xPON - Fiber-To-The-x for Cable Operators

October 2014

Agenda

- 1:30-1:40 Introductions
- 1:40-2:30 From HFC Networks to RFoG Networks
  - Optical Fiber in our Networks
  - Extend HFC so that the coax is only in the Home – called RFoG
  - Q&A – white board quiz
- 2:30-2:40 Break
- 2:40- 3:30 Reset to Square One - Ethernet transport
  - Migrate from Media Converter to PON
  - Explain splitting concept
  - Q&A – white board quiz
- 3:30-3:40 Break
- 3:40-4:30 OSP and integration of RFoG and PON
  - Identify where/why each should be used greenfield/brownfield
  - Review Construction practices
  - Q&A – white board quiz

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Fiber-To-The-X for Data, Voice and Video

- Explore the trade-offs and benefits of deploying Fiber-To-The-X architectures for delivery of data, voice and video services to subscribers.
- Solutions will include technologies such as RFoG, EPON, GPON, and point-to-point architectures.
- Alternatives will address high-density and low-density areas such as rural deployments or commercial/industrial parks, and
- Will assess factors that impact return-on-investment, ROI, and Payback periods.
- Comparisons of capital cost, construction capital and operating expenses relative to traditional cable operator HFC networks will be reviewed.
- Discuss how to plan for an FTTx build – designs, skills, tools, test equipment, construction best practices.

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Passive Optical Network

- PON, or Passive Optical Network, is a term that formerly represented modulation and protocol schemes associated with telephony networks.
- Now, it is being used to describe the actual passive optics that can carry a variety of signals, whether from Telcos, data ISPs or cable operators.
- A variety of methods of serving 32 - 64 subscribers from a single PON fiber, using centralized splitters, distributed splitters, or distributed taps, can be utilized for any of the signal formats and have varying benefits depending on high or low-density service areas.

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Market Dynamics Drive New Solutions

- Consumer bandwidth consumption creates network bottlenecks
  - Operators are reconfiguring networks to meet the bandwidth demand.
  - HFC - Higher modulation schemes needed in forward and reverse path to support growth – DOCSIS 3.1 – OFDM
- Wireless bandwidth demand creates demand for backhaul services
  - 4G/LTE networks - exponential growth in bandwidth due to mobile video
  - Cable operators access this revenue opportunity with optical fiber.
- Government funding of rural broadband raises the bar for existing operators to offer competitive services.
  - Stimulus-funded FTTH networks built in rural areas will pull subscribers from adjacent cable operators and promote growth in rural communities.
- Google Fiber – building 32 major cities.

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Network Operators using Fiber for Bandwidth and Revenue

- Cable network operators have deployed video, data and voice networks to capitalize on demand for services which generate profitable revenue, because their networks have provided the needed bandwidth.
- Where bandwidth has been a limitation, a number of other capital-intensive steps have met this need, including:
  - Increasing QAM modulation from 64 to 256 (is 4096 QAM possible?) for digital channels,
  - removing analog channels for a 10:1 channel expansion,
  - Introducing Switched Digital Video, which increases the amount of focused content for a given bandwidth,
  - Introducing more “edge-QAM” devices in the network for customized content
- Other methods of expanding available bandwidth in HFC networks have been used, including
- Deploying fiber optic cable to the subscriber, or FTTx.

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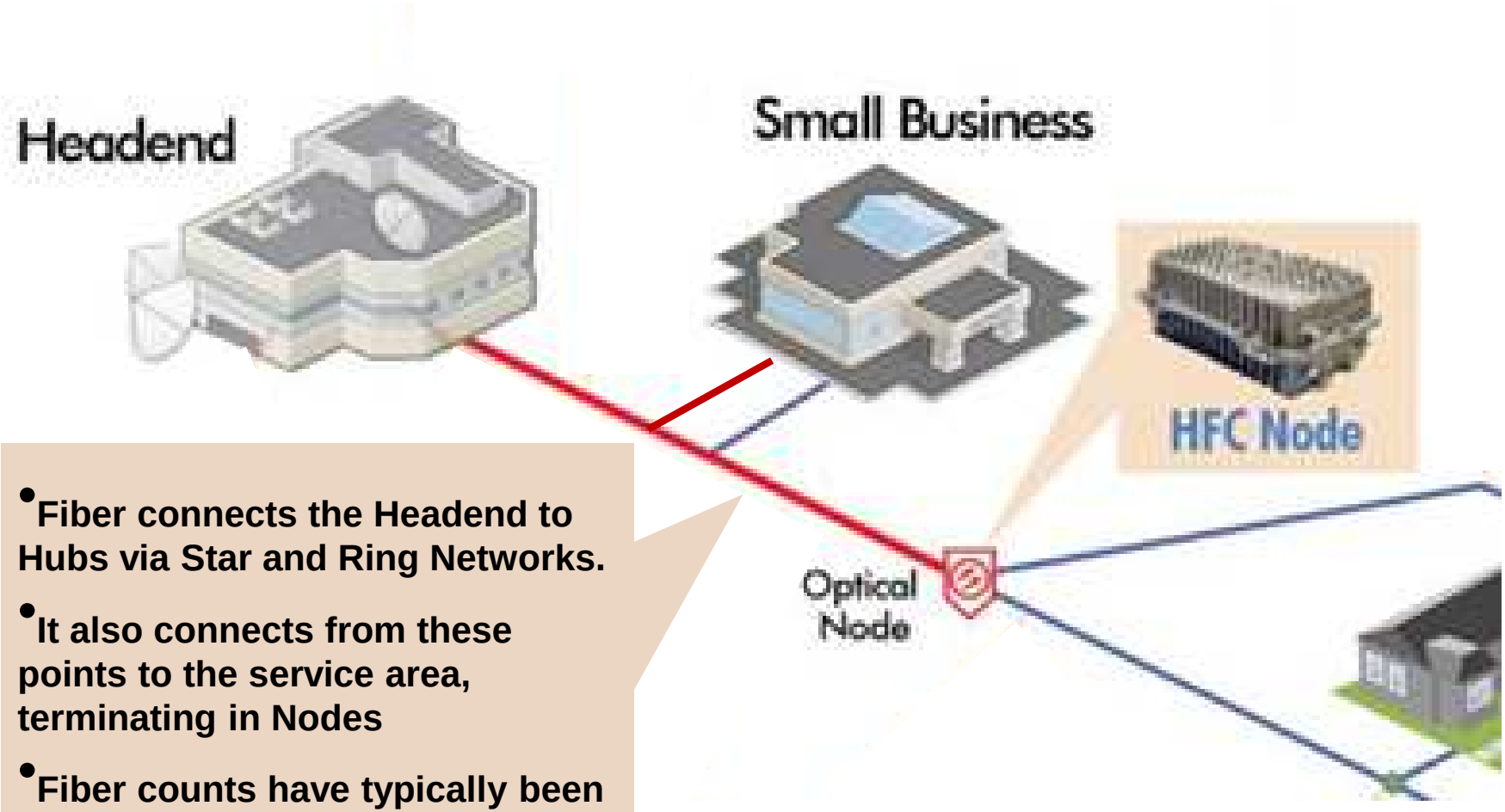
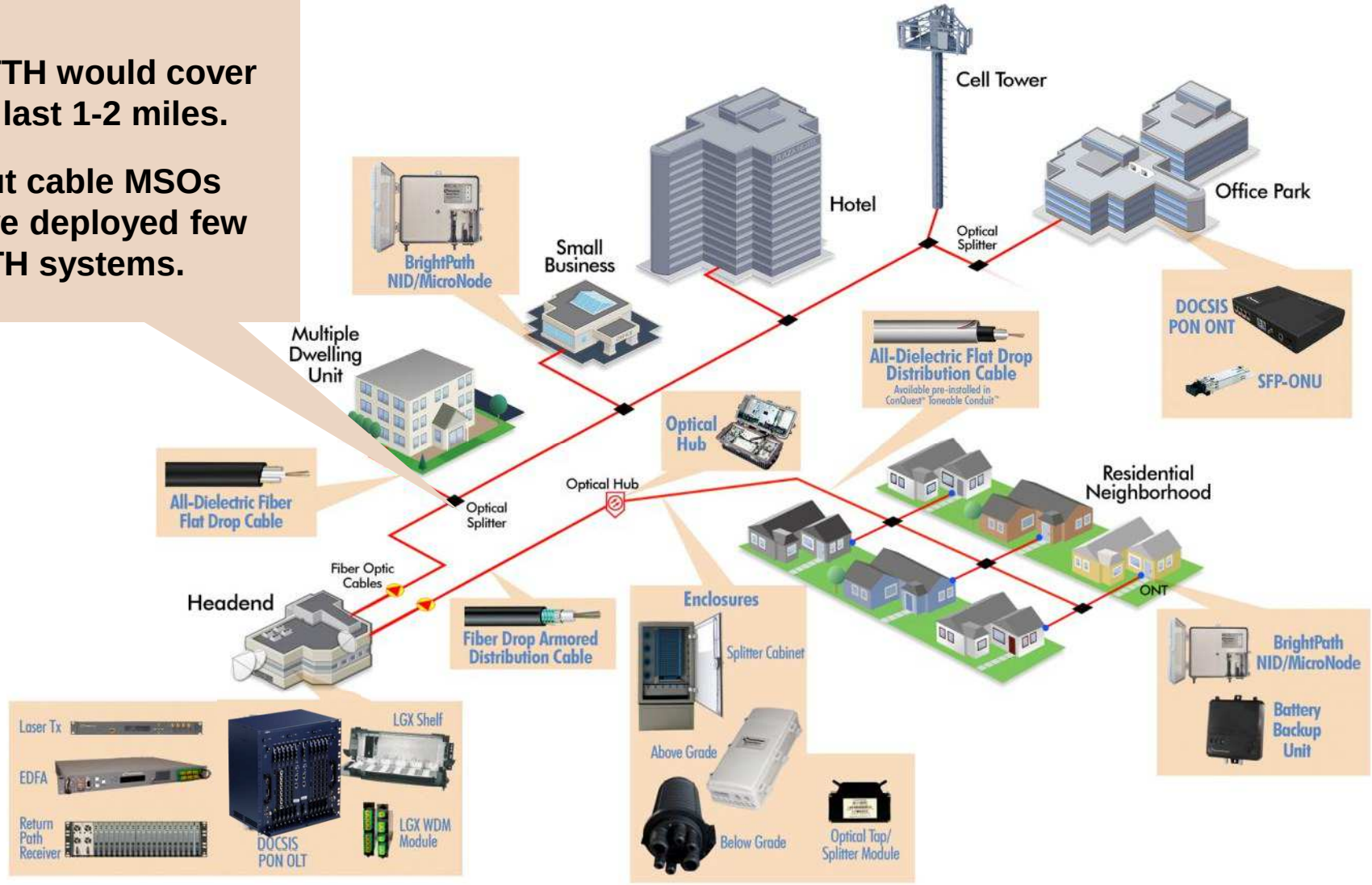
Fiber in the HFC Network



- Fiber connects the Headend to Hubs via Star and Ring Networks.
- It also connects from these points to the service area, terminating in Nodes
- Fiber counts have typically been low, with 4-6 going to the nodes.
- However, fiber probably covers 80 % of the serving area, short of the home by 1-2 miles.

Comprehensive FTTx Solutions

- **FTTH would cover the last 1-2 miles.**
- **But cable MSOs have deployed few FTTH systems.**



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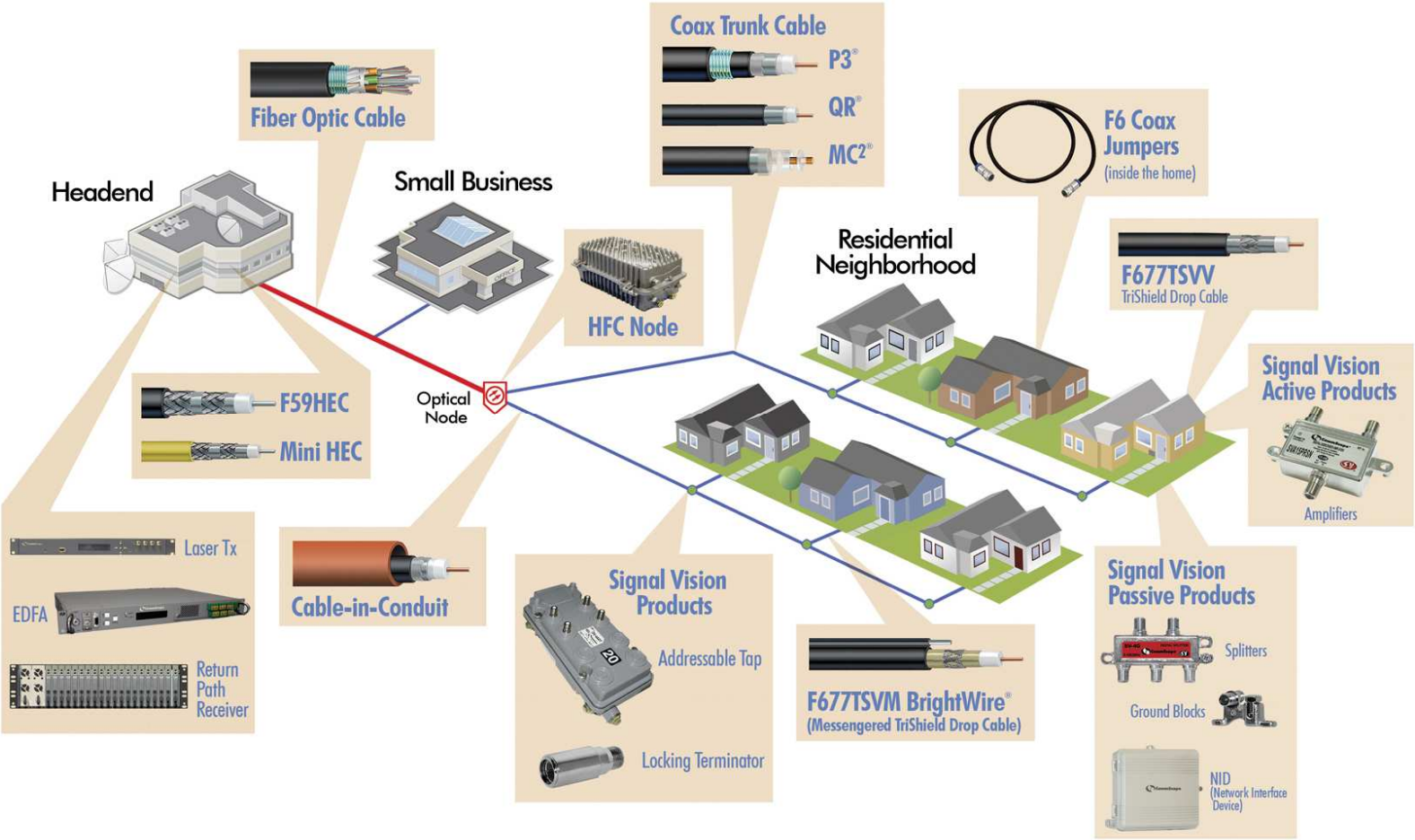
Comprehensive HFC Solutions



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Fiber Migration

- Operators have taken fiber deeper into the network, closing the gap of the last mile between fiber plant and subscribers
- As the RF portion of the plant constitutes the “last mile” and operators are reducing node sizes, from 1000 to 500 to 250 and now 125 homes passed, the fiber is actually getting closer to the home than the last mile.
- As fiber costs are a small portion of the last mile relative to the construction labor costs, and the labor costs climb while fiber gets cheaper, greenfield builds are no longer the sole domain of FTTH networks. Brownfields, or rebuilds of existing plant are becoming a more attractive target.

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DOCSIS
(Data Over Cable Service Interface Specification)

- DOCSIS 3.0 permits bonding of channels to increase data throughput
- Present deployments are bonding 4 channels and offering 100+Mbps downstream and 15 upstream

Channel configuration		Downstream throughput	Upstream throughput
Number of downstream channels	Number of upstream channels	DOCSIS	
4	4	171.52 (152) Mbit/s	122.88 (108) Mbit/s
8	4	343.04 (304) Mbit/s	122.88 (108) Mbit/s

- There is no limit to the number of channels that can be bonded.
- The Cable Show 2011 had demonstrations of 4.5 Gbps with 128 bonded channels.
- Operators are now bonding 16 channels with more recently announced at Expo’14

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Technology Solutions

- **RFoG (RF-over-Glass)**
  - Integrates with existing HFC plant, HE and Subscriber equipment
  - Relies on continued use of video and DOCSIS data services
  - Reduces operating expenses and can even be lower cost than HFC
- **DPoE - DOCSIS Provisioning of E-PON**
  - Uses Gigabit EPON networks with DOCSIS provisioning for transparency of the network. Requires interoperability OLTs and ONUs.
  - Can provide greater data through-put than HFC or RFoG.
- **Co-existence?**
  - The SCTE's RFoG standard provides for the coexistence of the two networks on the same fiber plant.
- **Migration Path?**
  - The fiber optic cable and passives work for either solution, so migration from HFC to RFoG to PON is straightforward and stages CapEx spending to match revenue growth.

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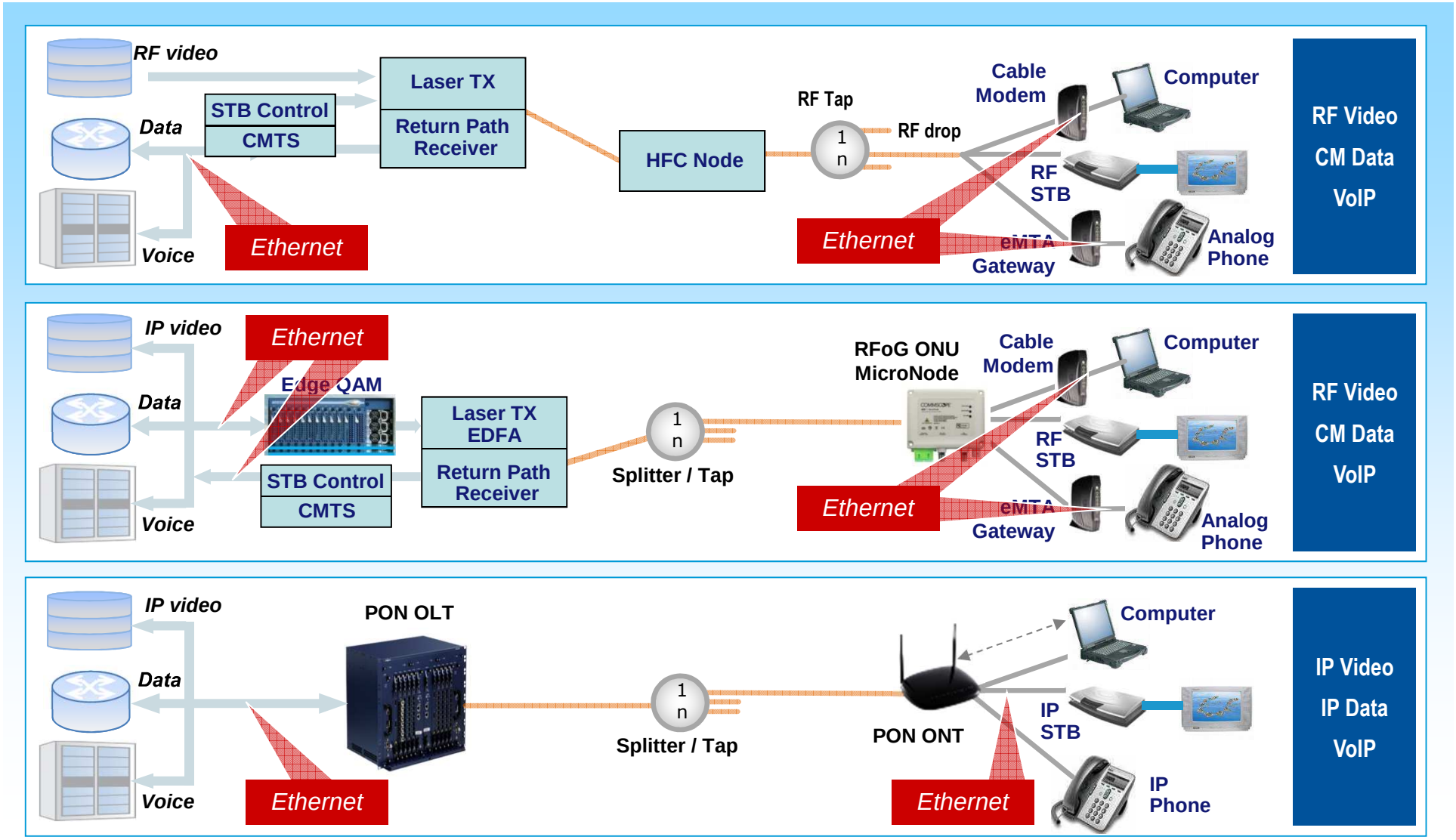
BOS RF-over-Glass RFoG

BrightPath Optical Solutions = BOS

Ethernet Points in Cable Networks



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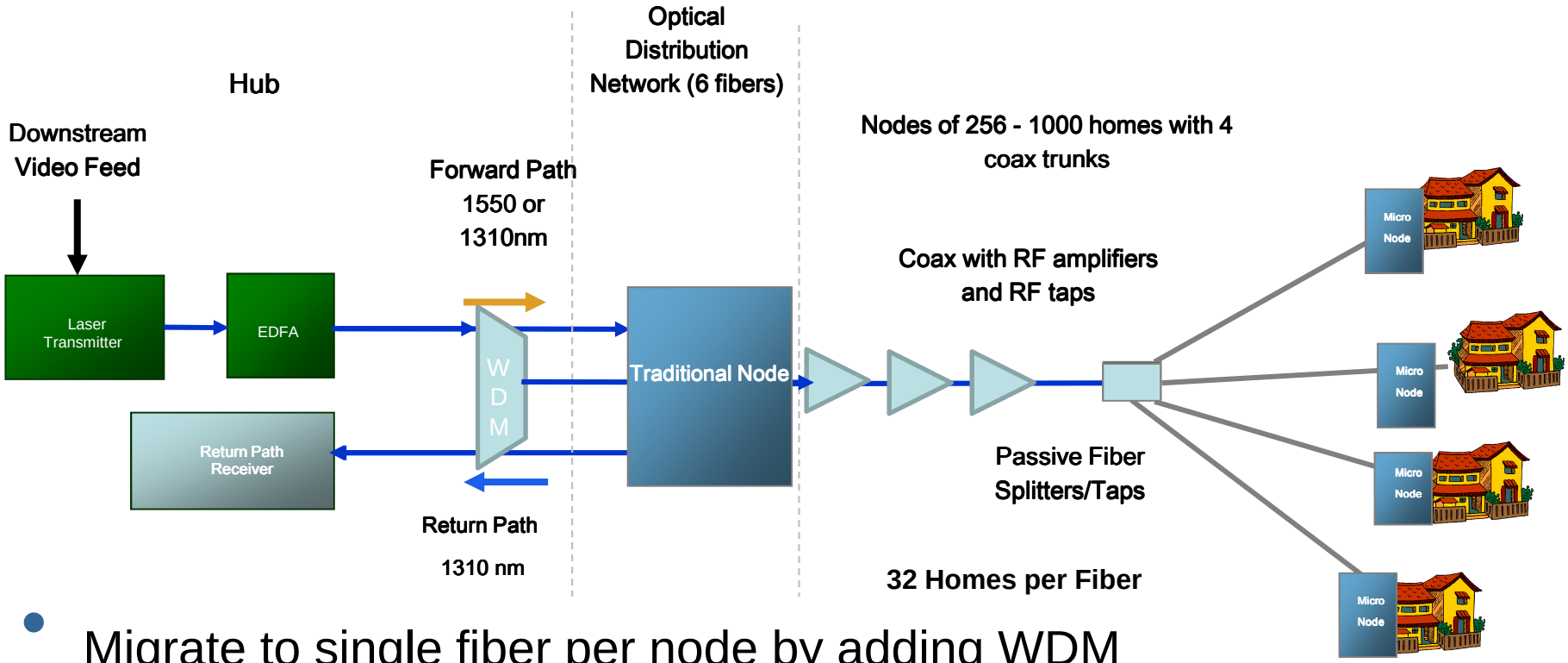
Evolution to RFoG Architecture



- Migrate to single fiber per node by adding WDM
- Remove amplifiers and RF Taps
- Shrink the HFC node and place one with each subscriber
- Take fiber to each home via taps and splitters

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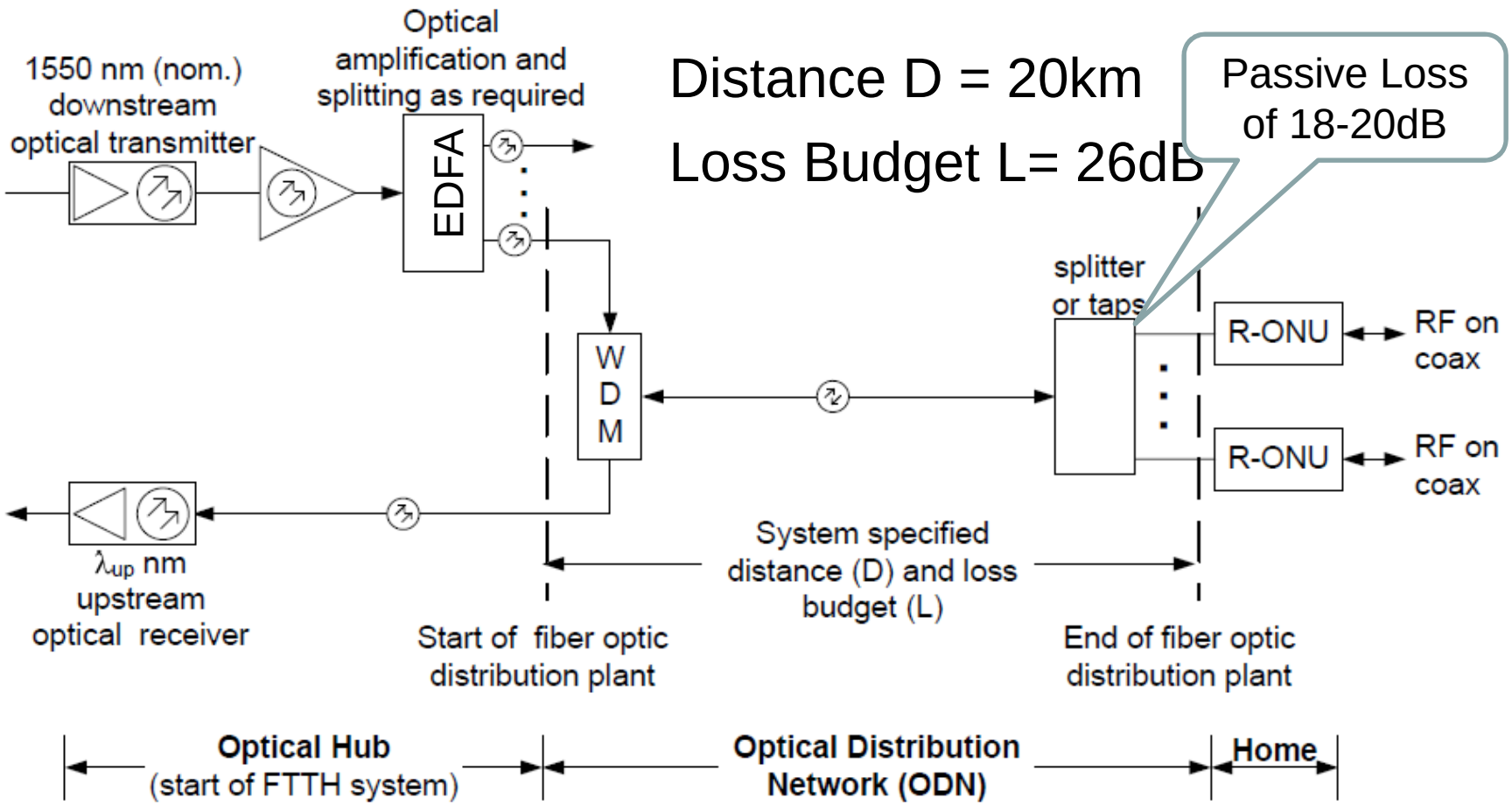
HFC Network with RF Taps

CommScope BOS Optical Network with Distributed Taps

RFoG Reference Architecture



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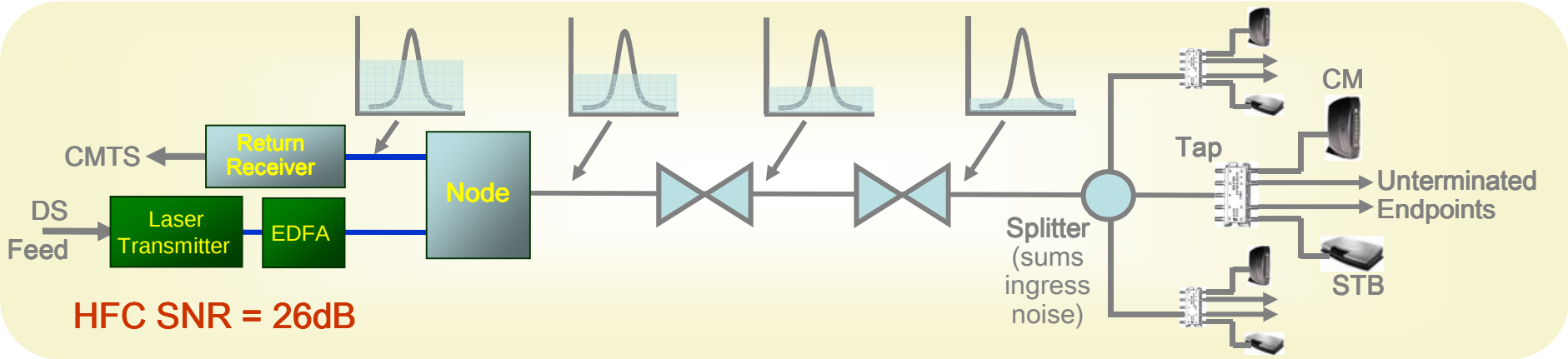
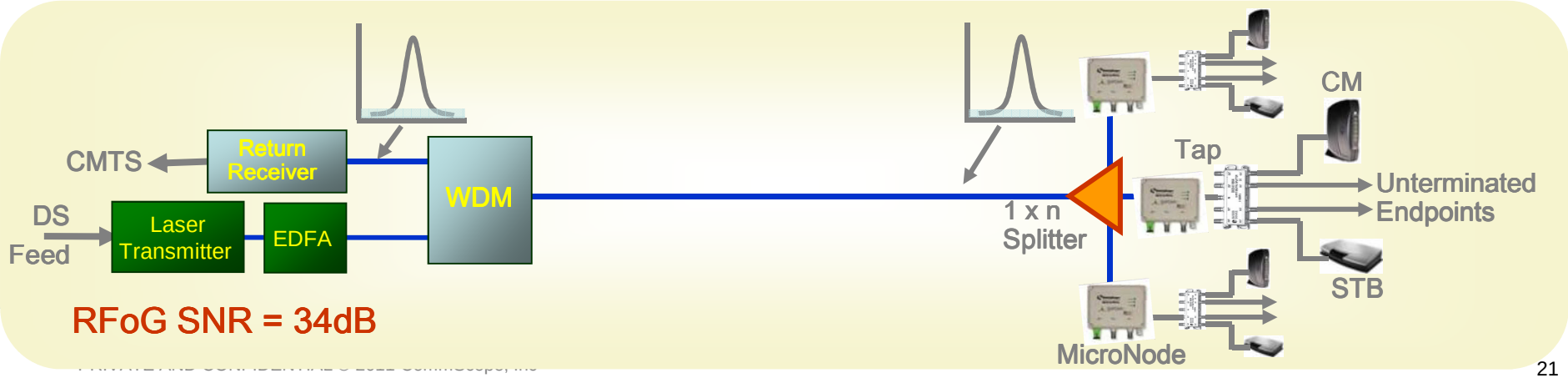
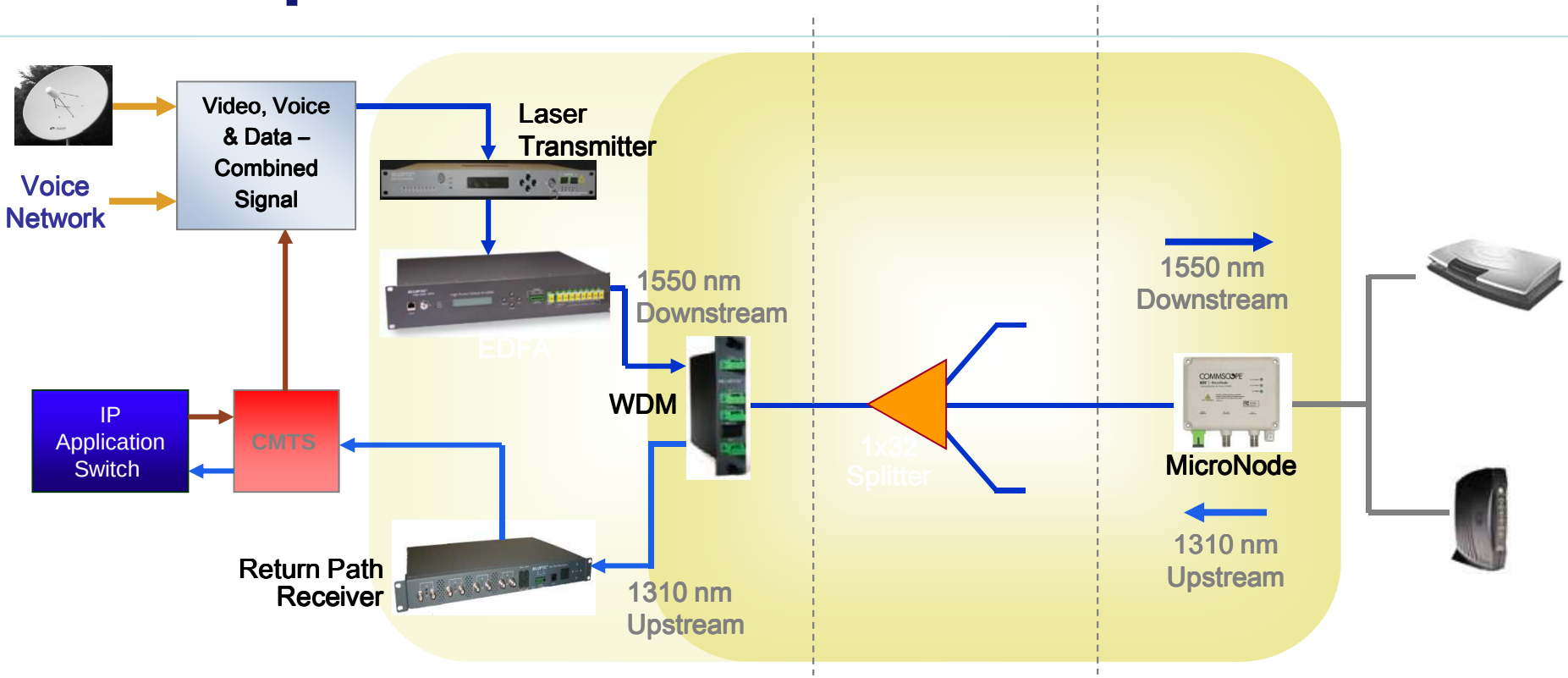
RFoG Improves SNR



- Downstream
  - Better Distance / Density
    - Low Noise Receiver
    - 20Km range with 32 splits
  - Bandwidth to 1GHz
- Upstream - Higher SNR than HFC
  - Recovers 10MHz Lost to Ingress Noise
  - Enables 64QAM upstream channel bonding (27Mbps → 108Mbps)



RFoG Operation



- Single fiber supports both forward and return path
- One return path receiver can be shared by 32 MicroNode transceivers
- MicroNode operates upstream in “Burst Mode”
  - Upstream laser is “on” only during an RF burst from the cable modem or STB
  - Ingress and impulse noise is substantially reduced or eliminated entirely
  - Allows recovery of lower 10MHz of upstream spectrum

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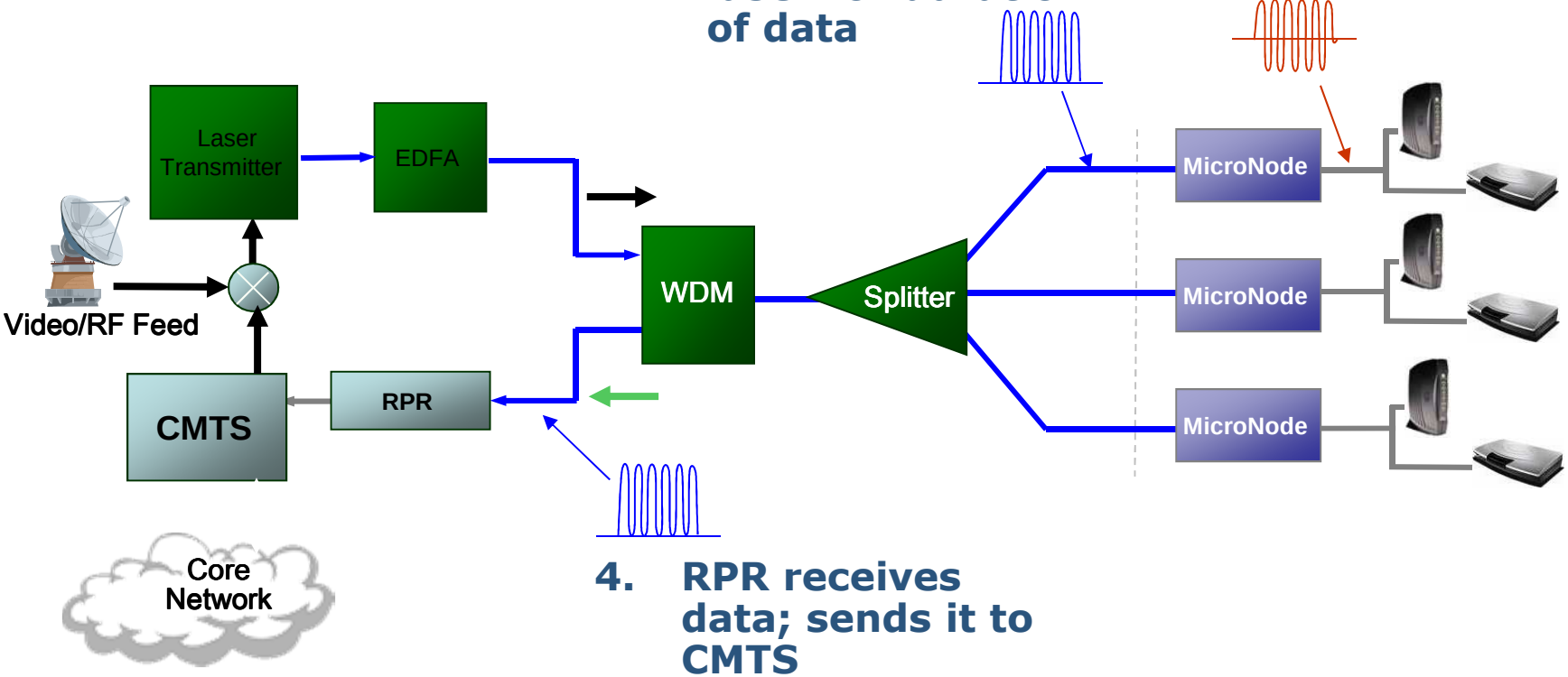
Burst Mode Operation

1. **CMTS schedules the Cable Modem to transmit data**

3. **MicroNode senses burst; turns on laser for duration of data**

2. **Cable modem sends burst of data**



4. **RPR receives data; sends it to CMTS**

5. **CMTS continues to next scheduled device**

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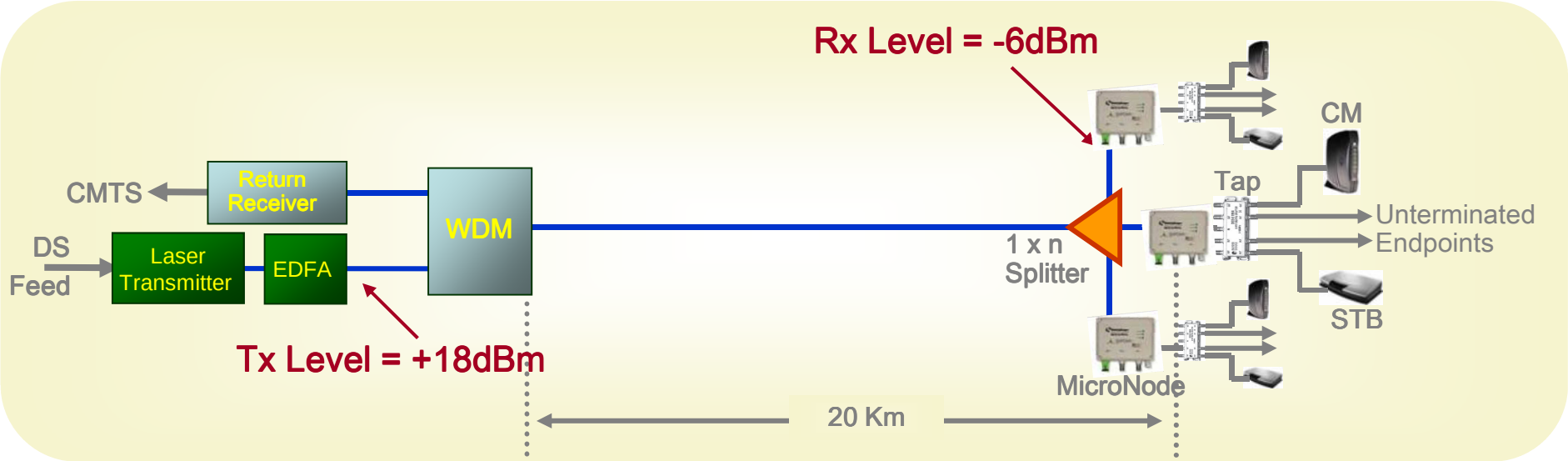
MicroNode Range/Density



- 20Km reach with 32 splits requires 23dB optical budget
- CommScope achieves this with a low-noise receiver, allowing low-power, low-cost EDFAs

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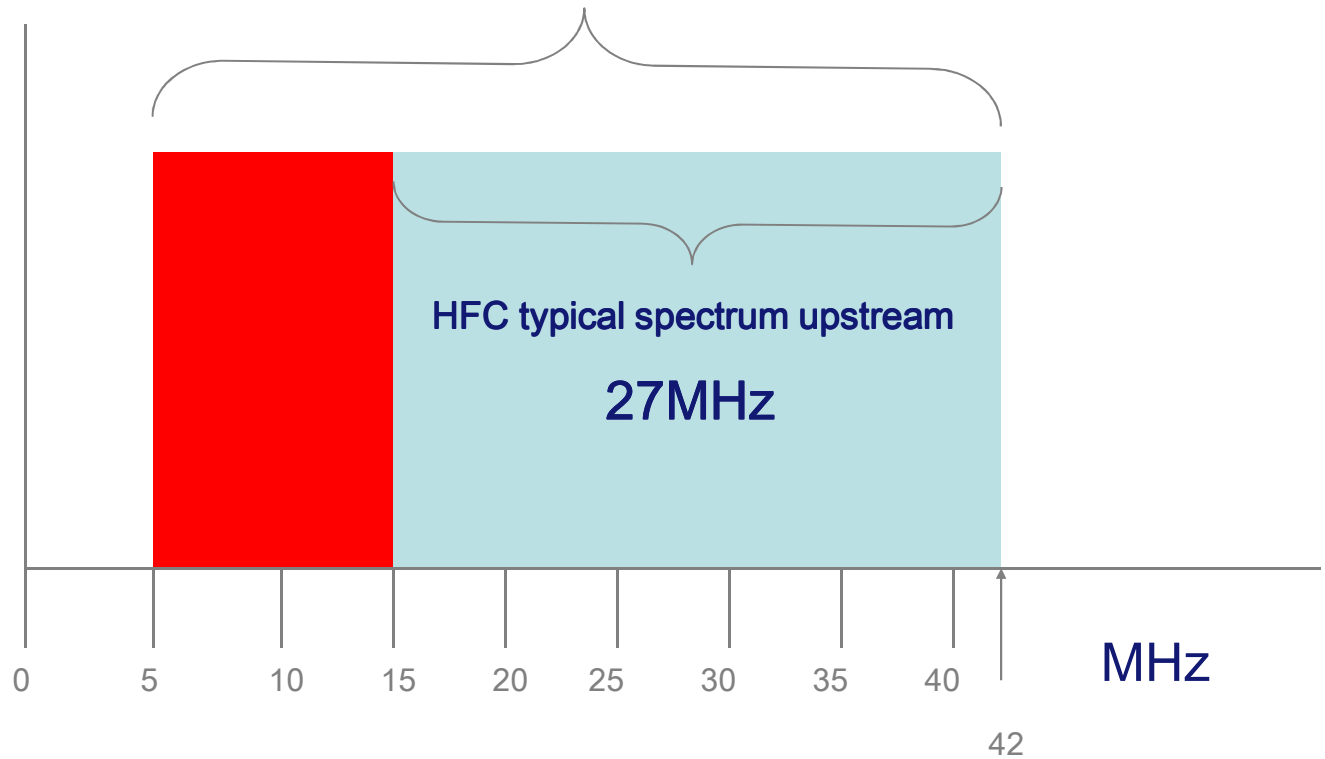
Bandwidth Upstream Improvement

MicroNode usable spectrum upstream = 37MHz



RFoG and MicroNode have 37% more usable RF upstream

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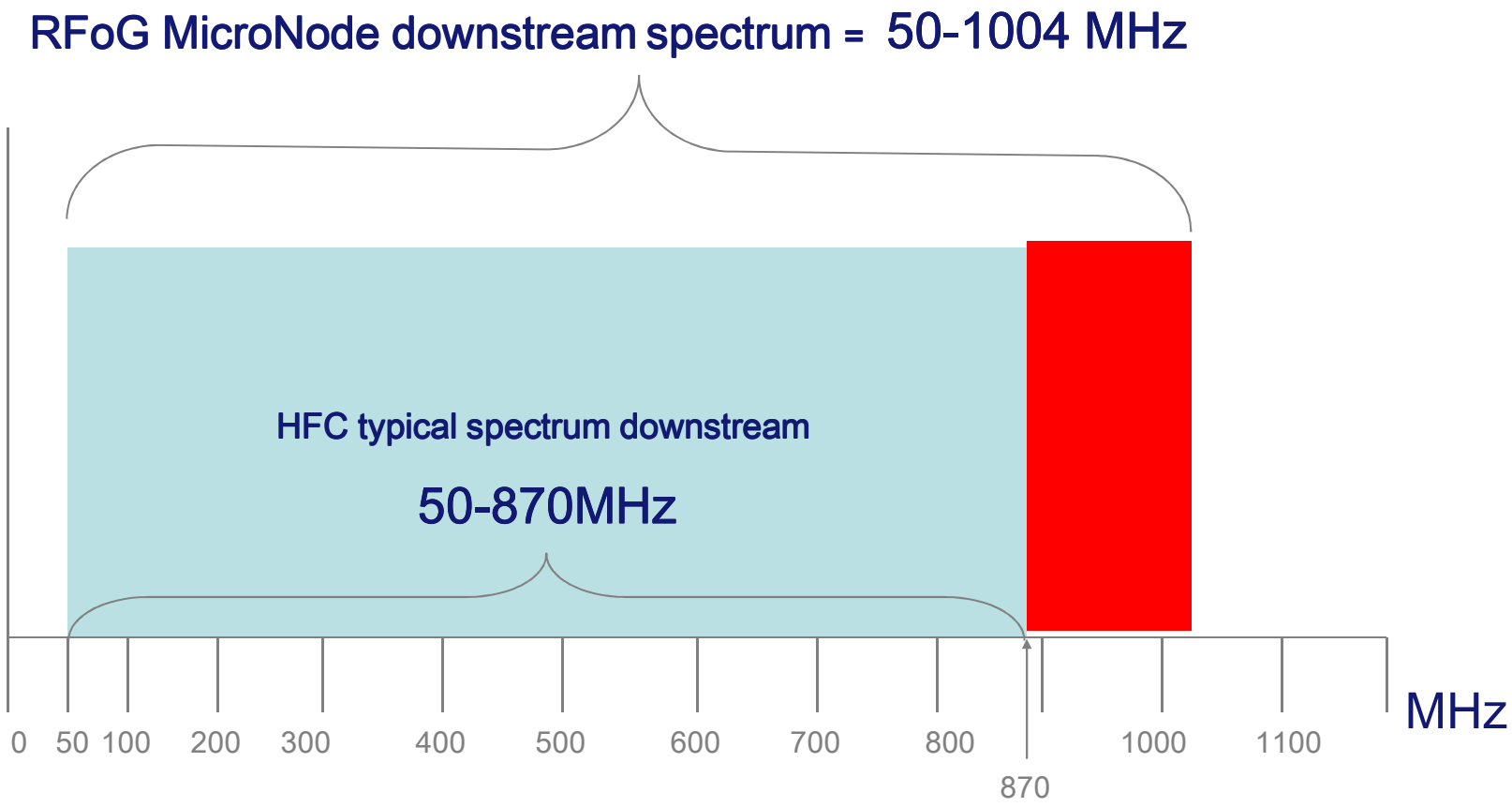
Bandwidth Downstream Improvement



RFoG MicroNodes have 15% more downstream BW

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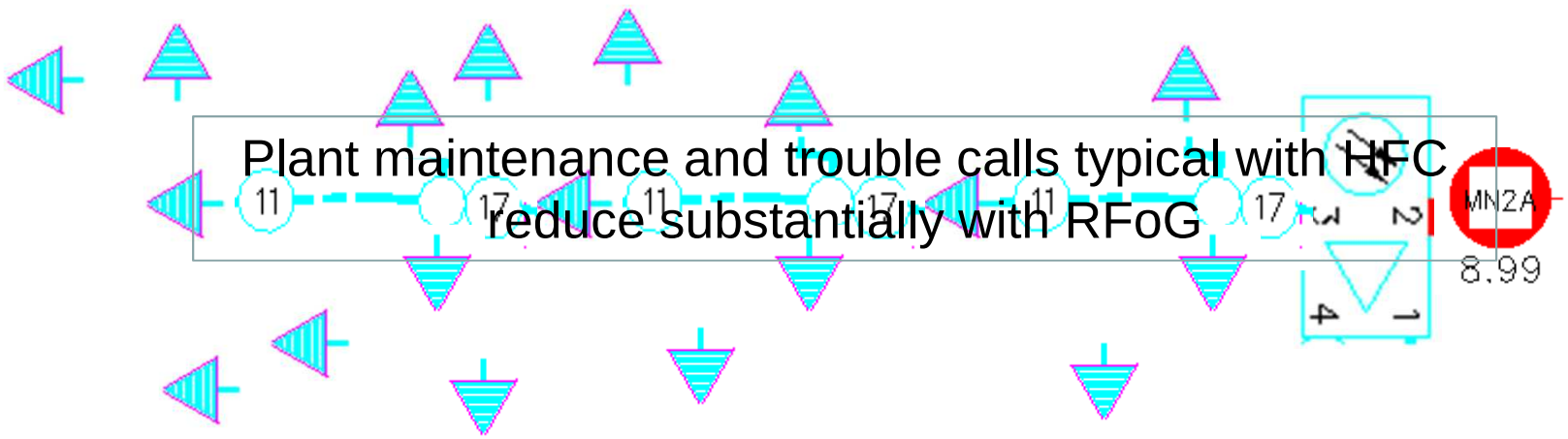
RFoG Costs Different from HFC

When HFC and RFoG cost the same to build, typically around 30 HPM and 50% penetration:

95% of the HFC cost is in construction, where only about 60% of the RFoG cost is construction.



Plant maintenance and trouble calls typical with HFC reduce substantially with RFoG

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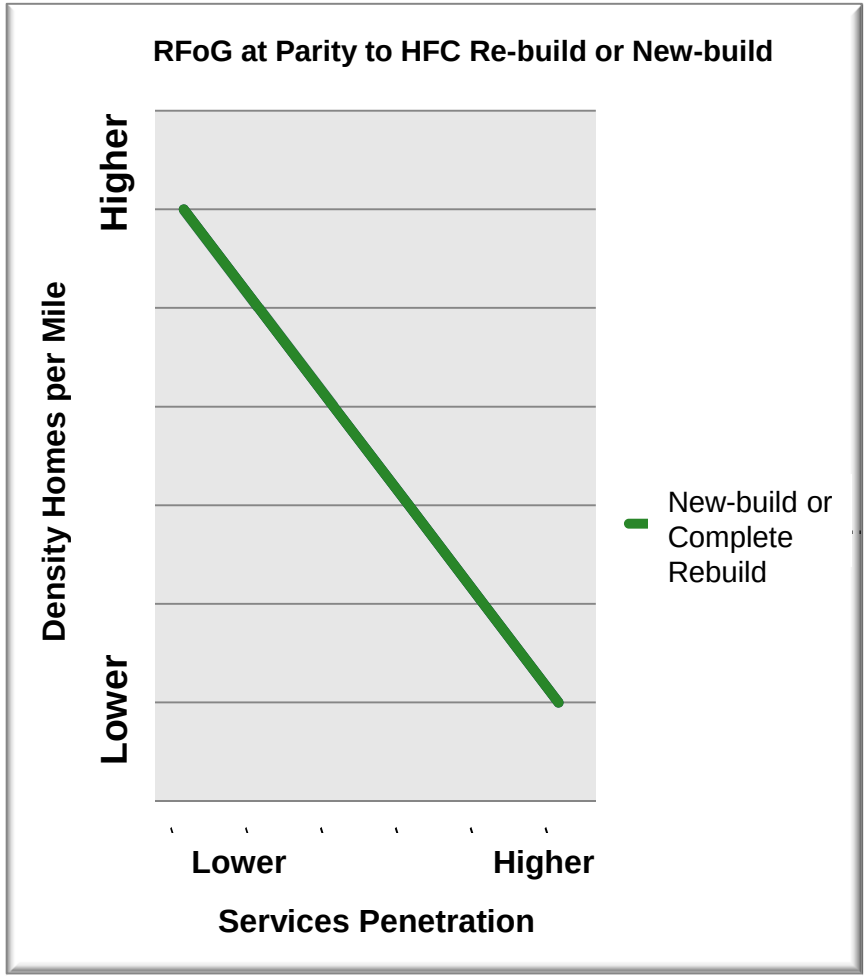
RFoG Costs vs. HFC

- At some combination of density, (homes per mile), and penetration rates, RFoG and HFC will cost the same – see curve/line
- The nature of the curve varies by equipment supplier and by operator.
- The curve represents capital costs only, since we all know RFoG operational costs are lower than HFC.
- Capital costs are split between construction and subscriber.



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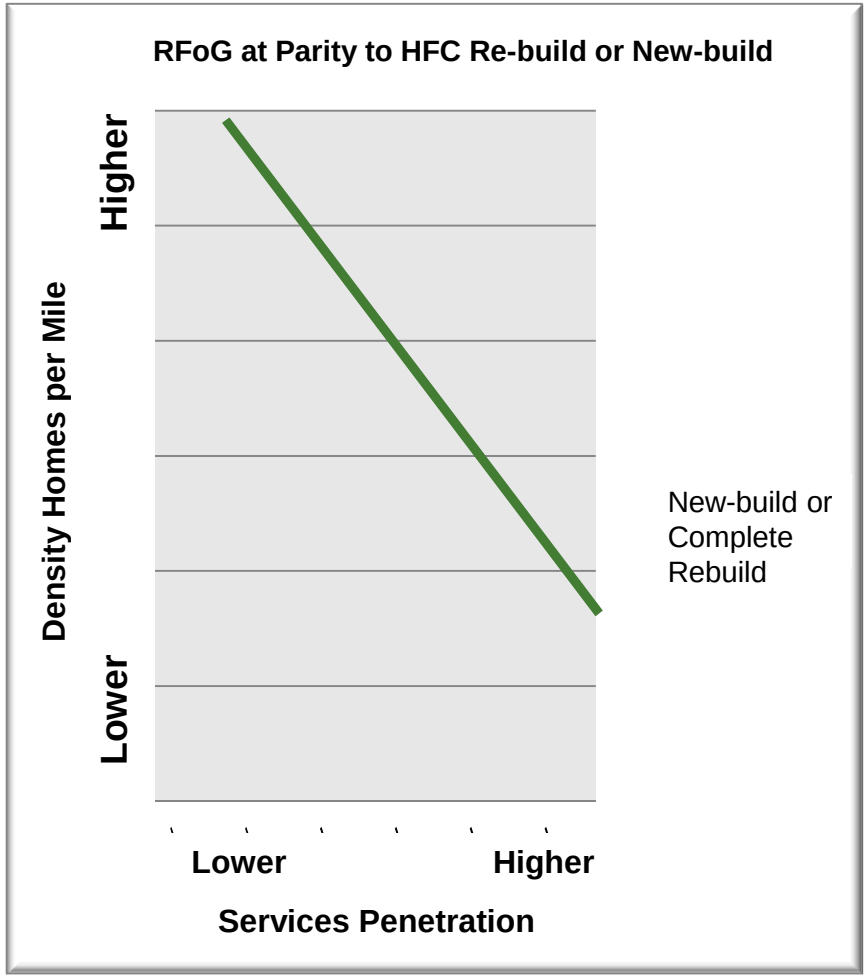
RFoG Costs vs. HFC

- At some combination of density, (homes per mile), and penetration rates, RFoG and HFC will cost the same – see curve/line
- The position of the curve rises on the chart as headend optics and field active optics get cheaper, meaning RFoG is competitive at higher densities and higher penetrations.



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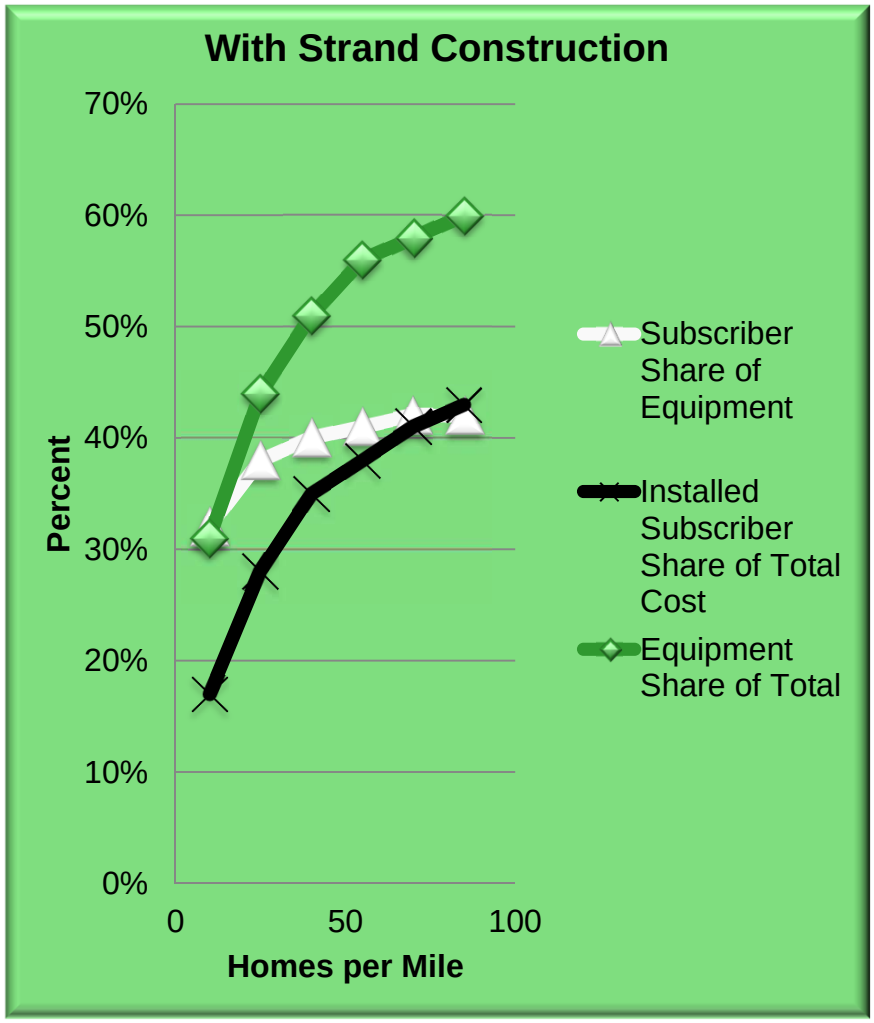
RFoG Construction Capital

- The mix of construction capital and subscriber capital are dependent, again, on homes per mile and penetration rate, which is fixed in this example.
- The “Installed Subscriber Share of Total Cost” approaches 40% in higher density areas.
- If the construction department was funded based on miles to build, they could build 50% more miles on the same funds in this example.
- RFoG presents significant advantages to operators overbuilding or with new-builds since the capital costs for subscribers happen after the plant construction.



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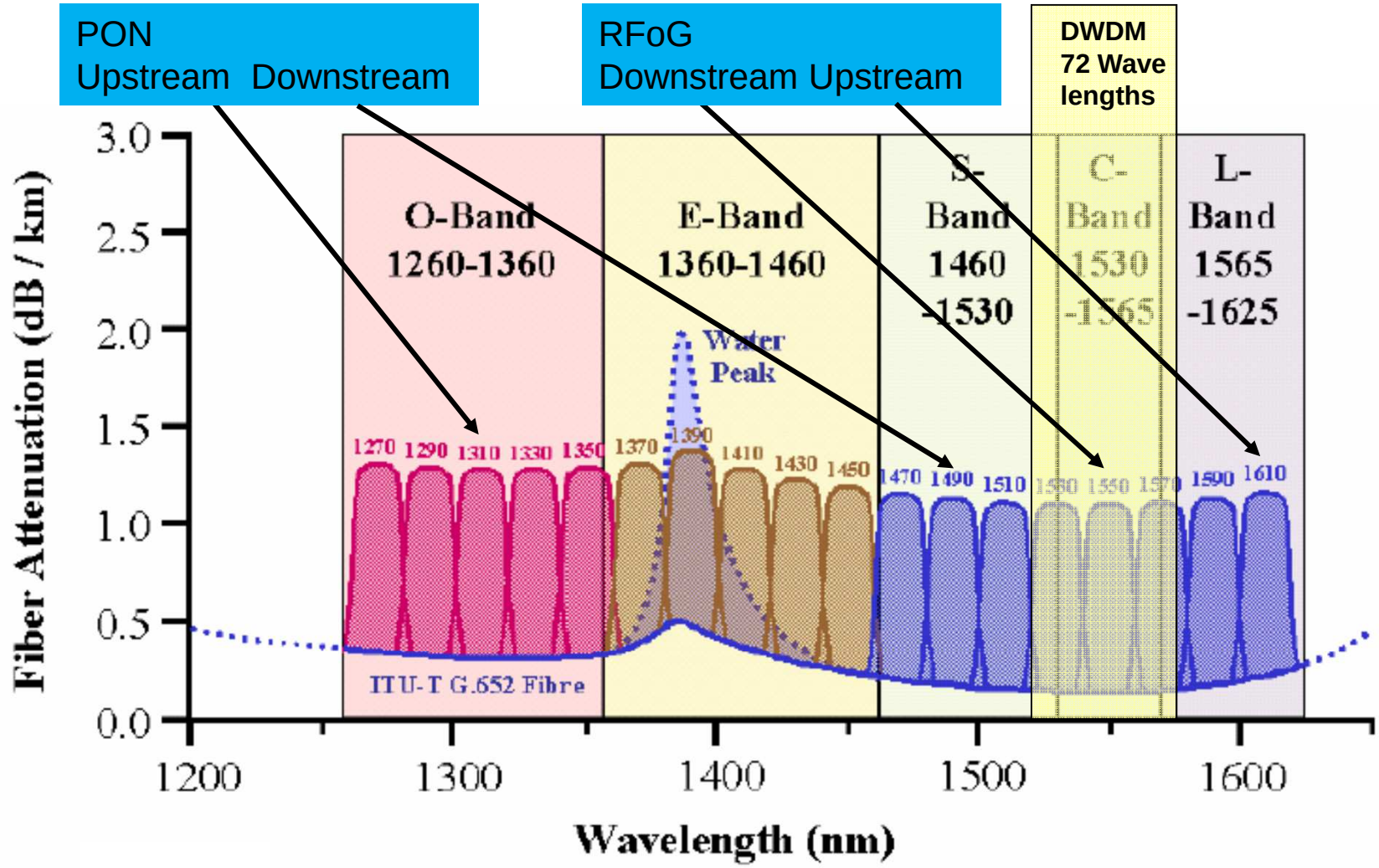
CommScope Optical Passives Support O-Band Through L-Band



Metro CWDM Wavelength Grid as specified by ITU-T G.694.2

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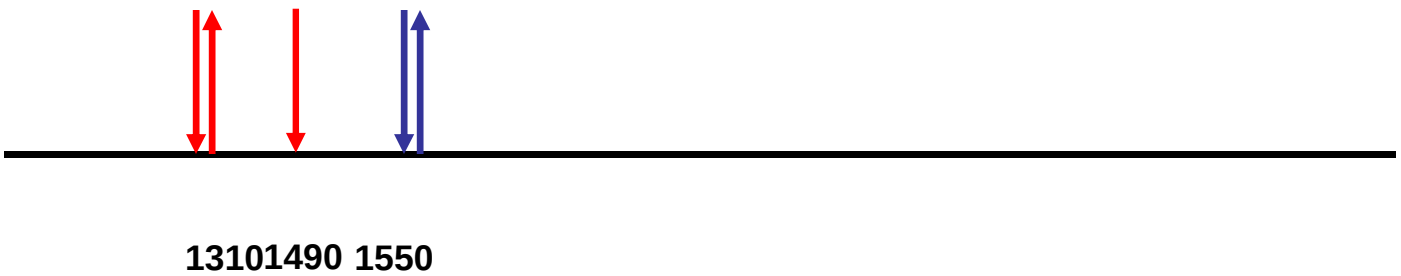
Spectrum Use in Fiber Plant



SCTE RFoG goal – RFoG and PON on the same fiber

- PONs use 1490nm down and 1310nm upstream
- HFC used 1550 and 1310 down or upstream

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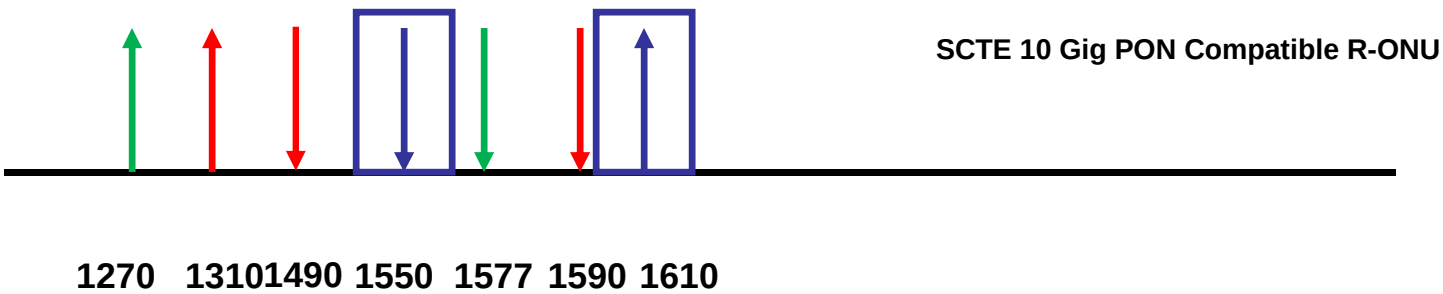
Spectrum Use in Fiber Plant



Align RFoG separate from PON wavelengths

- RFoG to use 1550nm down and 1610nm upstream
- Other ITU/IEEE systems also compatible, ie 10G
- RFoG R-ONUs have to have excellent filtering

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Break Quiz

- RFoG is compatible with HFC networks in which of the following ways:

1. It works with the same headend equipment and subscriber equipment as with HFC
2. It is less expensive to maintain than HFC
3. It can be less expensive to build in rural areas
4. All of the above

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Break Quiz

- The high passive losses in an RFoG network are overcome in the downstream by using:

1. An RF Amplifier in the field
2. An EDFA in the field
3. An EDFA in the headend
4. An EDFA at the subscriber site

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Break Quiz

- Which of the leading technologies is not used in an RFoG solution

1. High SBS-suppression laser transmitters
2. Burst-mode return path transmitters
3. Ethernet 1G optical transponders
4. High-sensitivity, low-noise, headend receivers

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