Fiber 101

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ACCELERATE THE DEPLOYMENT OF TECHNOLOGY
TO THE ADVANTAGE OF OUR INDUSTRY.

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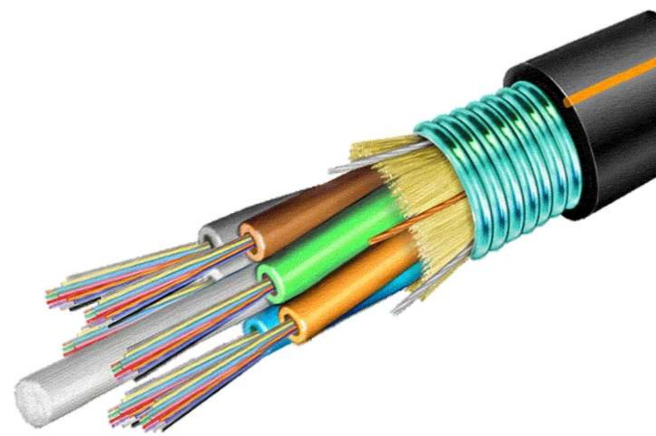
CCTA
CARIBBEAN CABLE & TELECOMMUNICATIONS ASSOCIATION

Fiber 101

- Brief view of the industry and activities
- Identify latest optical standards deployed by SCTE members around the globe
- Recognize the FTTH components, various architectures used, and key differences from an HFC network
- Explore optical power budgets
- Calculate an optical power budget


Hey, I heard fiber is coming to our neighborhood.
Good, I'm tired of chewing through this old coaxial cable!

Brief view of industry and activities



Exponential Growth of Broadband Service Offerings

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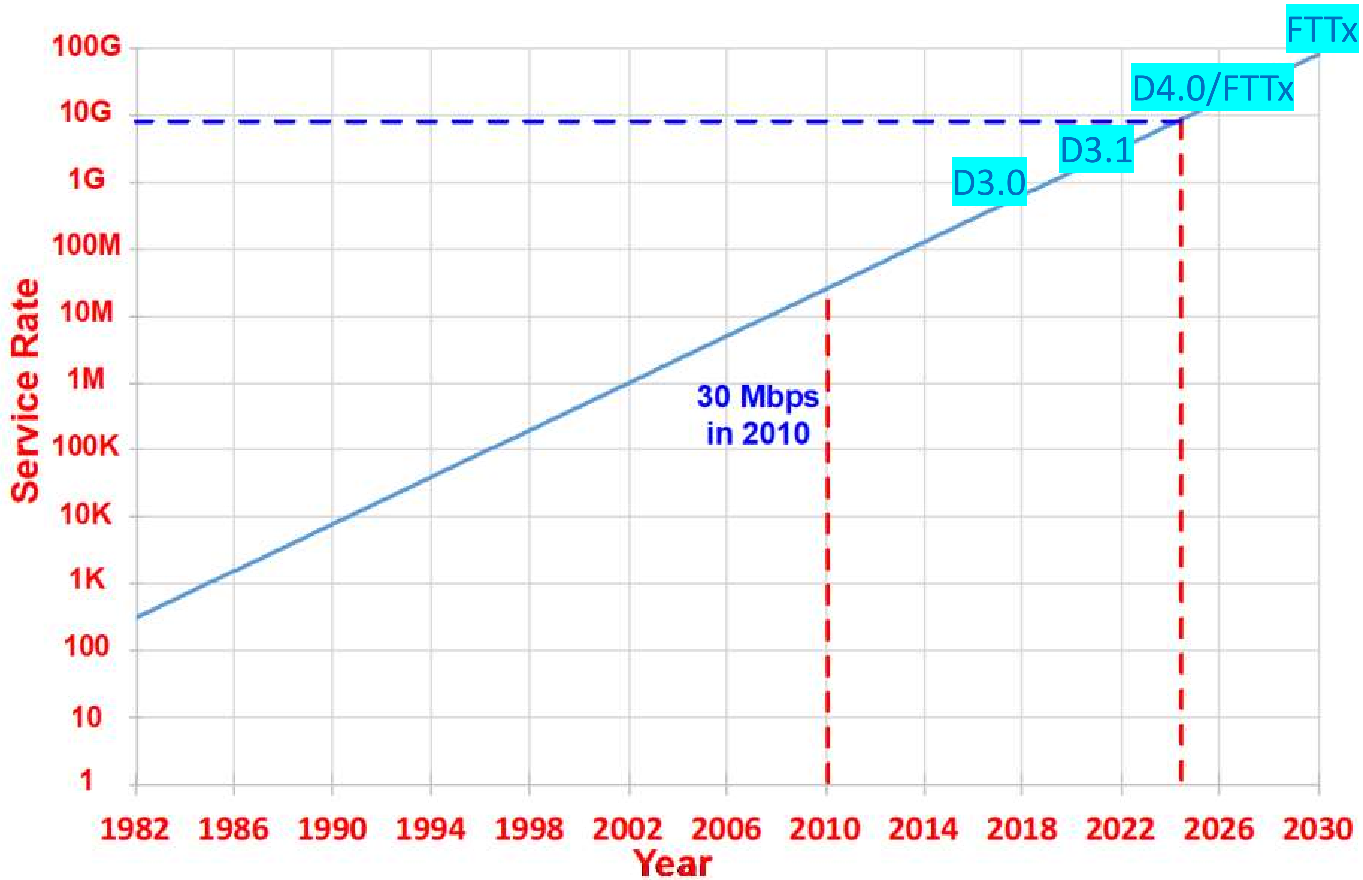
http://scte.org/BFI



Why Fiber?

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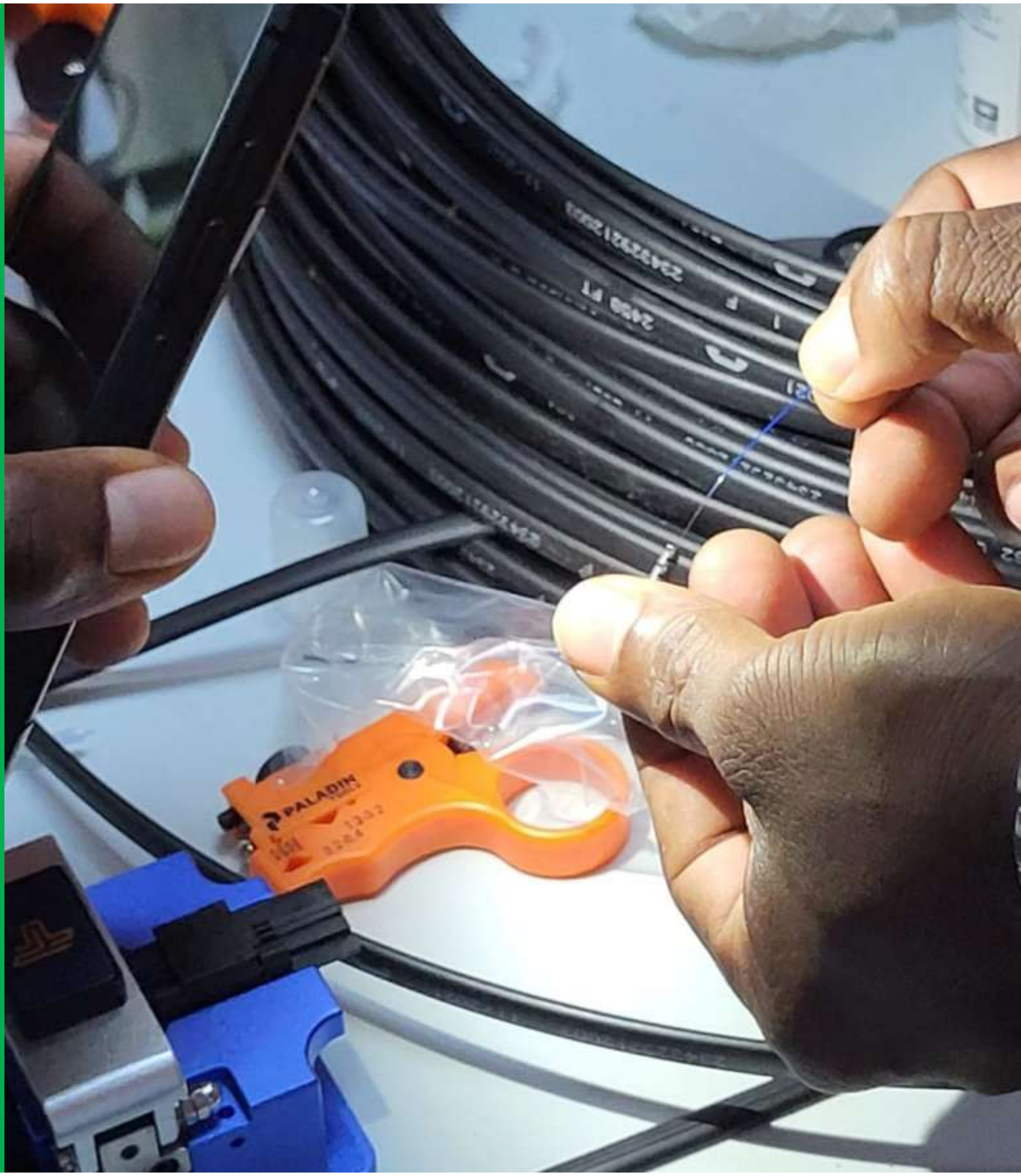
- Operators have been delivering **more telecom services over fiber optics**.
- Fiber delivers video, voice and data, an attractive option to coax, with **customer perception** that fiber is more valuable.
- Offers high bandwidth capability to subscribers, while improving overall reliability and reducing signal egress.
  – e.g., improved video quality like 4K/HDR and content options. Or future VR/AR services.
- Energy management and conservation, optimizing CapEx and reduces OpEx.

Why Fiber?

- Most offering 150 Mbps+ today, US 1Gbps.
  - 500 Mbps, 1000 Gbps options available, 10, 40, 100 and 400 Gbps options.
  - Optical fiber "future proofs" networks.
- Support for the latest video options and Wi-Fi technologies.
- Offers competitive advantages over fixed wireless.
- Knowledge of fiber optics provides additional skills to cable installers and engineers, which can help open the door for new opportunities!



Recent Activity

Cable Bahamas taps Nokia for FTTH deployment

CARIBBEAN MOBILE TOP STORIES

Mark Bowen | 9 May, 2022

Nokia will deploy its XGS-PON equipment for Cable Bahamas's new fibre-to-the-home (FTTH) network, as part of the operator's comprehensive network upgrade.

Liberty has over 19,300km of HFC cable and FTTH network deployed in Puerto Rico, connecting 1.16mn homes (homes passed) as of December 2021. This network is used to offer "market-leading" 600Mbps broadband speed plans, according to the company.

Altice improved its fiber optics coverage by 10% last year and increased FTTH adoption by 6% over the growth of fixed services. Churn was reduced by 8 percentage points due to the adoption of fiber, the company said during the investors' presentation.

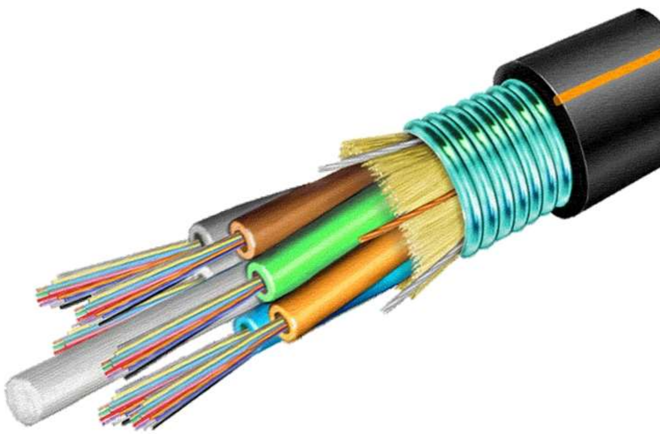
FLOW announces end to copper wire as fiber optics is fully in operation

Article by
Marlon Madden

Published on
October 1, 2021

Barbados has become the first island in the Caribbean to be fully wired by fiber optics, said FLOW, the regional subsidiary of telecommunications giant Cable & Wireless as it completed its fibre to the home (FTTH) network rollout.

Latest optical standards deployed by SCTE members around the globe



A FEW TERMS…

PON – Passive Optical Network

IEEE = Institute of Electrical and Electronics Engineers

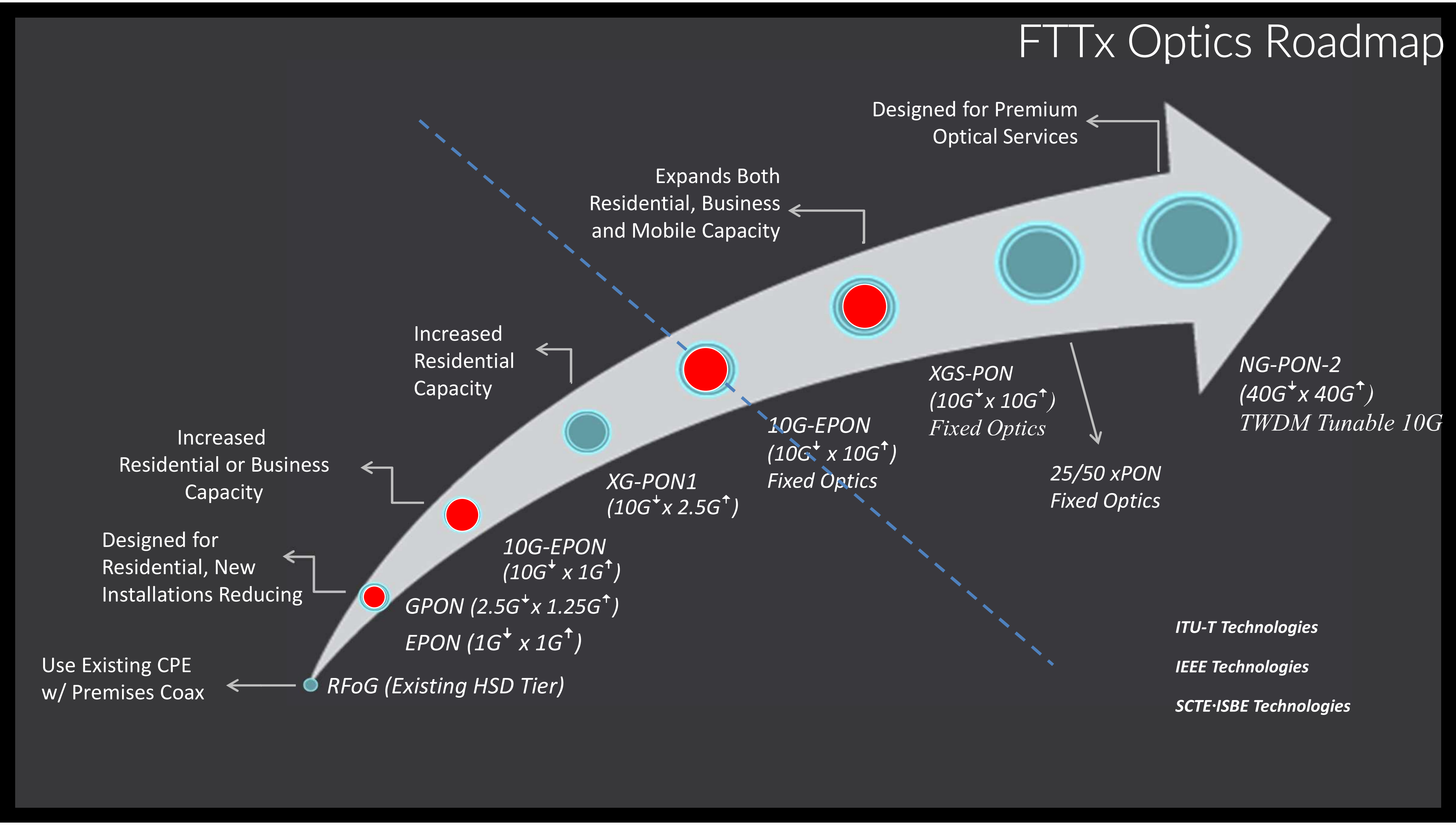
ITU – International Telecommunication Union

EPON – Ethernet PON (IEEE)

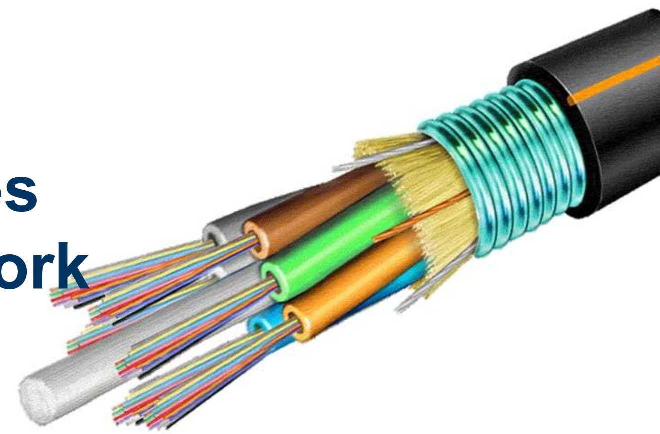
GPON – Gigabit PON (ITU)

XGS-PON - Extended Gigabit Symmetrical PON (ITU)

NG-PON2 – Next Generation PON II (ITU)


FTTx Optics Roadmap
Designed for Premium Optical Services
Expands Both Residential, Business and Mobile Capacity
Increased Residential Capacity
Increased Residential or Business Capacity
Designed for Residential, New Installations Reducing
Use Existing CPE w/ Premises Coax
RFoG (Existing HSD Tier)
EPON (1G↓ x 1G↑)
GPON (2.5G↓x 1.25G↑)
10G-EPON (10G↓ x 1G↑)
XG-PON1 (10G↓x 2.5G↑)
10G-EPON (10G↓ x 10G↑) Fixed Optics
XGS-PON (10G↓x 10G↑) Fixed Optics
25/50 xPON Fixed Optics
NG-PON-2 (40G↓x 40G↑) TWDM Tunable 10G
ITU-T Technologies
IEEE Technologies
SCTE·ISBE Technologies

FTTH components and key differences from an HFC network



A FEW MORE TERMS…

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FTTH- Fiber to the Home

CPE = Customer Premises Equipment

OLT = Optical Line Terminal

ODN = Optical Distribution Network

ONT = Optical Network Terminal

ONU = Optical Network Unit

FDC = Fiber Distribution Cabinet

WDM = Wave Division Multiplexing

EDFA = Erbium Doped Fiber Amplifier

V-HUB = Virtual Hub

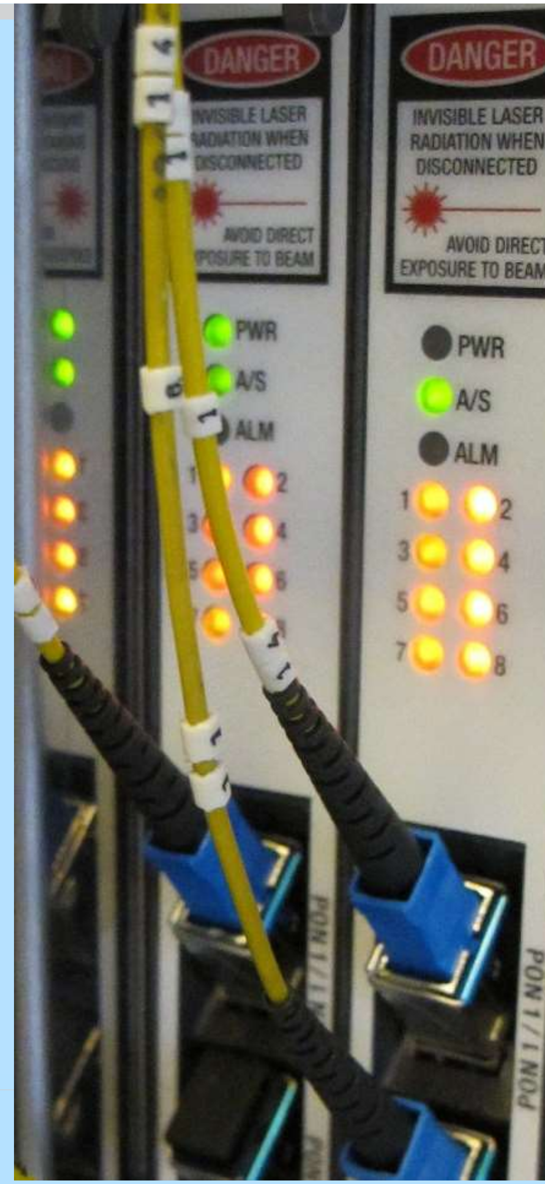
Raise Your Hands….

What is FTTH?

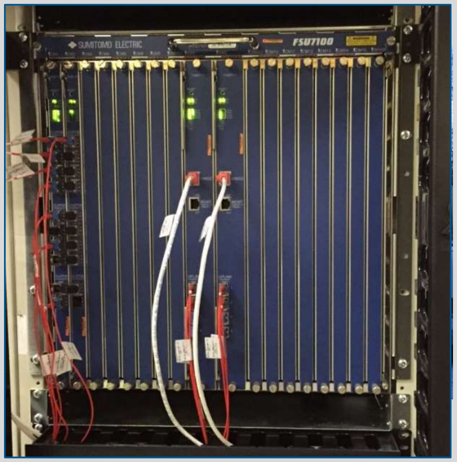
A broadband service using digital fiber optics from operator to premises (customer).

What is PON?

A network architecture that does not require power, or active devices in the delivery telecommunication services.



WHAT IS FTTH?



Facility
OLT

Optical Line Terminal

ODN
Splitter(s)

Optical Distribution Network
(20 km / 12.74 m)

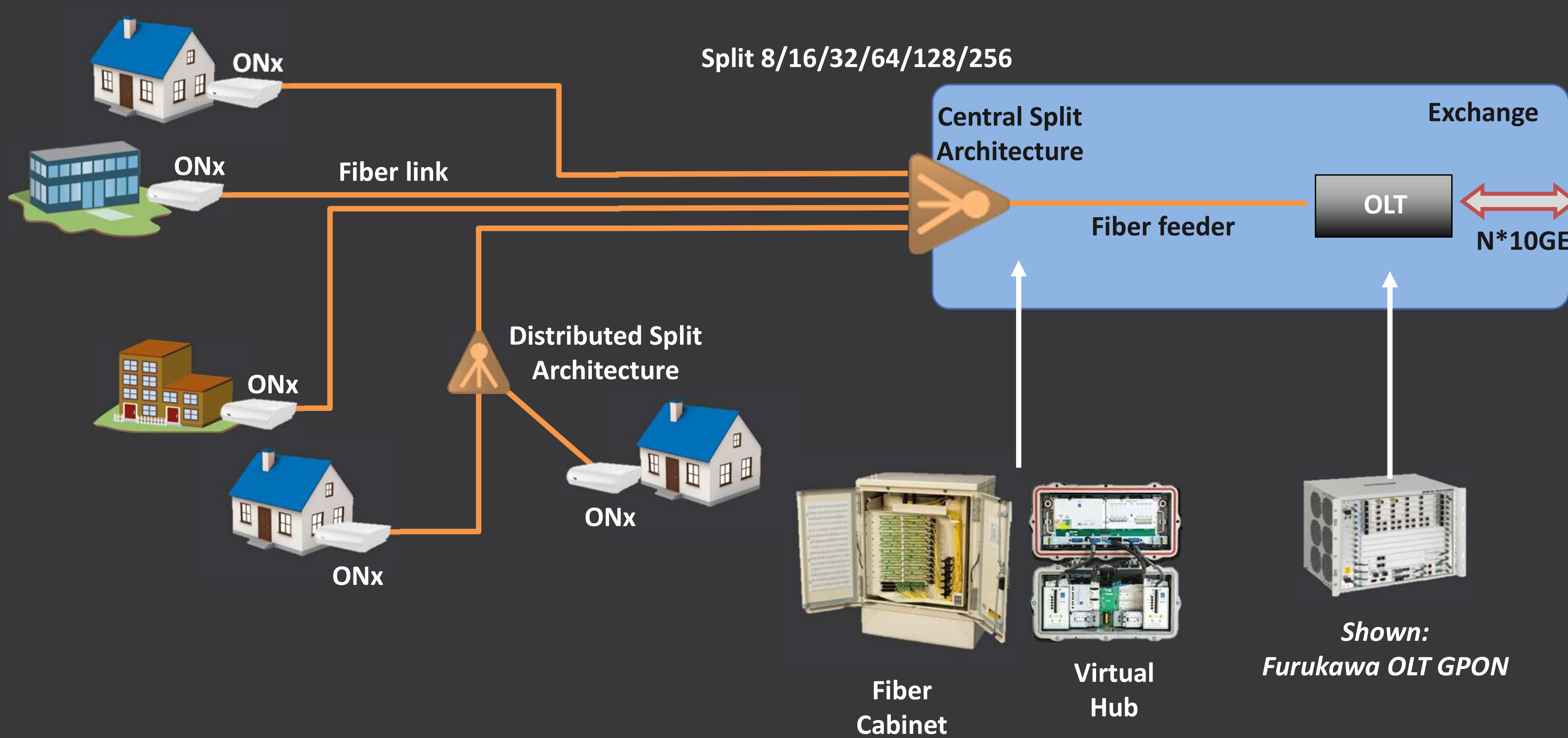
CPE
ONx

Optical Network Terminal or
Optical Network Unit
(Optics ⇔ Ethernet/Wi-Fi)

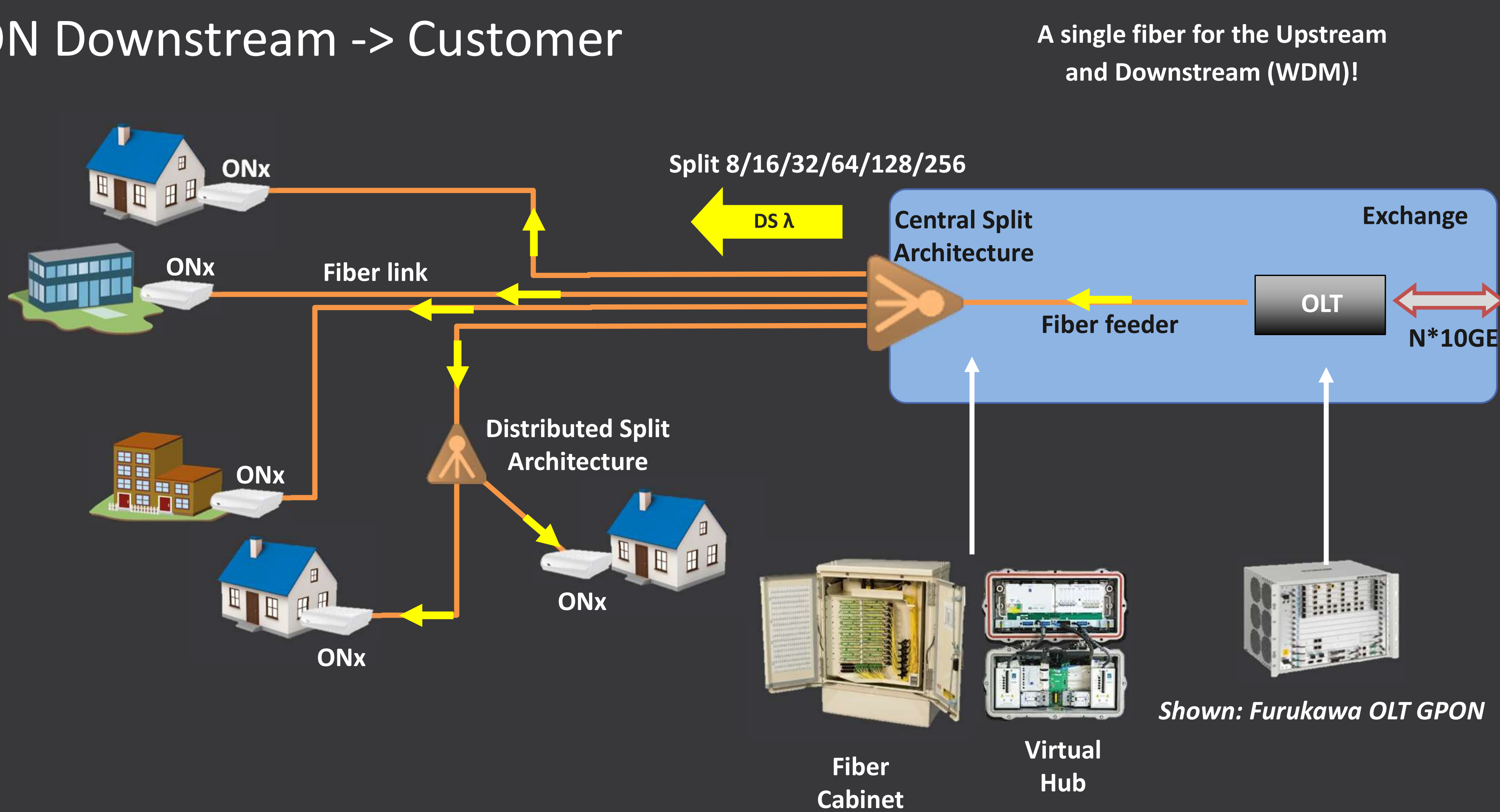
Optical Power Budget

What is PON?

A single fiber for the Upstream and Downstream (WDM)!

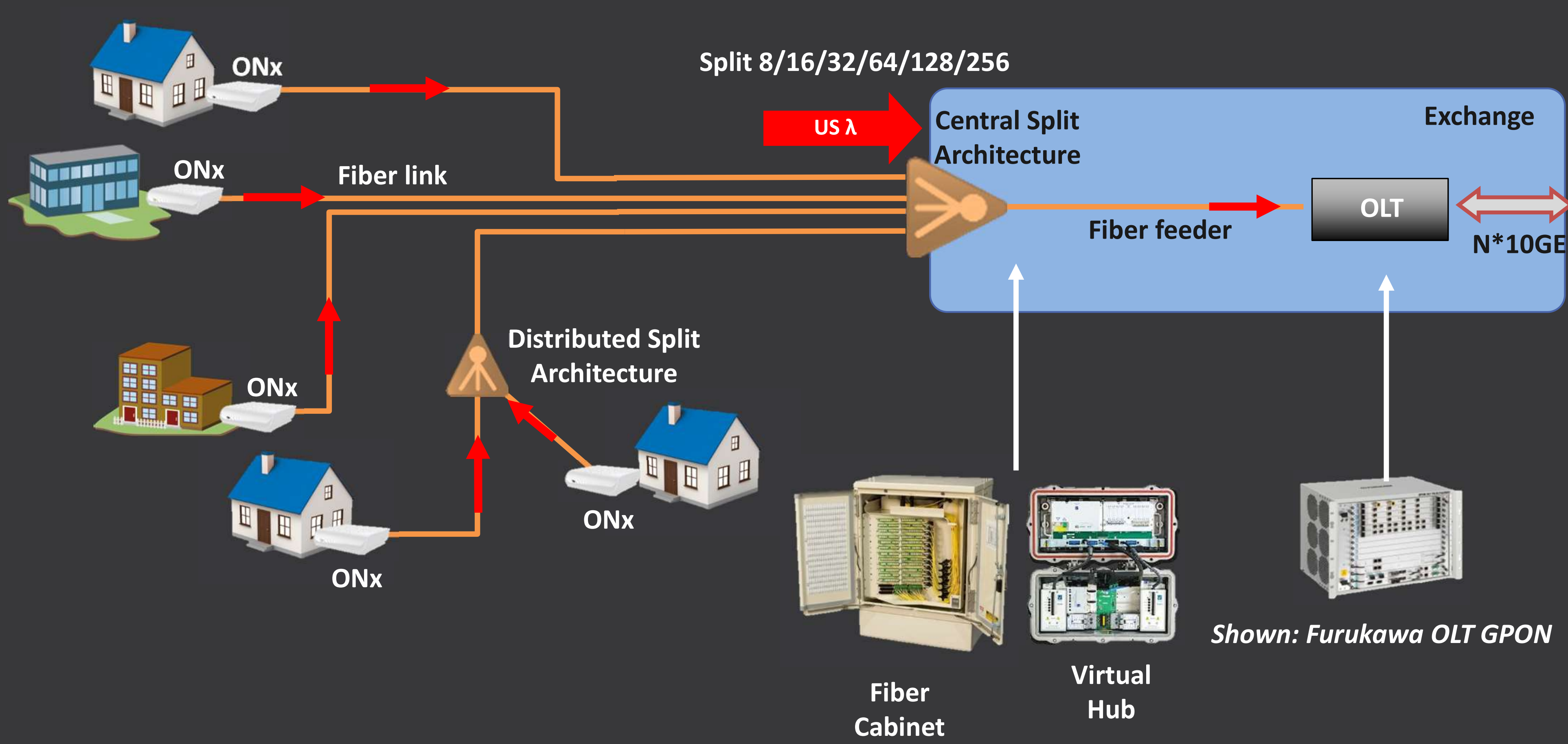


PON Downstream -> Customer



PON Upstream -> Operator

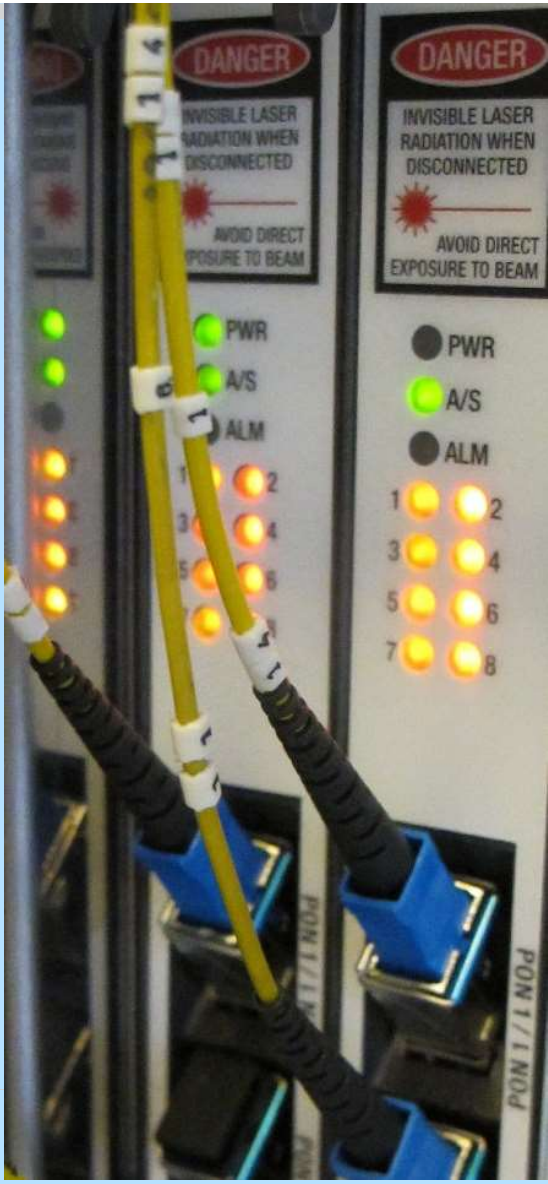
A single fiber for the Upstream and Downstream (WDM)!



Raise Your Hands….

What is symmetrical?

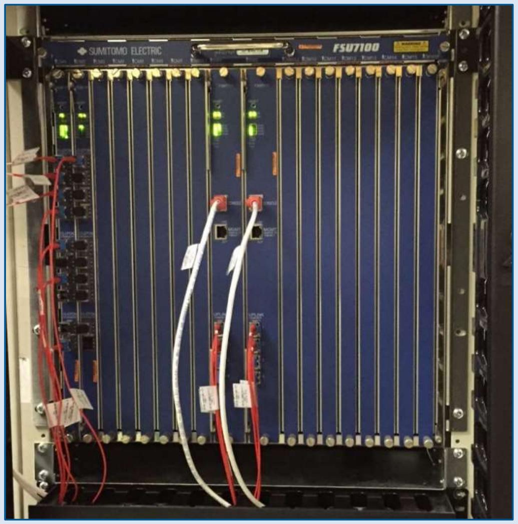
Downstream and Upstream speeds match one another. For example, 500 Mbps downstream and 500 Mbps upstream.



FTTH Components: Facility

OLT | EDFA | ODN | FDC | V-HUB | Optical Tap | ONT/ONU

- Connects the hub to the ODN and ONU
- Time reference for the network
- Allocates bandwidth to the ONUs
- Performs initial and periodic ranging of ONUs
- Controls ONU registration



FTTH Components

OLT | **EDFA** | ODN | FDC | V-HUB | Optical Tap | ONT/ONU

- An erbium doped fiber amplifier (EDFA) consists of a piece of fiber whose core is uniformly doped with Erbium ions.
- The Gain depends on the total number of excited ions in the fiber; the more the ions, the larger the average number of stimulated emissions per input photon

FTTH Components

OLT → EDFA → **ODN** → FDC → V-HUB → Optical Tap → ONT/ONU

- A WDM is used to transmit the signals
- WDM EDFA signals are fed into an optical splitter
- Splitter typical divides the optical signals 1:32
- RFoG Optical Network Unit is located at the premises
- 25 dB link budget is recommended which spans a maximum of 20 km

FTTH Components (Fiber Distribution Cabinet)

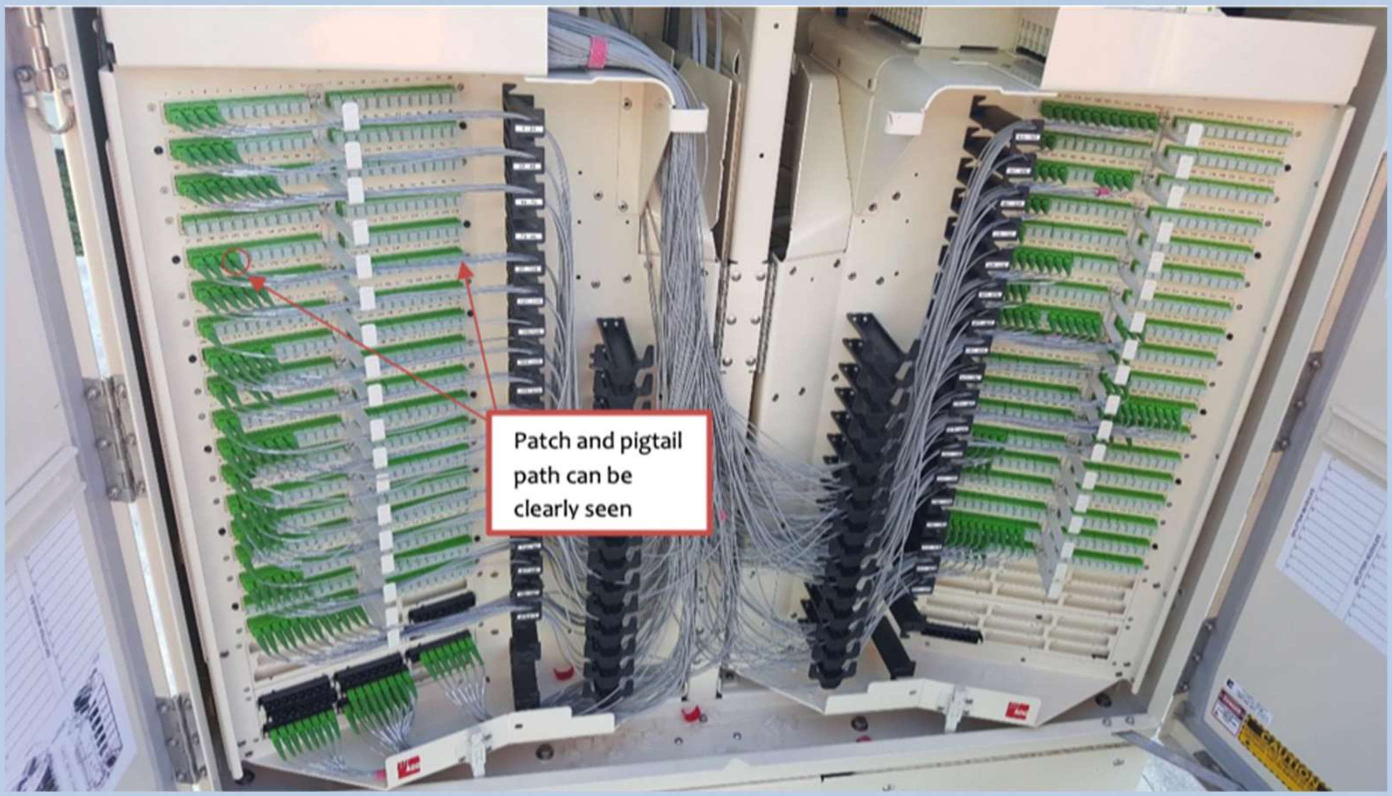
OLT | EDFA | ODN | **FDC** | V-HUB | Optical Tap | ONT/ONU

- Optical splice trays
- Optical bulkhead
- Optical splitters
- Hardened cabinet

FTTH Components (Fiber Distribution Cabinet)

OLT | EDFA | ODN | **FDC** | V-HUB | Optical Tap | ONT/ONU

- Optical splice trays
- Optical bulkhead
- Optical splitters
- Hardened cabinet



FTTH Components

OLT → EDFA → ODN → FDC → **V-HUB** → Optical Tap → ONT/ONU

- GREATLY extends the reach of a FTTH based access network
- Really, the only powered portion (if used) of an FTTH network – no need for amplifiers & line extenders from the virtual hub (V-Hub) to the customer
- Some models support up to 256 subscribers with the maximum number of modules installed
- With up to four digital receivers in the V-Hub, effectively 128 or 256 subscribers share the upstream bandwidth

1 fiber in

Up to
256 fibers out

FTTH Components

OLT | EDFA | ODN | FDC | V-HUB | **Optical Tap** | ONT/ONU

FTTH Components

OLT | EDFA | ODN | FDC | V-HUB | Optical Tap | **ONT/ONU**

Premises Network Interface Device

APC Coupler

FTTH Components

OLT → EDFA → ODN → FDC → V-HUB → Optical Tap → **ONT/ONU**

- Relatively easy to install
- If the received level is good – there's usually an LED indicator illuminated
- For some, voltage test points are provided

Calix 10G ONT

Sumitomo 1G ONU

Charter 10G ONU

FTTH Components

OLT | EDFA | ODN | FDC | V-HUB | Optical Tap | **ONT/ONU**

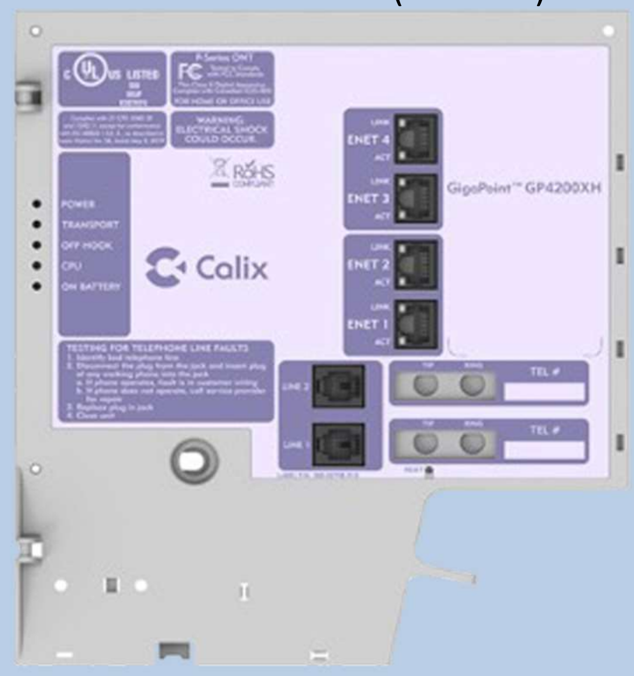
ARRIS GPON ONT

RJ11 Phone Jacks

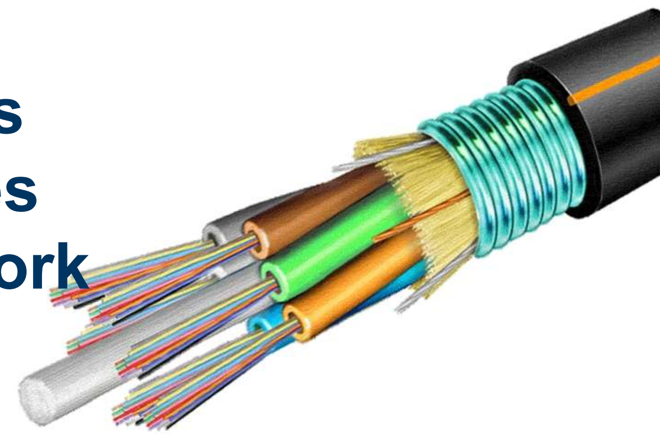
RJ45 Ethernet LAN Ports

SC/APC PON Connection

Calix 10G ONT (outdoor)



FTTH architectures and key differences from an HFC network



A FEW ADDITIONAL TERMS…

FTTC = Fiber to the Curb

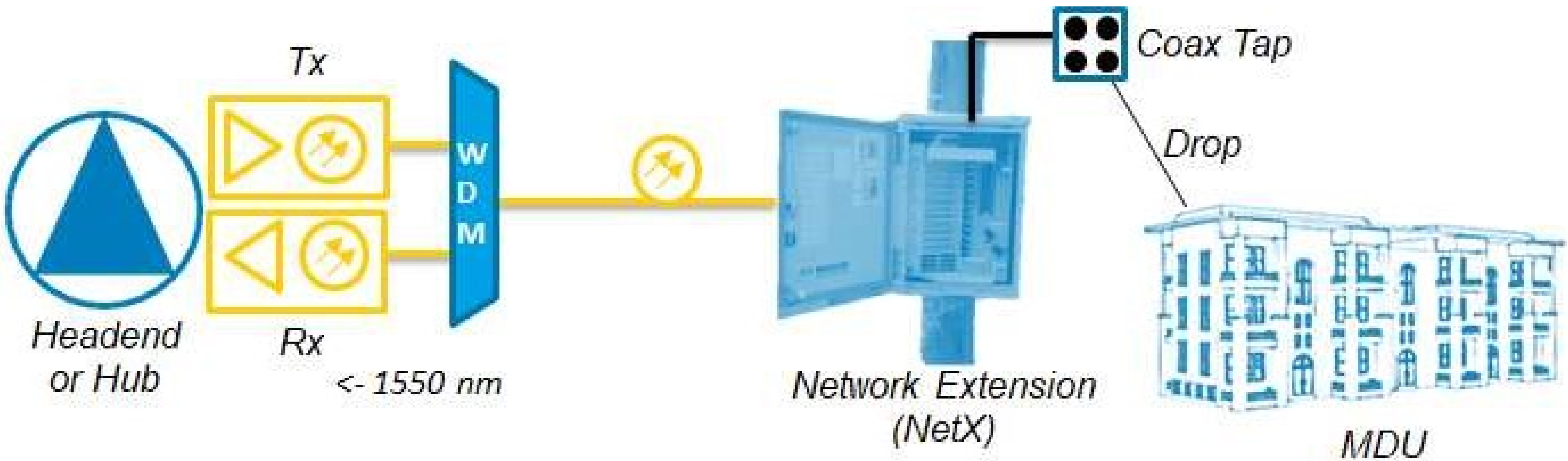
FTTB = Fiber to the Business

FTTMDU = Fiber to the MDU

FTTH = Fiber to the Home

FTTP = Fiber to the Premises

Fiber to the Curb



Fiber to the Business

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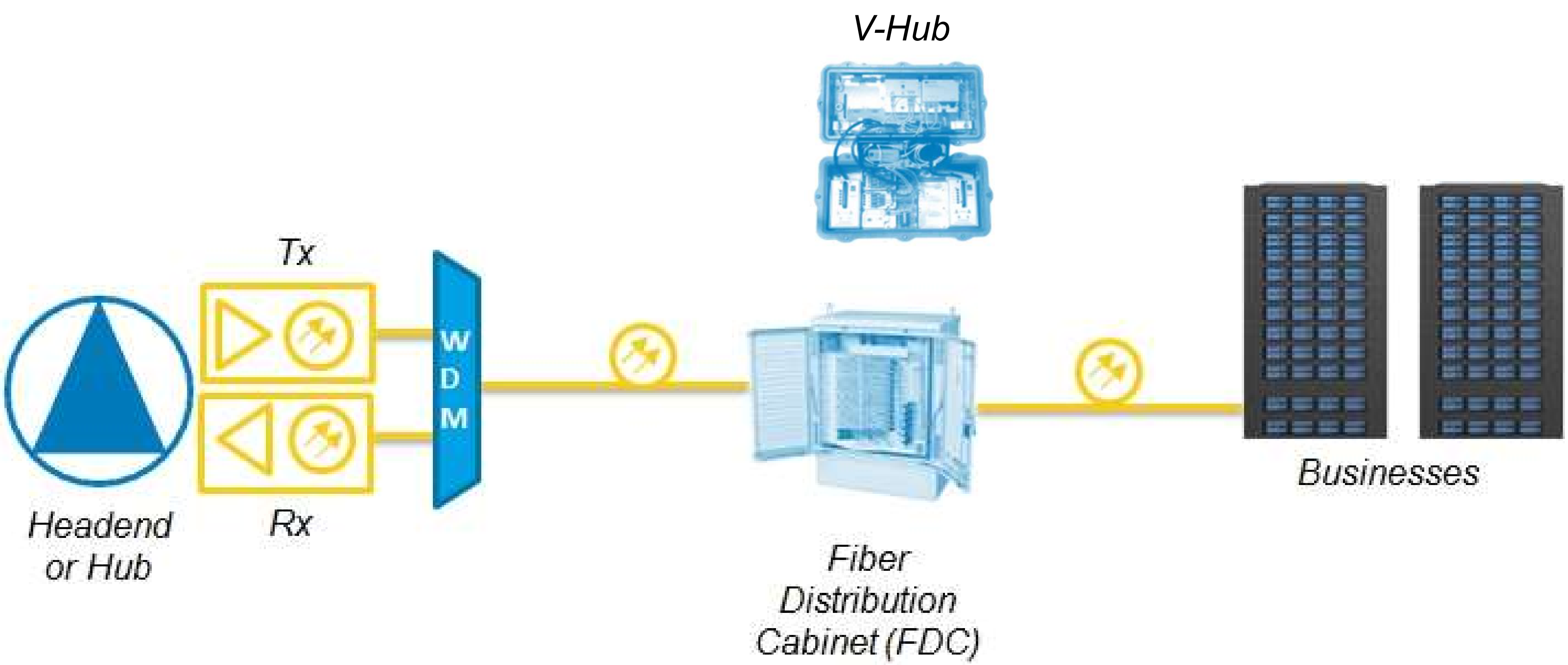

Fiber to the MDU (Apartment)

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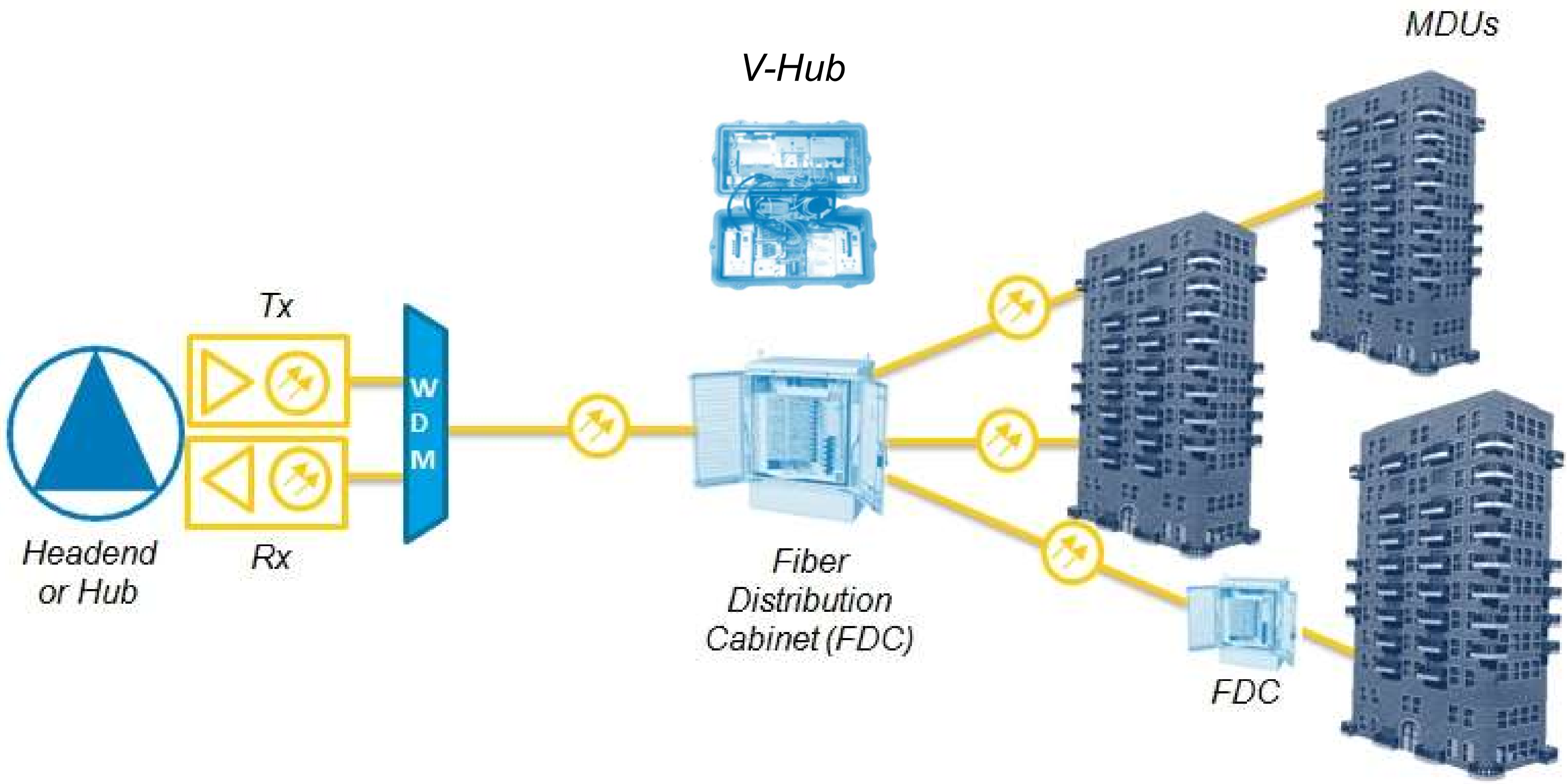

Fiber to the Home or Fiber to the Premises

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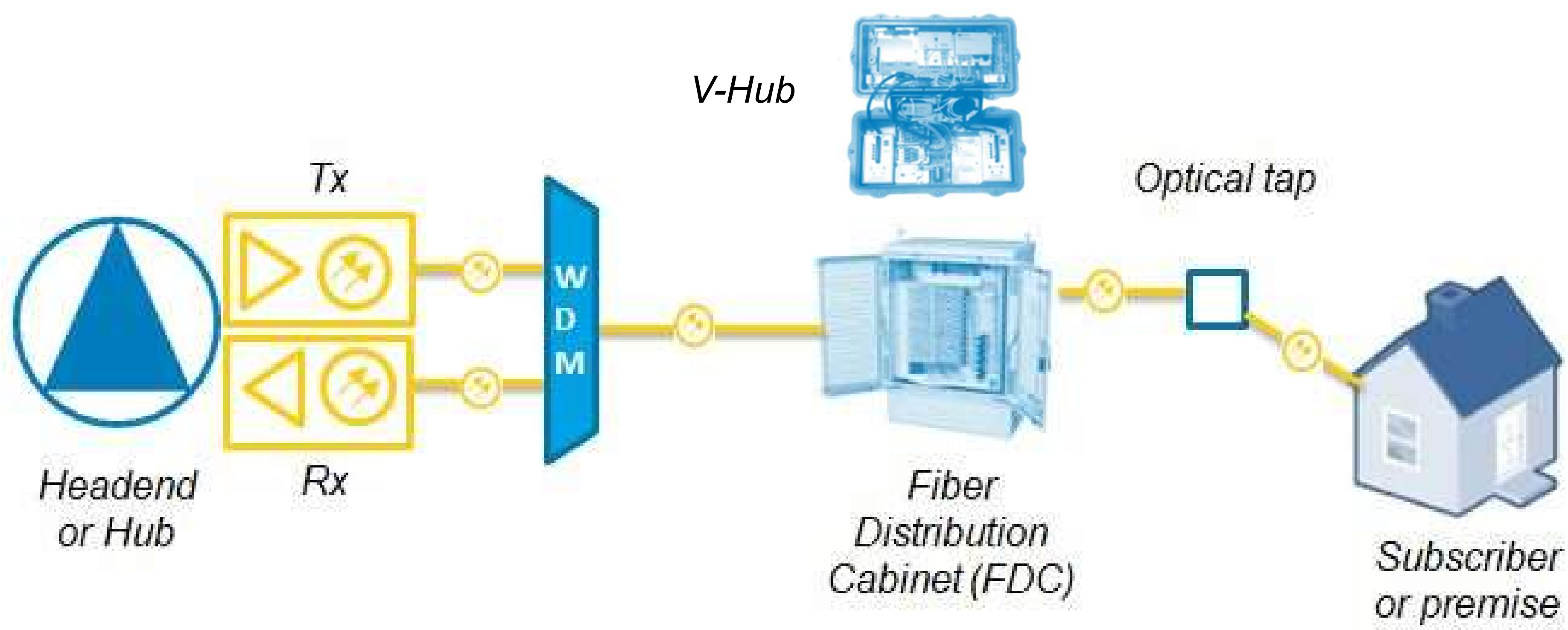
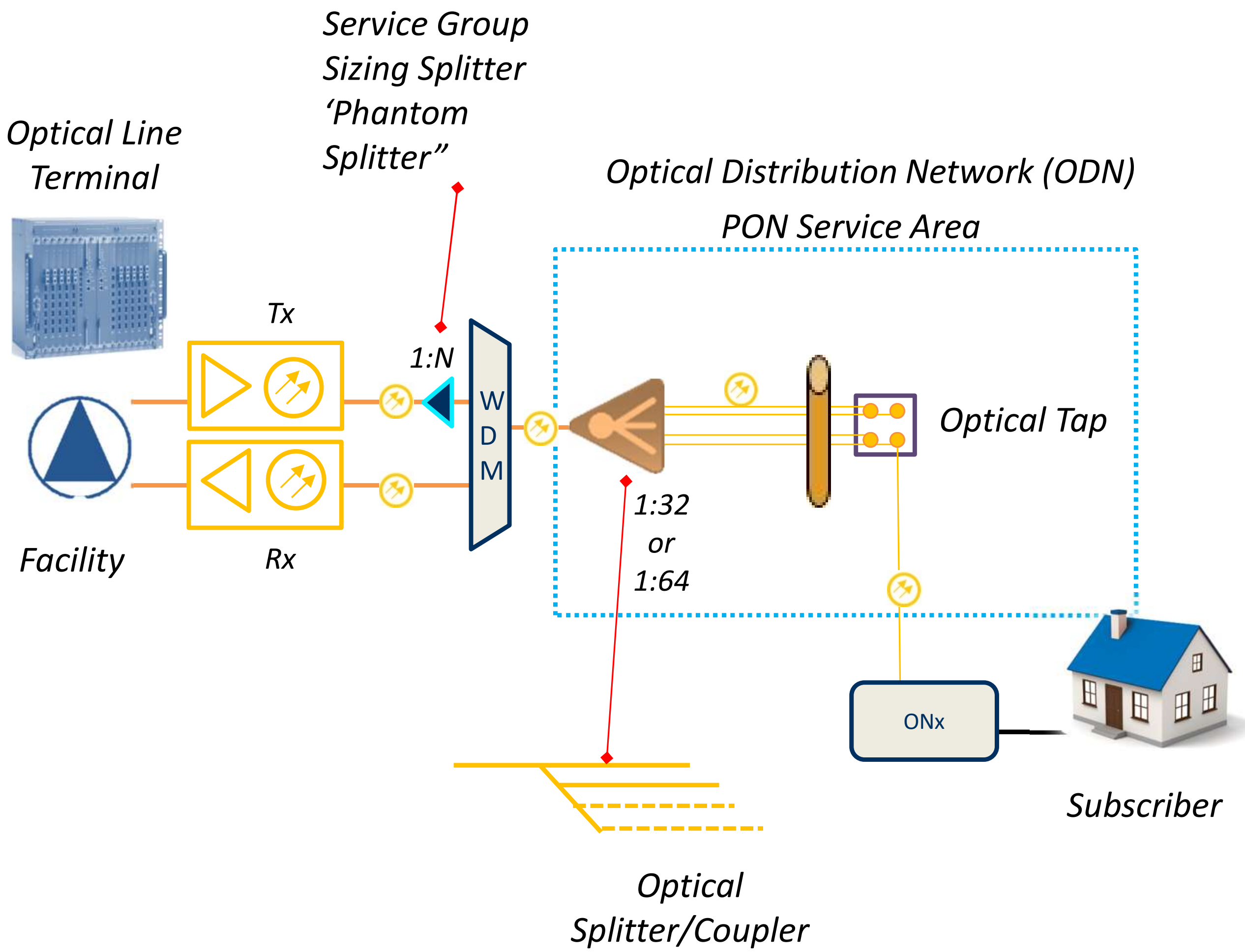


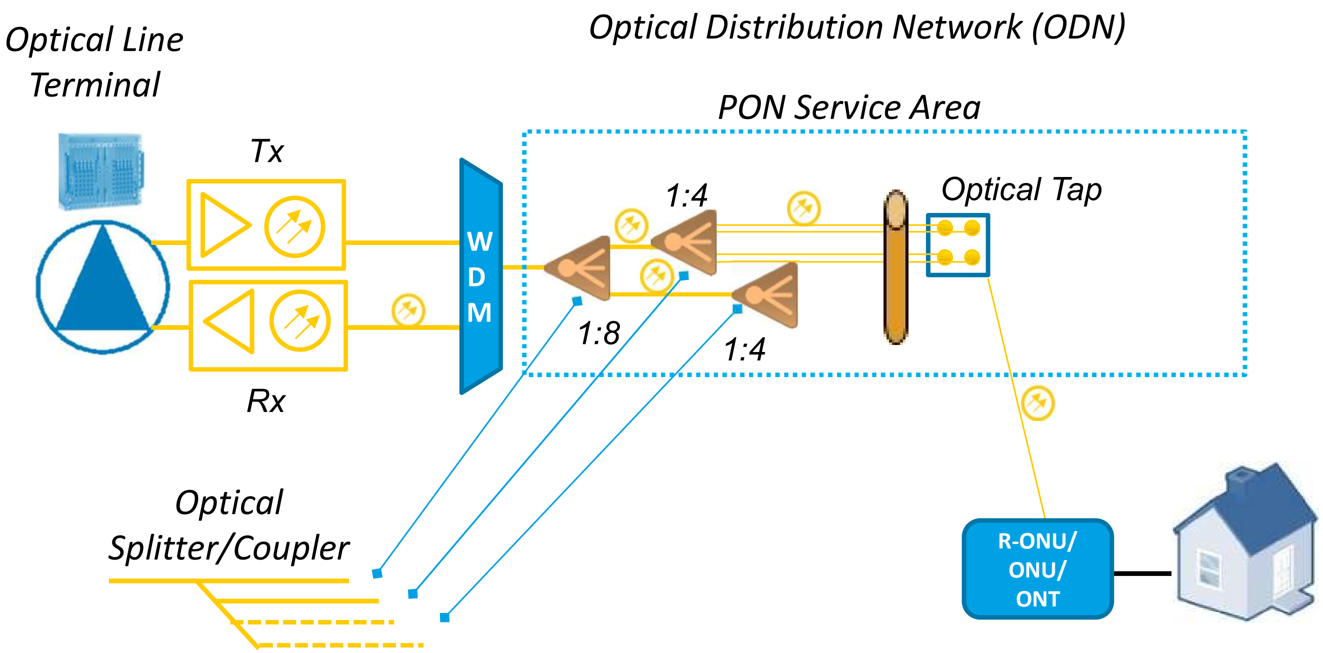
PON Central Split Architecture



Breaking it Down

- Preferred architecture by cable operators
- Headend or hubsite contains Tx and Rx lasers
- Phantom 1:2 split for service group resizing
- OLT used for 1 GPON and 10 XGS-PON
- 32 or 64 sub PON service area
- ODN
  - 20 km optical fiber
  - 1:16 to 1:128 Splitter
  - Optical taps & drops
- ONT at subscriber

PON Distributed Split Architecture



Another popular PON architecture, not a preferred approach.

Breaking it Down

- Headend or hubsite contains Tx and Rx lasers
- OLT used for 1GE-PON and 10GE-PON
- 32 sub PON service area in this example
- ODN
  - 20 km optical fiber
  - 1:8 split feeds 1:4 splits
  - Optical taps
  - Optical drops
- ONU, ONT or RFoG ONU at subscriber

HFC Overlay using Passive Optical Network

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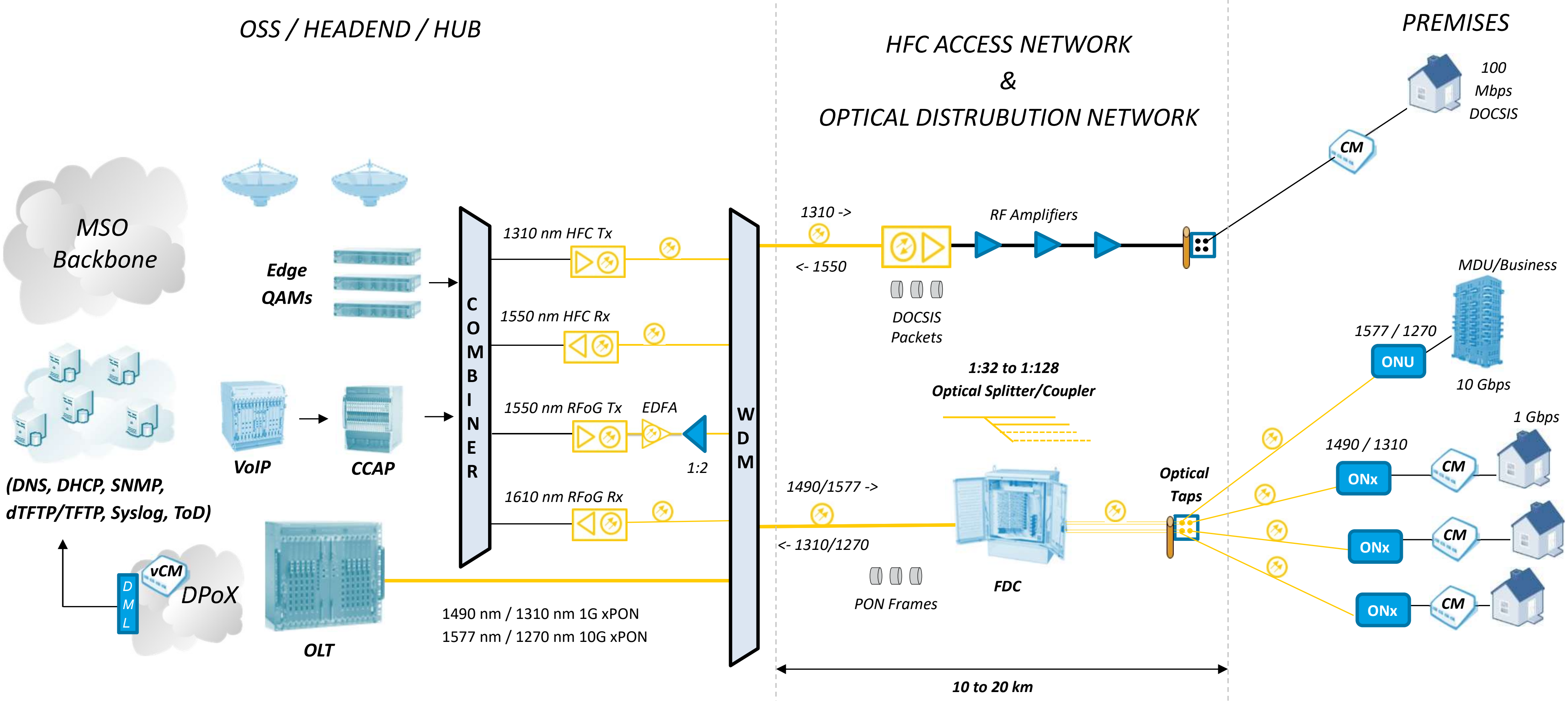

Summary

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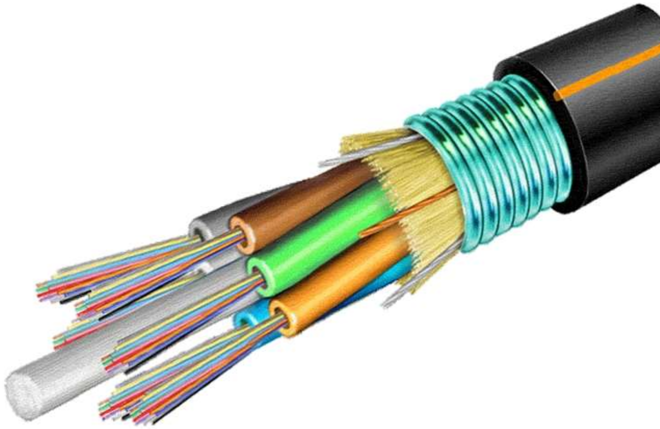
	Standard / Option	Distance	Split / Mux	Bandwidth (DS/US)	Protocol	Video	Wavelengths
DAA	R-PHY, MAC/PHY & Split MAC	Varies	n/a	Depends on DOCSIS	DOCSIS	RF/MPEG	1550 nm DS 1310 nm US
Fiber Deep	Node + 0	Varies	DWDM	Depends on DOCSIS or PON	DOCSIS, Ethernet, GEM	RF/MPEG, IP, RF Overlay	1550 nm DS 1310 nm US
PON	ITU-G.982	20 km	32	10 Mbps / 10 Mbps	SONET/SDH, ATM, T1/E1	n/a	1550 nm DS 1310 nm US
A-PON	ITU-G.983	20 km	32	622 Mbps / 155 Mbps	ATM	n/a	1550 nm DS 1310 nm US
B-PON	ITU-G.983	20 km	32	622 Mbps / 155 Mbps	POTS, ISDN, SONET/SDH, ATM, Ethernet, T1/E1	RF Overlay	1550 nm RF DS 1490 nm DS 1310 nm US
G-PON	ITU-G.984	20 km	32 and 64	2.488 Gbps / 1.244 Gbps	GEM	Data Only	1550 nm RF DS 1490 nm DS 1310 nm US
NG-PON1 XG-PON1	ITU-G.987	20 to 60 km	32 and 64	10 Gbps / 2.5 Gbps	GEM	RF Overlay w/ WDM	1577 nm DS 1270 nm US
NG-PON2 TDWM-PON	ITU-G.989	20 to 60 km	32, 64, 128 and 256	2.488 – 10 Gbps	XGEM	RF Overlay w/ WDM	1596-1603 nm DS 1524-1544 nm US Wide
E-PON / GE-PON	IEEE 802.3ah	10 to 20 km	32 and 64	1.244 Gbps	Ethernet	IP	1490 nm DS 1310 nm US
10GE-PON	IEEE 802.3av	10 to 20 km	32, 64, 128, 256 and beyond	10 Gbps	Ethernet	IP	1577 nm DS 1270 nm US
RFoG	SCTE 174	20 km	32, 64 and 128	Depends on DOCSIS	DOCSIS	QAM/FM	1550 nm DS 1310 nm US non-PON 1610 nm US PON

Optical Power Budgets



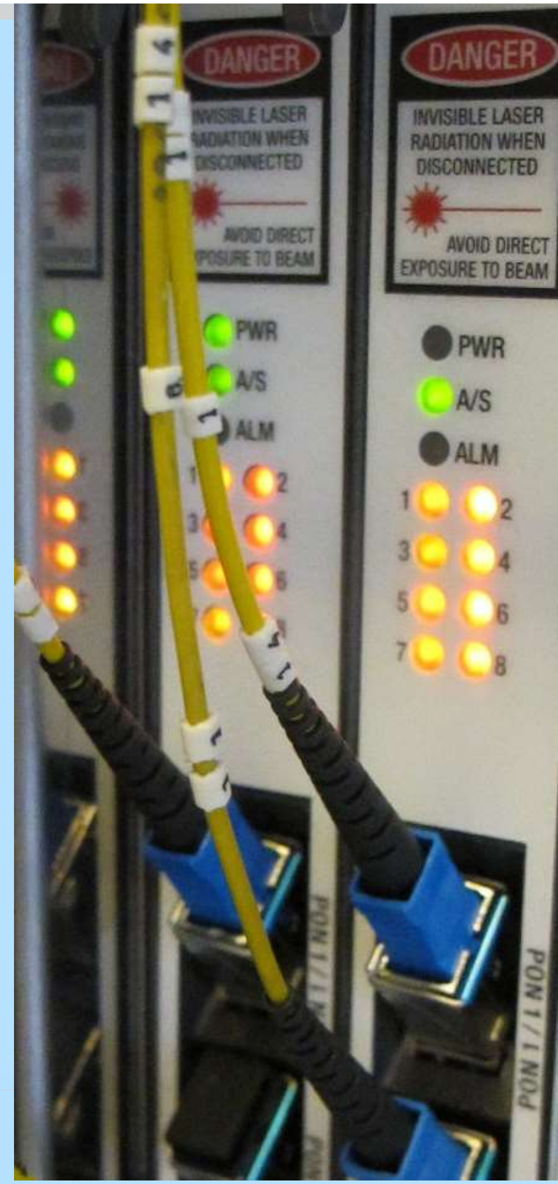
Raise Your Hands….

How do we measure the absolute power level of an optical network?

milliwatts or 10^{-3} watts

How do we measure the relative power level of an optical network?

Decibels relative to a mW



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Absolute (mW) and Relative Measurements (dBm) for Optical Networks

mW	W	dBm	dbW
0	0		
1	0.001	0	-30
2	0.002	3.010	-26.98970004
3	0.003	4.771	-25.22878745
4	0.004	6.021	-23.97940009
5	0.005	6.990	-23.01029996
6	0.006	7.782	-22.2184875
7	0.007	8.451	-21.5490196
8	0.008	9.031	-20.96910013
9	0.009	9.542	-20.45757491
10	0.01	10	-20
100	0.1	20	-10
1000	1	30	0

<u>Rule #1</u>
1 mW = 0 dBm
(starting point)

Absolute (mW) and Relative Measurements (dBm) for Optical Networks

mW	W	dBm	dbW
0	0	∞	
1	0.001	0	-30
2	0.002	3.010	-26.98970004
3	0.003	4.771	-25.22878745
4	0.004	6.021	-23.97940009
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8	0.008	9.031	-20.96910013
9	0.009	9.542	-20.45757491
10	0.01	10	-20
100	0.1	20	-10
1000	1	30	0

<u>Rule #2</u>
Double mW (power) increase by 3 dB
1 mW = 0 dBm
2 mW = 3 dBm
4 mW = 6 dBm
8 mW = 9 dBm

<u>Rule #3</u>
Half mW (power) decrease by 3 dB
8 mW = 9 dBm
4 mW = 6 dBm
2 mW = 3 dBm
1 mW = 0 dBm

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Absolute (mW) and Relative Measurements (dBm) for Optical Networks

<u>Rule #4</u>
Add 10 dB
increase mW x 10
0 dBm = 1 mW
10 dBm = 10 mW
20 dBm = 100 mW
30 dBm = 1000 mW

<u>Rule #5</u>
Subtract 10 dB
increase mW / 10
30 dBm = 1000 mW
20 dBm = 100 mW
10 dBm = 10 mW
0 dBm = 1 mW

mW	W	dBm	dbW
0	0	∞	
1	0.001	0	-30
2	0.002	3.010	-26.98970004
3	0.003	4.771	-25.22878745
4	0.004	6.021	-23.97940009
5	0.005	6.990	-23.01029996
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8	0.008	9.031	-20.96910013
9	0.009	9.542	-20.45757491
1 10	0.01	2 10	-20
3 100	0.1	4 20	-10
5 1000	1	6 30	0

Raise Your Hands….

What is the desired optical receive level at the ONx or OLT?

-25 dBm or better?

Most ONx manufactures support a dynamic range for dBm and mW.

dBm = -28 dBm to – 8 dBm

mW = 0.0016 mW to .16 mW

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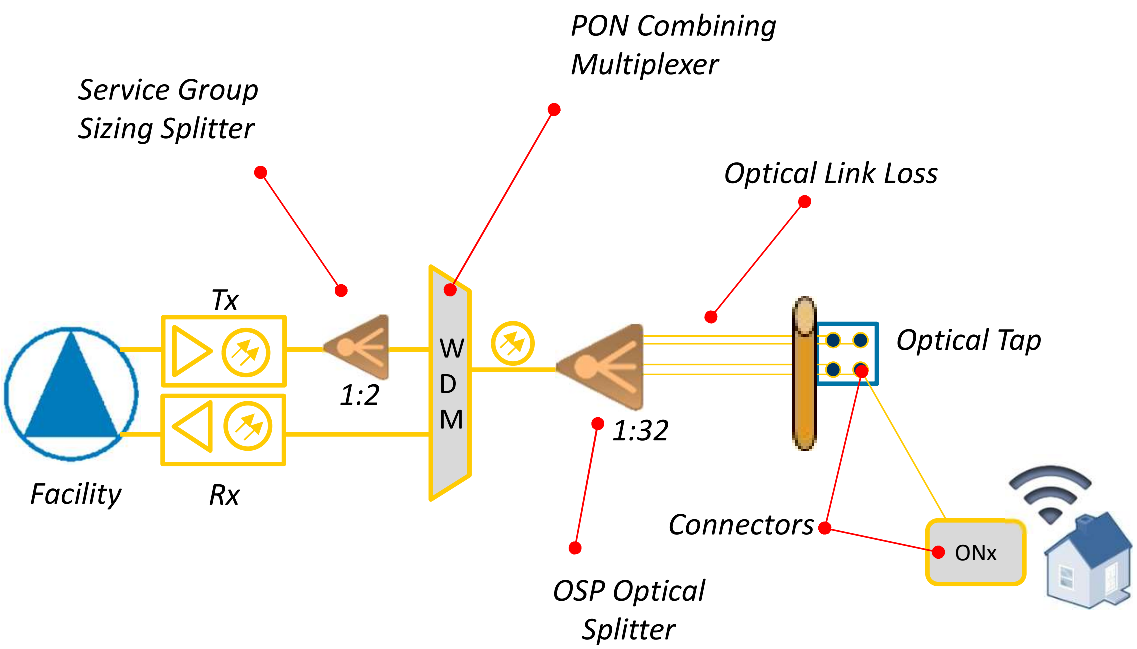
Downstream Loss Budget Scenario



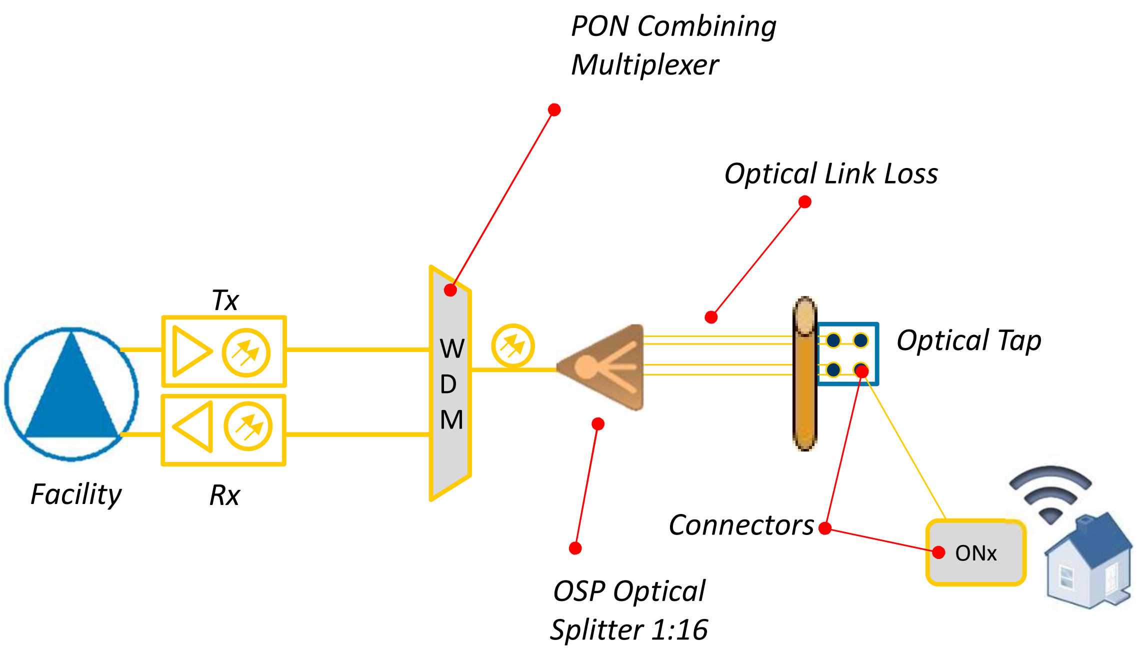
Budget

1. Service Group Sizing Splitter
   - 3.5 dB
2. PON Combining Multiplexer (WDM)
   - 3 dB
3. Optical Link Loss (1550 nm)
   - .18 dB/km x 20 km = 3.6 dB
4. Connector Loss Headroom
   - 2 dB
5. OSP Splitter Loss
   - 15 dB + 2.5 dB overhead

= 29.6 dB of loss

ODN = 20 km typical

Activity: Downstream Loss Budget Calculation

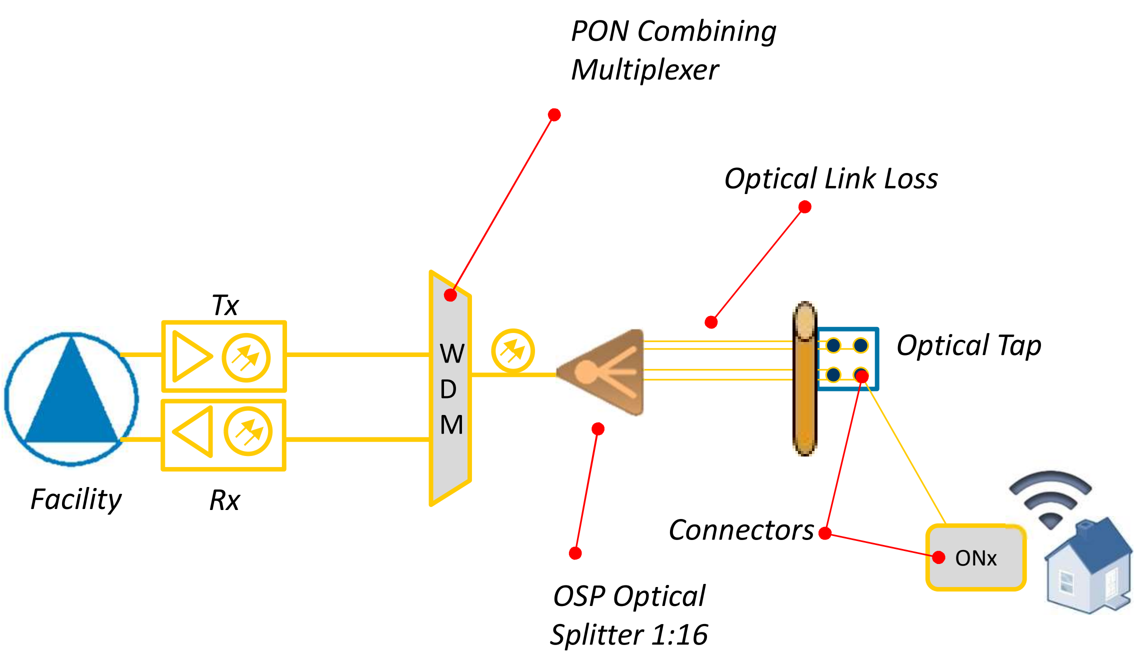


ODN = 10 km

Budget Scenario

1. No Service Group Sizing Splitter
2. PON Combining Multiplexer
3. Optical Link Loss (1550 nm)
   - .25 dB per km
4. Connector Loss Headroom
5. OSP Splitter Loss

Activity: Downstream Loss Budget Calculation



ODN = 10 km

Budget Scenario

1. No Service Group Sizing Splitter
   - 0 dB
2. PON Combining Multiplexer
   - 3 dB
3. Optical Link Loss (1550 nm)
   - .25 dB per km = 2.5 dB
4. Connector Loss Headroom
   - 2 dB
5. OSP Splitter Loss
   - 12 dB + 2.5 overhead = 14.5 dB

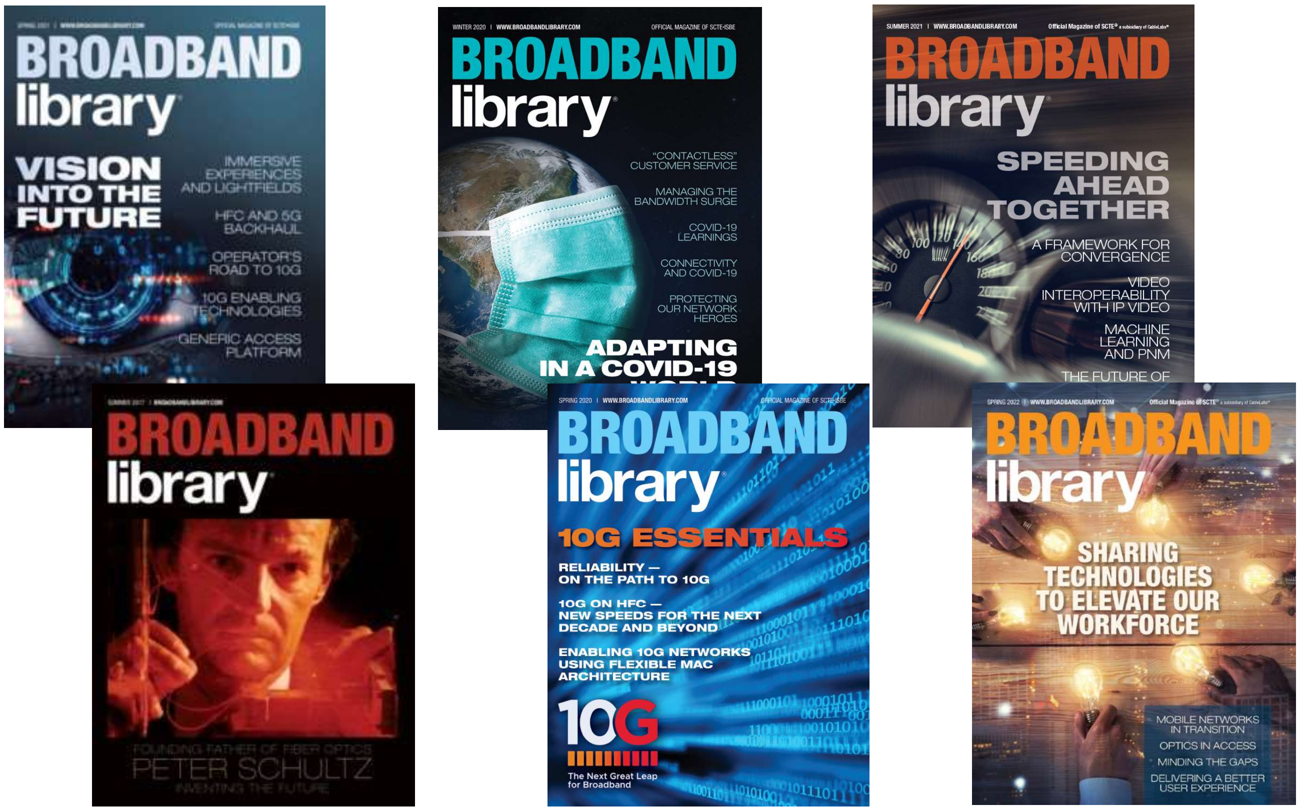
= 22.0 dB of loss

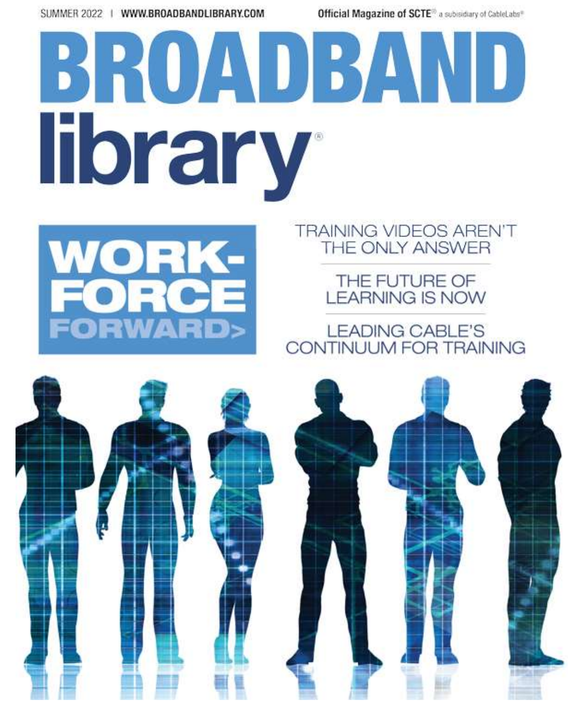
Conclusion

- A view of the industry and activities
- Identified latest optical standards deployed by SCTE members
- Recognized the FTTH components, various architectures used, and key differences from an HFC network
- Explored optical power budgets
- Calculated an optical power budget

Broadband Library Magazine

Member Benefit





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What are Optical Signals?

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Steve is an international SME and thought leader, and the executive director of education and business development for SCTE. He is responsible for overseeing the architecture and evolution of educational programs, credentialing, and customized career progressions, as well as business development and partnerships. His team is responsible for an education library that is now 900+ modules, designed to drive business results. With more than 30 years in education, he has taught much of the contents of the library, with a dynamic approach to the delivery of highly complex topics.

You may have noticed that optical fiber has been more abundant in our access networks over the last few years. Operators are creating the next generation access networks to deliver 10G and beyond. The industry has deployed distinct networks that have leveraged additional optical signals like fiber to the x (FTTx), fiber deep, and distributed access architecture (DAA) networks. Remember, HFC has been using optical signals for quite some time now. There are numerous reasons for fiber deployments: less attenuation (loss) than copper (e.g., coaxial cable), less weight than copper cabling, reduced deployment cost, information capacity (50 THz), and immunity to electromagnetic radiation. Furthermore, optical signals using single mode fiber are able to propagate tens of kilometers (km) without amplification.

A common misconception is that optical signals and radio frequency (RF) signals are not related. Both optical and RF signals are part of the electromagnetic spectrum, with RF having longer wavelengths and lower frequencies than optical signals. The RF part of the electromagnetic spectrum is in the roughly 3 kHz to 300 GHz range, while light (infrared, visible, and ultraviolet) is in the roughly 300 GHz to 30 PHz range. Our cable networks operate in the MHz and lower GHz range, and our fiber links in the THz range.. Previous knowledge of RF in the coaxial domain provides a strong foundation for those that will be working in the optical domain. For our telecommunications networks, optical communication to the premises occurs when a bidirectional optical link is established over the access network. The link is used to pass information in the form of optical signals between a transmitter and receiver. For example, in fiber to the home (FTTH) a telecommunication operator's facility will transmit optical signals from the optical line terminal (OLT) to the customer premises' optical network device (ONx) where they are received. The link in this example is sending information as an optical signal over the access network using pulses of light generated by a laser.

Optical signals are electromagnetic (EM) energy waves, or EM radiation. The EM spectrum includes RF, light, X-rays, and gamma rays. The optical signals in the EM spectrum comprise oscillating electric fields and magnetic fields that are orthogonal to one another, traveling in a particular direction as shown in Figure 2.

From the early days of a person's career in telecommunications they know the higher the frequency the greater the loss of energy. The good news is that the loss in optical fiber is much less per unit length than coaxial cabling, making optical fiber ideal for achieving a long signal distance (km) with low attenuation. When working with optical signals, the wavelength (e.g., 1550 nm) is used instead of its frequency. One reason is that optical signals use light, and this is defined by wavelength. A wavelength is shown in Figure 2, the distance between the peaks of an electromagnetic wave. The wavelengths for optical signals are shorter due to their higher frequency, expressed in nanometers (10^{-9} meter). A nm is a unit of length that is equivalent to a billionth of a meter. Finally, wavelength and frequency are inversely related, as wavelengths increase, frequency decreases. For example, 1490 nm is a lower frequency than 1290 nm.

Light is EM energy waves that travel through free space at about 3×10^8 m/s. To harness the power of light for transmitting information, a channel or wave guide in the form of optical fiber is used to transmit information over an access network. Furthermore, all optical signals in telecommunications must be encoded with the information to be transmitted (e.g., TDM = time division multiplexing) before they are transmitted and then decoded before the information is to be received by customer premises equipment (CPE).

In today's access networks we use three main types of optical signals. The first type is the analog optical signal, simply referred to as analog intensity modulation (AIM). AIM is used to modulate ("encode") the optical signal with RF before it is transmitted over the link in an HFC

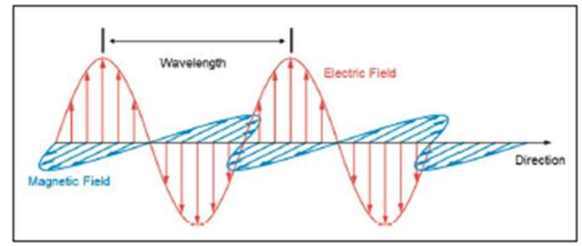

Figure 2. An electromagnetic signal

1490 nm ≈ 201.1 THz

1310 nm ≈ 228.8 THz

Figure 3. Inverse relationship of wavelength and frequency

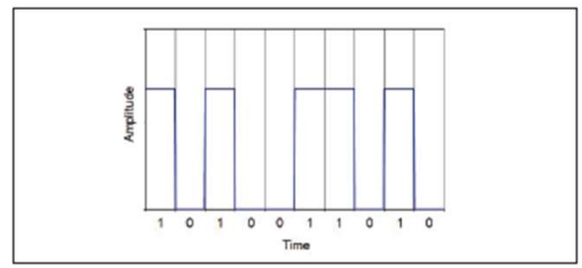

Figure 4. Baseband digital modulation

THANK YOU!

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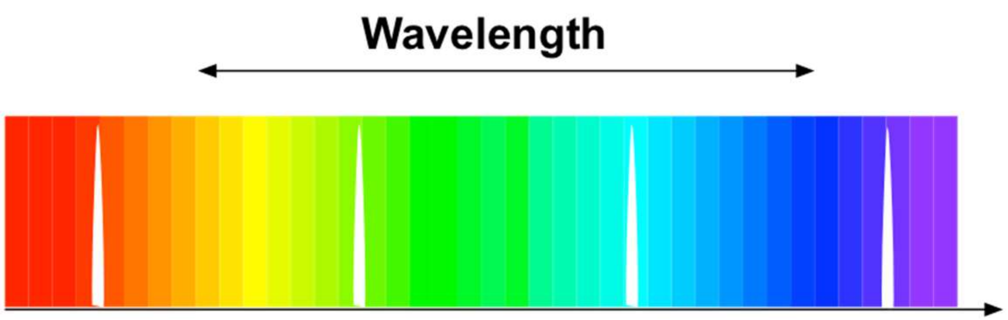
The Future of Optics

Analog Optics

- The bottleneck over our networks, and the most costly to upgrade, is the fiber infrastructure between the headend and the fiber node.
- Access network DS performance is largely determined by the AM optical link
- Analog optics do not work well with protocol like IP, since IP is bursty in nature.
- Analog high transport medium requires increasing the optical TX power, reduces the number of optical analog carriers a fiber can support

Fiber spectrum with 4 analog carriers =



Digital Optics (non-coherent)

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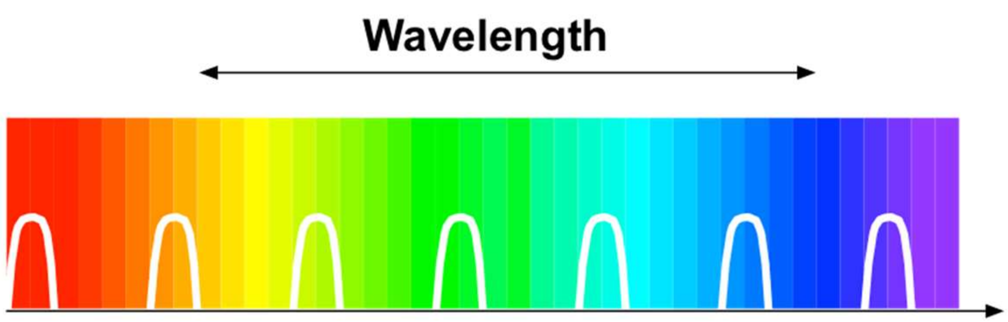
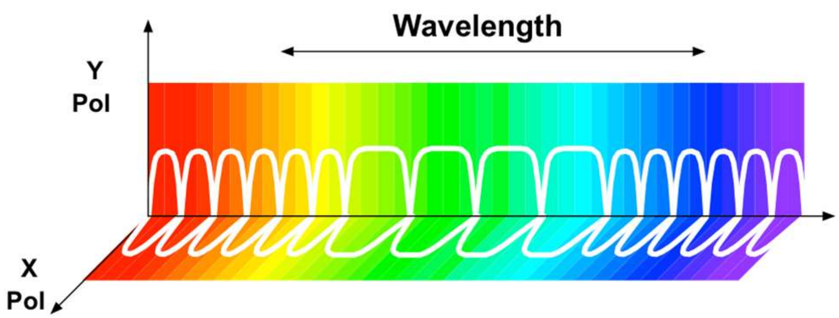
- A digital optical link (non-coherent) uses intensity modulated on-off keying (OOK) such as the ones found in 10 gigabit Ethernet links and in passive optical networks (PON). High-capacity supports 100 Gbps using 10 wavelengths.
- Digital optics increases the number of wavelength per fiber.
- Node output S/N performance can now match the HE/hub.
- OOK is a non-coherent system, achieved by simply switching the laser source off and on. Non-coherent systems operate at lower power than analog optics and can therefore make better use of the wavelength spectrum in fiber.

Fiber spectrum with intensity modulated non-coherent carriers



Coherent Optics

- In coherent optics, both amplitude and phase modulation are used to send information.
- Enables QPSK and QAM constellations to carry information.
- Optics used for long-haul fiber optic networks, adapted the technology for use in short-haul access networks, reducing cost



Fiber spectrum with intensity modulated non-coherent carriers

CableLabs has shown 256 Gbps over an 80 km fiber link, that is just the beginning! Tbps are possible, more than 1,000 times more capacity than we have today.