Network Transformation and the Road to 10G

A Technical Paper prepared for SCTE by

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1. Introduction

This paper provides an overview of the Cox hybrid fiber-coax (HFC) network and its transformation towards delivering the 10G vision. The network roadmap maps different customer service tiers to HFC configurations, such as the sub-split, mid-split, high-split, and ultra-high split 1.8GHz configurations. The goal of achieving 10G is enabled by DOCSIS® 4.0 (D4.0), 1.8 GHz plant, ultra-high split, All-IP video migration, and other network component upgrades. The All-IP migration program and customer premise equipment align with this network transformation, with a recommendation to implement the premise architecture as All-IP and single-outlet. This long-range plan aims to achieve the All-IP 10G Network via DOCSIS 4.0, providing multi-gig services with 10G capacity across much of the HFC network.

2. Overview of the Cox HFC Network

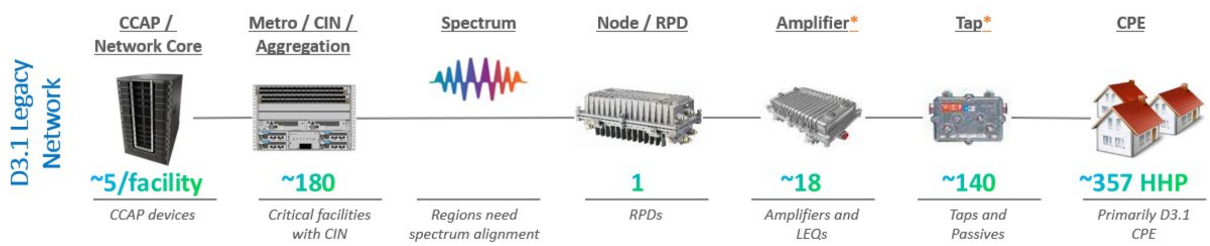

Figure 1 – Cox HFC Access Network Overview

An average node in the Cox HFC access network passes around 360 households or businesses and uses 140 taps and passives along with 18 amplifiers or line-extenders. Roughly 5 Cable Modem Termination Systems (CMTS) or Convergence Cable Access Platform (CCAP) devices in each of 180 critical facilities across 21 markets connect these nodes across the metro and backbone networks to the primary data centers and the broader internet.

3. Services and HFC Architecture on the Road to 10G

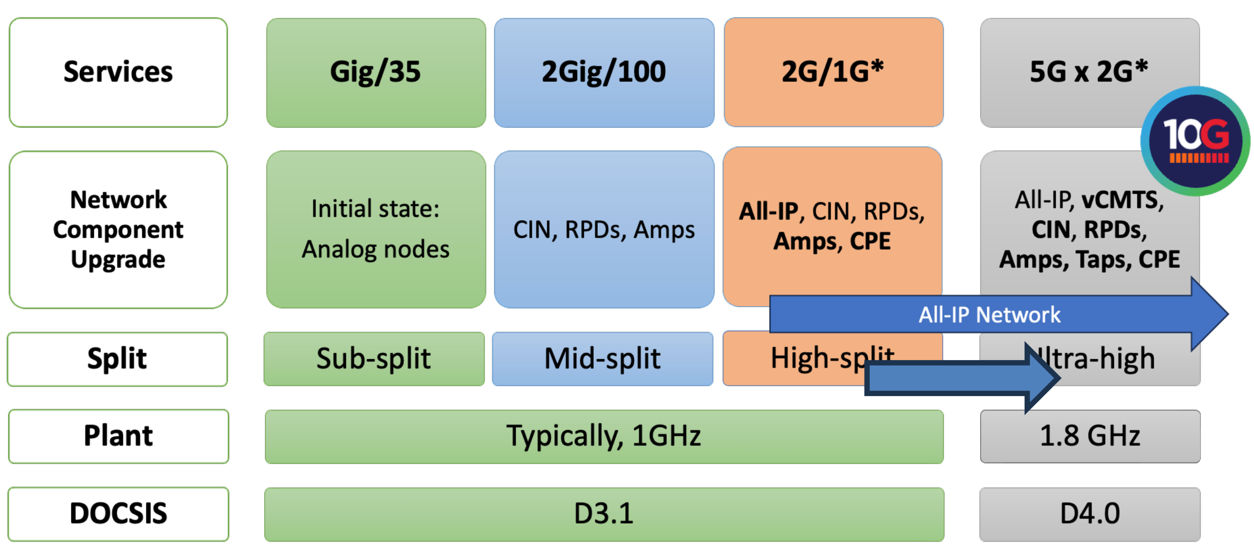

Figure 2 – Services and HFC Architecture Mapping

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This high-level service roadmap above maps these various access network components and technologies to the service they ultimately enable for our customers. The goal of 10G is enabled by D4.0, 1.8 GHz plant, ultra-high split, All-IP and a host of network component upgrades.

While it is necessary for us to develop the capability to deploy these interim technologies along the way, most of our network will only see a couple of these configurations. And all will ultimately realize the 10G configuration.

4. HFC Access Network Spectrum Roadmap

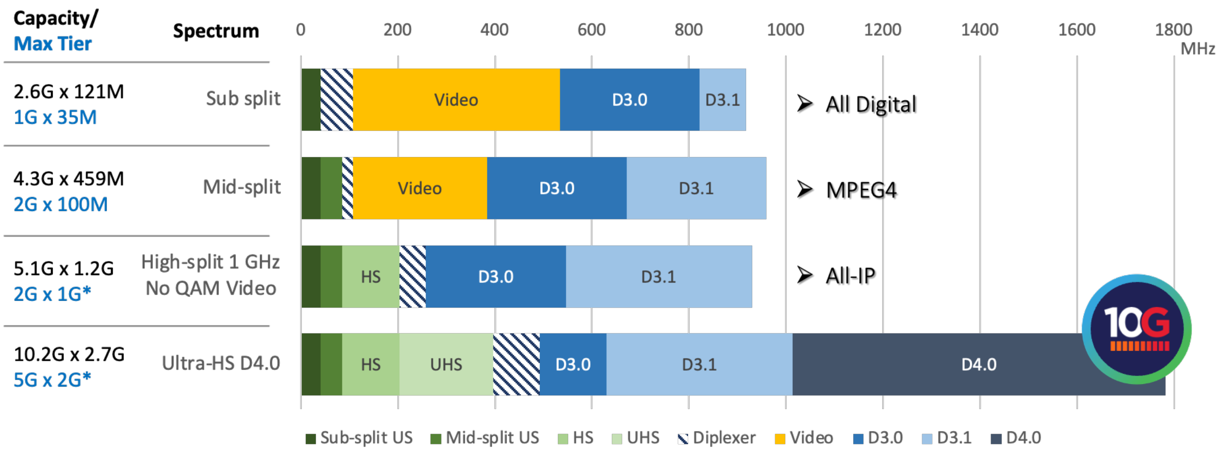

Figure 3 – HFC Access Spectrum Roadmap

Not quite half of Cox's HFC network is sub-split and 1 GHz or 860 MHz plant, with 120 Mbps upstream data capacity, and not quite 3 Gbps downstream data capacity and with a significant amount of the spectrum supporting legacy video. This configuration enables services tiers up to 1 Gbps/35 Mbps.

The next major network configuration was enabled by several initiatives: a conversion to all MPEG-4 compressed legacy video spectrum down to around 250 MHz, which enabled downstream data capacity expansion with additional OFDM blocks. And, of course, the mid-split upgrade program expands upstream data capacity more than 3-fold. The resulting total downstream+upstream node capacity approaches 5 Gbps, allowing high penetration of service tiers up to 2 Gbps by 100 Mbps.

The next major capability: high-split. With a commitment to reclaim and repurpose legacy video spectrum for upstream and downstream data, our network can be configured as high-split with actives similar to the mid-split upgrade and implemented with existing DOCSIS 3.1 (D3.1) silicon. This enables service tiers of up to 2 Gbps/1 Gbps. This step significantly de-risks the D4.0 timeline.

Lastly, as multi-gigabit downstream and upstream speed tiers are needed via HFC, we upgrade taps to 2 GHz, actives to 1.8 GHz ultra-high-split, and nodes to D4.0 to enable a 10 Gbps by 2.7 Gbps node capacity offering speeds up to 5 Gbps/2 Gbps. This is the realization of the "All-IP 10G Network".

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5. HFC DOCSIS Evolution Stages

5.1. HFC DOCSIS 3.1 Sub-split Network Overview

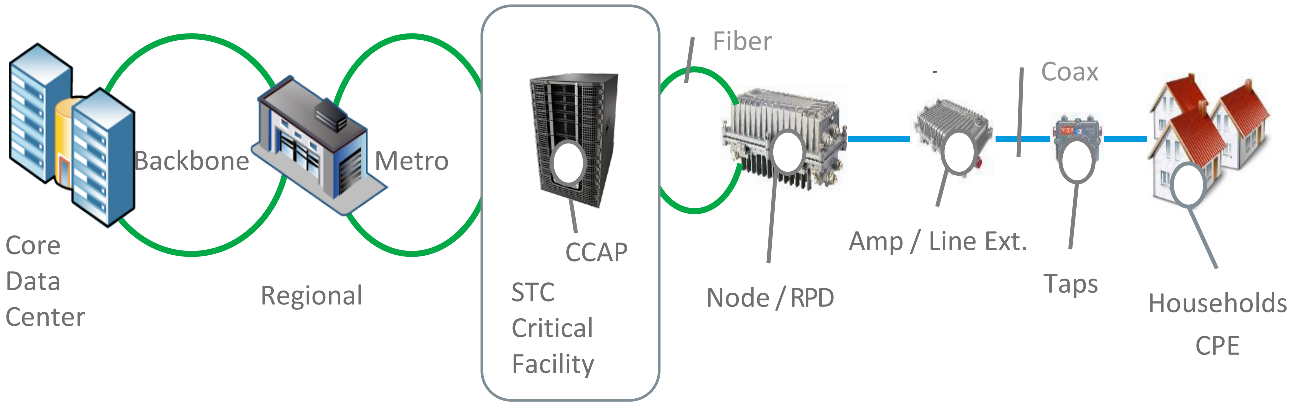

Figure 4 – D3.1 Sub-split Network

The figure above outlines the typical DOCSIS 3.1 sub-split network. This standard architecture connects equipment at the customer premises via the coax drop to the tap, usually though amplifiers, to an analog node, which is connected via the access fiber ring to the CCAP housed in the critical facility. Those facilities are connected via the metro fiber ring to the regional data center(s) which are connected via the backbone fiber ring to core data centers.

5.2. HFC DOCSIS 3.1 Mid-split Network Overview

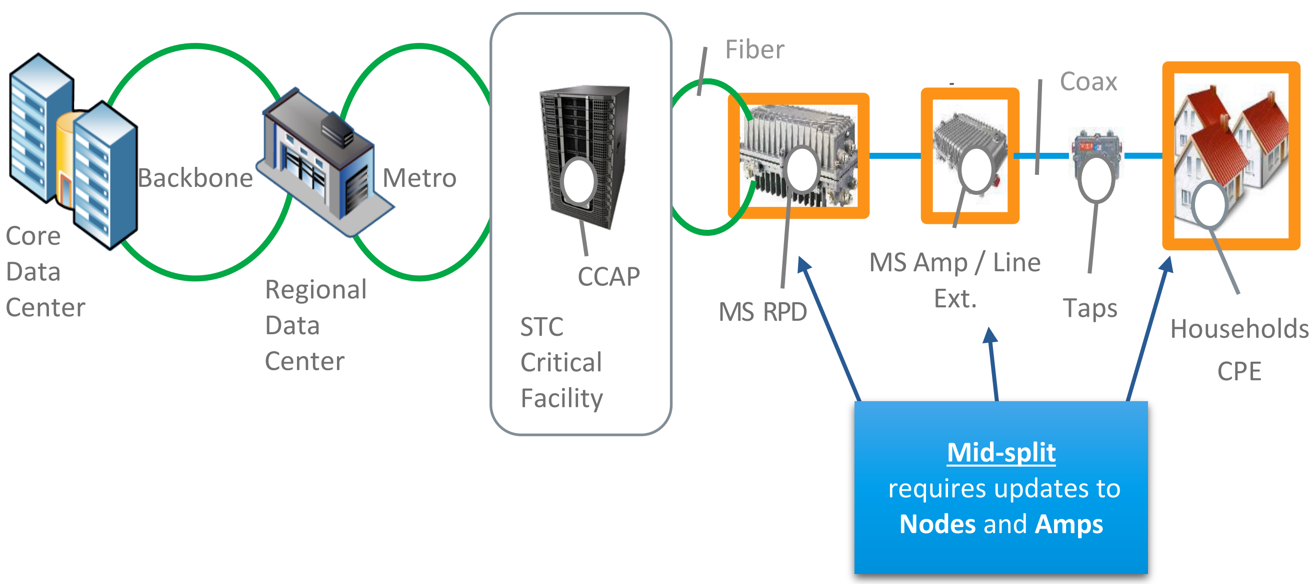

Figure 5 – D3.1 Mid-split Network

The figure above highlights the network component changes necessary to upgrade to the mid-split distributed access architecture (DAA) network. The node is upgraded to a mid-split Remote PHY device (RPD) with a redundant 10 GbE fiber-optic connection to the CCAP. Amplifiers are upgraded to mid-split. And, of course, D3.1 mid-split customer premises equipment (CPE) are required.

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5.3. HFC DOCSIS 3.1 High-split 1 GHz Network Overview

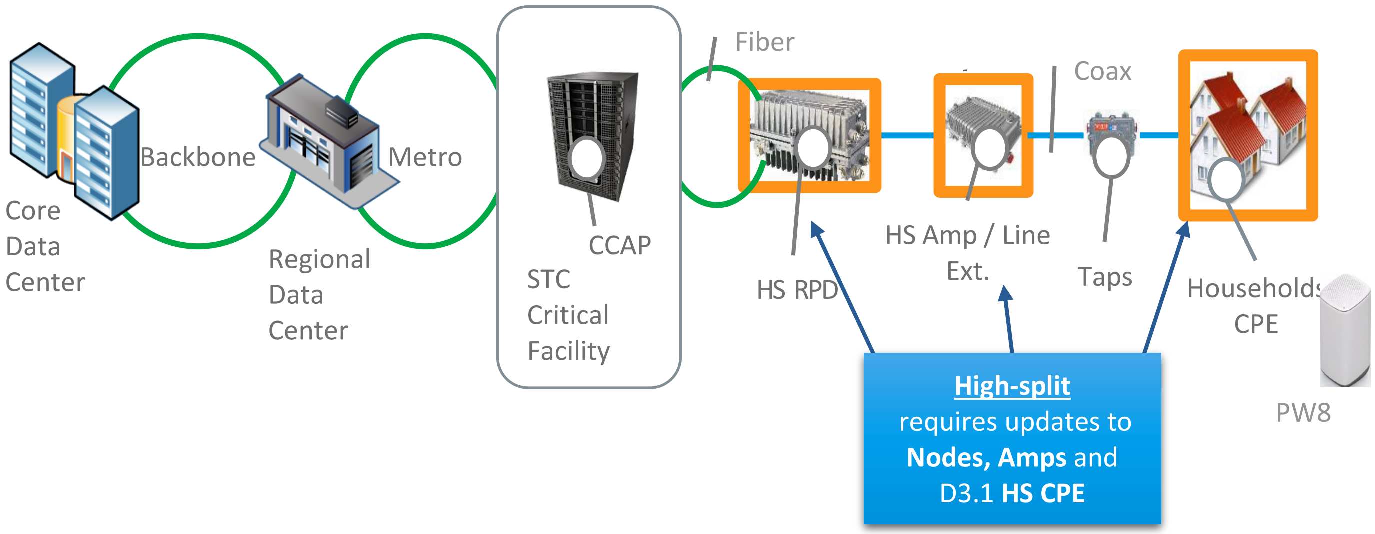

Figure 6 – D3.1 High-split 1 GHz Network

This figure above highlights the network component changes necessary to upgrade to the high-split DAA network. This transition is very similar to mid-split. The sub-split node is upgraded to a high-split RPD with a redundant 10 GbE fiber-optic connection to the CCAP. Amplifiers are upgraded to high-split 1.8GHz. And, of course, D3.1 high-split CPE are required. The high-split capable premises also begins the migration to single-outlet in preparation for a future transition to D4.0 1.8 GHz.

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5.4. HFC DOCSIS 4.0 Ultra-high-split 1.8GHz Network Overview

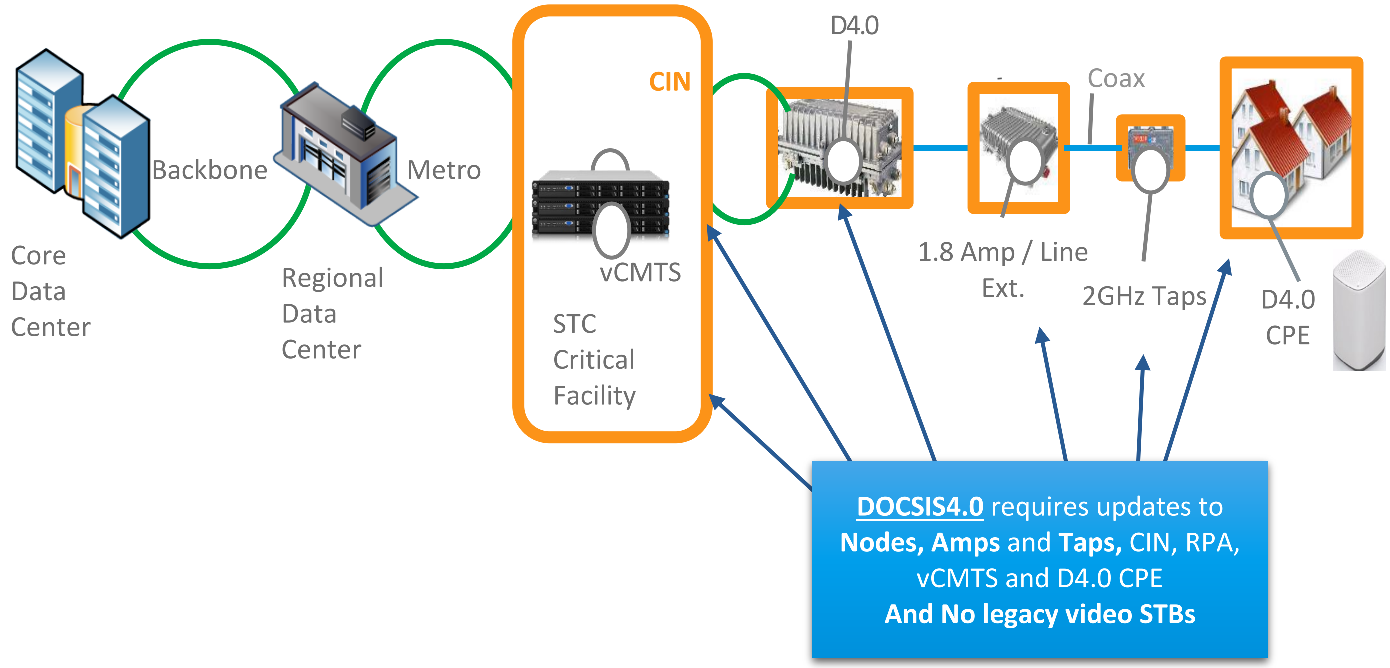

Figure 7 – D4.0 Ultra-high-split 1.8GHz Network

This final figure highlights the network component changes necessary to upgrade to the D4.0 ultra-high-split 1.8 GHz network. The D4.0 architecture will be supported by a virtualized CMTS (vCMTS) in the critical facility with 25 GbE converged interconnect network (CIN). The node is upgraded to a D4.0 ultra-high-split 1.8 GHz RPD. Amplifiers are upgraded to ultra-high-split 1.8GHz. Taps and passives are upgraded to 2.0 GHz. And, of course, D4.0 ultra-high-split 1.8 GHz CPE are required. The D4.0 ultra-high-split premises generally requires single-outlet.

6. All-IP Transition

Cox began deploying IP video approximately three years ago. Currently IP video subscribers represent about 14% of our video subscriber base. DOCSIS 4.0 is designed as a point-of-entry technology, and as such can't support splitters within the home that would connect to QAM based video set tops, thus requiring IP video within the home distributed via Wi fi or Ethernet. Cox is also planning to move homes that subscribe to tiers requiring high-split service to single point-of-entry and IP video. This decision is based on two primary factors: 1) to remove the possibility of high split modem upstream transmissions interfering into sub-split or mid-split video CPE within the home, and 2) prepare the home for eventual conversion to DOCSIS 4.0.

While the above can be done on a home-by-home basis, there is a significant advantage of converting all video subscribers in a market (or even on a node-by-node basis) to All-IP. When Cox converted all video to MPEG4 from MPEG2, we recovered more than 1/3 of the spectrum devoted to QAM video delivery. Moving to All-IP video allows us to recover approximately 250 MHz of spectrum to devote to DOCSIS. That video traffic moves to DOCSIS, but the amount of bandwidth used is far less. We observe that the

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average IP video subscriber uses approximately 6 Mbps of DOCSIS capacity at busy hour. On average we have less than 100 video subscribers per service group, or less than 600 Mbps of DOCSIS video traffic. This represents approximately 1/3 of the capacity of a 192 MHz OFDM channel.

While there is significant expense in replacing QAM-based video CPE with IP CPE, analysis has shown this is a cost-effective way to increase the DOCSIS bandwidth of the network. The majority of the Cox network is 1 GHz, with a small percentage at 860 MHz. Our mid-split 1 GHz plant has sufficient downstream capacity to offer a 2 Gbps top tier; however, moving the plant to high-split reduces the downstream available spectrum to the point that a 2 Gbps top tier could only be offered if the plant is converted to All-IP video. 860 MHz plant only has the capacity to offer 2 GHz downstream tier in a mid-split configuration if the plant is converted to All-IP. With an ultra-high split DOCSIS 4.0 deployment, legacy 1 GHz DOCSIS CPE would have very little downstream bandwidth available to them unless legacy QAM video was removed.

There are other advantages of moving to All-IP video. It simplifies the network by having all services delivered over IP, reduces complexity in the headend, eliminates the need for CableCard and out-of-band signaling, and provides a common method of delivering video to both our HFC and passive optical networking (PON) networks.

Cox is embarking on a multi-year transition plan to remove video CPE that is exclusive to QAM based video delivery and replace it with Wi-Fi™ enabled IP video devices. Some currently QAM based CPE, for example the Contour 2, contain DOCSIS 3.0 modems and can transition to IP delivery.

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7. Target High-split and D4.0 Premises Architecture

Figure 8 – Target High-split and D4.0 Premises

One rather important implication that results from this network roadmap is the future premises architecture. Since our long-term plan realizes the All-IP network, which means reclaiming legacy video spectrum and replacing legacy STBs, the straight-forward recommendation is this:
The high-split and D4.0 1.8 GHz premises architecture also be All-IP and single-outlet. Single-outlet means essentially all splitters and house-amps can be eliminated. All-IP means no legacy video QAM devices, no MoCA (Multimedia over Coax Alliance), and existing POE (Point-of-Entry) filters should be removed. Wi-Fi becomes the primary connection within the home, and Ethernet the secondary.

7.1. Preparing the home for DOCSIS 4.0

The DOCSIS 4.0 specifications were developed with the concept that the CPE is a point-of-entry device, that is, it is the only device in the home connected to the network and there are no splitters, amplifiers, or filters between it and the network. With a potential upstream frequency of up to 684 MHz and a maximum transmit power of 65 dBmV, a pre-equalized maximum power spectral density (PSD) was specified for the ultra-high split bands. Based on the analysis in the figure below, it shows that operation as a single point-of-entry device is required. Another compelling reason for both D4.0 modems and high-split modems to be single point-of-entry is that their upstream transmit frequencies fall within the

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downstream passband of sub-split and mid-split legacy video CPE. The transmit levels of these modems can overload the wideband front end of the legacy CPE within the same home, producing errors across the entire band.

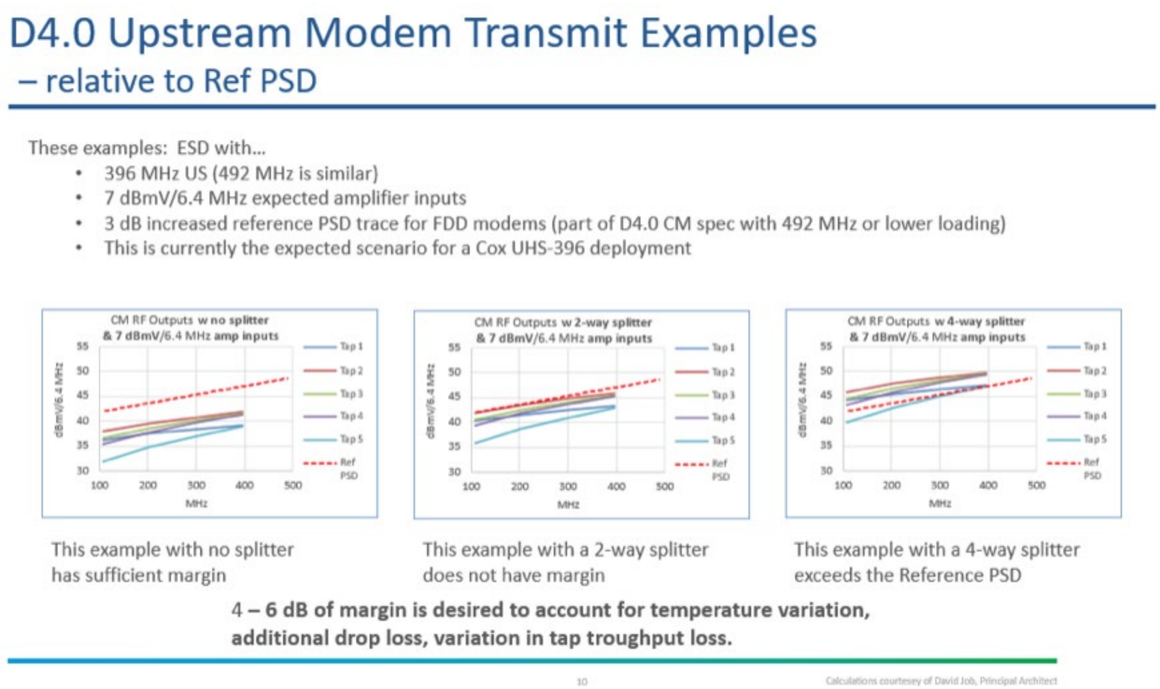

Figure 9 – Analysis of Single Point-of-Entry for D4.0 Modems

Single point-of-entry also significantly reduces the number of potential ingress points within the network, improving network performance and reliability. Early estimates are that 75% of ingress originates in the home, and single point-of-entry may reduce that ingress by 75%. Trials are underway to validate these assumptions.

Removal of splitters, MoCA point-of-entry filters, and house amps would require a technician to enter the home; however, Cox would like to preserve the ability for customers to self-install. Approximately 70% of current installations are self-installs. We are exploring different methods to accomplish a significant number of self-installs. One approach would have a technician, any time they enter a customer's home for any reason, convert that home to single point-of-entry whenever possible. That way the home would be ready for a self-install whenever the customer needs to upgrade their service.

High-split modems and D4.0 modems operating in high-split mode are not limited by the PSD requirements of ultra-high split and can in most cases work behind splitters. Legacy video equipment must still be removed. It would be possible to create self-install kits including IP video set-tops that could work in homes not yet wired for single outlet. In the case of D4.0 modems, they would be limited to service tiers supported by high-split and would require a technician visit to remove splitters if a higher service tier is required. A more immediate service call would be required if a house amplifier or MoCA POE filter was in place.

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8. The Road to 10G and CPE Lifetimes

How do services and spectrum transformation initiatives align to programs and CPE?

This series of figures attempts to illustrate that relationship between video and data CPE volumes over their lifetimes and the technology programs to which they relate.

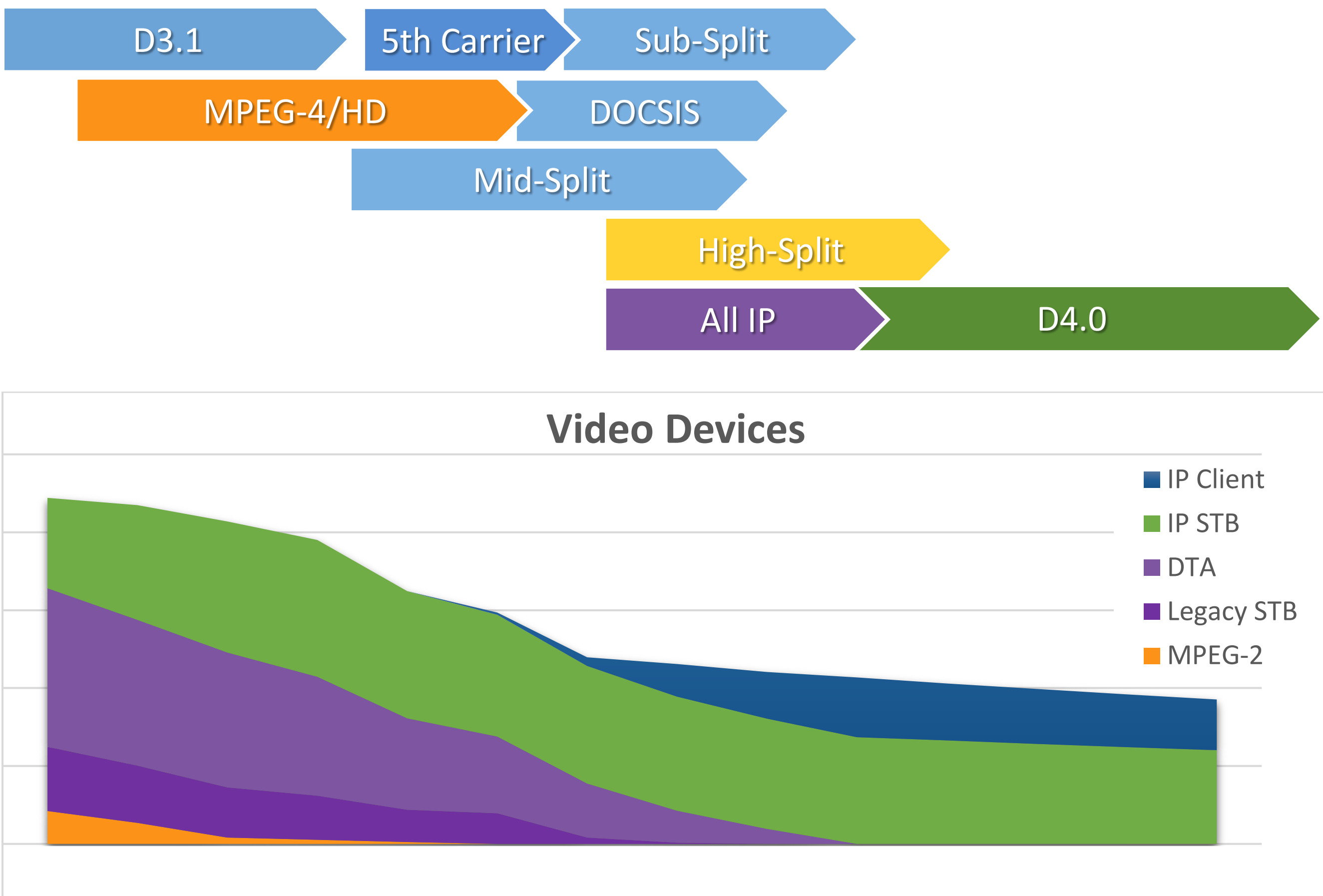

Figure 10 – Video Device Transitions

For example, the MPEG-4 program (orange) spans the end of life of MPEG-2 boxes. Likewise, All-IP, including legacy video retirement (purple) spans the end of life of legacy set-top boxes (STBs) and digital terminal adapters (DTAs), with only IP STBs and IP clients remaining long-term.

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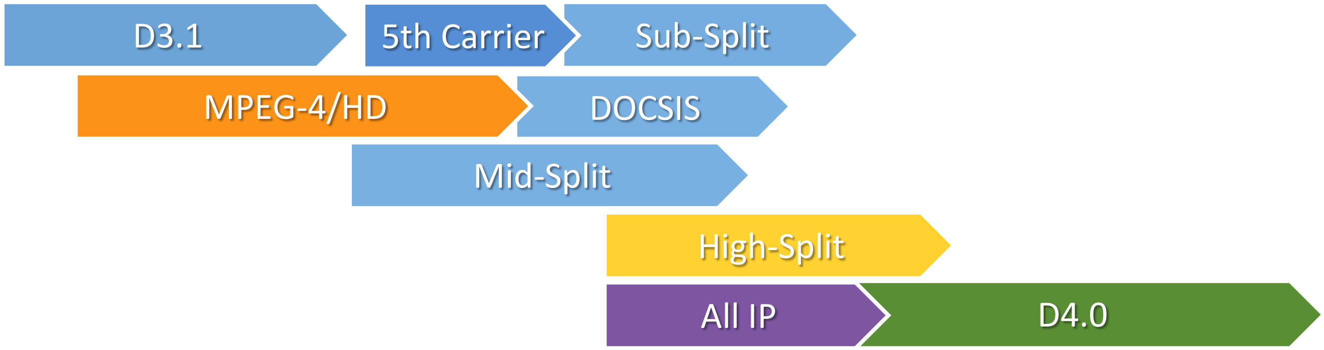

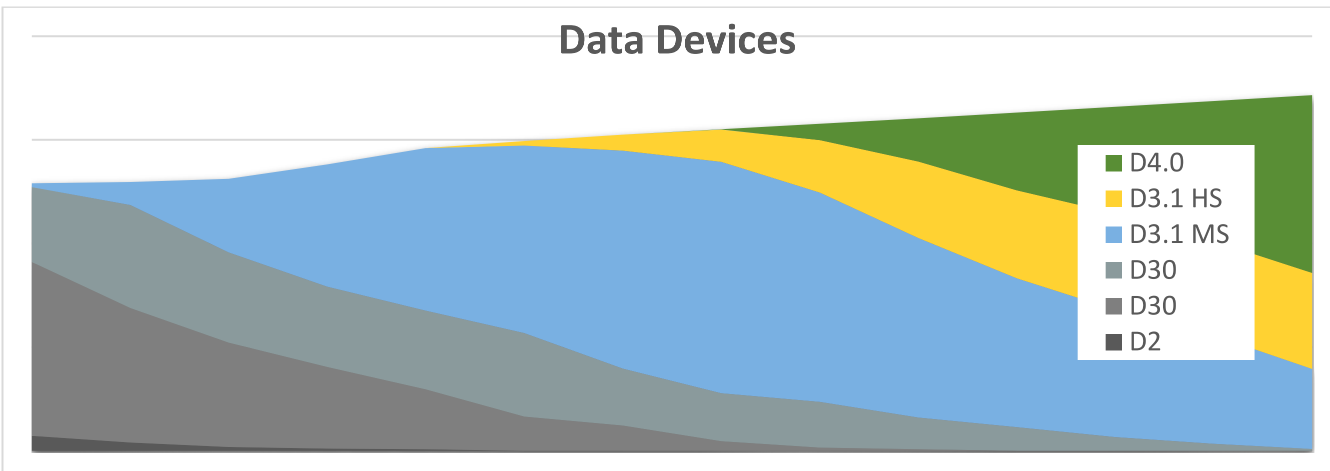

Figure 11 – Data Device Transitions

The introduction, and expansion of the D3.1 gateway (blue) with the D3.1 program supports sub-split OFDMA, OFDM Expansion, and Mid-split. High-split (yellow), which paces legacy video retirement, leverages the D3.1 high-split 1.2 GHz gateway.

And of course, the D4.0 Ultra-high-split program (dark green), requires legacy video retirement completion, and leverages the D4.0 ultra-high-split 1.8GHz cable modem (CM).

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9. Network Footprint Evolution

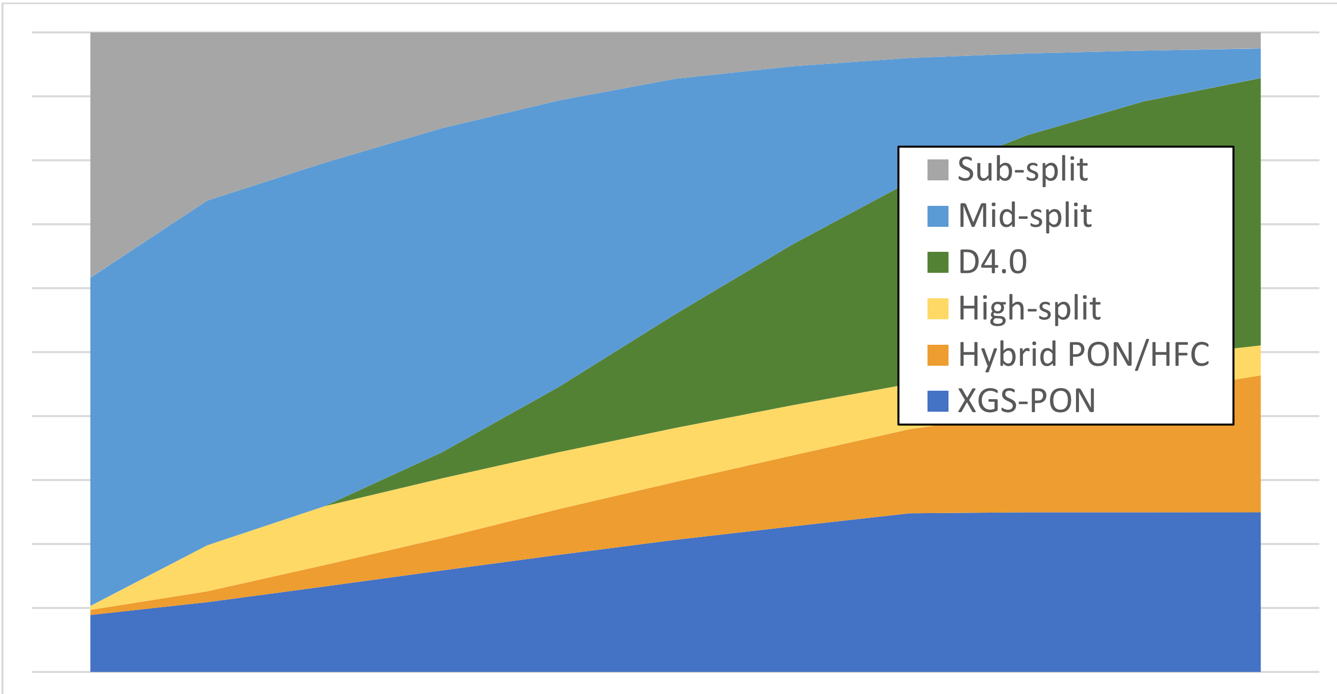

Figure 12 – Network Footprint Transition

The figure above demonstrates the enterprise-wide technology footprint that would be available given the long-range network plan. A healthy amount of mid-split 1 GHz footprint is already network ready and supporting multi-gig service tiers. High-split footprint grows as the All-IP transition commences. And, of course, the D4.0 and fiber-to-the-premises (FTTP) footprints as well, which are capable of 5 Gbps or better.

Once legacy video reclamation is complete, a preponderance of the network will be capable of 2 Gbps down or better. And moving rapidly forward with 5 Gbps or better.

10. Conclusion

This paper has outlined a long-term plan for Cox to get to a 10G network through stages of development that ends with a DOCSIS 4.0 1.8 GHz All-IP network that complements our XGS-PON deployments. The plan includes node actions that both solve network congestion and provide increasing speed tiers as needed to address competition. The result is a more reliable network that is designed to the state of the art.

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Abbreviations

CCAP	Converged Cable Access Platform
CIN	Converged Interconnect Network
CM	Cable Modem
CMTS	Cable Modem Termination System
CPE	Customer Premises Equipment
D3.1	DOCSIS 3.1
D4.0	DOCSIS 4.0
DAA	Distributed Access Architecture
dBmV	Decibel millivolts
DOCSIS	Data over Cable Service Interface Specification
FTTP	Fiber to the Premises
Gbps	Gigabits per second
GHz	Gigahertz
HFC	Hybrid Fiber-Coax
IP	Internet Protocol
Mbps	Megabits per second
MHz	Megahertz
MoCA	Multimedia over Coax Alliance
MPEG	Motion Picture Experts Group
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
POE	Point-of-Entry
PON	Passive Optical Network
PSD	Power Spectral Density
QAM	Quadrature Amplitude Modulation
RPD	Remote PHY Device
STB	Set-Top Box
vCMTS	Virtualized Cable Modem Termination System
XGS-PON	10-Gigabit-capable Passive Optical Network

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