VSB TECHNICAL UNIVERSITY OF OSTRAVA | FACULTY OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE | DEPARTMENT OF TELECOMMUNICATIONS

Telecommunication Networks

Access Networks

Libor Michalek

Access Network

- Part of the communication network that directly connects the customer with the service provider (e.g. Internet).
- **Can be built using**
  1. **Metallic symmetric or asymmetrical lines**
  2. **Optical fibers**
  3. **Wireless technology**

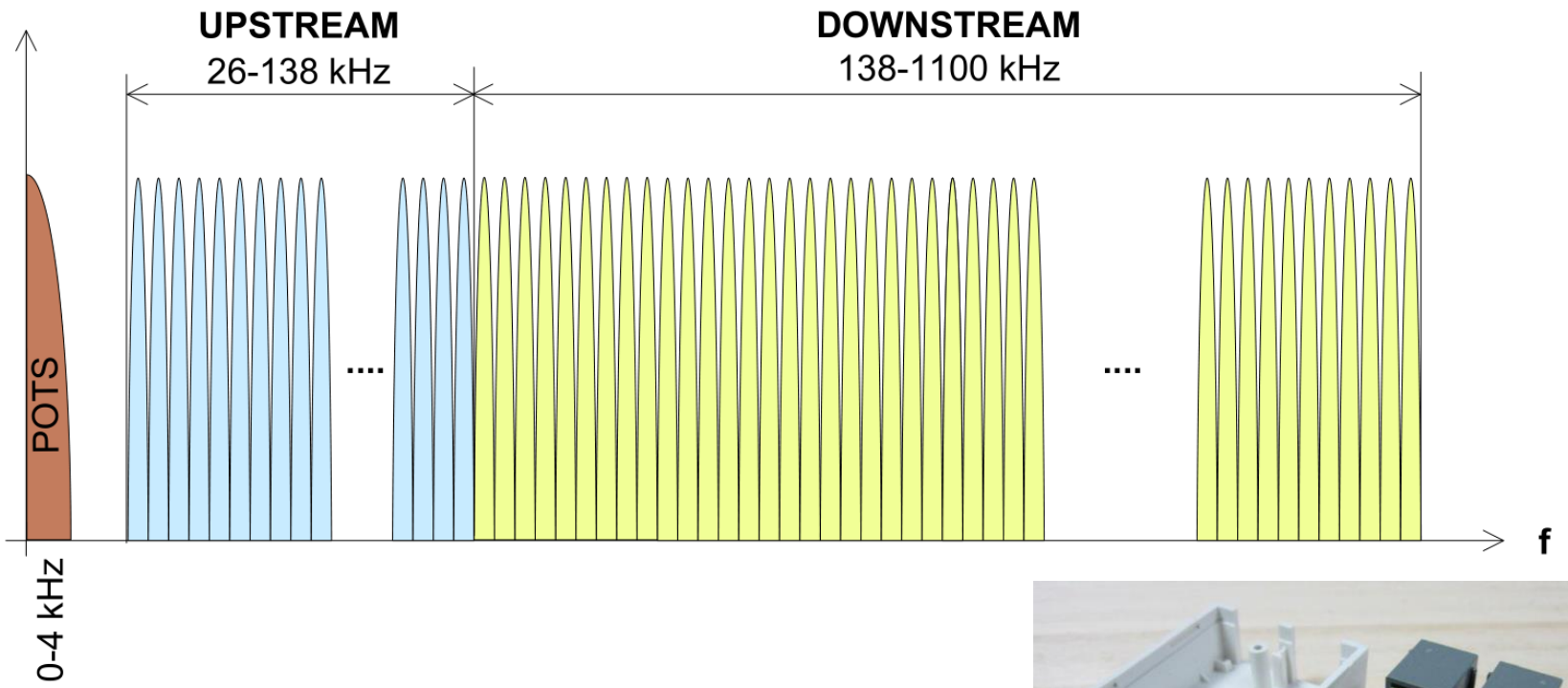
xDSL

- called as **DSL (Digital Subscriber Line)** family
- include several variations, the lower case ***x*** in front of DSL include:
  - Asymmetric Digital Subscriber Line (ADSL)
  - ISDN (like) Digital Subscriber Digital Line (IDSL)
  - Consumer Digital Subscriber LIne (CDSL)
  - Single High Speed DSL (SHDSL)
  - Rate-adaptive Subscriber Digital Line (RADSL)
  - Very High-bit Rate Digital Subscriber Line (VDSL)
  - Symmetric Digital Subscriber Line (SDSL)

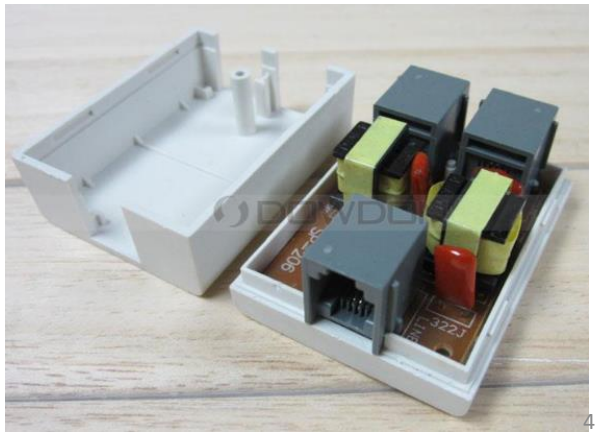
ADSL (Asymmetric Digital Subscriber Line)

- asymmetric = data flow is greater in one direction than the other, 8 Mbps
- ITU-T G.992.1
- using the existing twisted pair telephone lines into the high-speed communications access
- communication is full duplex using most the FDD (Frequency Division Duplex)
- **ADSL2** (ITU-T G.992.3 and G.992.4)
  - dynamic data rate adaptation, flexible structure of frame
  - reduces the initialization time to less than 3 seconds
  - max. 12 Mbps downlink

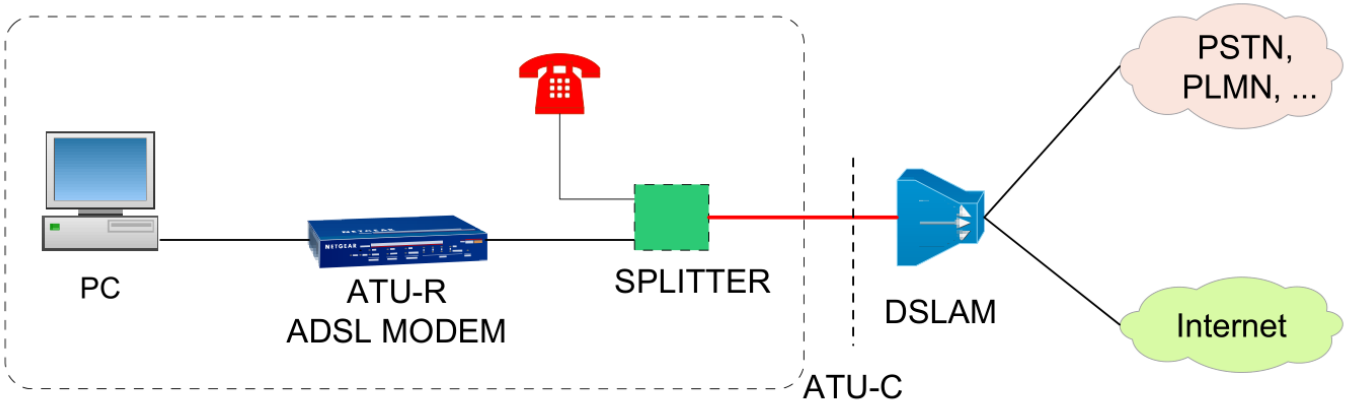
ADSL – frequency allocation



DSL and POTS (Plain Old Telephone Service) band is splitted by so called **splitter** – low pass filter

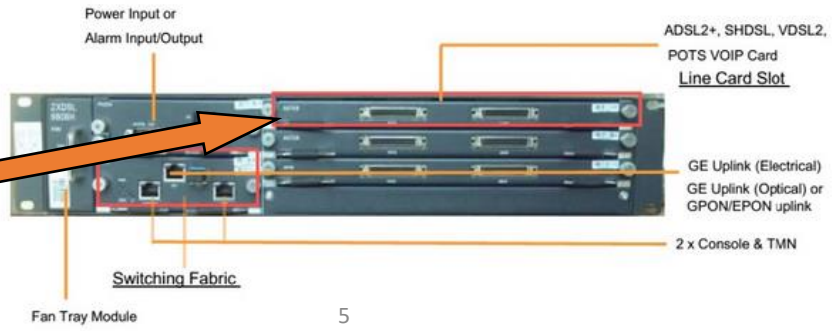


ADSL architecture



DSLAM (DSL Access Multiplexer)

- located in the telephony exchanges of the service providers
- intermixes voice traffic and DSL traffic on the customer's DSL line
- acts like a massive network switch since its functionality is only on L2
- each DSLAM has multiple aggregation cards, and each such card can have multiple ports to which the customers lines are connected



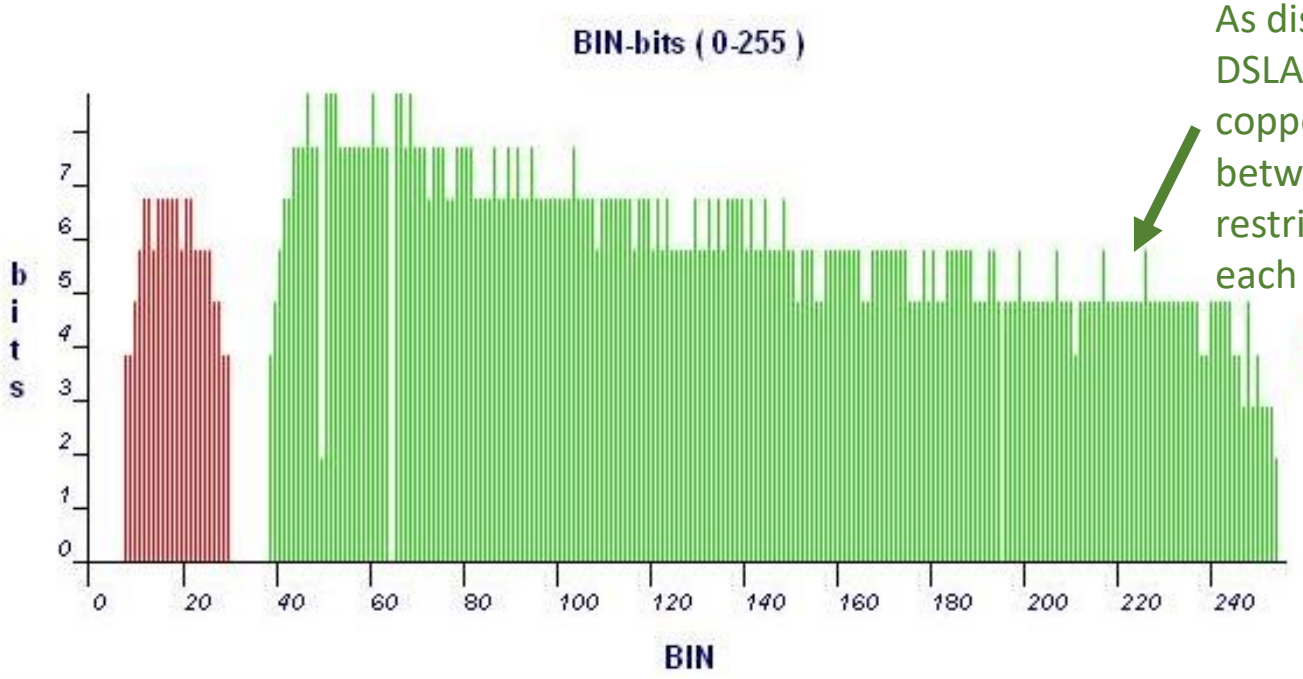
DSLAM

ADSL standards overview

Standard name	Common name	Downstream rate	Upstream rate	Approved in
ANSI T1.413-1998 Issue 2	ADSL	8 Mbit/s	1.0 Mbit/s	1998
ITU G.992.1	ADSL (G.DMT)	12 Mbit/s	1.3 Mbit/s	1999-07
ITU G.992.1 Annex A	ADSL over POTS	12 Mbit/s	1.3 MBit/s	
ITU G.992.1 Annex B	ADSL over ISDN	12 Mbit/s	1.8 MBit/s	
ITU G.992.2	ADSL Lite (G.Lite)	1.5 Mbit/s	0.5 Mbit/s	1999-07
ITU G.992.3	ADSL2	12 Mbit/s	1.0 Mbit/s	2002-07
ITU G.992.3 Annex J	ADSL2	12 Mbit/s	3.5 Mbit/s	
ITU G.992.3 Annex L	RE-ADSL2	5 Mbit/s	0.8 Mbit/s	
ITU G.992.4	splitterless ADSL2	1.5 Mbit/s	0.5 Mbit/s	2002-07
ITU G.992.5	ADSL2+	24 Mbit/s	1.0 Mbit/s	2003-05
ITU G.992.5 Annex M	ADSL2+M	24 Mbit/s	3.5 Mbit/s	

G.DMT - Discrete Multitone Modulation

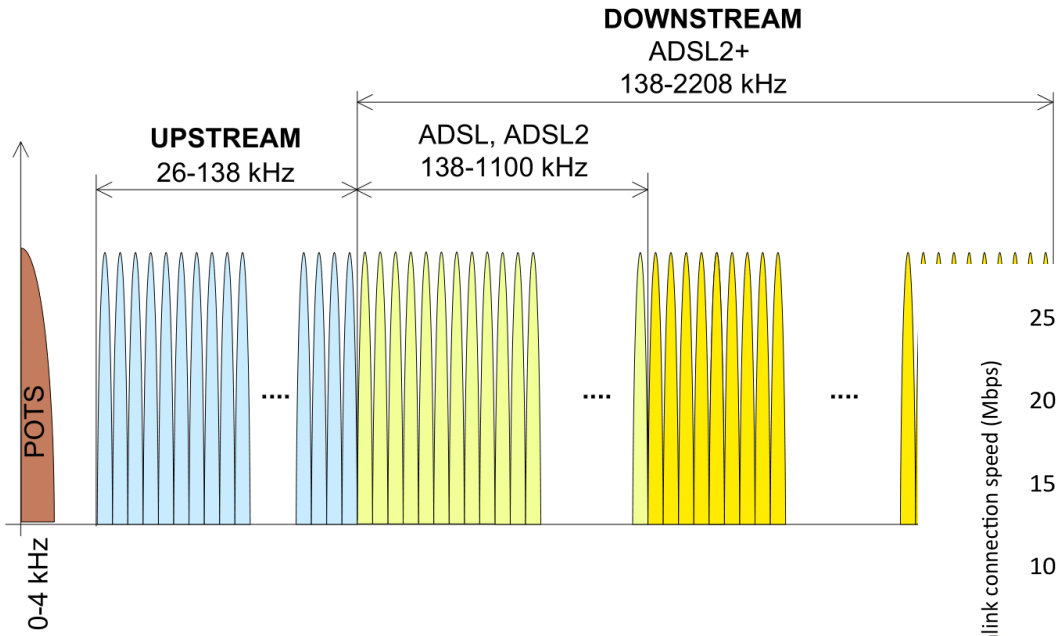
- separates the ADSL signal into carriers (bins/tones) centered on multiples of **4.3125 kHz**
- the number of bits encoded on each bin depending on the **attenuation** and **signal to noise ratio for that bin,** tones are <u>independent</u> of one another
- when the modem is initialized, the number of bits is assigned to a tone

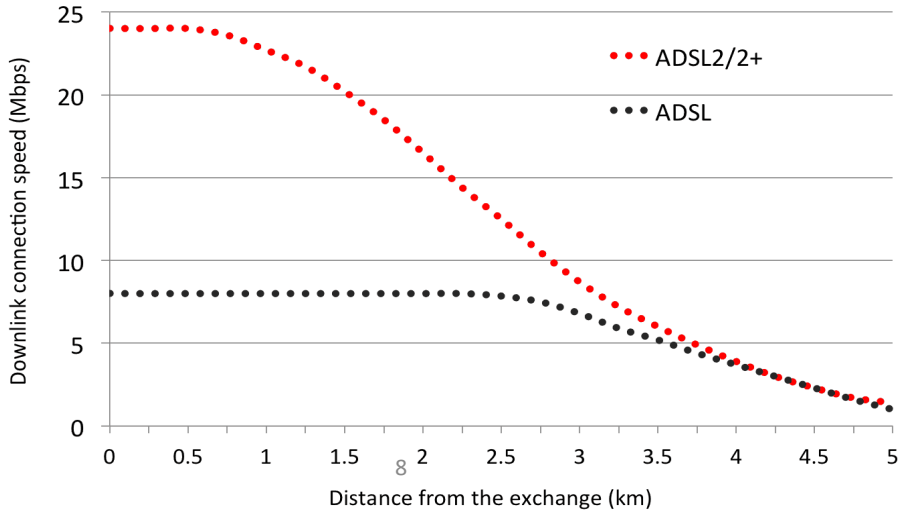


As distance increases from the DSLAM, signals attenuate on the copper loop reducing difference between noise and the signal restricting the number of bits each DMT carrier can support.

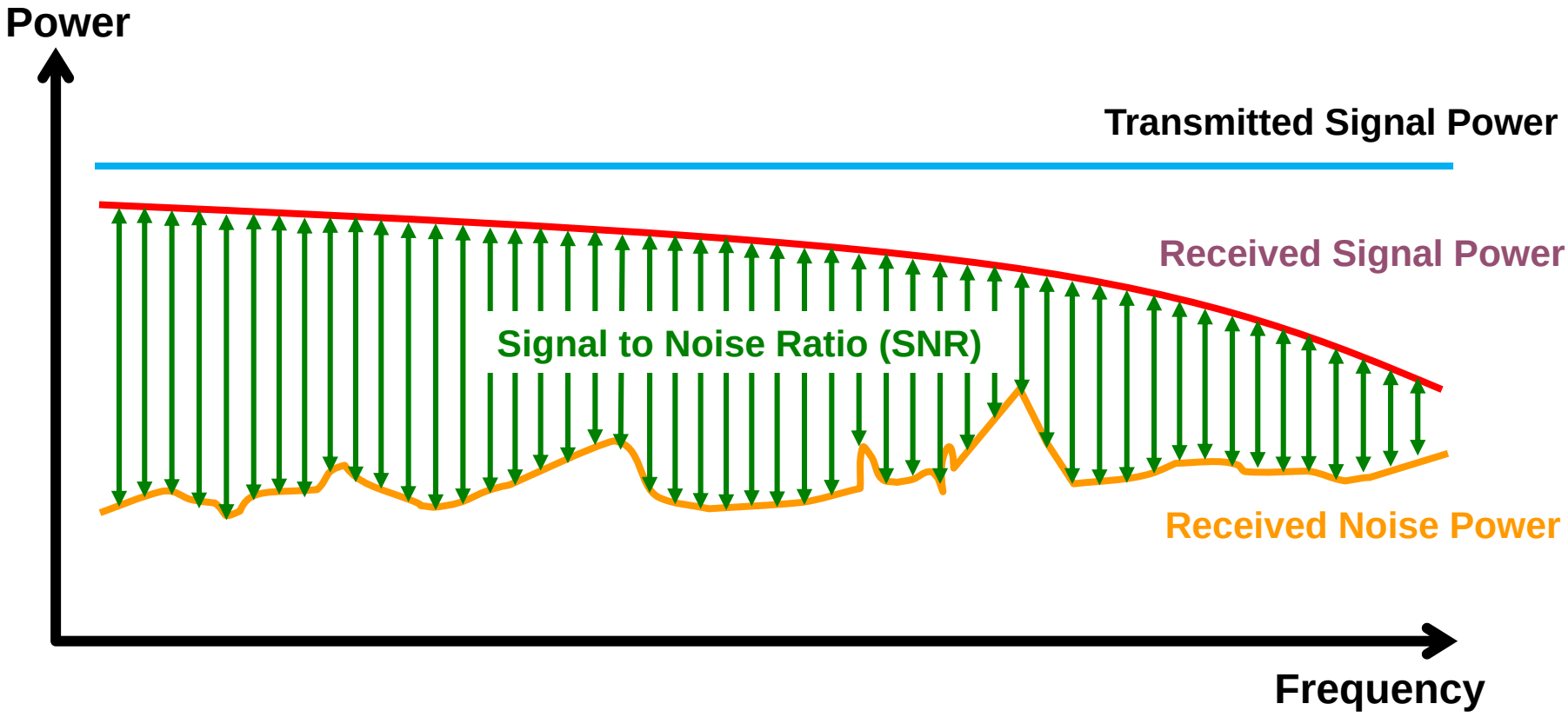
ADSL2+

- increased frequency band to **2,208 MHz**
- DMT has 511 downstream frequency bins and up to 36 upstream bins (tones)
- up to 24 Mbit/s for downstream
- local loop >3km – problem with attenuation and crosstalk





SNR is responsible for performance



VDSL/VDSL2

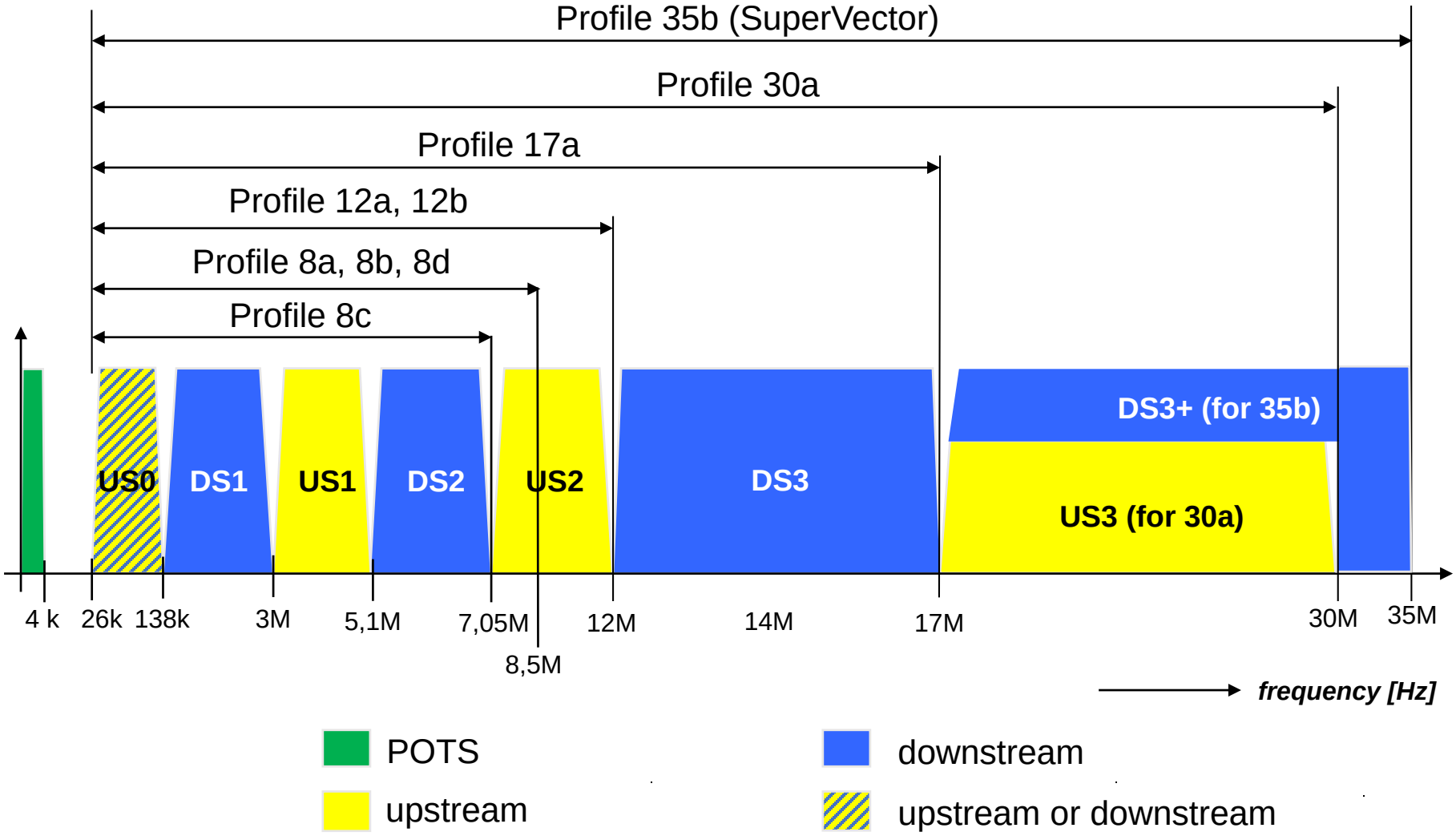
- Very-High-Data-Rate Digital Subscriber Line
- same philosophy as ADSL, up to 35 MHz
- VDSL2 profiles (G.993.2): 8a, 8b, 8c, 8d, 12a, 12b, 17a, 30a, 35b

Type	ADSL2	ADSL2+	VDSL2 (8a)	VDSL2(17a)	VDSL2 (30a)	VDSL2 (35b)
Margin of subchannels [Hz]	4312,5	4312,5	4312,5	4312,5	8625	4312,5
Number of Subchannels	256	512	1972	4096	3479	8192
Bandwidth [MHz]	1,1	2,2	8,5	17,7	30	35
Downrate [Mbps]	12	24	50	100	200	300

sometimes confuses with „VDSL3“

Compatible profiles for Vectoring

VDSL2 bandwidth (Annex B - Plan 997 for Europe)

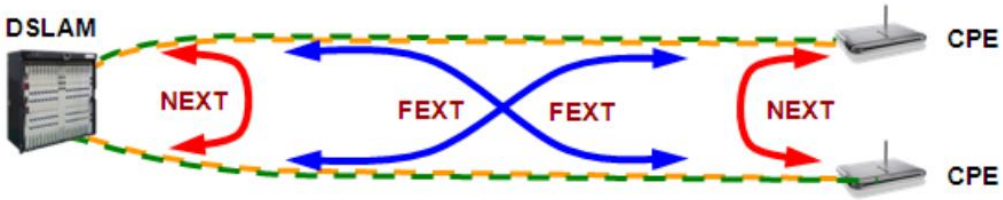


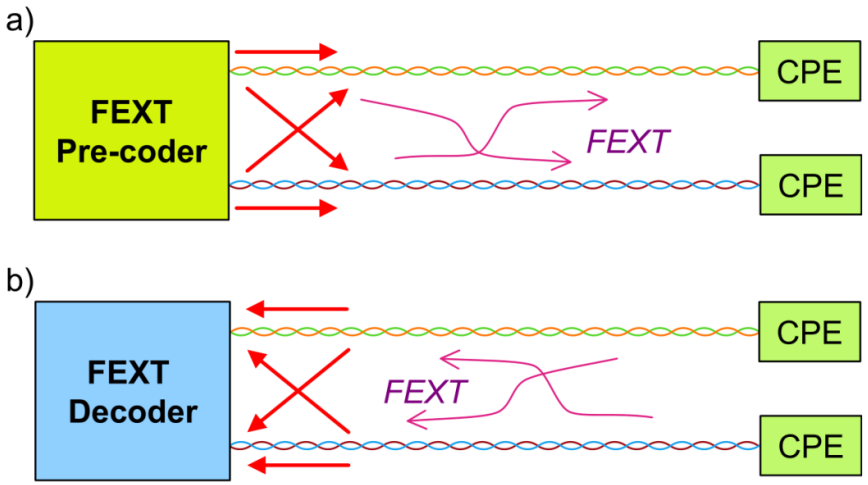
VDSL2 Vectoring (ITU-T G.993.5)

- FEXT in VDSL2 is more serious than other traditional DSL technologies and becomes the main factor that affects its performance
- FEXT leads to signal-to-noise ratio (SNR) decrease, which reduces the line data rate or increases the bit error rate (BER)

a) CPE sends back the FEXT information and then the CO uses the FEXT pre-coder to pre-code the FEXT to cancel it

b) FEXT decoder is used to extract the FEXT information and then removes the FEXT information from the original Rx signals.

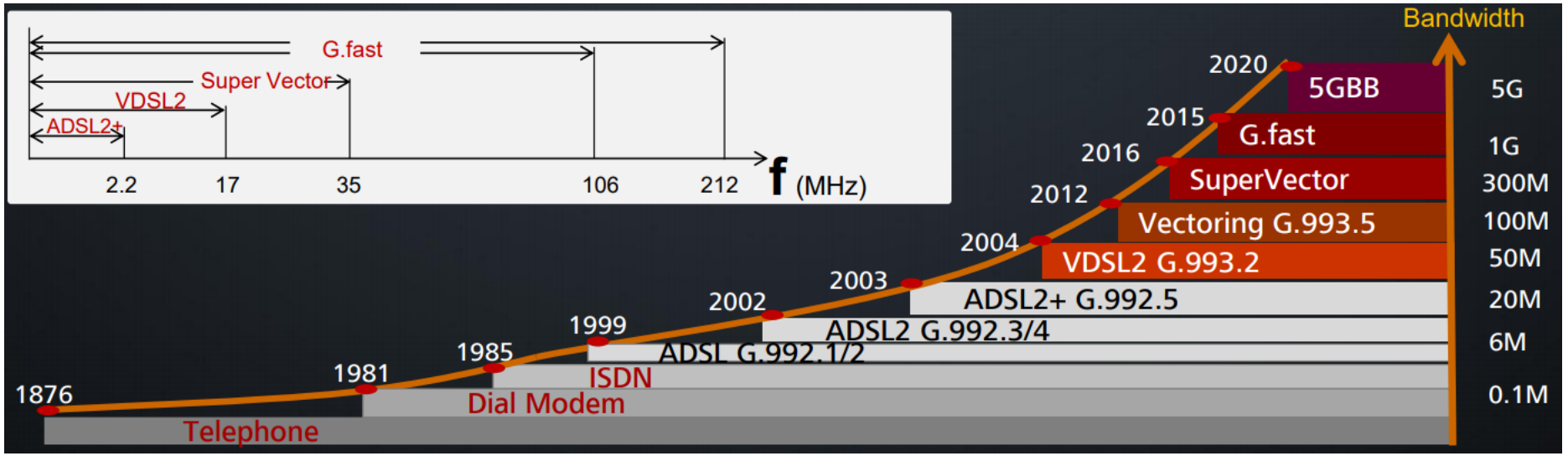




G.Fast

- under G.9701, approved in 2014
- up to **106 MHz** (212 MHz profile in a future)
- **TDD** instead of FDD used → Can easily vary download/upload asymmetry ratio
- discrete multi-tone (DMT) - only 2048 subchannels for 106 MHz, 4096 subchannels for 212 MHz
- margin of subchannels **51,75 kHz** (contrary to 8,625 kHz for VDSL2)
- mandatory support for **vectoring**
- only for short loops (up to 250m)
- <100m ~ 1 Gbps, 200m ~ 500Mbps, 300m ~ 300Mbps
- successor XG.FAST as 5th generation broadband (5GBB) technology, 10Gbps up to 130 m, 500-800 MHz

„Giga Access“ on Copper



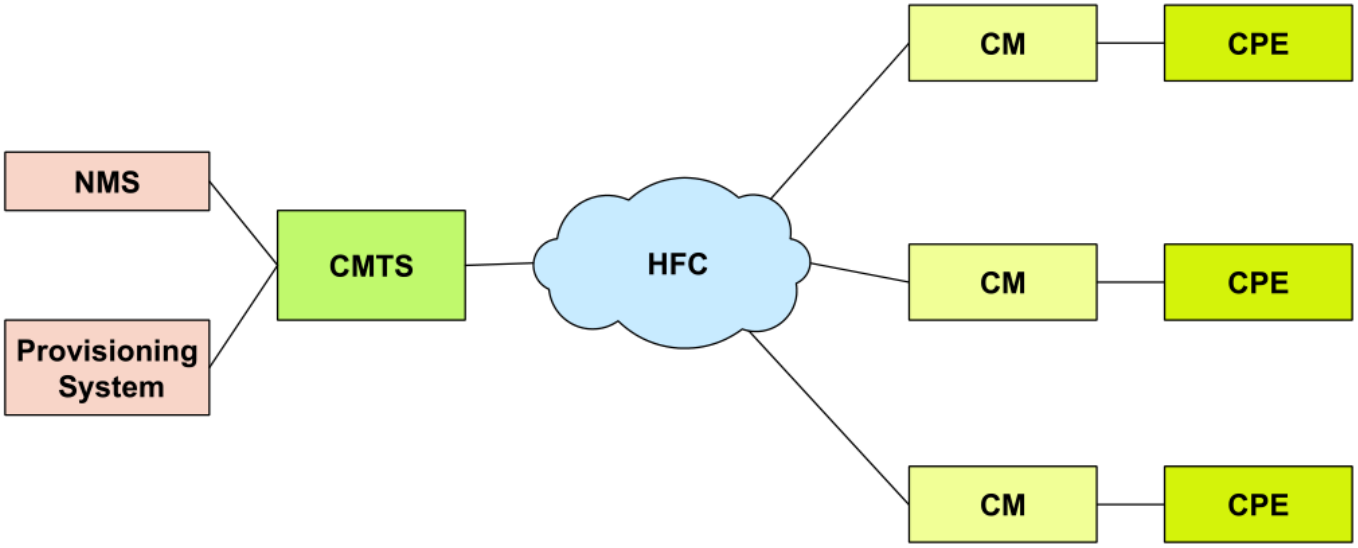
source: Huawei.com

Installation – rDSLAM cabinets

DOCSIS (Data Over Cable Service Interface Specification)

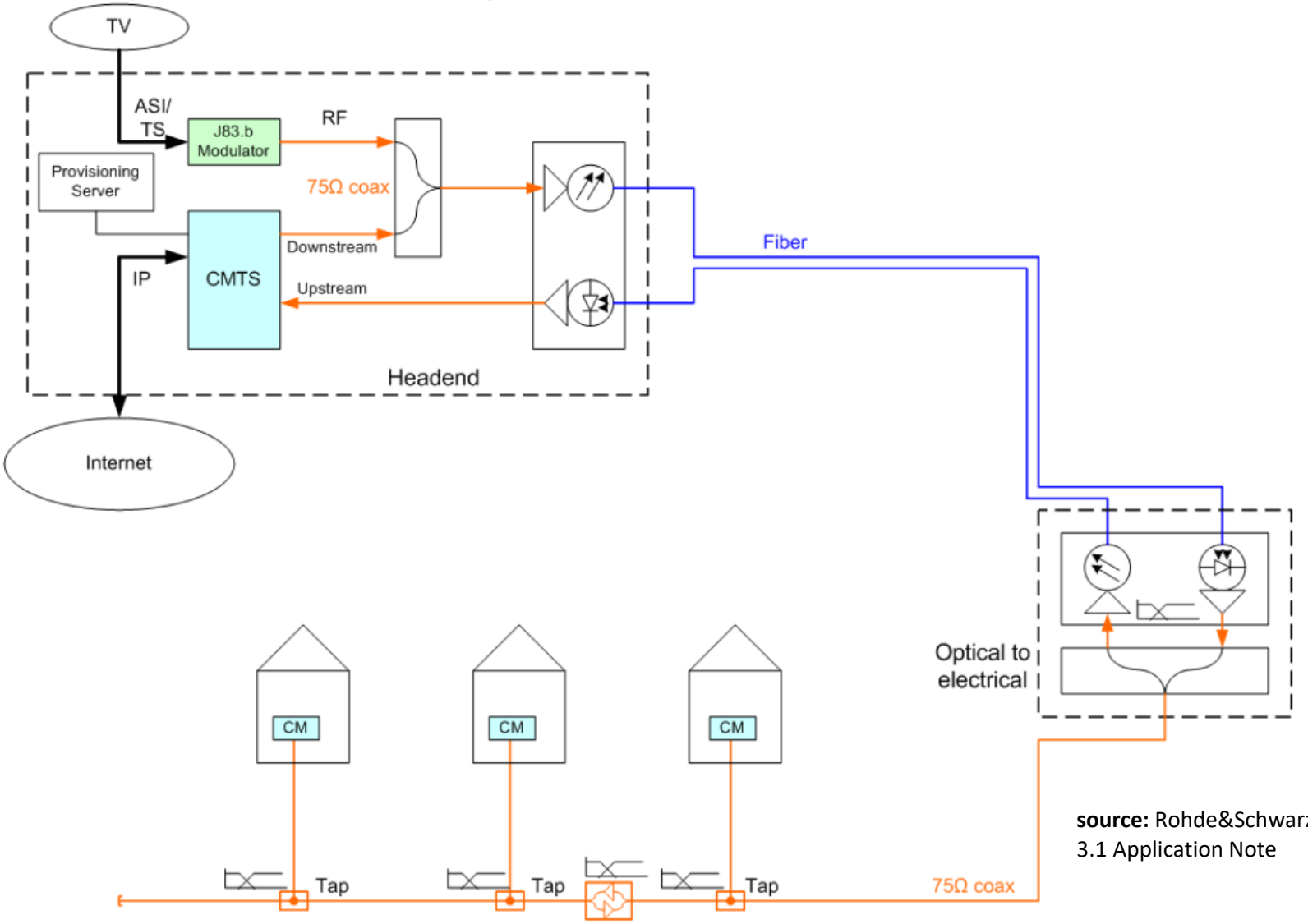
- defines interface requirements for cable modems involved in high-speed data distribution over CATV systems
- developed by CableLabs
- frequency allocation band plans differ between U.S. and European CATV → EuroDOCSIS
- 3 versions of standard (1.0, 2.0, 3.0)
- version 3.1 ratified in 2014

DOCSIS architecture



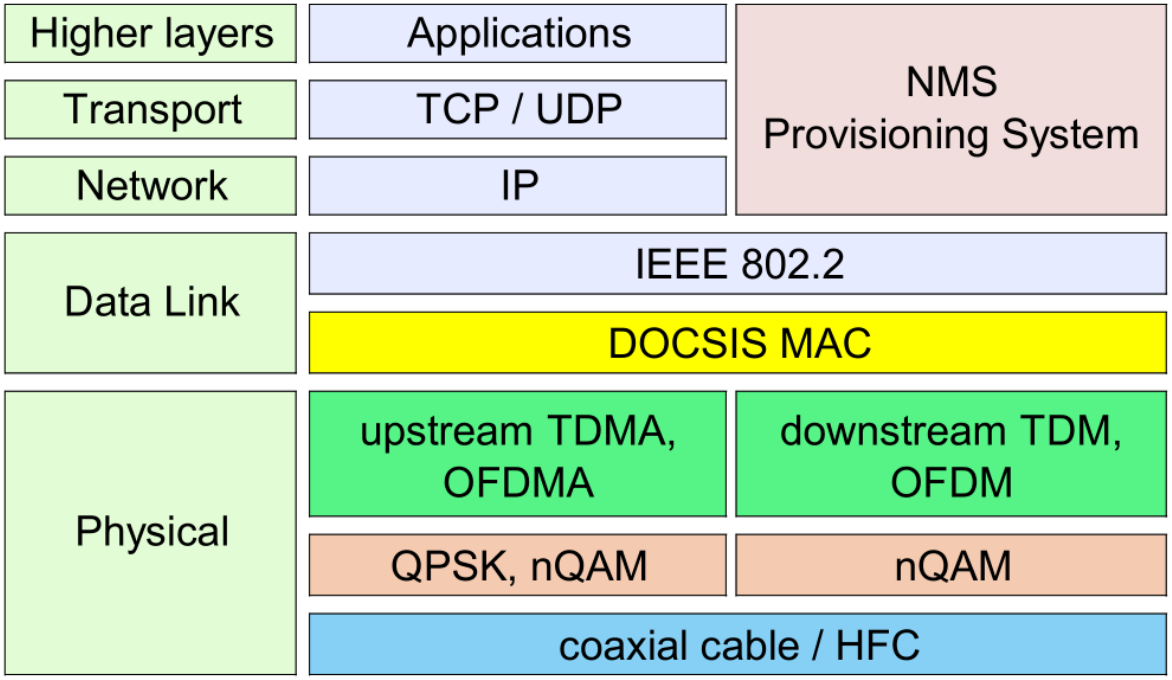
- **CPE** (Customer Premises Equipment) – most often the PC
- **CM** (Cable Modem) - located at the customer premises
- **CMTS** (Cable Modem Termination System) - located at the CATV headend
- **HFC** (Hybrid Fibre-Coax) is a network which is based on a combination of optical fibre and coaxial cable

Schematic diagram of the cable TV network



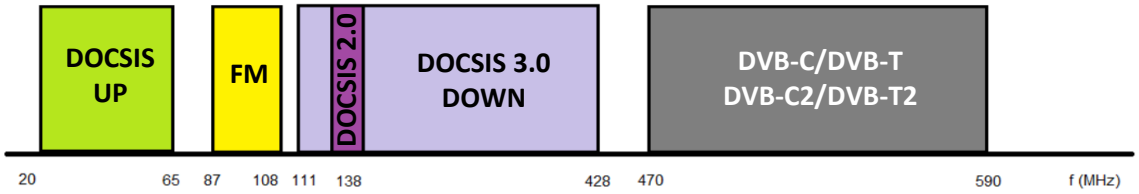
source: Rohde&Schwarz, DOCSIS 3.1 Application Note

DOCSIS – Protocol Stack



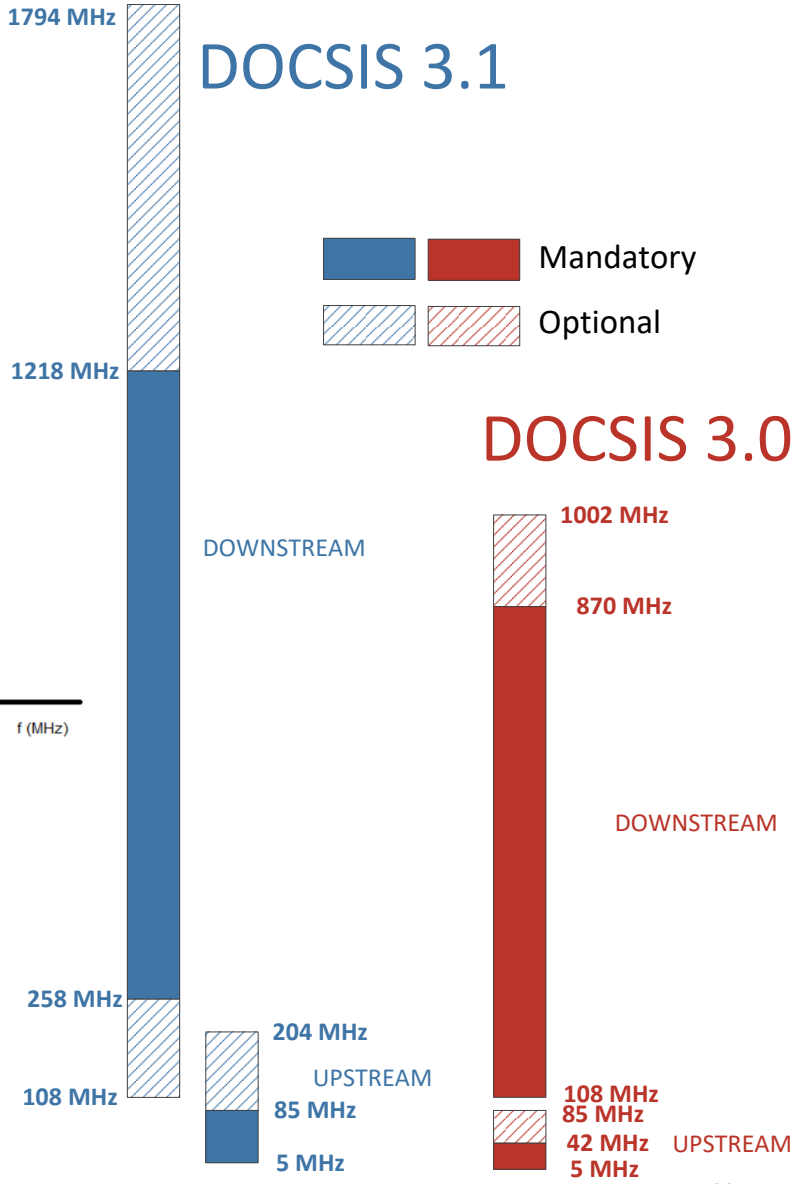
DOCSIS 3.1 layers

- **Physical Layer**
  - 5-85 MHz for upstream
  - 258-1218 MHZ for downstream
  - **OFDM/OFDMA** use up to 8000 subcarriers
  - up to 4096QAM, in future up to 16384QAM



Example of arrangement

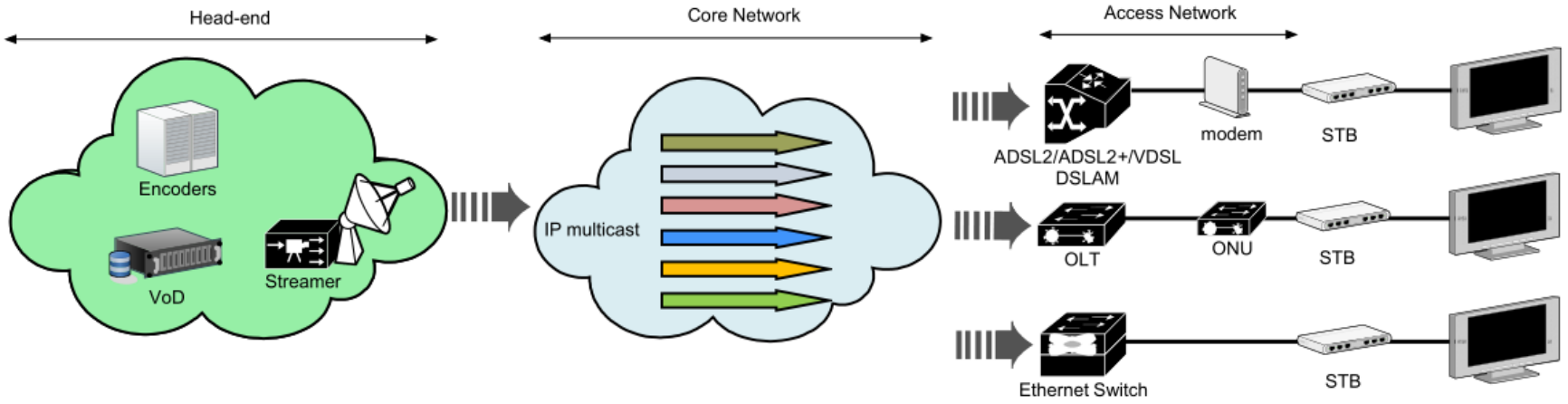
- **MAC layer**
  - DOCSIS frame is defined
  - QoS and capacity assignment



IPTV

- Internet Protocol Television
- service for the delivery of broadcast TV
- IPTV system may also include Internet services such as Web access and VOIP where it may be called **Triple Play** and is typically supplied by a broadband operator using the same infrastructure
- describes a system where a digital television service is delivered using the Internet Protocol (IP) over a network infrastructure
- it‘s not Internet Video
- contains EPG (Electronic Program Guide) that allows easy navigation, quick program information
- last mile to the subscriber can be based on:
  - ADSL2+, VDSL, VDSL2
  - FTTx based on PON (Passive Optical Network)
  - Ethernet (metallic cables distribution)
  - WLAN IEEE 802.11

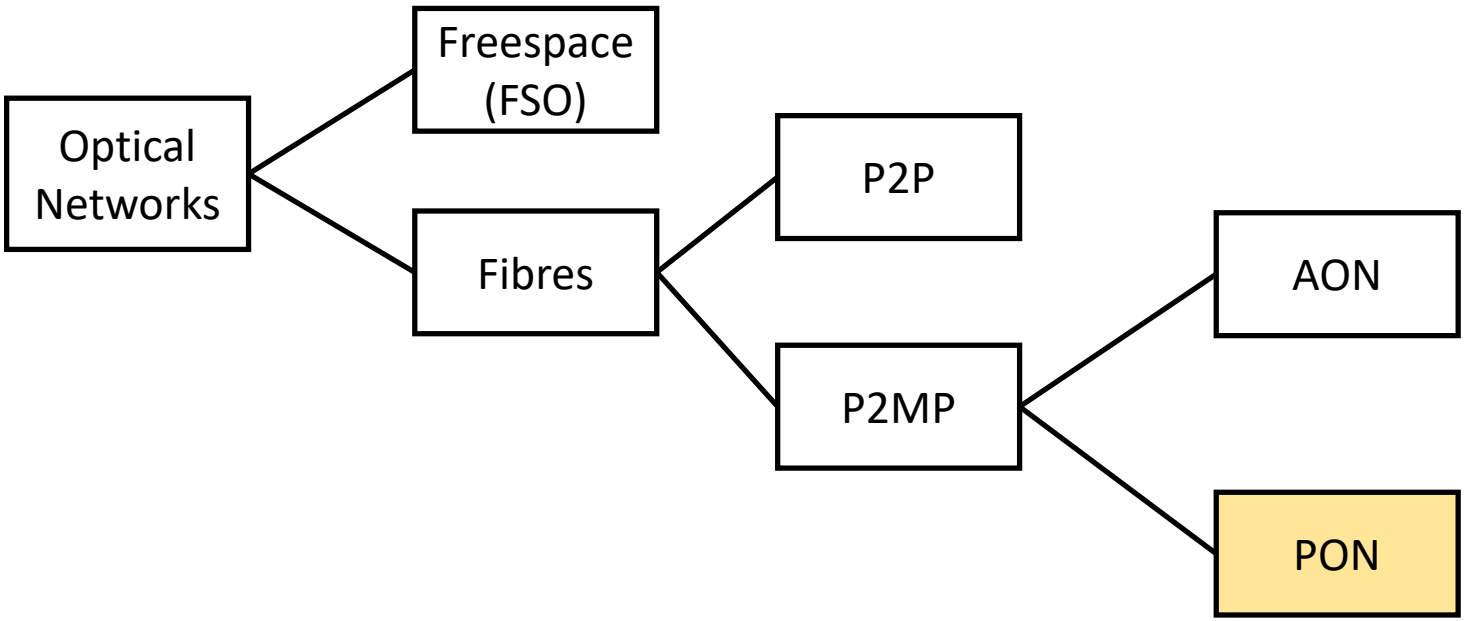
IPTV Architecture



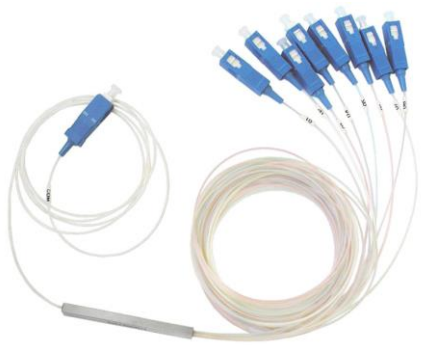
- **Head-end** - TV channels are encoded, encrypted and delivered in the form of IP multicast streams.
- **Core Network** - primarily provides interconnection and transfer between edge networks (based on optic fibres)
  - *multicast* - a single source sends data to *multiple destinations* at a single time. Each broadcast TV channel would have a unique IP multicast group.
  - *unicast* - For each unicast VOD session, there is a separate content stream on the network for each user
- **Access Network** - portion of a communication network that allows individual subscribers or devices to connect the core network, it can be xDSL based, cable, wireless broadband or metallic.
- **User's set-top box** - equipment at the user's home that decodes and decrypts TV and VOD content and displays it on the TV screen.

Passive Optical Networks

- A PON is a optical fiber network that only uses fibers and passive components like splitters and combiners instead of active components like amplifiers



PON Architecture



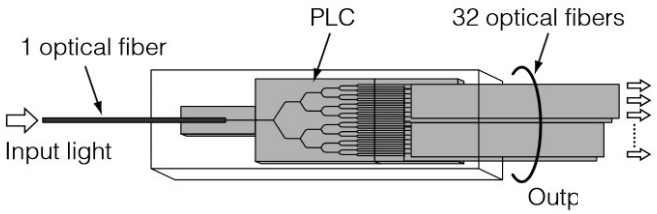
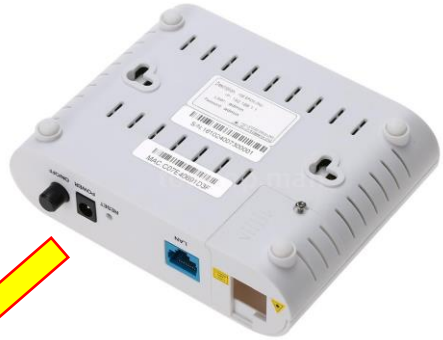
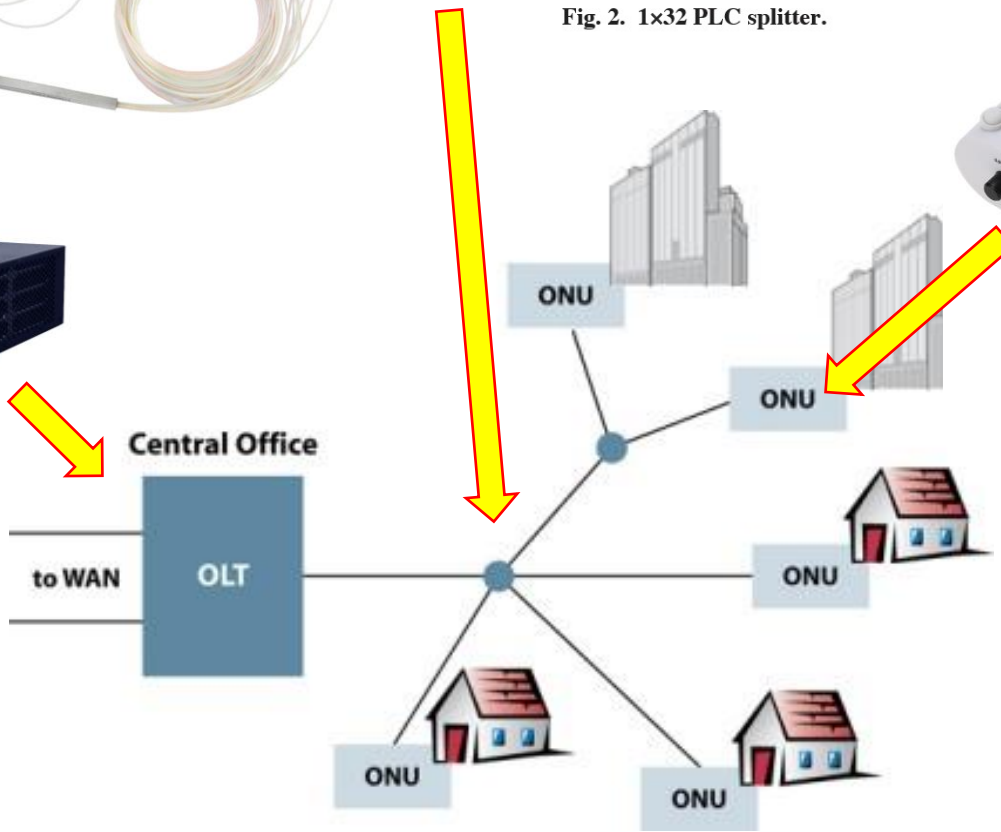
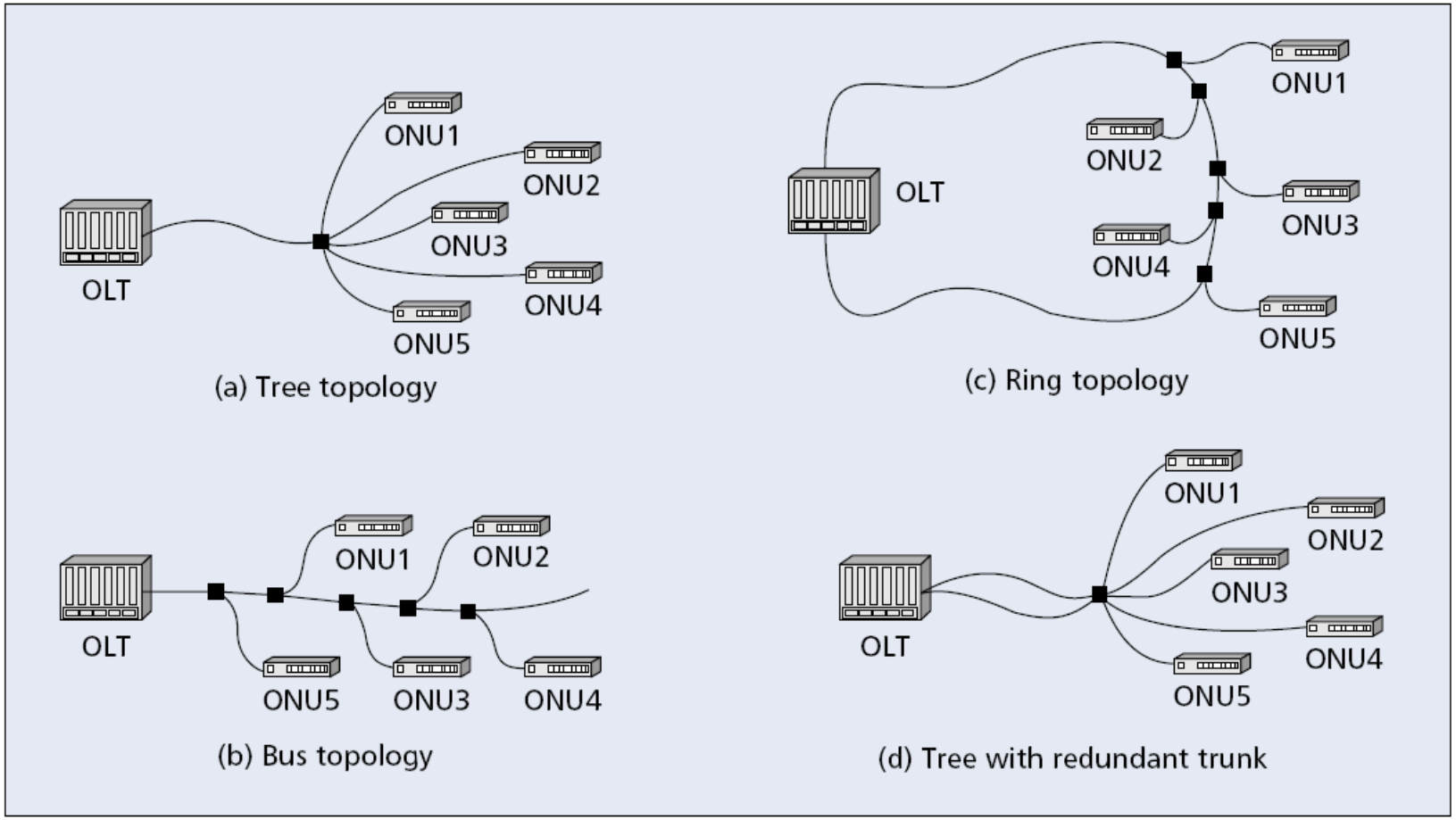


Fig. 2. 1×32 PLC splitter.





PON Topologies



source: KRAMER, Glen; PESAVENTO, Gerry. Ethernet passive optical network (EPON): building a next-generation optical access network. *IEEE Communications magazine*, 2002, 40.2: 66-73.

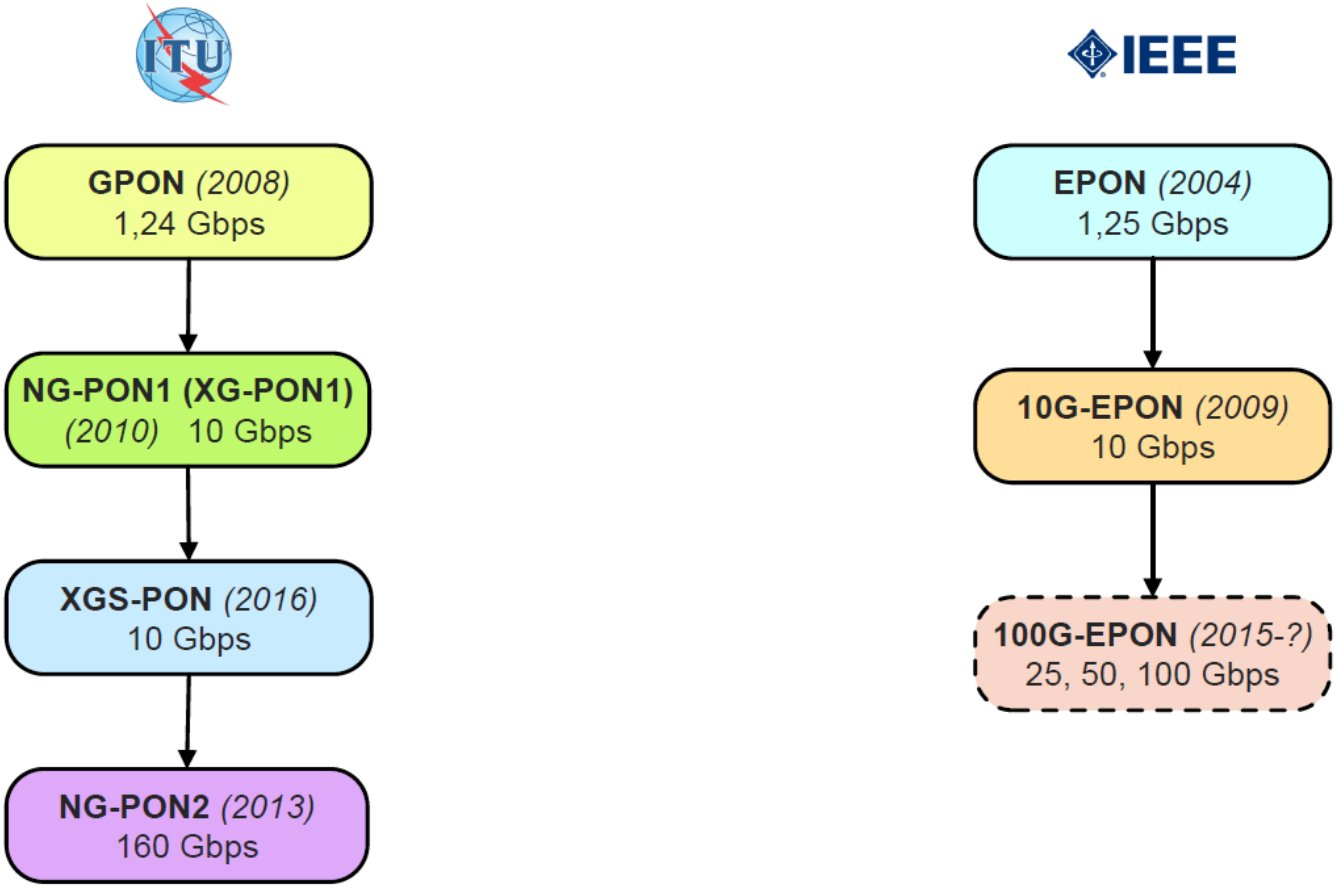
PON nodes

- **Optical Line Terminal** (OLT) - Central Office node
- **Optical Network Units** (ONU) – one or more user node
- **Optical Distribution Network** (ODN) - optical fibers and splitters between ONU and OLT

FTTx – Fiber to the …?

- Fibre to the x (FTTX) is a generic term for network architecture using optical fiber to provide **all** or **part** of the local loop used for last mile.
- We distinguish:
  - **FTTB** (Fiber-to-the-building) - fiber reaches the boundary of the building.
  - **FTTC** (Fiber-to-the-curb / Fiber to the cabinet) - this is very similar to FTTN, but the street cabinet or pole is closer to the user's premises; typically within 300m.
  - **FTTD** (Fiber-to-the-desk) - fiber connection is installed from the main computer room to an outlet near the user’s desk.
  - **FTTH** (Fiber-to-the-home) - fiber reaches the boundary of the living space, such as a box on the outside wall of a home.
  - **FTTN** (Fiber-to-the-node) - fiber is terminated in a street cabinet up to several kilometers away from the customer premises.

Evolution of PON



GPON (G.984.1)

- Gigabit Passive Optical Networks
- defined by ITU uses the general PON architecture
- Optical Splitter merely divides the optical power into N separate paths to the users. The optical paths can vary between 2 to 128.
- basic parameters:
  - downlink and uplink bitrate up to 2,488 Gbit/s
  - range up to 20 km
  - dividing ratio up to 1:64
- new protocol GEM (GPON Encapsulation Method) is defined

IEEE EPON (802.3ah)

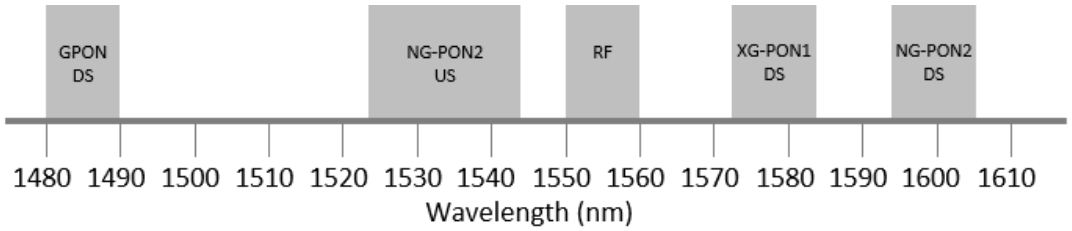
- Gigabit Ethernet Passive Optical Networks
- defined by IEEE 802.3ah
- uses the general PON architecture
- basic parameters:
  - downlink and uplink bitrate up to 1,25 Gbit/s
- a standard **Ethernet** frames are used
- basic parameters:
  - downlink and uplink bitrate up to 1,25 Gbit/s
  - range up to 20 km
  - dividing ratio up to 1:32

XG-PON (G.987)

- asymetric 10/2,5 Gb/s

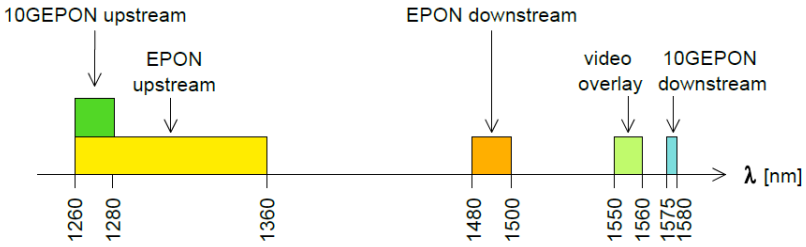
NG-PON2 (G.989.2)

- max 40 km, 1:64
- **TWDM-PON -** downstream and upstream is divided into 8 channels (wavelengths) → 8x10 Gb/s
- up to 80 Gb/s symmetrically per one fibre!
- flexible transition from GPON → NG-PON2



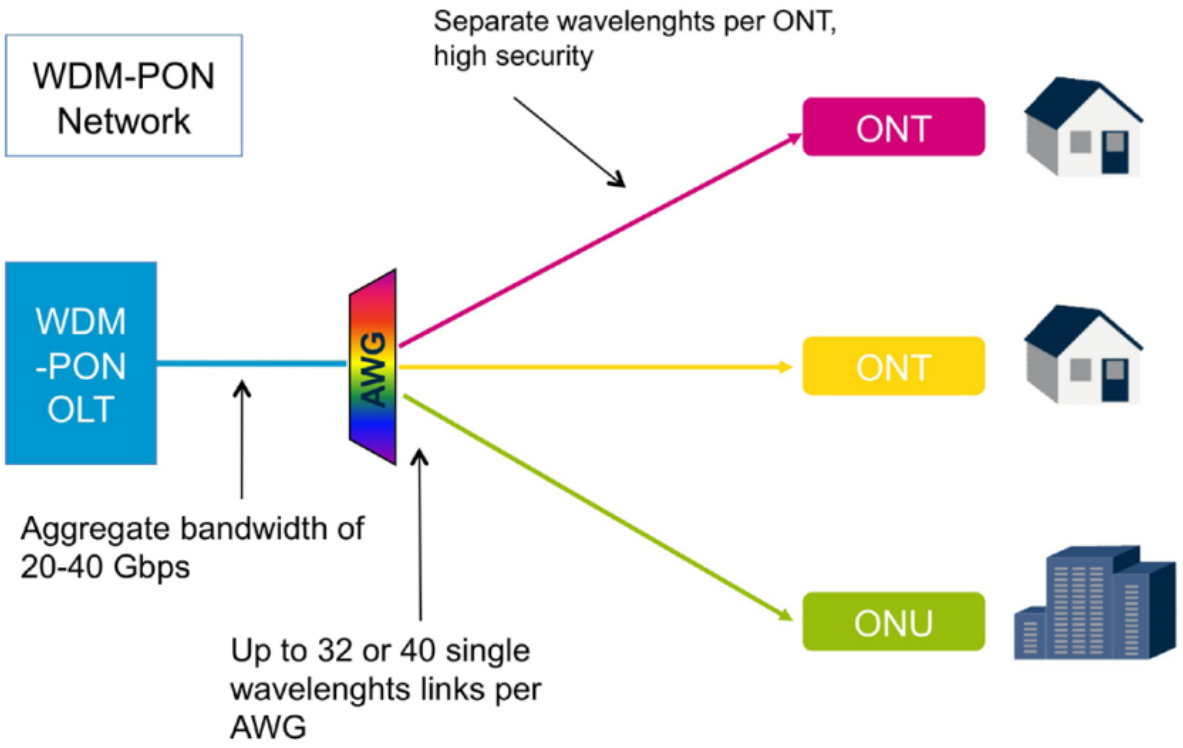
IEEE 10G-EPON (802.3av)

- 10Gbit/s symetric
- **back compatible with 802.3ah**
- 10/1GBASE-PRX
- 10GBASE-PR - 10 Gbit/s symmetrically
- flexible transition from EPON → 10G-EPON
- Next Generation PON 100G-EPON (IEEE 802.3ca) – not approved

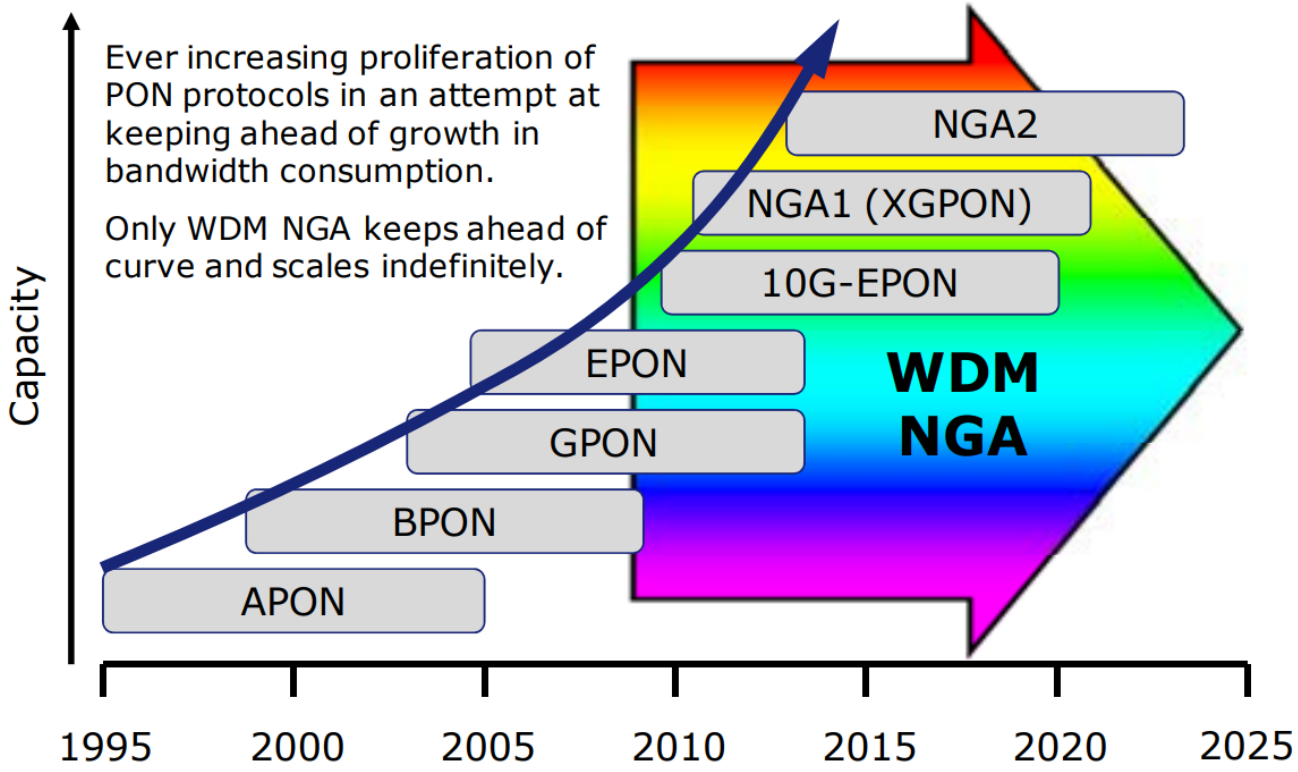


WDM-PON

- aim: combine more optical channels to one fibre by Wavelength Division Multiplex
- use of a completely separate downstream wavelength for each of the subscribers.
- this separate wavelength provides more bandwidth to each subscriber

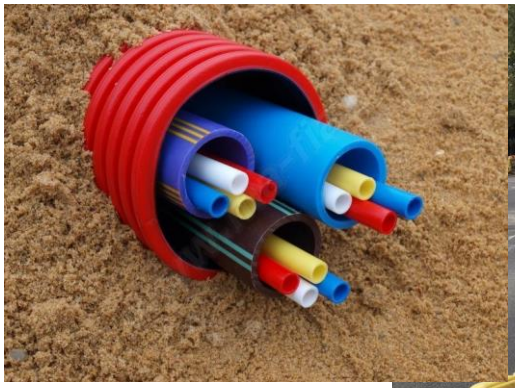


Capacity Trend for PON

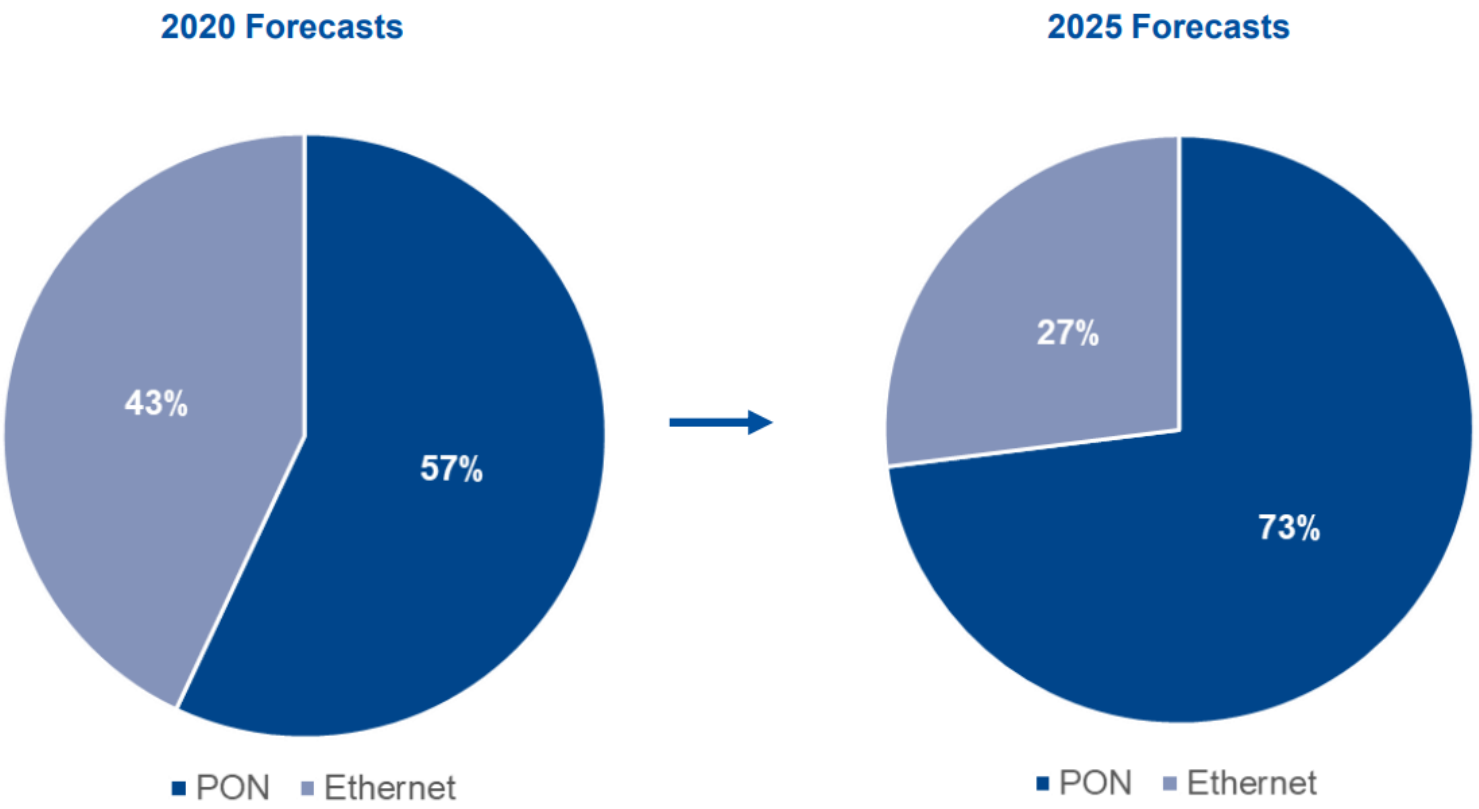


Source: INTRODUCING WDM INTO NEXTGENERATION ACCESS NETWORKS, ADVA Optical Networking

PON installation



FTTH Architecture & Technology trends



source: : IDATE for FTTH Council EUROPE

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