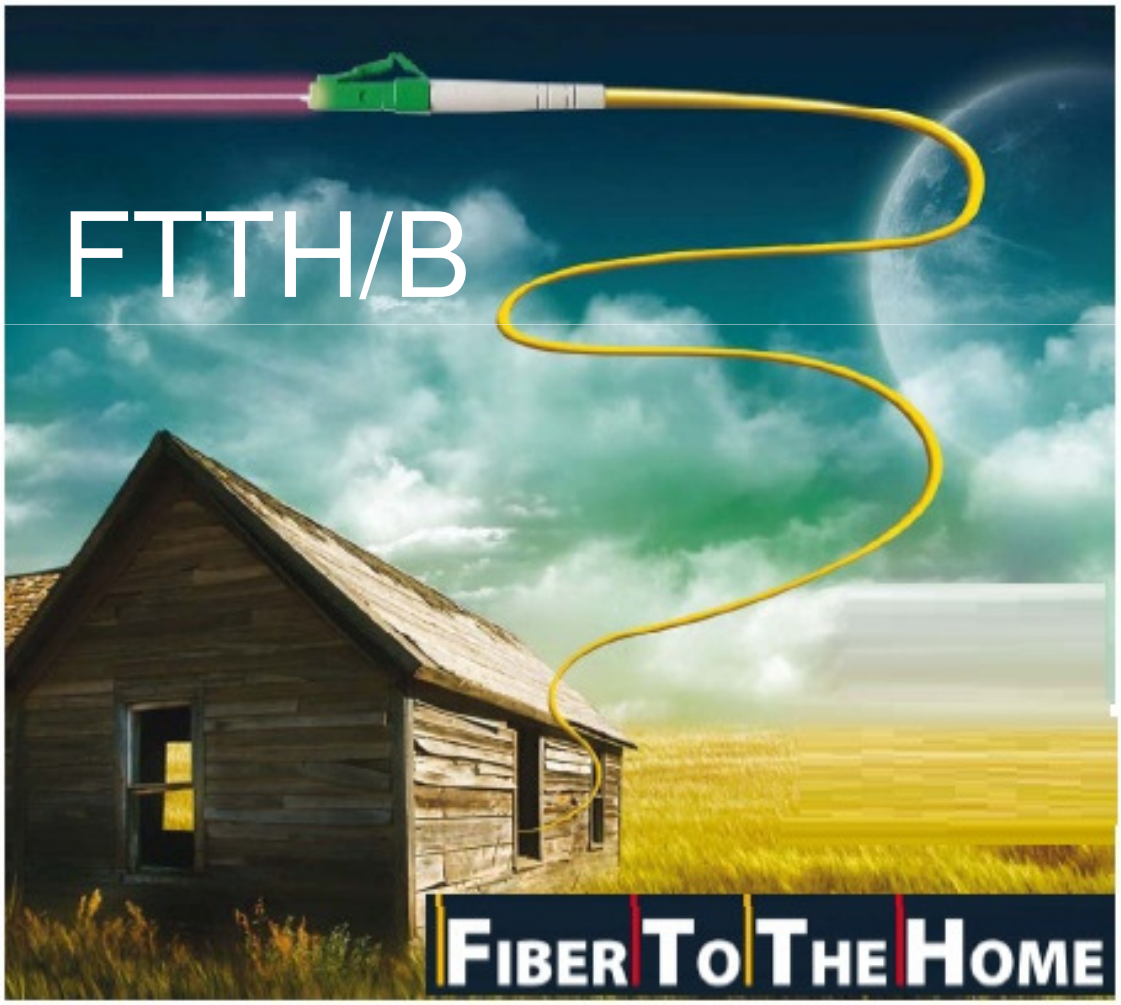
Uvod v optična dostopovna omrežja

Vlakno do doma



Mobitel d.d., izobraževanje

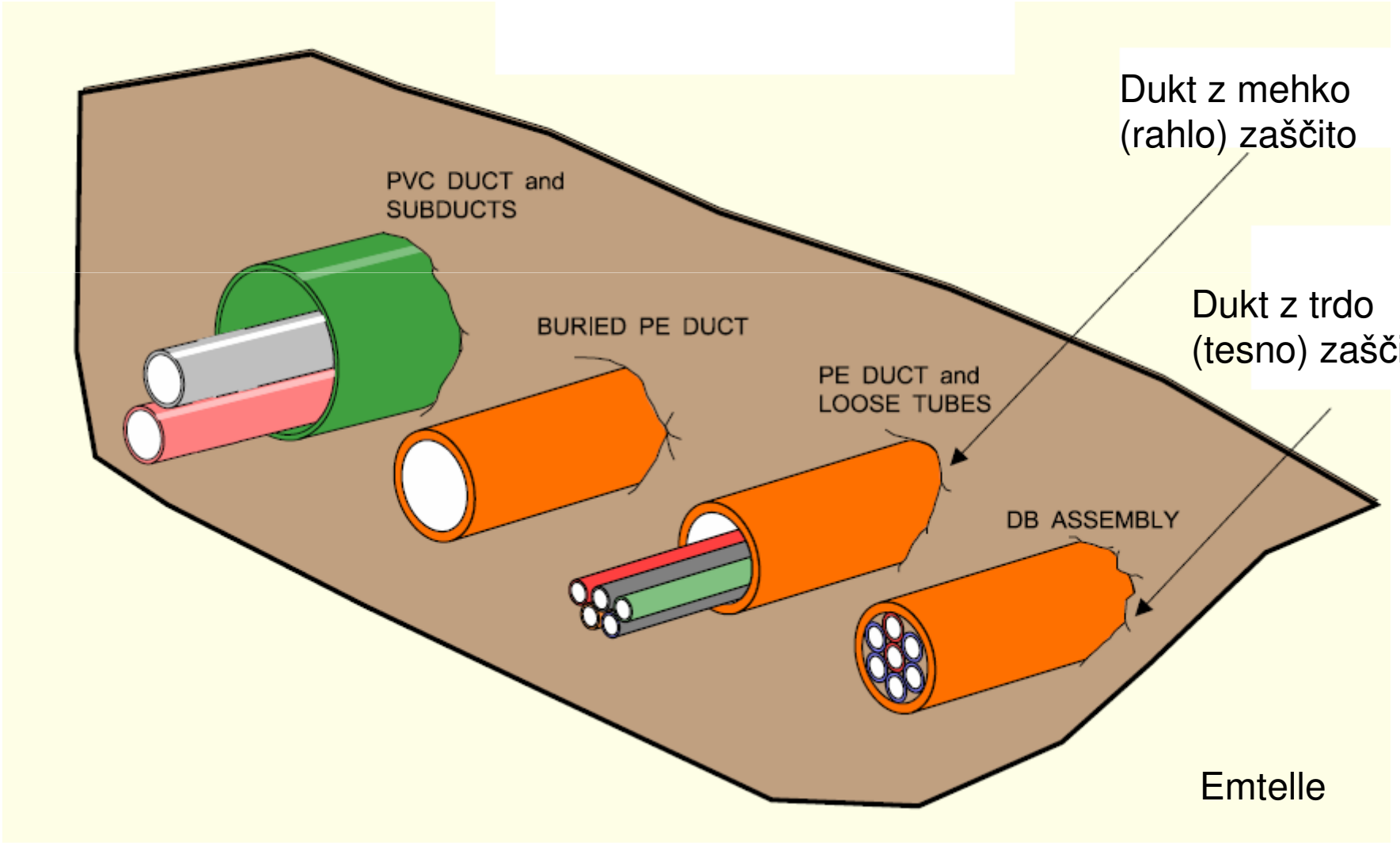
10. 9. 2010, predavanje 15

Prof. dr. Jožko Budin

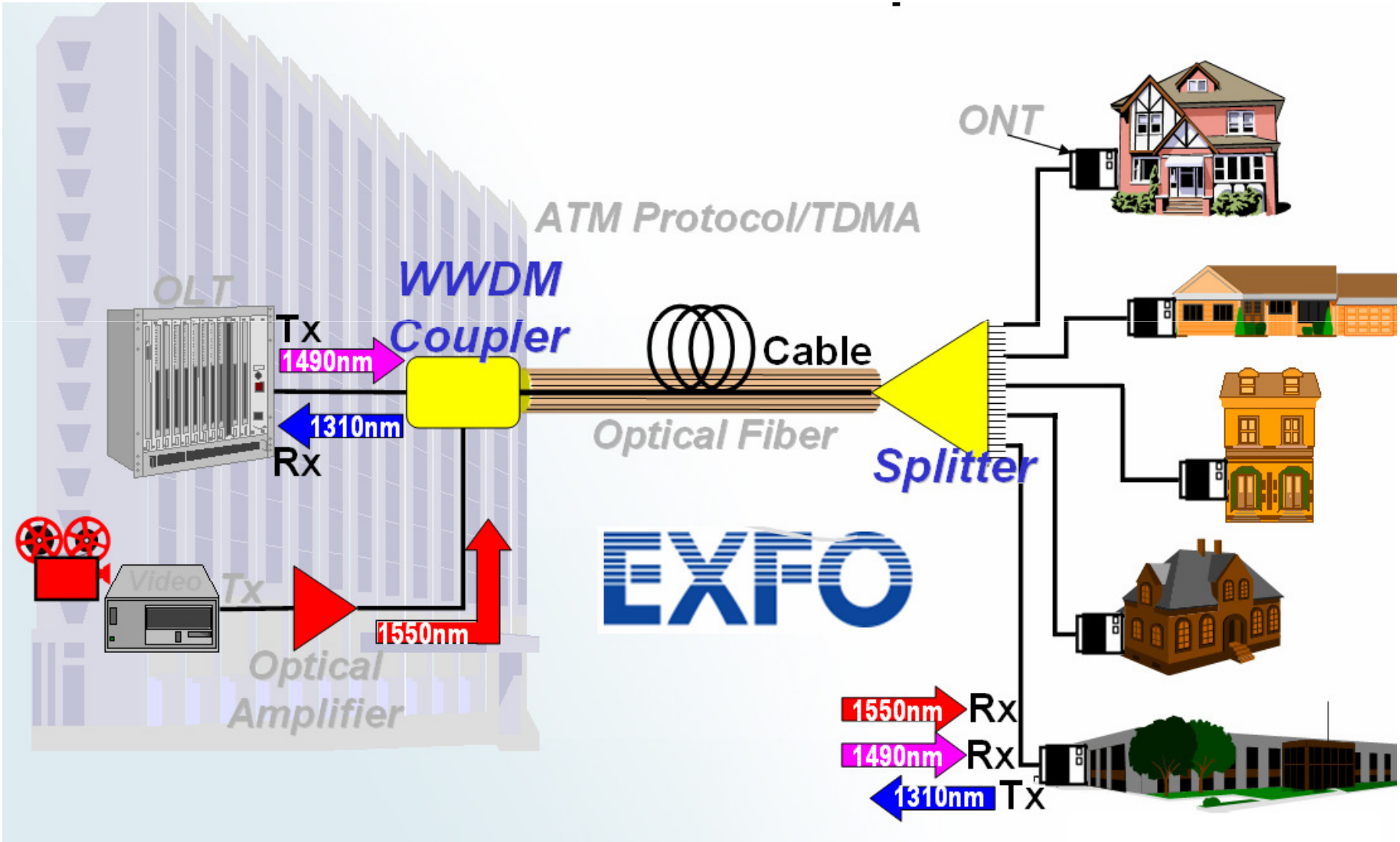
Vsebina

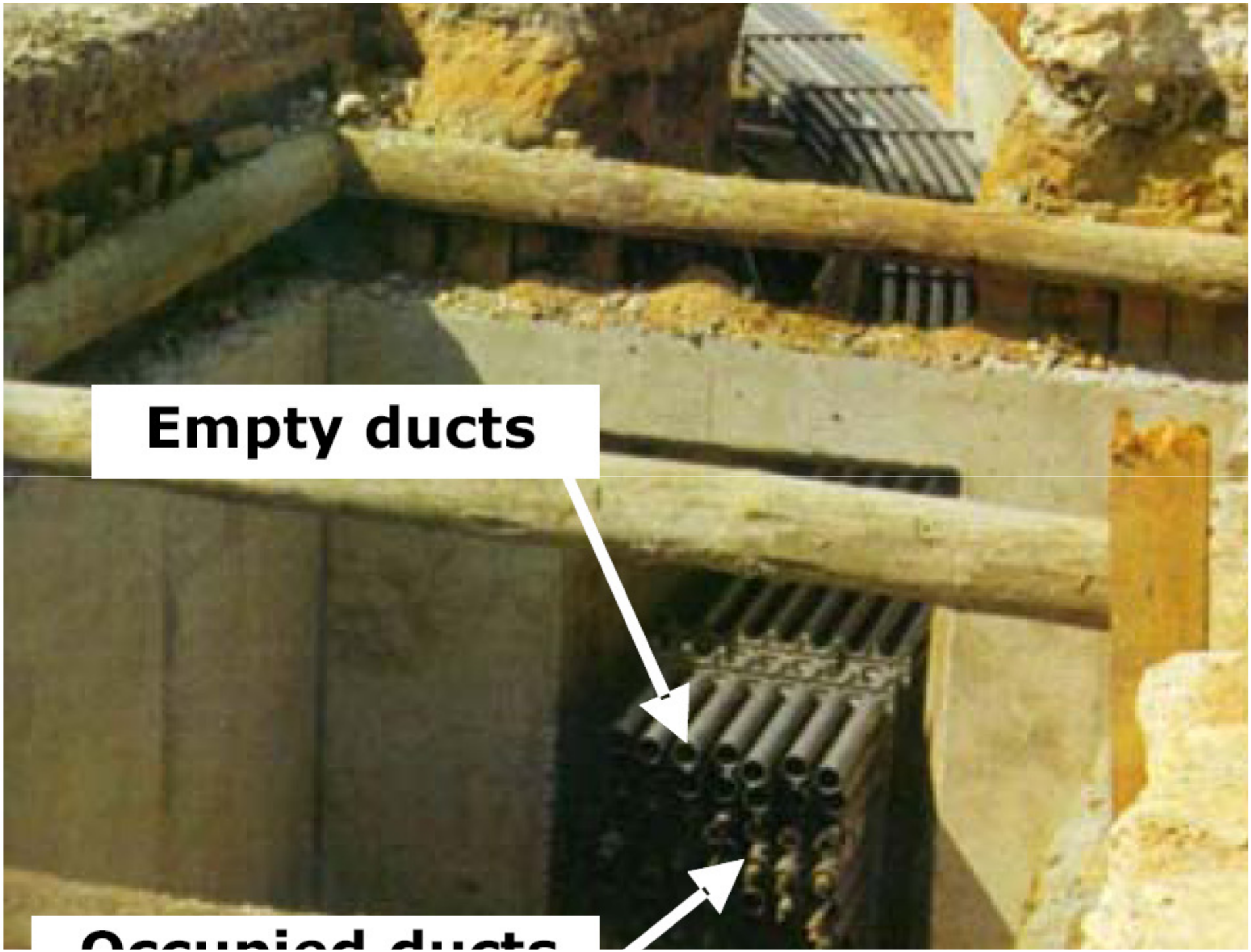
1. Tehnologije dostopovnega omrežja splošno
2. Vodniški (žični in vlakenski) ter brezžični dostop
3. Potrebe po širokopasovnosti
4. Vrste vlakenskega dostopa
   - vlakno do vozlišča, vlakno do doma
   - topologija, tehnologija, arhitektura
5. T-T in PON (T-MT), dotok in odtok, razvrščanje
6. Primerjave, prednosti in pomanjkljivosti
7. Razvojne smeri, WDM/TDM PON, LR NGPON

Optični teledukti

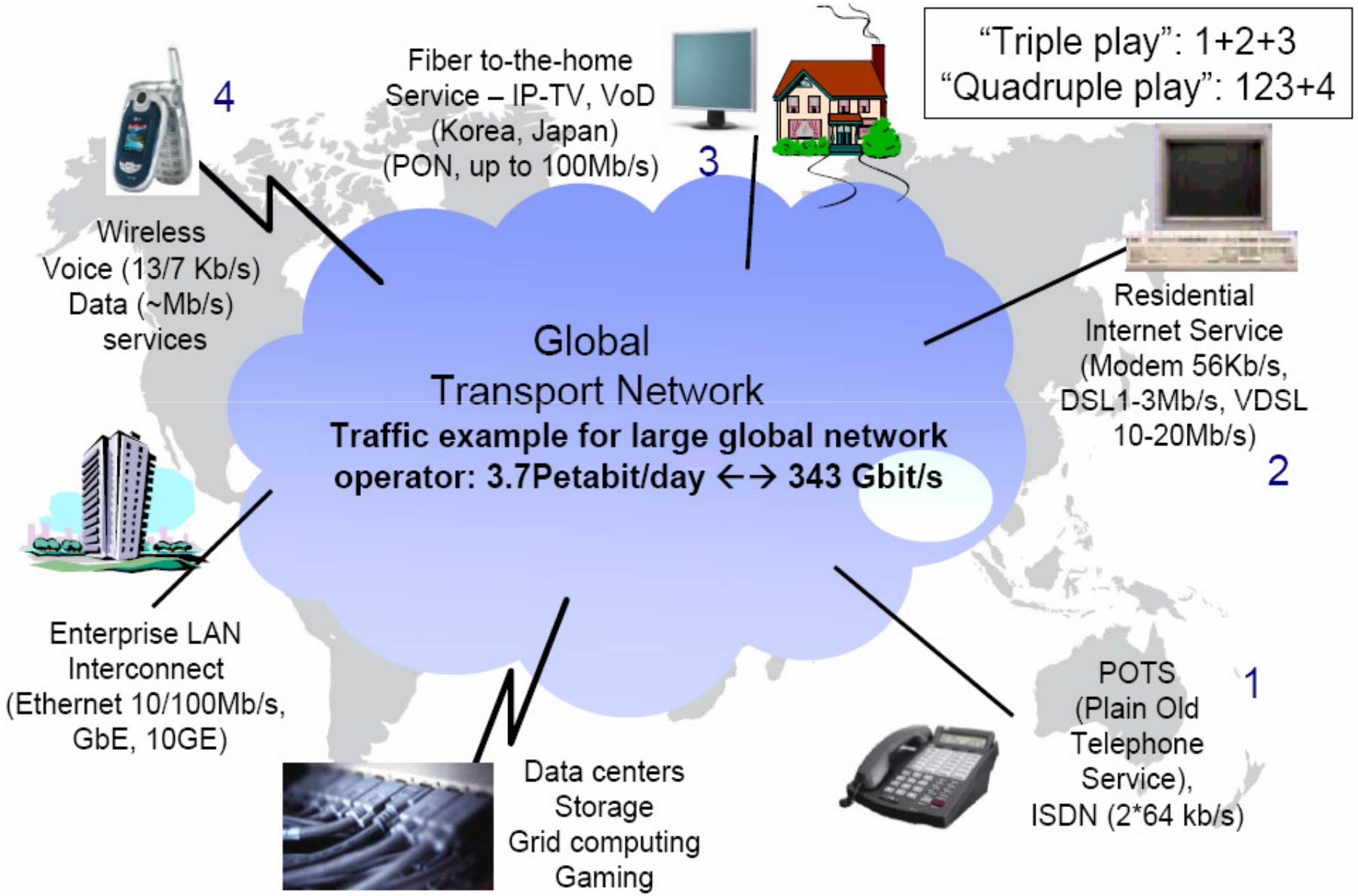


PON


ONT
ATM Protocol/TDMA
OLT
WWDM
Coupler
Tx
1490nm
1310nm
Rx
Cable
Optical Fiber
Splitter
EXFO
Video Tx
1550nm
Optical
Amplifier
1550nm Rx
1490nm Rx
1310nm Tx


Empty ducts

Aplikacije in storitve



Alcatel-Lucent 2008

Dostopovno omrežje

FTTx **FTTP** FTTH

FTTB FTTU FTTA

FTTD FTTO FTTZ

FTTCabFTTc FTTN

FTTx = Fiber-to-the-x

FTTH - Home
FTTC - Curb
FTTN - Node or Neighborhood
FTTP - Premise
FTTB - Building or Business
FTTU - User
FTTZ - Zone
FTTO - Office
FTTD - Desk

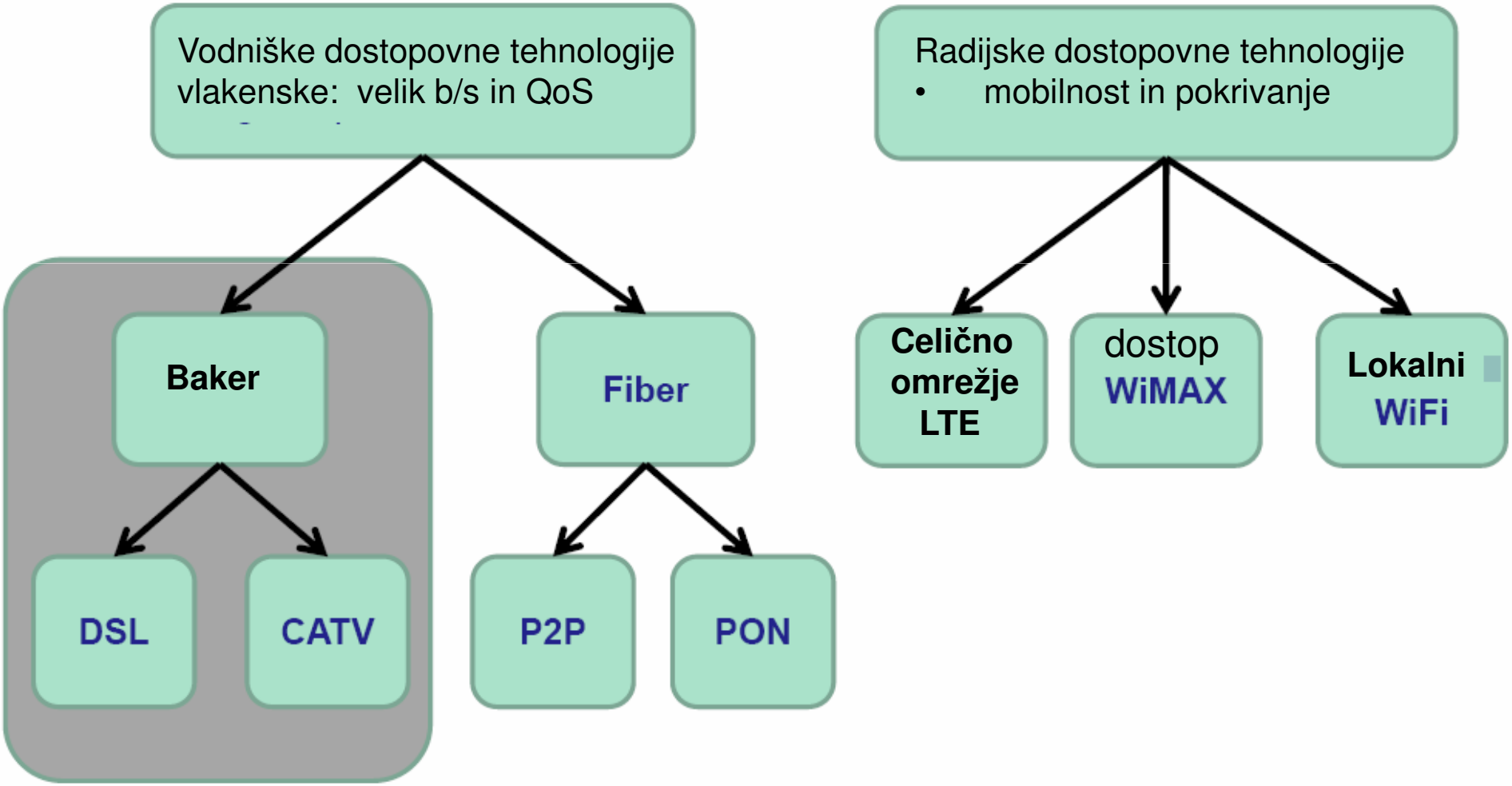
Dostopovne tehnologije

Vodniško omrežje

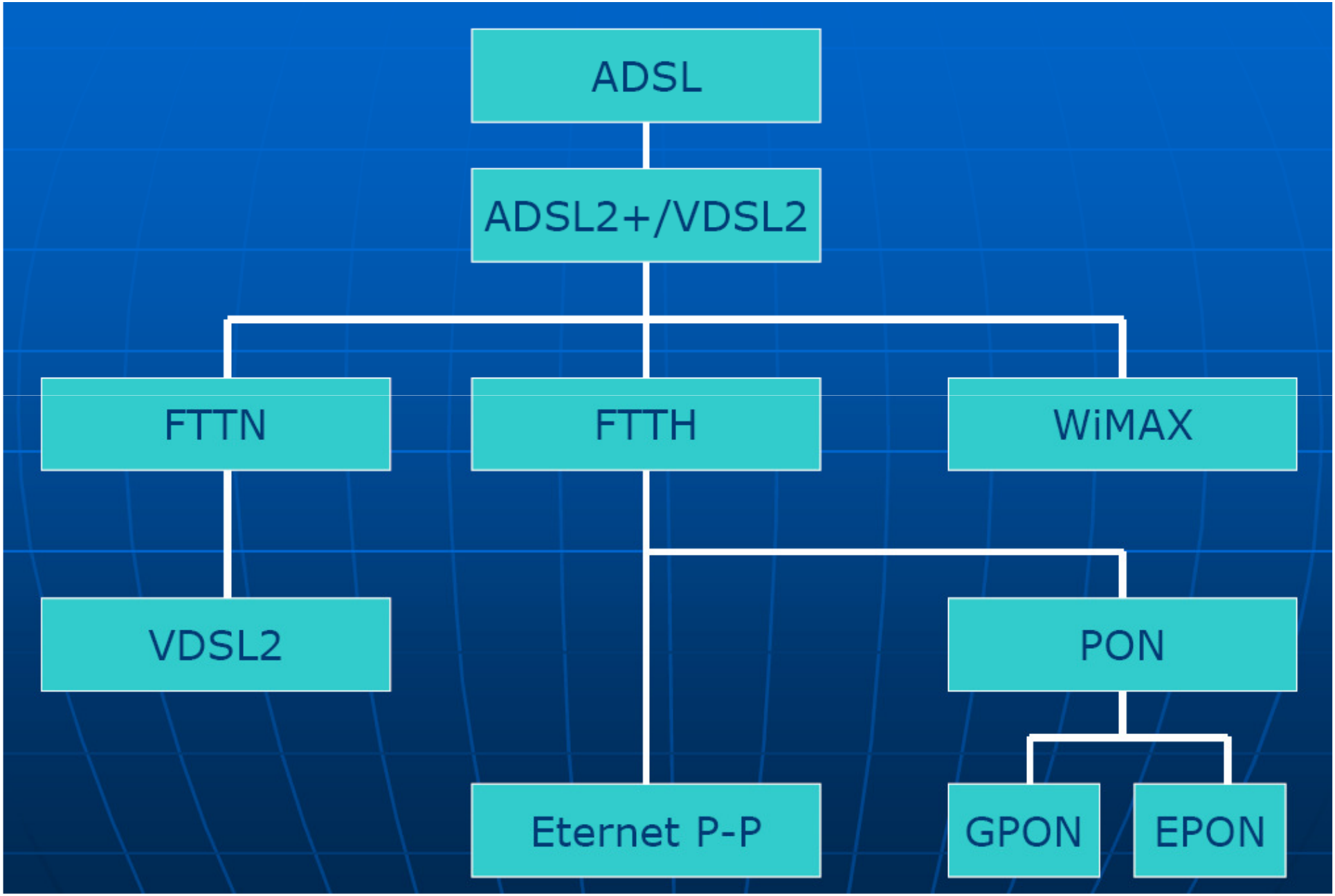
Žično in vlakensko omrežje

Brezvodniško omrežje

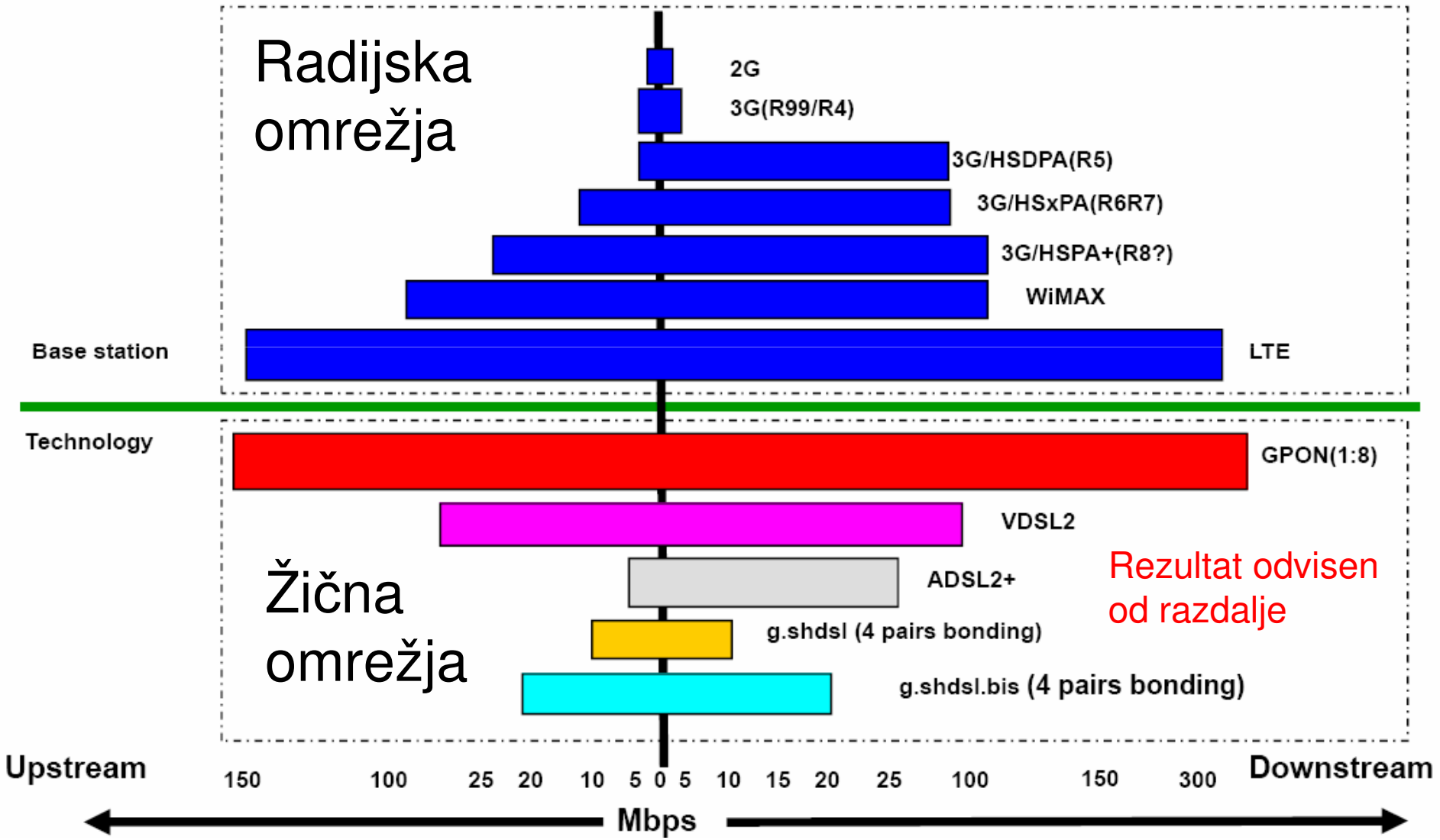
Brezžično omrežje



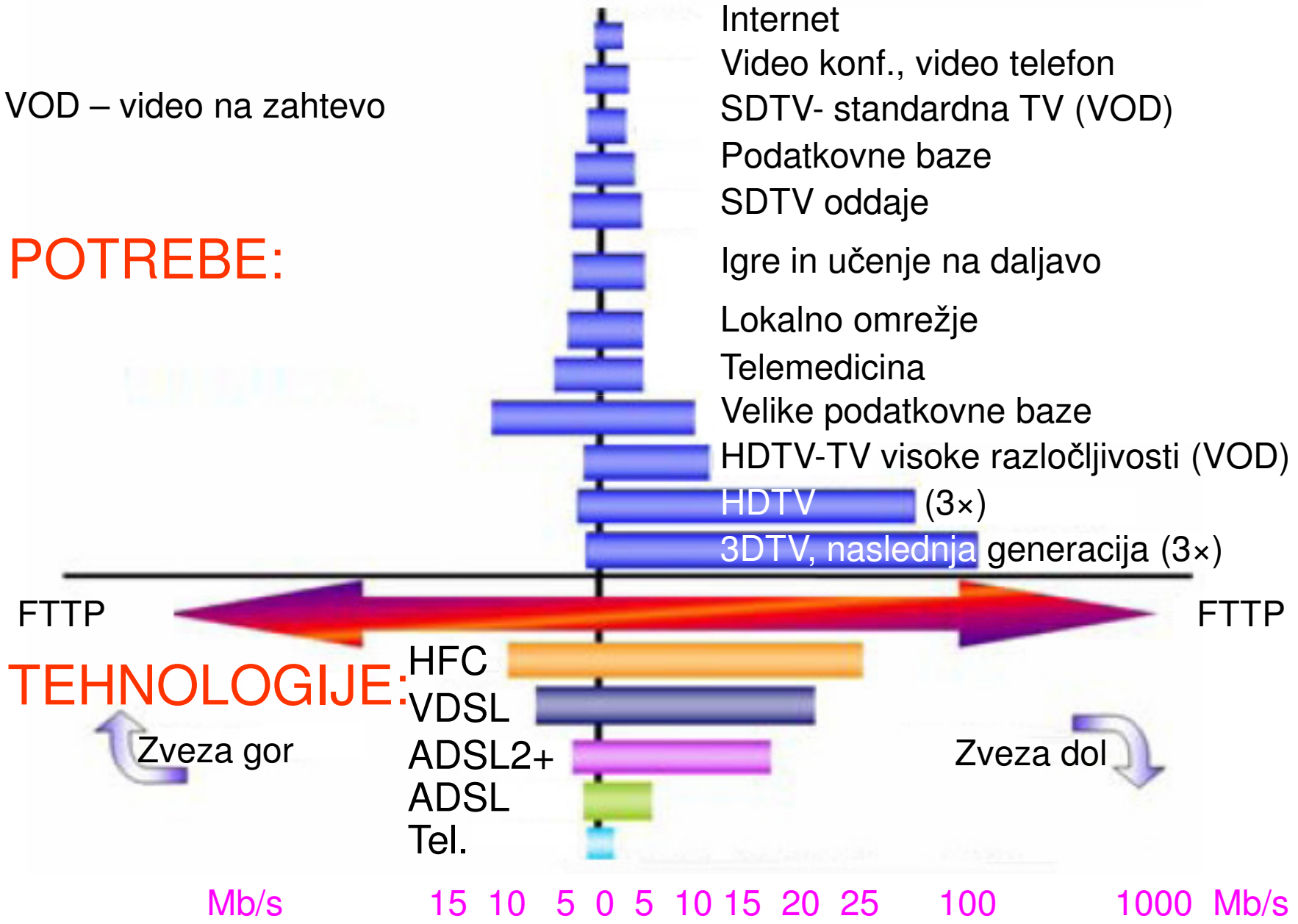
Razvojne smeri dostopovnega omrežja



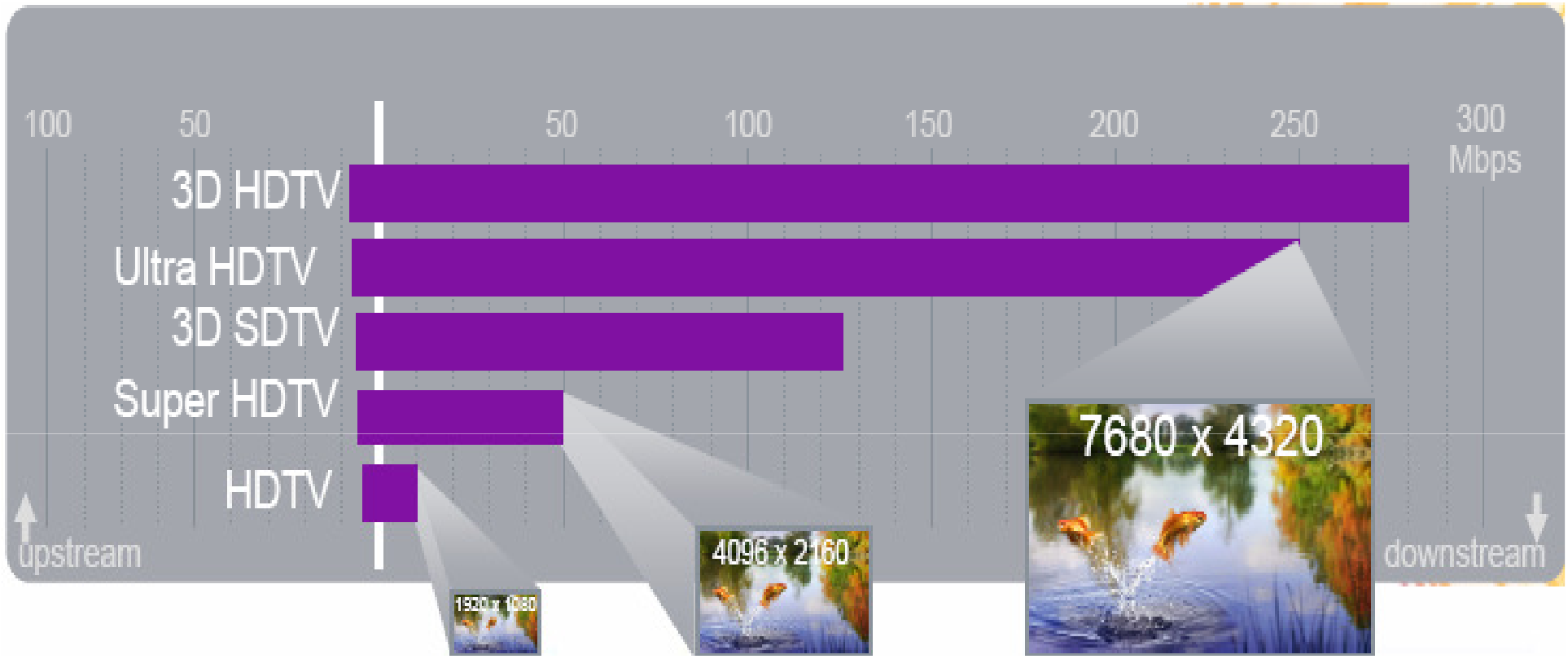
Radijski in žični dostop



Spekter, storitve in tehnologije



TV formati



Napoved:

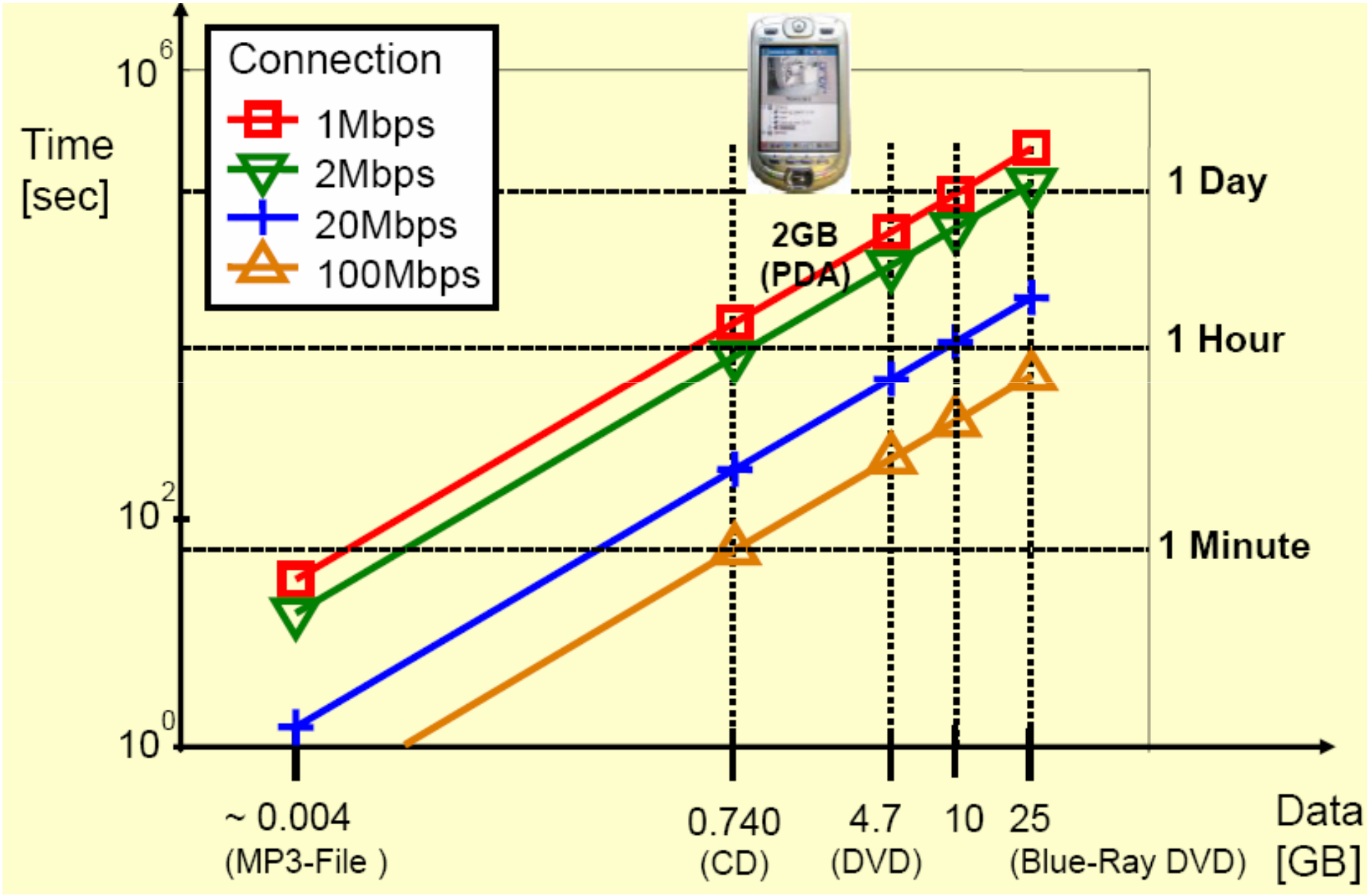
3D HDTV 2010 - 2015 ? (brez očal)

Ultra HDTV 2011 – 2012 ?

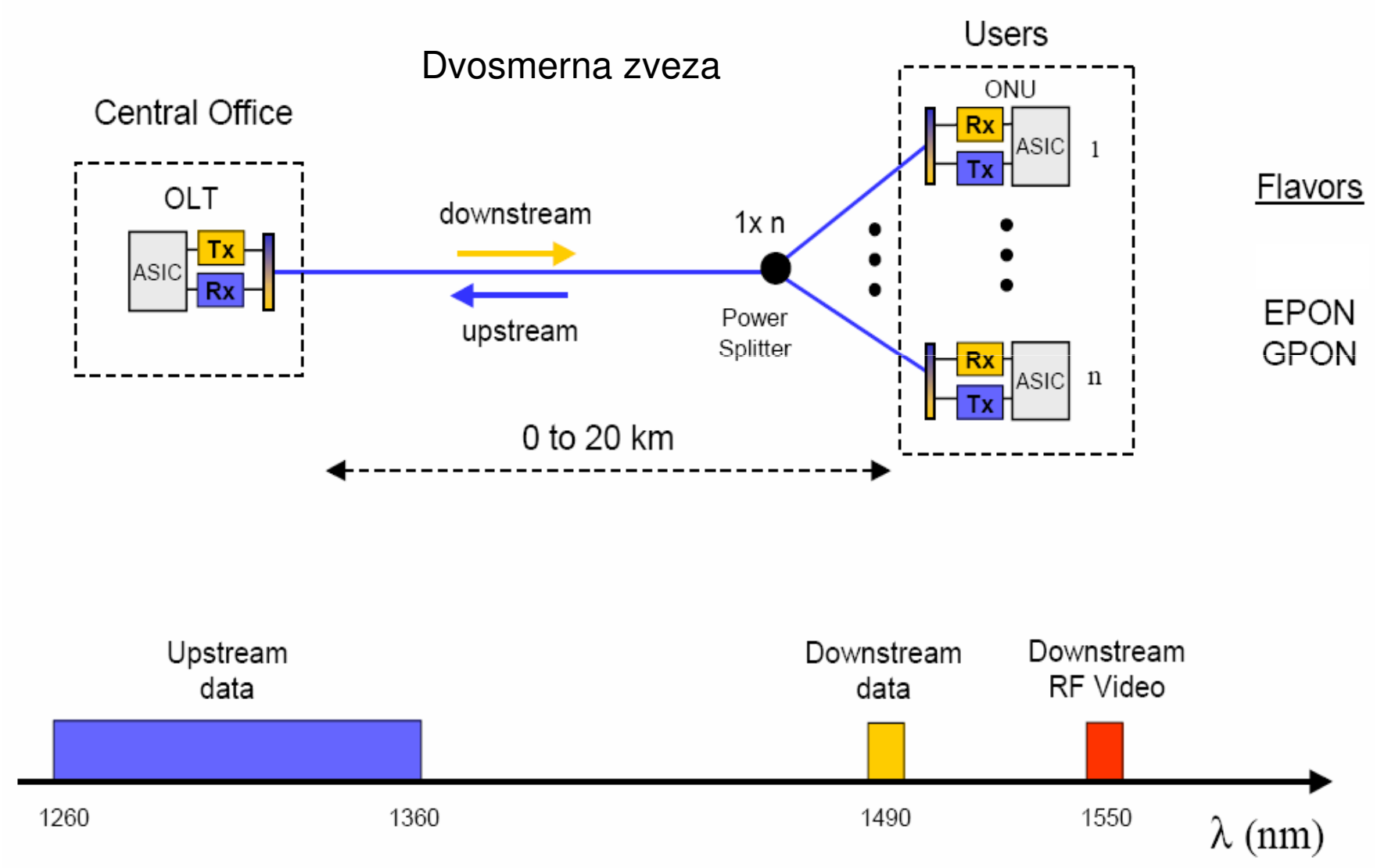
Nokia Siemens, 2010

3D TV je storitev, ki bo kot glavni porabnik b/s močno pospeševala razvoj.

Čas sprejema datotek

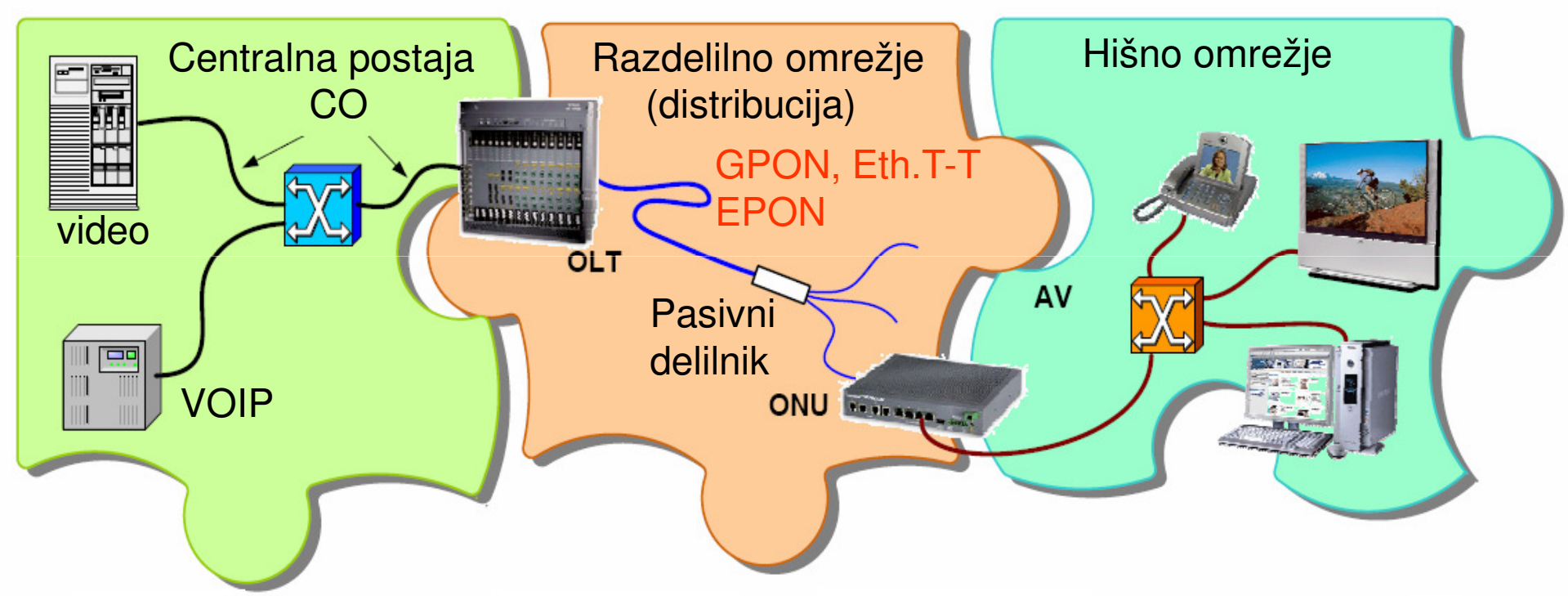


Dostop


Dvosmerna zveza
Central Office
OLT
ASIC
Tx
Rx
downstream
upstream
1x n
Power
Splitter
Users
ONU
Rx
Tx
ASIC
1
n
0 to 20 km
Flavors
EPON
GPON
Upstream
data
Downstream
data
Downstream
RF Video
1260
1360
1490
1550
λ (nm)

Segmenti dostopovnega omrežja

PON, GPON, EPON, Eth.T-T

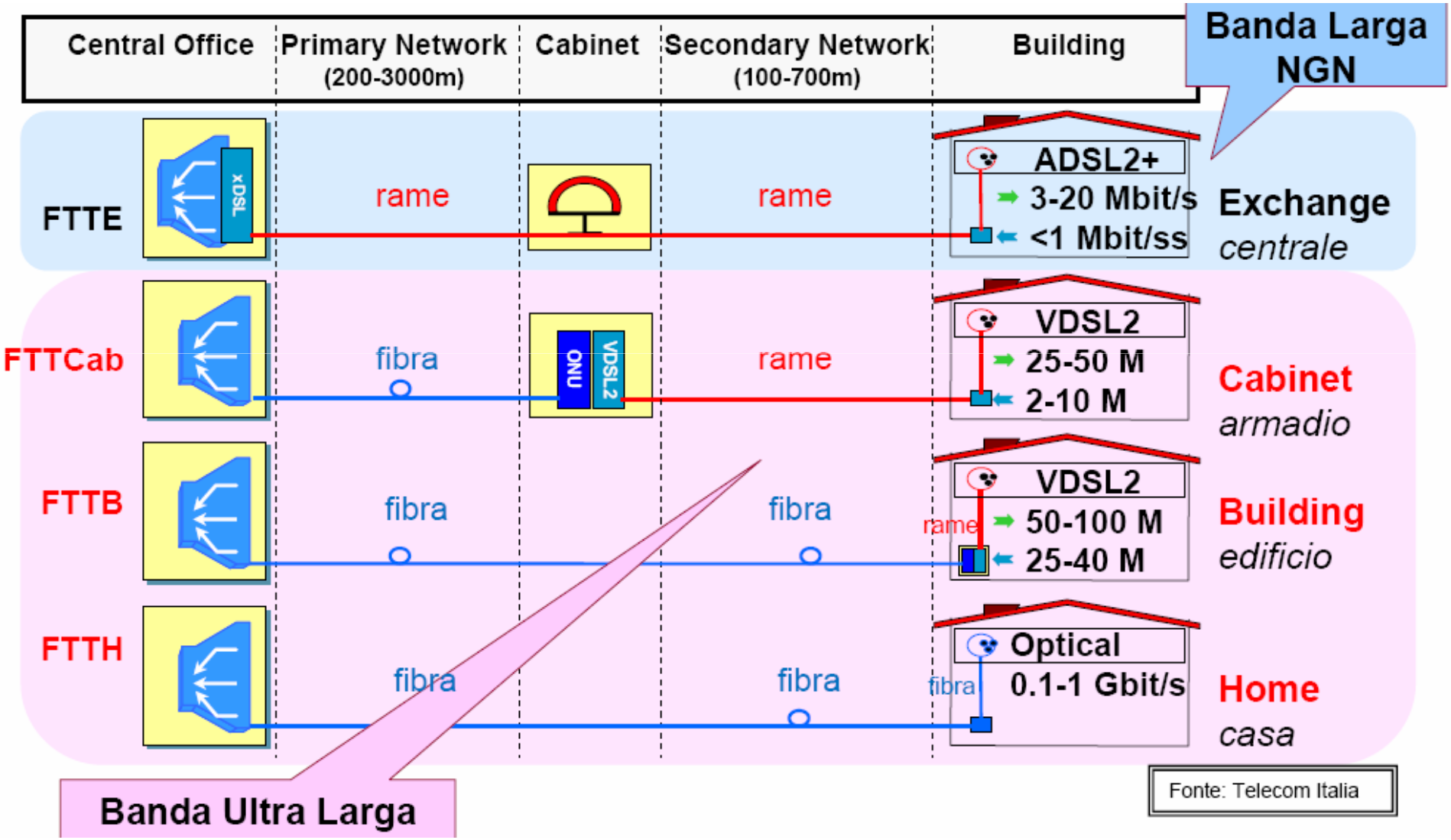


Centrala
CO

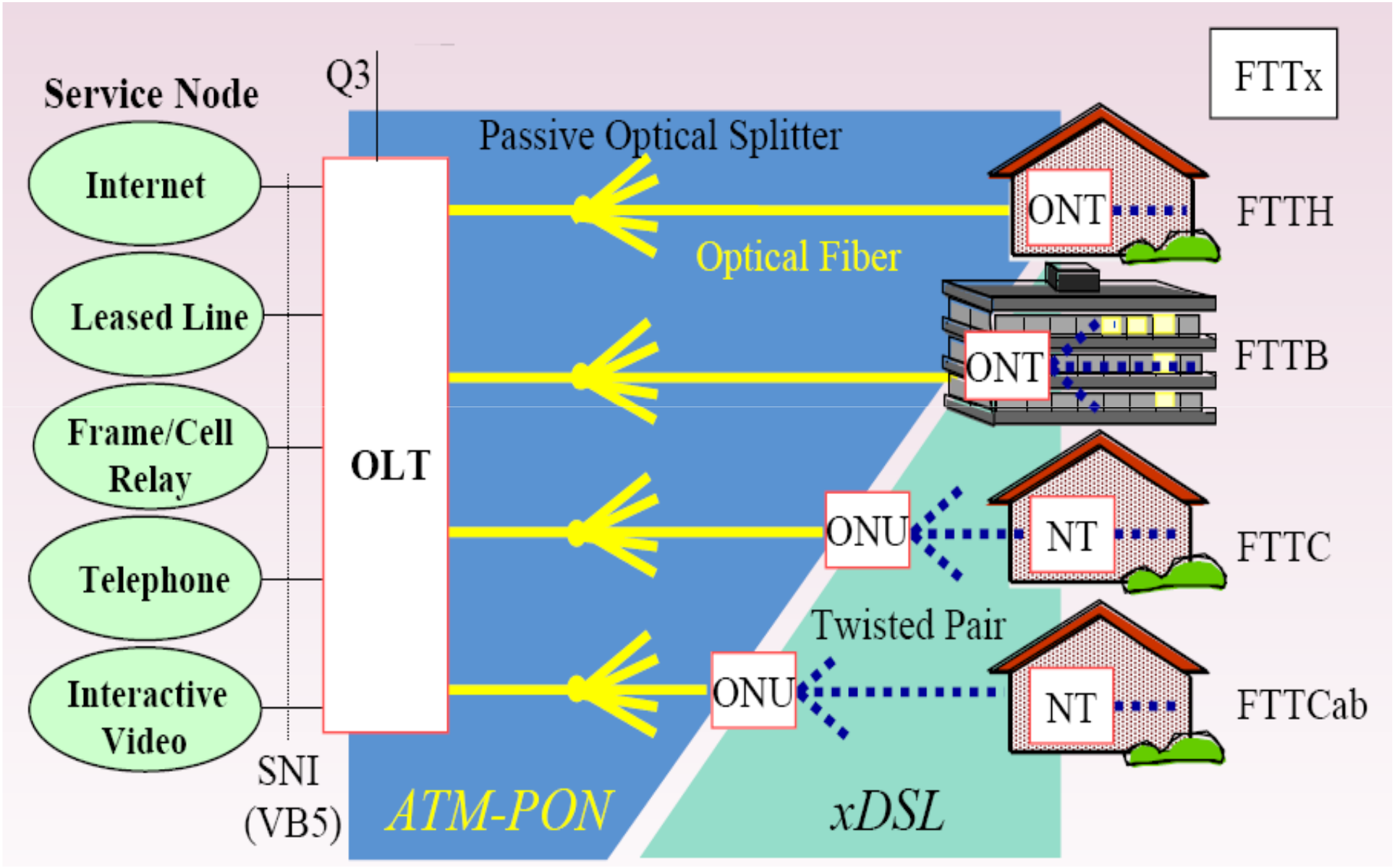
Omrežje
ODN

Objekt

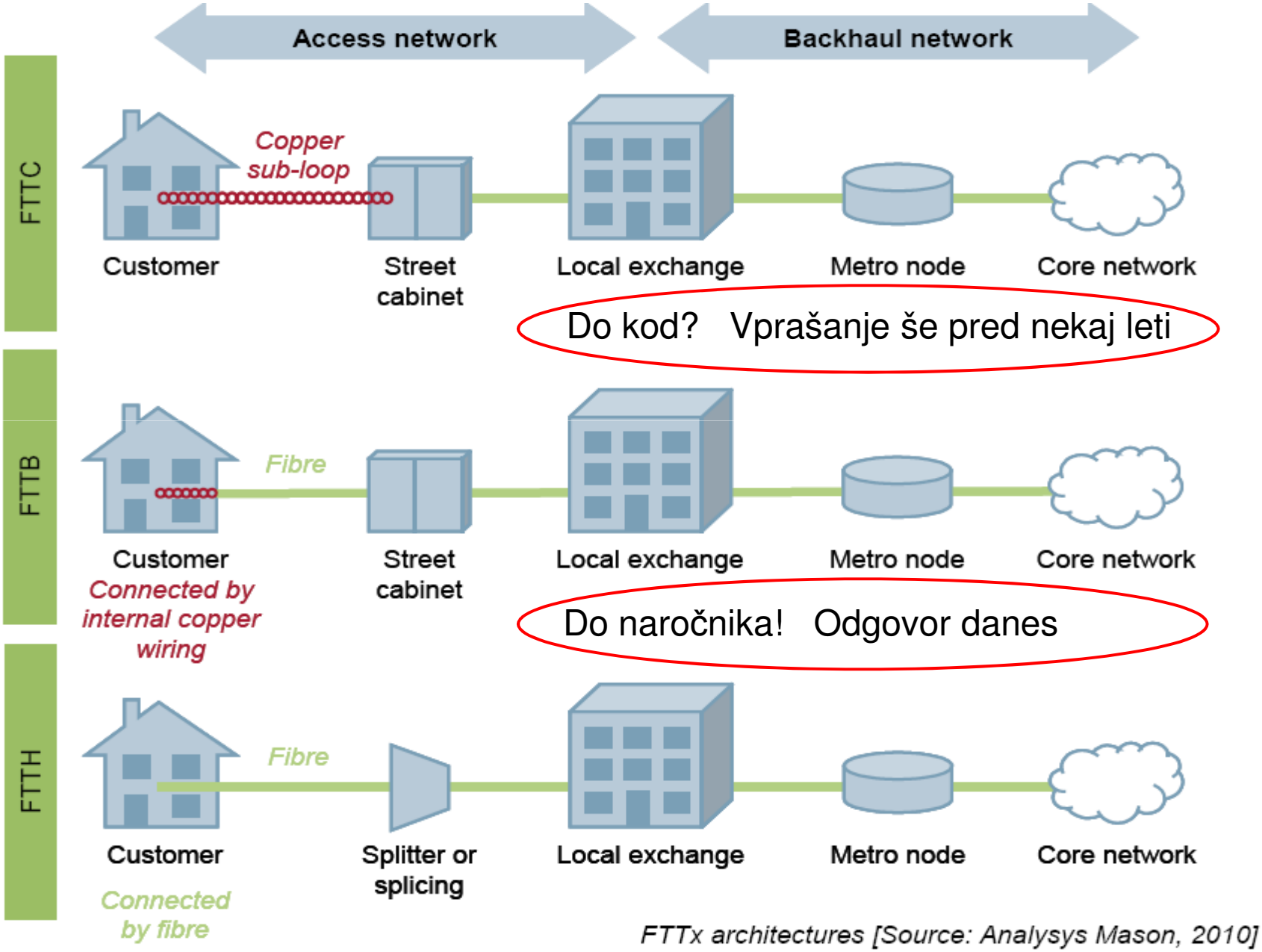
Sistemi žičnega in vlakenskega dostopa



Napredovanje vlakna proti naročniku



Prodiranje vlakna proti naročniku



FTTx architectures [Source: Analysys Mason, 2010]

Območja dostopovnega omrežja

1. Novo dostopovno območje (greenfield):

- območje stanovanjskih hiš, novogradnje (SFU, single flat unit)
- območje stanovanjskih blokov (MDU, multi-dwelling unit)

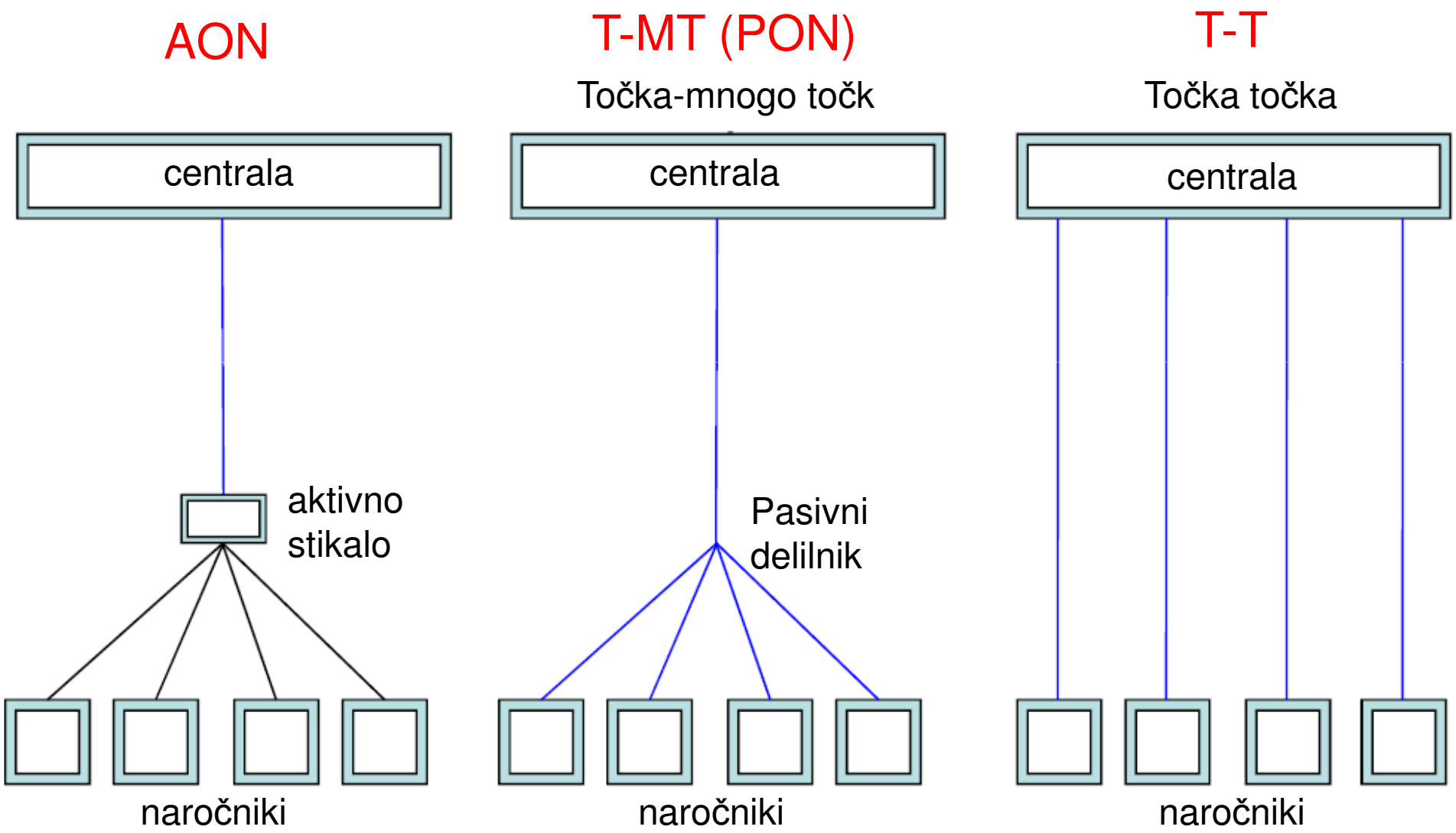
2. Obstoječe dostopovno omrežje (brownfield):

- Gosto pozidano urbano področje, mestna jedra, dostopnost kanalske infrastrukture

3. Regulacija:

- Razvezava zanke (Japonska, Koreja, Eu)
- Novo grajena omrežja izvzeta iz razvezave (ZDA)
  - učinek na povečanje števila novozgrajenih priključkov (Verizon, AT&T, pooblaščene organizacije – “incumbents”)

Tri glavne dostopovne topologije



Tehnologije dostopovnega omrežja

Aktualne tehnologije (2010):

- GPON (Gigabit PON), xGPON; priporočila ITU
- EPON (Ethernet PON), GEPON; standardi IEEE
- Eth. T-T (Ethernet T-T)
- AON (aktivni elementi v omrežju, ojačevalniki, stikala)

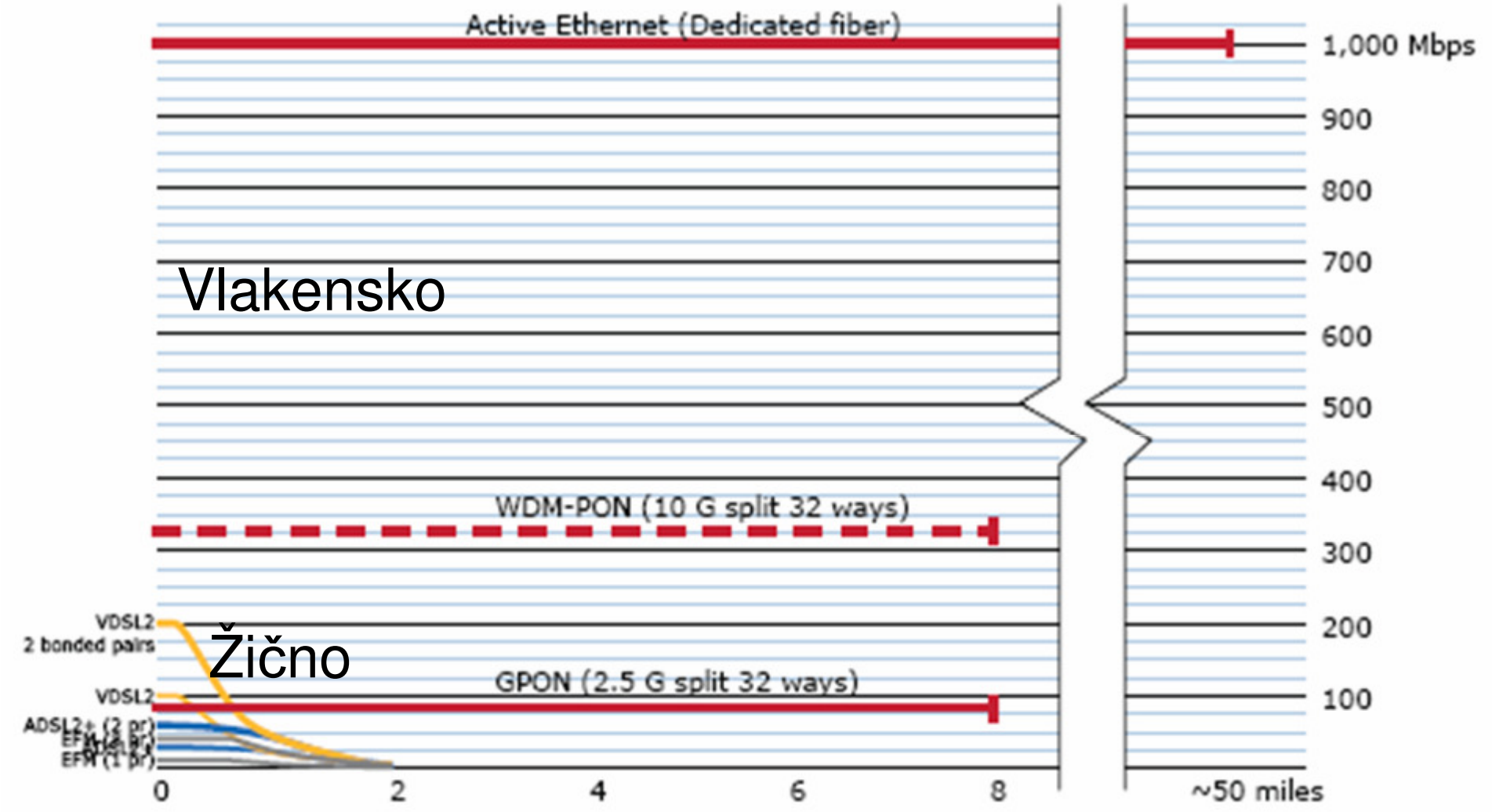
Nove tehnologije (2010 – 2020):

- WDM PON (CWDM, DWDM, standard v pripravi)
- WDM T-T
- TDM/WDM PON

Prihodnje tehnologije (2010 – 2030):

- NG PON1, nova generacija LR PONa za velike razdalje
- NG PON2, NG PON3,...

Zmogljivost žičnega in vlakenskega omrežja

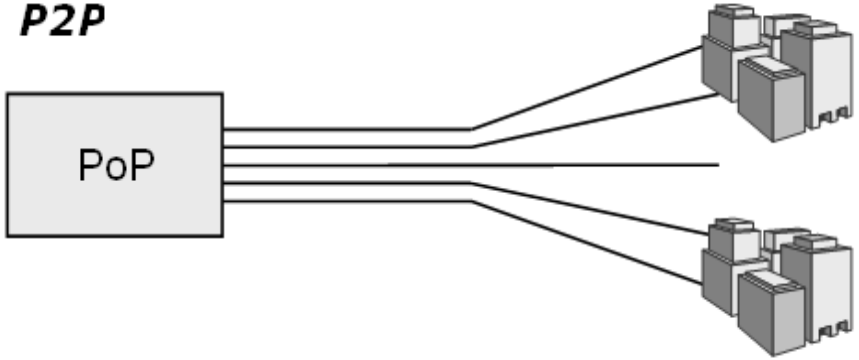


Žično: Nizka do srednja vrednost b/s
zelo kratka do kratka razdalja

Vlakensko: skoraj neomejena b/s
srednje do velike razdalje

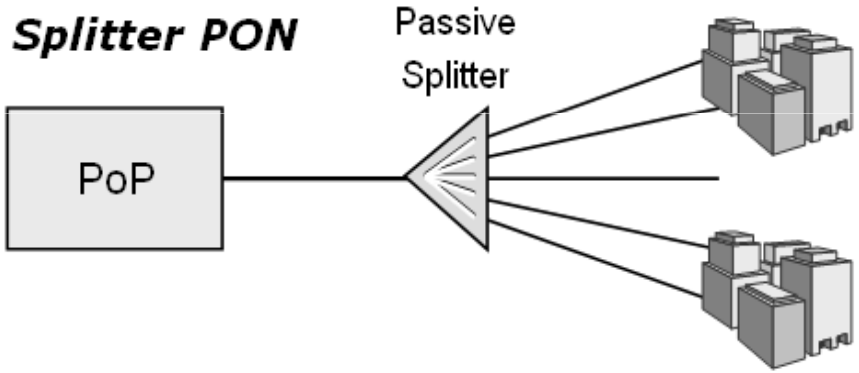
Primerjave med vlakenskimi omrežji

P2P



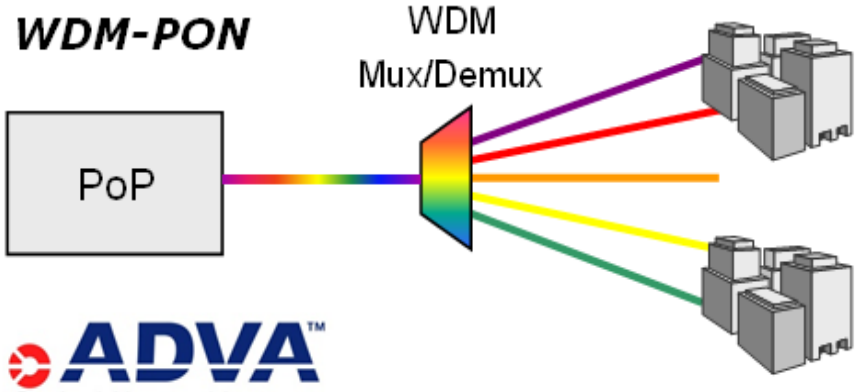
\+ Scalable and transparent bandwidth per customer
\+ Highest security/availability due to physical/logical separation of customer links
– High fiber count in access network (i.e., high OPEX)
– High space and power consumption

Splitter PON



\+ Very low fiber count in feeder network part
\+ Low port (interface) number, and space and power consumption in PoP
– Limited bandwidth and bandwidth upgrade
– Reduced security/availability in case of TDMA
– High insertion loss, low max. reach

WDM-PON

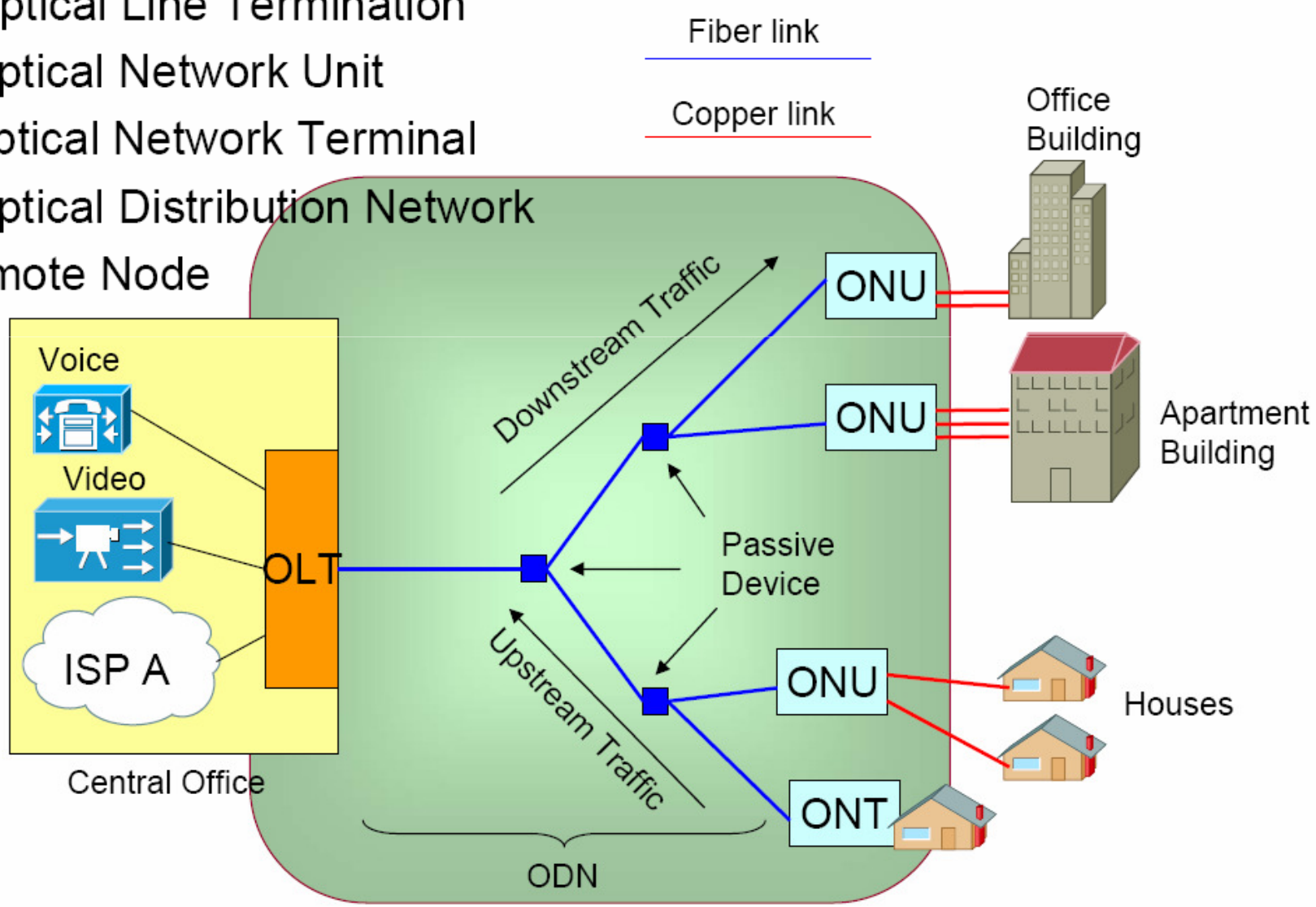


\+ Very low fiber count in feeder network part
\+ Scalable and transparent bandwidth per customer
\+ High security/availability due to optical/logical separation of customer links
– High port number in PoP equipment

ADVA™
Optical Networking

Sestavni deli omržja PON

OLT: Optical Line Termination
ONU: Optical Network Unit
ONT: Optical Network Terminal
ODN: Optical Distribution Network
RN: Remote Node

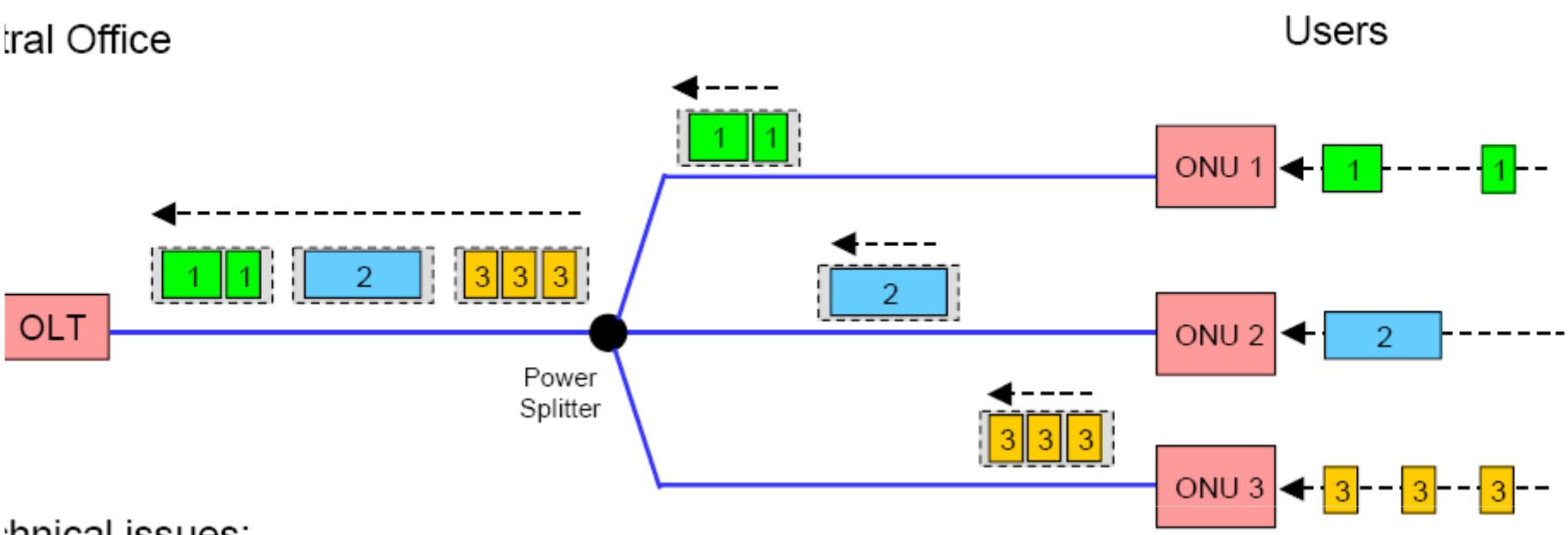


PON v dostopovnem omrežju

Arhitekture in tehnologije:

- G PON (Gigabit PON)
- GE PON (Gigabit Ethernet PON)
- ER/LR PON – nadgradnja GPON
- WDM PON – nadgradnja GPON
- WDM/TDM PON
- LR WDM PON (VelePON)
- LR WDM/TDM PON
- OFDMA – PON?
- Koherentni PON

tral Office



chnical issues:

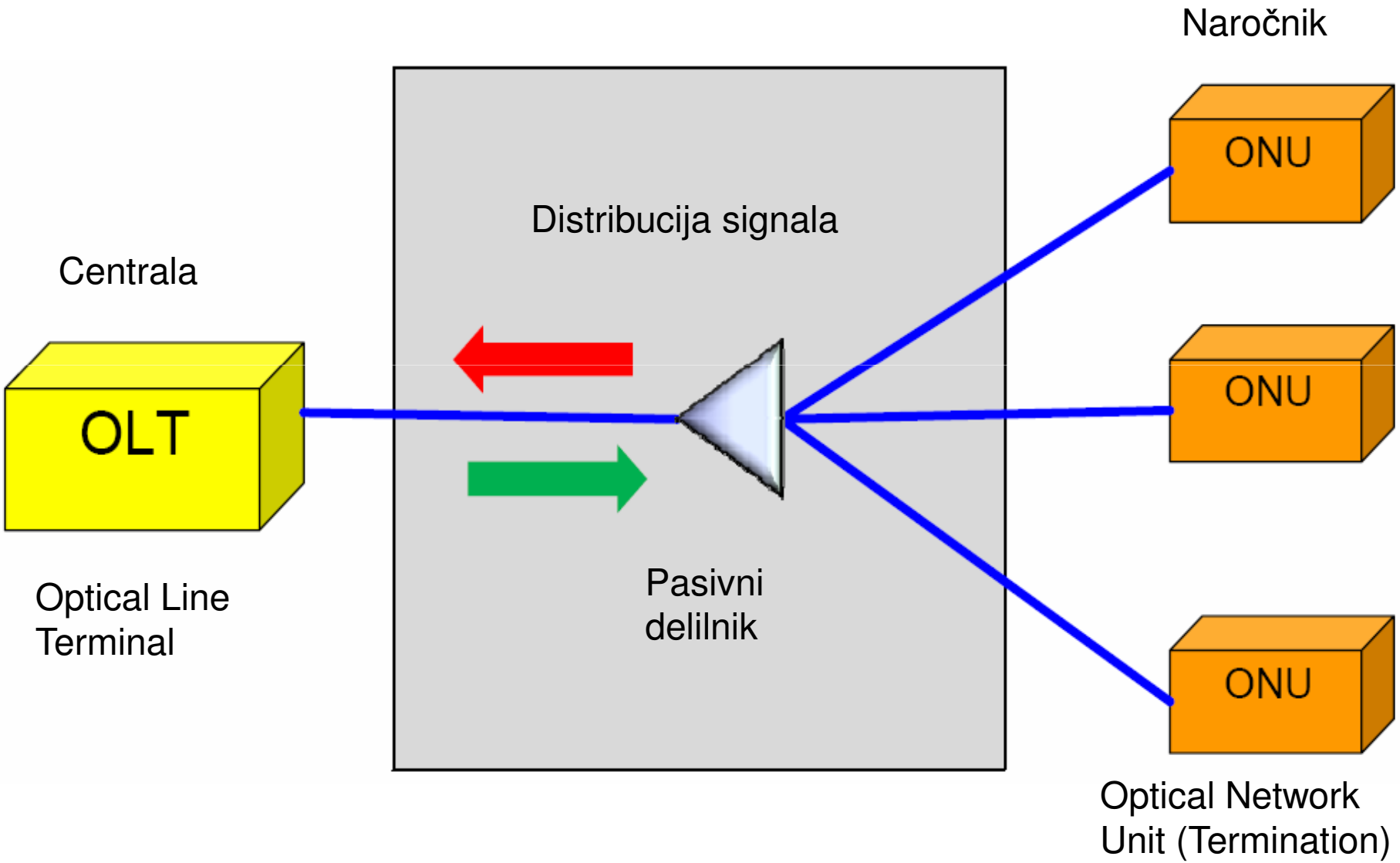
ging

st Tx and Rx (gain & clock)

allocation

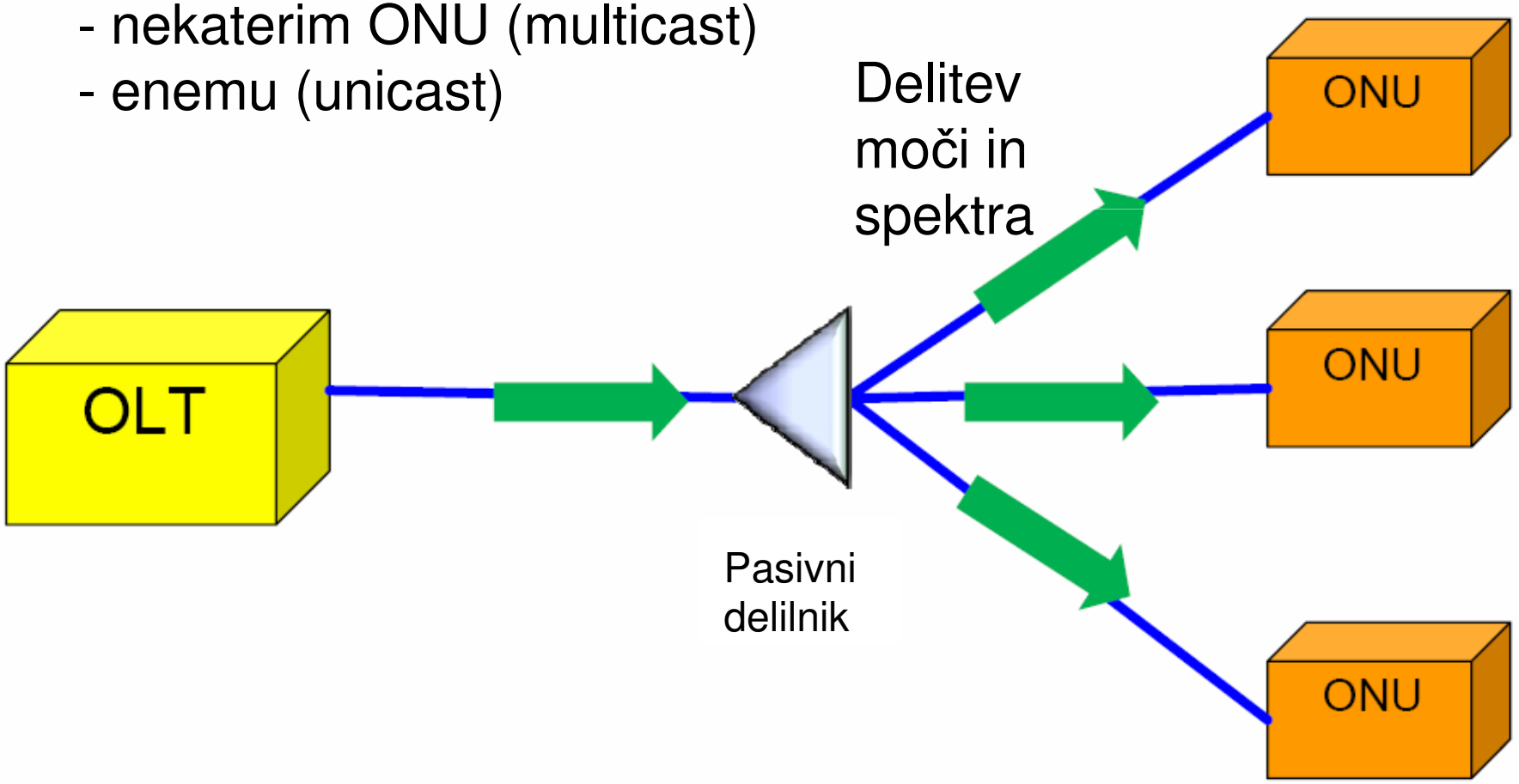
Downstream – Broadcast to all users, identification by packet addresses

Optično delilno omrežje PON



Zveza od centrale do naročnika

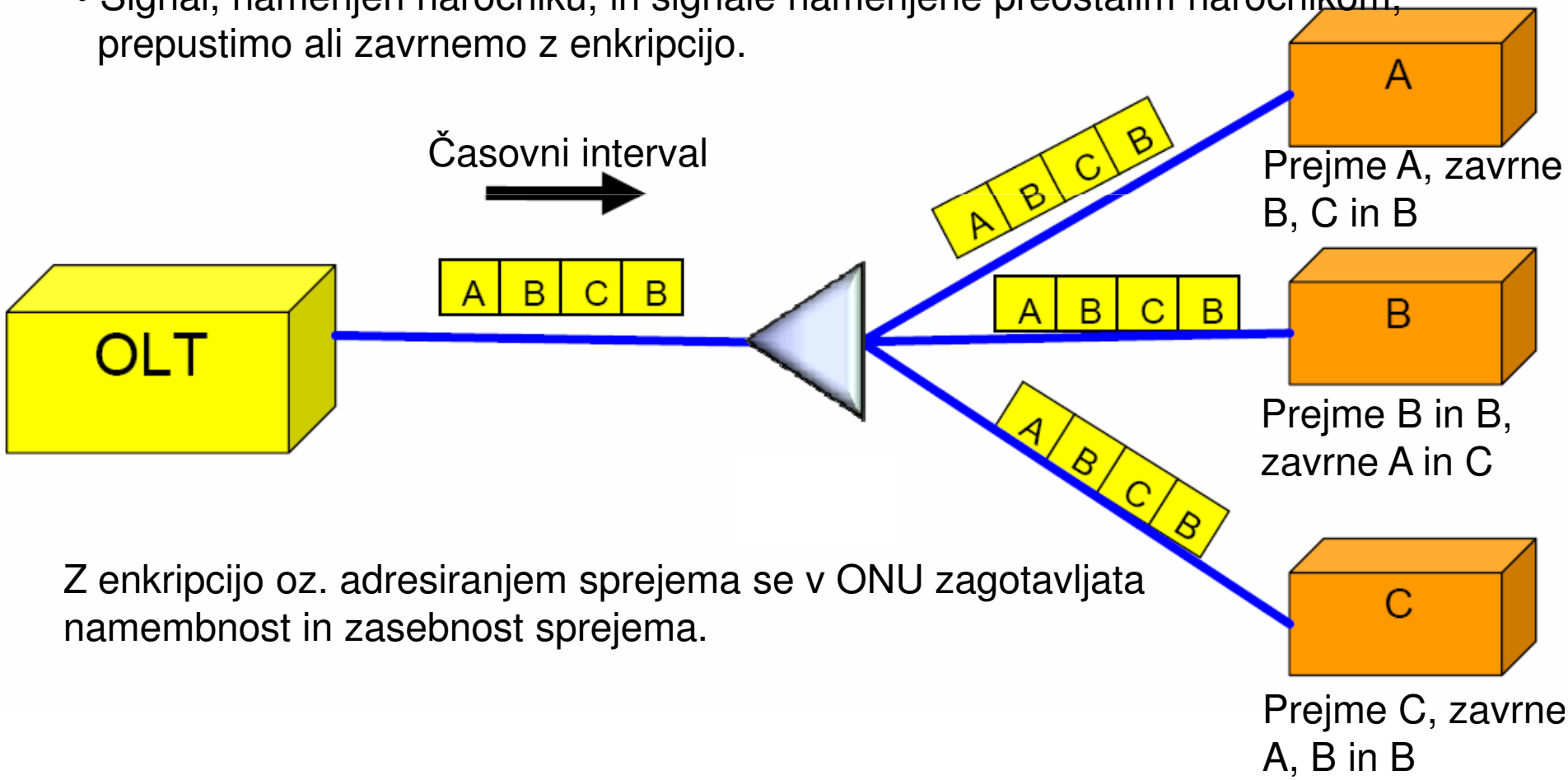
- Zveza T-MT navzdol, dotok (downstream)
- Načini delitve signala iz OLTa:
  - vsem ONU (broadcast)
  - nekaterim ONU (multicast)
  - enemu (unicast)



Zveza TDM navzdol

Zagotavljanje namembnosti in zasebnosti (tajnosti) sporočila:

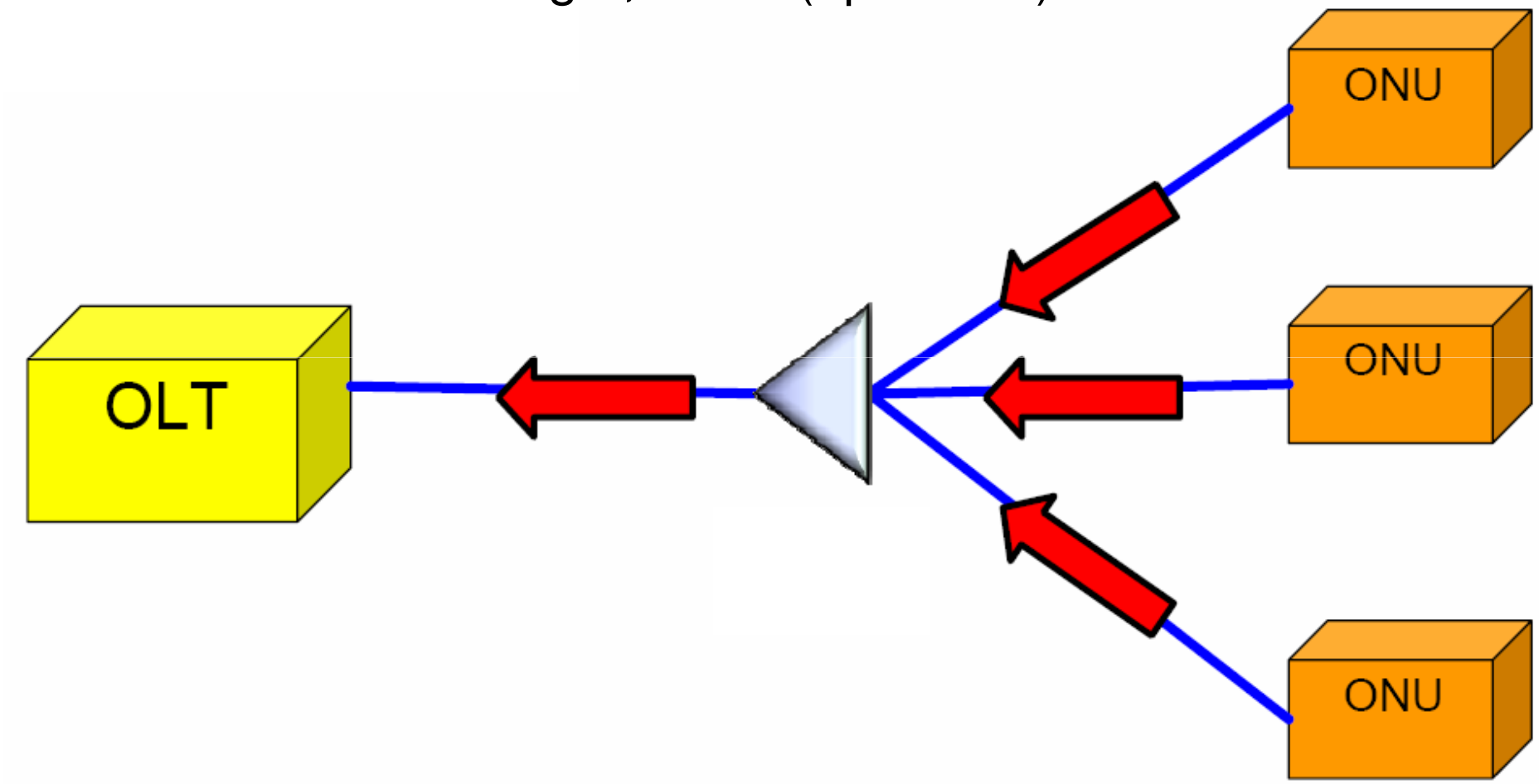
- Vsem naročnikom pošljamo skupen signal, ki obsega vse signale, namenjene vsem prejemnikom. Deli signala, namenjeni določenemu naročniku, so označeni z adreso naročnika.
- Signal, namenjen naročniku, in signale namenjene preostalim naročnikom, prepustimo ali zavrnemo z enkripcijo.



Z enkripcijo oz. adresiranjem sprejema se v ONU zagotavljata namembnost in zasebnost sprejema.

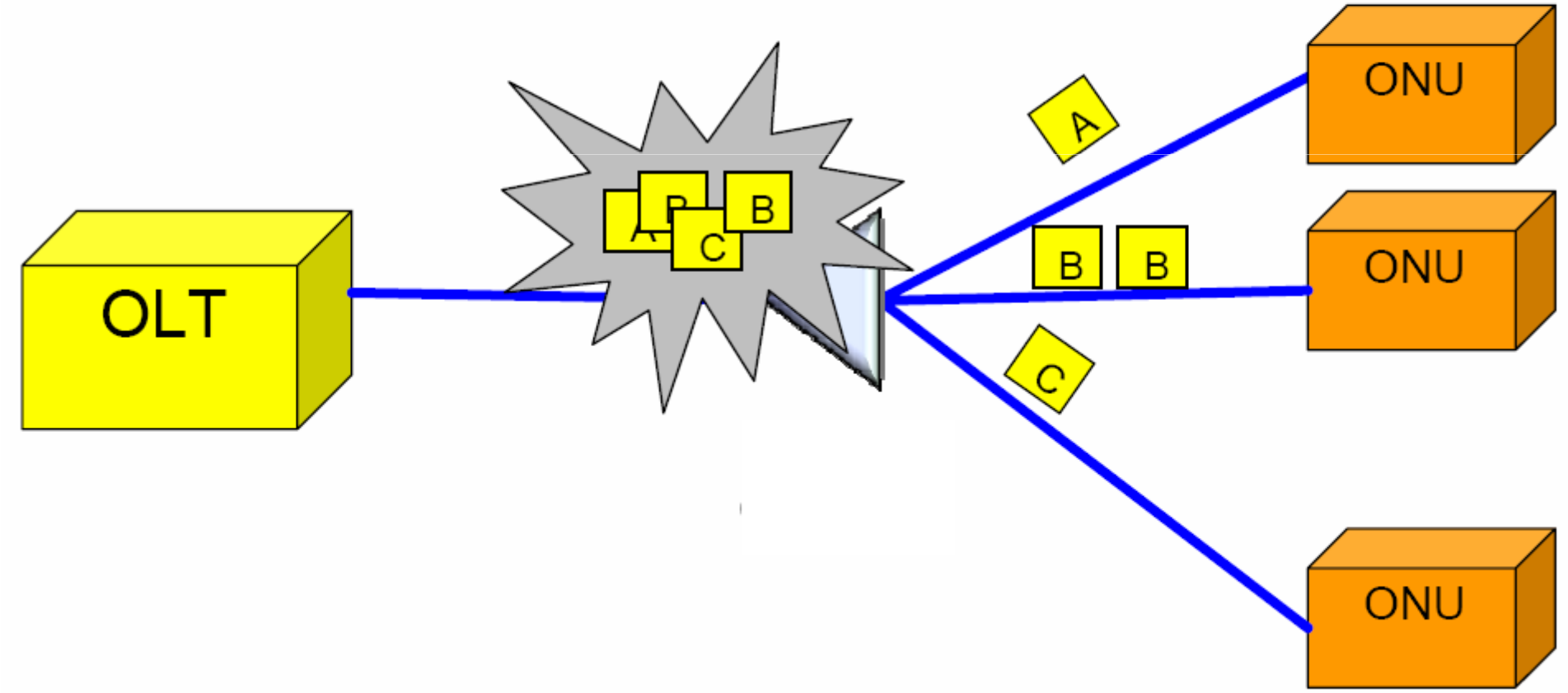
Zveza od naročnika do centrale

- Zveza T-MT navzgor, odtok (upstream)



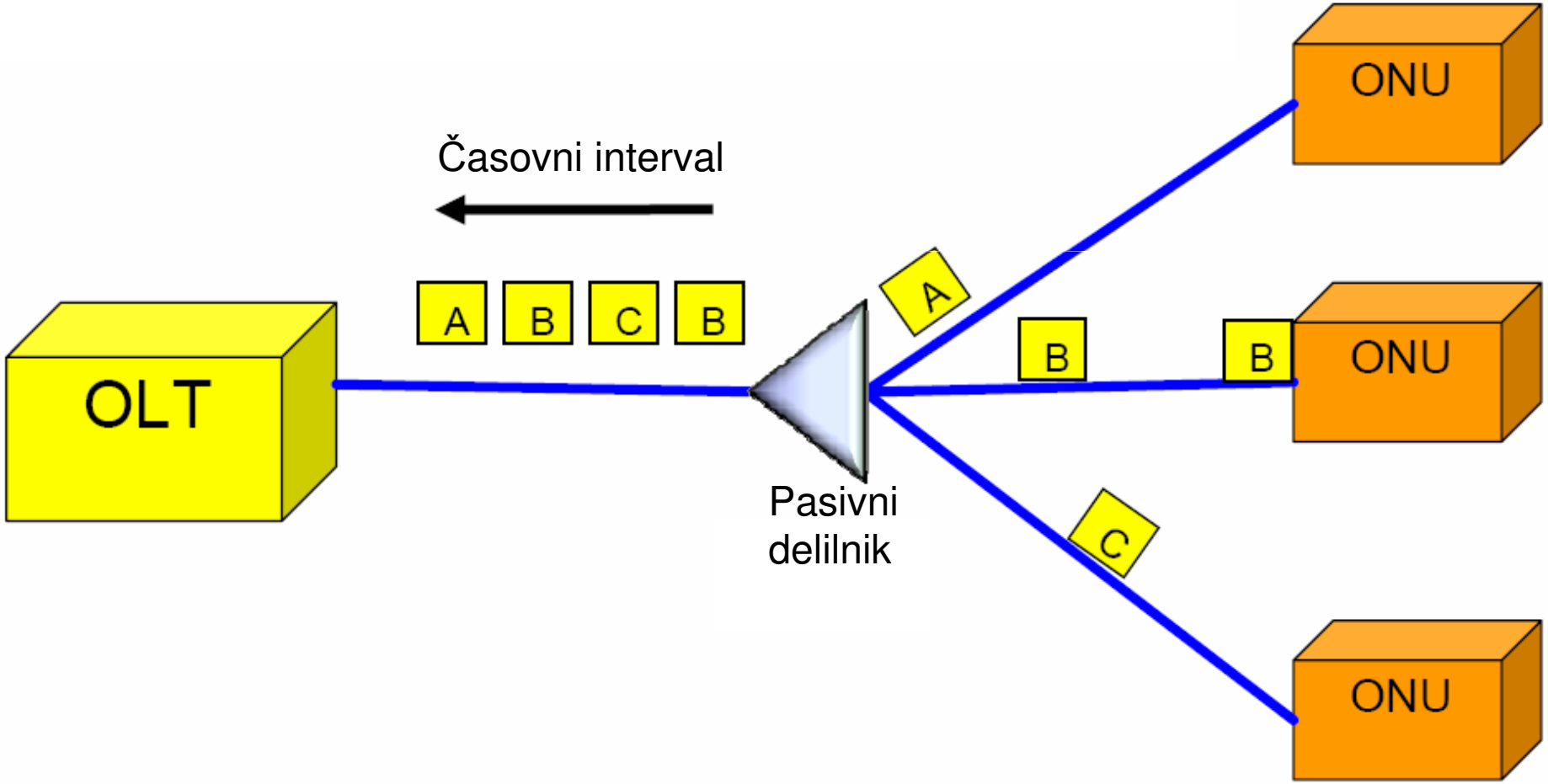
Primer nekoordiniranega odtoka

- Kolizija odtočnih signalov zaradi časovne neusklajenosti oddaje v ONUjih.



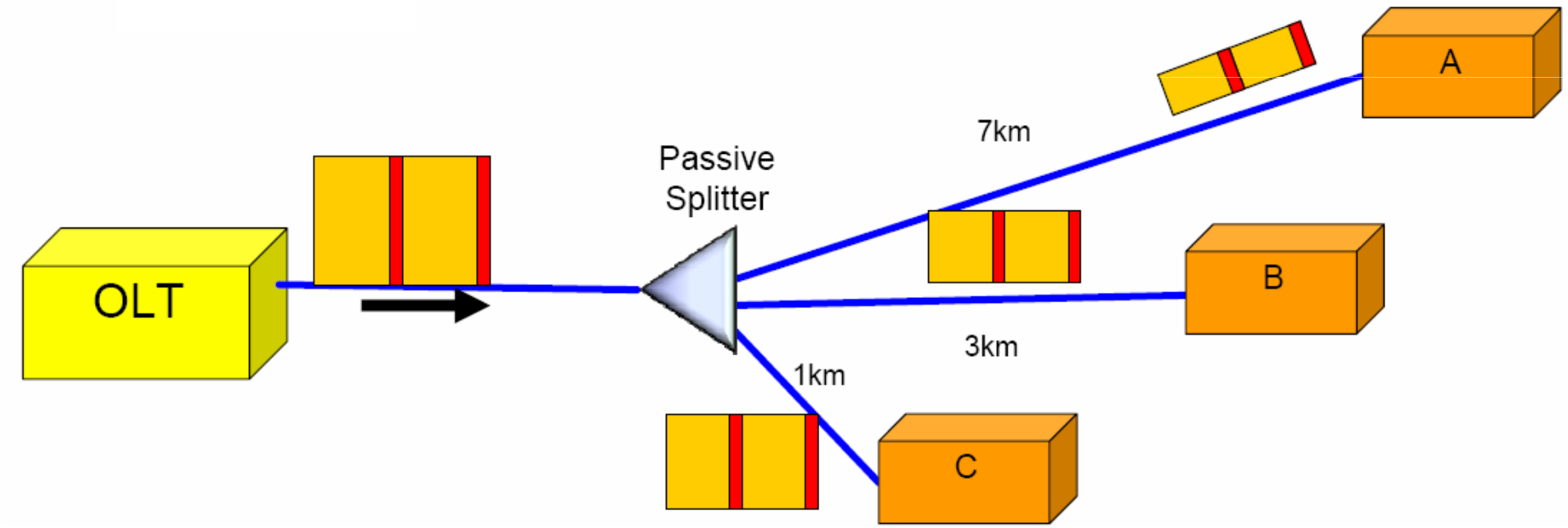
Zveza TDMA navzgor

- ONU med seboj sinhronizirajo svoje signale glede različne razdalje do pasivnega delilnika tako, da ne pride do časovne kolizije med njimi.
- Pri tem je pomembna razdalja med ONU in pasivnim delilnikom.



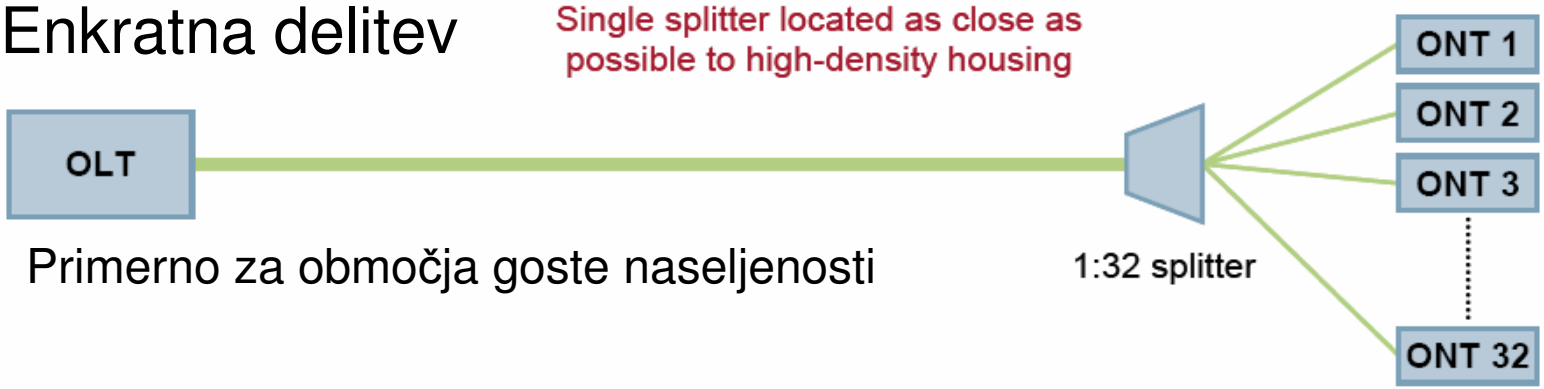
PON

- prostrano območje pokrivanja, večja razlika v razdaljah
- različno slabljenje in moč pri sprejemu
- razdalje pomembne za časovno sinhronizacijo odtoka



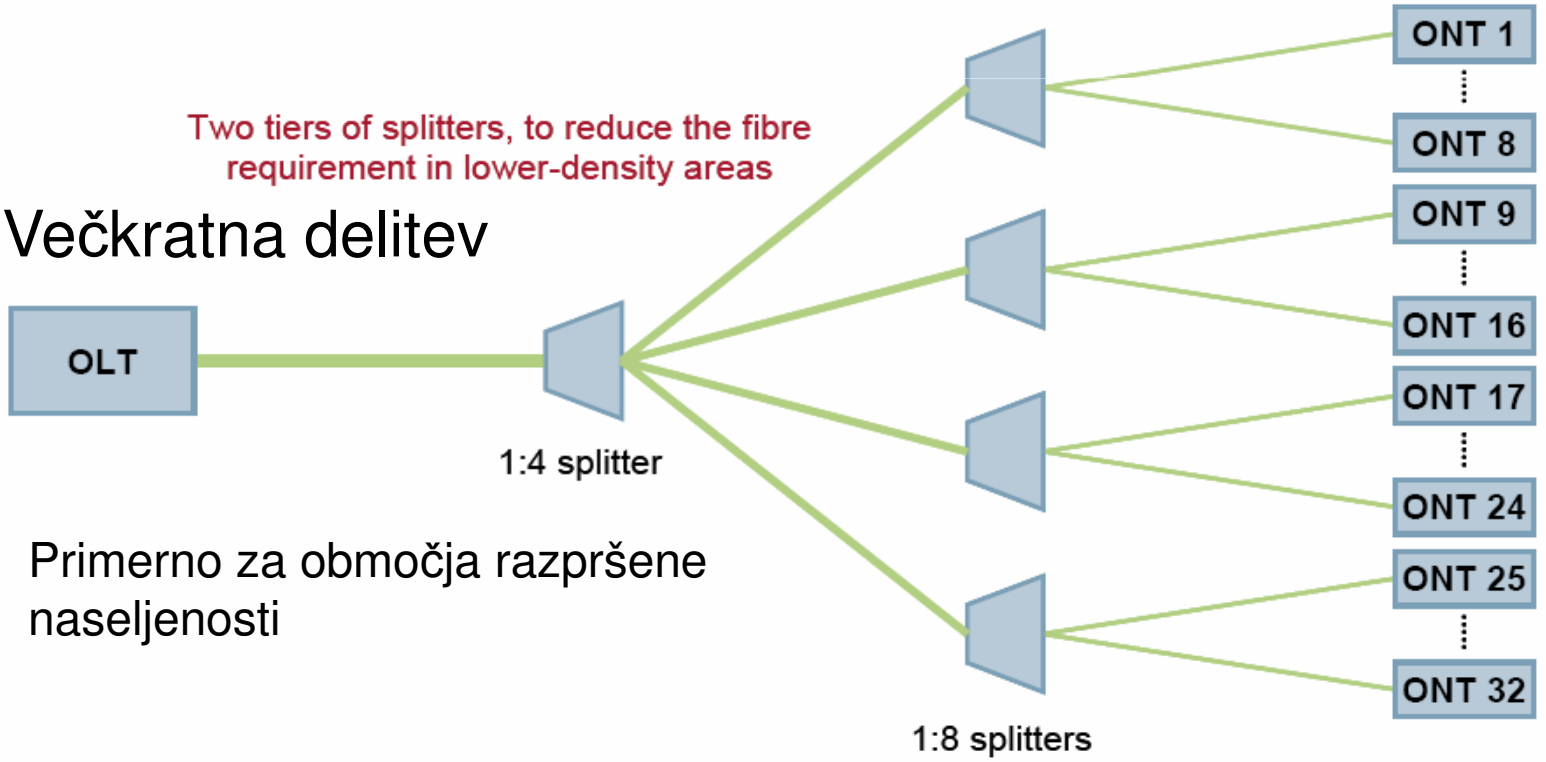
PON – eno- in večkratna pasivna delitev

Enkratna delitev



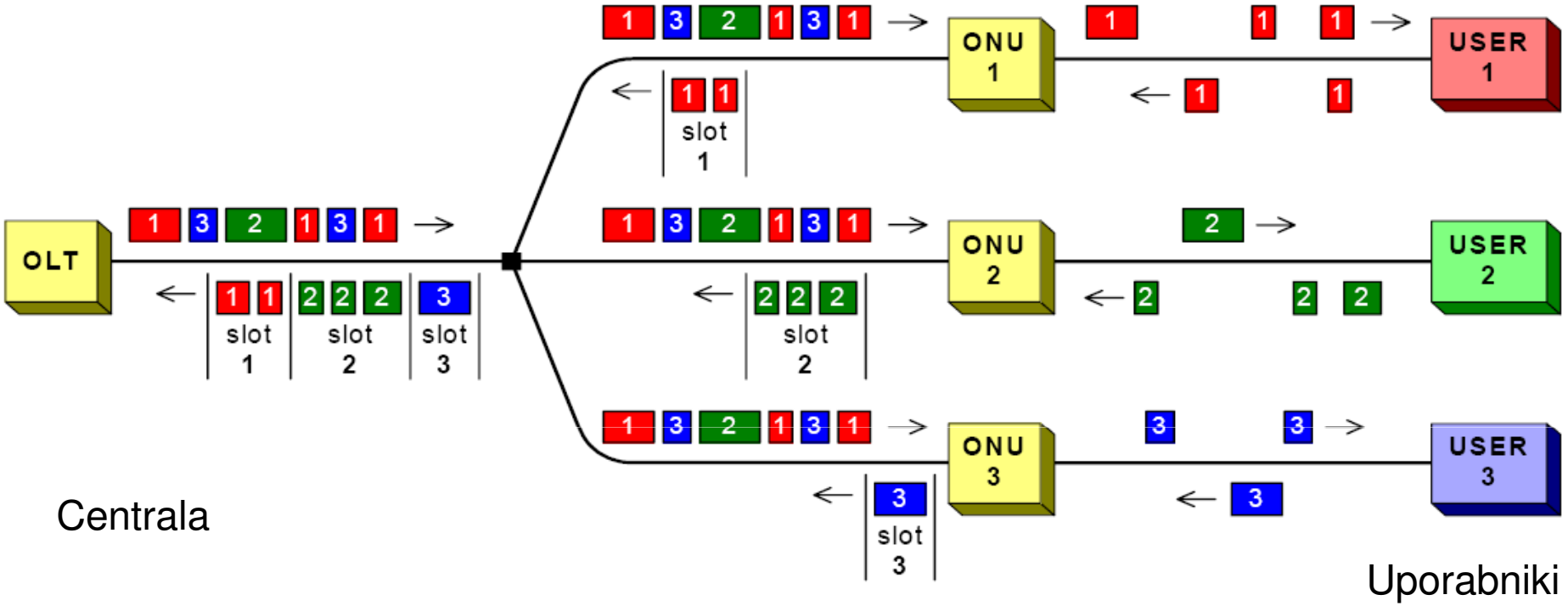
Primerno za območja goste naseljenosti

Večkratna delitev



Primerno za območja razpršene naseljenosti

Dotok in odtok

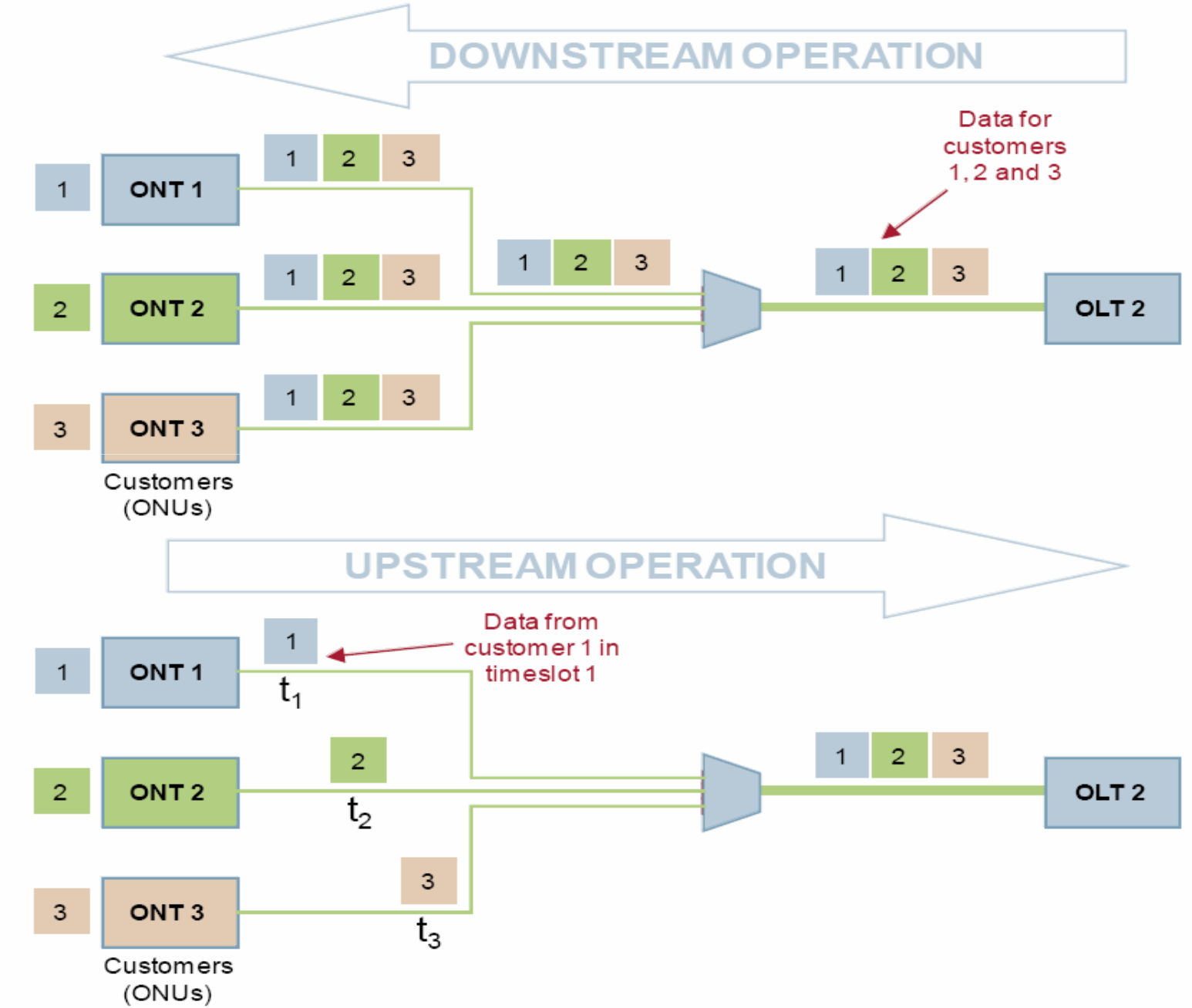


- **Dotok [➔] TDM**
  - Vse sprejemne enote (ONU) prejmejo enako vsebino (broadcast)
  - Sprejemne enote z enkripcijo izločijo njim namenjeno vsebino in s tem zagotavljajo zasebnost,.

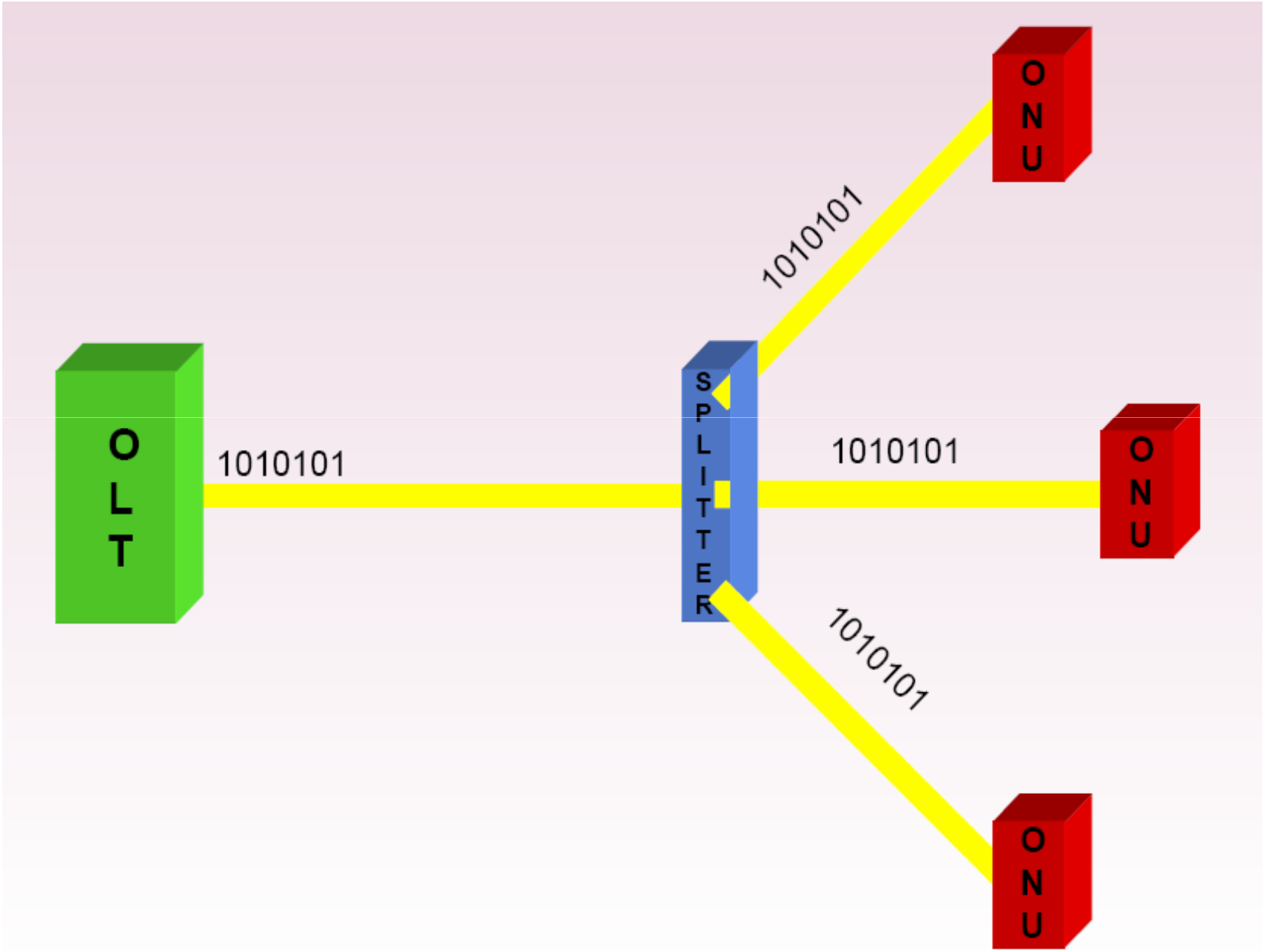
Odtok [➔] TDMA

- Sprejemne enote sinhronizirajo oddajo posameznega uporabnika v časovne intervale tako, da se ne prekrivajo.

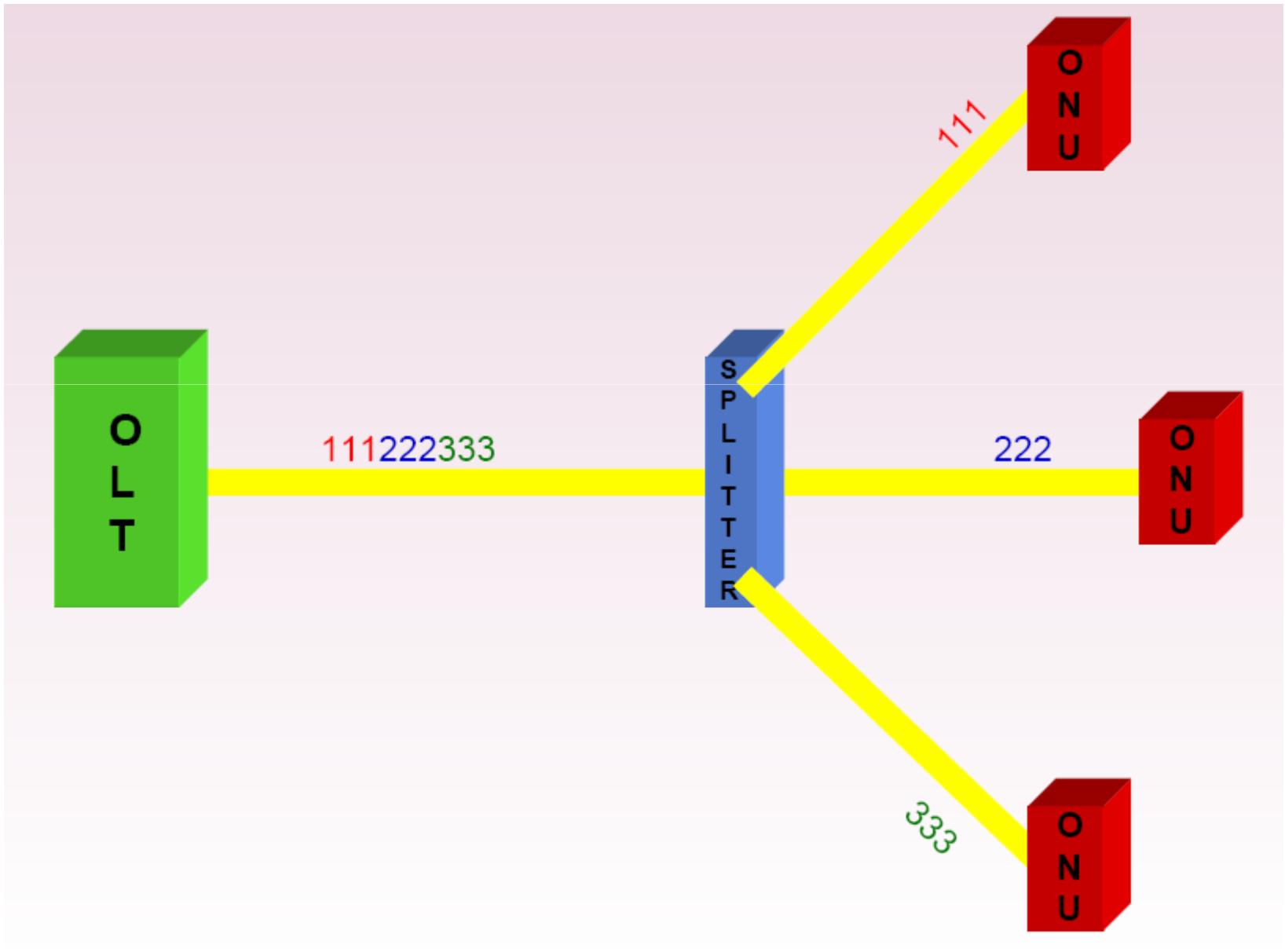
PON dotok in odtok



PON – zveza navzdol

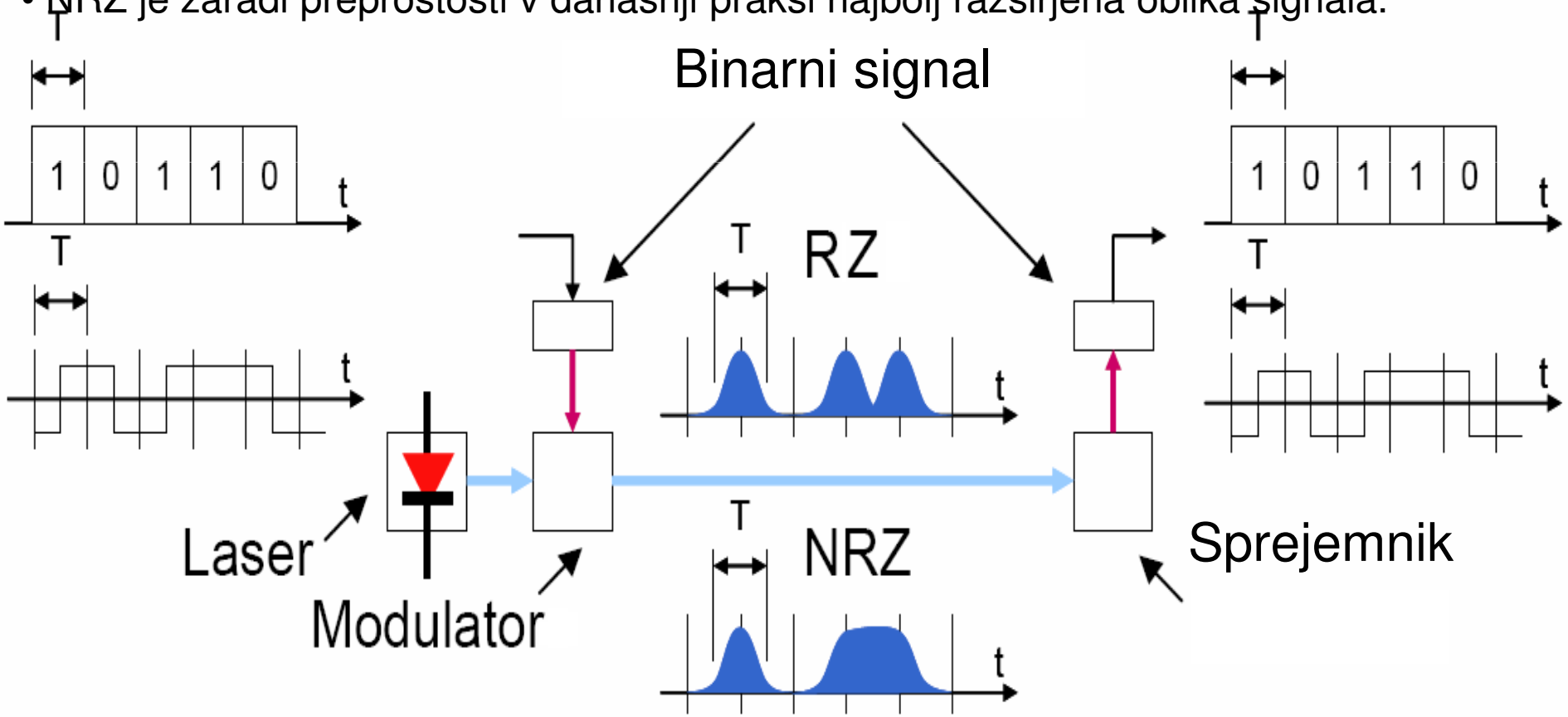


PON – zveza navzgor

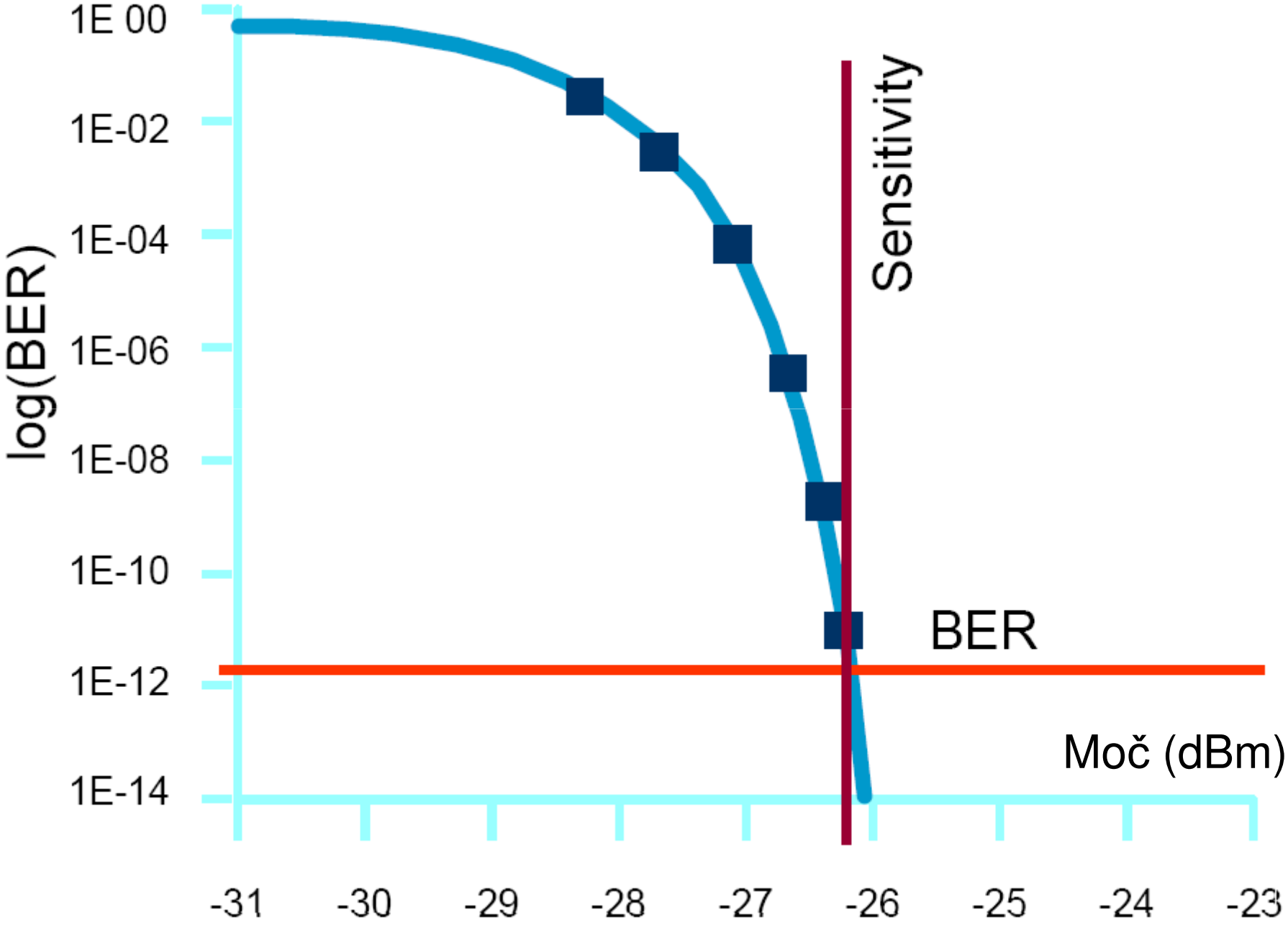


Zveza z RZ in NRZ signalom

- Signalna oblika optičnega signala v vlaknu je RZ (Return to Zero, povratno na nič) in NRZ (Non Return to Zero, nepovratno na nič).
- Različni digitalni modulacijski formati (npr. QAM) uporabljajo obe obliki.
- RZ je zahtevnejša oblika signala, potrebuje 2×širši spekter, je občutljiva na disperzijo, odporna na nelinearne motnje in omogoča večji doseg.
- NRZ je zaradi preprostosti v današnji praksi najbolj razširjena oblika signala.



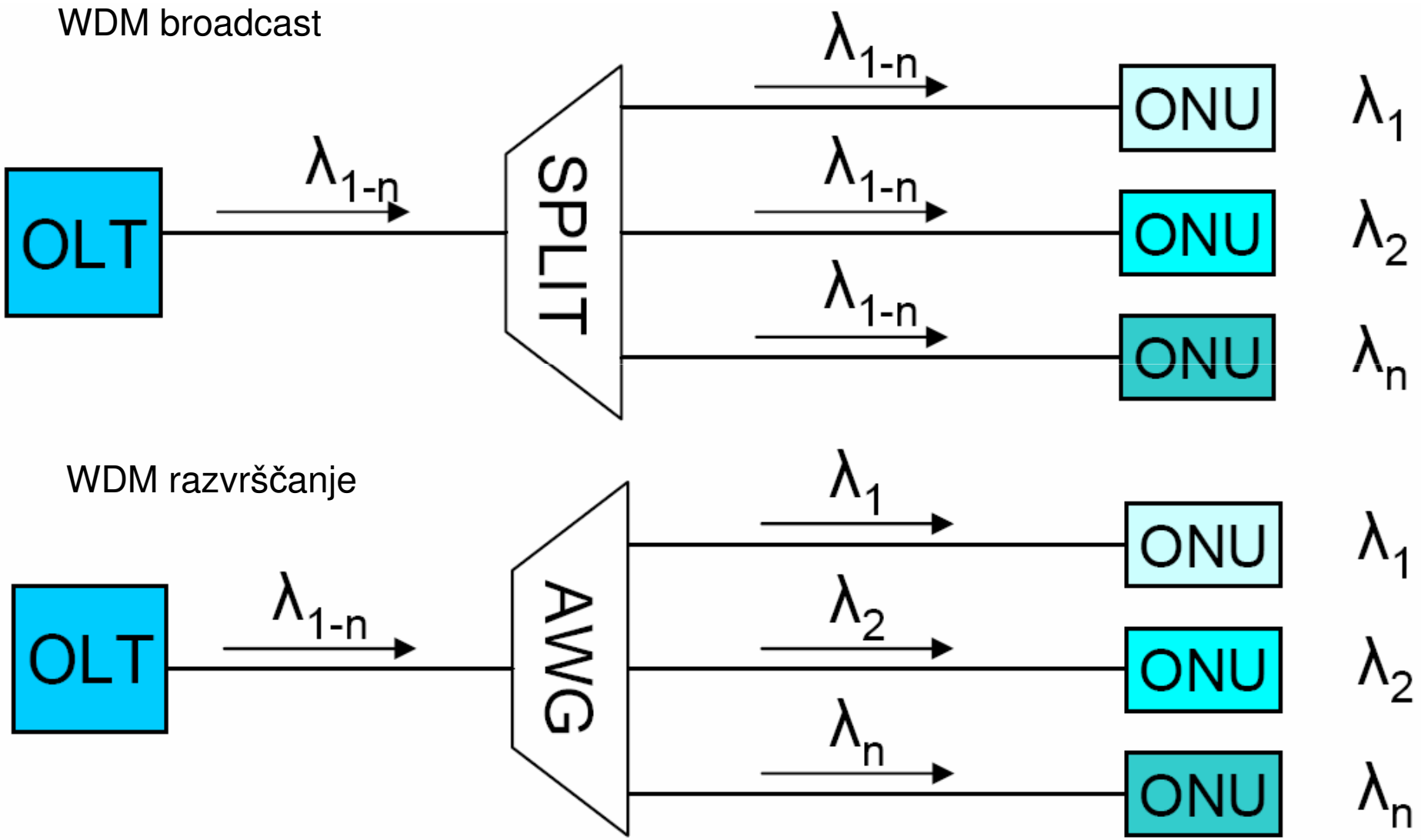
BER in sprejeta moč



Multipleksiranje (razvrščanje) v dostopu

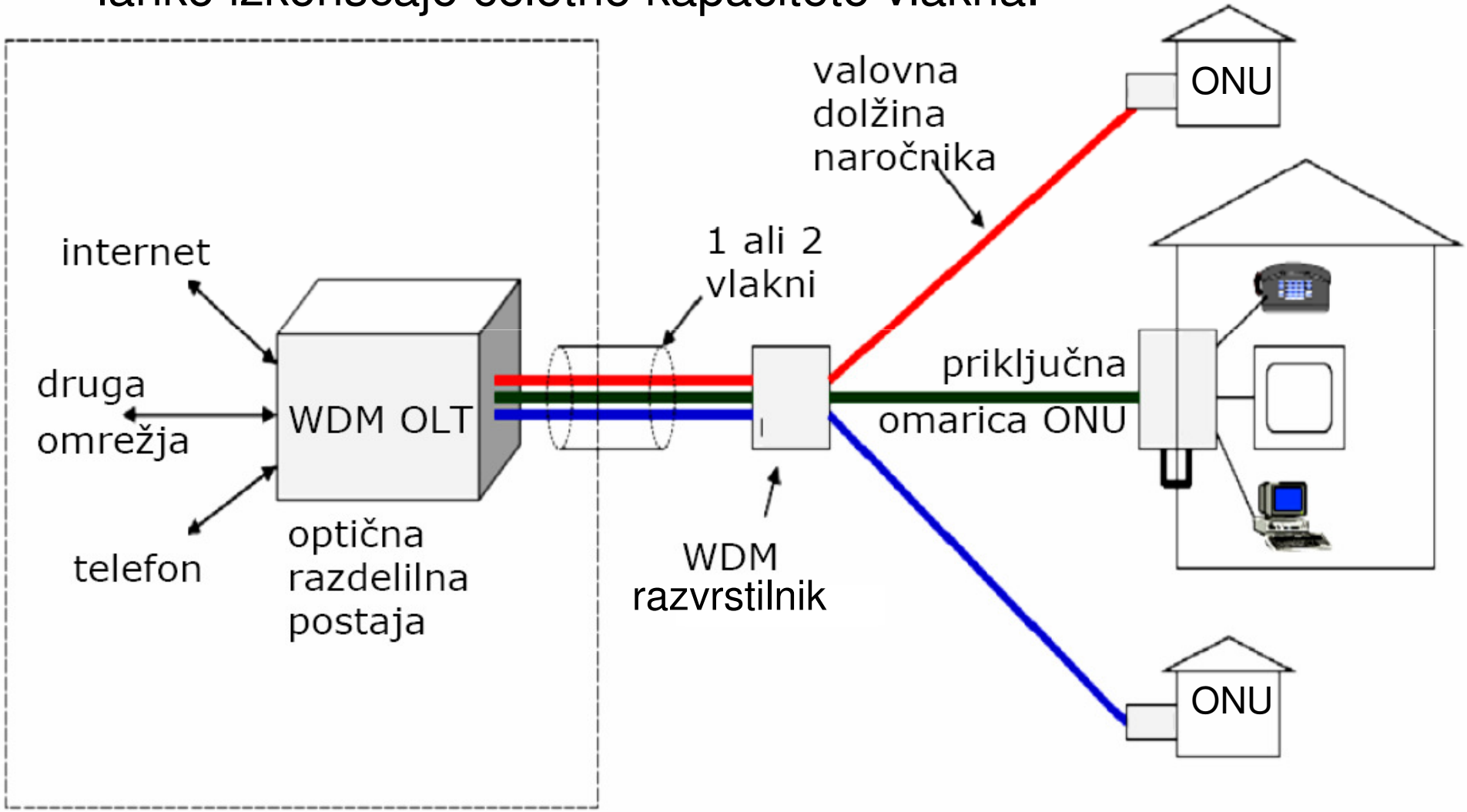
1. SDM (prostorsko)
2. TDM (časovno)
3. WDM (valovno)
4. TDM/WDM (HPON) (hibridno)
5. SCM/OFDM (podnosilniško)
6. OFDMA (ortognalno frekvenčno)

Barvni delilnik in razvrstilnik



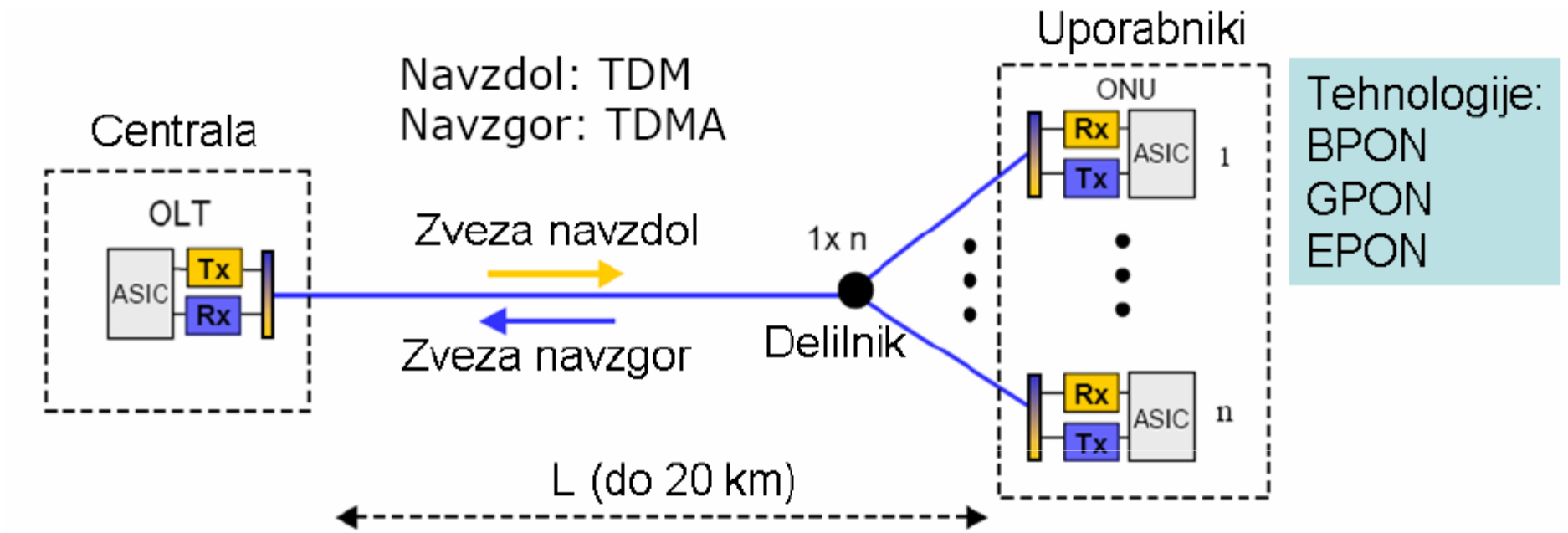
WDM PON

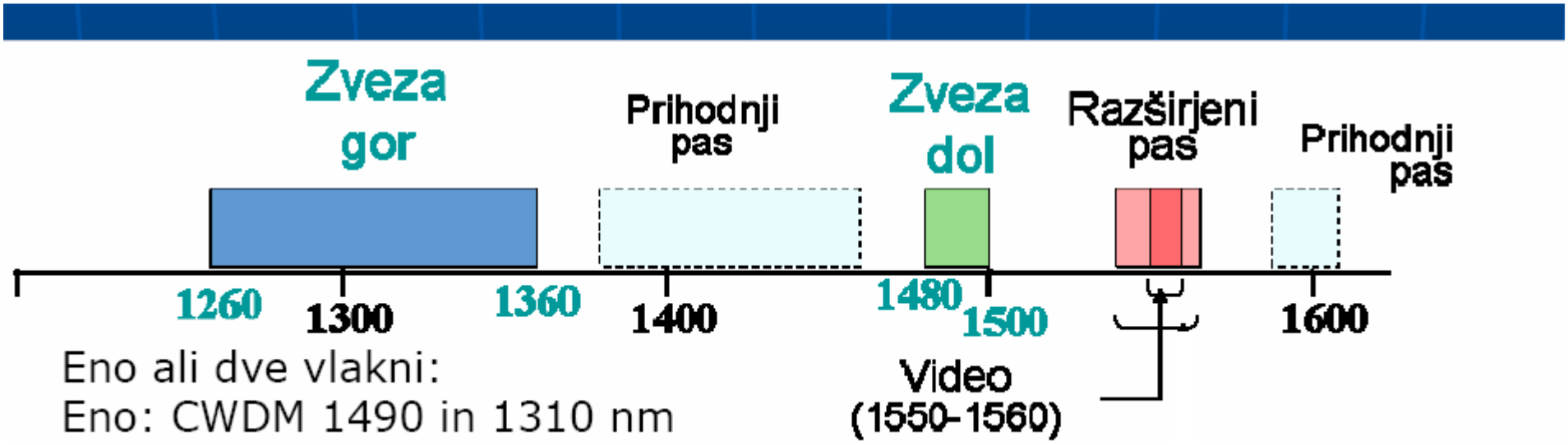
- Naročniki uporabljajo vsak svojo valovno dolžino in tako lahko izkoriščajo celotno kapaciteto vlakna.



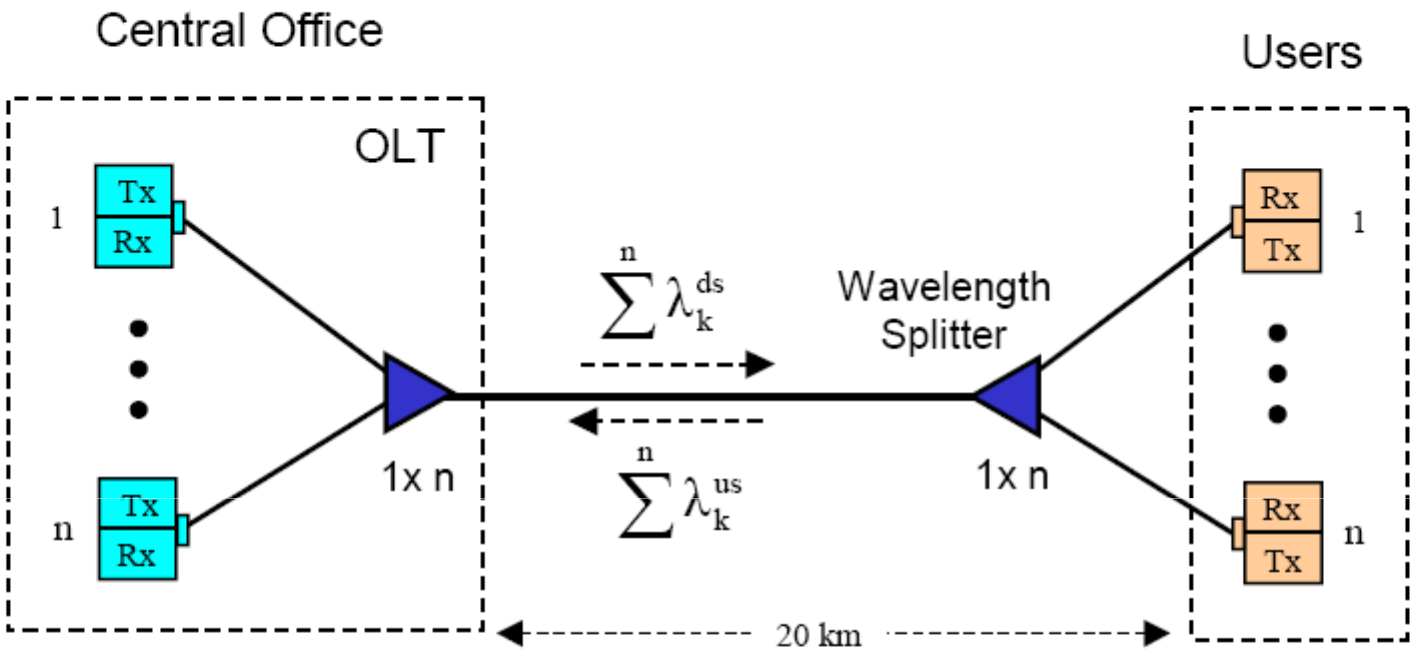
WDM PON je virtualni P-P

TDM dotok in TDMA odtok





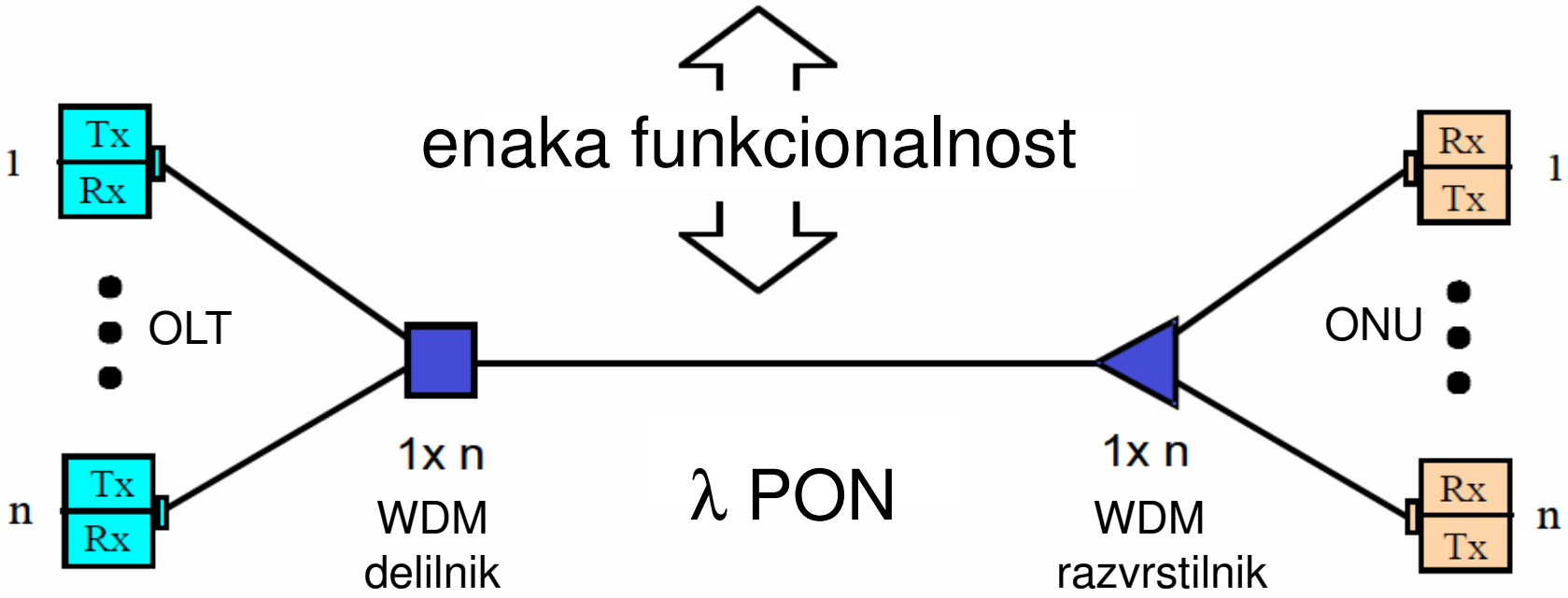
Benefits of point-point over a shared infrastructure



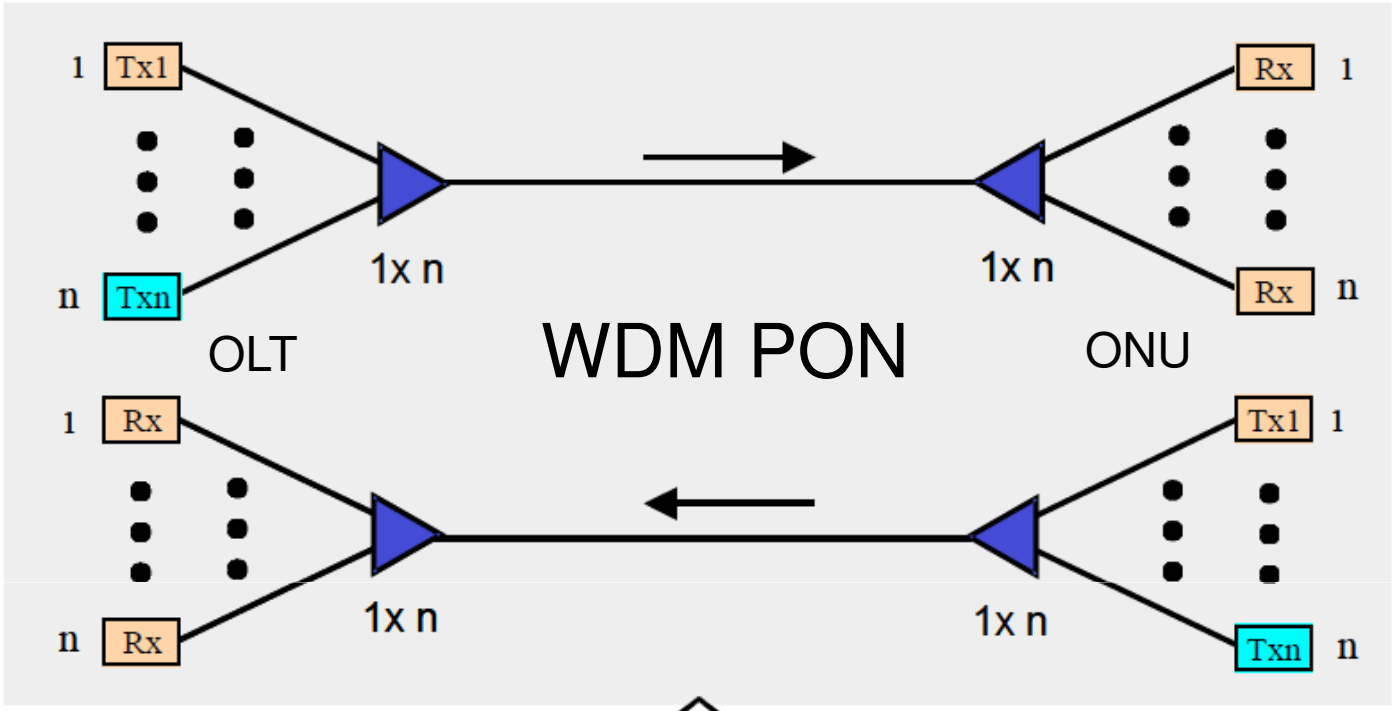
Access Requirements:

- Passive remote node
- Common TxRx for each user
- Single fiber connectivity

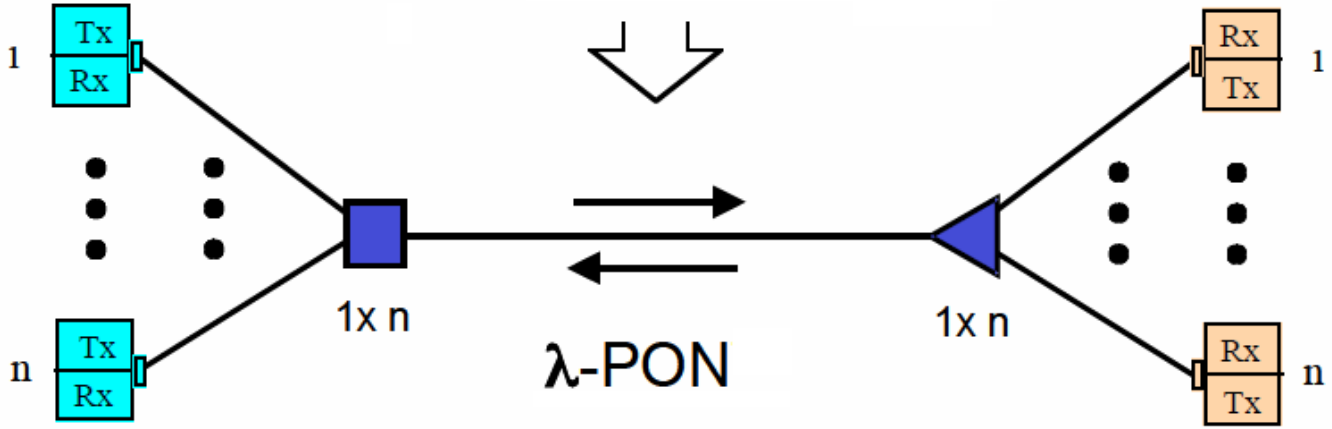
Primerjava zveze T-T in WDM



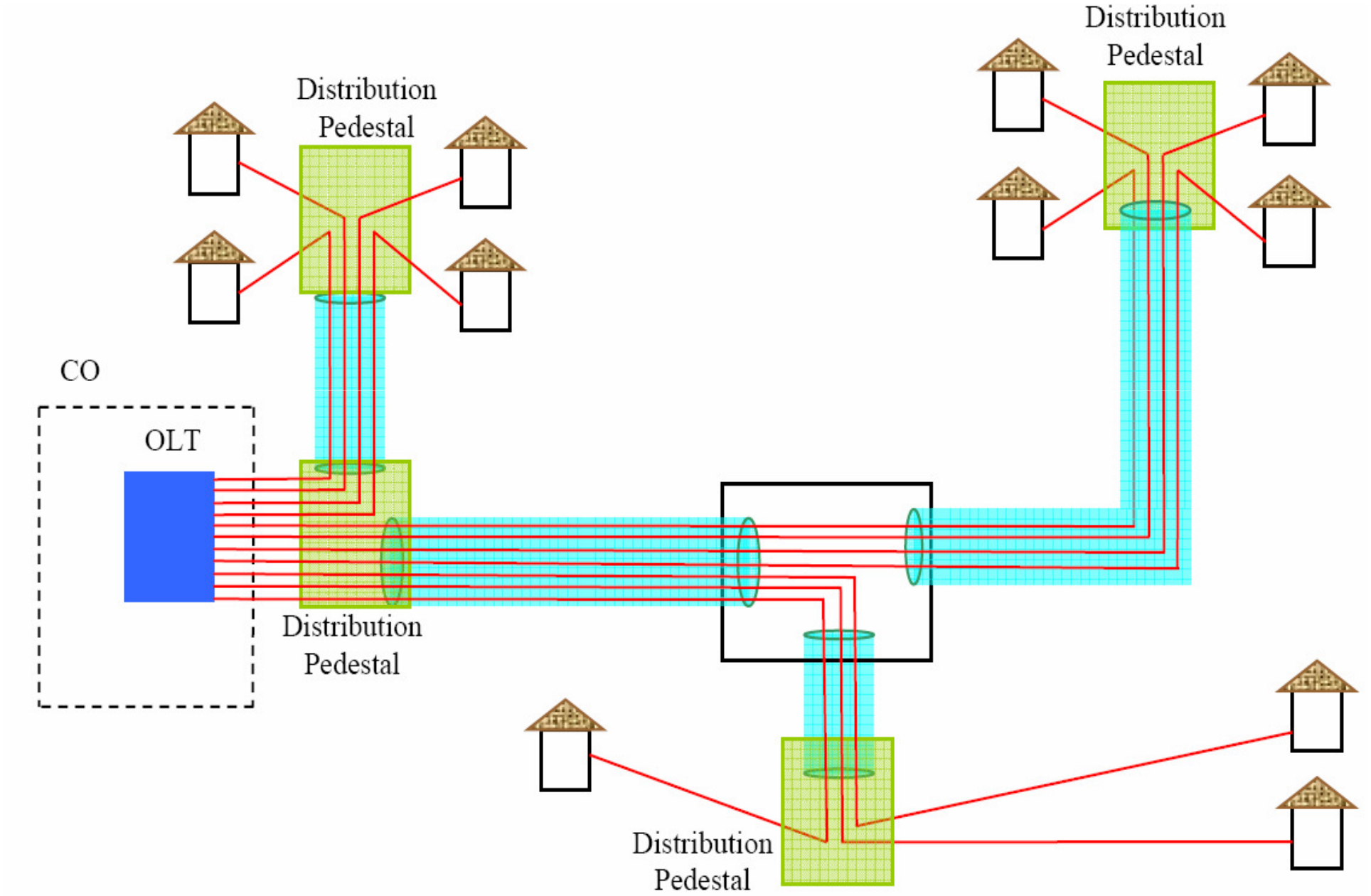
Modifikacija λ PONa



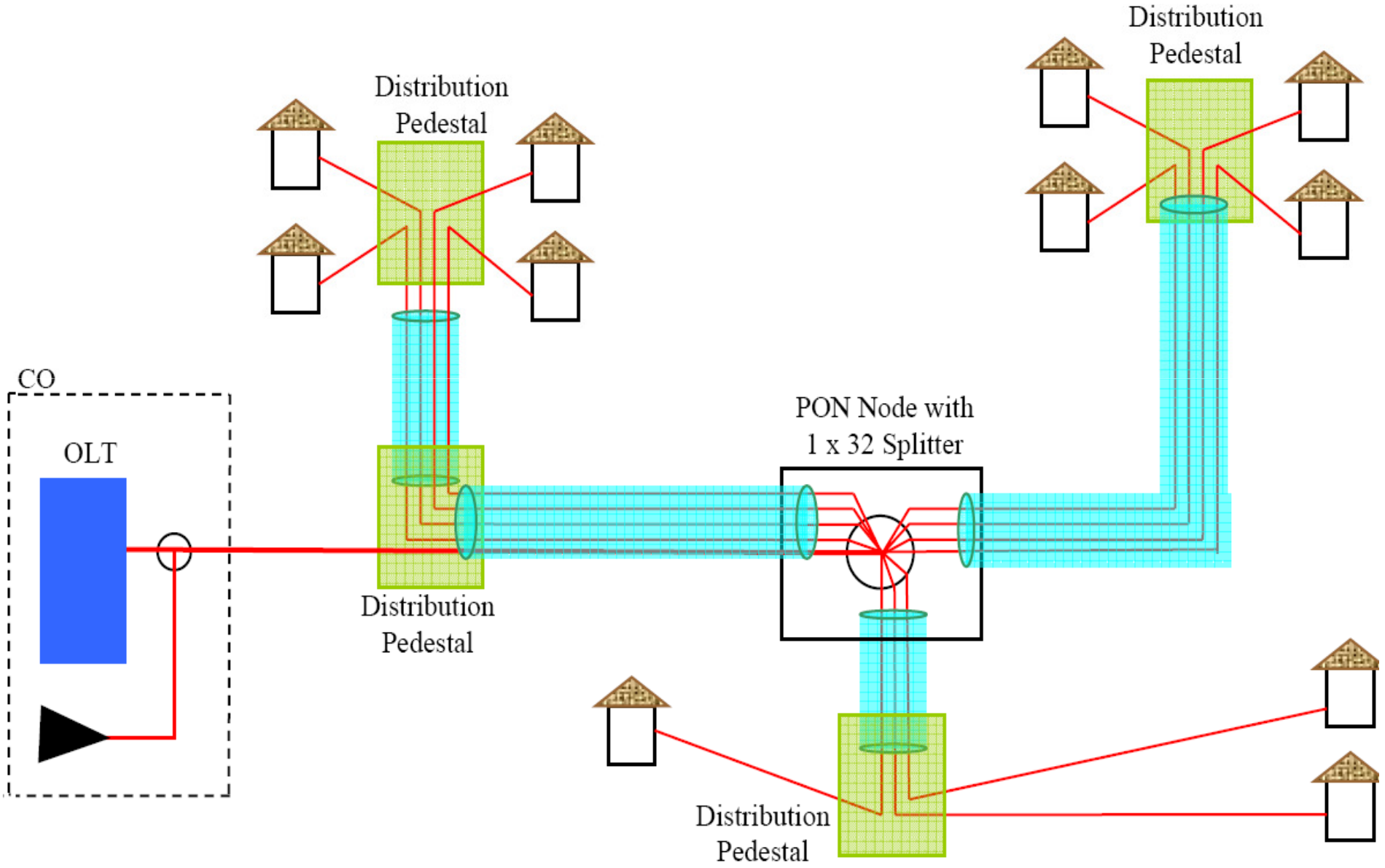
enaka funkcionalnost



Topologija T-T

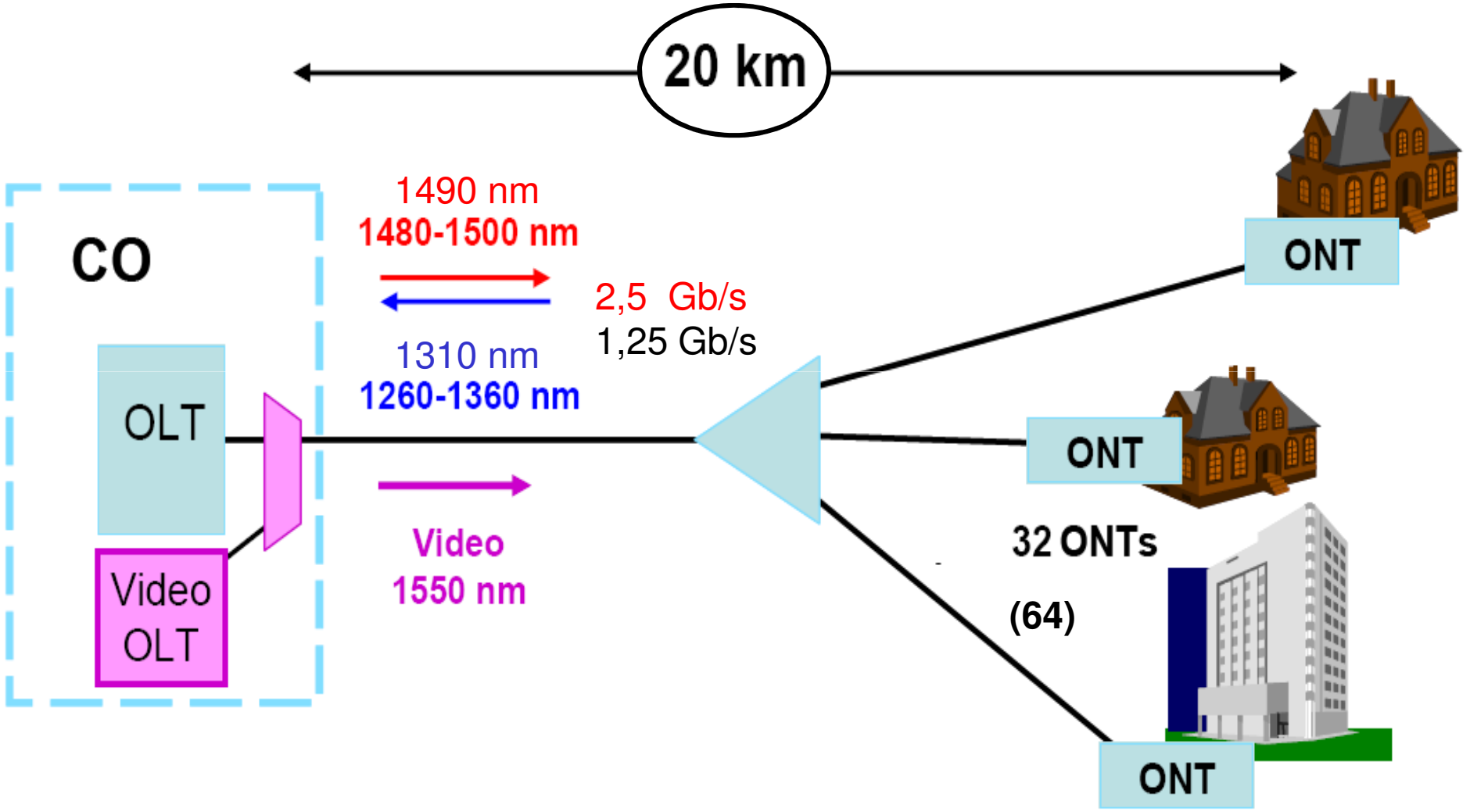


GPON v topologiji T-MT



Današnji PON – evolucija v NG PON

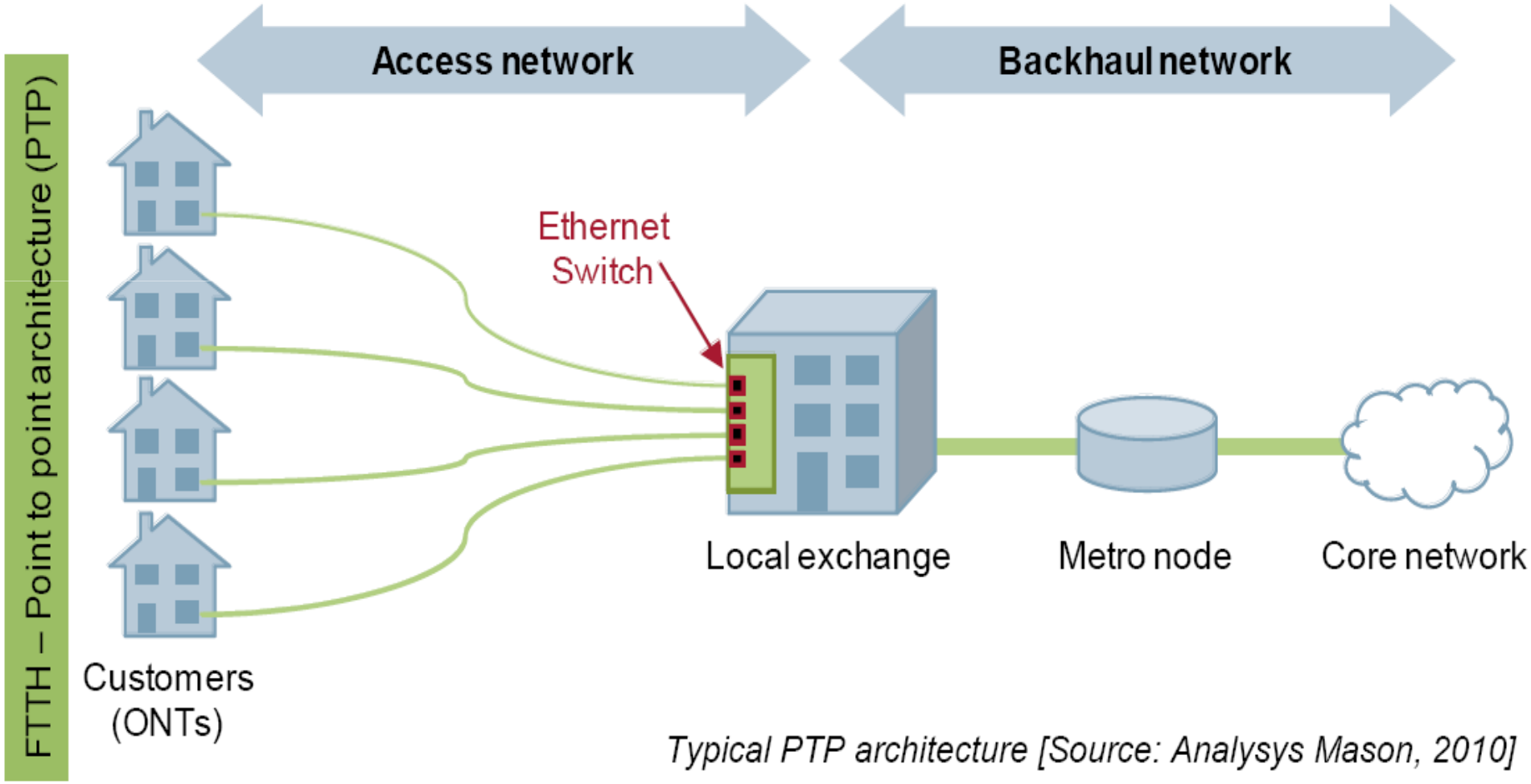
Omejitve: razdalja 20 km, skupni b/s in naročniški b/s



OLT = Optical line terminal

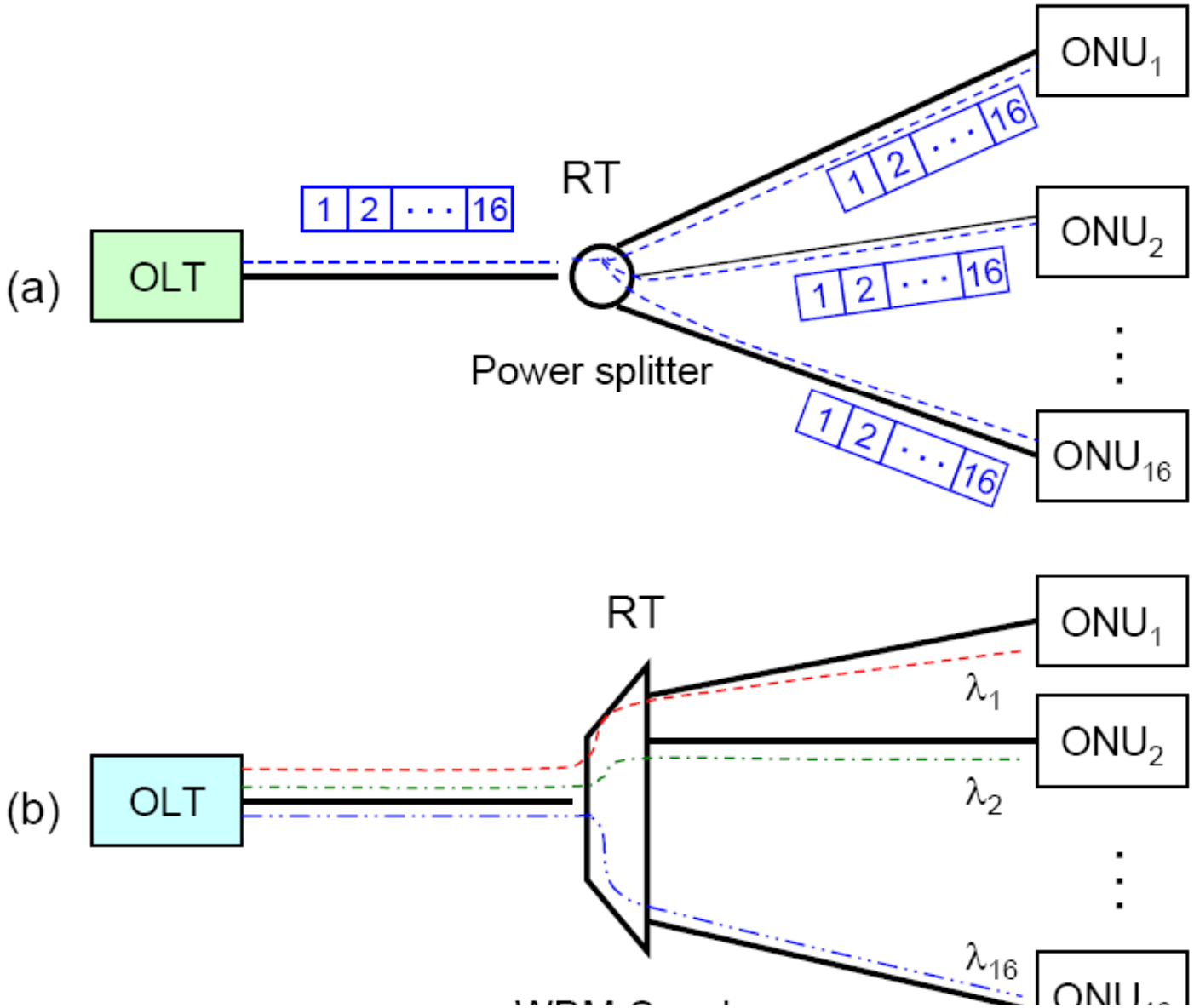
ONT = Optical network terminal

T-T z aktivnim stikalom



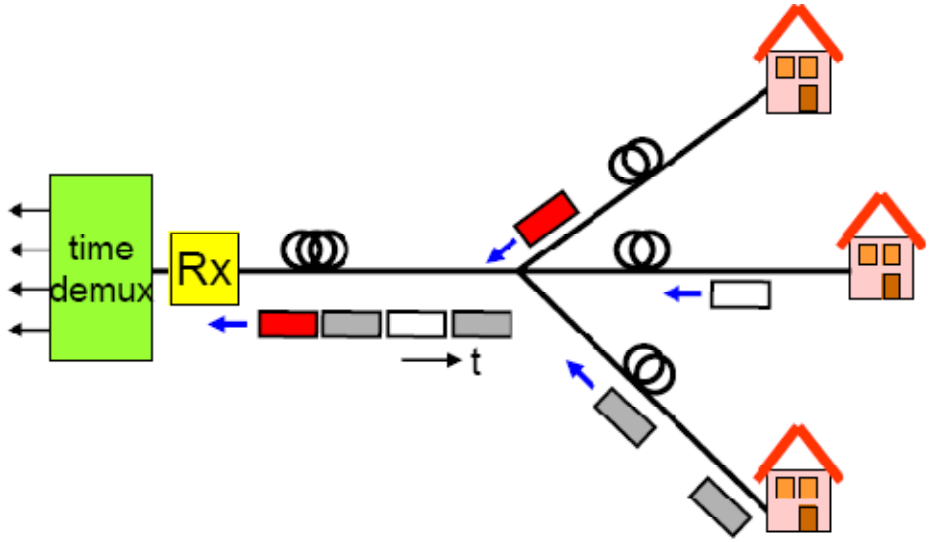
Typical PTP architecture [Source: Analysys Mason, 2010]

TDM in WDM PON



- **GPON**
- **EPON**
- **Future Upgrade**

TDM-PON, WDM-PON

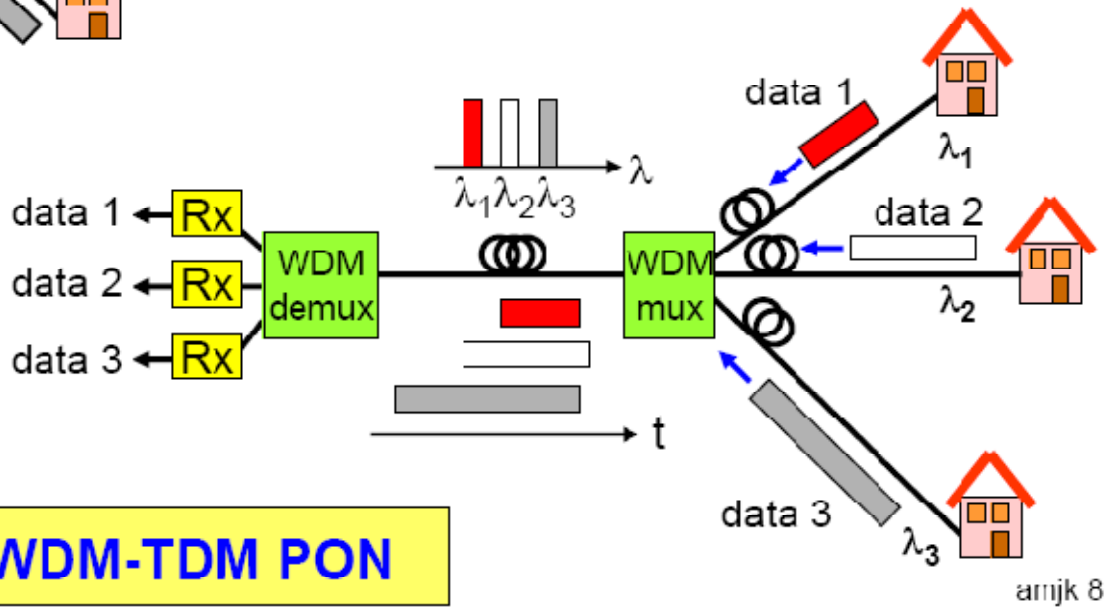


TDM-PON

- ☺ Flexible sharing of LT capacity ⇨ efficient
- ☹ Time slot(s) per user ⇨ congestion at high loads

WDM-PON

- ☺ each user own λ-channel ⇨ no congestion
- ☺ Virtual P2P
- ☹ No sharing of capacity ⇨ inefficient

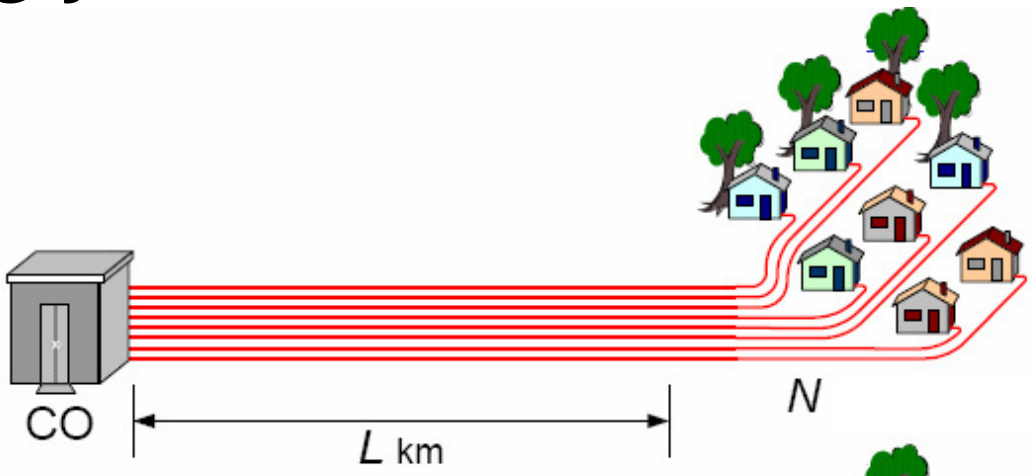


⇨ **Combine into hybrid WDM-TDM PON**

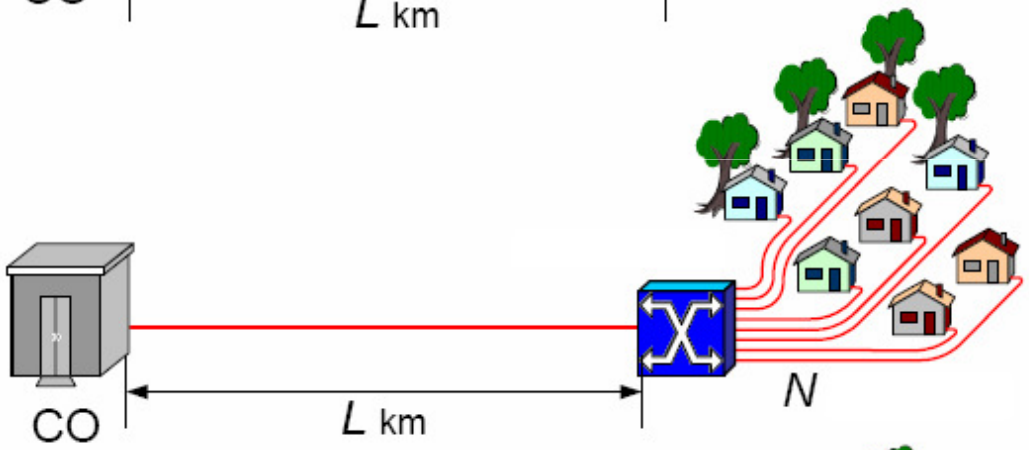
Koonen, ECOC, 2007

Topologiji T-T in T-MT

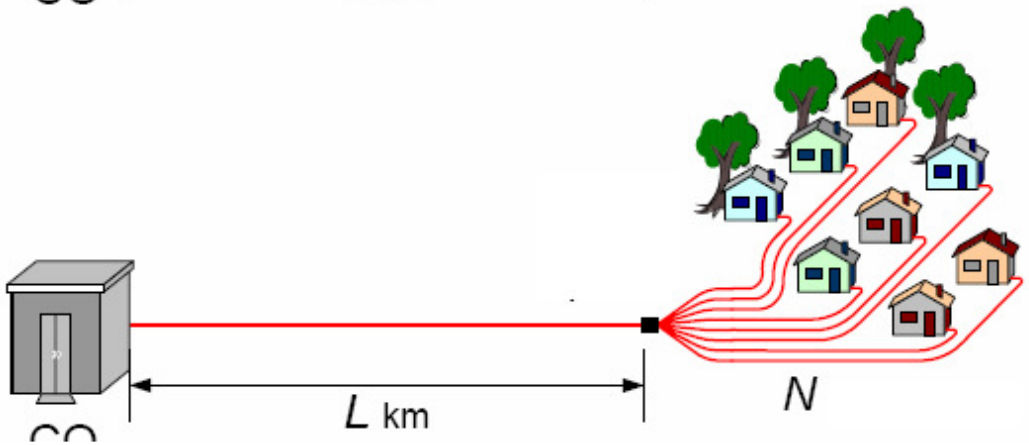
Zvezda, T-T



Aktivno stikalo



Drevo, T-MT, PON



Količina vlakna in elektronske opreme

Point-to-point links

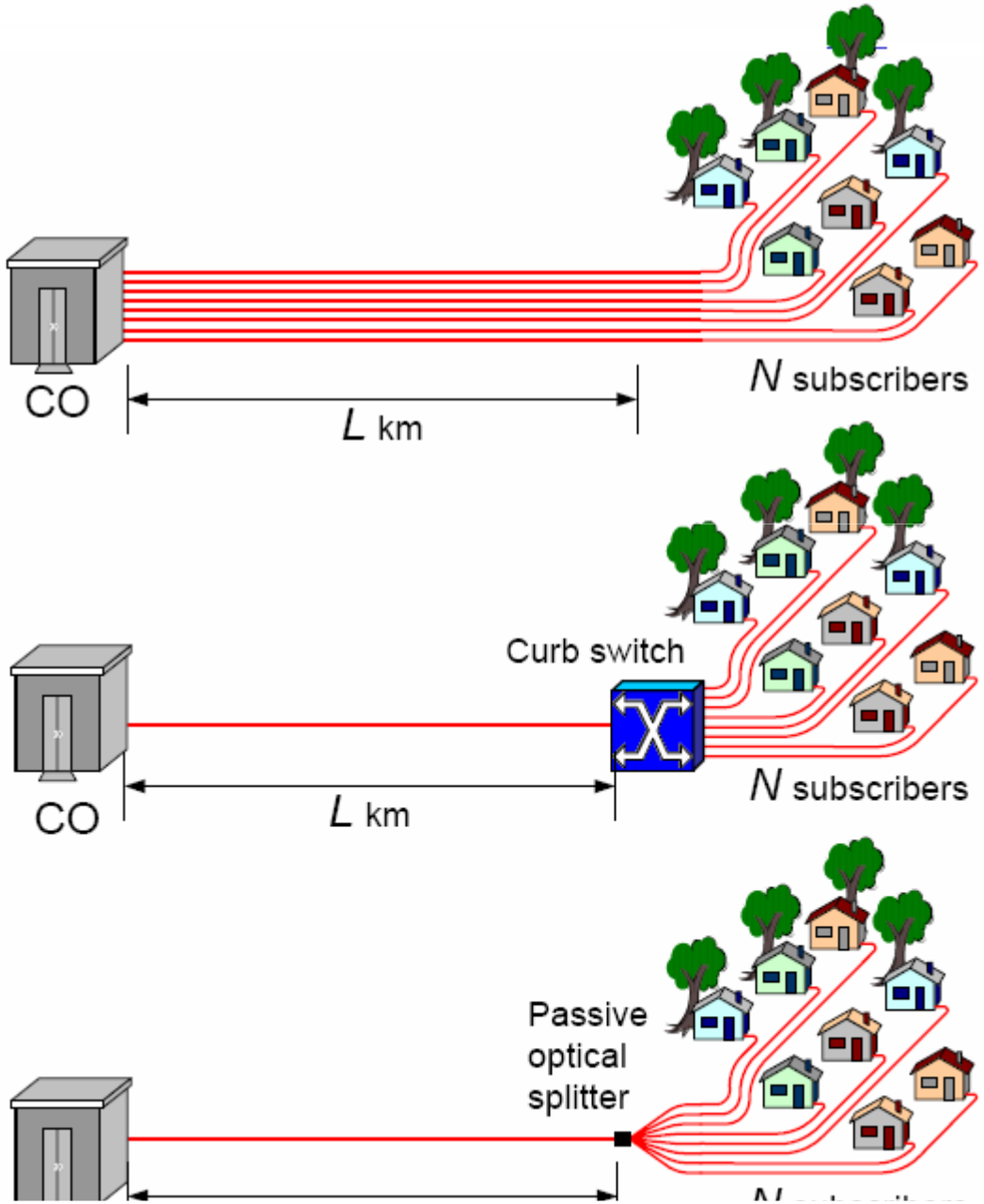
- *N* fiber lines
- 2*N* transceivers

Concentration switch in the neighborhood

+ *1* fiber line
- Power in the field
- 2*N* + 2 transceivers

PON – a distributed switch

+ *1* fiber line
+ *N* + 1 transceivers
+ Path transparency



Primerjave

T-T

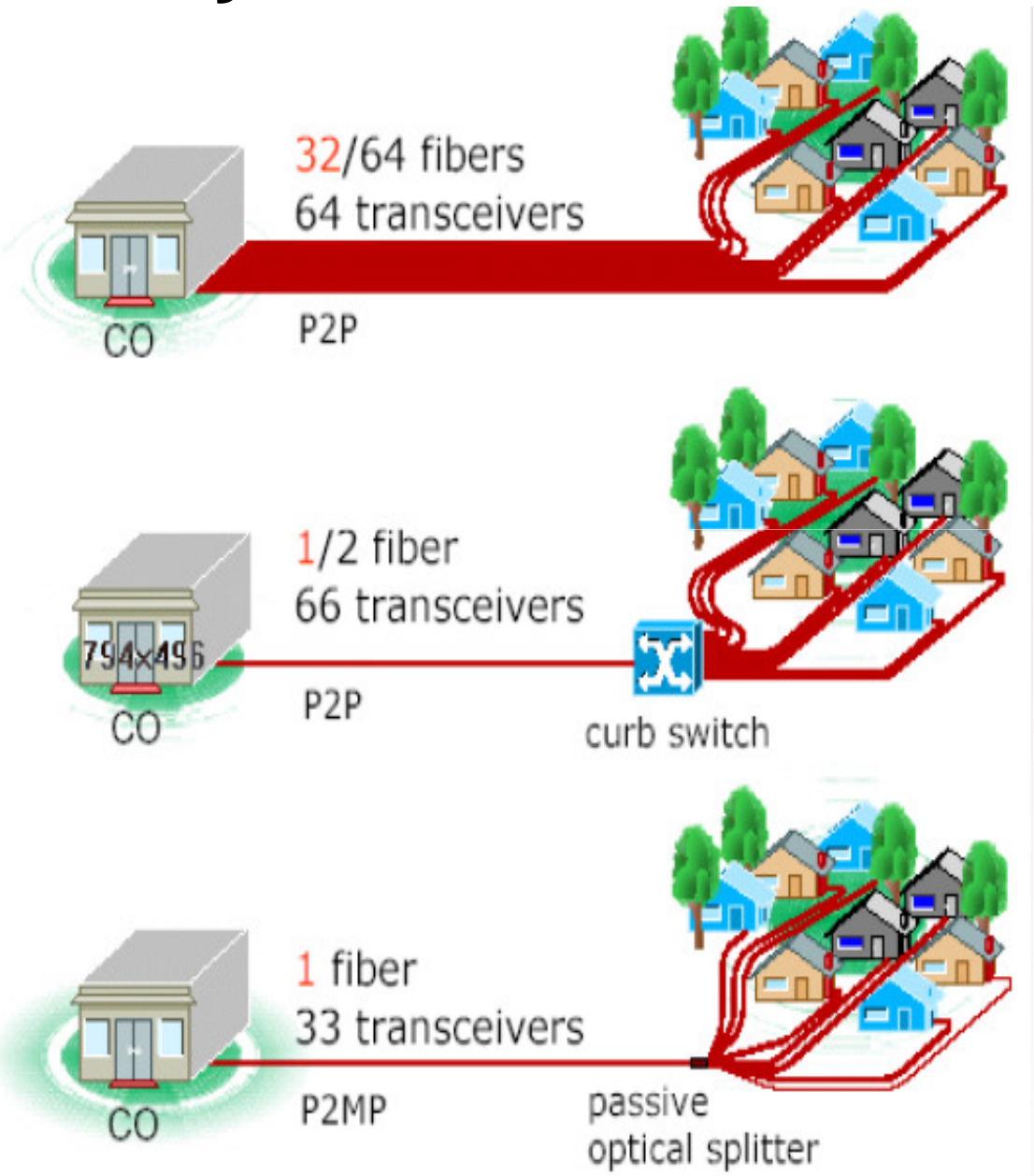
- N fibers
- 2N optical transceivers

AON

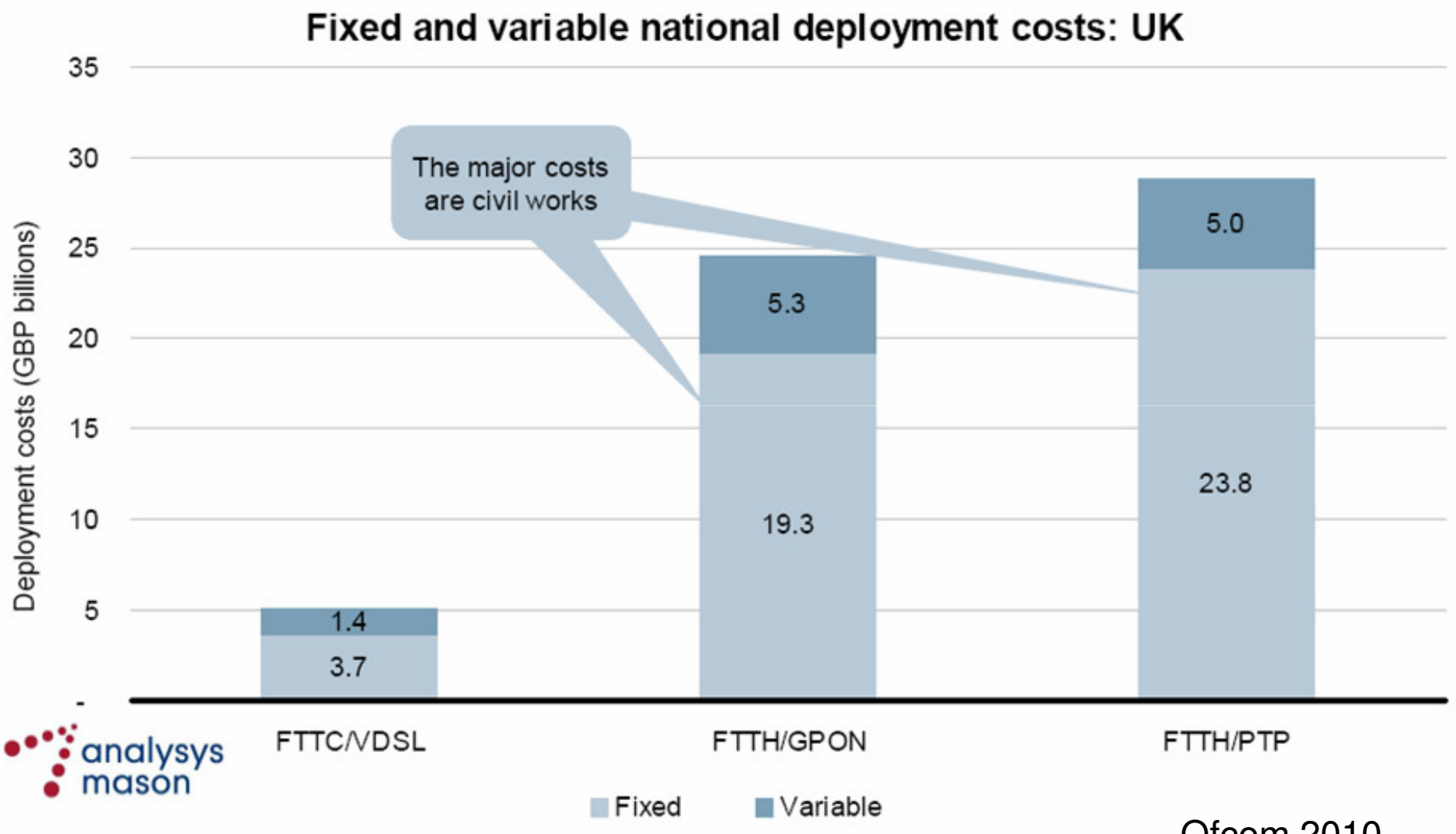
- 1 fiber
- Minimum fiber/space in CO
- 2N+2 optical transceivers
- Electrical power in the field

T-MT (PON)

- 1 fiber
- Minimum fibers/space in CO
- N+1 optical transceivers
- No electrical power in field
- Drop throughput up to trunk rate
- Downstream broadcast (video)



Cene



Ofcom 2010

Od T-T do NGOA

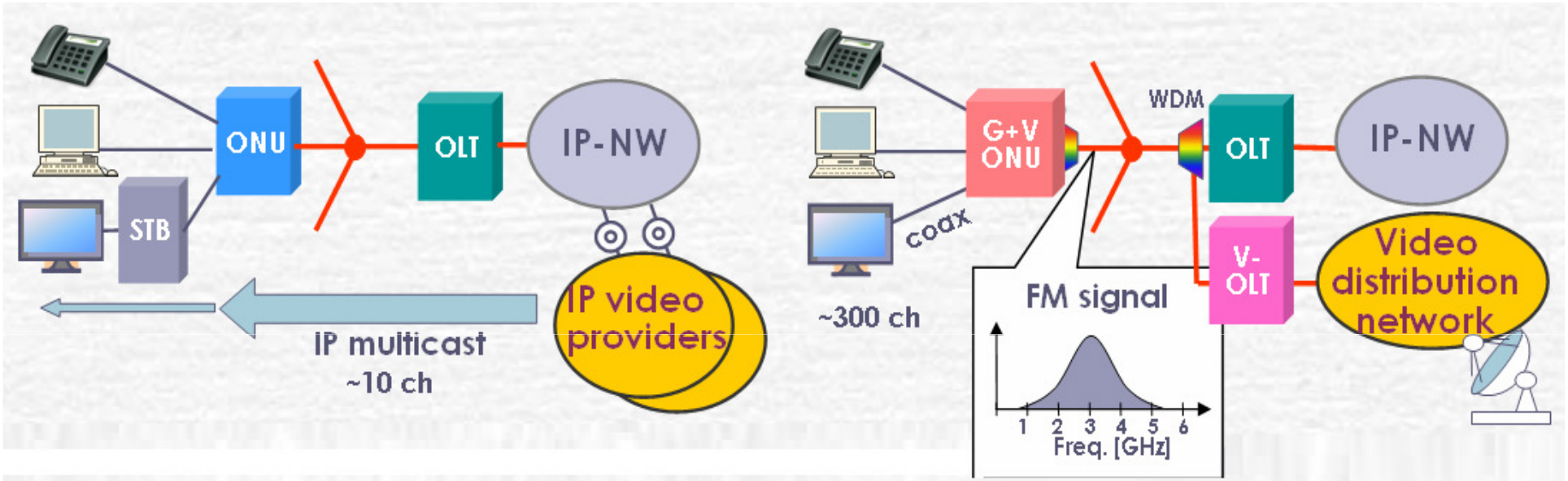
Arhitekturi T-T in PON imata vsaka svoje prednosti in pomanjkljivosti.

T-T ima prednost za zahtevne uporabnike, PON za množične uporabnike (stroški).

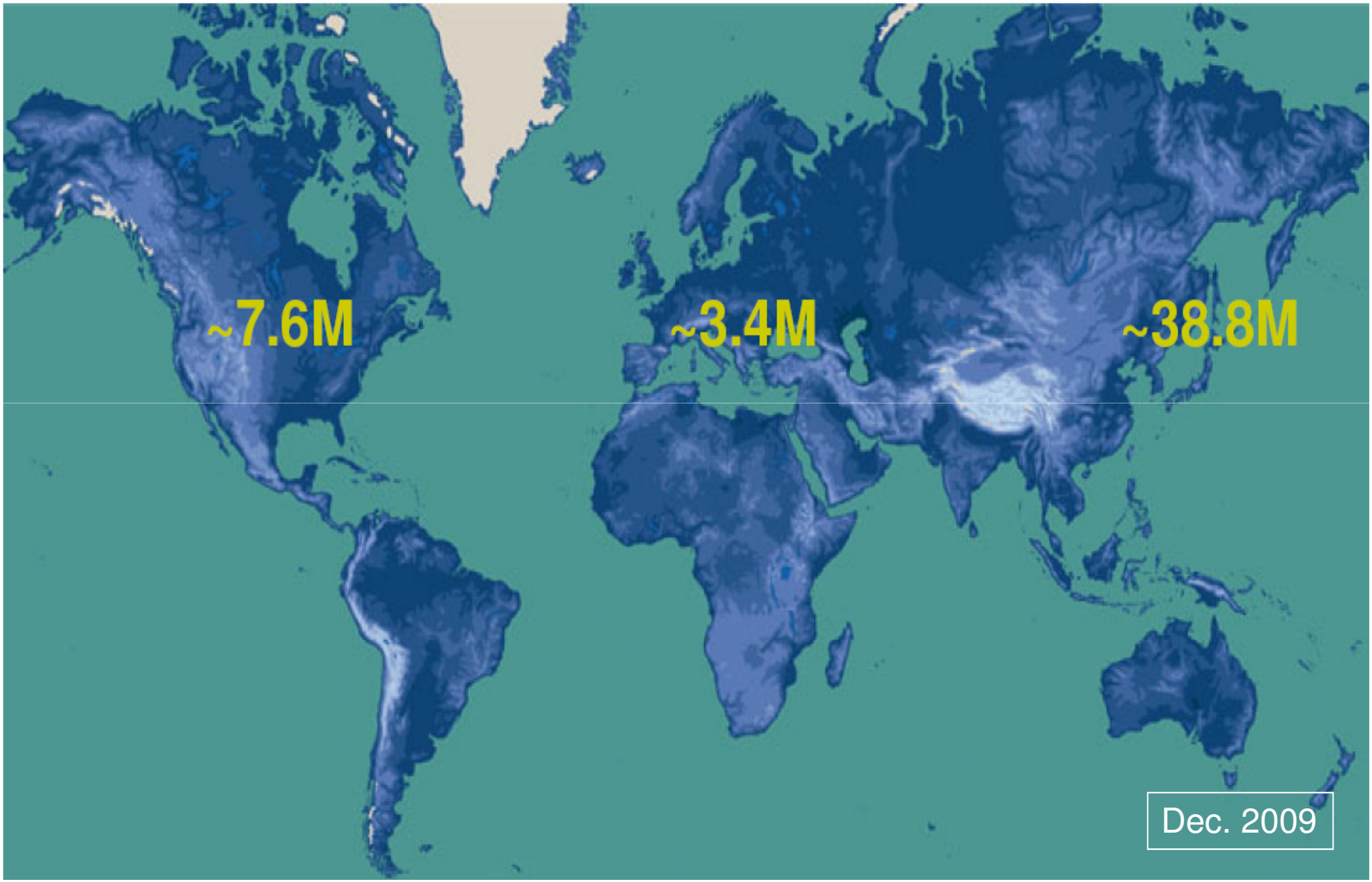
Arhitektura WDM PON združuje prednosti obeh in je najbolj perspektivna.

LR WDM/TDM PON je najobetavnejša in najcenejša izbira prihodnjega NGOA.

IP–TV in RF-TV


ONU
OLT
IP-NW
STB
IP video providers
IP multicast
~10 ch
G+V ONU
WDM
OLT
IP-NW
coax
~300 ch
FM signal
V-OLT
Video distribution network
1 2 3 4 5 6
Freq. [GHz]

FTTH/B naročniški priključki, 2010



Širokopasovni dostop v svetu, 2009

- junij 2009

	FTTH/B	VDSL	FTTLA	FTTx+LAN	*Total FTTx*
Western Europe (1)	1 806 515	1 645 350	20 000	0	*3 471 865*
Eastern & Central Europe (1)	962 165	34 000	225 393	0	*1 221 558*
North America (2)	4 805 500	1 585 000	na	0	*6 390 500*
Latin America	2 000	0	na	0	*2 000*
Asia	26 293 000	1 500	na	16 900 000	*43 194 500*
Middle East & Africa	66 100	0	0	0	*66 100*
TOTAL WORLD	**33 935 280**	**3 265 850**	**245 393**	**16 900 000**	***54 346 523***

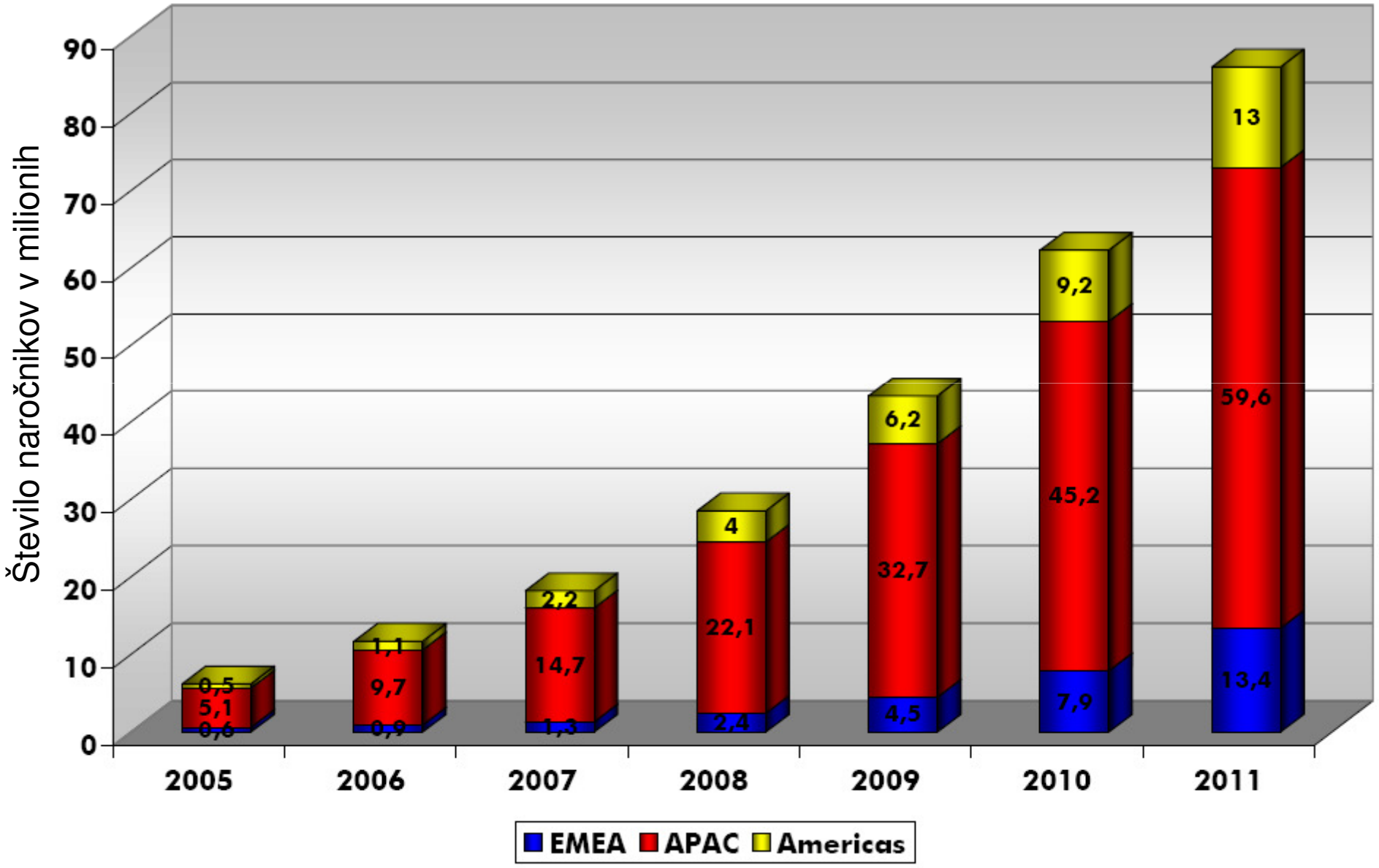
(1) Western, Eastern & Central Europe counts EU27+Norway+Switzerland+Iceland+Andorra+Luxembourg+Croatia+Russia

(3) USA, Canada & Mexico

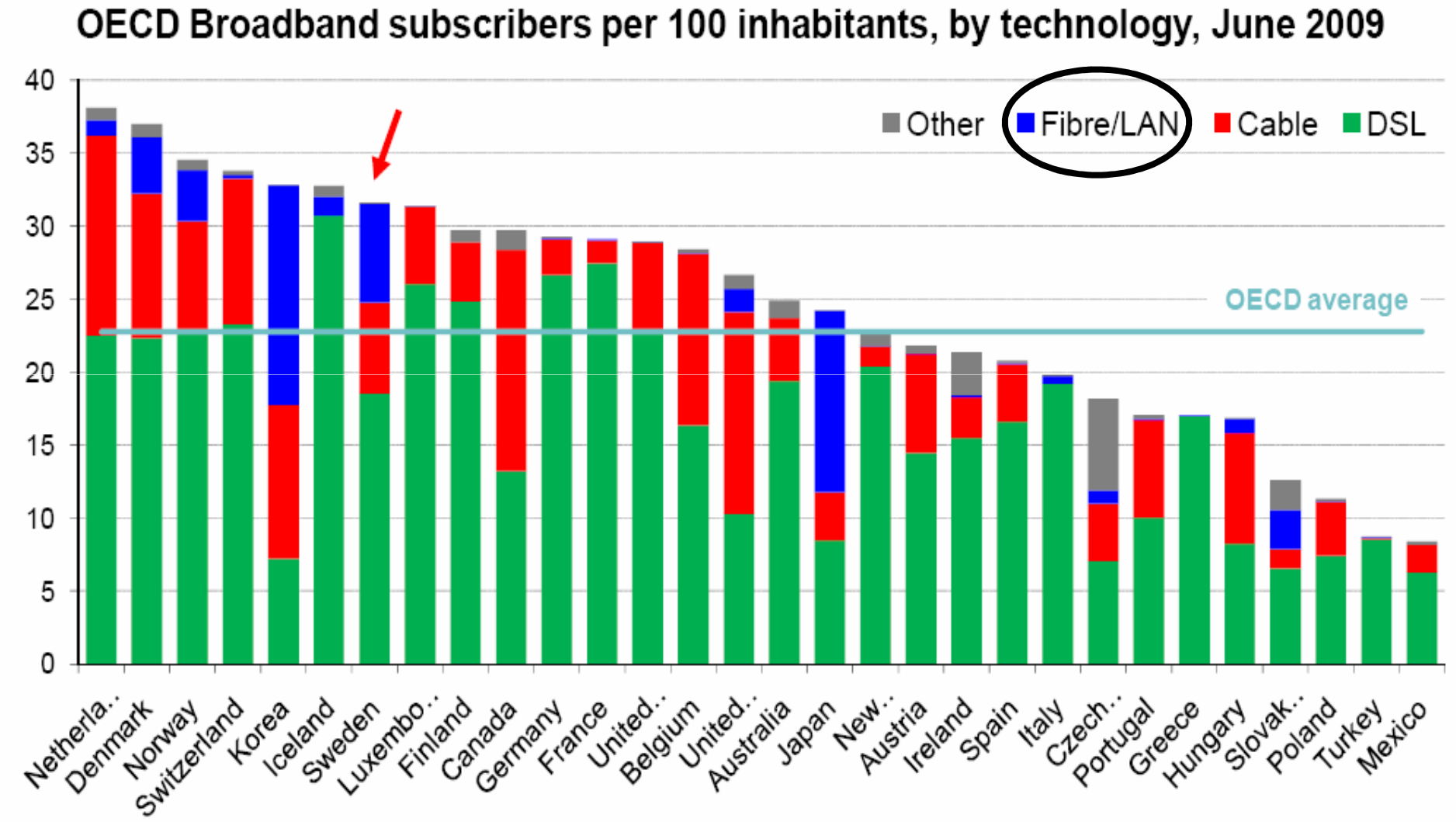
Source: IDATE and FTTH Council Europe

- V prvi polovici 2009 je bila svetovna rast 17%.
- Premočno vodstvo Azije v graditvi dostopovnega omrežjaFTTH/B (80% svetovnega števila naročnikov FTTH/B v 2009).
- Evropa (z Rusijo) ima le 8,3% delež vseh naročnikov v svetu.

Rast FTTx v svetu



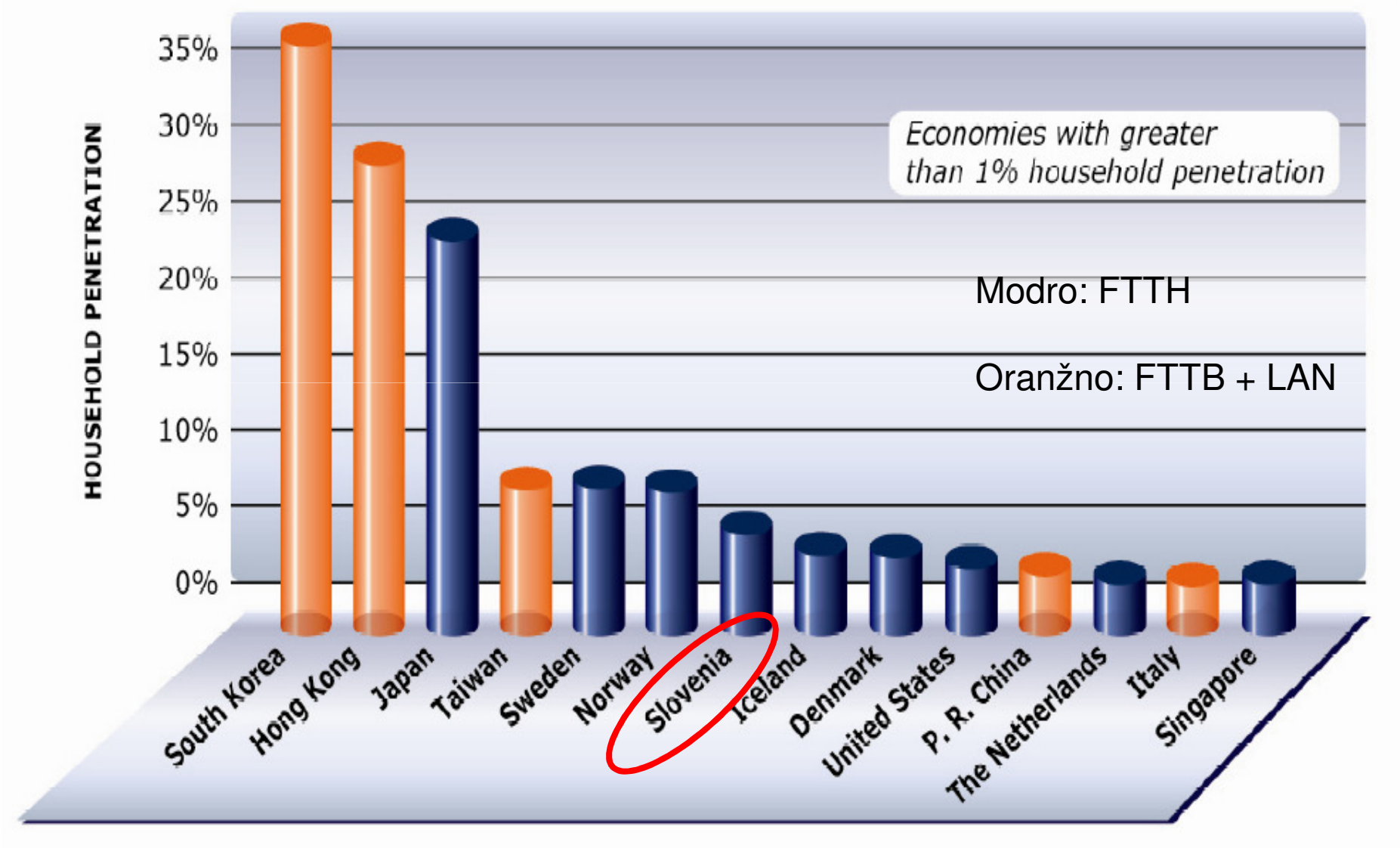
Število širokopasovnih naročnikov (BB)



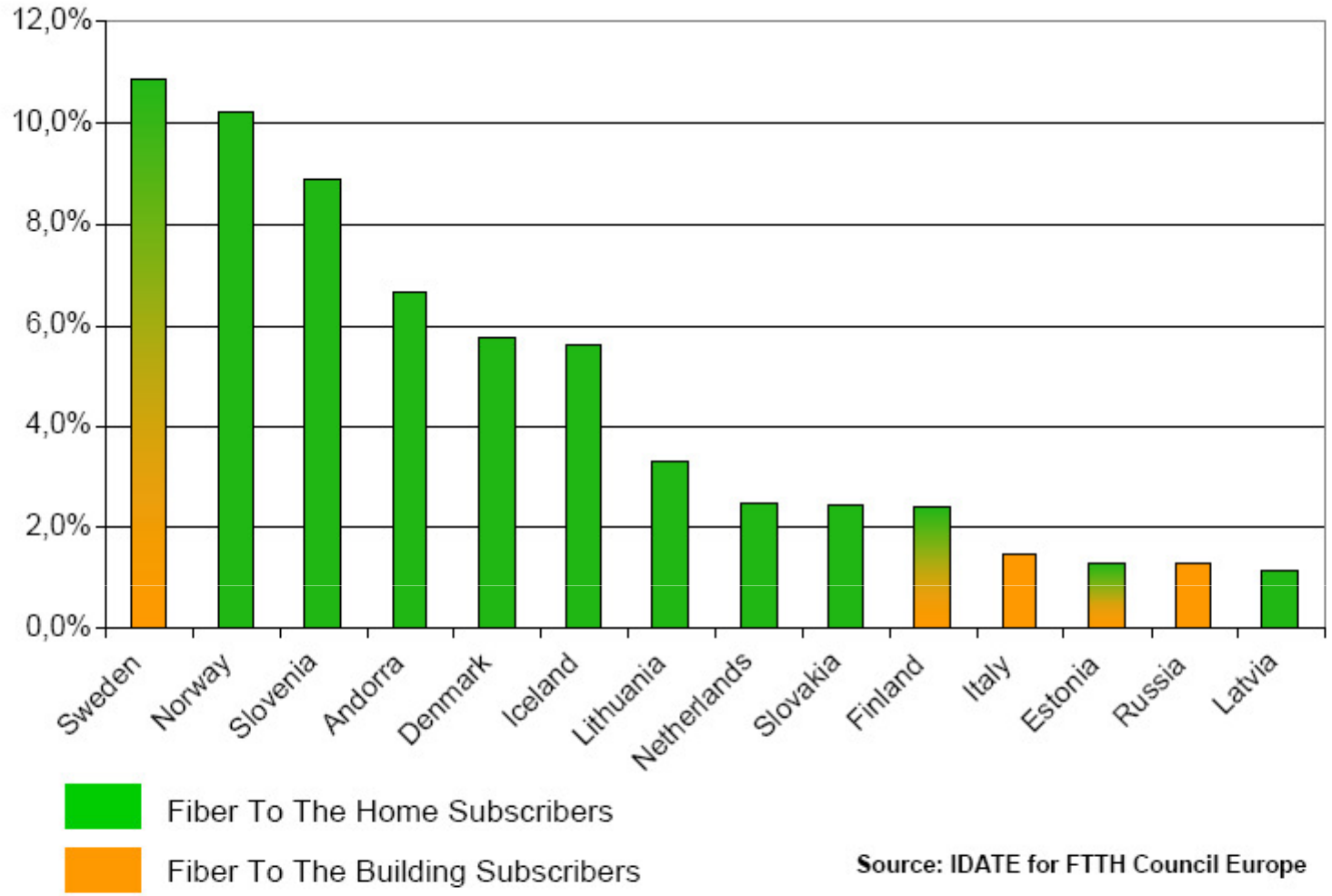
- The OECD statistics is good for global comparison over the years
- NB: Fixed wireless access not adequately included

OECD 2009

FTTH/B leta 2008



FTTH Council 2008

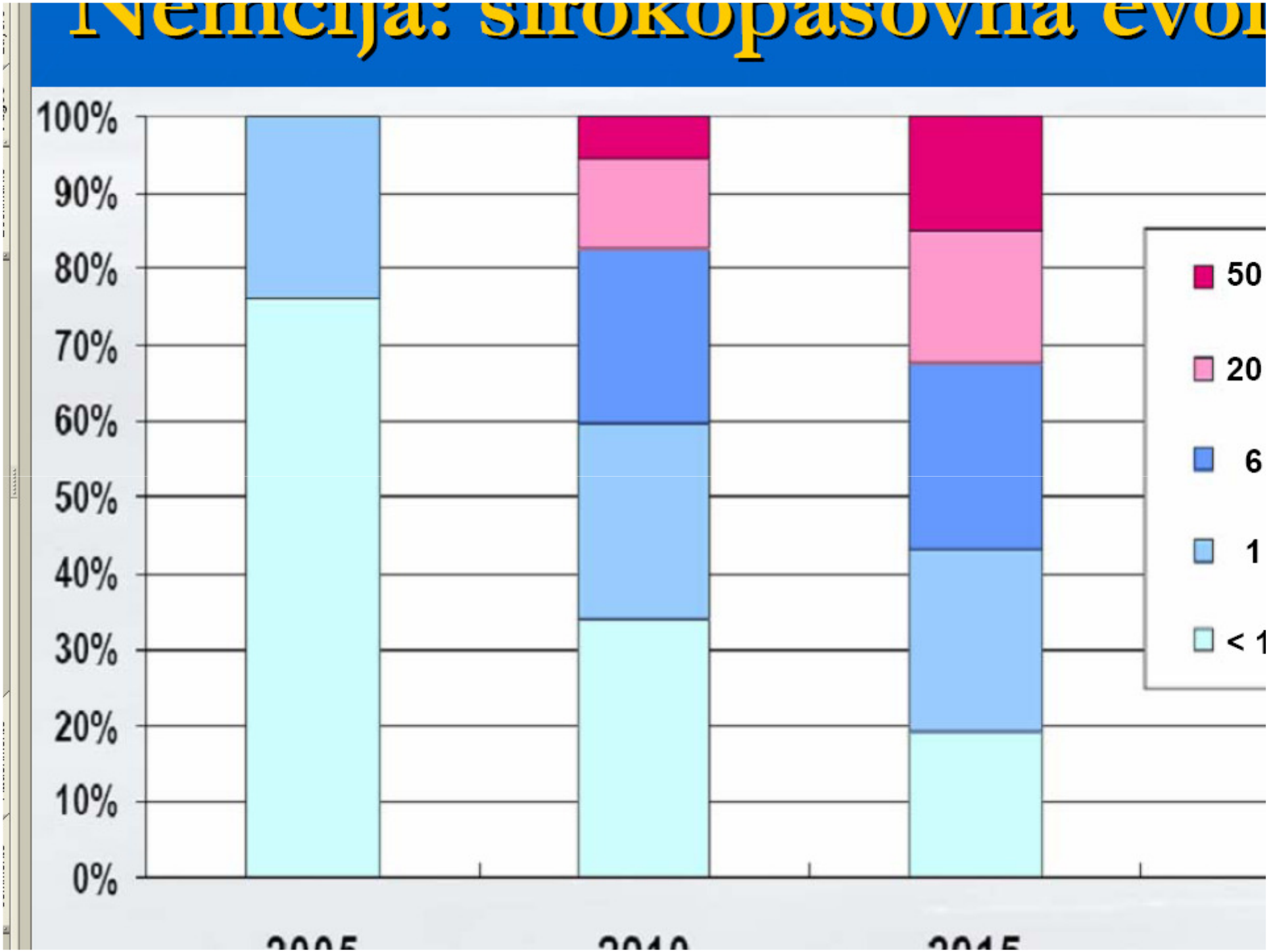


Source: IDATE for FTTH Council Europe

Europe mid 200

- 2M FTTH/B subscribers
- 13M FTTH/B homes passed
- 4M FTTx subscribers
- 30M FTTx homes passed

The Nordics is taking the lead, with Central and Eastern Europe making good progress. Major European economies still not in top-10.


Nemčija: strokopasovna evol
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
50
20
6
1
< 1

Operaterji in tehnologije

FTTH operator	*Technology deployed*	*Location*
BT	GPON	Ebbsfleet, UK
FT	GPON	France
Lyse	PTP	Norway
NTT	EPON	Japan
SK Telecom	GPON	South Korea
Swisscom	PTP	Switzerland
Telekom Slovenije	PTP	Slovenia
Unet	WDM PON	The Netherlands
Verizon	GPON	USA
Virgin Media	Cable	UK

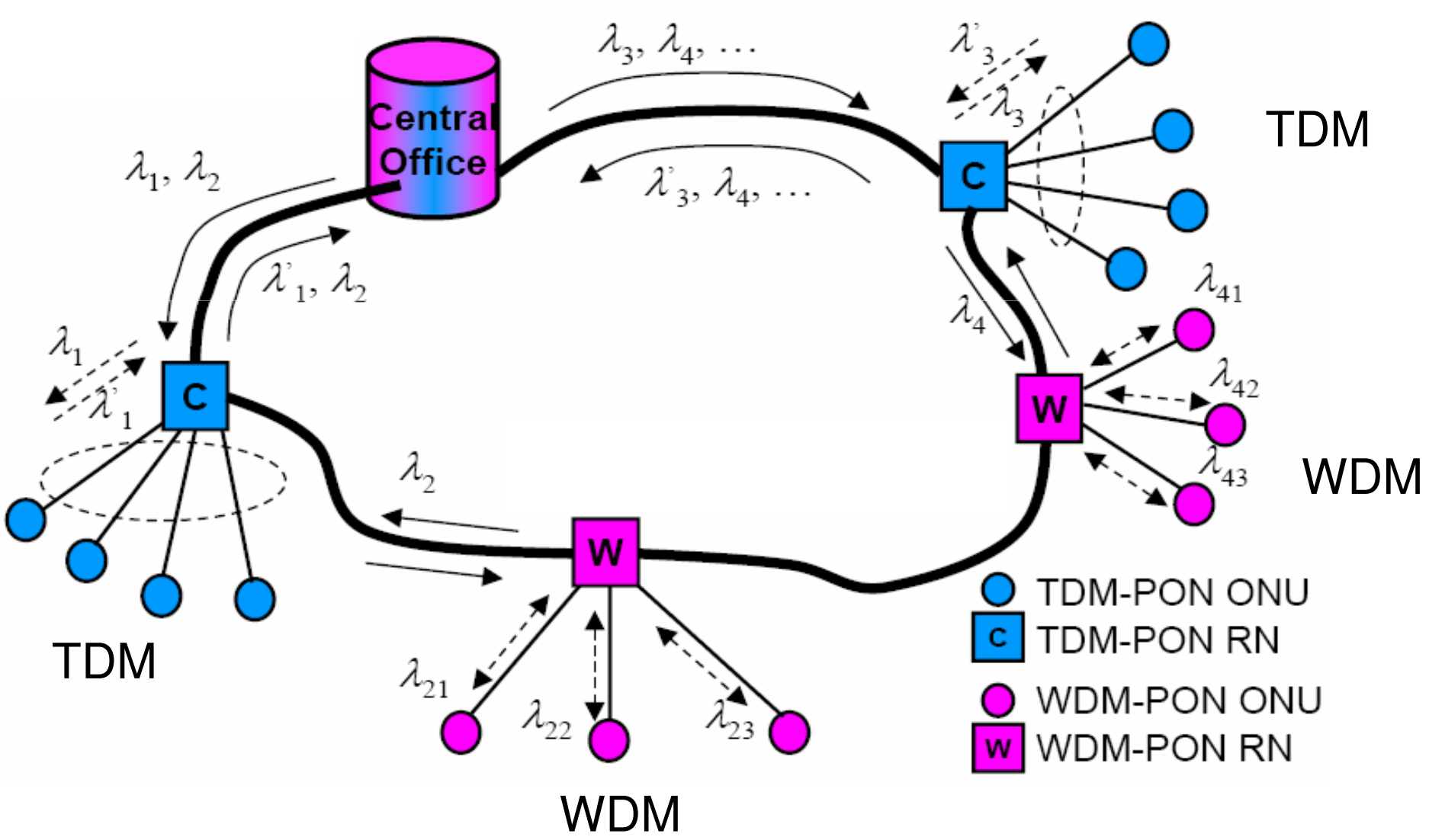
Figure 6.1: Case studies [Source: Analysys Mason, 2010]

Ofcom

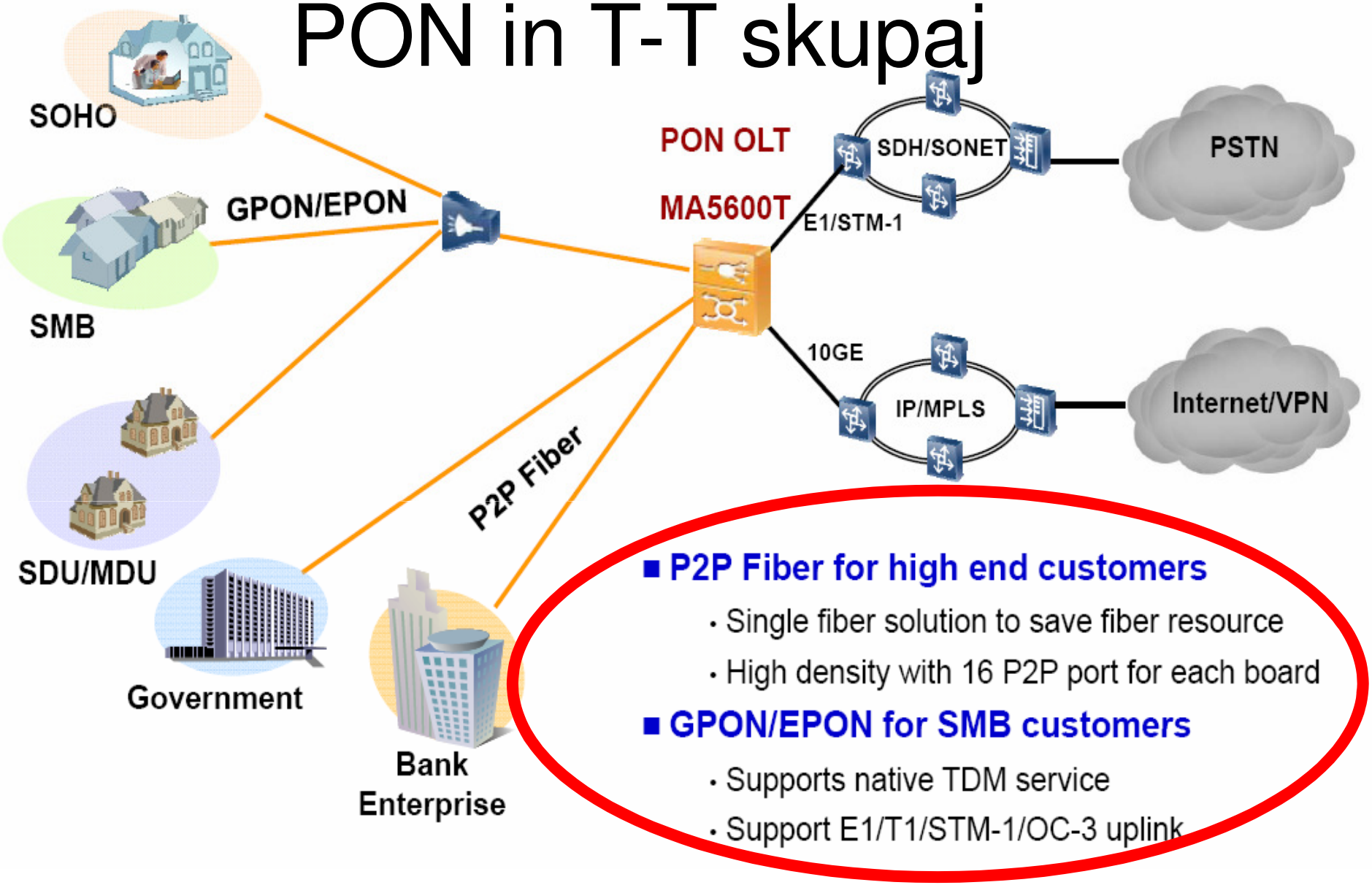
WDM/TDM PON

PON naslednje generacije (>2020) s TDM in WDM odcepi

- primer kombinacije topologij



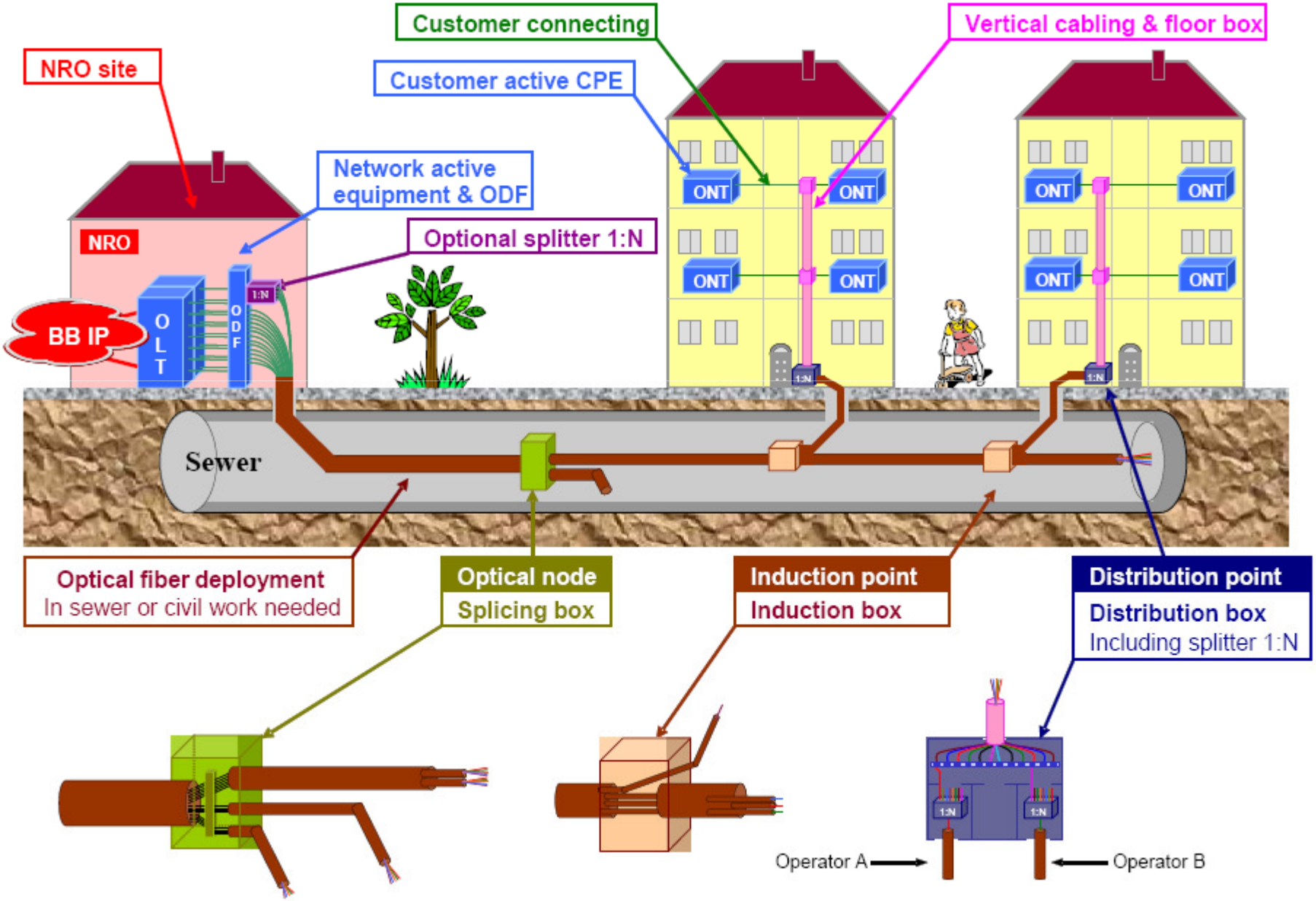
PON in T-T skupaj



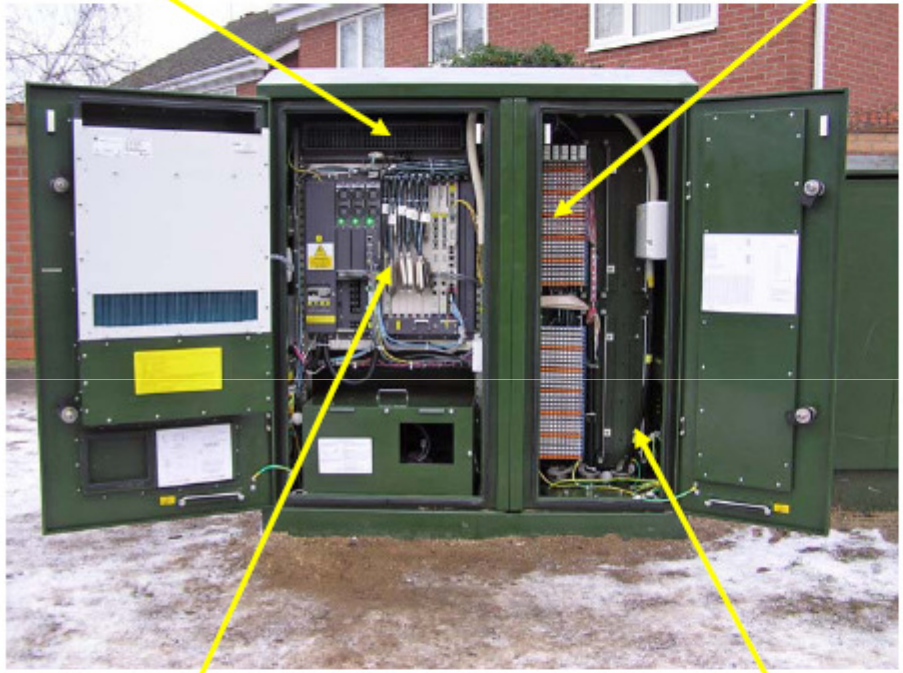
- **P2P Fiber for high end customers**
  - Single fiber solution to save fiber resource
  - High density with 16 P2P port for each board
- **GPON/EPON for SMB customers**
  - Supports native TDM service
  - Support E1/T1/STM-1/OC-3 uplink

In practice both Point to Point and Passive Optical Networks will co-exist in the network for different market situations. However PON will be the mass market solution.

Položeno vlakno



fibre street cabinets and electronics equipment



BT

The Slot Cutting process

Making worksite safe

)etail of
tting tool

Opening
a micro-
trench

Mechanised network
installation system

Good duct installation methods

Duct installation quality is essential for a good futureproof network

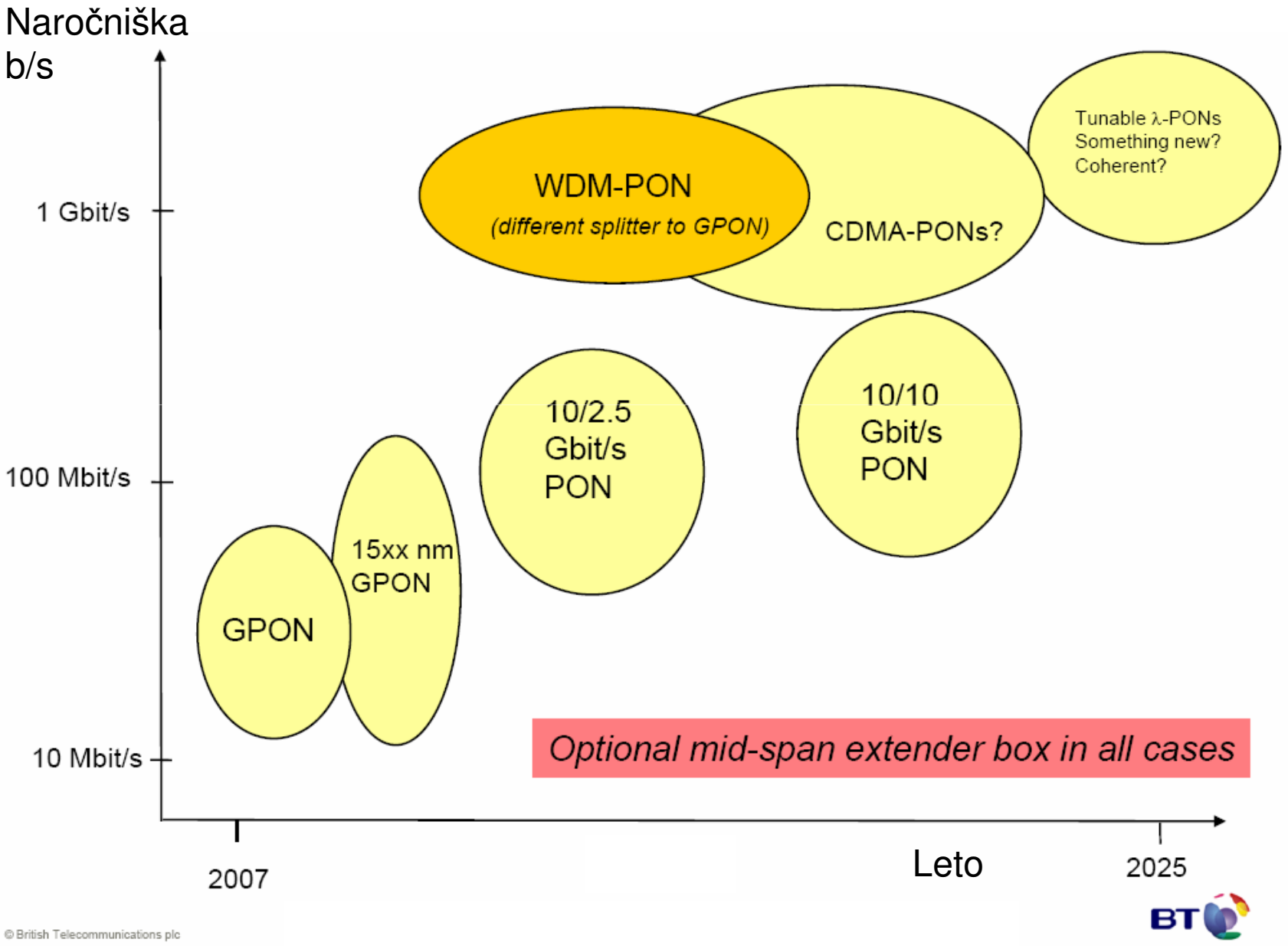
FTTx, 10 največjih operaterjev

Rank	Operator	Country	Main technology & architecture	FTTx subscribers
1	NTT	Japan	FTTH/B GEPON	11 793 000
2	China Telecom (1)	China	FTTH - FTTx+LAN EPON LAN/DSL	11 160 000
3	KT	South Korea	FTTB EPON/GEPON	3 555 644
4	Verizon	USA	FTTH BPON/GPON	3 100 000
5	SK Broadband	South Korea	FTTB/LAN GEPON	2 733 141
6	AT&T	USA	FTTN VDSL2	1 585 000
7	LG Powercom	South Korea	FTTH/B EPON/GEPON	1 504 090
8	Chunghwa Telecom	Taiwan	FTTB GEPON	1 342 000
9	KDDI	Japan	FTTH/B EPON/GEPON	1 211 000
10	Beeline	Russia	FTTB EP2P	724 000

(1) 560 000 FTTH subscribers and 10.6 millions FTTx/LAN subscribers

- Izmed 10 največjih svetovnih operaterjev jih je 7 iz Azije, 2 iz Severne Amerike in 1 iz Rusije. Med njimi ni nobenega iz Zahodne Evrope.
- NTT je največji svetovni operater, tesno mu sledi ChinaTelecom.

Napoved razvoja sistemov - BT



Zahtevnost 3DTV in primerjava stroškov

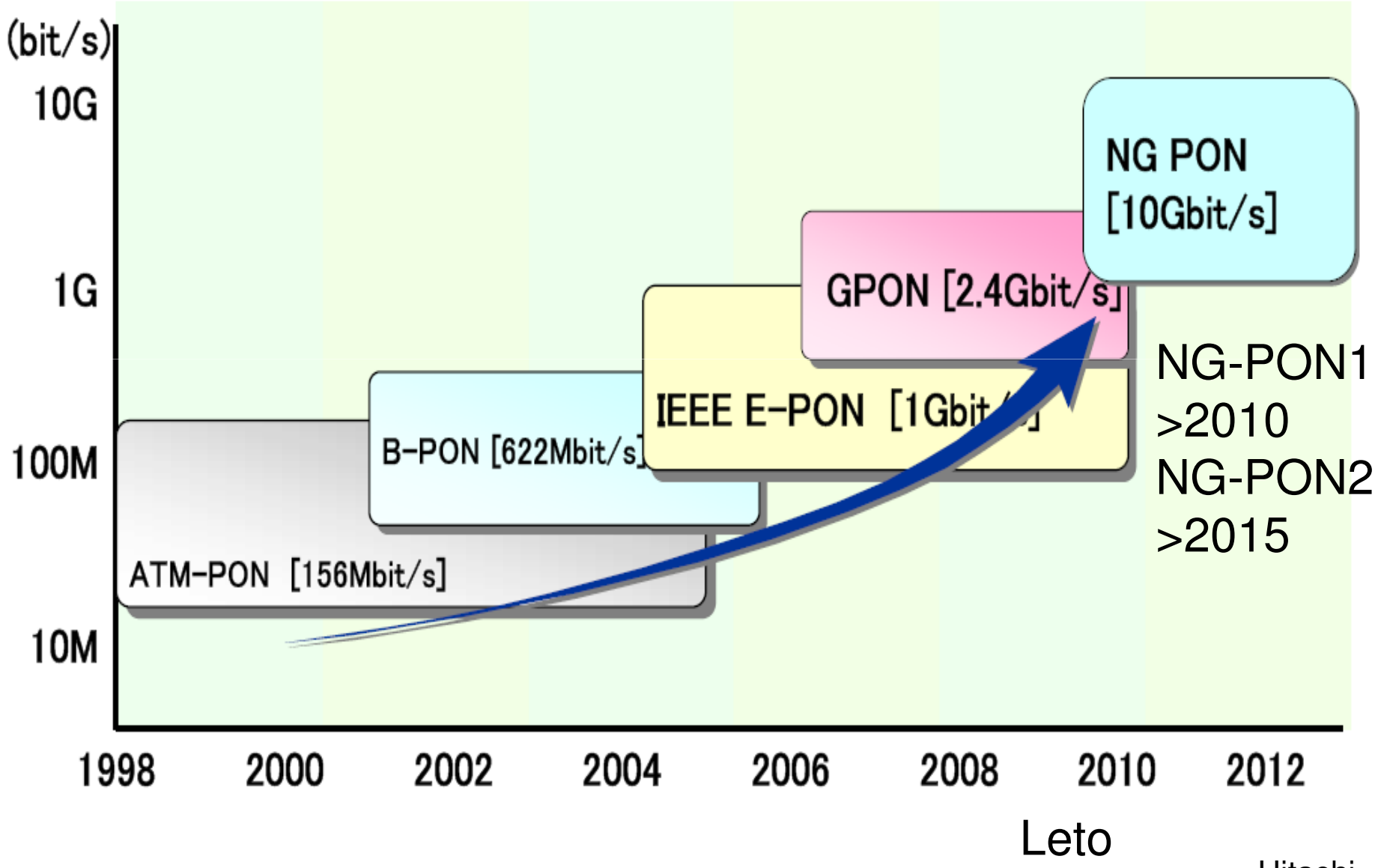
Mb/s

Timescale	*TV service type*	*Downstream bandwidth requirements*
2015	3DTV	30Mbit/s (x3)
2025	High-definition 3DTV	100Mbit/s (x3)
2035	Ultra high-definition 3DTV	300Mbit/s (x3)[55]

Stroški za hišni priključek

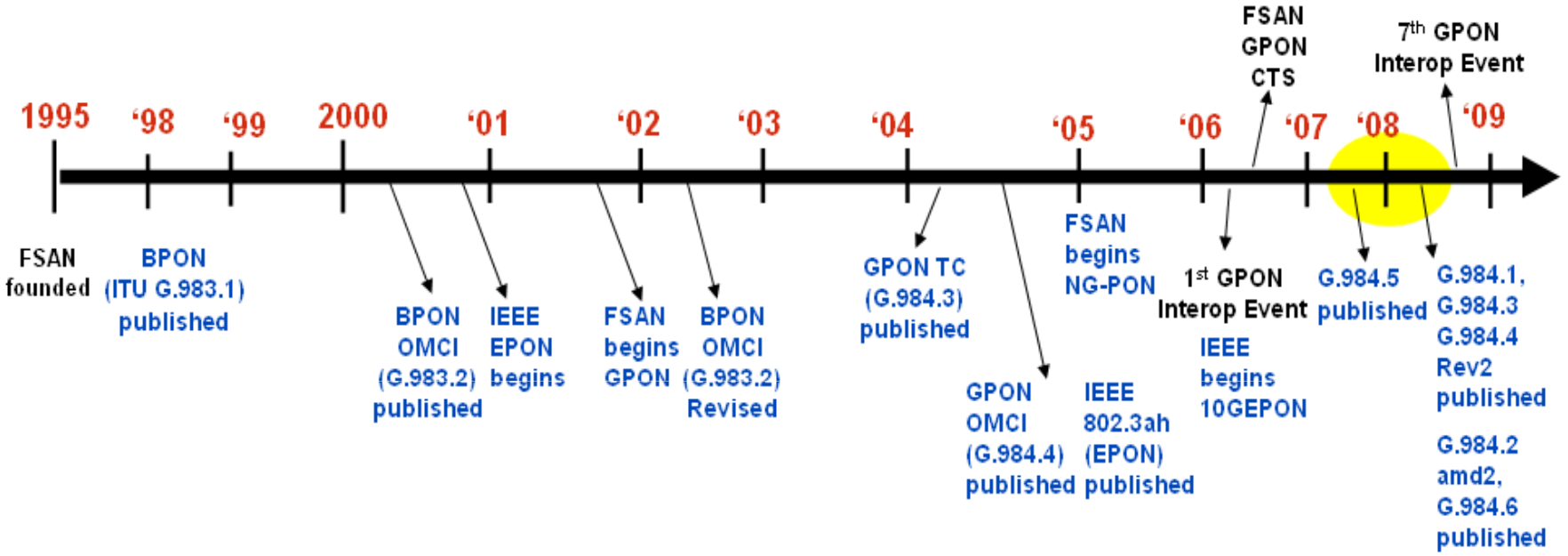
Active equipment cost (GBP)	*TDM PON (GPON)*	*WDM PON*	*PTP*
Active equipment (per user)	**120**	**650**	**140**
OLT (per user)	*40*	*350*	*80*
ONT (per user)	*80*	*300*	*60*
Passive infrastructure (per home connected)	**2275**	**2364**	**2708**
Total (per home connected)	**2395**	**3014**	**2848**

Razvoj PONa



Hitachi

Kronologija nastajanja GPONa



BPON Completed: April 2000

BPON 1st Interop Event: March 2004

BPON 1st wide-scale deployment: May 2004

GPON Completed: June 2004

GPON 1st Interop Event: Jan 2006

GPON 1st wide-scale deployment: 4Q 2007

GPON Specs focused & enhanced: 3Q07-1Q08

Telcordia

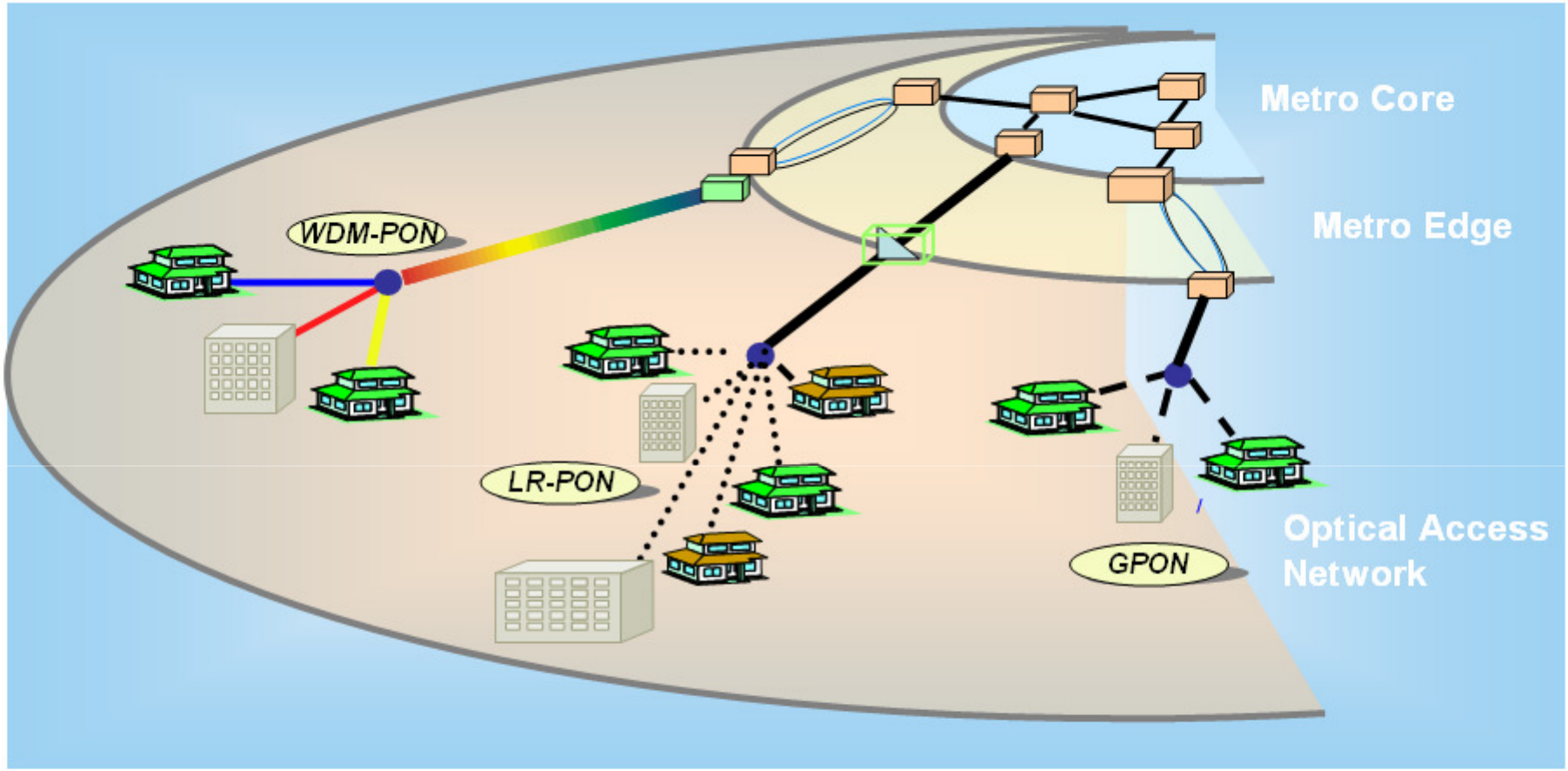
Nova generacija NG – PON 1

- 2010 - 2015
- TDM PON
- Kompatibilnost z GPON in GEPON
- 10 Gb/s dotok, 2,5 (ali 10) Gb/s odtok
- Zagotovljeni b/s na uporabnika 160 – 320 Mb/s dotok, 40 – 80 Mb/s odtok
- Delilno razmerje 64 : 1
- Standardizacija 2010, prvi preizkusi konec 2010, uvajanje 2012

Nova generacija NG PON 2

- 2015 - 2020
- HPON – Hybrid TDM/WDM PON
- CDM, OFDM
- 40 Gb/s oz. 1 Gb/s/λ
- Doseg 80 km
- Veliko delilno razmerje 128:1

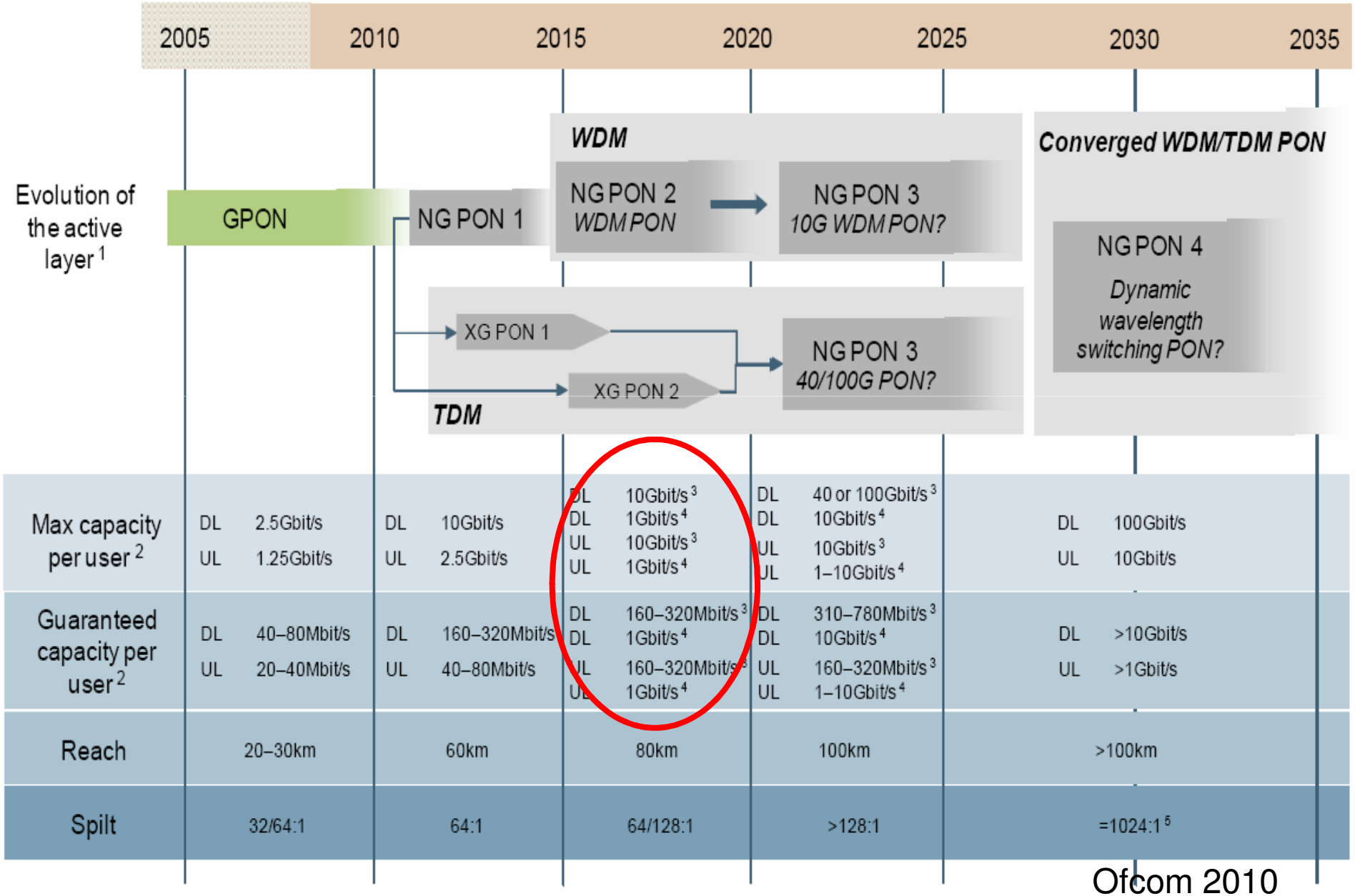
Next-Gen Broadband Architecture Options



- WDM PON: Dedicated wavelengths (high capacity) per user
- Long Reach PON: Consolidation of metro (telecom) and access networks

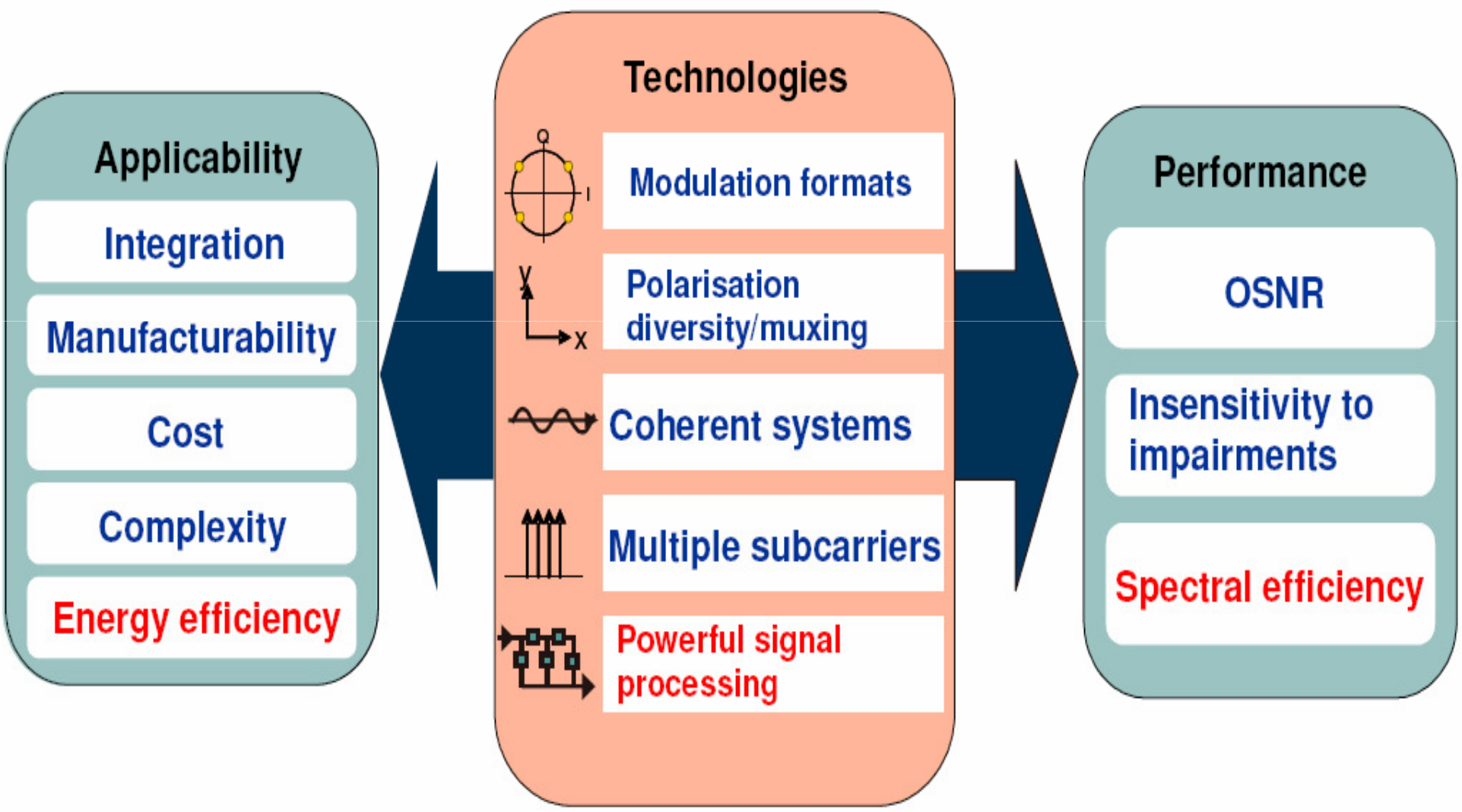
CiPS AT MIT

Napoved razvoja PONa

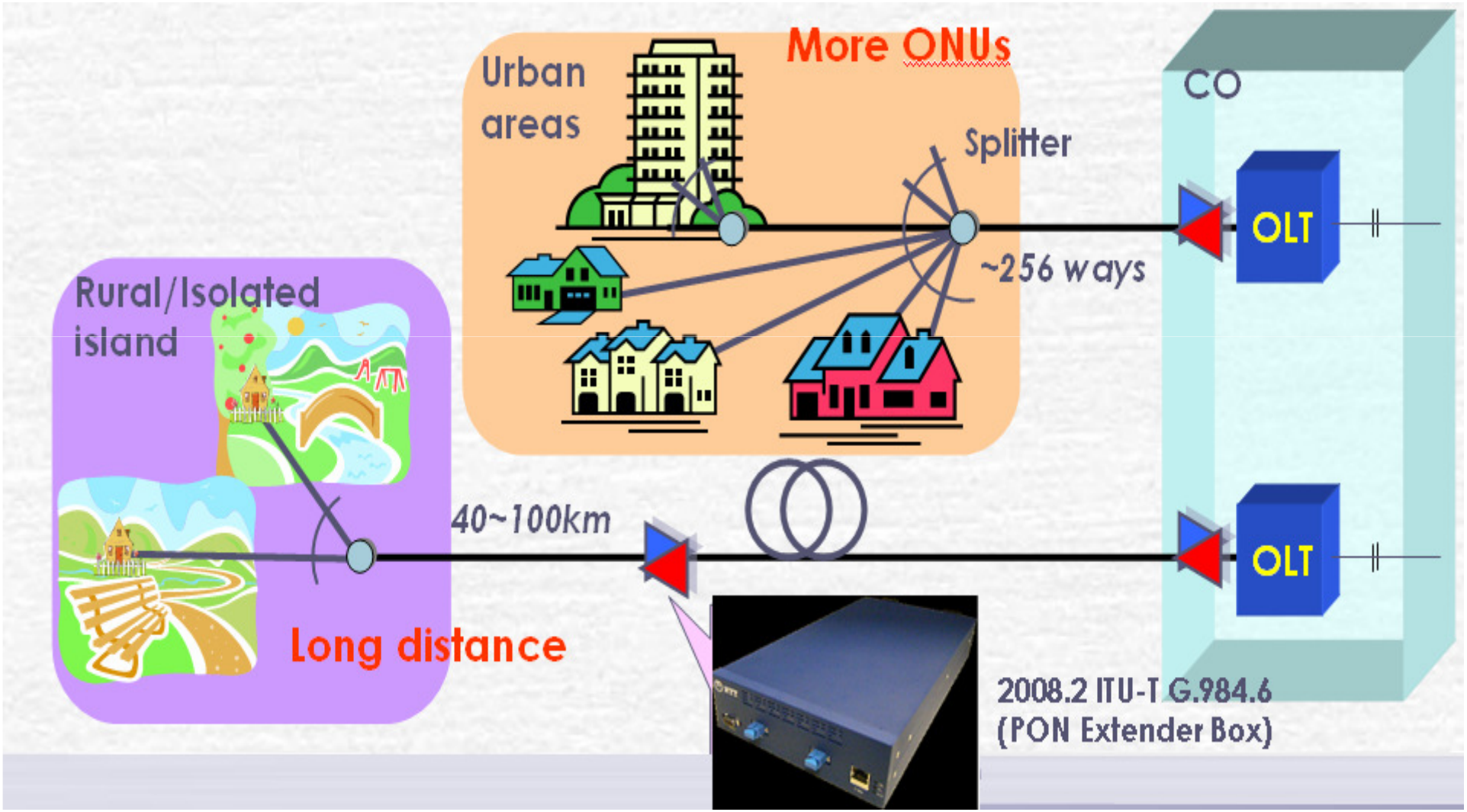


Ofcom 2010

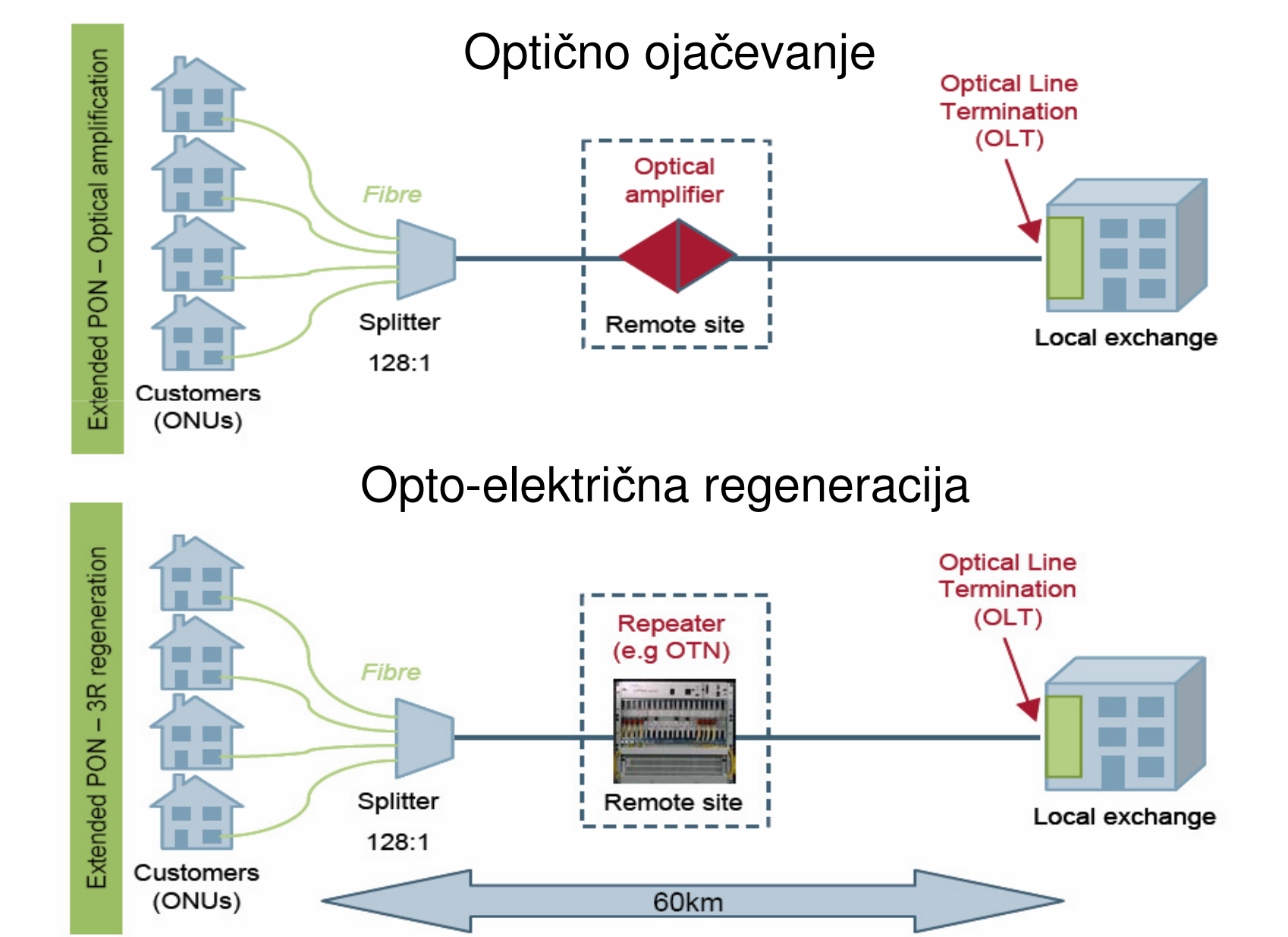
Nove tehnologije in njihov vpliv



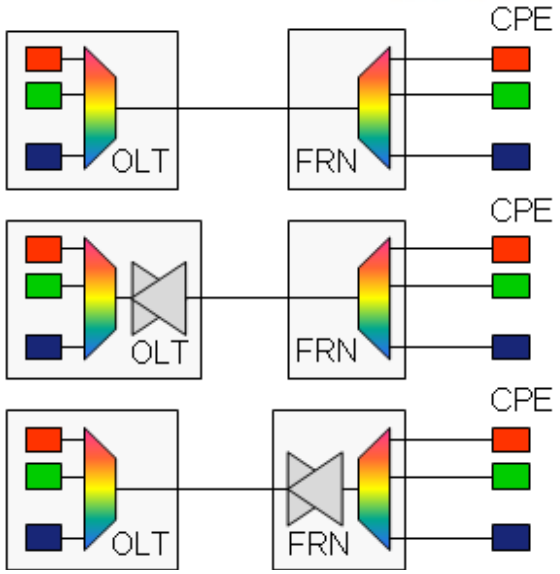
PON za urbano in ruralno področje



NG (ER ali LR) PON za velike razdalje



Budžet moči

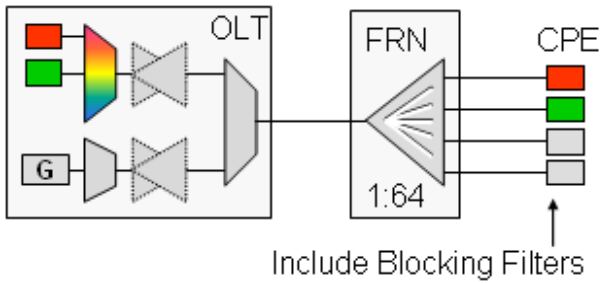


*WDM-PON, **DFW***

	Unamplified	OLT amp*	FRN amp**
Power budget	32.0 dB	32.0 dB	60.0 dB
Filter losses	12.0 dB	6.0 dB	12.0 dB
Patch cord/connector losses	0.9 dB	0.6 dB	1.2 dB
Optical path penalty	2.0 dB	2.0 dB	3.0 dB
System margin	1.0 dB	1.0 dB	1.0 dB
Link budget	16.1 dB	25.8 dB	42.8 dB
Link loss/km	0.3 dB	0.3 dB	0.3 dB
Link length in km	**53.7** km	**74.7** km	**142.7** km

*) With EDFA-C-**S**20-GCB

) With EDFA-C-D**20-VGC and DCG dispersion compensation



NG-GPON

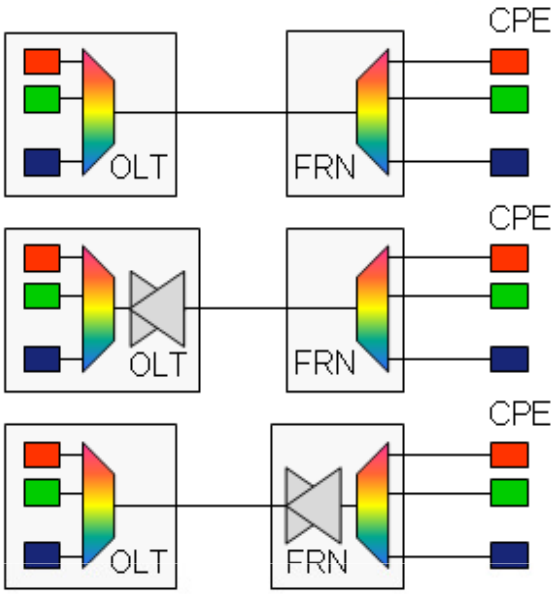
	GPON unampl.	WDM unampl.	GPON OLT ampl.	WDM OLT ampl.
Power budget	***33.0*** dB	***36.0*** dB	***37.0*** dB	36.0 dB
Filter and splitter losses	22.0 dB	27.0 dB	22.0 dB	22.0 dB
Patch cord/connector losses	0.9 dB	1.2 dB	0.9 dB	0.9 dB
Optical path penalty	1.0 dB	1.0 dB	1.0 dB	1.0 dB
System margin	1.0 dB	1.0 dB	1.0 dB	1.0 dB
Link budget	8.1 dB	5.8 dB	12.1 dB	11.1 dB
Link loss/km	0.4 dB	0.3 dB	0.4 dB	0.3 dB
Link length in km	**20.3** km	**19.3** km	**30.3** km	**37.0** km

33 dB (10G): +4 dBm...-26 dBm + 3 dB FEC gain, 36 dB (2G5): +4 dBm...-32 dBm

Power budget – razmerje v dB moči oddajnika in občutljivosti sprejemnika

Link budget – razmerje v dB moči na vhodu in izhodu vlakna (vključuje vsa slabljenja)

WDM PON, NG PON – budžet moči



*WDM-PON, **DFW***

	Unamplified	OLT amp*	FRN amp**
Power budget	32.0 dB	32.0 dB	60.0 dB
Filter losses	12.0 dB	6.0 dB	12.0 dB
Patch cord/connector losses	0.9 dB	0.6 dB	1.2 dB
Optical path penalty	2.0 dB	2.0 dB	3.0 dB
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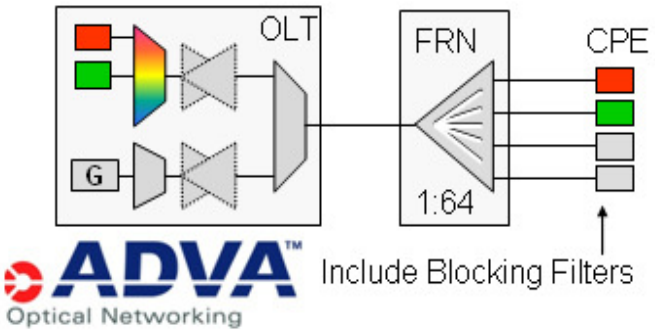
*) With EDFA-C-**S**20-GCB

) With EDFA-C-D**20-VGC and DCG dispersion compensation



NG-GPON

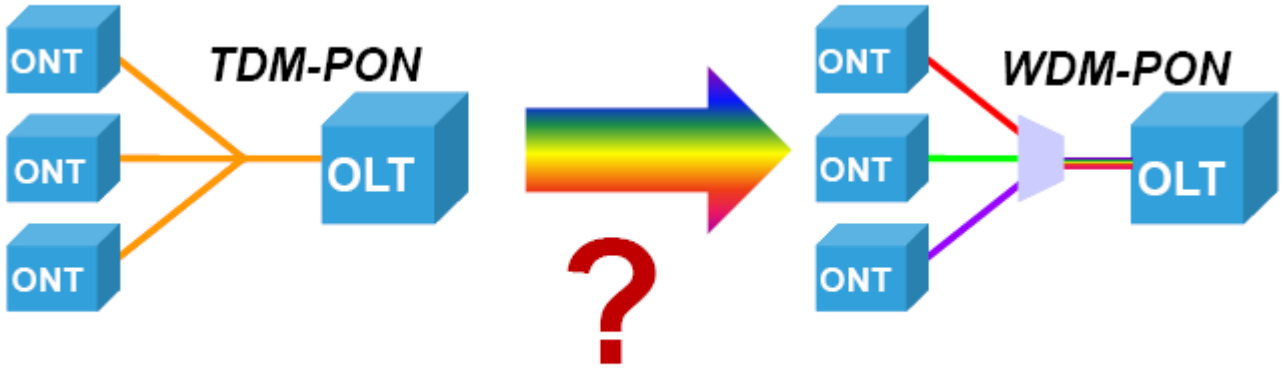
	GPON unampl.	WDM unampl.	GPON OLT ampl.	WDM OLT ampl.
Power budget	***33.0*** dB	***36.0*** dB	***37.0*** dB	36.0 dB
Filter and splitter losses	22.0 dB	27.0 dB	22.0 dB	22.0 dB
Patch cord/connector losses	0.9 dB	1.2 dB	0.9 dB	0.9 dB
Optical path penalty	1.0 dB	1.0 dB	1.0 dB	1.0 dB
System margin	1.0 dB	1.0 dB	1.0 dB	1.0 dB
Link budget	8.1 dB	5.8 dB	12.1 dB	11.1 dB
Link loss/km	0.4 dB	0.3 dB	0.4 dB	0.3 dB
Link length in km	**20.3** km	**19.3** km	**30.3** km	**37.0** km

33 dB (10G): +4 dBm...-26 dBm + 3 dB FEC gain, 36 dB (2G5): +4 dBm...-32 dBm

Budžet moči – razlika v dB med močjo oddajnika in občutljivostjo sprejemnika

Budžet zveze – slabljenje zveze v dB

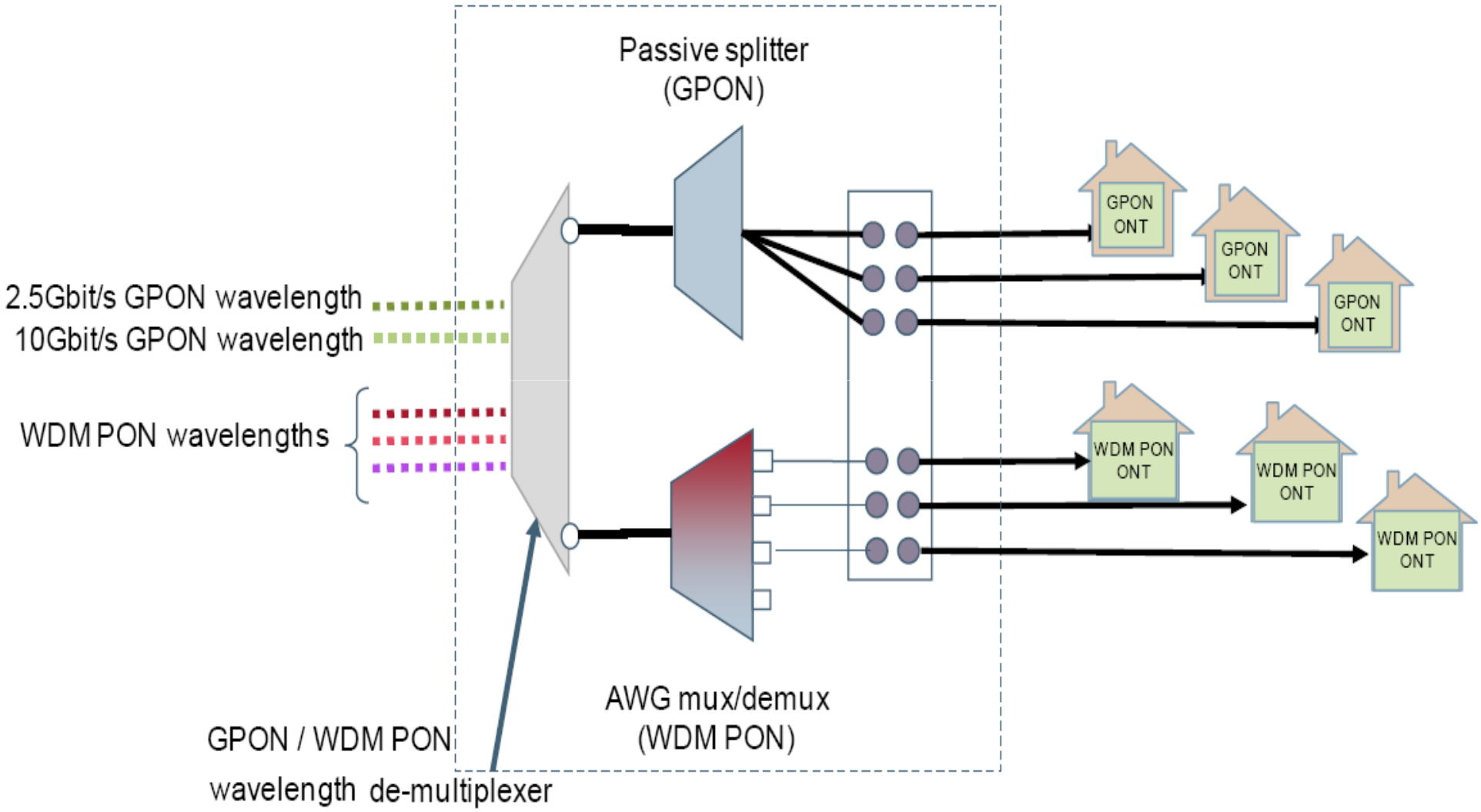
Nežna evolucija



- ***WDM* may be the best solution for future PONs**
- **The challenge is how to get to it with:**
  - Cost efficiency and scalable upgrades.
  - ***Graceful evolution priorities:***
    - Support legacy equipment (TDM PONs);
    - Add new customers and new services in existing PONs:
      - ✓ Improve service to current customers with no disruptions;
      - ✓ No improvement, no disruption to current customers;
      - ✓ Temporary disruption of service.
    - Greenfield installation only.

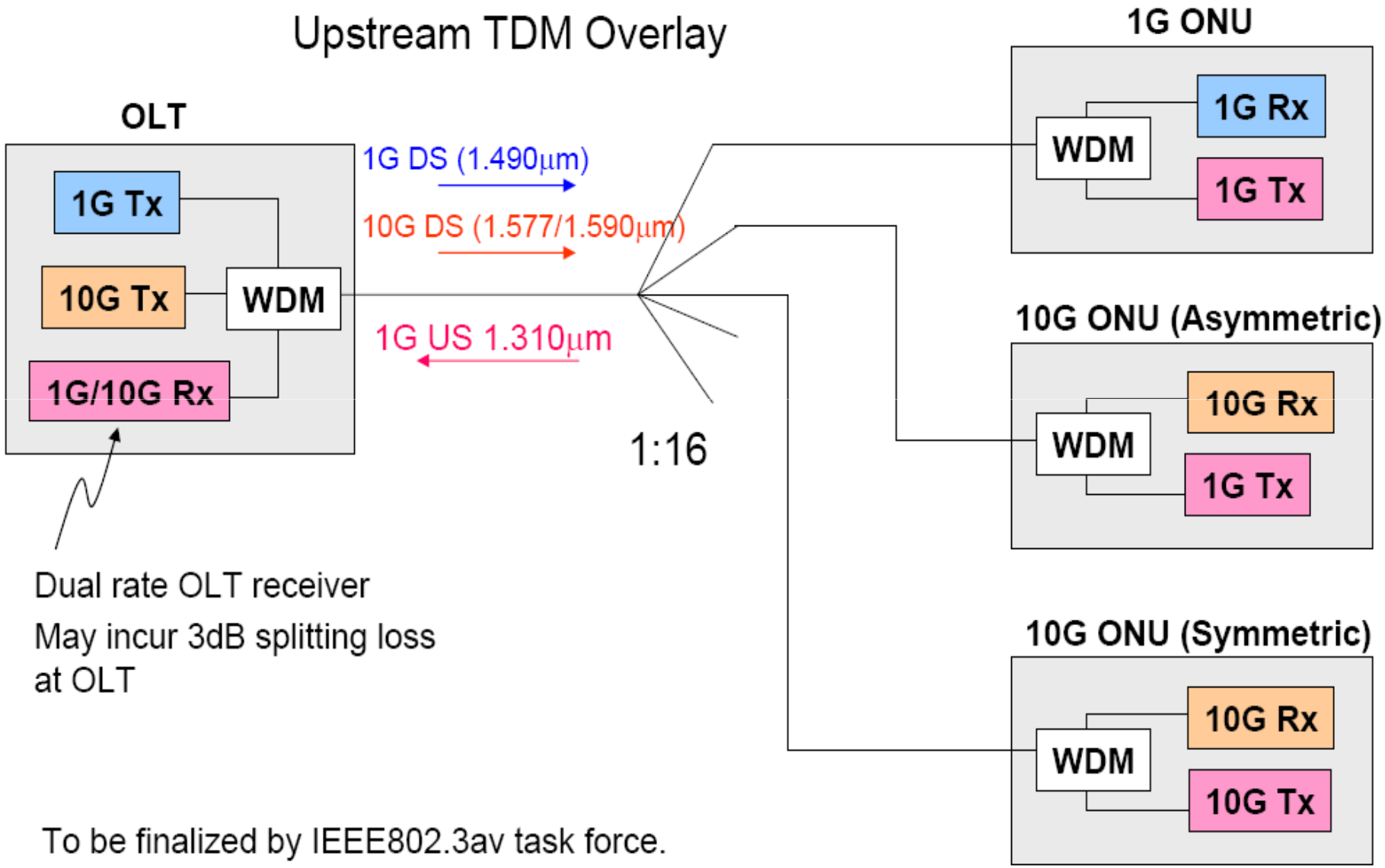
PNRL Stanford University

Nadgradnja GPONa z WDM PONom

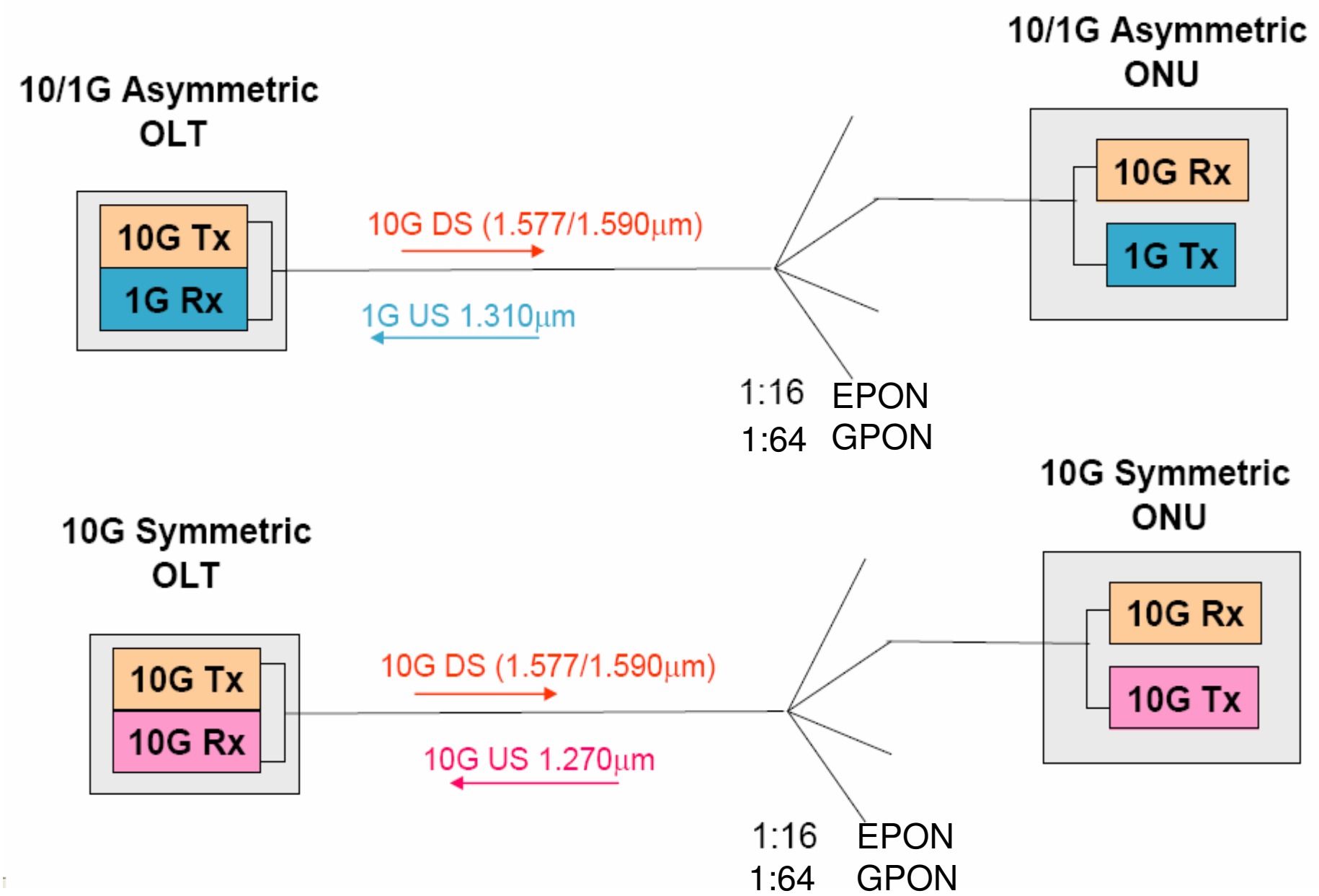


WDM PON upgrade over existing PON network [Source: Analysys Mason, 2010]

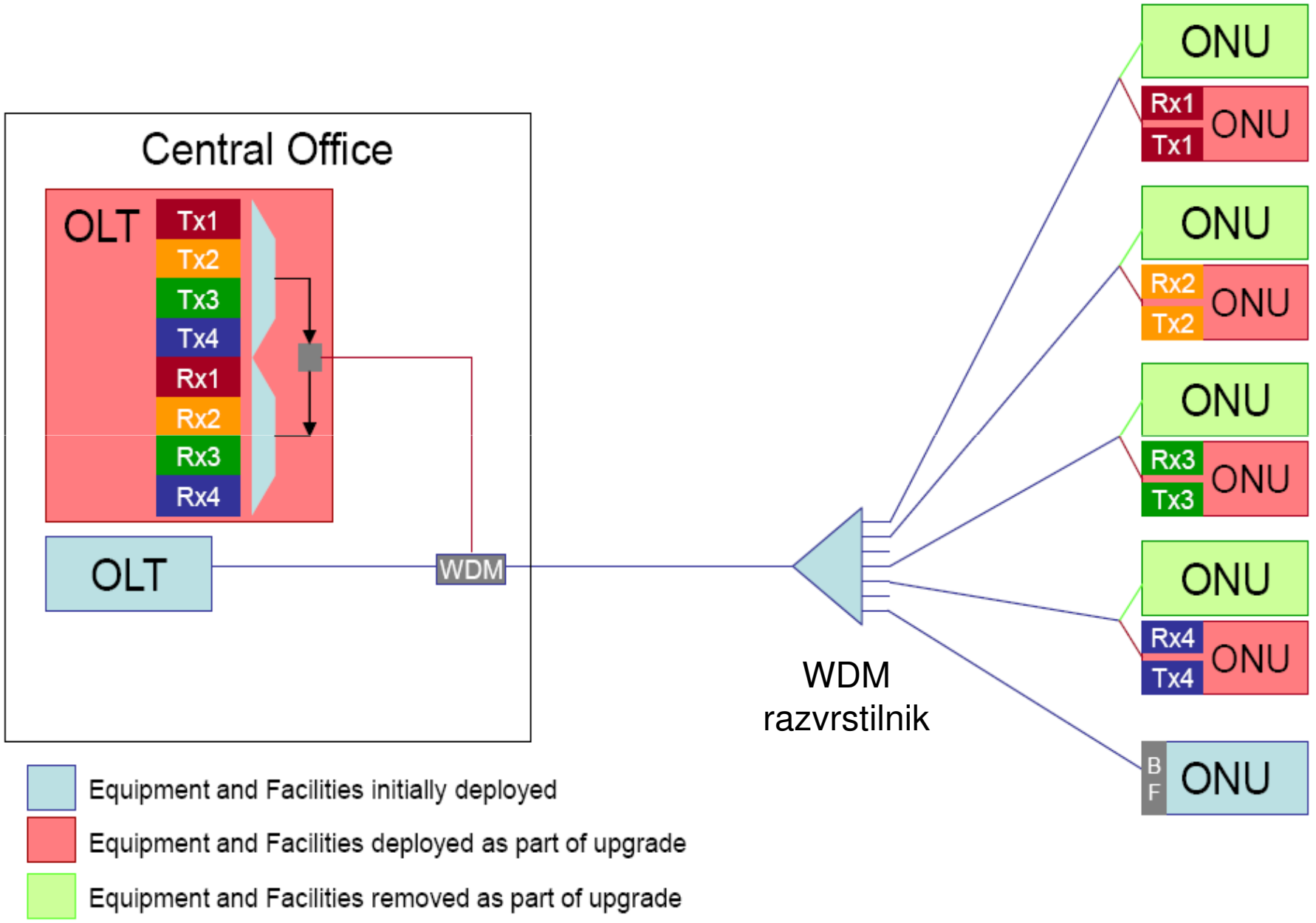
1/10 Gb/s zveza EPON



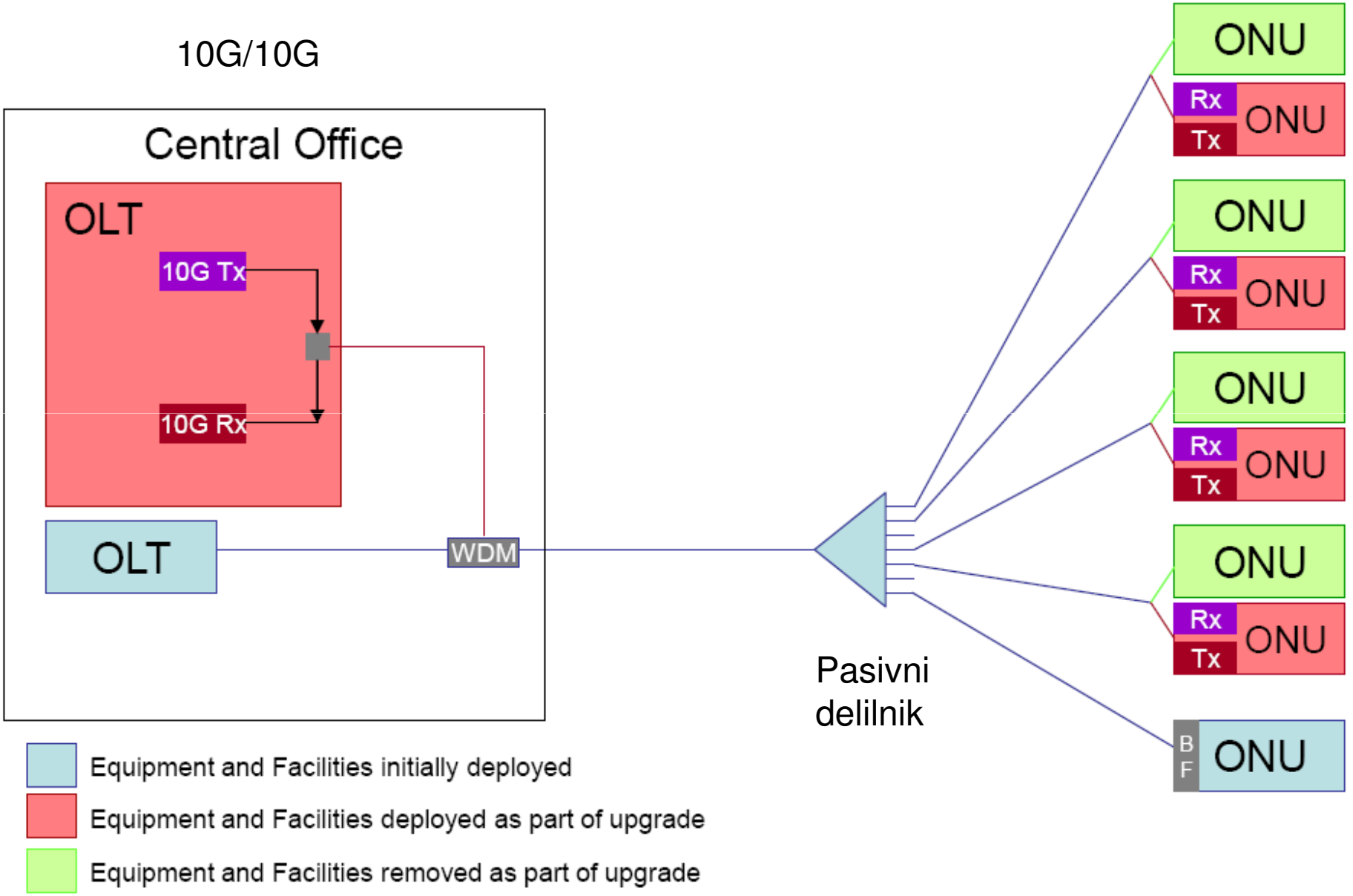
Asimetrični in simetrični EPON, GPON



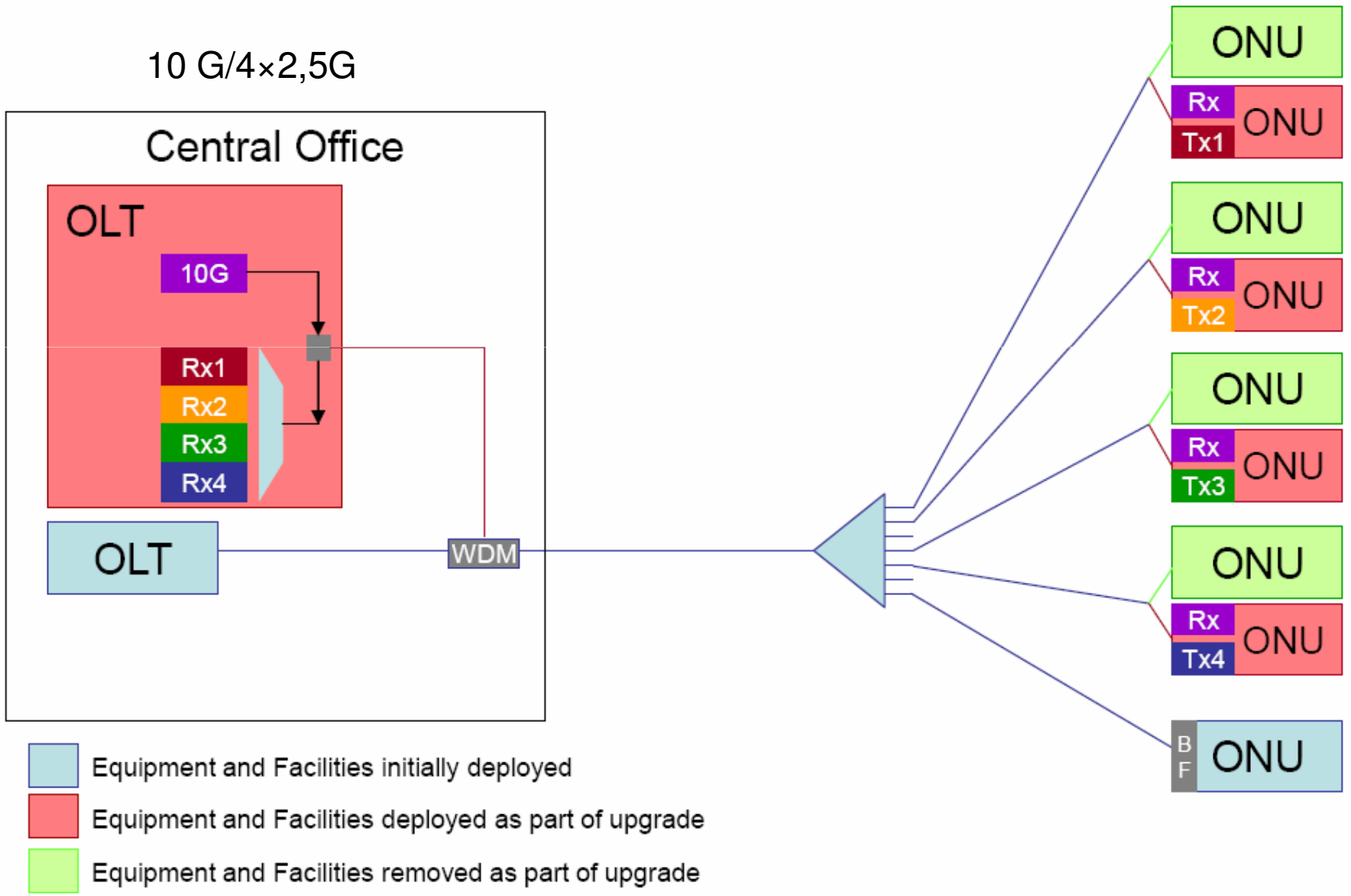
Koeksistenca NG PON 2



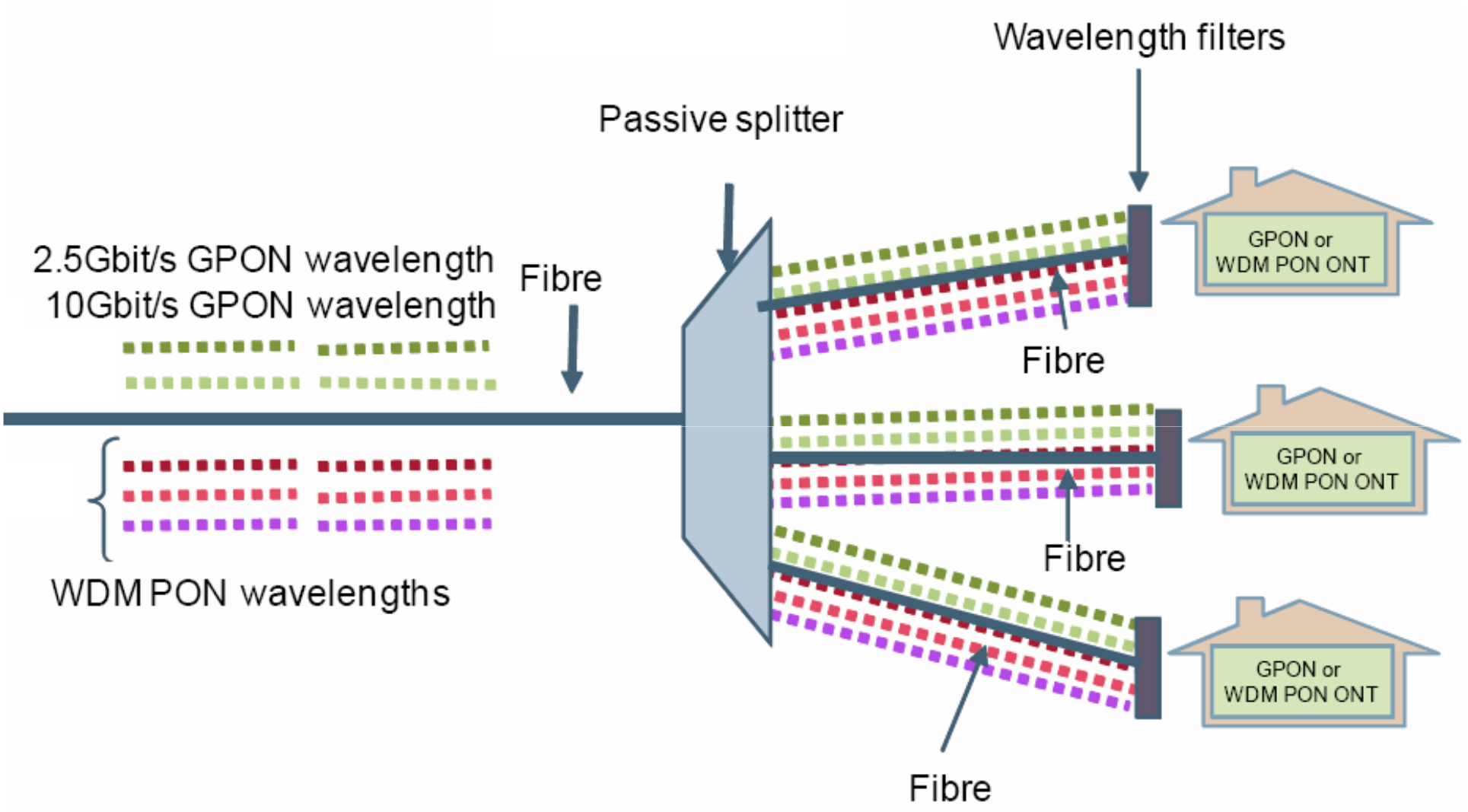
Koeksistenca NG PON 1



Koesistenca NG PON1

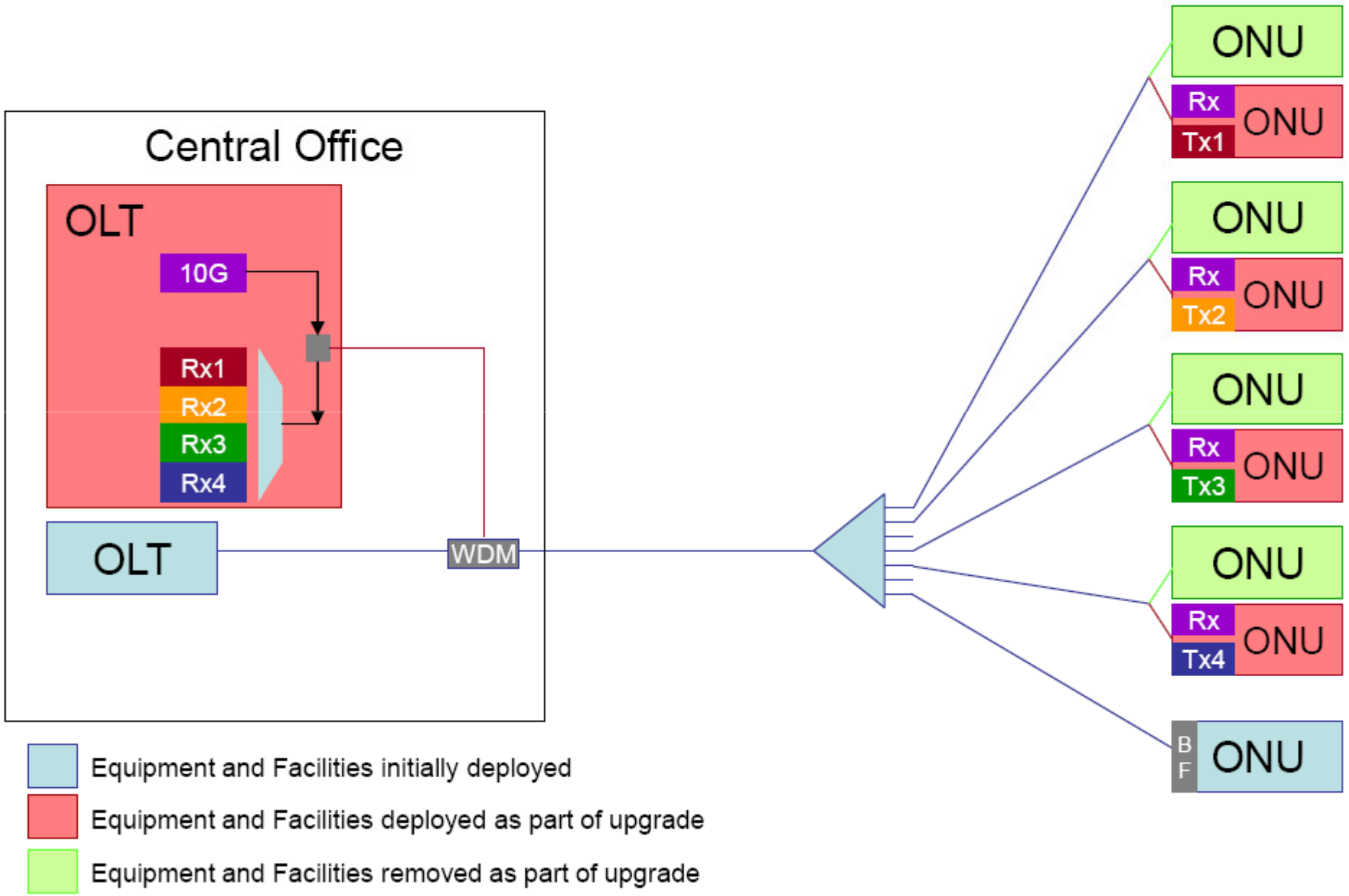


Koeksistenca GPONa in WDM PONa



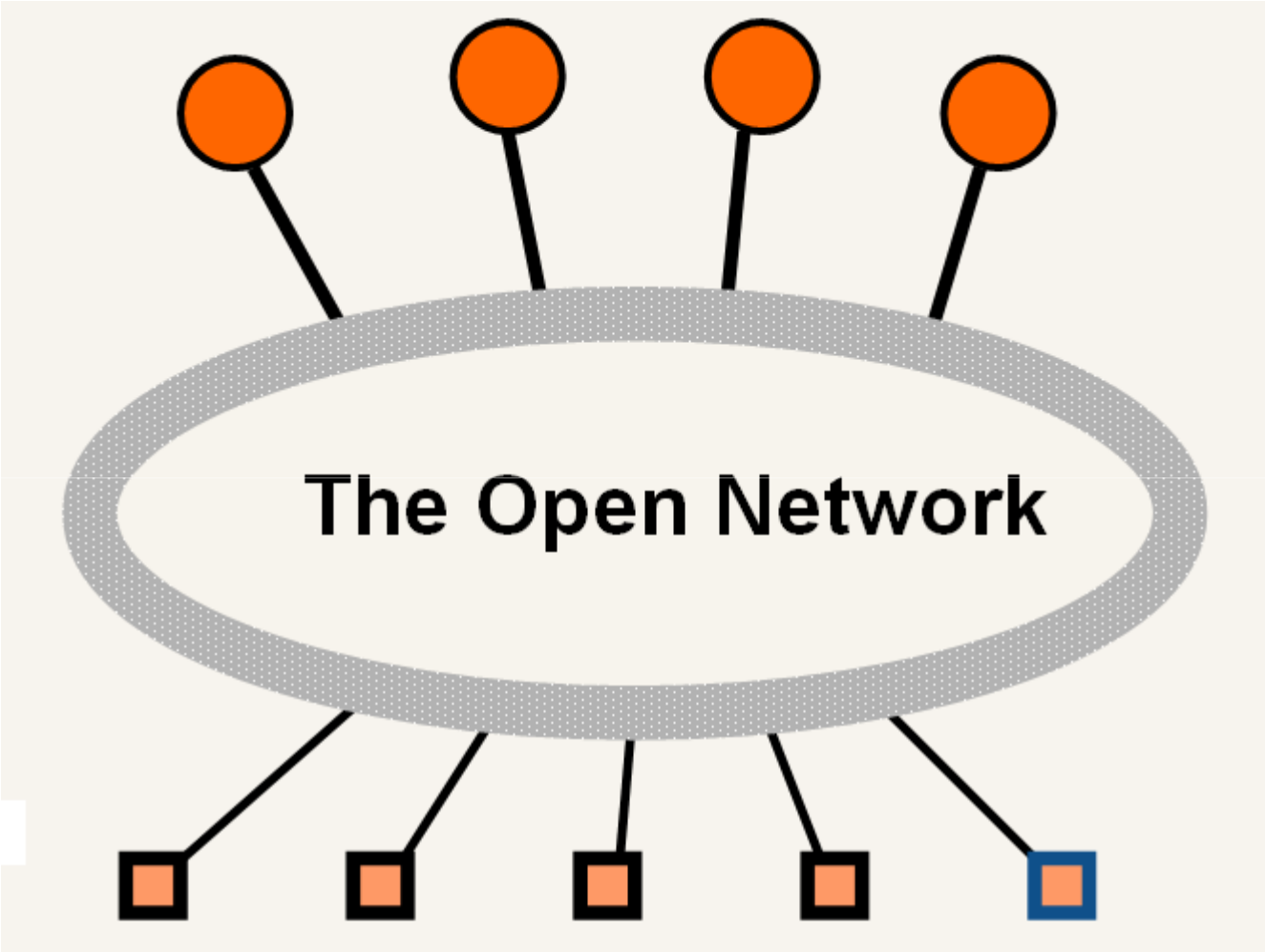
Coexistence of GPON and WDM PON at one site [Source: Analysys Mason, 2010]

10/Nx2.5G Scheme "XG-PON1"



Odprto omrežje

Ponudniki storitev

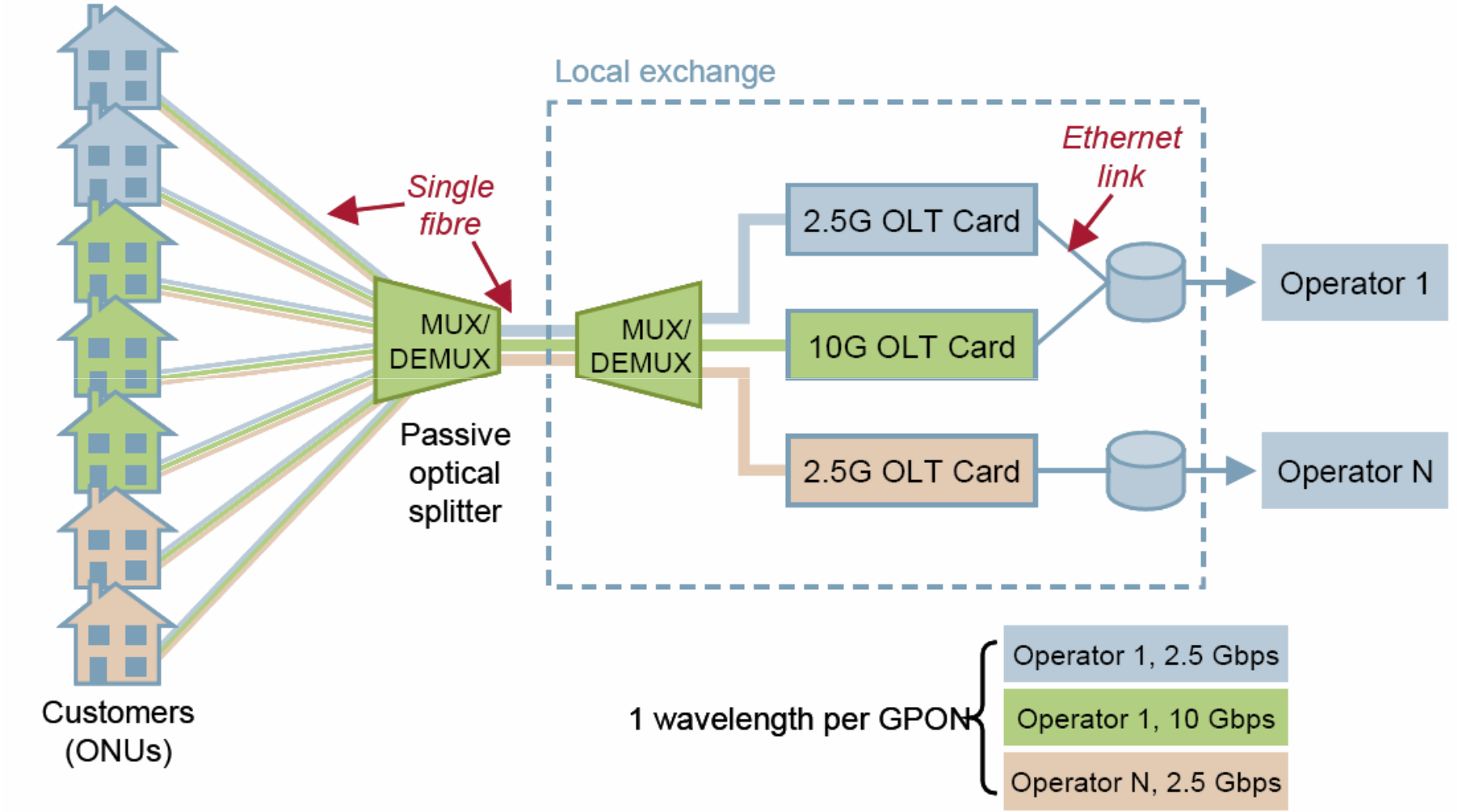


Naročniki

Kaj je odprto omrežje

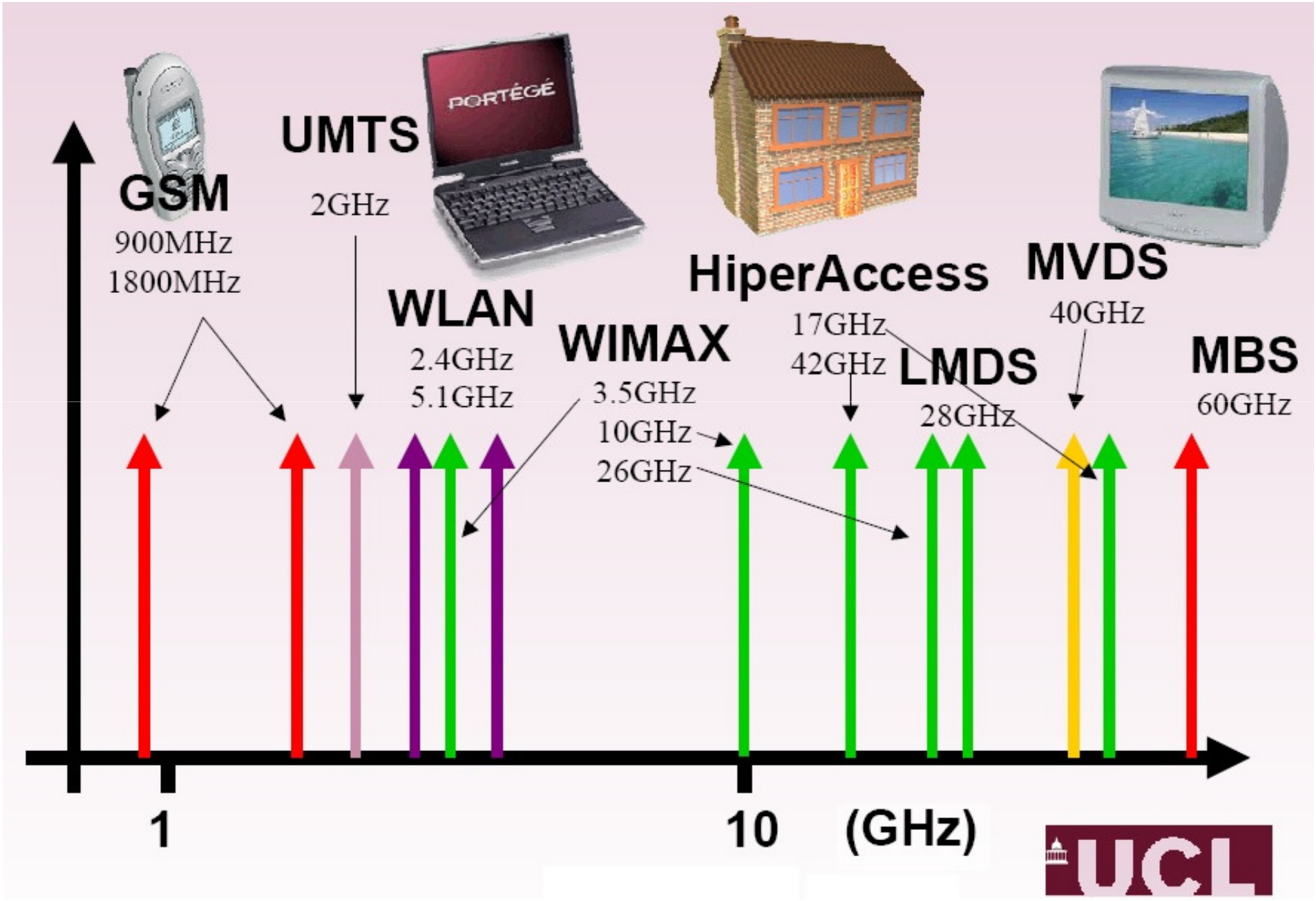
- A network that:
  - Network Operator and Service Operator are discrete entities
  - Reciprocal contracts between end users and service providers
  - Network Operator is not involved in any other operation except for the connectivity service
  - End users may select a service from any service provider over a shared infrastructure controlled by the network operator
- This is an **OPEN NETWORK**

Razvezava WDM PONa



Ofcom, Analysys Mason 2010

Frekvence radijskega dostopa



Sklep

- Vlakenski dostop je **končna rešitev** širokopasovnega dostopa do stacionarnega uporabnika za prihodnji čas, ko se bo močno razširila ponudba novih širokopasovnih storitev.
- Vlakenski dostop je edina tehnologija, ki omogoča prenos zelo širokih pasov (potencialno 100 Gb/s in več) na zelo velike razdalje (do 100 **k**m) med fiksnima točkama.
- Radijski dostop (WiMAX, LTE) za območje MAN obeta fiksnemu in mobilnemu uporabniku storitve do 50 oz. 25 Mb/s v ugodnih pogojih propagacije.
- Žični (xDSL) in kabelski (KOAX) dostop so vzporedne cenene tehnologije, ki kljub velikim izboljšavam v zadnjem času dolgoročno niso in ne bodo postale nadomestilo fiksnega optičnega dostopa. Radijski dostop (WiMAX) pa je nenadomestljiv v nomadskih in mobilnih zvezah.
- Žični in radijski dostop sta kratkoročno ekonomsko upravičena za običajne storitve oz. nekatera območja, in sicer žični za zelo kratke razdalje, radijski dostop pa za oddaljena prostrana redko naseljena področja.

Gostota naročnikov

Geotype		Cluster	Subscriber density per km^2
Urban	(1)	Dense Urban	> 10.000
	(2)	Urban	> 6.000
	(3)	Less Urban	> 2.000
Suburban	(4)	Dense Urban	> 1.500
	(5)	Suburban	> 1.000
	(6)	Less Suburban	> 500
Rural	(7)	Dense Rural	> 100
	(8)	Rural	≤ 100