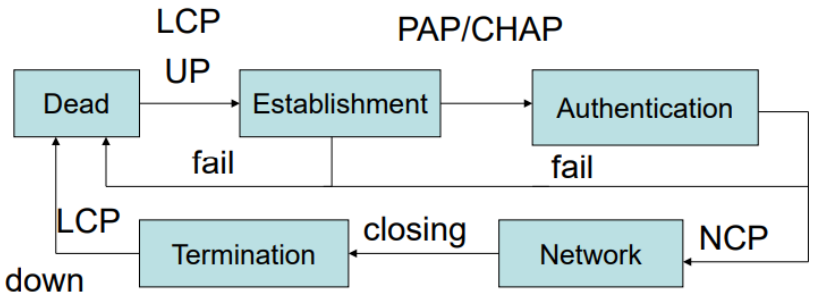
Here we will explain the structure of a PPP frame (Ethernet frame), which is the type of packed transmitted when we are using this protocol (in the image we speak always in term of byte)



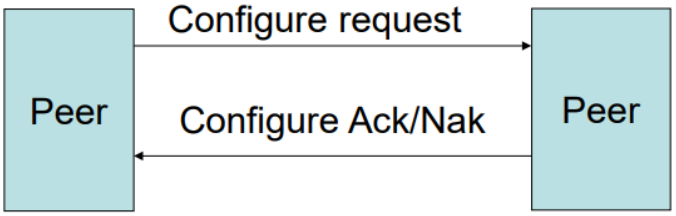
- **Protocol field:** is used to identify the type of datagram (e.g. IP or IPX packet) which have been encapsulated into the PPP frame. Is used by the RX to understannd how must treat the packet once received

- **Information field:** it contain effective data which must be transmitted and it can contain an IP packet or other type of data. Its dimension depend on Maxium Receive Unit (MRU), usually is 1500 byte. If packet is smaller the MRU lenght, it can be added padding
- **Address filed:** dummy field, represent broadcast packet

Link Establishment process

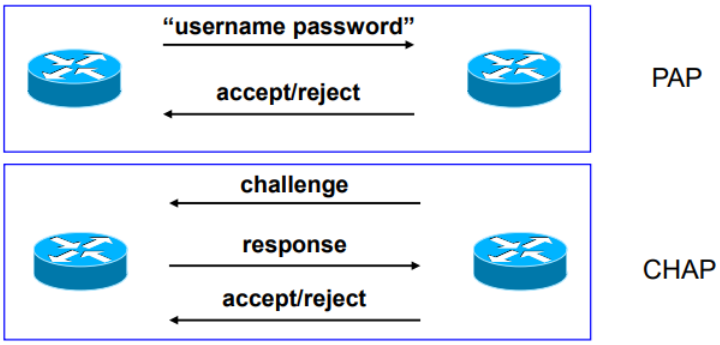


Link establishment phase use LCP: in Link Configuration Option (LCO) we can establish MRU, authetication ad protocol to be used for autheticaion, Protocl Field Compression, link qualitity monitoring, magic number, ...



The configure-request message is to to request a link establishment and contain varius options requested: it request is accepted it respond with Ack, otherwise with Nak

Authentication



Authetication Option use Password Authetication Protocol (PAP) or Challenge Handshake Authentication Protocol (CHAP), it depend by negotiation.

CHAP use one-way hashing algorithm which is know only to the user, to respond to a challenge sent by authenticator. CHAP is more secure then PAP

- PAP: it sent username and password: not secure
- CHAP: server sent a challenge which combine password of a client using an hashing operation. The client sent the result in hash form to the server and if the server match it, it accept it