Access Networks

Libor Michalek

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Department
of Telecommunications

Access Network

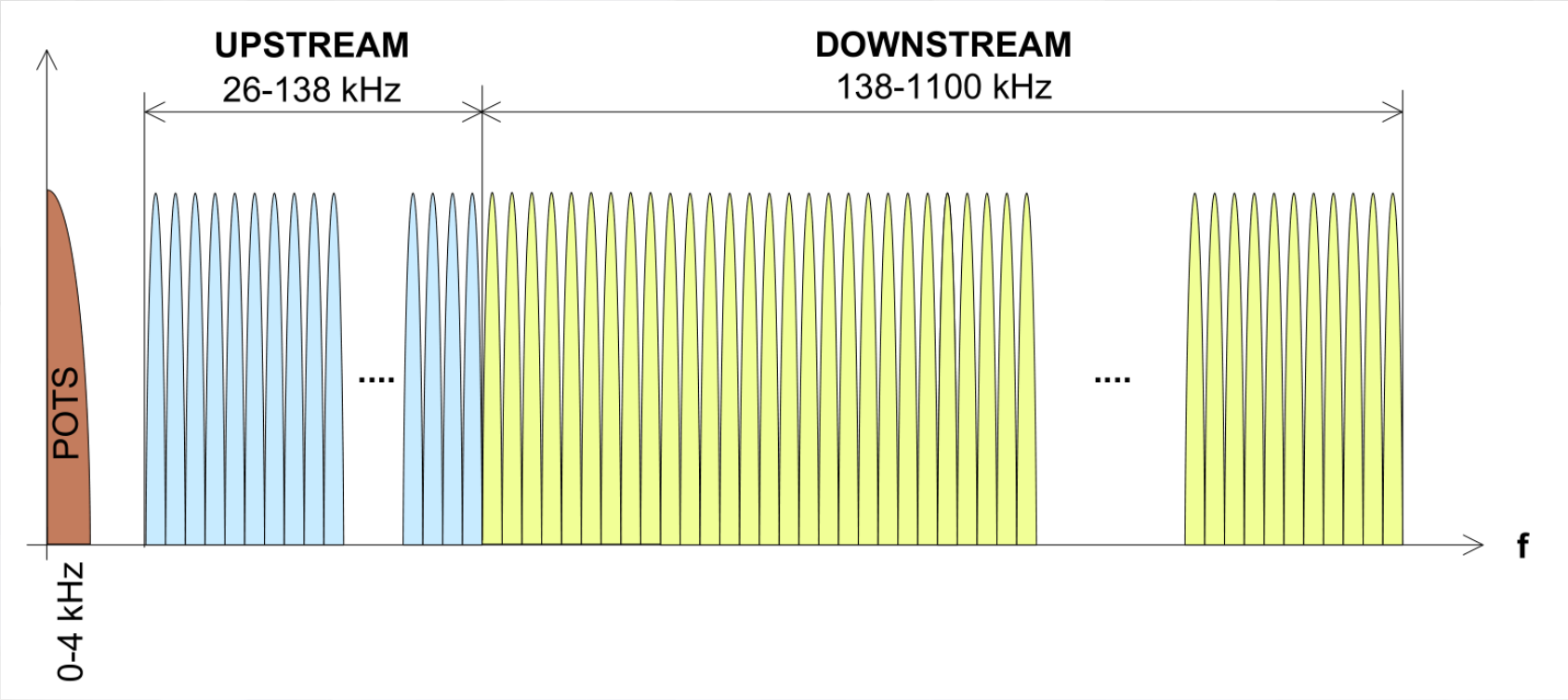
- Part of the communication network that directly connects the customer with the service provider (e.g. Internet).
- **Can be built using**
  1. **Wireless technology**
  2. **Metallic symmetric or asymmetrical lines**
  3. **Optical fiber**

xDSL

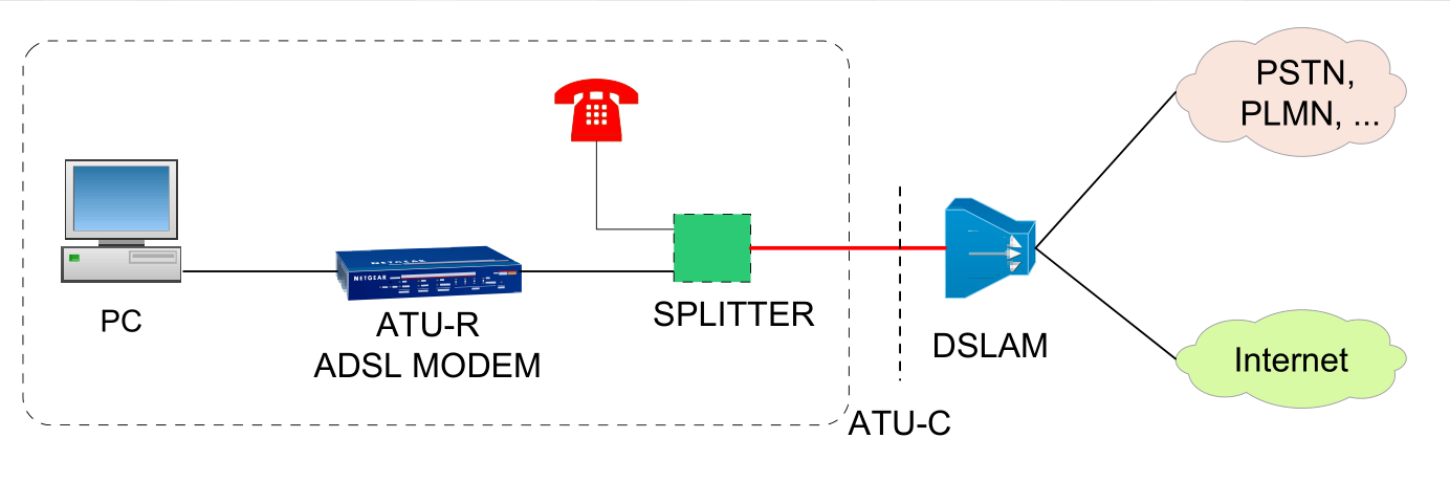
- called as DSL (Digital Subscriber Line) family
- include several variations, the lower case ***x*** in front of DSL include:
  - Asymmetric Digital Subscriber Line (ADSL)
  - ISDN (like) Digital Subscriber Digital Line (IDSL)
  - Consumer Digital Subscriber LIne (CDSL)
  - Single High Speed DSL (SHDSL)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

ADSL systems

- Asymmetric Digital Subscriber Line
- converge the existing twisted pair telephone lines into the high-speed communications access
- modem technology used to transmit speeds of between 1,5 Mbps and 6 Mbps
- asymmetric = data flow is greater in one direction than the other
- communication is full duplex using most the FDD (Frequency Division Duplex)
- two separate bands – upstream and downstream
- upstream **25,875 kHz to 138 kHz**
- downstream **138 kHz – 1104 kHz**



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



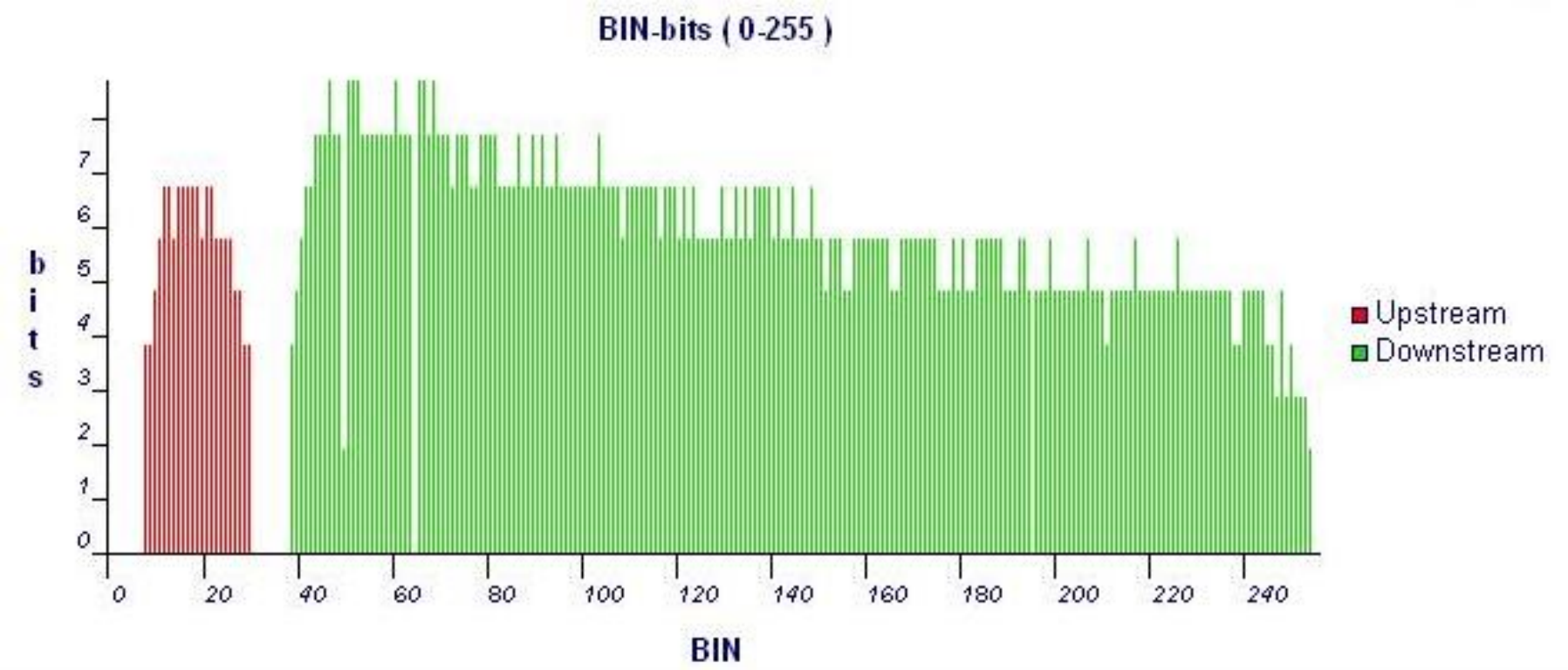
- main component is **DSLAM** (DSL Access Multiplexer)
  - located in the telephony exchanges of the service providers
  - intermixes voice traffic and DSL traffic on the customer's DSL line
  - collects the data from its many modem ports and aggregates their voice and data traffic into one complex composite signal via multiplexing
  - 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

ADSL standards

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	

- **ADSL** (G.DMT)
  - using discrete multitone modulation
  - separates the ADSL signal into 255 carriers (bins/tones) centered on multiples of **4.3125 kHz**
  - DMT has 224 downstream frequency bins and up to 31 upstream bins
  - up to 15 bits per symbol can be encoded on each bin on a good quality line
  - the number of bits encoded on each bin depending on the **attenuation** and **signal to noise ratio for that bin,** tones are independent of one another
  - QAM or phase-shift keying (PSK) is used to encode the bits within each bin
  - when the modem is initialized, the number of bits assigned to a tone is set to compensate the differences in transmission characteristics of line
  - Bits rates can be adjusted in small increments of a few tens of kilobits per second

Preview the arrangement of individual bits on each sub-carrier

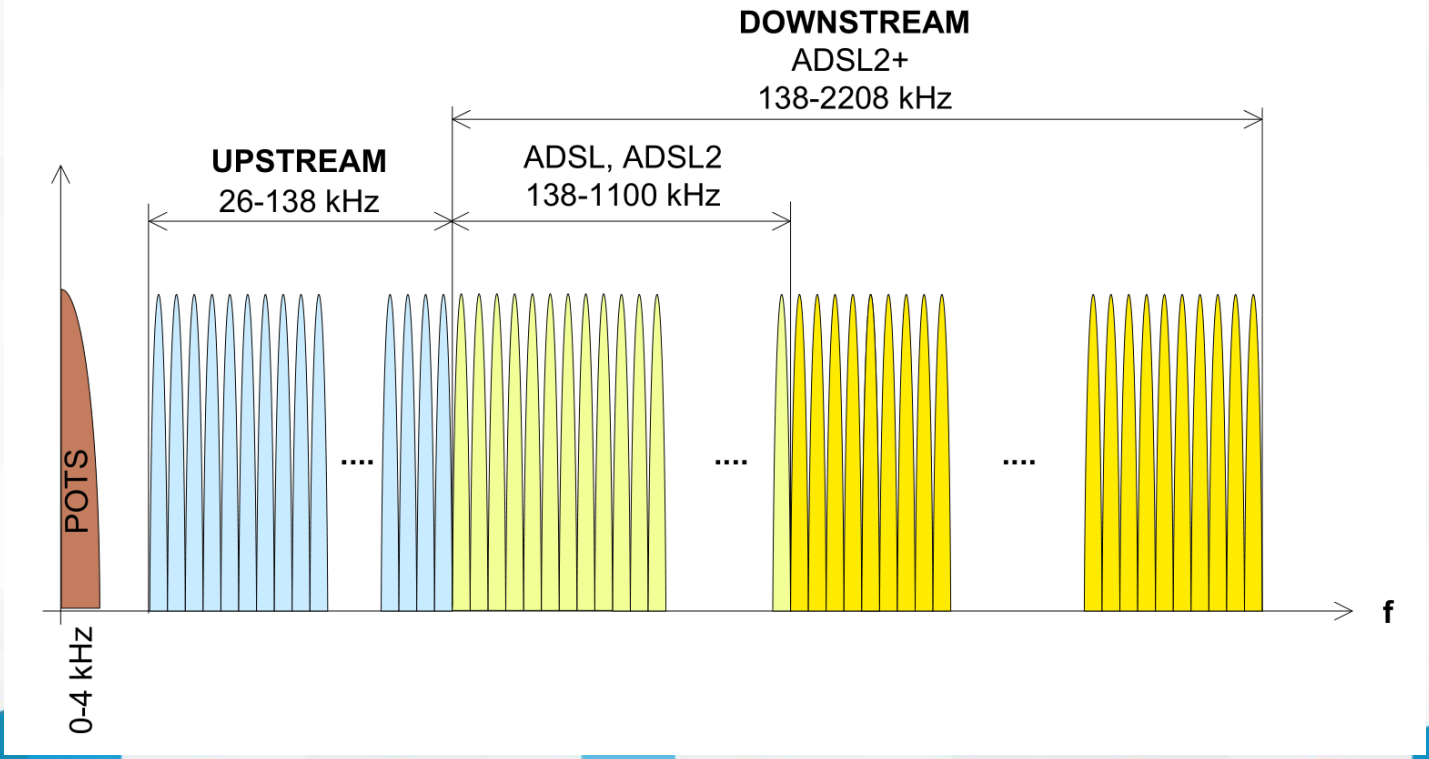


ADSL2

- ITU-T G.992.3 and G.992.4
- adds new features and functionality targeted at improving performance and interoperability
  - dynamic data rate adaptation
  - flexible structure of frame
  - reduces the initialization time to less than 3 seconds
- improve data rates
  - 12 Mbit/s downlink
  - 3,5 Mbit/s uplink

ADSL2+

- extends the capability of basic ADSL by increased frequency band to **2,208 MHz**
- DMT has 511 downstream frequency bins and up to 36 upstream bins
- data rates can be 24 Mbit/s for downstream – short lacal loop
- local loop >3km – problem with attenuation and crosstalk



VDSL

- Very-High-Data-Rate Digital Subscriber Line
- same philosophy as ADSL
- up to 30 MHz, max 1.6 km
- max 52 Mbit/s for downstream, 6.4 Mbit/s upstream

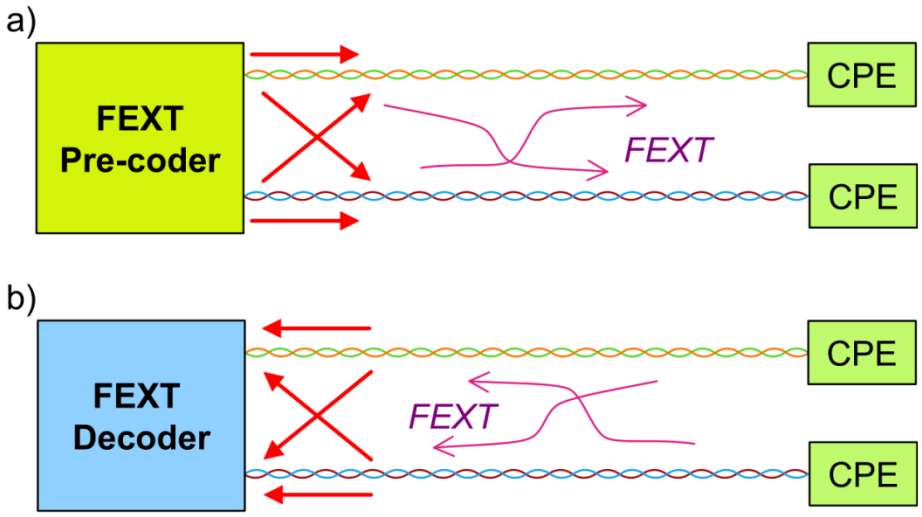
VDSL2

- Very-High-Data-Rate Digital Subscriber Line version 2
- same philosophy as ADSL
- up to 30 MHz with wider bandwith of subchannels **8,625 kHz**
- max 52 Mbit/s for downstream, 6.4 Mbit/s upstream

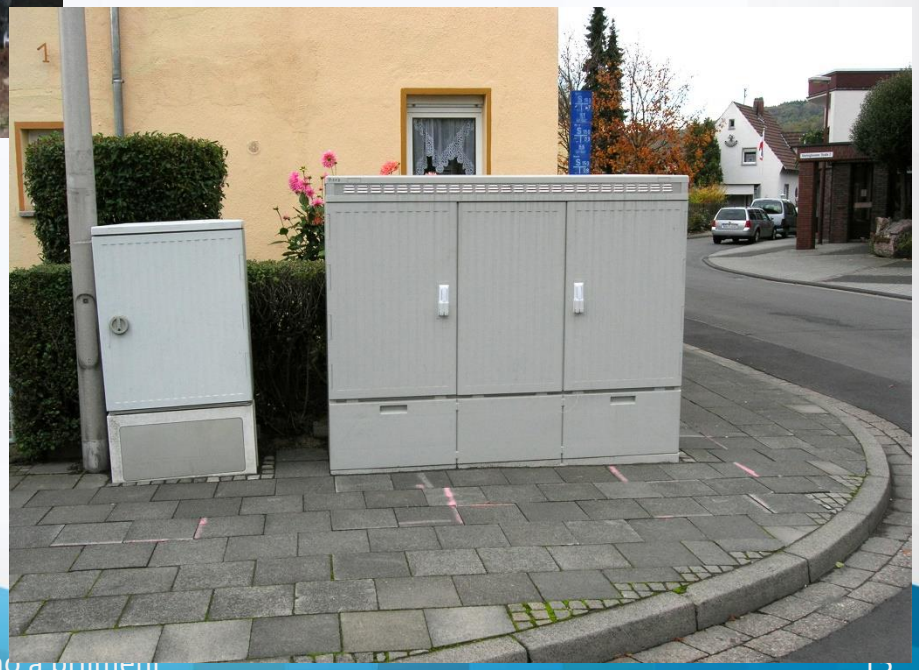
Type	ADSL2	ADSL2+	VDSL2	VDSL2	VDSL2
Margin of subchannels [Hz]	4312,5	4312,5	4312,5	4312,5	8625
Number of Subchannels	256	512	1972	4096	3479
Bandwidth [MHz]	1,1	2,2	**8,5**	**17,7**	**30**

G.FAST

- under G.9701, approved 12/2014
- up to **106 MHz**
- for short loops (up to 250m)
- <100m ~ 1 Gbps, 200m ~ 500Mbps, 300m ~ 300Mbps
- problem with crosstalk between multiple wire pairs
- self-FEXT (far-end crosstalk) cancellation is done by **vectoring**

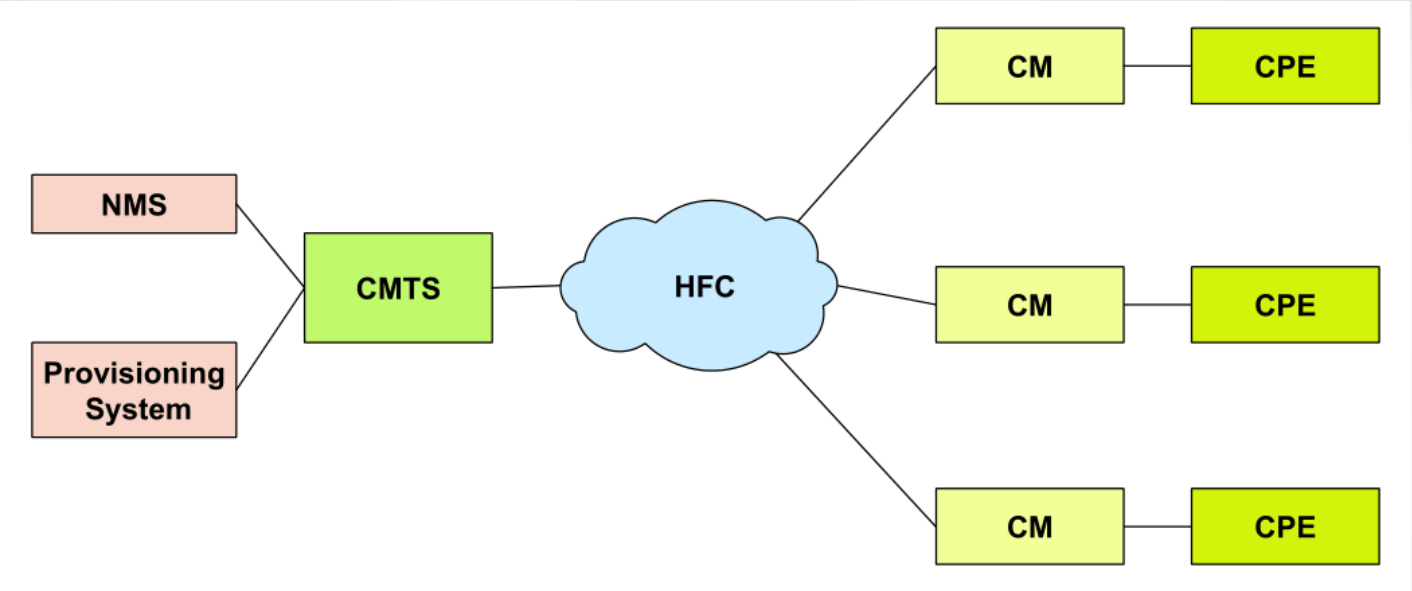


Installation



DOCSIS

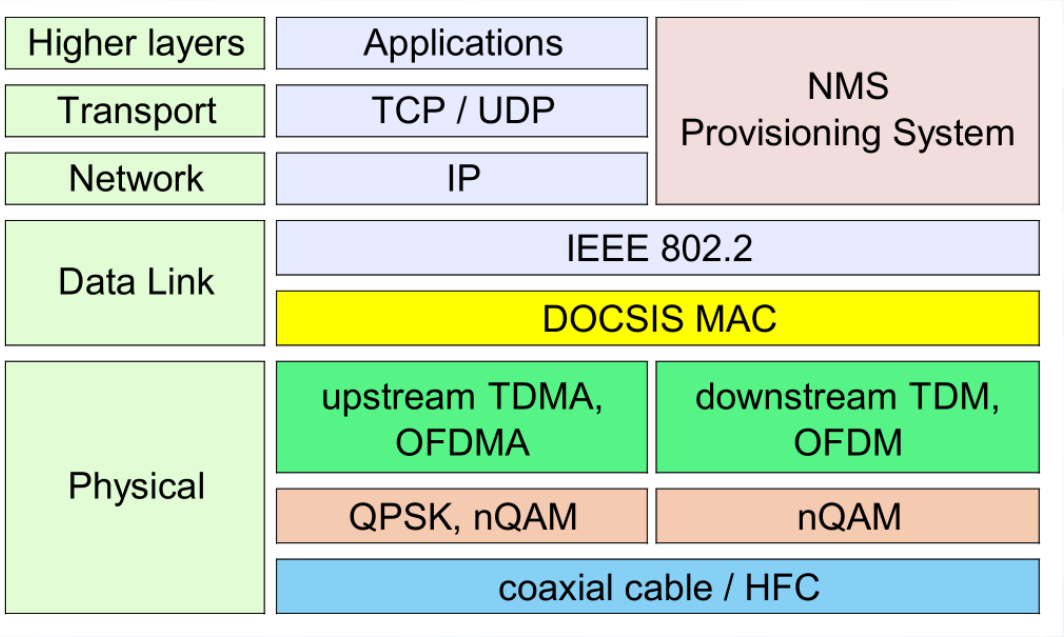
- Data Over Cable Service Interface Specification
- defines interface requirements for cable modems involved in high-speed data distribution over CATV systems
- developed by CableLabs
- frequency allocation band plans differ between U.S. and European CATV → EuroDOCSIS
- 3 versions of standard (1.0, 2.0,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



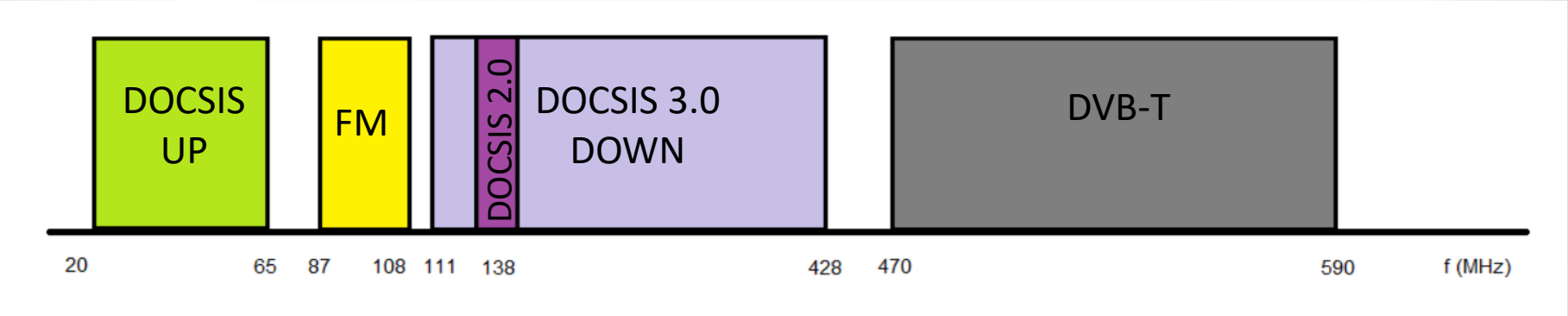
- **CPE** (Customer Premises Equipment) – most often the PC
- **CM** (Cable Modem) - located at the customer premises
- **CMTS** (Cable Modem Termination System) - located at the CATV headend
- **HFC** (Hybrid Fibre-Coax) is a network which is based on a combination of optical fibre and coaxial cable

DOCSIS – Protocol Stack

- defined the characteristics for **first** and **second** layer



- **Physical Layer**
  - 5-85 MHz for upstream
  - 254-1218 MHZ for downstream
  - OFDM/OFDMA use up to 8k subcarriers
  - up to 4096QAM, in future up to 16384QAM



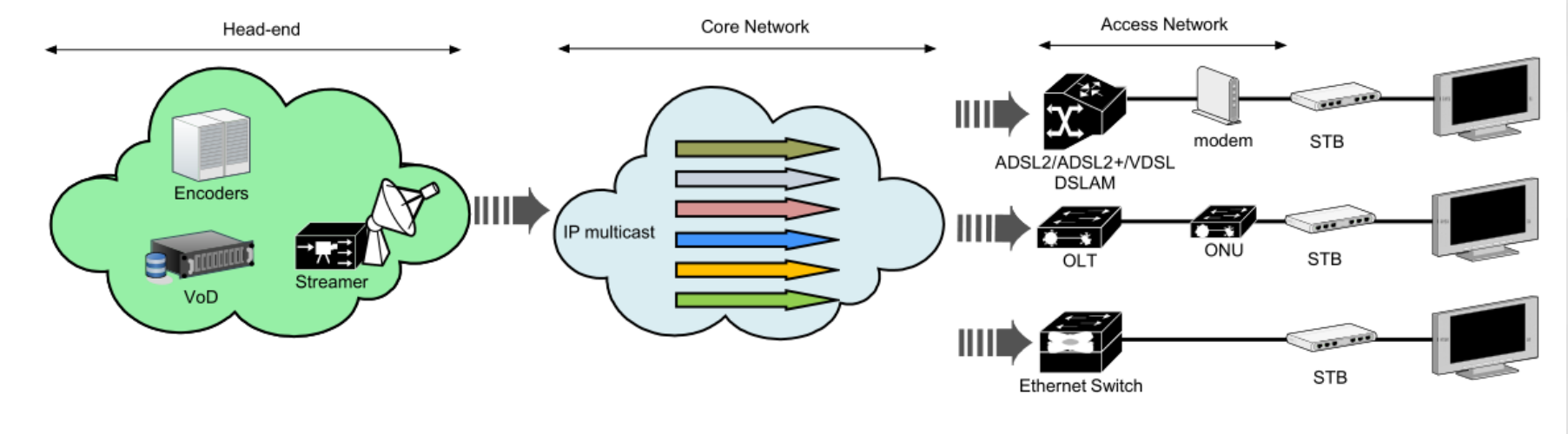
Example of arrangement of spectrum

- **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 Pla**y 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 802.11n

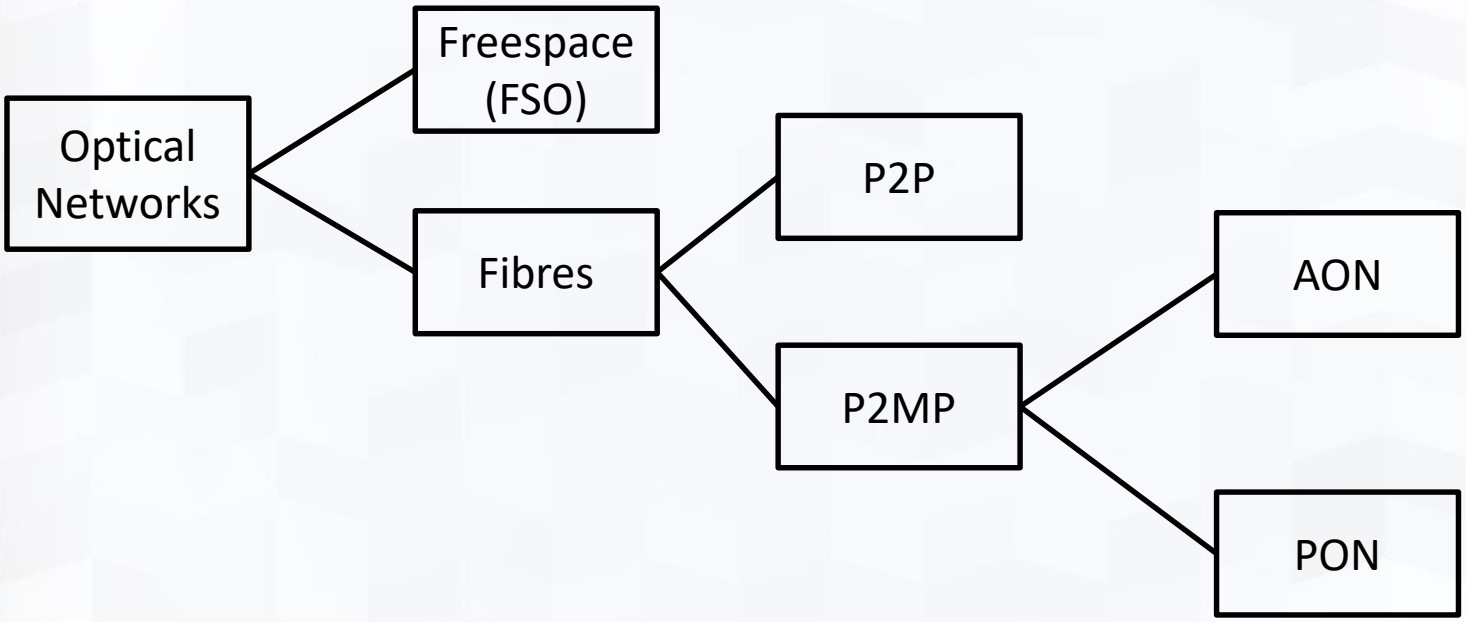
IPTV Architecture



- **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 Network

- 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

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

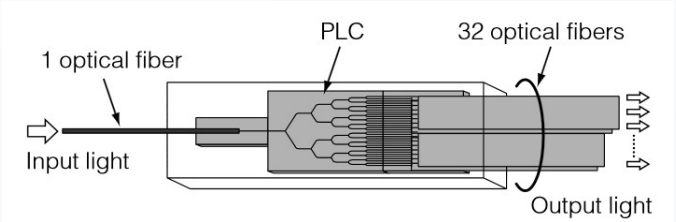
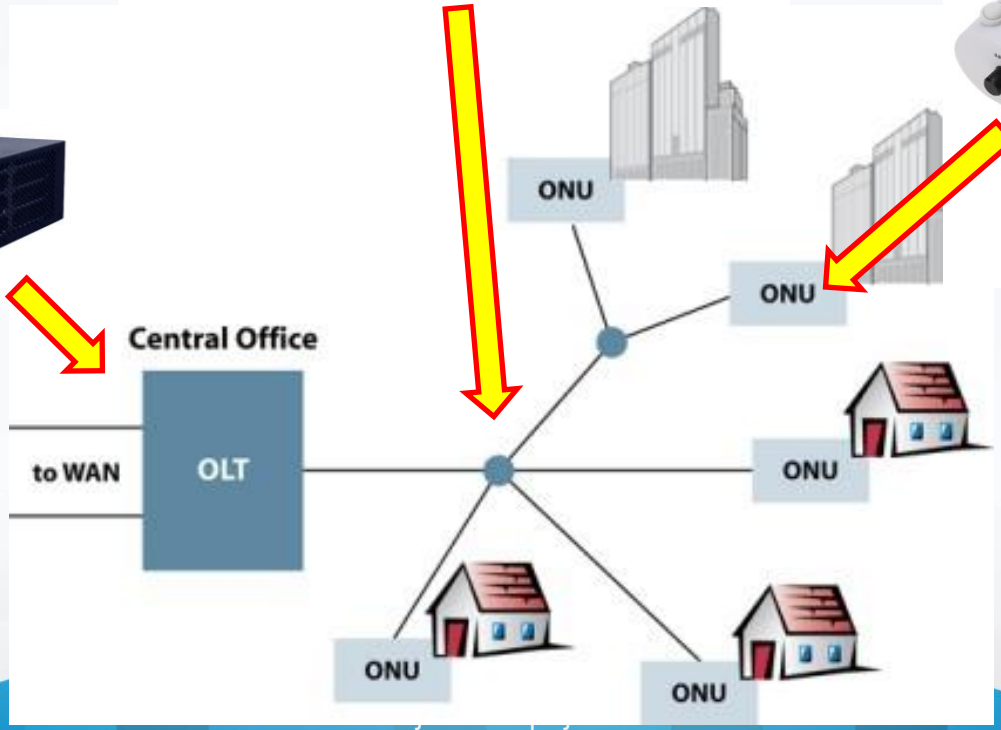


Fig. 2. 1×32 PLC splitter.



- 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.

GPON

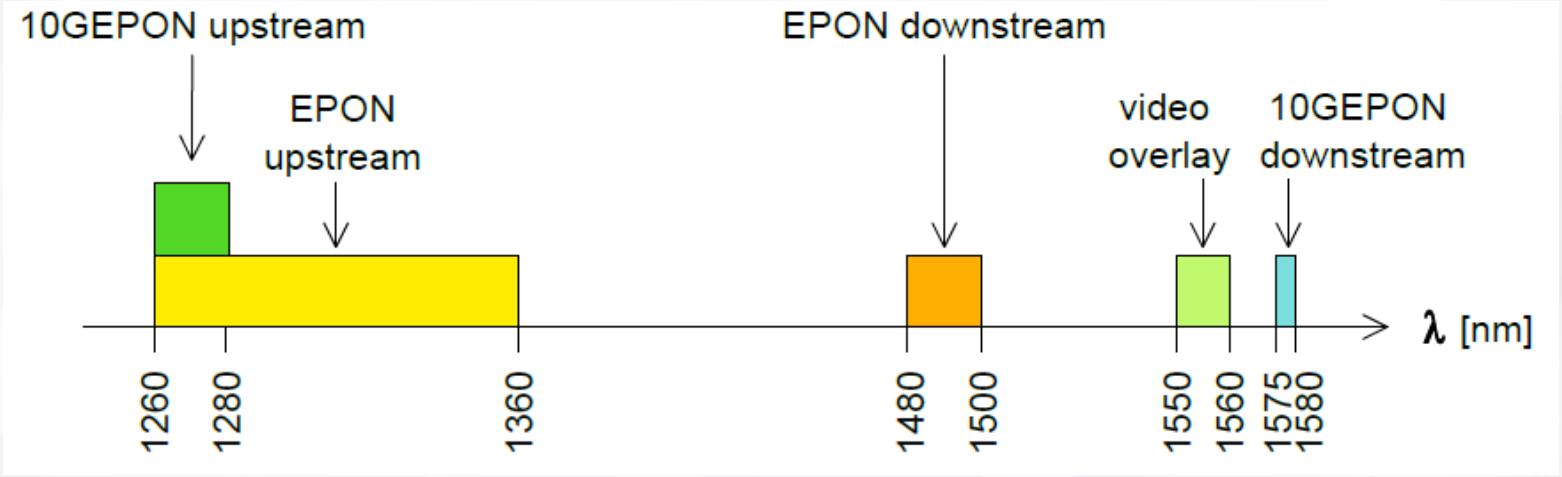
- Gigabit Passive Optical Networks
- defined by G.984.1
- uses the general PON architecture
- Optical Splitter merely divides the optical power into N separate paths to the users. The optical paths can vary between 2 to 128.
- basic parameters:
  - downlink and uplink bitrate up to 2,488 Gbit/s
  - range up to 20 km
  - dividing ratio up to 1:64
- new protocol GEM (GPON Encapsulation Method) is defined

EPON

- Gigabit Ethernet Passive Optical Networks
- defined by IEEE 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

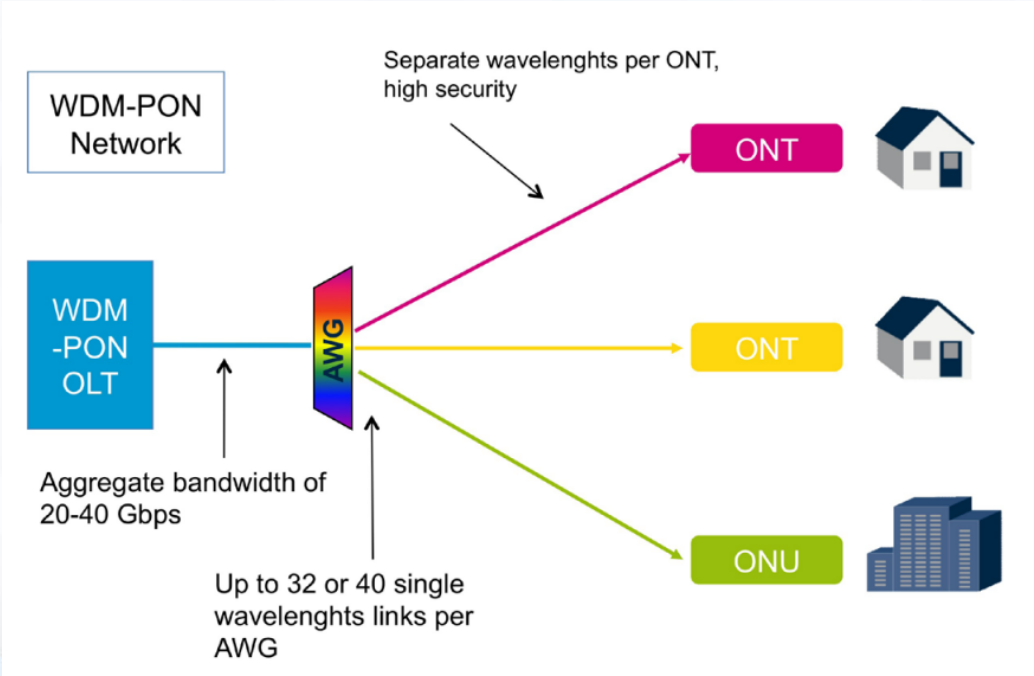
10GEPON

- 10Gbit/s variant
- **back compatible with 802.3ah**
- 10/1GBASE-PRX - 10 Gbit/s for downstream, 1 Gbit/s for upstream
- 10GBASE-PR - 10 Gbit/s symmetrically
- sharing of bandwidth is based on TMDA for upstream and on FDMA for downstream



WDM-PON

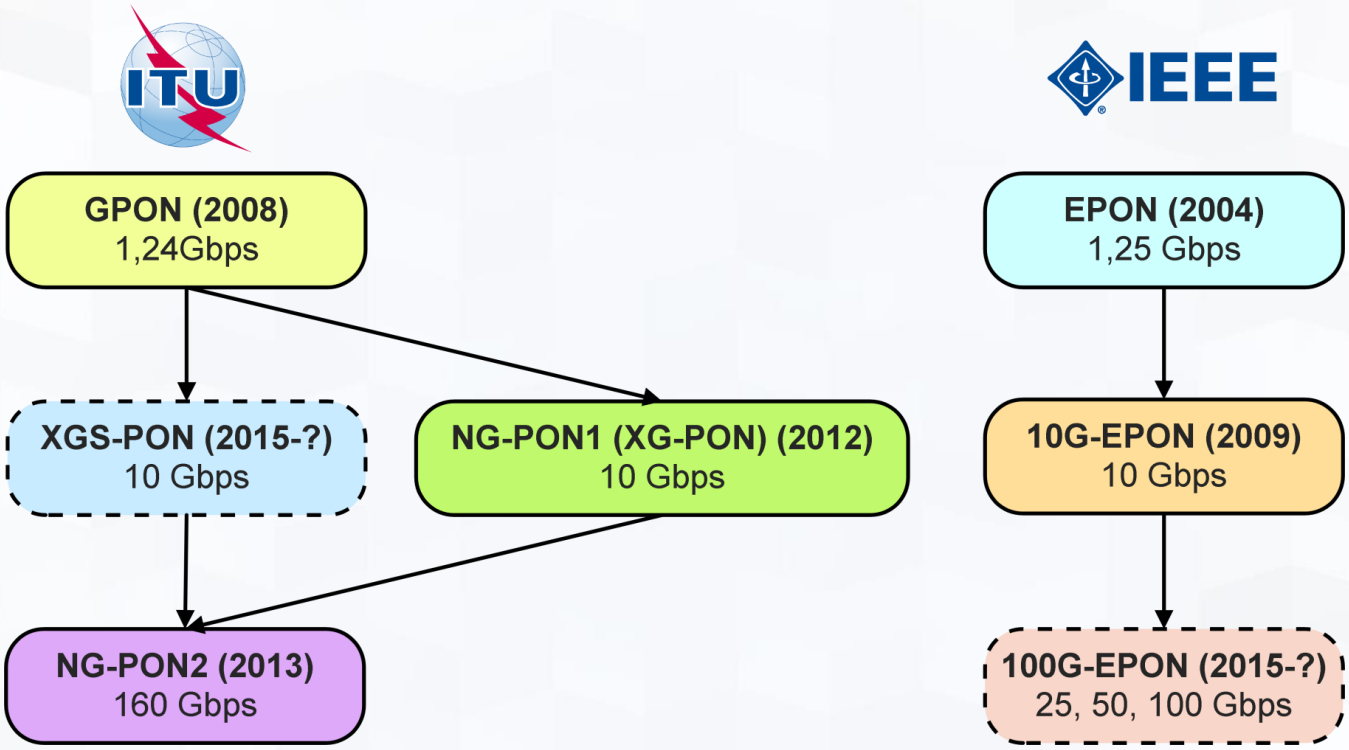
- aim: combine more optical channels to one fibre by Wavelength Division Multiplex
- use of a completely separate downstream wavelength for each of the subscribers.
- this separate wavelength provides more bandwidth to each subscriber



NG-PON

- **NG-PON1**, sometimes as XG-PON (ITU G.987)
- **NG-PON2**
  - over 40 Gb/s
  - over 40 km
  - 1:64
  - as final technology – **TWDM-PON** is used
  - flexible transition from GPON → NG-PON2
  - 1596-1603 nm for downstream,
  - 1524-1544 nm for upstream.
  - downstream and upstream is divided into 8 channels (wavelengths)
  - up to 80 Gb/s symmetrically per one fibre!

PON evolution



References I.

- ITU-T G.992.1: Asymmetric digital subscriber line (ADSL) transceivers. ITU-T, 1999.
- ITU-T G.992.3: Asymmetric digital subscriber line transceivers 2 (ADSL2). ITU-T, 1999.
- ITU-T G.992.4: Splitterless asymmetric digital subscriber line transceivers 2 (splitterless ADSL2). ITU-T, 2002.
- ITU-T G.992.5: Asymmetric digital subscriber line 2 transceivers (ADSL2)- Extended bandwidth ADSL2 (ADSL2plus). ITU-T, 2009.
- ITU-T G.993.1: Very high speed digital subscriber line transceivers (VDSL). ITU-T, 2004.
- ITU-T G.993.2: Very high speed digital subscriber line transceivers 2 (VDSL2). ITU-T, 2011.
- Vectoring Technology White Pager. Huawei Technologies Co., Ltd, 2012. http://www.huawei.com/es/static/HW-278064.pdf
- Vanhastel, Dr. Stefaan. The numbers are in: Vectoring 2.0 makes g.fast faster, July 2013. http://www2.alcatel-lucent.com/techzine/the-numbers-are-in-vectoring-2-0-makes-g-fast-faster
- Laboratories, Cable Television. Data-Over-Cable Service Interface Specifications DOCSIS 3.1. Physical Layer Specification CM-SP-PHYv3.1-I02-140320. Cable Television Laboratories, 2014.
- Laboratories, Cable Television. Data-Over-Cable Service Interface Specifications DOCSIS 3.1. MAC and Upper Layer Protocols Interface Specification. CM-SP--MULPIv3.1-I02-140320. Cable Television Laboratories, 2014.
- ITU-T J.112: Transmission systems for interactive cable television services. ITU-T, 1998.
- ITU-T J.122: Second-generation transmission systems for interactive cable television services - IP cable modems. ITU-T, 2007.

- Vectoring Technology White Pager. Huawei Technologies Co., Ltd, 2012. http://www.huawei.com/es/static/HW-278064.pdf
- Vanhastel, Dr. Stefaan. The numbers are in: Vectoring 2.0 makes g.fast faster, July 2013. http://www2.alcatel-lucent.com/techzine/the-numbers-are-in-vectoring-2-0-makes-g-fast-faster

References II.

- Laboratories, Cable Television. Data-Over-Cable Service Interface Specifications DOCSIS 3.1. Physical Layer Specification CM-SP-PHYv3.1-I02-140320. Cable Television Laboratories, 2014.
- Laboratories, Cable Television. Data-Over-Cable Service Interface Specifications DOCSIS 3.1. MAC and Upper Layer Protocols Interface Specification. CM-SP-MULPIv3.1-I02-140320. Cable Television Laboratories, 2014.
- ITU-T J.112: Transmission systems for interactive cable television services. ITU-T, 1998.
- ITU-T J.122: Second-generation transmission systems for interactive cable television services - IP cable modems. ITU-T, 2007.
- Weinstein, S.B.., Luo, Y.., and Wang, T.. The ComSoc Guide to Passive Optical Networks: Enhancing the Last Mile Access. The ComSoc Guides to Communications Technologies. Wiley, 2012. ISBN 9781118250532.
- ITU-T G.984.1: Gigabit-capable passive optical networks (GPON): General characteristics. ITU-T, 2008.
- ITU-T G.987: 10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations and acronyms. ITU-T, 2012.
- ITU-T G.989.1 - 40-Gigabit-capable passive optical networks (NG-PON2): General requirements. ITU-T, 2013.