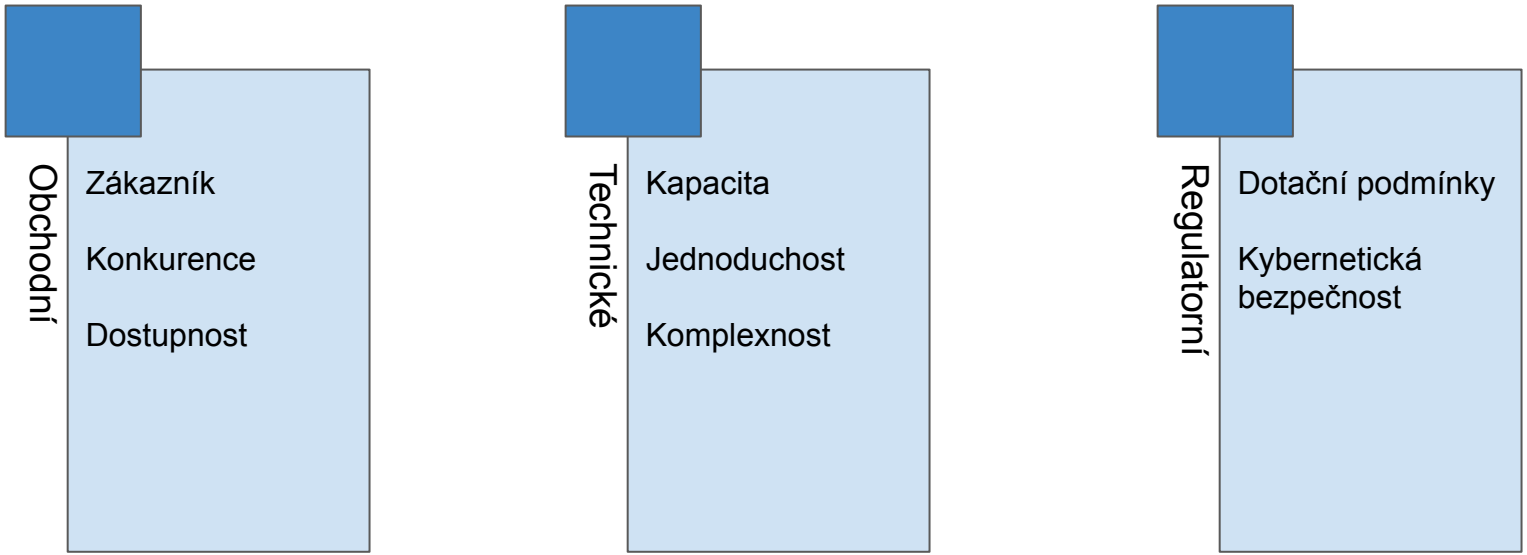
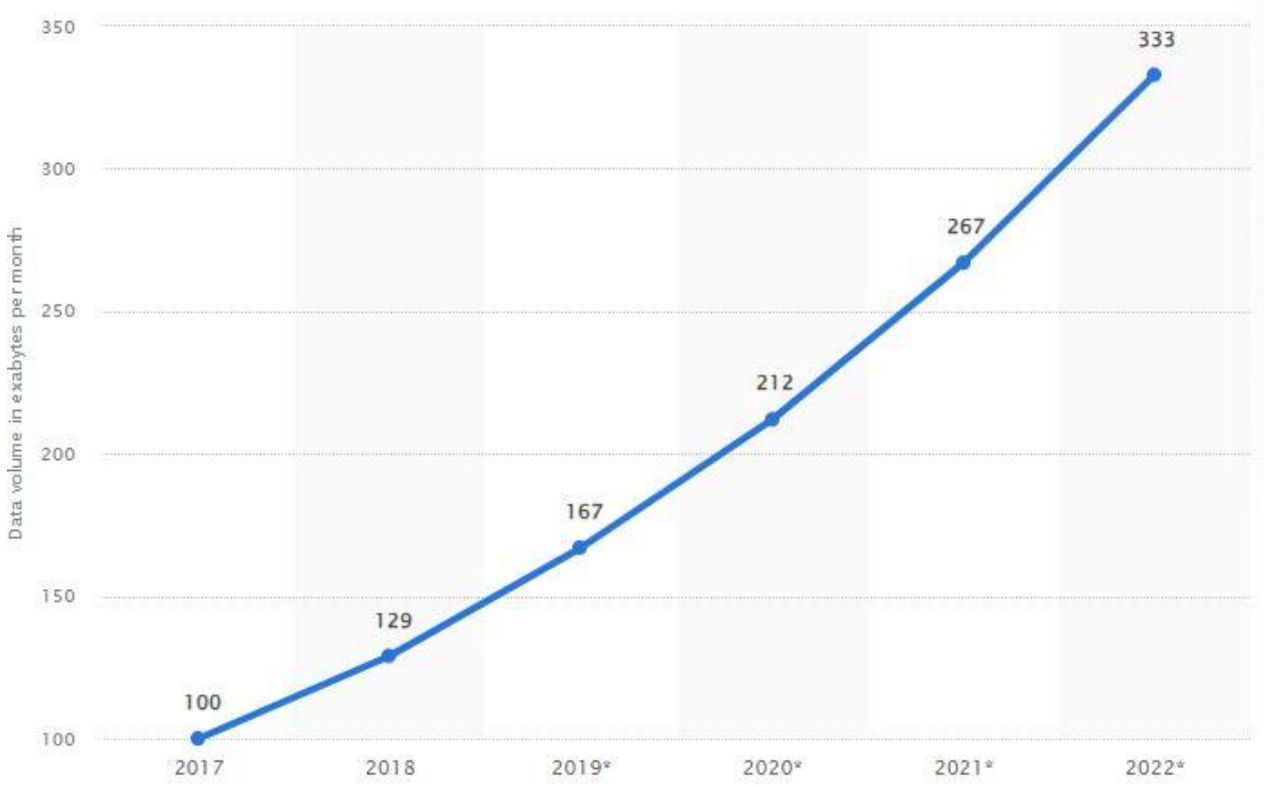
Budoucnost pasivních optických sítí

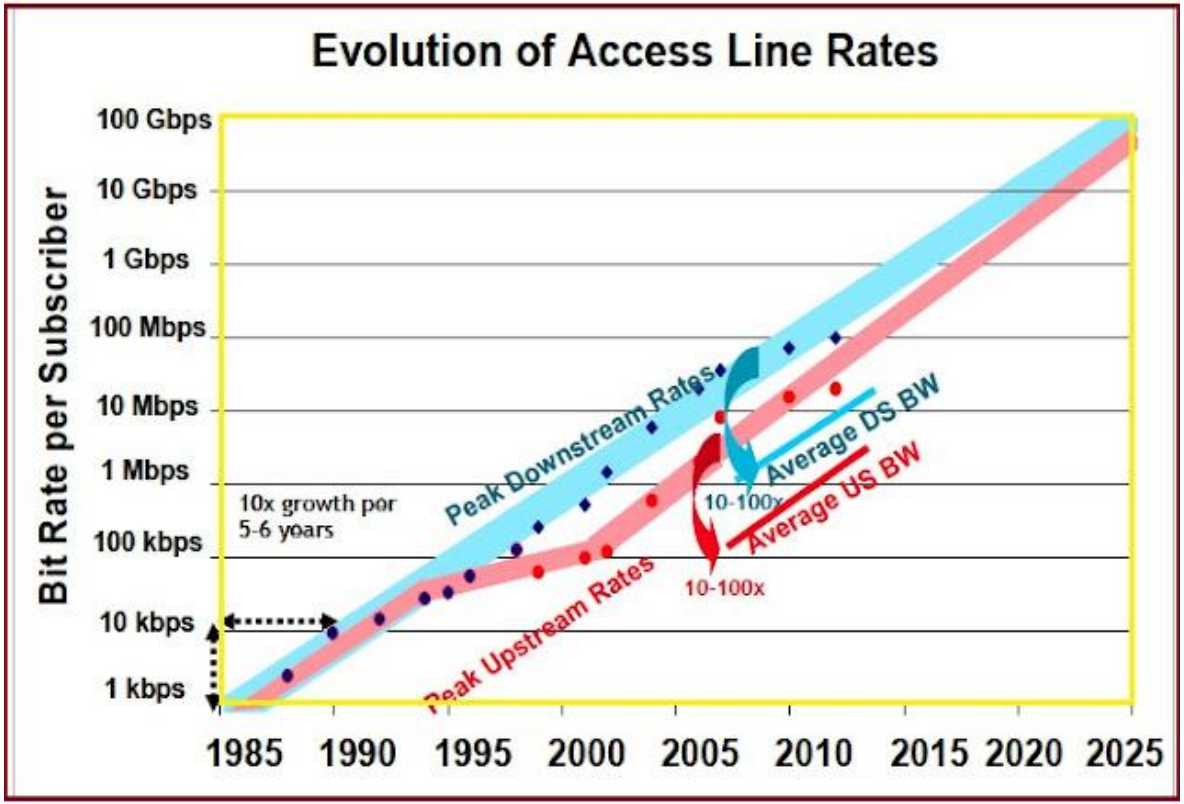
Štěpán Beneš


Obchodní
Zákazník
Konkurence
Dostupnost
Technické
Kapacita
Jednoduchost
Komplexnost
Regulatorní
Dotační podmínky
Kybernetická bezpečnost

Jakou rychlost budu potřebovat ?



Jakou rychlost budu potřebovat ?

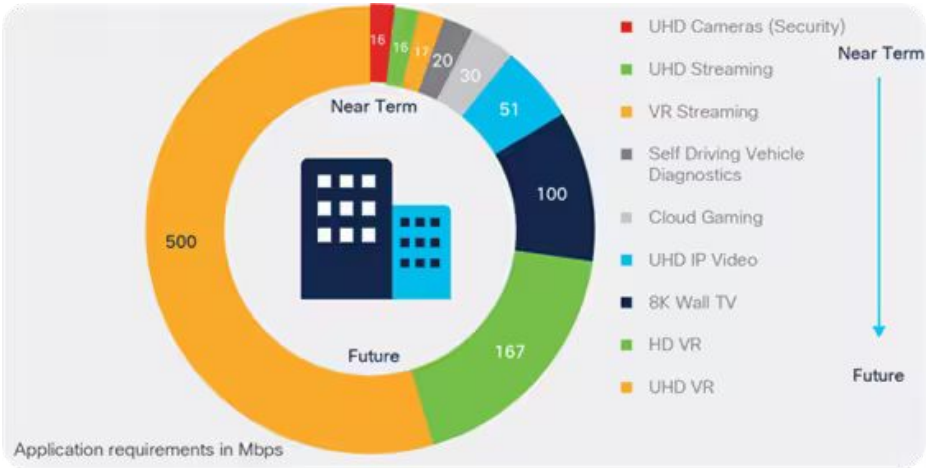


Jakou rychlost budu potřebovat ?

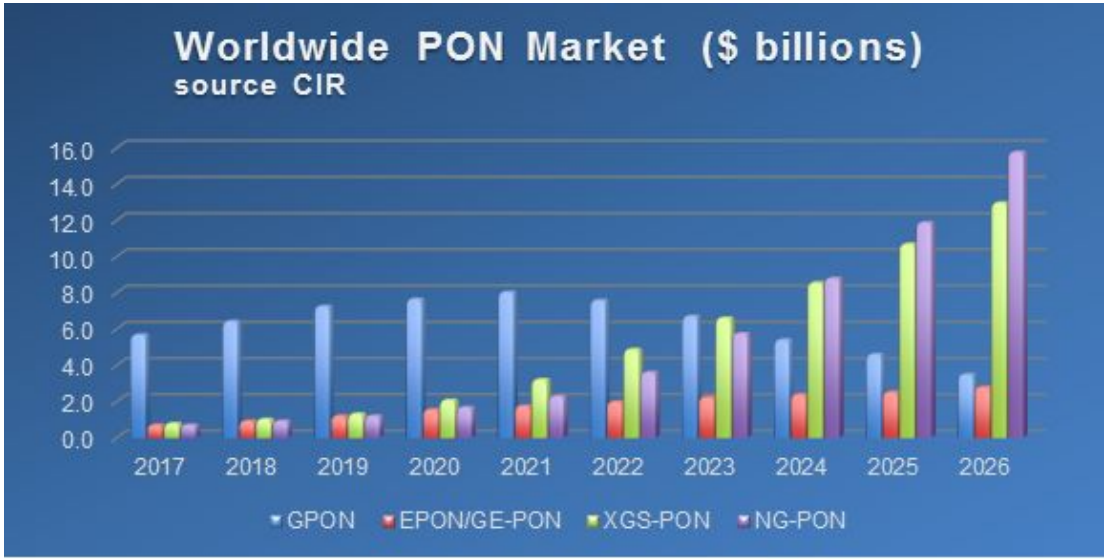
- Globální IP traffic vzrostl od roku 2017 (100 ExaB/měs) do roku 2022 více něž 3x (330 ExaB/měs)
- ve špičkách narostl dokonce 5x

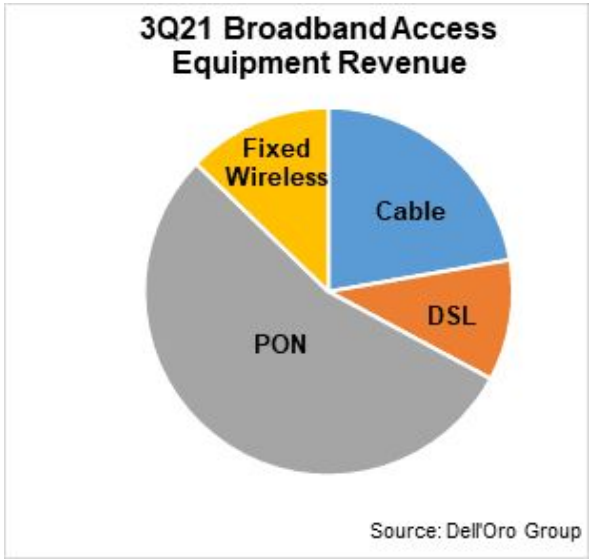
- roste náročnost jednotlivých aplikací
  - (u)HD streaming
  - (u)HD VoD (10+ Mbps)
- objevují se nové
  - cloud gaming (30+ Mbps)
  - Immersive VR (350 Mbps)

- CoVID
  - změna chování
  - virtuální office



Nástup 10G

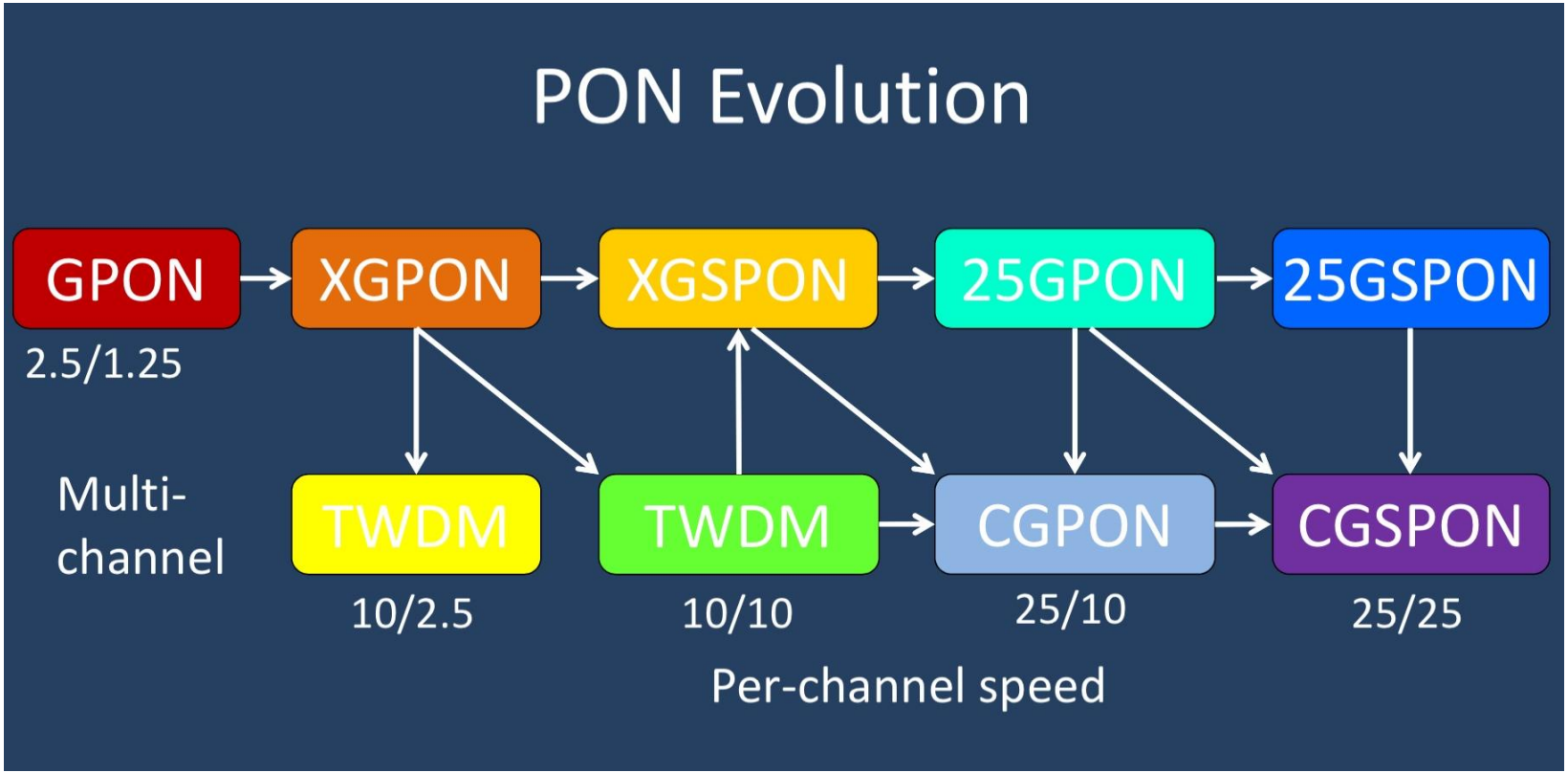

Worldwide PON Market ($ billions)
source CIR
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
GPON
EPON/GE-PON
XGS-PON
NG-PON


3Q21 Broadband Access Equipment Revenue
Fixed Wireless
Cable
DSL
PON
Source: Dell'Oro Group

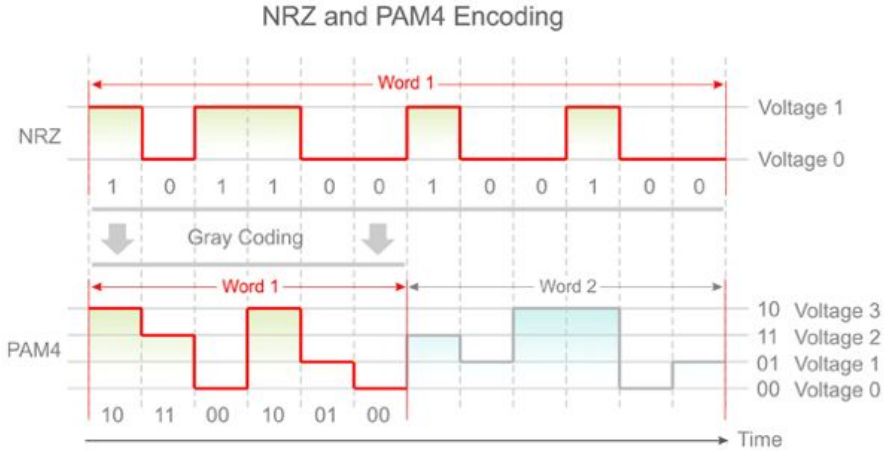
Pasivní část

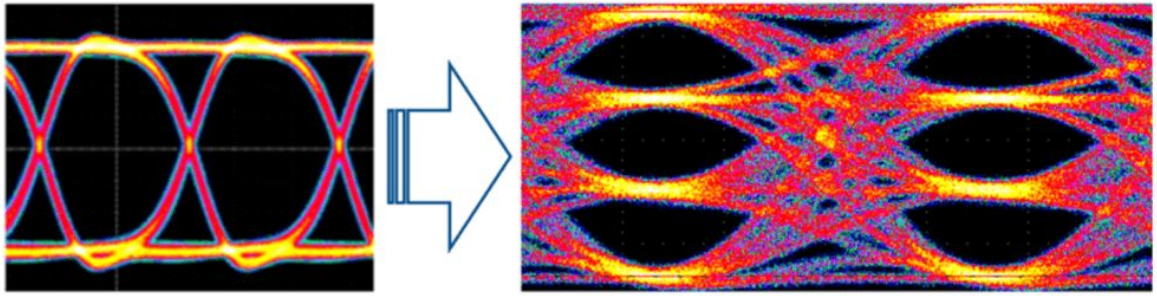
- šířka pásma [MHz . km];
- numerická apertura;
- disperze;
- útlum [dB];
- ztráty na makroskopických neregularitách;
- minimální poloměr ohybu;
- obsah OH;
- MDF

Evoluce

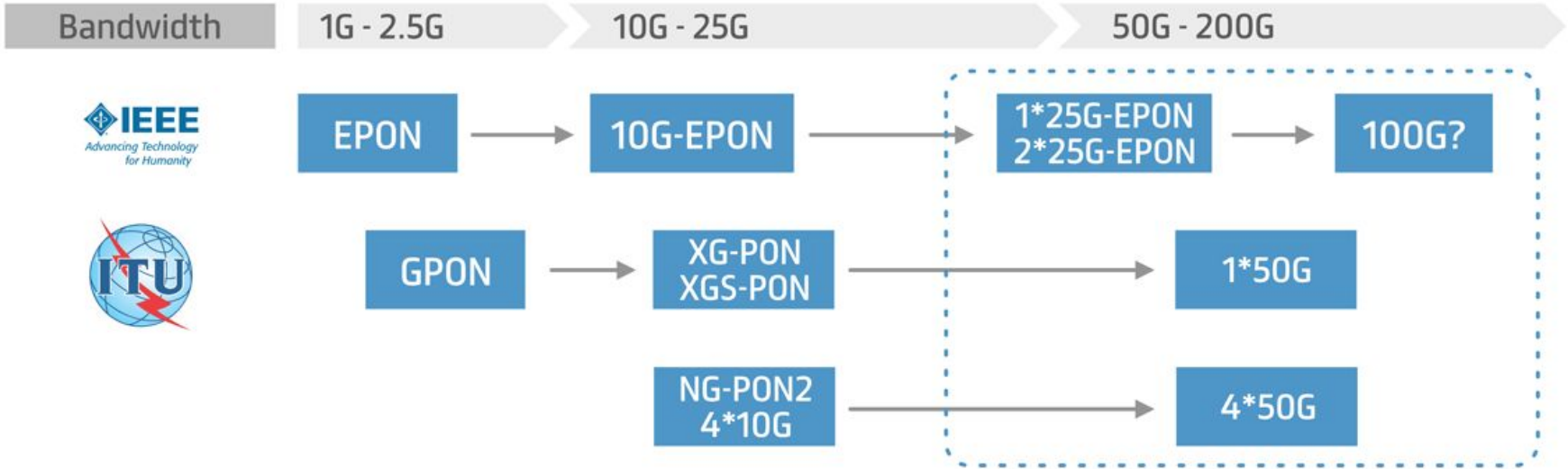

PON Evolution
GPON
XGPON
XGSPON
25GPON
25GSPON
2.5/1.25
Multi-
channel
TWDM
TWDM
CGPON
CGSPON
10/2.5
10/10
25/10
25/25
Per-channel speed

Modulace


NRZ and PAM4 Encoding
Word 1
NRZ
Voltage 1
Voltage 0
1 0 1 1 0 0 1 0 0 1 0 0
Gray Coding
Word 1
Word 2
PAM4
10 Voltage 3
11 Voltage 2
01 Voltage 1
00 Voltage 0
10 11 00 10 01 00
Time


NRZ
PAM4

Evoluce

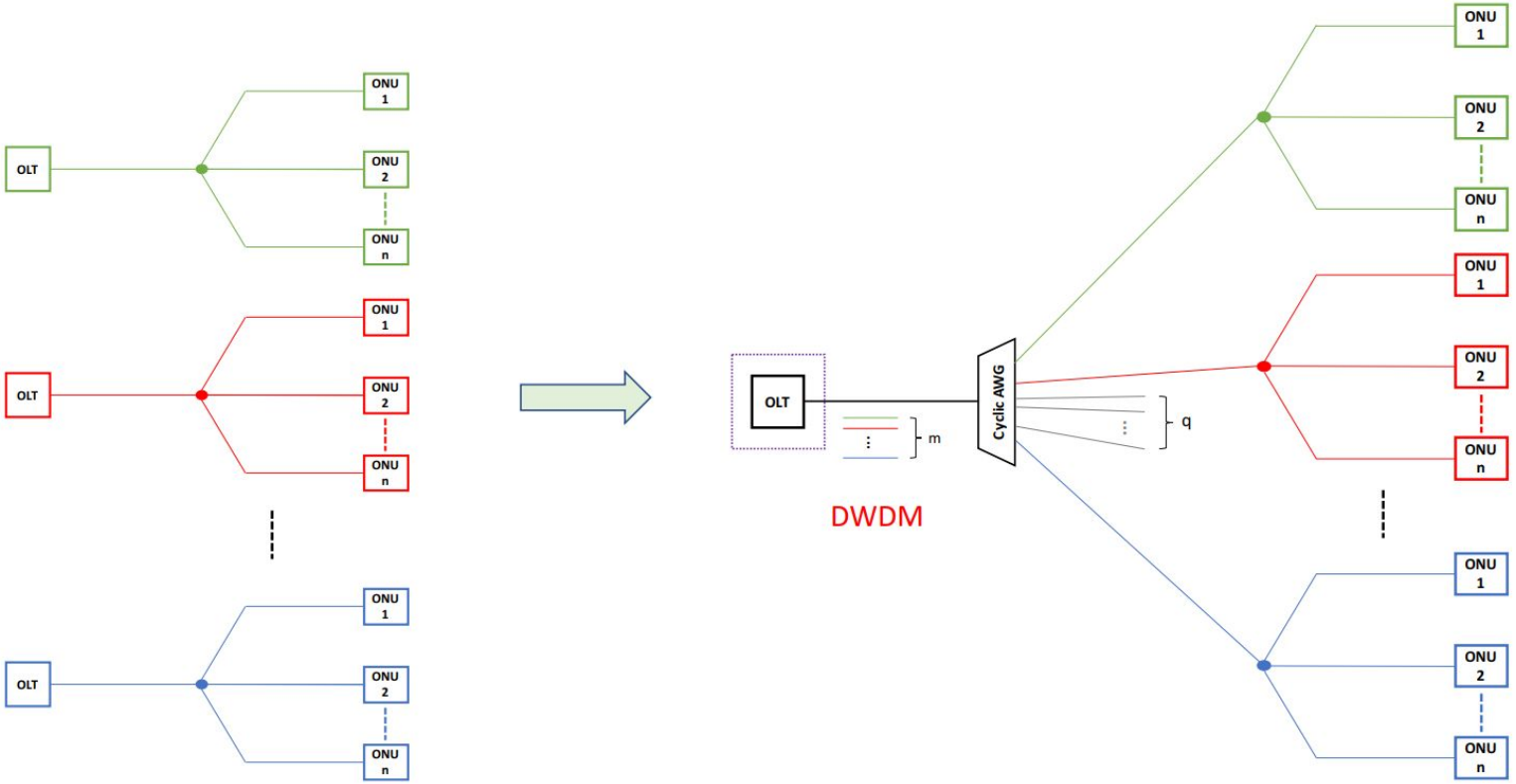

Bandwidth
1G - 2.5G
10G - 25G
50G - 200G
IEEE
Advancing Technology for Humanity
ITU
EPON
10G-EPON
1*25G-EPON
2*25G-EPON
100G?
GPON
XG-PON
XGS-PON
1*50G
NG-PON2
4*10G
4*50G

IEEE

TYP	EPON IEEE 802.3ah 2003	10G-EPON IEEE 802.3av 2009	XGSPON IEEE 802.3ca 2020
Mod. speed	Downstream: 1.25 Gbit/s Upstream: 1.25 Gbit/s	Downstream: 10.3125 Gbit/s Upstream: 10.3125 Gbit/s	Downstream: 25, 50 Gbit/s Upstream: 10, 25, 50 Gbit/s

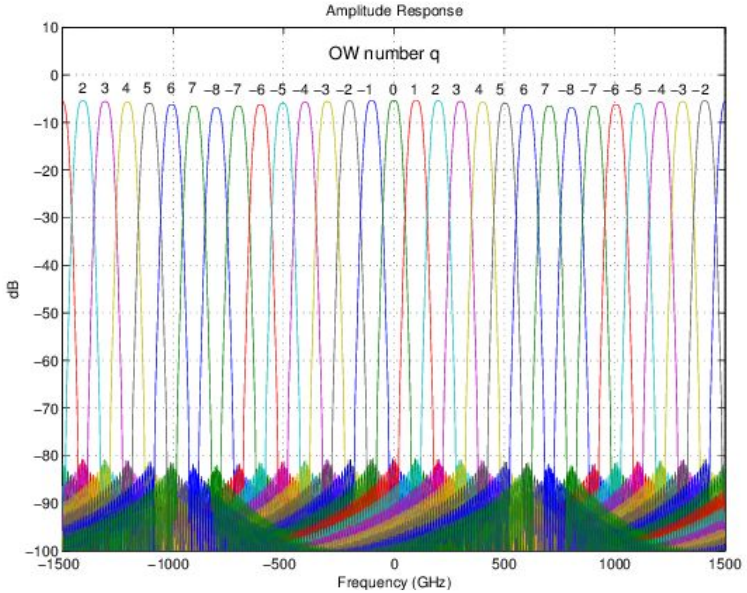
- 2016 IEEE 802.3bn - Definition of 10G-EPON and 10GPASS-XR passive optical networks over coaxial links.
- 2022 IEEE 802.3cs - "Super-PON" – increased-reach, 10 Gbit/s optical access with at least 50 km reach and 1:64 split ratio per wavelength pair, 16 wavelength pairs

Super PON


OLT
ONU 1
ONU 2
ONU n
OLT
ONU 1
ONU 2
ONU n
OLT
ONU 1
ONU 2
ONU n
OLT
m
Cyclic AWG
q
DWDM
ONU 1
ONU 2
ONU n
ONU 1
ONU 2
ONU n
ONU 1
ONU 2
ONU n

Super PON

AWG Splitter - λ router



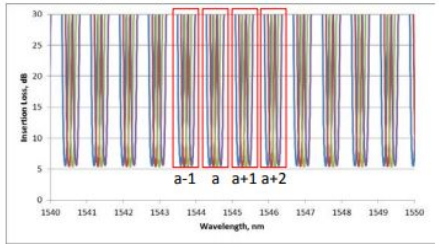
$$\lambda_c = \frac{n_c \times \Delta L}{m}$$

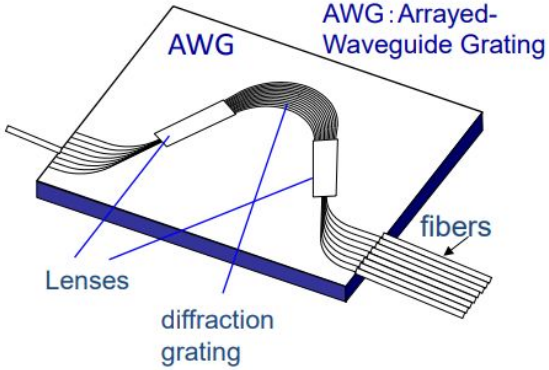
$m = a-1, \quad a, \quad a+1, \quad a+2 \cdots$

ΔL: Waveguide path length difference
m: Diffraction order
FSR: Free Spectral Range

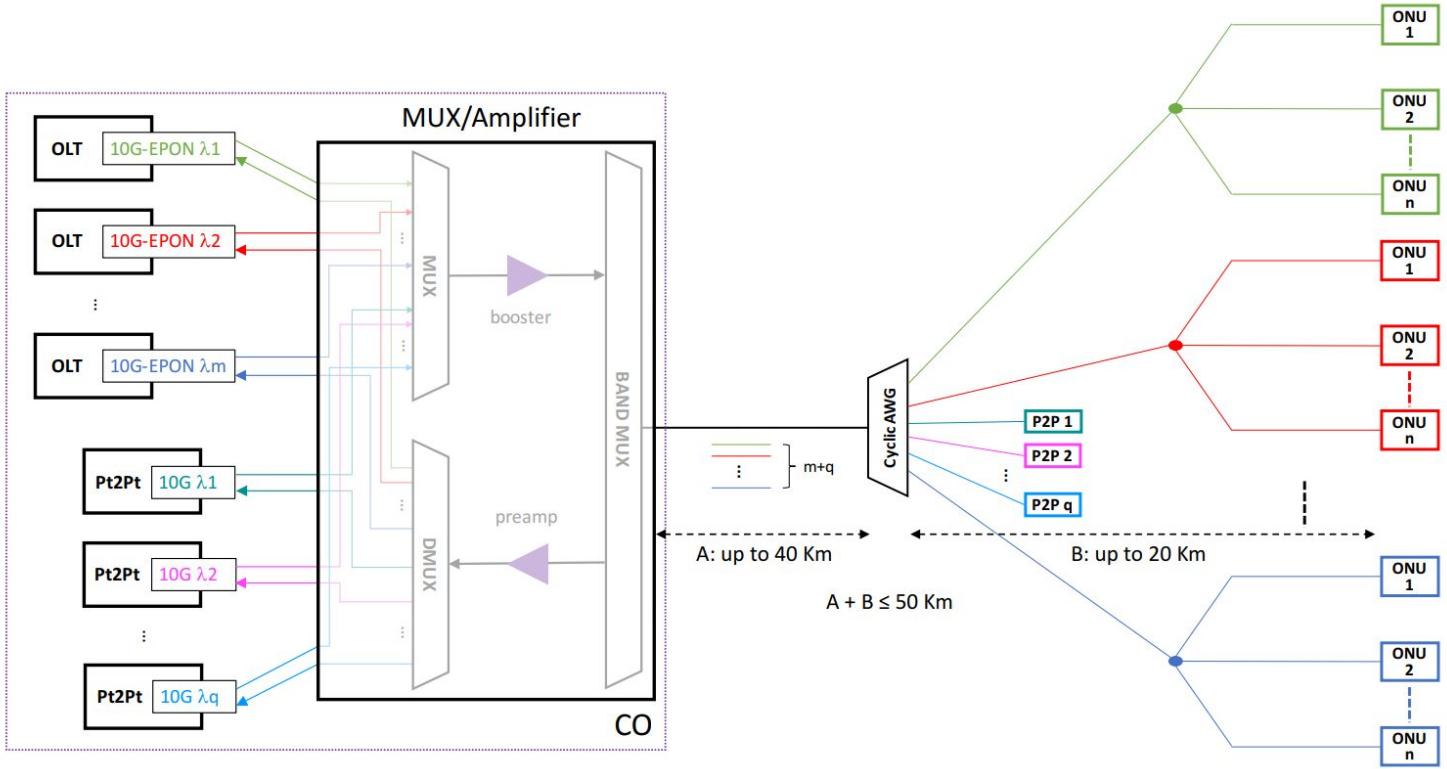
$$FSR = N\frac{\lambda_c}{m}$$

Example Cyclic AWG Spectrum

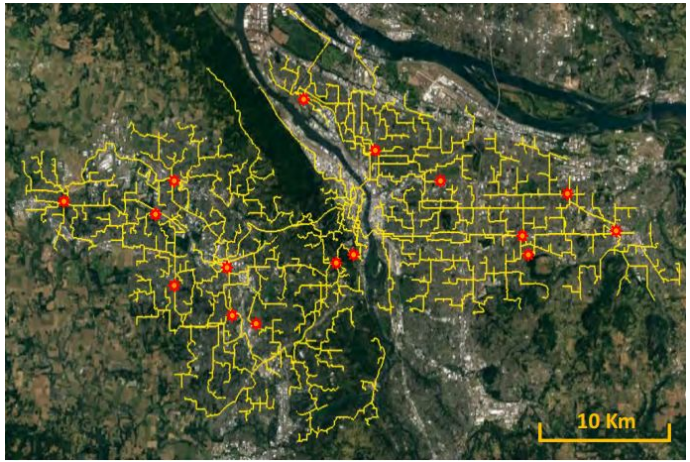


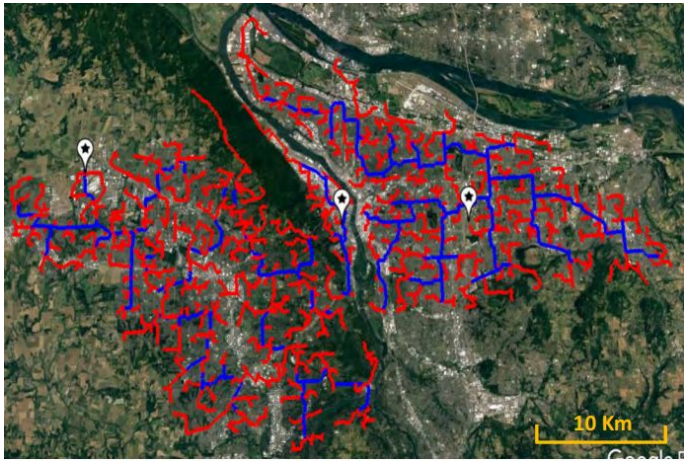


Super PON


MUX/Amplifier
OLT
10G-EPON λ1
OLT
10G-EPON λ2
OLT
10G-EPON λm
Pt2Pt
10G λ1
Pt2Pt
10G λ2
Pt2Pt
10G λq
MUX
DMUX
booster
preamp
BAND MUX
CO
m+q
Cyclic AWG
P2P 1
P2P 2
P2P q
A: up to 40 Km
B: up to 20 Km
A + B ≤ 50 Km
ONU 1
ONU 2
ONU n
ONU 1
ONU 2
ONU n
ONU 1
ONU 2
ONU n

Super PON





- Významně méně CO
- lepší utilizace backbone vláken

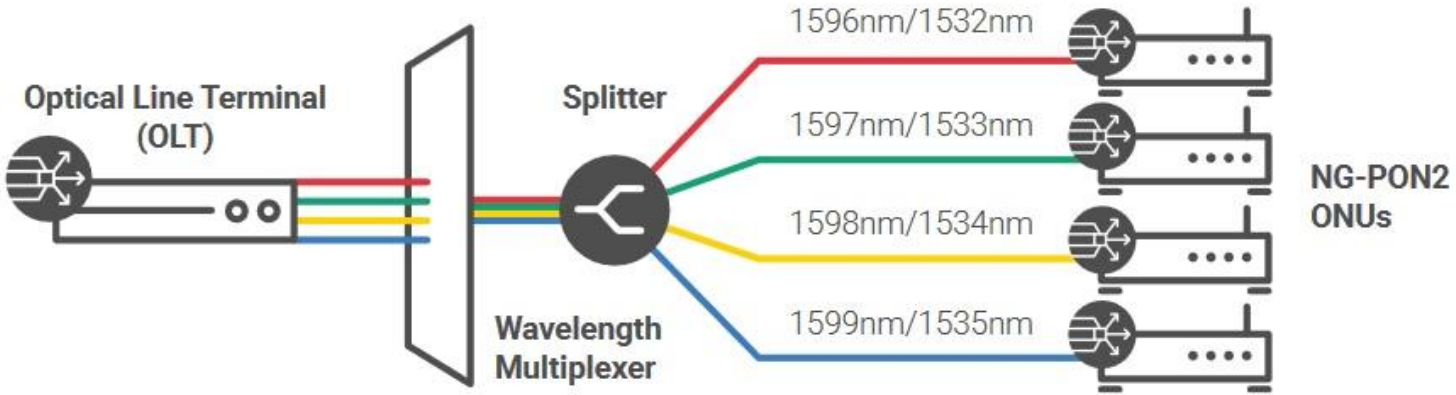
ITU TD/TDMA PON

TYP	GPON ITU G.984	XGPON ITU G.987	XGSPON ITU G.9807
Freq	Downstream: 1480 ~ 1500 nm Upstream: 1290 ~ 1330 nm	Downstream: 1575 ~ 1580 nm Upstream: 1260 ~ 1280 nm	Downstream: 1575 ~ 1580 nm Upstream: 1260 ~ 1280 nm
Split ratio	1:64 (1:128)	1:256	1:256
Max. distance	60km	100km	100km
Mod. speed	Downstream: 2.488 Gbit/s Upstream: 1.244 Gbit/s	Downstream: 9.953 Gbit/s Upstream: 2.488 Gbit/s	Downstream: 9.953 Gbit/s Upstream: 9.953 Gbit/s

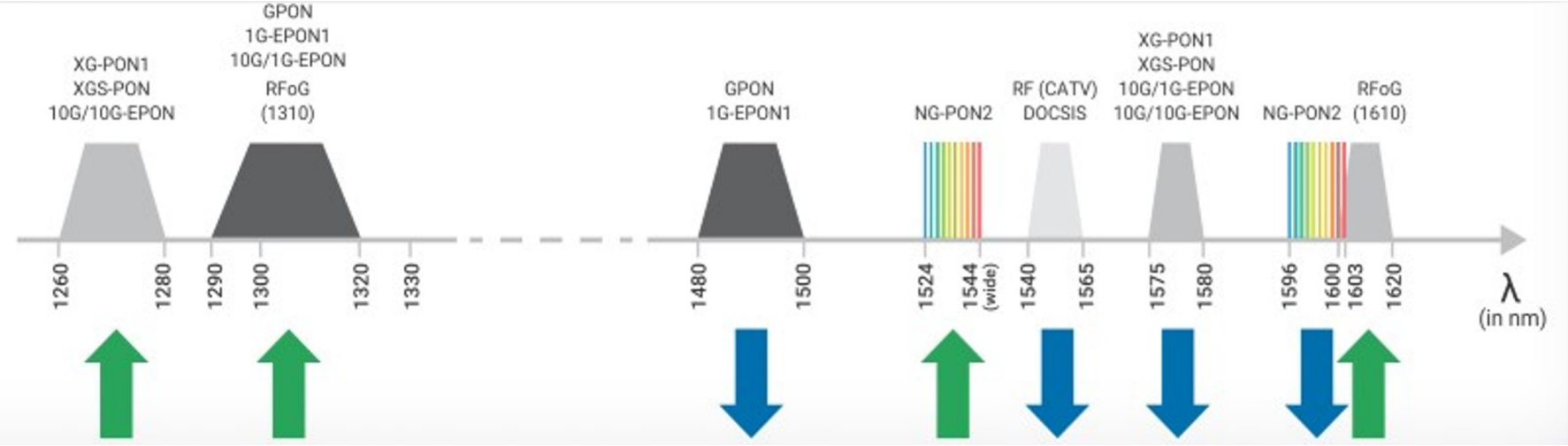
- 09/2021 ITU G.9804 50 Gbps single-channel PON system (50G-PON)
  - 50/10-25-50 Gbps
  - Swiss Telecom

ITU TWDM

- ITU-T G.989 - NG-PON2
- 4x10Gbps + 8x P2P channel

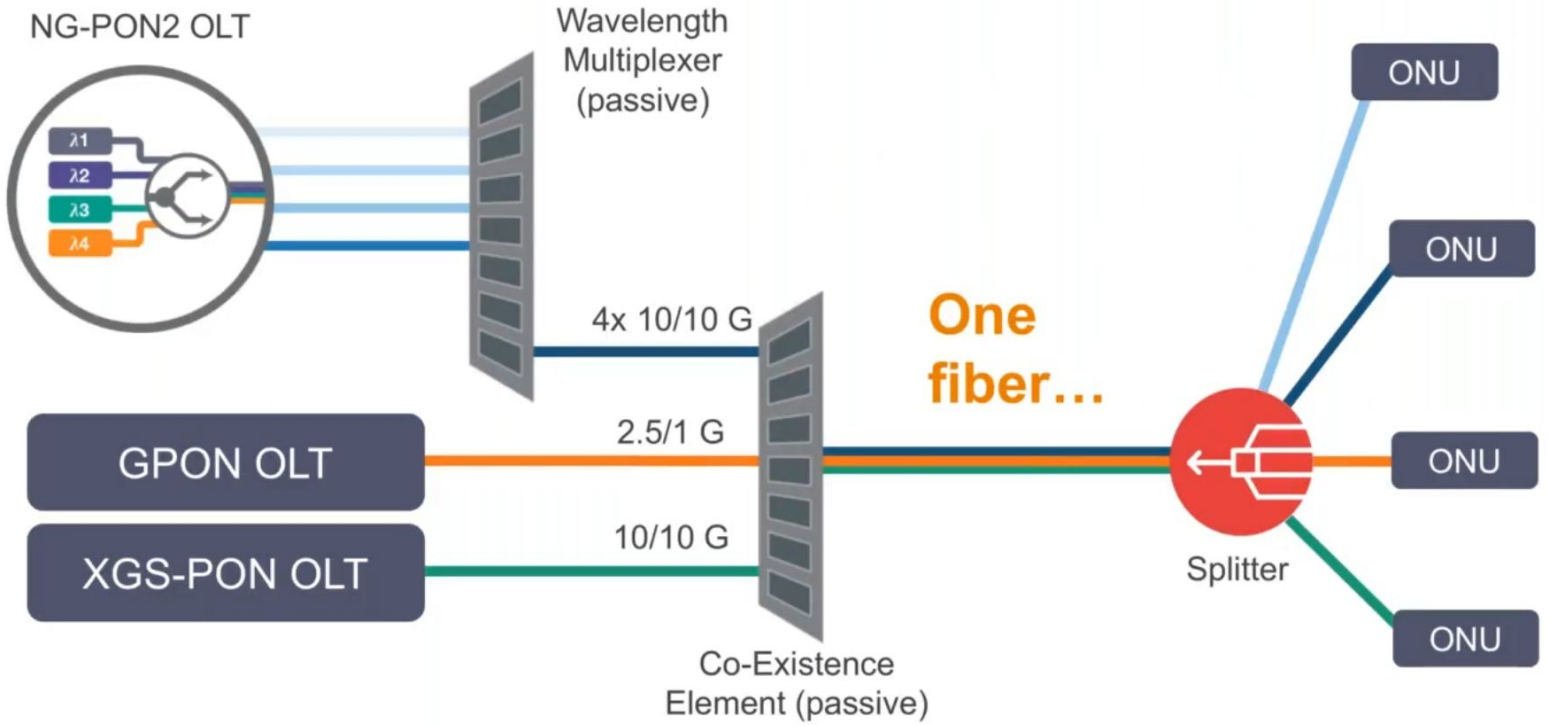


Koexistence xPON

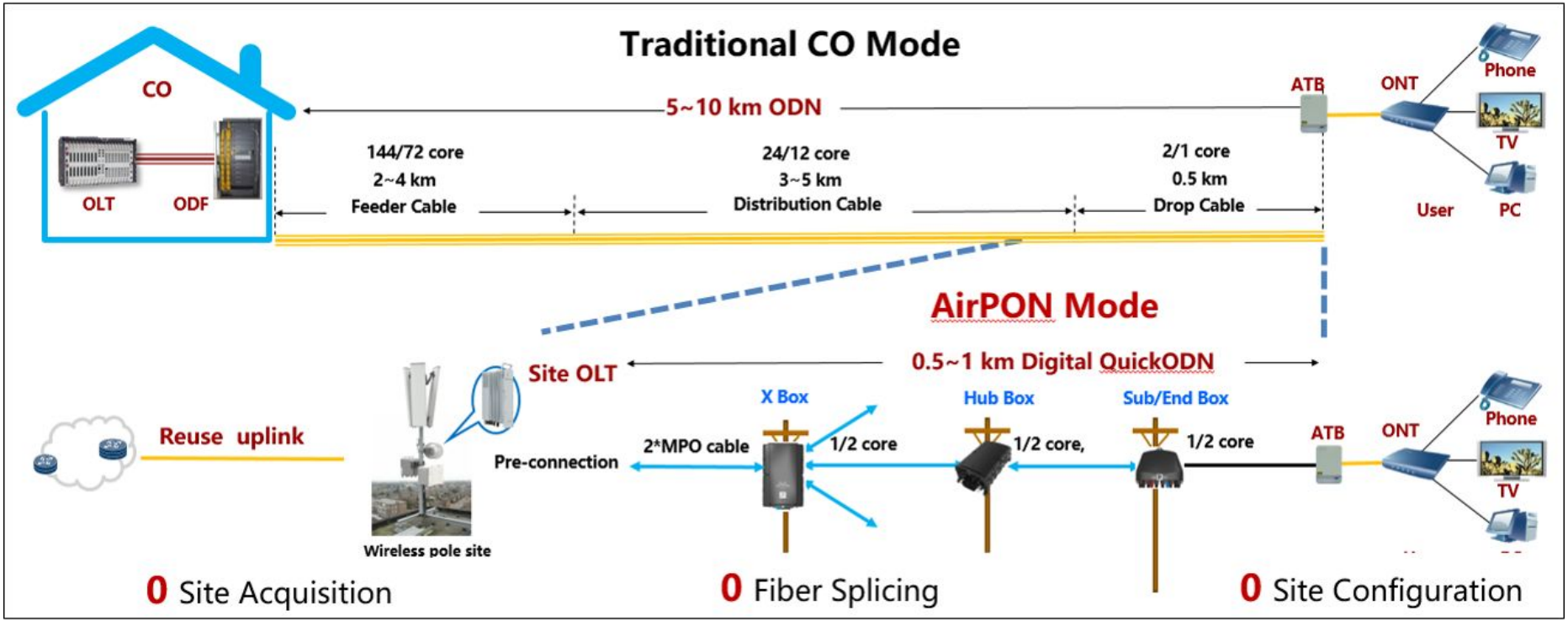


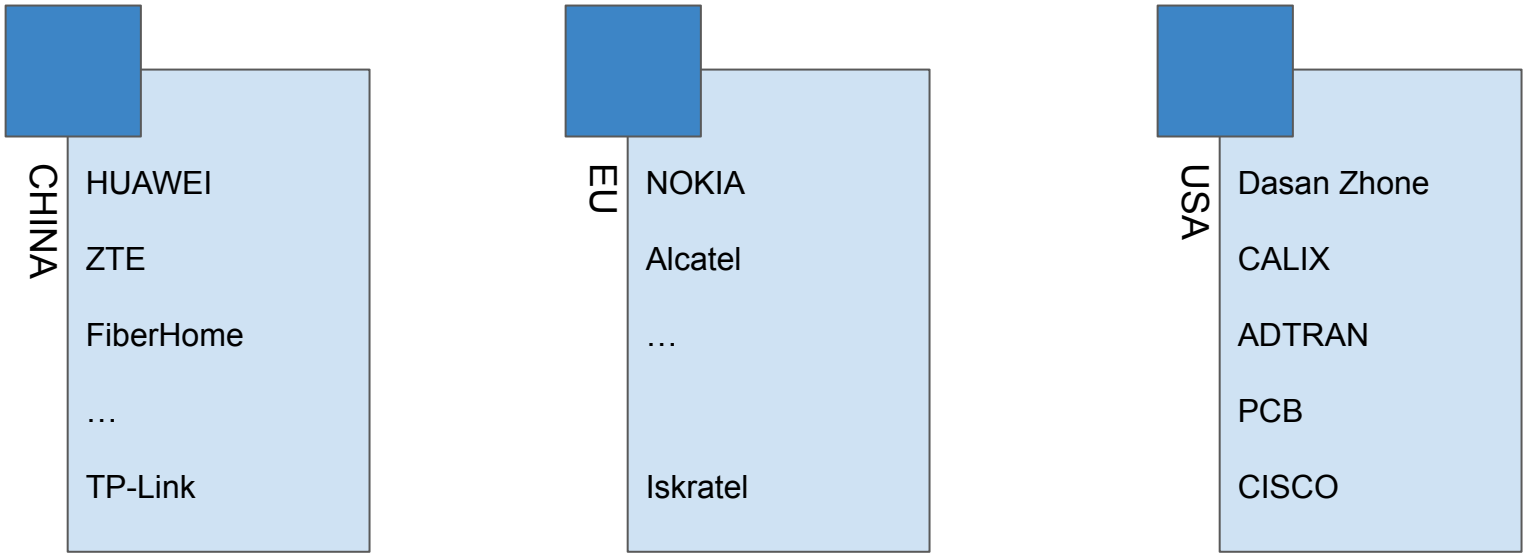
Koexistence xPON - WDM1r

Koexistence xPON

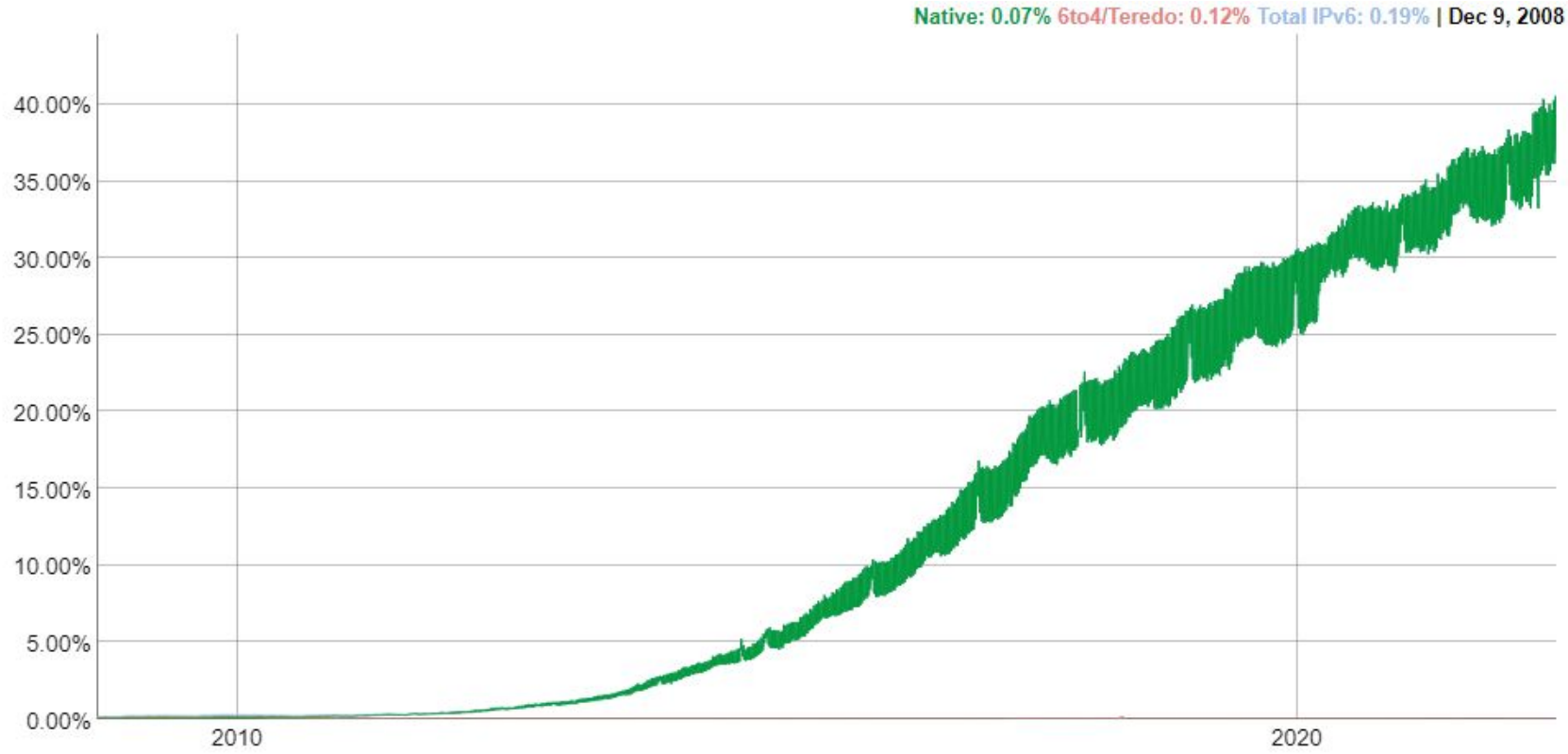


AirPON


Traditional CO Mode
CO
OLT
ODF
5~10 km ODN
144/72 core
2~4 km
Feeder Cable
24/12 core
3~5 km
Distribution Cable
2/1 core
0.5 km
Drop Cable
ATB
ONT
Phone
TV
User
PC
AirPON Mode
Site OLT
0.5~1 km Digital QuickODN
Reuse uplink
Pre-connection
2*MPO cable
X Box
1/2 core
Hub Box
1/2 core,
Sub/End Box
1/2 core
ATB
ONT
Phone
TV
Wireless pole site
0 Site Acquisition
0 Fiber Splicing
0 Site Configuration


CHINA
HUAWEI
ZTE
FiberHome
…
TP-Link
EU
NOKIA
Alcatel
…
Iskratel
USA
Dasan Zhone
CALIX
ADTRAN
PCB
CISCO

IPv6


Native: 0.07% 6to4/Teredo: 0.12% Total IPv6: 0.19% | Dec 9, 2008
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
2010
2020

IPv6

Per-Country IPv6 adoption