xDSL

OVERVIEW OF IMPORTANT

DIGITAL SUBSCRIBER LINE TECHNOLOGIES

Peter R. Egli
peteregli.net

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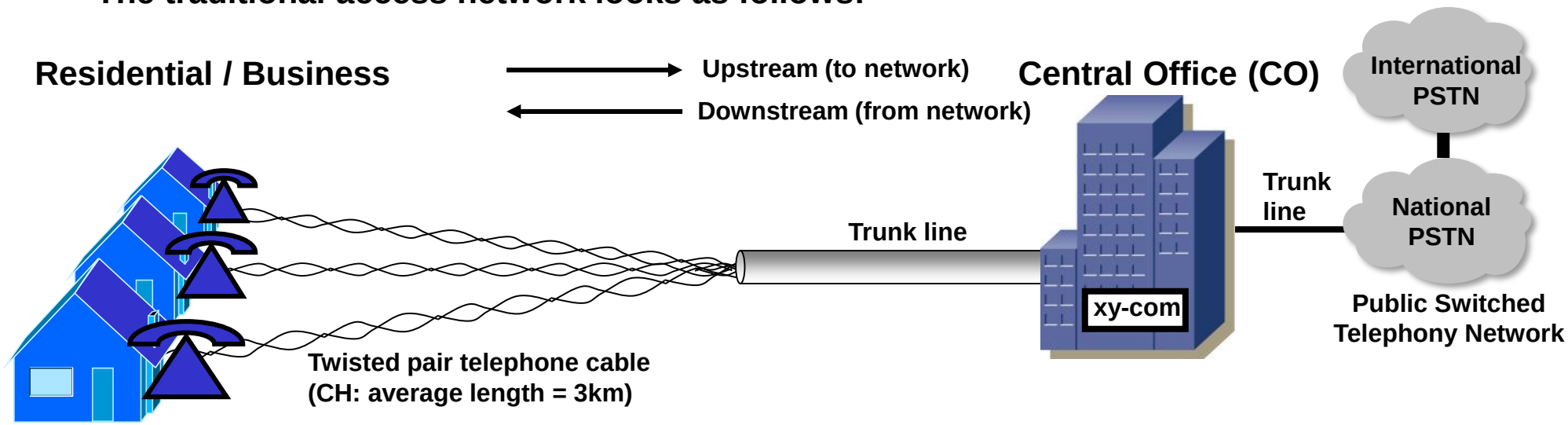
1. What is xDSL?

- xDSL is a collective term for transmission technologies for the access / local loop / last mile (sometimes also called ‚first mile‘).
- The traditional access network looks as follows:



- Digital modem (modulation / demodulation) technique is used to put bits onto traditional telephone wire lines (2 wires, 4 wires).
- The ‚x‘ stands for many different flavors of DSL (different modulation techniques).
- xDSL is on OSI layer 1 (physical medium).
- The different xDSL techniques usually use a specific layer 2 framing protocol (e.g. ADSL is usually used in CH on layer 1 together with ATM on layer 2).
- xDSL is commercially very attractive since it offers high bandwidth on traditional (already installed) telephone wire (installation is cheap compared to other technologies like wireless).
- Central office: Termination of access lines / local loop, connection to PSTN (CH: ~900 COs).

2. xDSL technology overview (1/2)

Main characteristics:

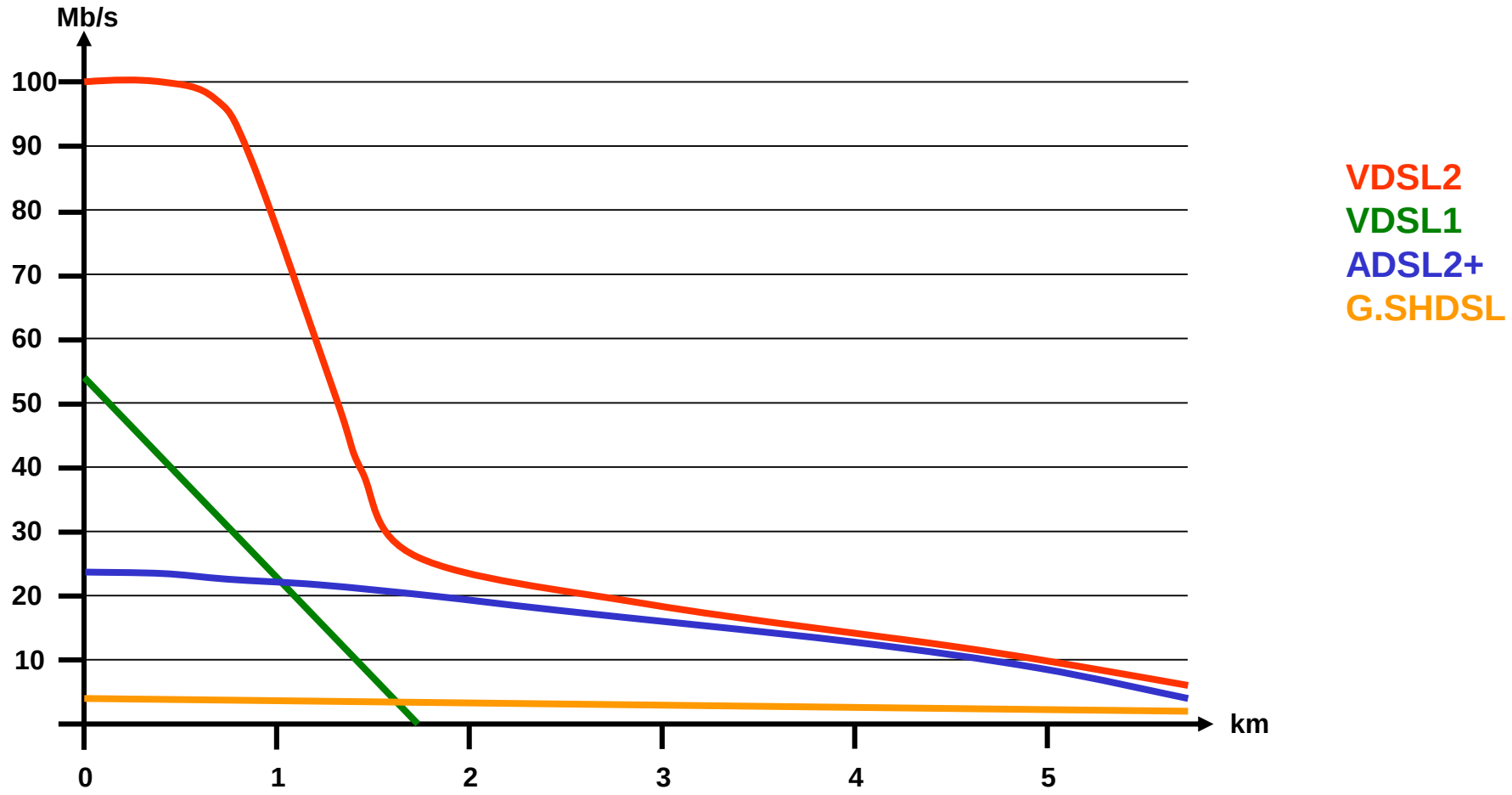
Name	Standard	Speed	Wires	Mode	Distance	Comment
ADSL (G.dmt)	G.992.1	1.5 - 9Mbps DS 16 - 640Kbps US	Single pair	Downstream & upstream	6km	Needs splitter
ADSL2+	G.992.5	...24Mbps DS ...3.3Mbps US	Single pair	Downstream & upstream	6km	Needs splitter
G.Lite=DSL Lite	G.992.2	1Mbps DS 128Kbps US	Single pair	Downstream & upstream	6km	Does not need splitter
HDSL		1.54Mbps	Two pairs	Duplex (symmetric)	5km	-
HDSL-II	G.991.1	1.54Mbps	Single pair	Duplex (symmetric)	5km	-
IDSL	I.430	144Kbps	Single pair	Duplex (symmetric)	6km	-
RADSL		1 - 7Mbps 128Kbps - 1.5Mbps	Single pair	Downstream & upstream	6km	Automatically adapts bit rate to line
G.SHDSL	G.991.2	192Kbps - 2.3Mbps	Single pair	Duplex (symmetric)	3.3km	No POTS/ISDN
VDSL1	G.993.1	13 - 52Mbps 1.5 - 2.3Mbps	Single pair	Downstream & upstream	1.2km	No POTS/ISDN
VDSL2	G.993.2	...100Mbps ...50Mbps	Single pair	Downstream & upstream	1.5km	No POTS/ISDN

- ADSL Asymmetric Digital Subscriber Line suited for home users (asymmetric traffic pattern).
- G.SHDSL Symmetrical High Bitrate Digital Subscriber Line is suited for businesses with higher and symmetric bandwidth demand.
- VDSL Very High Datarate Digitial Subscriber Line is popular for very high bandwidth over short distances demands (connections between/within buildings).

2. xDSL technology overview (2/2)

Speed versus distance:

Distance must be traded off against bandwidth (the higher the bandwidth the lower the range).

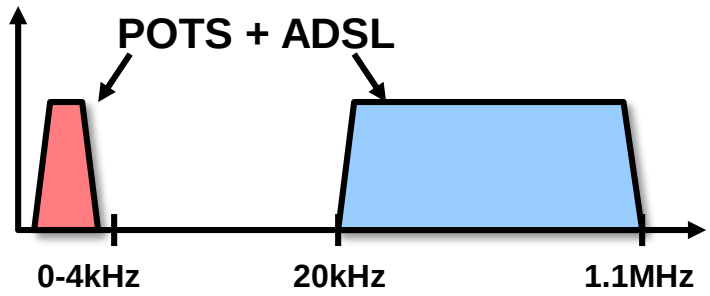


3. ADSL physical layer (1/3)

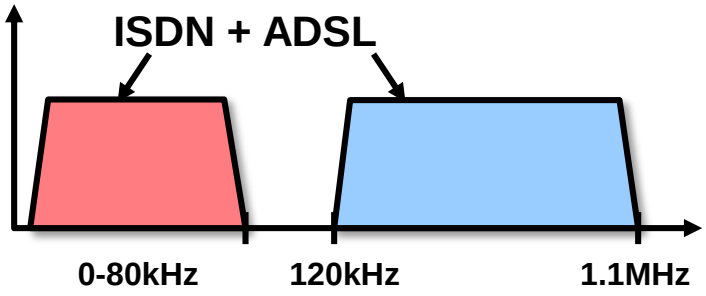
ADSL exploits the fact that (today's) Internet traffic is largely asymmetric (much higher traffic downstream = to user, low traffic upstream = from user).

ADSL is made to coexist with POTS or ISDN (G.991.2 Annex A (POTS) and Annex B (ISDN)).

Frequency usage of ADSL:



POTS' + ADSL's frequencies are not overlapping thus there is no problem.



ISDN's and ADSL's frequencies are overlapping, thus ADSL and ISDN frequency bands need to be separated (ADSL with out-of-band ISDN does not use frequencies in ISDN band).

3. ADSL physical layer (2/3)

Possible ADSL modulations:

1. CAP Carrierless Amplitude Phase:

Phase modulation coupled with amplitude modulation.

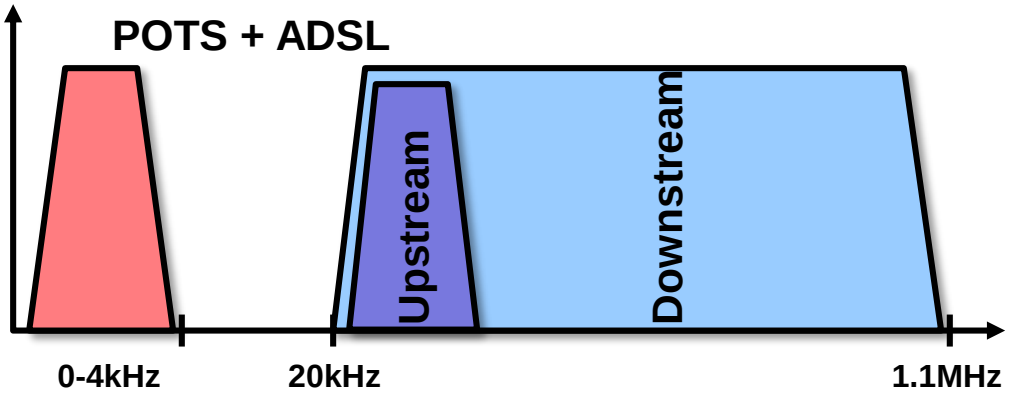
2. DMT Discrete Multitone:

Frequency spectrum from 0 thru 1.1MHz is divided into 256 or 512 sub-bands (channels 0-5/20 are not used - these frequencies are used for POTS/ISDN).
Each sub-channel uses QAM and offers a different bit capacity (depending on Signal to Noise Ratio SNR).
Sub-channels 6/21 thru 31 are used for upstream while sub-channels 33 thru 255 are used for downstream traffic.

3. ADSL physical layer (3/3)

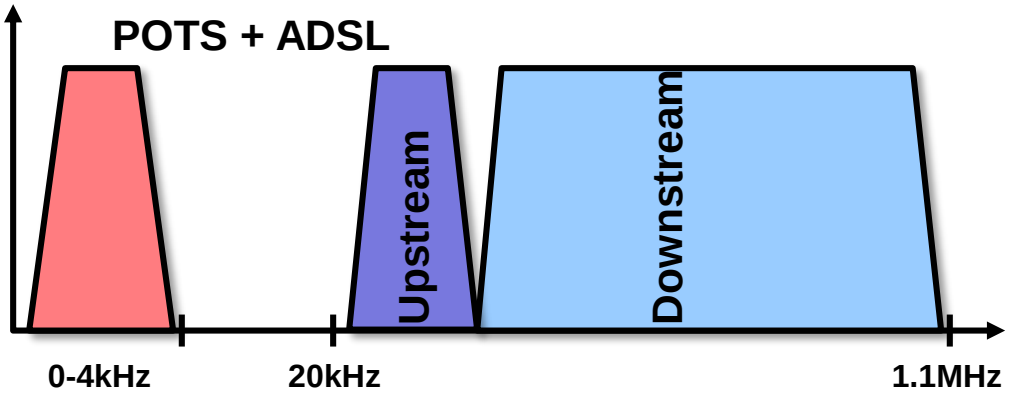
Separation of upstream (towards network) and downstream (from network) signals (remember: there are only 2 wires for both directions):

Solution 1: Usage of echo canceller:



Upstream and downstream use overlapping frequency bands, but the signals are separated with an echo canceller.

Solution 2: Usage of frequency division multiplexing:

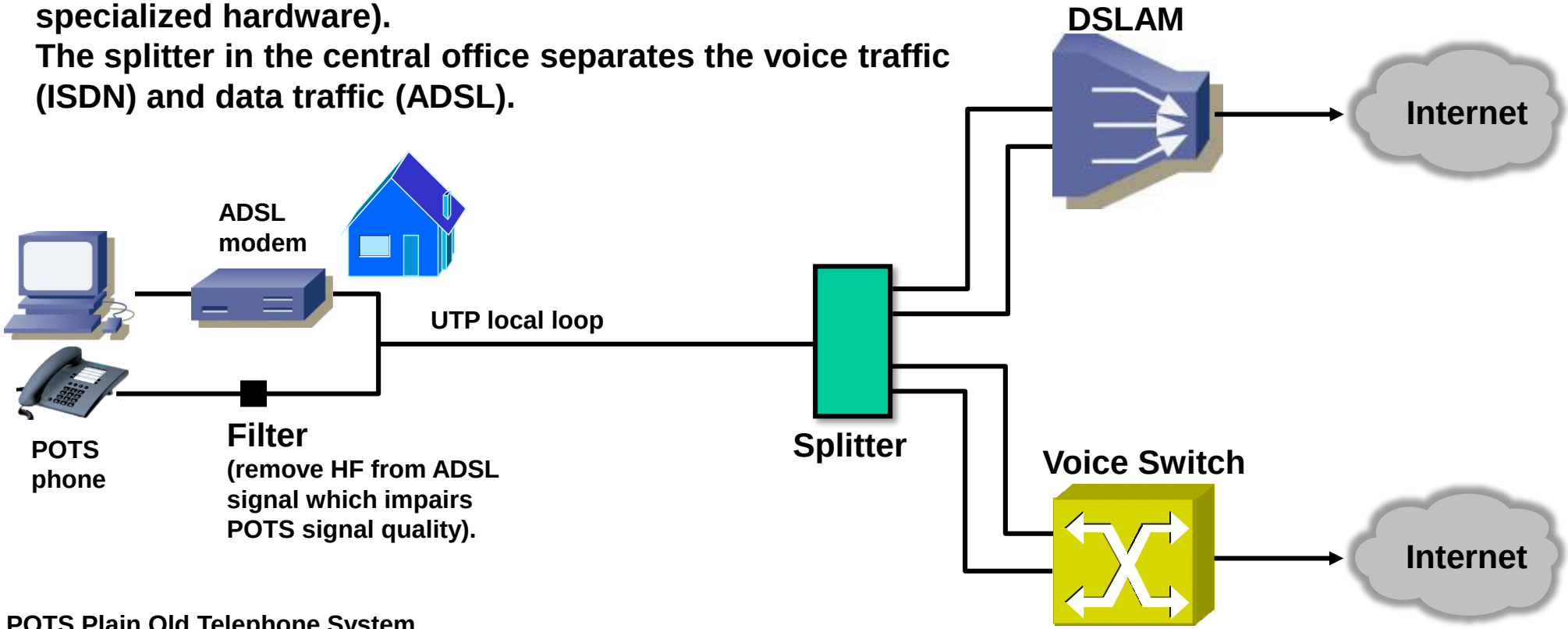


Upstream and downstream use non-overlapping frequency bands.

4. ADSL network architecture (1/3)

Subscriber infrastructure „ADSL over POTS“:

A passive filter protects analog devices (mostly analog = POTS phones) from ADSL frequencies.
The DSLAM is a big box with hundreds of ADSL modems (software modems that run on specialized hardware).
The splitter in the central office separates the voice traffic (ISDN) and data traffic (ADSL).

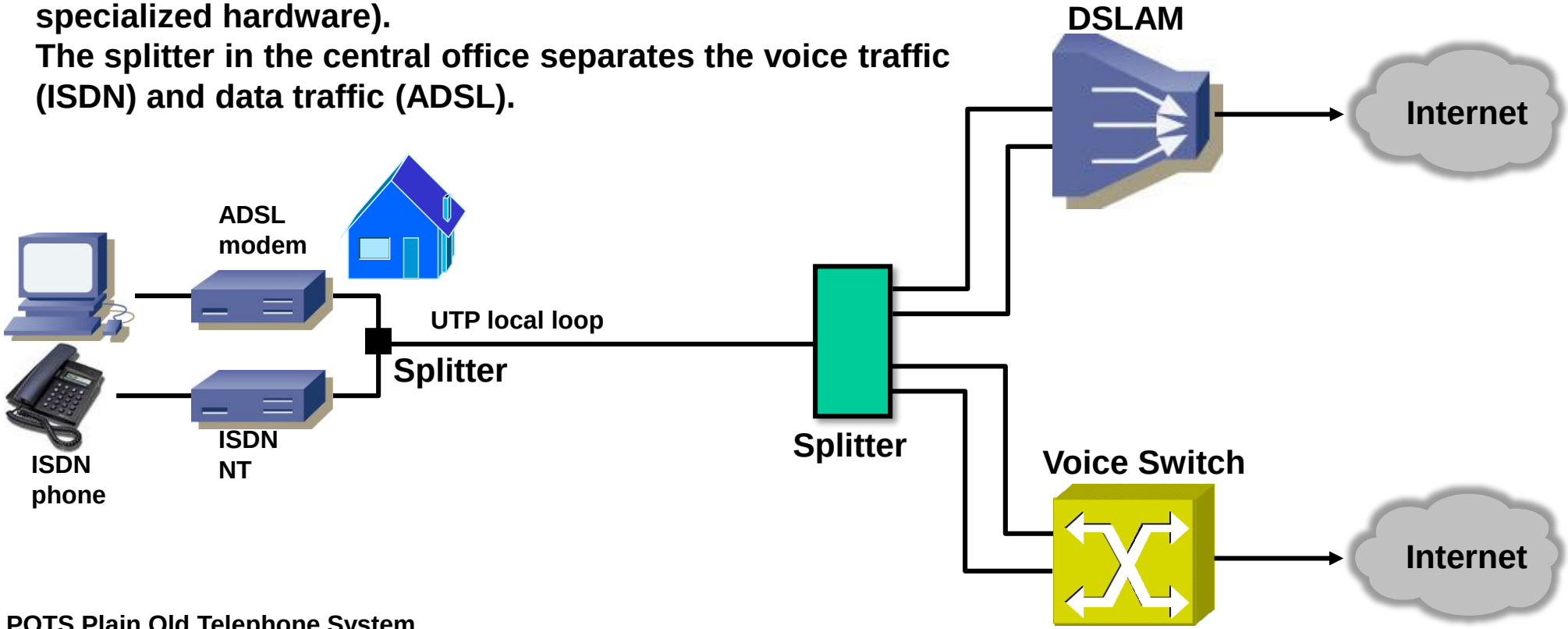


POTS Plain Old Telephone System
DSLAM Digital Subscriber Line Access Multiplexer = Modem Pool (high number of modems)
UTP Unshielded Twisted Pair
NT Network Termination (ISDN modem)

4. ADSL network architecture (2/3)

Subscriber infrastructure „ADSL over ISDN“:

The splitters (passive device) separate/combine the ISDN and ADSL frequencies.
The DSLAM is a big box with hundreds of ADSL modems (software modems that run on specialized hardware).
The splitter in the central office separates the voice traffic (ISDN) and data traffic (ADSL).



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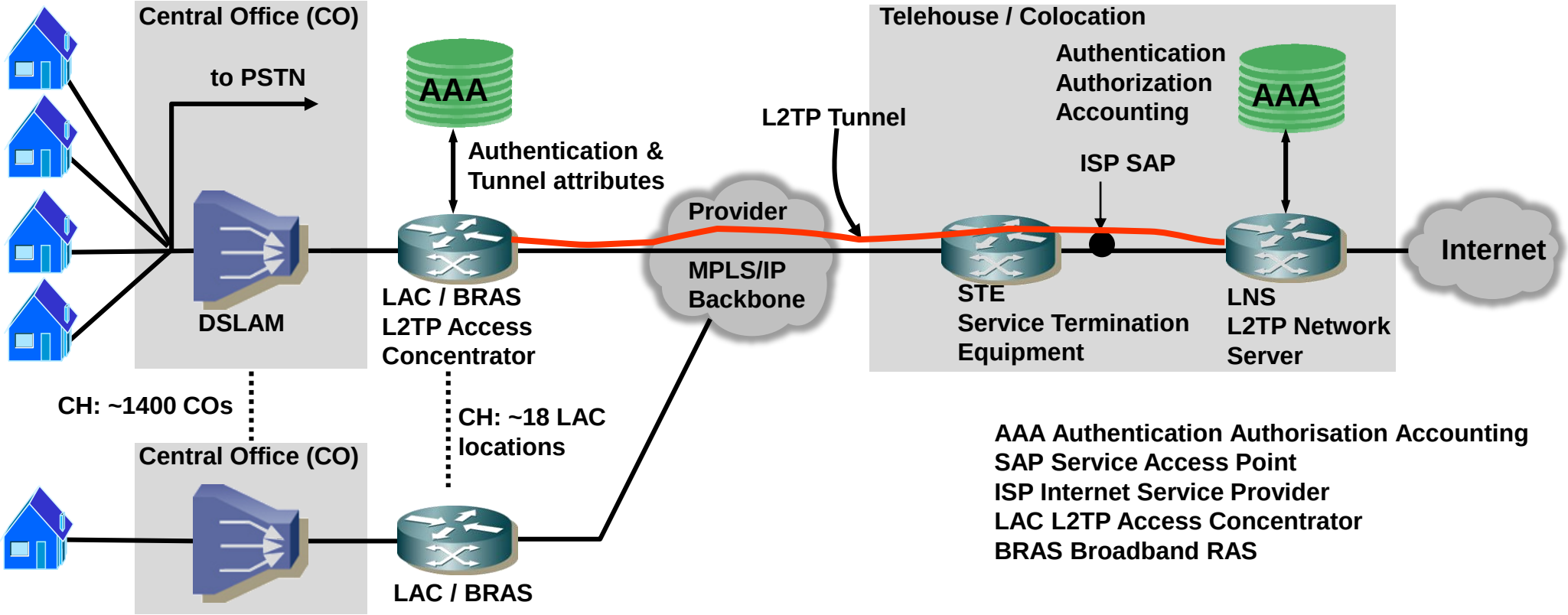
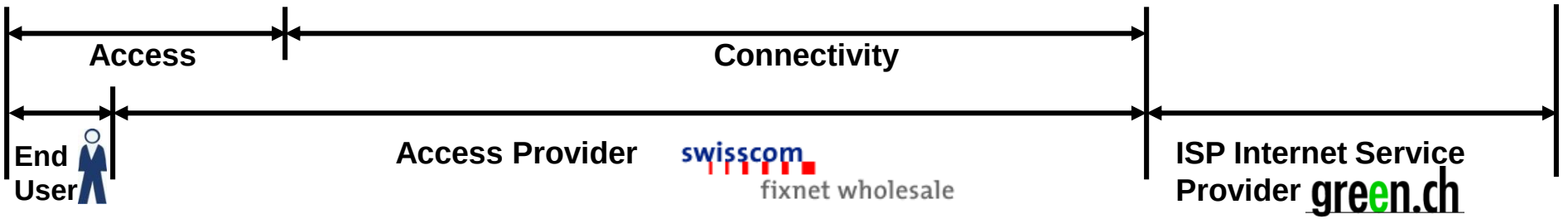
4. ADSL network architecture (3/3)

Provider network infrastructure:



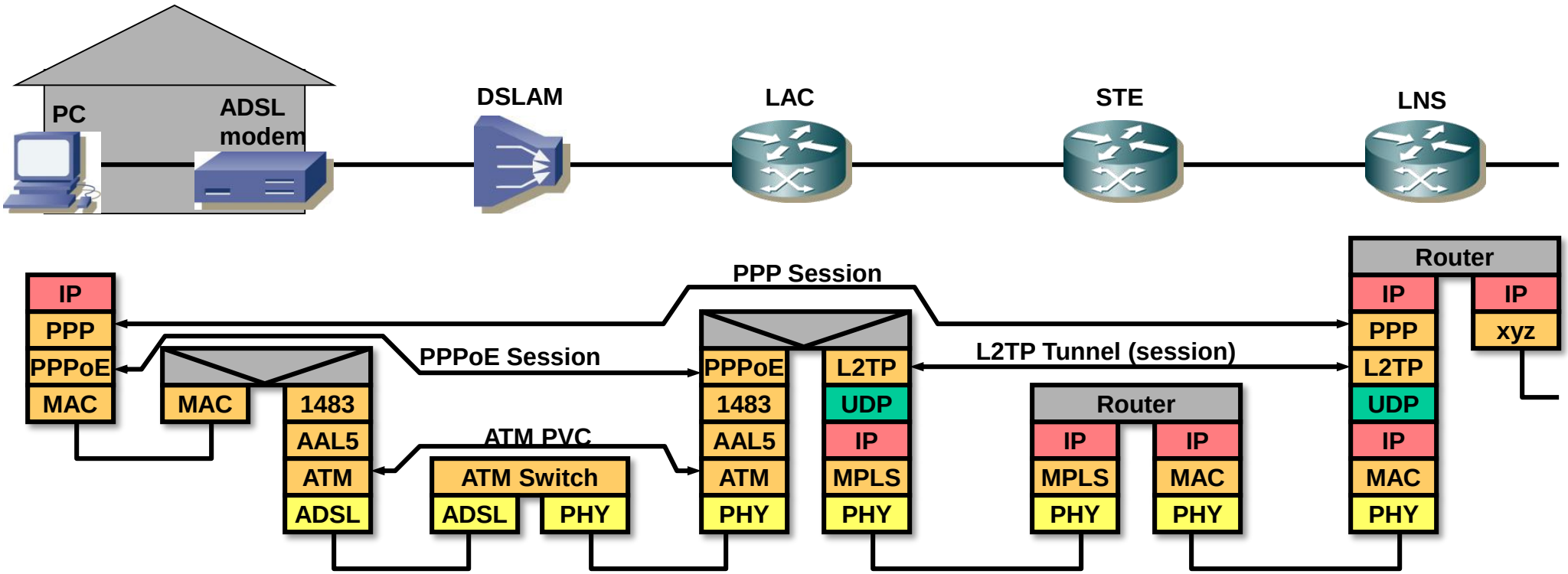
AAA Authentication Authorisation Accounting
SAP Service Access Point
ISP Internet Service Provider
LAC L2TP Access Concentrator
BRAS Broadband RAS



5. Protocols used with ADSL (CH and most other countries)

A PPPoE session provides layer 2 connectivity between ADSL modem and LAC in order to transport PPP frames. With PPP the Internet provider assigns a dynamic IP address to the ADSL modem/router.

The L2TP tunnel endpoints use static IP addresses (no dynamic routing due to security).



PPP Point to Point Protocol
MPLS Multiprotocol Label Switching
1483 RFC1483 Multiprotocol over ATM Adaptation Layer 5

PPPoE PPP over Ethernet
PHY Physical Layer

6. Setup of an Internet session (1/2)

A. Tunnel selection with PPPoE service-name:

1. PC or ADSL router starts PPP session

2. PPP session activates PPPoE session (PADI, PADO, PADR, PADS packets, see below)

3. AAA Query + Tunnel endpoint lookup:
The LAC ascertains the L2TP tunnel based on the PPPoE Service-Name tag (service selection).
Example Service-Name tag: „green.ch“.

4. LAC forwards all PPP packets (LCP, CHAP, IPCP, data packets) to the L2TP tunnel ascertained in step 3 (based on PPPoE Service-Name).

5. The PC or ADSL modem and the LNS bring up the PPP link (LCP phase).

6. The LNS authenticates (AAA) the PC or ADSL modem with CHAP.

7. The LNS assigns an IP address and DNS server to the PC or ADSL modem (IPCP).

8. The PC or ADSL router exchange user data.

6. Setup of an Internet session (2/2)

B. Tunnel selection with AAA on LAC (done by Swisscom in Switzerland):

1. PC or ADSL router starts PPP session

2. PPP session activates PPPoE session (PADI, PADO, PADR, PADS packets, see below)

3. AAA Query + Tunnel endpoint lookup:
The LAC sends a CHAP Challenge packet upon which the PC or ADSL router sends back a CHAP Response packet containing the login „user@green.ch“. The domain name of the login „green.ch“ is then used for the lookup of the tunnel endpoint (through AAA lookup).

4. The LAC makes an AAA query to authorize the user (let him continue). Thus the LAC performs the AAA on behalf of the ISP. This requires that the ISP has access to the access provider‘s (Swisscom) AAA database (add/modify/delete users).

5. The LAC and LNS bring up the link (new PPP session between LAC and LNS).

6. Optional: LNS authenticates LAC again (same CHAP secret as above).

7. LAC forwards all PPP packets from the PC or ADSL modem to the L2TP tunnel ascertained in step 3.

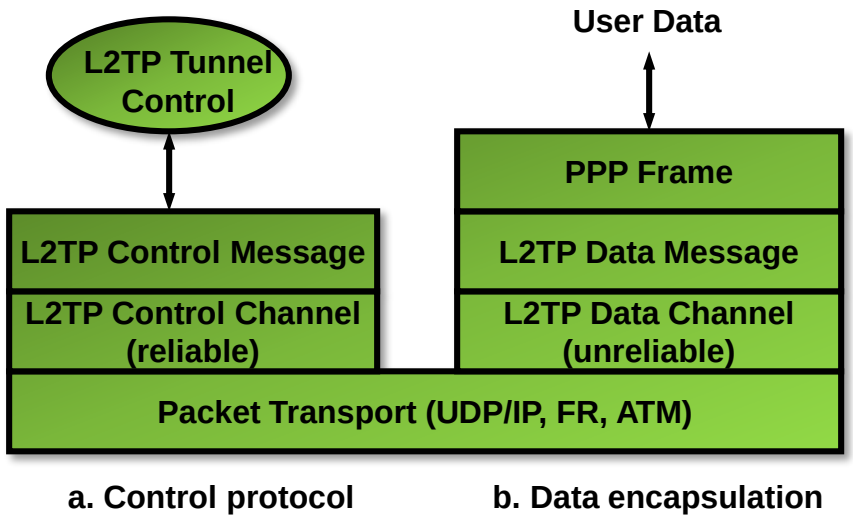
8. The LNS assigns an IP address and DNS server to the PC or ADSL modem (IPCP).

9. The PC or ADSL router exchange user data.

7. L2TP RFC2661 (1/2)

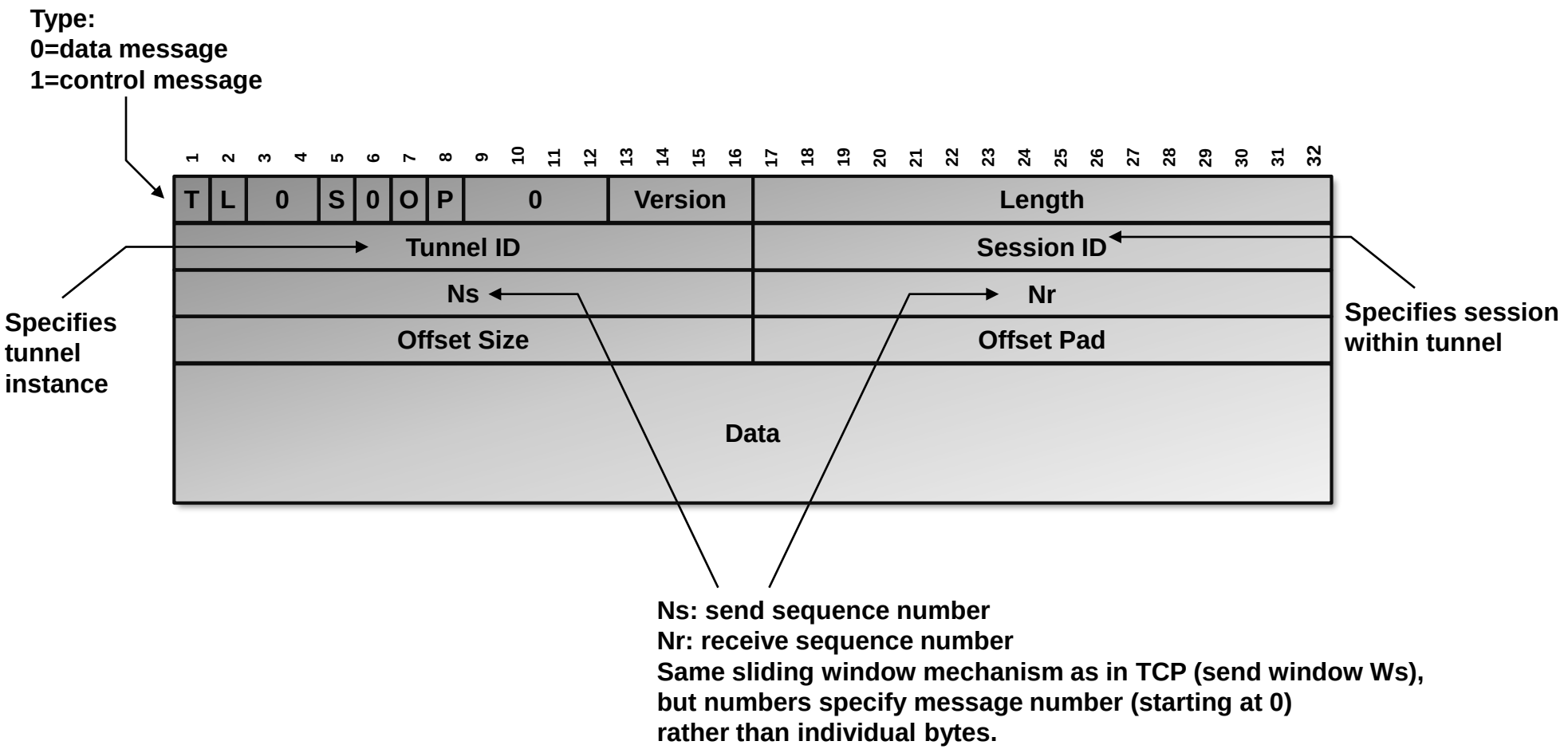
- L2TP allows to tunnel PPP over any packet switched network.
- L2TP inherited the best of L2F (Layer 2 Framing protocol by Cisco) and PPTP (Point to Point Tunneling Protocol by Microsoft).
- L2TP (along with other layer 2 tunneling protocols) allows a provider to offer remote access services (RAS) to customers over existing packet based infrastructure.
- L2TP is run over UDP/IP to make it pass firewalls.
- L2TP is:

  a. A control protocol do dynamically setup and teardown connections (tunnels); this control uses a reliable transport (that uses the Ns and Nr sequence numbers for reliability).
  b. Data encapsulation for tunneling user data frames (PPP); the data packet transport is unreliable, that is makes not use of Ns and Nr sequence numbers.



7. L2TP RFC2661 (2/2)

L2TP header fields:



8. PPPoE RFC2516

- PPPoE allows to establish connections over Ethernet for PPP sessions into the Internet.
- PPPoE solves 2 main problems:
  1. Dynamic IP address assignment without using broadcasts (PPP).
     ➔ PPPoE (and thus PPP) is only active if the computer wants to access the Internet.

  2. Excessive broadcasts in large bridged networks.
     ➔ With PPPoE everything is nicely contained in point to point connections.

- PPPoE is needed as convergence layer when computer does not have its own ATM interface (otherwise it could do PPPoA which is simply PPP over ATM).

- PPPoE trace (PPPoE session):

Creation of PPPoE session

Creation of PPP session

User data exchange

PPPoE session termination
(can be initiated by client or server)

```
C: 1    0.000000 00:30:2b:00:0b:fc -> ff:ff:ff:ff:ff:ff PPPoED Active Discovery Initiation (PADI)
S: 2    0.030894 00:02:16:5e:0e:b7 -> 00:30:2b:00:0b:fc PPPoED Active Discovery Offer (PADO)
C: 3    0.031742 00:30:2b:00:0b:fc -> 00:02:16:5e:0e:b7 PPPoED Active Discovery Request (PADR)
S: 4    0.069048 00:02:16:5e:0e:b7 -> 00:30:2b:00:0b:fc PPPoED Active Discovery Session-confirmation (PADS)
LCP Link Control Protocol (PPP LCP frames encapsulated in PPPoE)
CHAP/PAP (PPP CHAP/PAP frames encapsulated in PPPoE)
NCP Network Control Protocol (PPP NCP frames encapsulated in PPPoE)

... (user PPP frames incapsulated in PPPoE)


C: N    12.34256 00:30:2b:00:0b:fc -> 00:02:16:5e:0e:b7 PPPoED Active Discovery Terminate (PADT)
```

9. RFC1483 Multiprotocol Encapsulation over ATM Adapation Layer 5

RFC1483 is used for the encapsulation/multiplexing of upper layer protocols (Ethernet, IP) into ATM.