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Network Migration to 1.8 GHz:
Operational "Spectral Analysis" Measured in nano-Hertz, a 30-Year Perspective

Zoran Maricevic

Engineering Fellow
CommScope
zoran.maricevic@commscope.com

SCTE CABLE-TEC EXPO 22
SEPTEMBER 19-22 • PHILADELPHIA, PA

2022 Fall Technical Forum
SCTE • CABLELABS • NCTA

AGENDA:

- ✓ Broadband Traffic Engineering – what drives network upgrades
- ✓ Downstream Tavg Growth Projections
- ✓ Network Upgrade Considerations & Initial CAPEX
- ✓ Total Cost of Ownership & Sensitivity Analysis
- ✓ Conclusions

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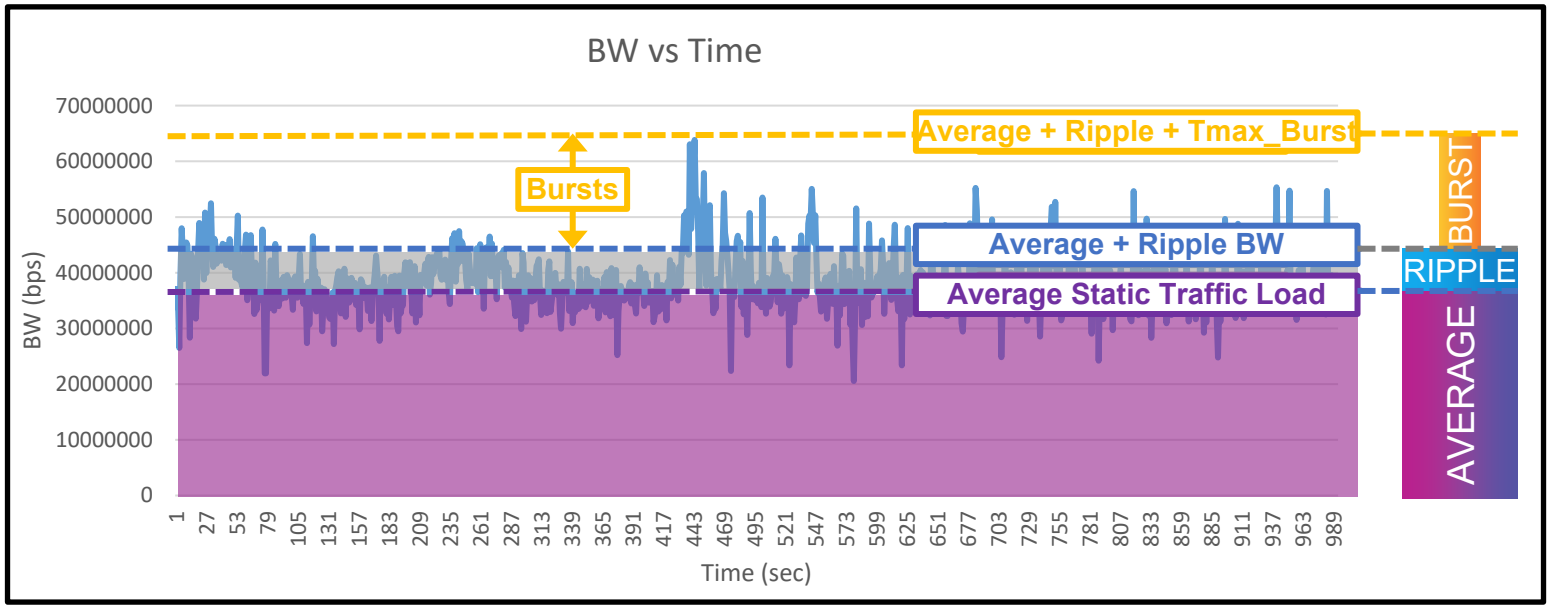
Broadband Traffic Engineering

CommScope Patented Probability-based QoE Traffic Engineering Research

Modified COMMSCOPE/CLOONAN'S CAPACITY EQUATION: THE "BASIC" TRAFFIC ENGINEERING FORMULA (BASED ON Tmax_max):

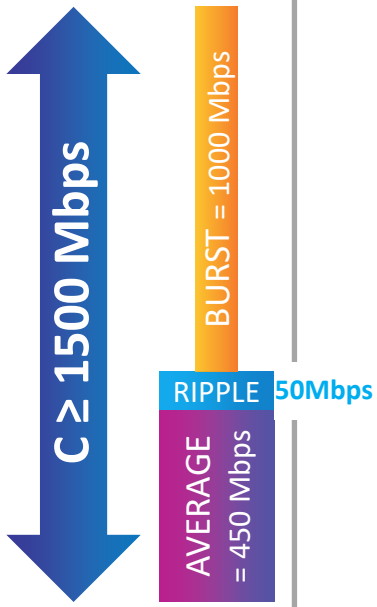
$$C \geq (Nsub*Tavg) + (K-1)*Tmax\_max + Tmax\_max$$

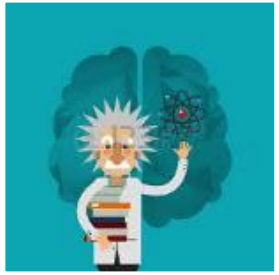
C	(Nsub*Tavg)	(K-1)*Tmax_max	Tmax_max
Required SG Bandwidth Capacity	Peak Busy Period Average Consumption	Peak Busy Period Ripple	Headroom for Service Tier Burst



Example

Nsub = 150
Tavg = 3 Mbps
K = 1.05
Tmax_max = 1 Gbps



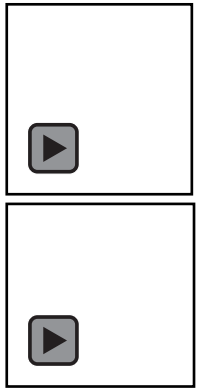


Broadband Subscriber Traffic Demand – Tmax_max

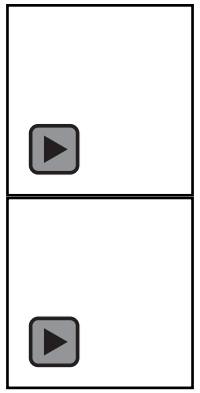
As of now:

Downstream:

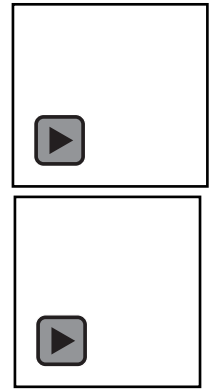
Upstream:



In the near term:



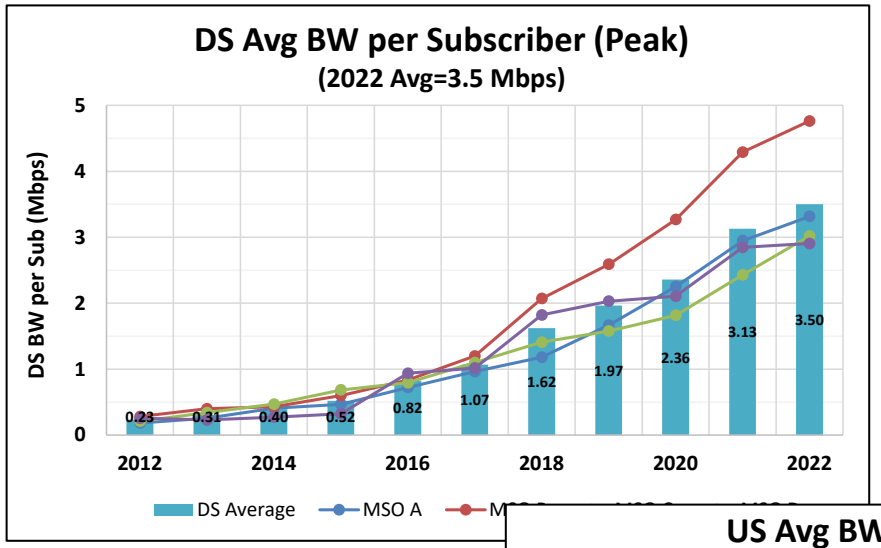
In the long term:

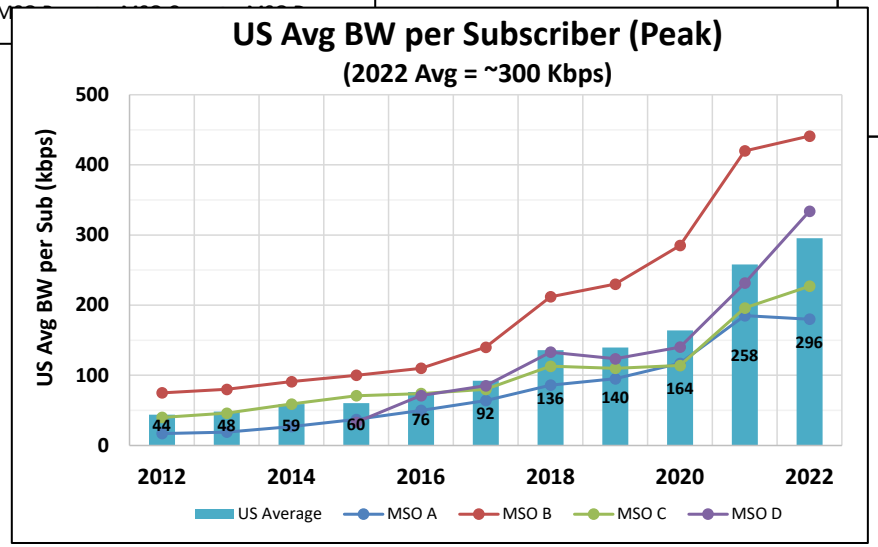


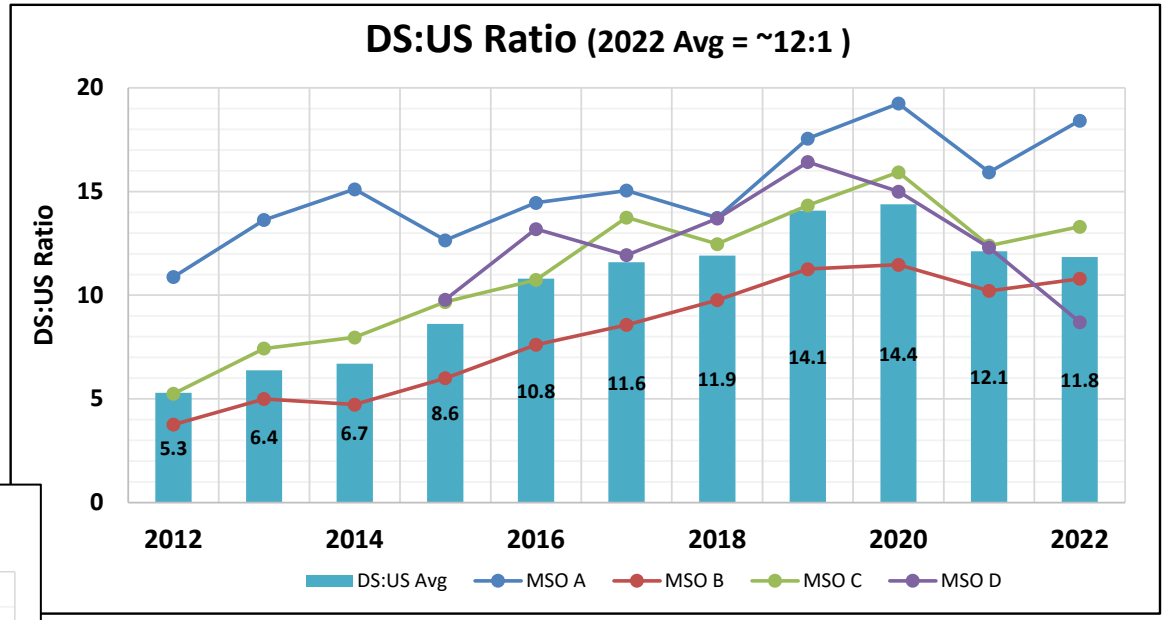
✓ 5,000 Mbps DS / 1,000 Mbps US selected as Tmax_max

Broadband Subscriber Traffic Consumption – Tavg

Based on 10+ years of consistent data collection from the same 4 operators







Do Consumers ***need*** **Full Symmetric BW???**
No!!!! – just maybe a bit **MORE Symmetric**

Symmetry driven by competitive market demands

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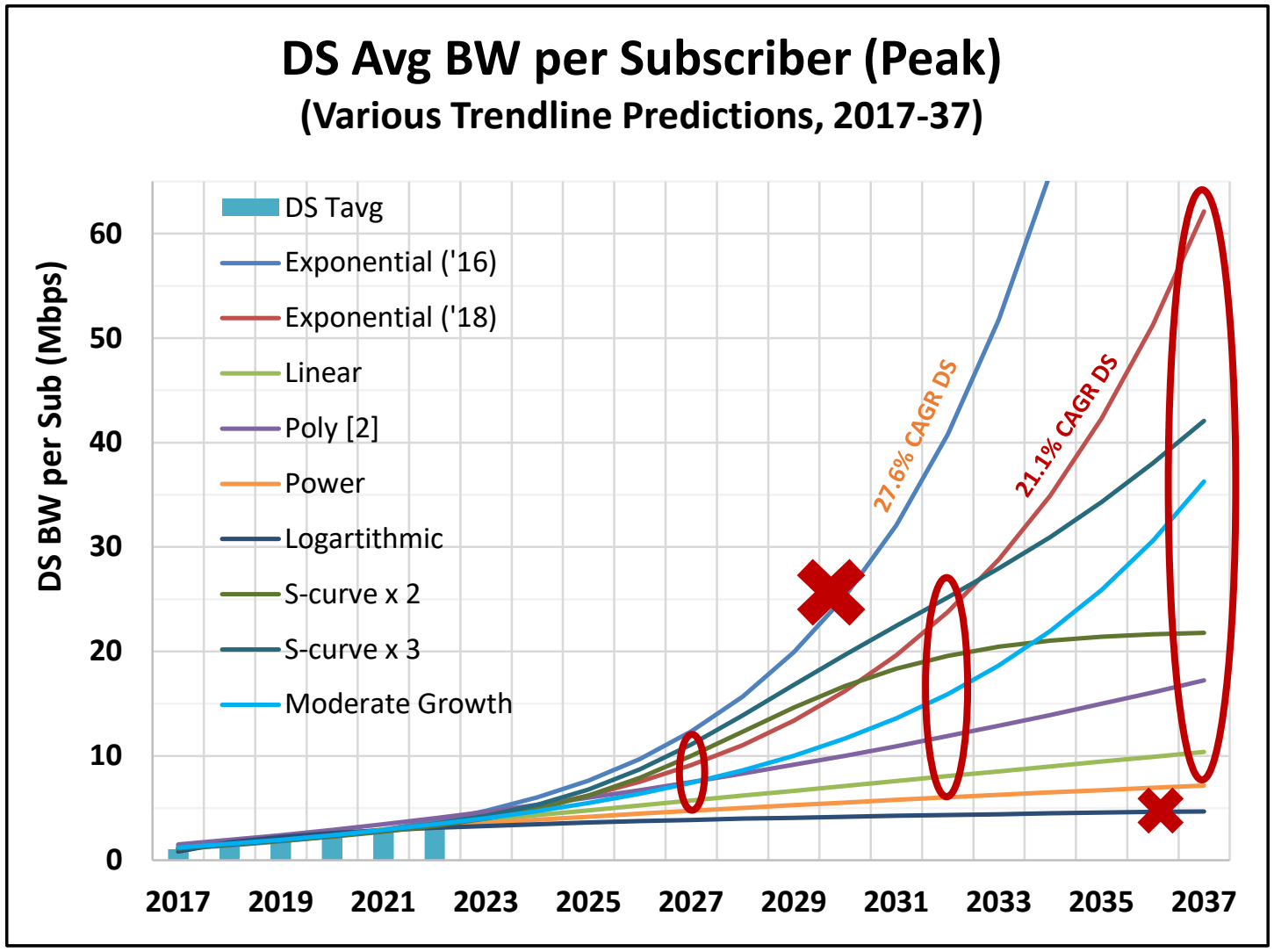
Downstream Tavg Growth Projections

DS Tavg Predictions: 2017 to 2037

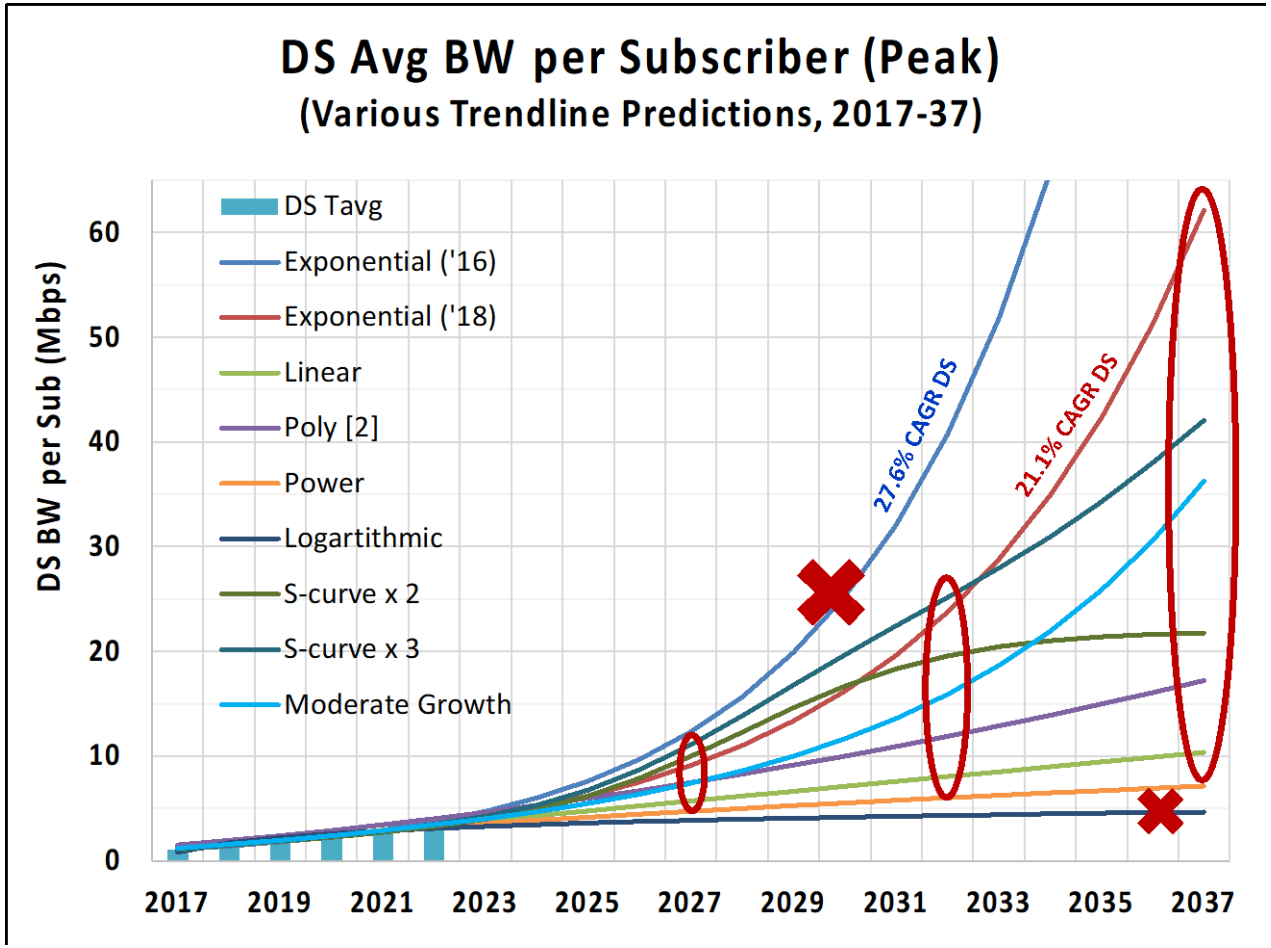
Cone of Uncertainty:

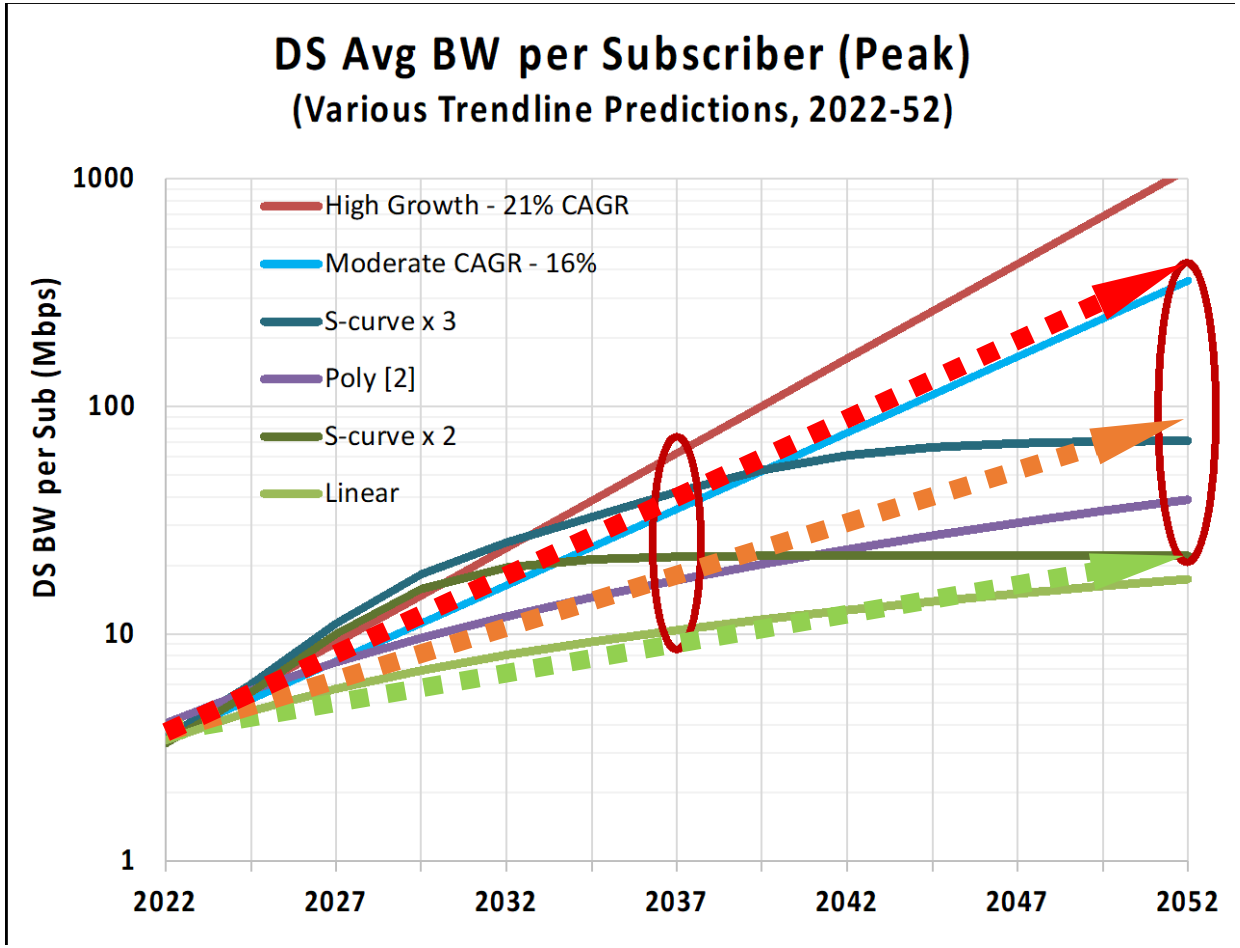
- 2027 expected DS Tavg – 5-12 Mbps range
- 2032 expected DS Tavg – 7-25 Mbps range
- 2037 expected DS Tavg – in the 8-65 Mbps range

At **21% CAGR**, DS Tavg exceeds 100Mbps **by 2040**
With **Linear growth**, DS Tavg exceeds 100Mbps **in 200+ yrs**



DS Tavg Projections: 2022 to 2052





2037 DS Tavg = 8 - 65 Mbps

2052 DS Tavg = 20 – 350 Mbps

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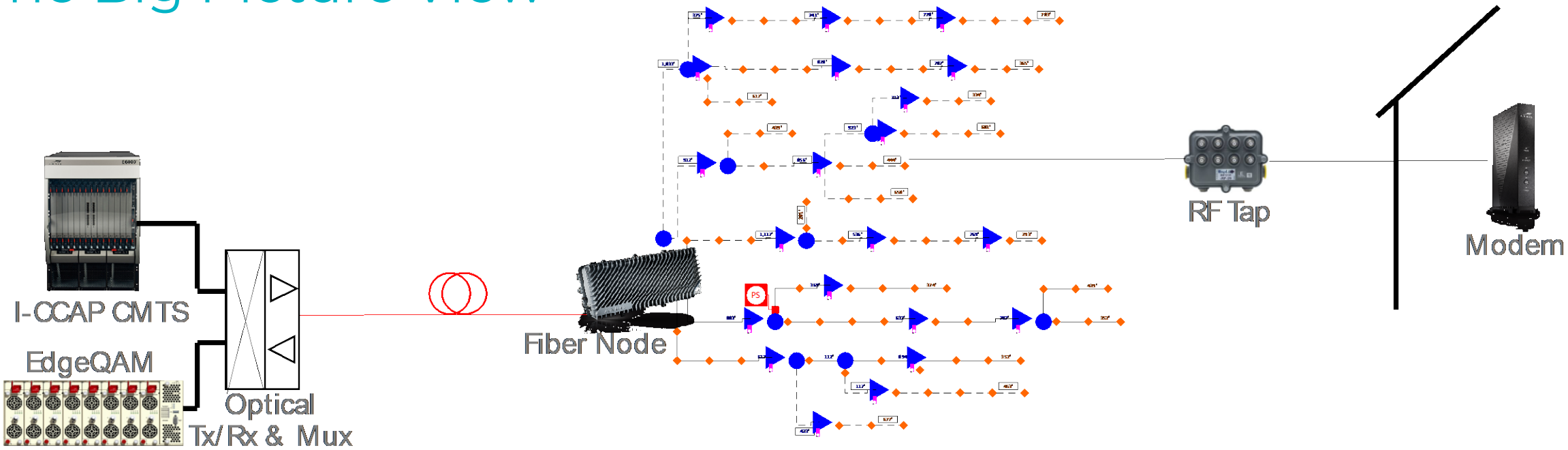
Network Upgrade Considerations

The Big Picture View

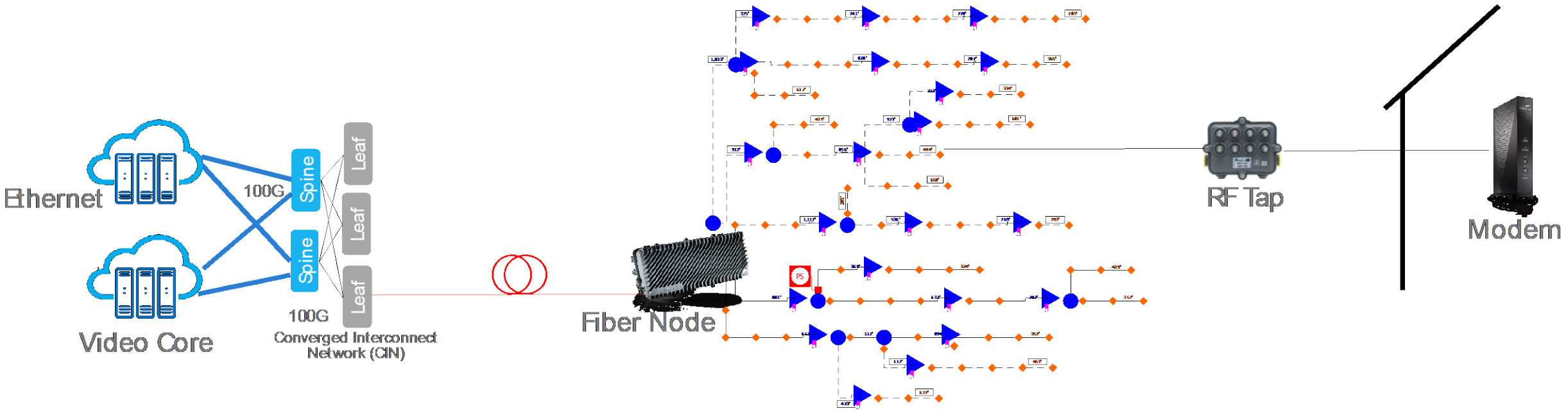


1 Head-End Port 1 Fiber Node 7 Bridger Amps 14 Line Extenders 100 Taps	4 Miles of hard-line plant 400 Homes Passed 200 Subscribers

100 Homes-passed per mile
~19 Homes-passed per amp
4 Homes-passed per tap

5.25 RF Amps per mile
~5 taps per RF amp

Head-end Changes for DAA D4.0 FDD Upgrade



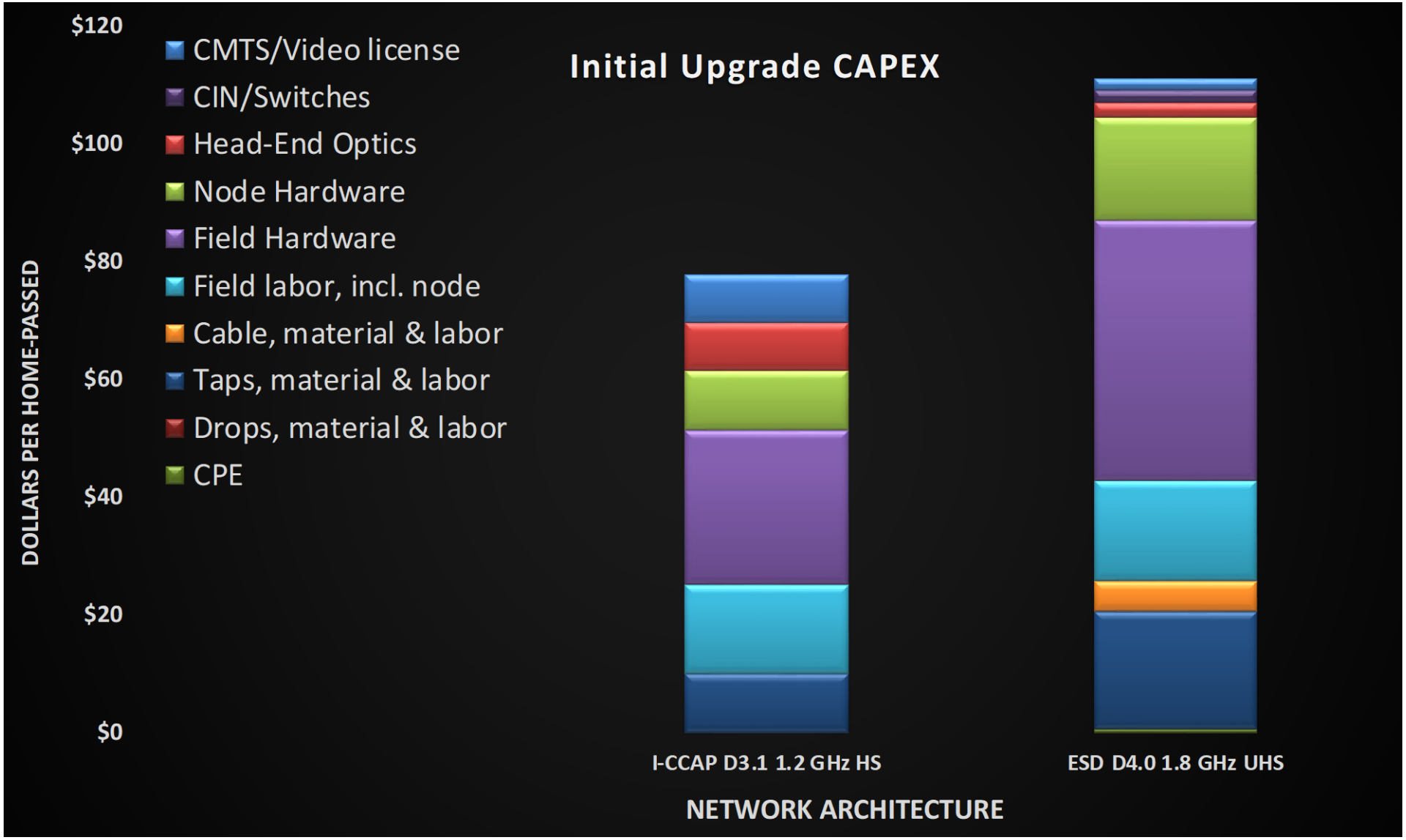
≦ 1 GHz RF Amps | 1 GHz RF Taps | 3.0 & 3.1 CMs

Upgrade ***Upgrade*** ****No Change*** ***Replace***

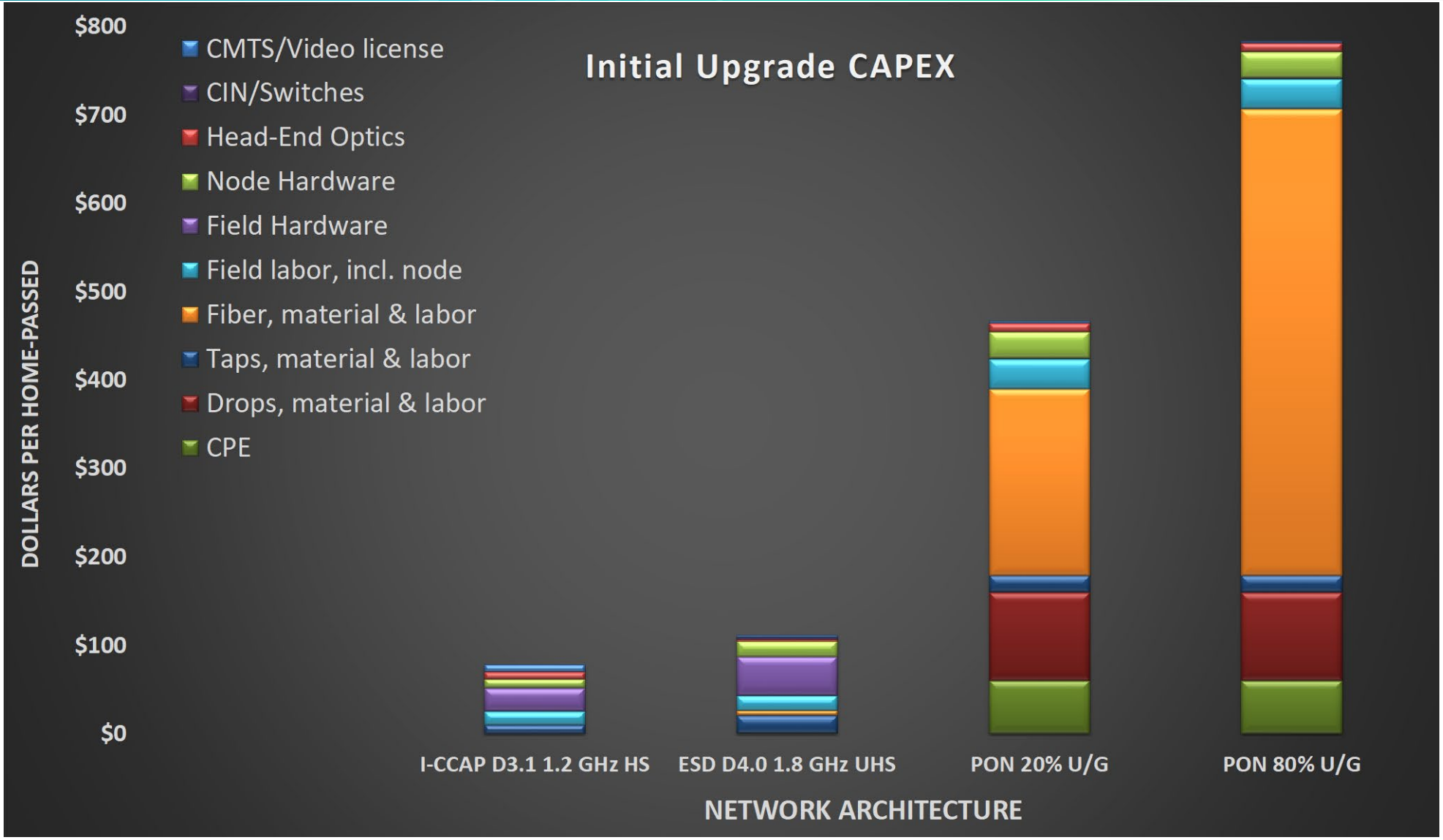
RF Amps | RF Taps | Modems | Modems

** if CM = DOCSIS 3.1* ***NEW DOCSIS 4.0 CMs***

Initial Upgrade CAPEX, in $ per home-passed



Initial Upgrade CAPEX, in $ per home-passed



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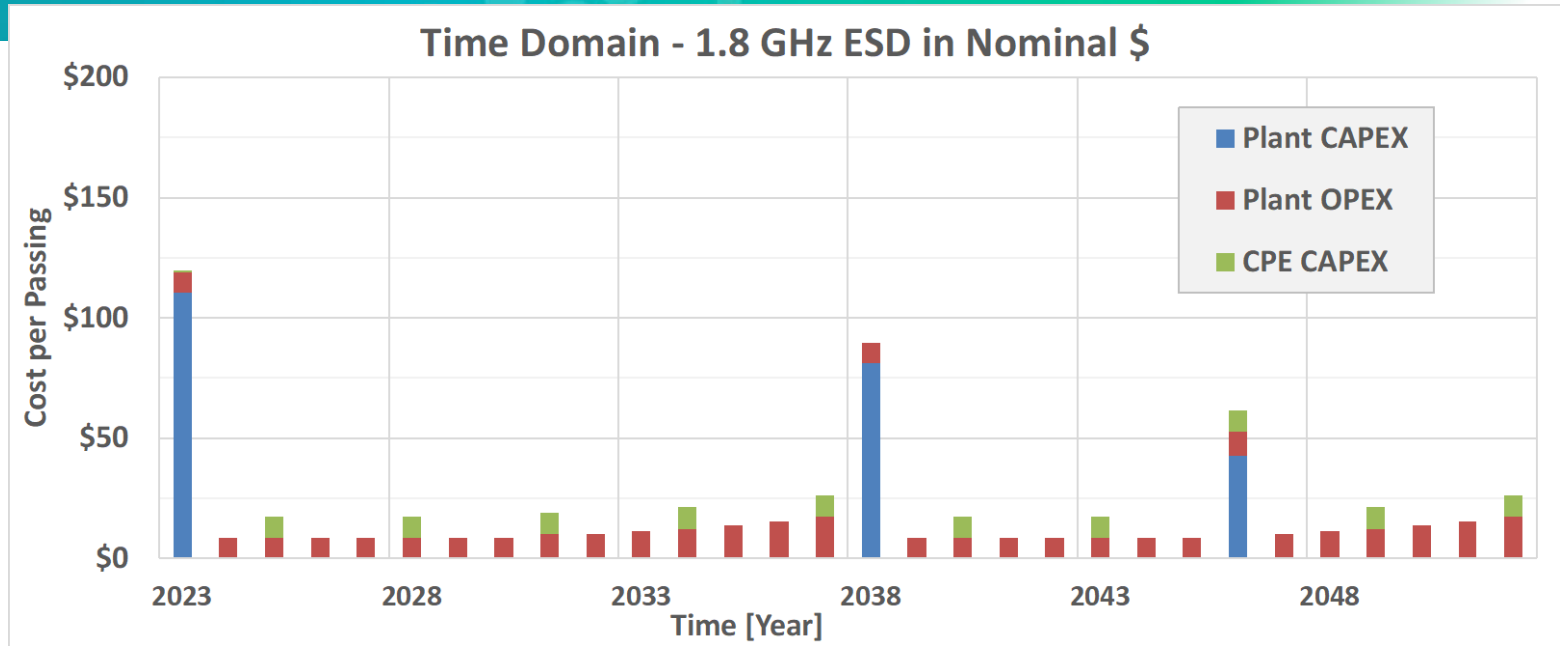
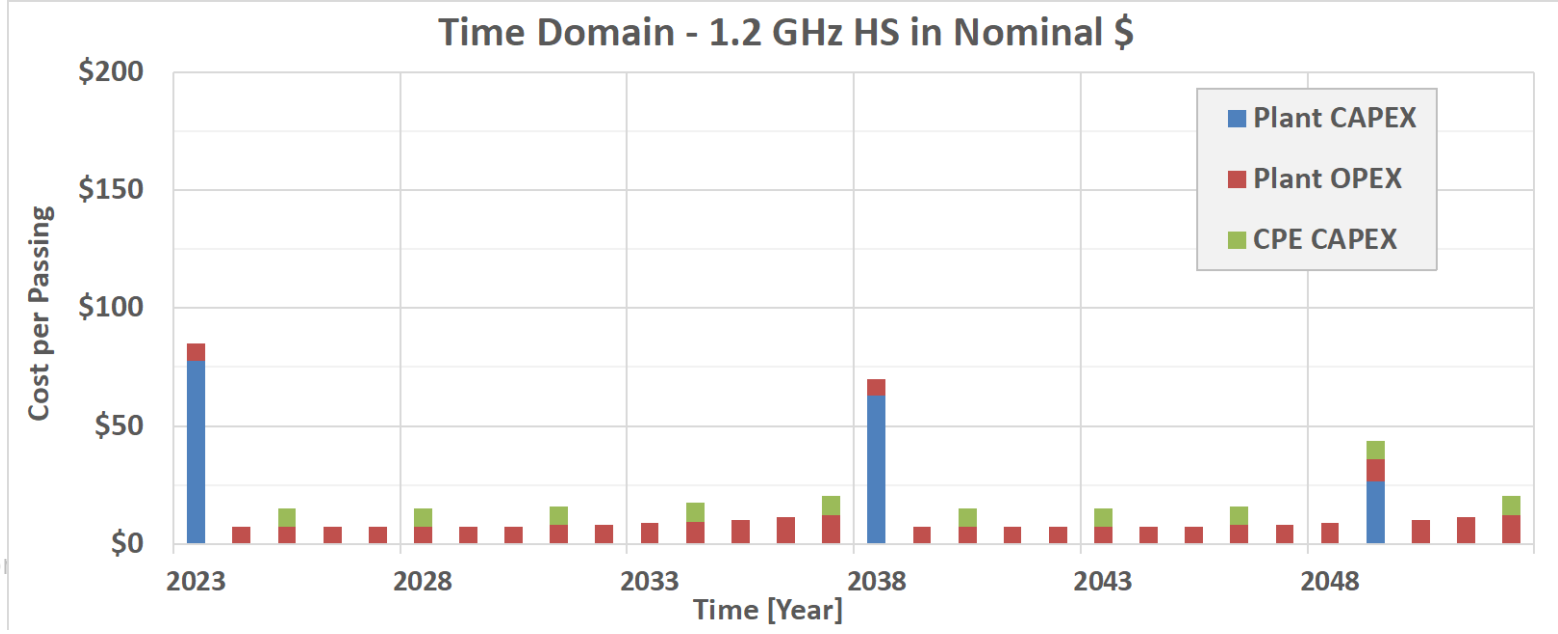
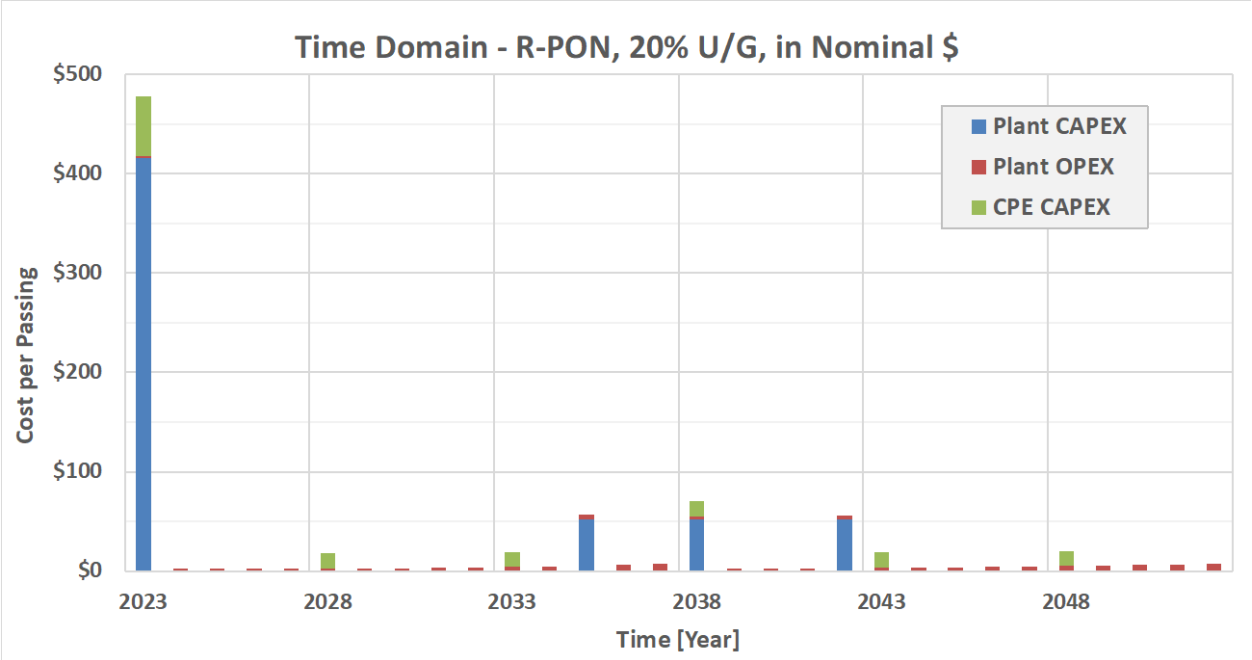
Network Upgrade CAPEX vs. Total Cost of Ownership

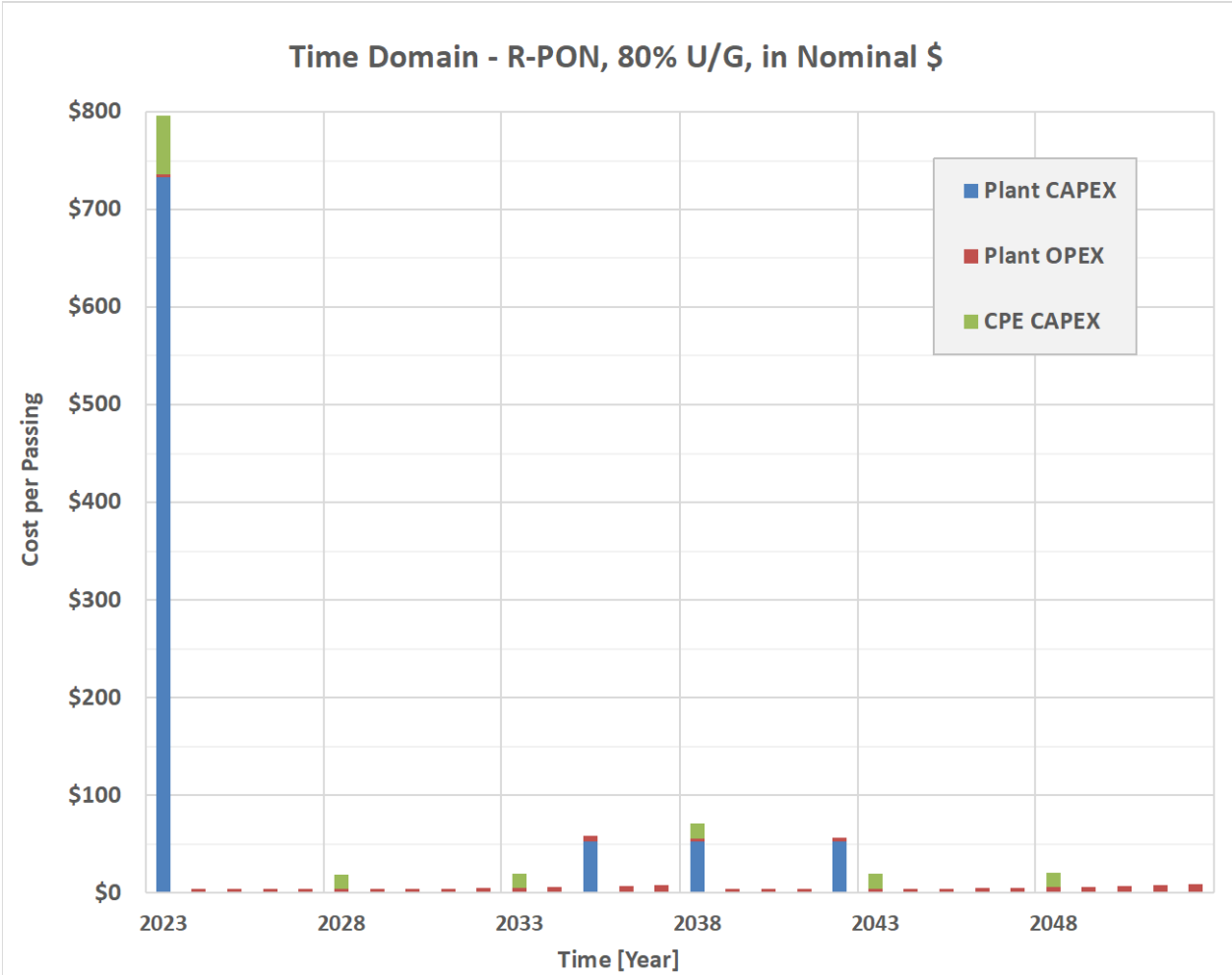
CAPEX & OPEX, 1.8 GHz ESD and 1.2 GHz HS upgrades



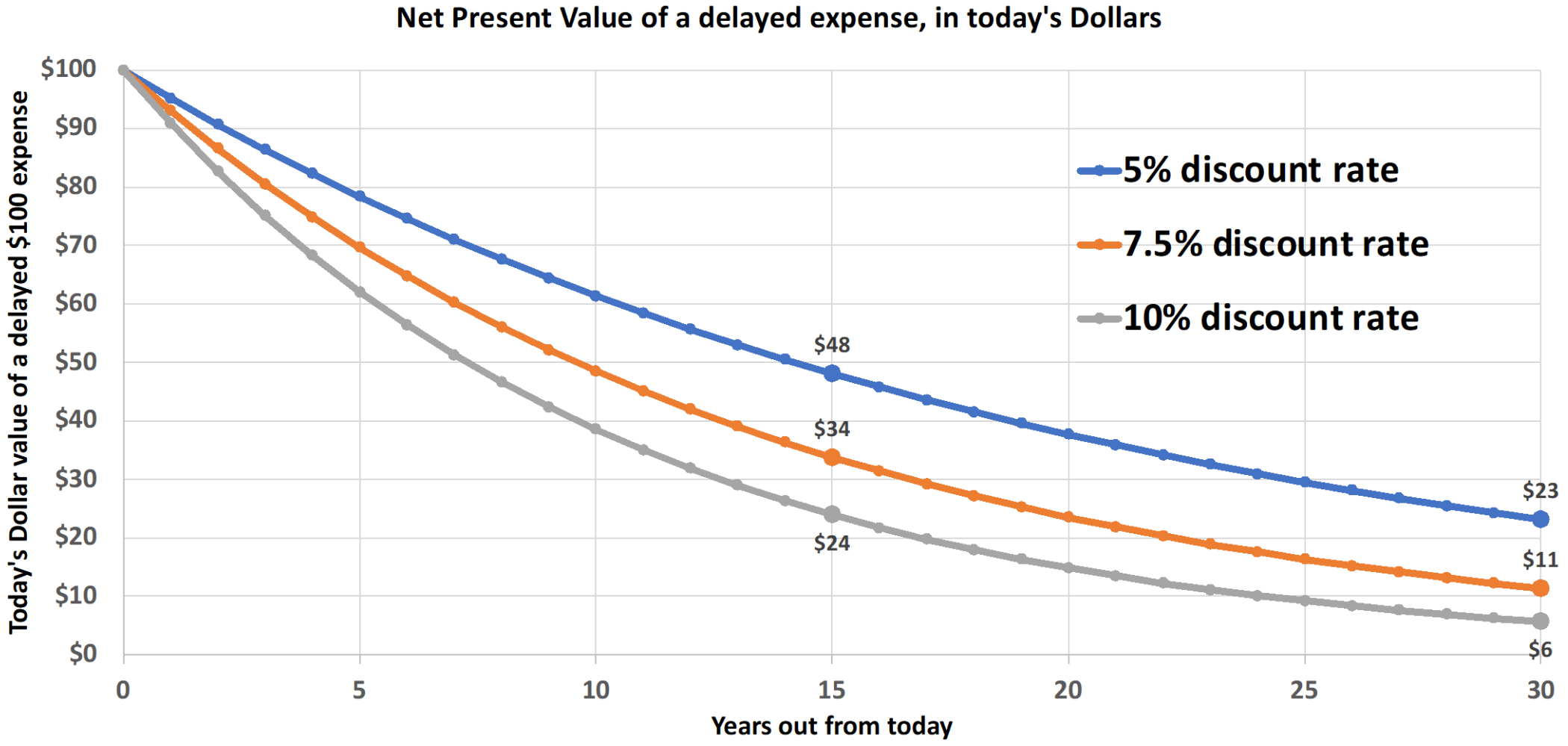


CAPEX & OPEX, 10G R-PON upgrades





Cost, in Today's Dollars, of a $100 Postponed Expense



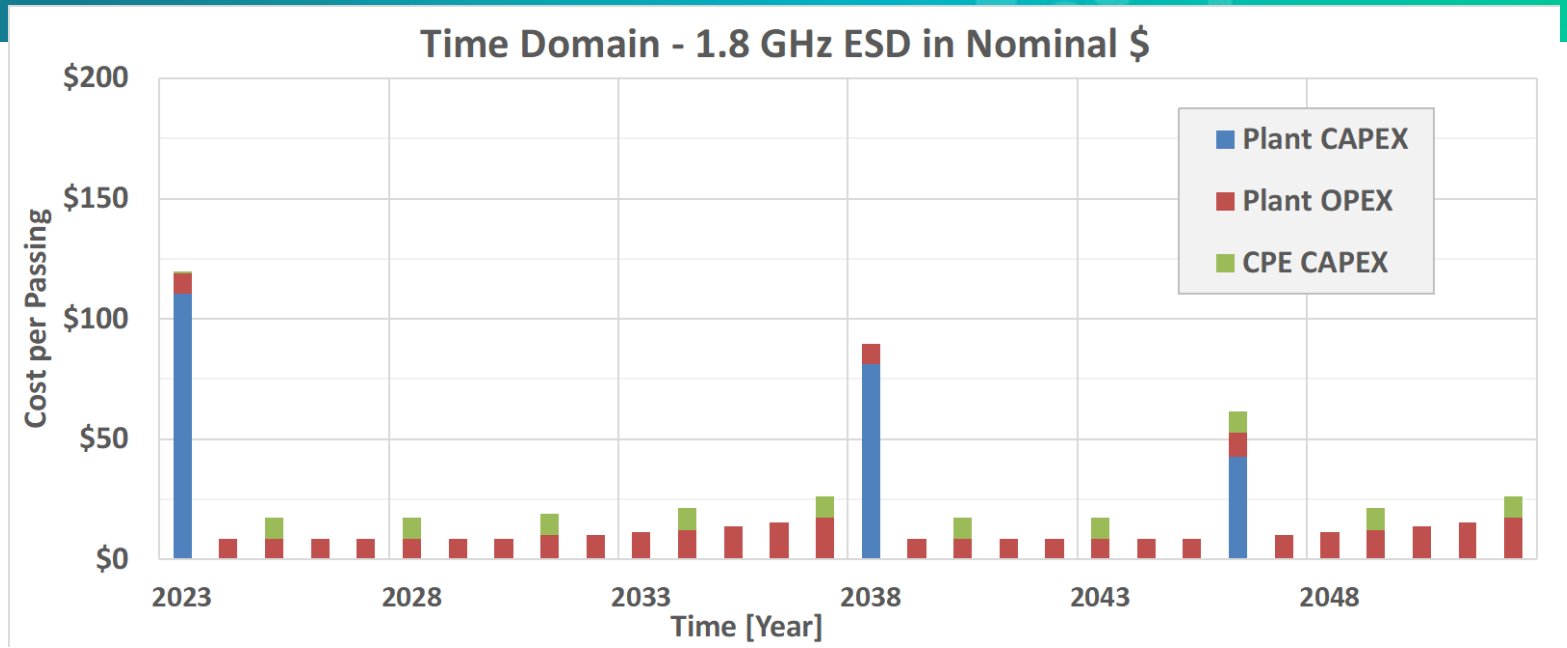
@7.5% disc. rate:

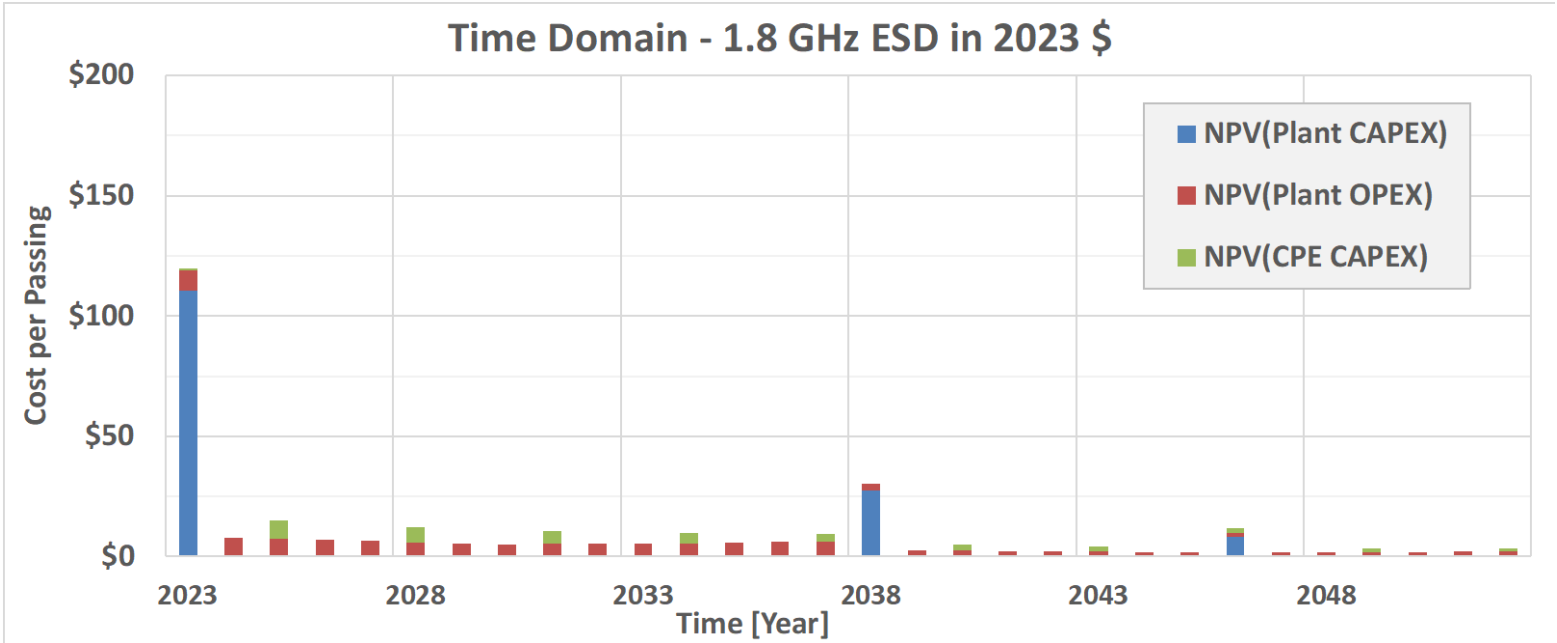
5 years: 30% savings

10 years: 50% savings

15 years: 66% savings

Nominal vs. 2023 $, CAPEX & OPEX, 1.8 GHz ESD upgrades





Enter “Frequency Domain”

1 year = 31,557,600 seconds

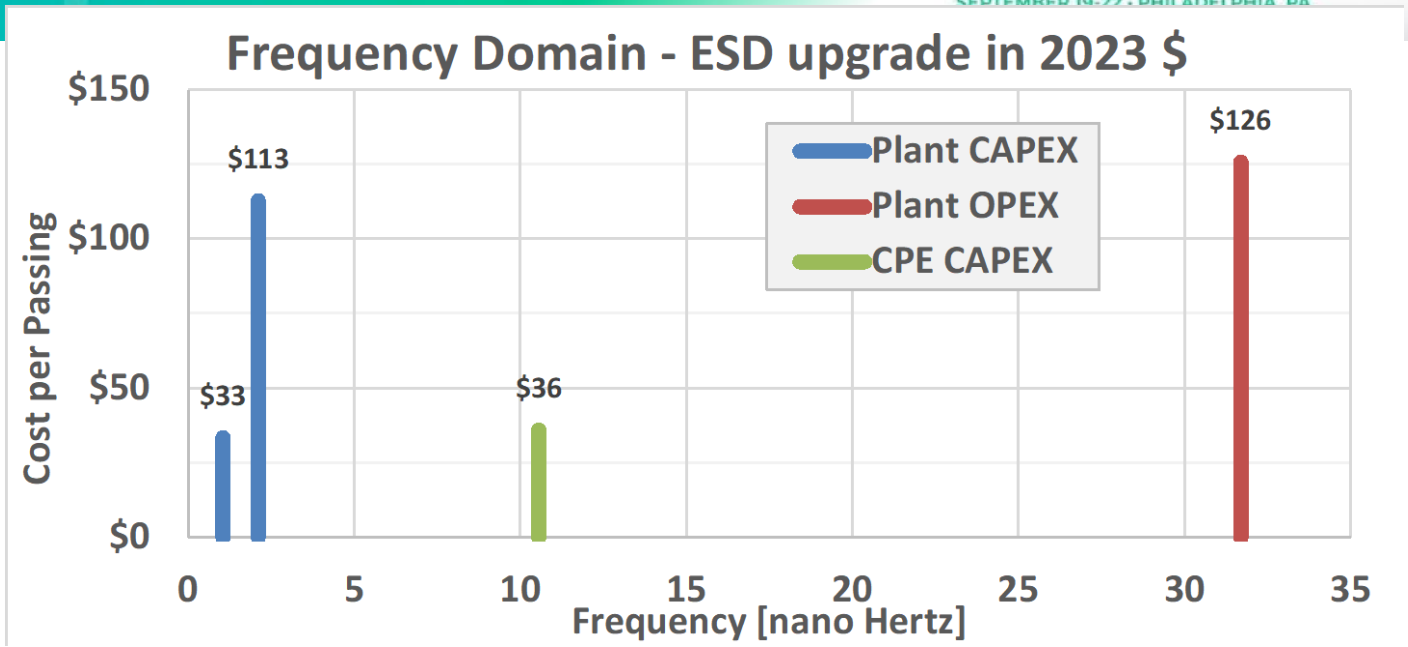
1/year = 1/31,557,600 per sec

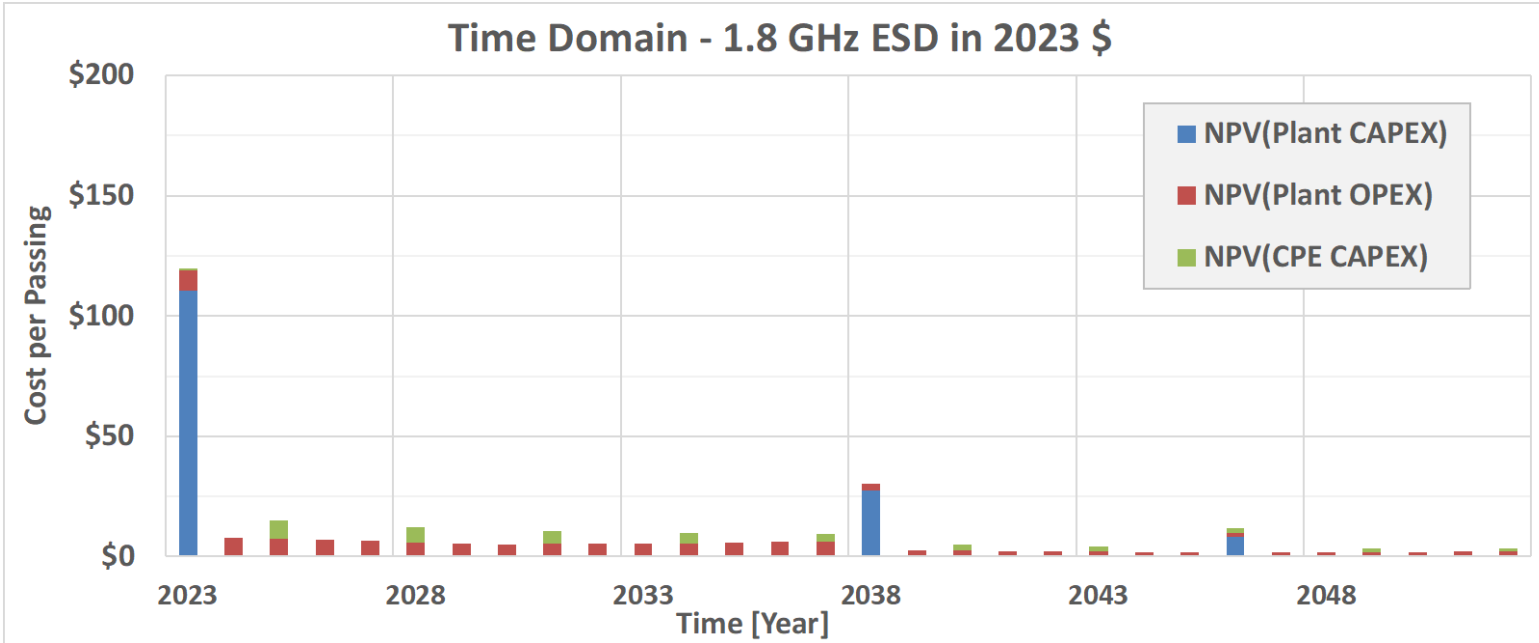
1/year = 31.7 x 10^{-9}Hz = ~32 nano Hz

1/3 year = ~10 nHz

1/15 year = ~2 nHz

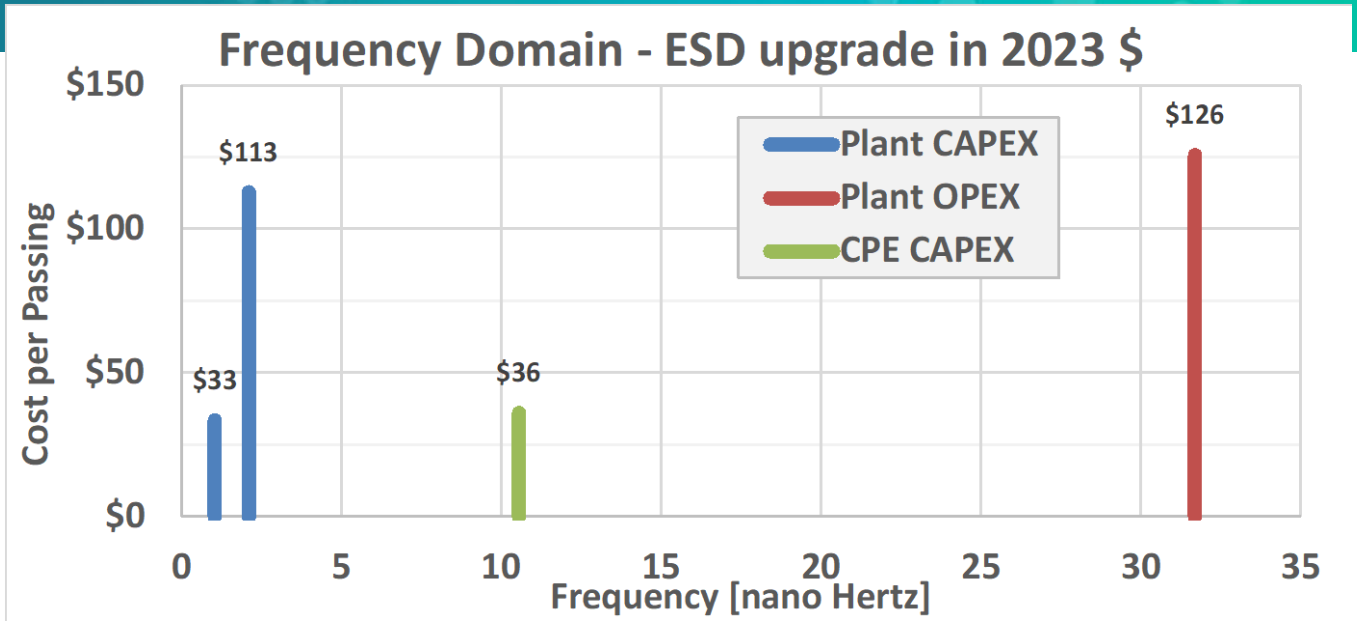
1/30 year = ~1 nHz

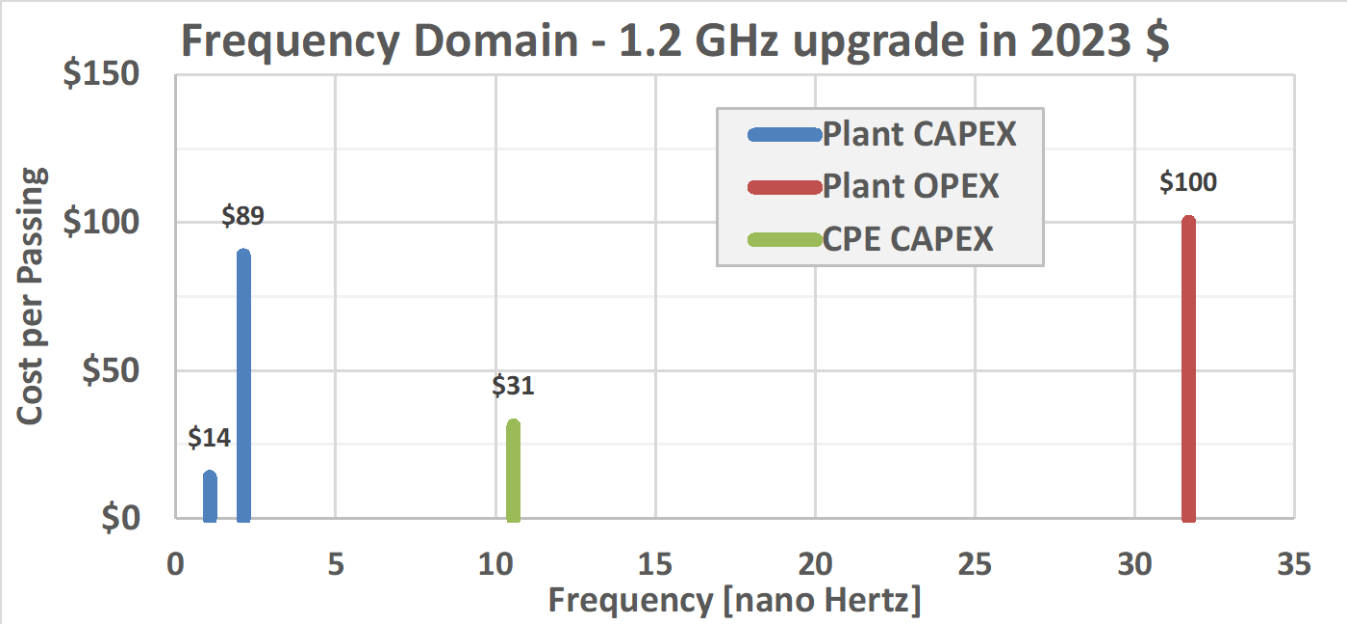


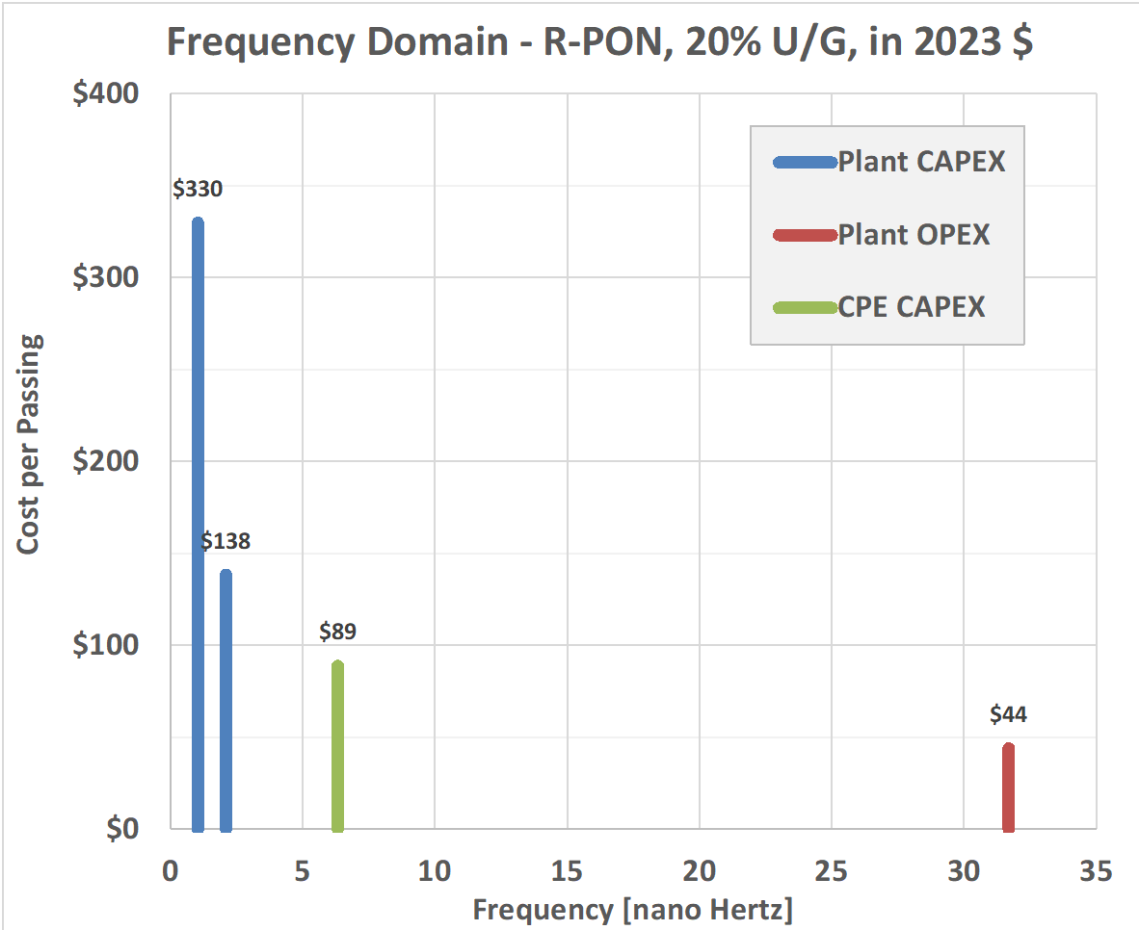


How often an expense repeats is captured in the Frequency Domain

Frequency Domains compared: 1.8 GHz & 1.2 GHz & 10G PON



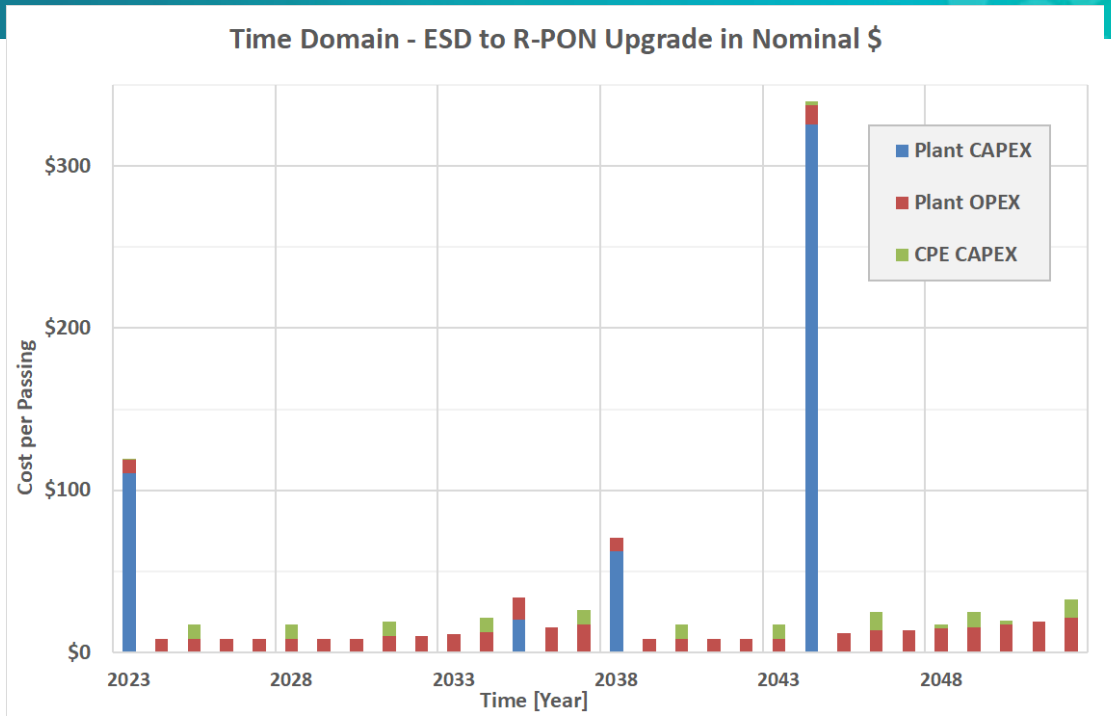


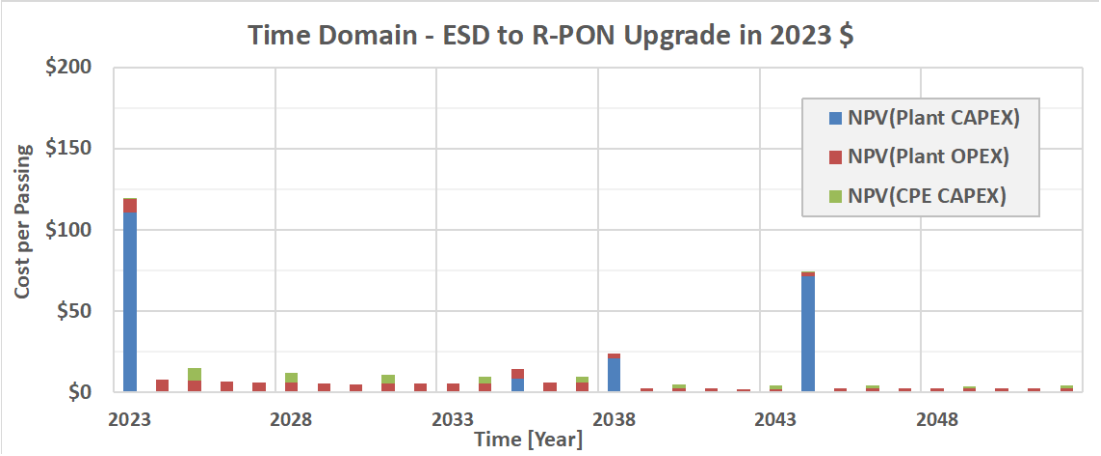


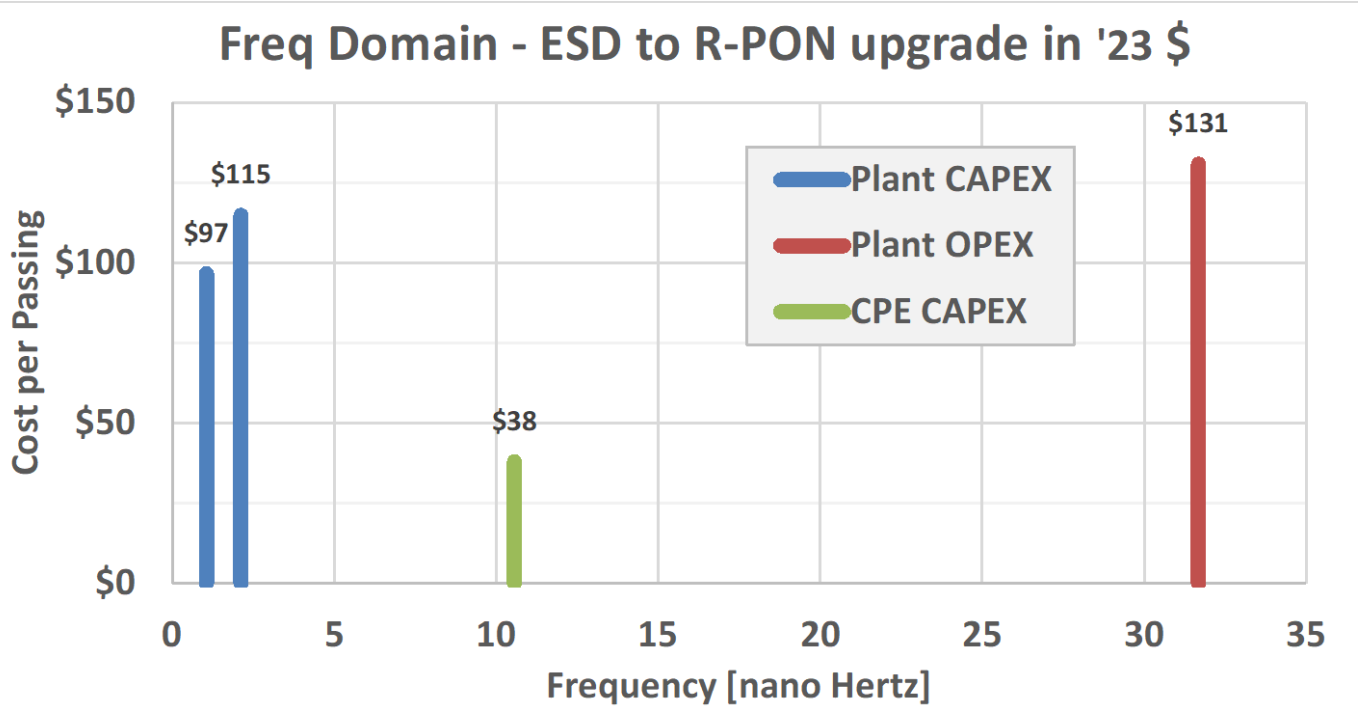
Upgrade Paths Compared

Upgrade Scenario	1.2 GHz D3.1 HS	1.2 GHz; →1.8 GHz	1.8 GHz D4.0 FDD	1.8 GHz FDD (w PON overlay'44)	10G R-PON 20% Underground	10G R-PON 80% Underground
Tavg Growth Scenario	Low	Low→Med	Medium	High	High	High
NPV (Plant CAPEX)	$103	$119	$146	$209	$468	$785
NPV (Plant OPEX)	$100	$107	$126	$131	$44	$58
NPV (CPE CAPEX)	$31	$35	$36	$38	$89	$89
NPV TCO (7.5% TVM)	**$235**	**$261**	**$308**	**$380**	**$601**	**$932**
Total cash outlays over time	*$496*	*$596*	*$643*	*$971*	*$826*	*$1,176*

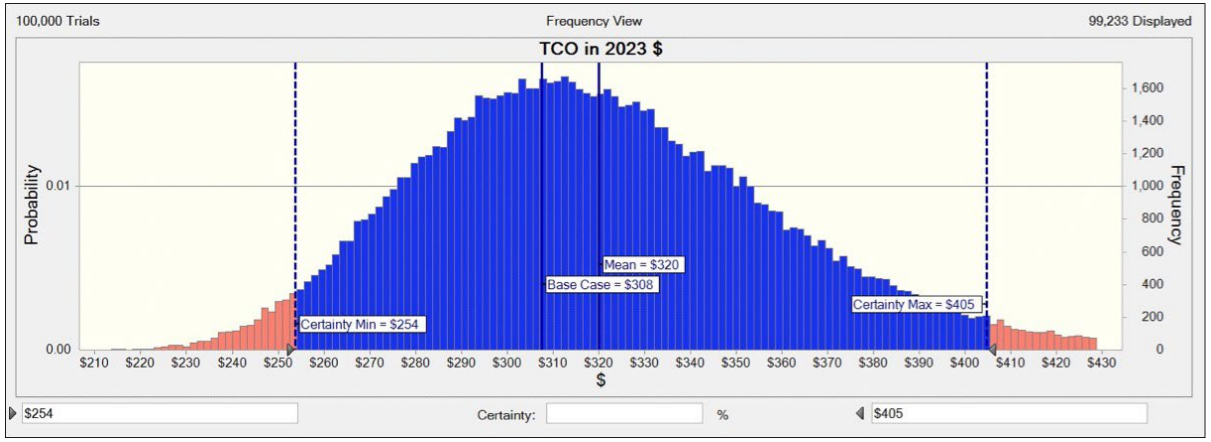
1.8 GHz ESD upgrade; followed by R-PON overlay in '44

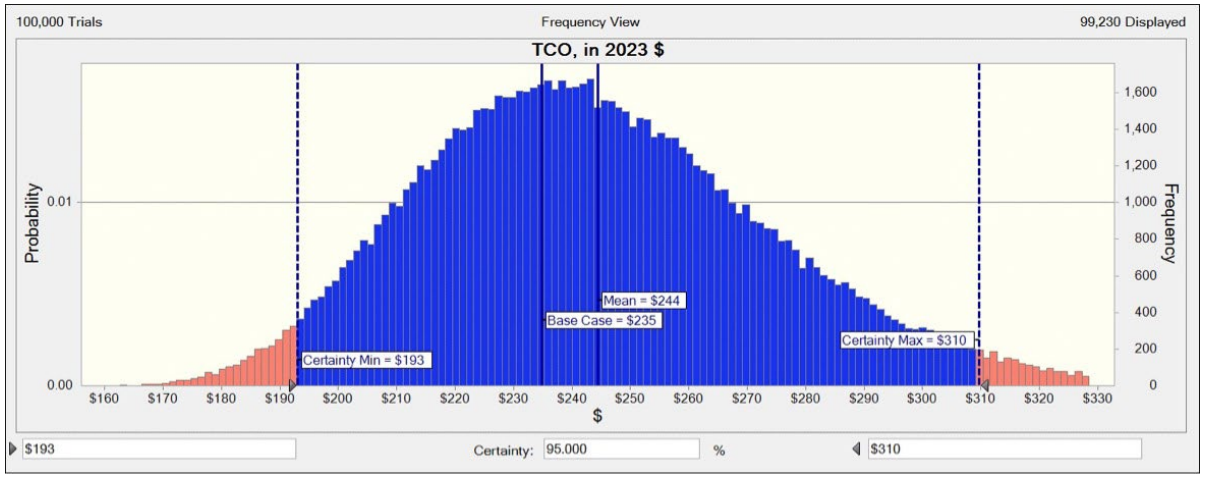


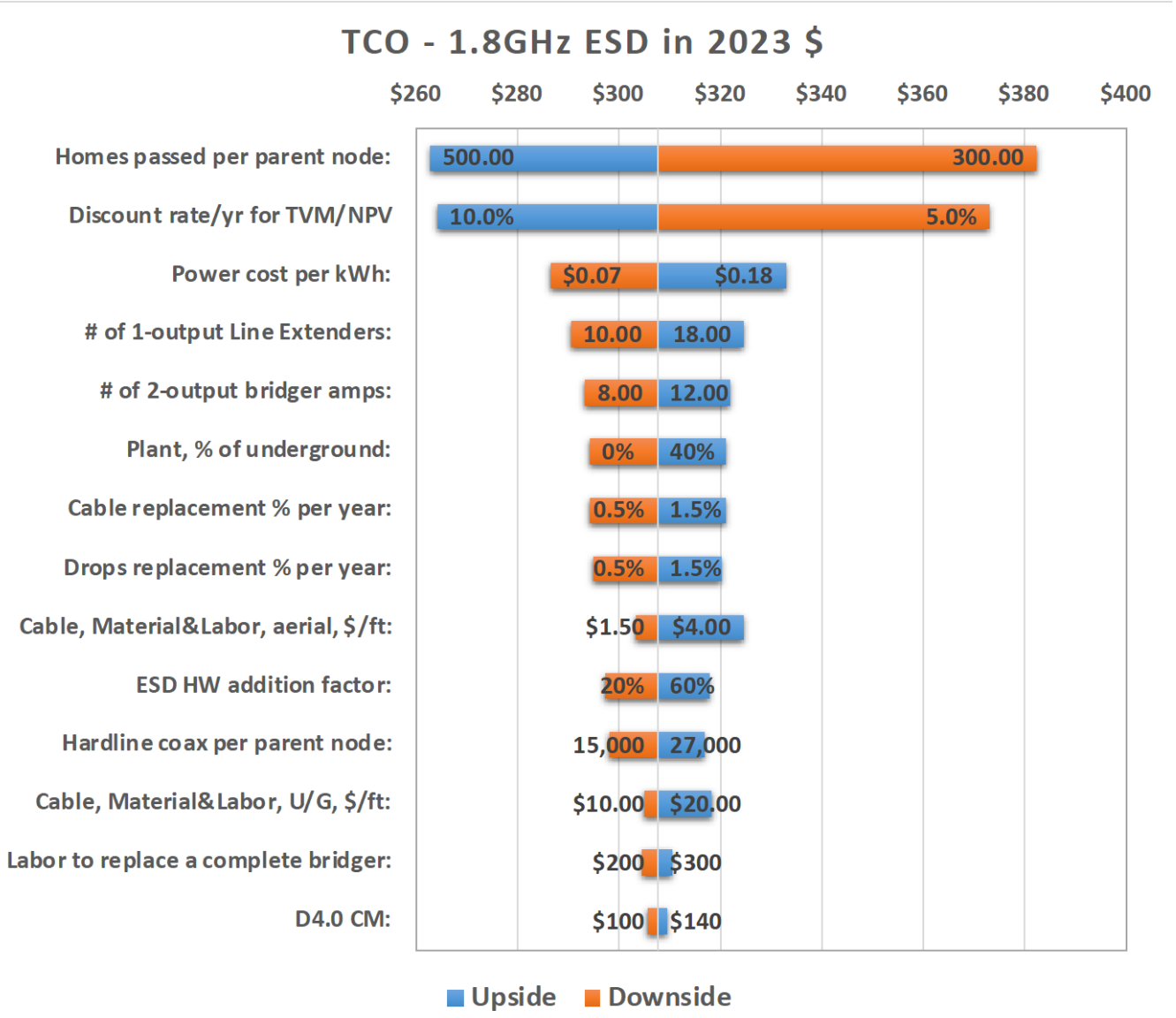




Variations/ Monte-Carlo Sensitivity Analysis







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Conclusions

Conclusions

- ✓ Common to all upgrade scenarios is the brownfield starting point of 400 HP, 200 subs per node, with the long-term top tier 5 Gbps DS / 1 Gbps US advertised speeds
- ✓ Initial upgrade costs are 5x to 10x higher for PON as compared to HFC upgrades
- ✓ PON OPEX, however, is 2x lower, and thus favors PON for the greenfield installations
- ✓ The 1.8 GHz ESD plant upgrade handled low to moderate Tavg growth with aplomb. TCO, over the next 30 years, comes at $308/HP, in ‘23 dollars
- ✓ 1.2 GHz high-split upgrade held up surprisingly well – with just one node split required – under the low Tavg growth assumption. TCO = $235/HP, in ’23 dollars
- ✓ 10G R-PON addressed the high Tavt growth – at a premium. TCO = $601/$932, with 20% vs. 80% of plant located underground
- ✓ Postponement of big spend pays dividends, as seen in “1.8 GHz upgrade now, overbuild with fiber in ‘44” scenario. TCO = $380/HP in ‘23 dollars
- ✓ Caveat Emptor – mileage may vary – above conclusions are based on a long list of assumptions. Variation analysis & sensitivity analysis, however, are provided

David Bowler, for expert guidance on finer aspects of 1.8 GHz ESD plant upgrade

Co-Authors

John.Ulm
@commscope.com

Craig.Coogan
@commscope.com

Zoran.Maricevic
@commscope.com

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Thank You!

Zoran Maricevic

Engineering Fellow
CommScope
zoran.maricevic@commscope.com