The Video Conundrum

Migrating to IP Video

A Technical Paper prepared for the Society of Cable Telecommunications Engineers
By

Samir Parikh
Director, Product Management
Gainspeed Inc.
295 Santa Ana Court, Sunnyvale, CA, 94085
408-675-5069 ext 2008
samir@gainspeed.com

Overview

Dramatic changes in TV viewing habits, coupled with the insatiable demand for high-speed data services, are driving cable operators to migrate to IP-based video delivery. The combination of IP Video's statistical multiplexing capabilities and advanced codecs will enable operators to significantly improve hybrid fiber coax (HFC) network utilization and longevity. In addition, IP's flexible service delivery model enables "TV anywhere" services to address the over-the-top (OTT) competitive threat from video providers such as Amazon, Netflix, Hulu, and Apple.

The transition from legacy QAM-based video delivery to IP-based video delivery requires significant investment from cable operators and affects many facets of their operational systems, including the following:

1. Back-office Systems
2. Video Processing Infrastructure: transcoding, trans-rating, ad-insertion, content security/DRM, etc.
3. Content Delivery Infrastructure: streamers, caches, vaults
4. Content License Agreements
5. Clients: STB, gateways, tablet and phone applications
6. Network Infrastructure: IP/MPLS core and edge, DWDM transport, CMTS, EQAM, fiber nodes, analog optics, etc.

Over the past couple of years, operators have focused energy and investment to bring content to third-screen devices such as smartphones, PCs and tablets. These efforts have almost completely addressed the first five areas above. As a result, for operators to deliver IP video to the main screen, they now need to concentrate on the sixth item – network infrastructure.

Most operators have built a national IP backbone and deliver the majority of content to the headend/hub over IP. The access infrastructure is the last holdout. This paper focuses on the problems related to the access infrastructure – HFC infrastructure including the CMTS, EQAM, fiber node and analog optics – and what can be done to resolve them.

Contents

Cable Access Infrastructure Challenges

Cable networks were not designed for IP delivery. As a result, many hurdles must be overcome to migrate the network to an all-IP architecture.

Challenge #1 – Cost Per Channel

IP Video requires additional DOCSIS capacity. Migrating to IP Video will require operators to transition a large number of QAM video channels to DOCSIS channels. DOCSIS channels have historically cost around eight times more than QAM video channels. Infonetics Research has calculated the average price per channel for DOCSIS at roughly $1,000 and the average price per channel for QAM video at $120 **[MARKET]**.

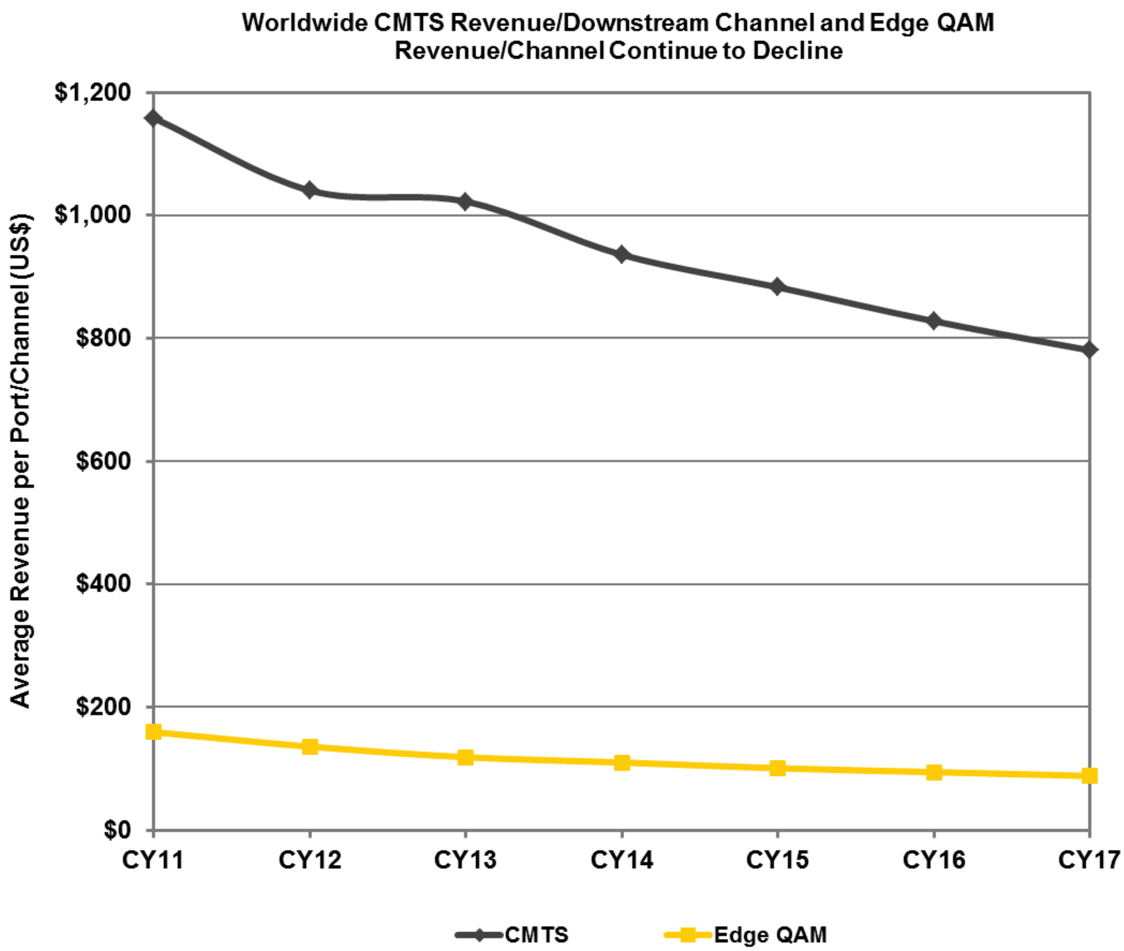

Figure 1: CMTS and EQAM Price Trend [MARKET]

While there are many components required to deliver an IPTV service, the CMTS is approximately ten times the cost of the other major components, making it the most significant cost driver for IP video. **[WHITE 2012]**

CMTS cost is not a new concern. The high cost of the CMTS has led to the development of several alternative solutions including Motorola's DOCSIS IPTV Bypass Architecture (BIPA) and BigBand Networks' vIP PASS. However, these products introduce significant complexity and have realized limited market success.

One of the efficiencies operators gain with IP video is that they can leverage advanced codecs (H.264 AVC or H.265 HEVC) to reduce the number of channels required to carry the same number of video programs.

The table below taken from **[HEVC]** highlights the improvements operators can expect with H.264 AVC and H.265 HEVC encoding.

Resolution/FPS	HEVC	AVC	MPEG-2
UHDTV- 4K/60	8-15 Mbps	18-22 Mbps	High
HD- 1080/720P60	1.5-3.5 Mbps	5-9 Mbps	9-15 Mbps
HD- 720p30	0.8-2.0 Mbps	1.5-4 Mbps	3-5 Mbps
SD	0.4-0.7 Mbps	0.7-1.5 Mbps	2-3 Mbps

Table 1: MPEG HEVC Performance over Typical and Anticipated Video Services (Linear/VOD)

Compared to MPEG-2, H.264 AVC provides a 1.5-2x efficiency gain and H.265 HEVC a 4x-5x efficiency gain. However, these gains are not enough to offset the >8x cost delta.

Some equipment vendors claim that CCAP will make the move to IP video economically and technically practical. CCAP, which specifies full spectrum per port (158 DS RF channels), was envisioned to dramatically lower cost by significantly increasing channel density and providing flexibility in allocating any channel to any service. While these DS channels are specified to be flexibly allocated between video and DOCSIS services, there are two problems. First, not all of the channels can be used for DOCSIS; 64 channels are typically reserved exclusively for broadcast video. Second, most CCAP products only support 96 DS channels per port, not the specified158 channels. Multiple generations of CCAP products will be required before the specification is met.

Therefore, it will still be some years before CCAP from traditional vendors reaches its potential and provides the necessary economic benefits for the IP video transition.

Challenge #2 - Bandwidth Requirements

Changes in cable subscribers' viewing behaviors are chipping away at the efficiency of broadcast video delivery. Viewers simply want to watch whatever they want any time they want. Technologies such as switched digital video (SDV) have been deployed by a number of operators to take advantage of statistical multiplexing gains across low viewership channels – the long tail. However, SDV doesn't address the time-shifted viewing habits of consumers enabled by DVRs and video-on-demand.

Consumers are increasingly "binging" on TV shows, catching up on past seasons over the period of a few days. Comcast held a "Watch-a-thon Week" in March 2013 during which subscribers were able to catch up on entire seasons of popular shows. On-demand usage jumped 25% during that week.

In addition, increasing consumption of IP video (e.g., Netflix, Hulu), online gaming and general Internet usage is driving high-speed data demand. As predicted by Nielsen's Law, bandwidth demand has increased approximately 50% per year for the past 25 years, and this trend shows no signs of abating. In fact, all signs indicate it is gaining speed. (See Figure 2 [BW CURVE])

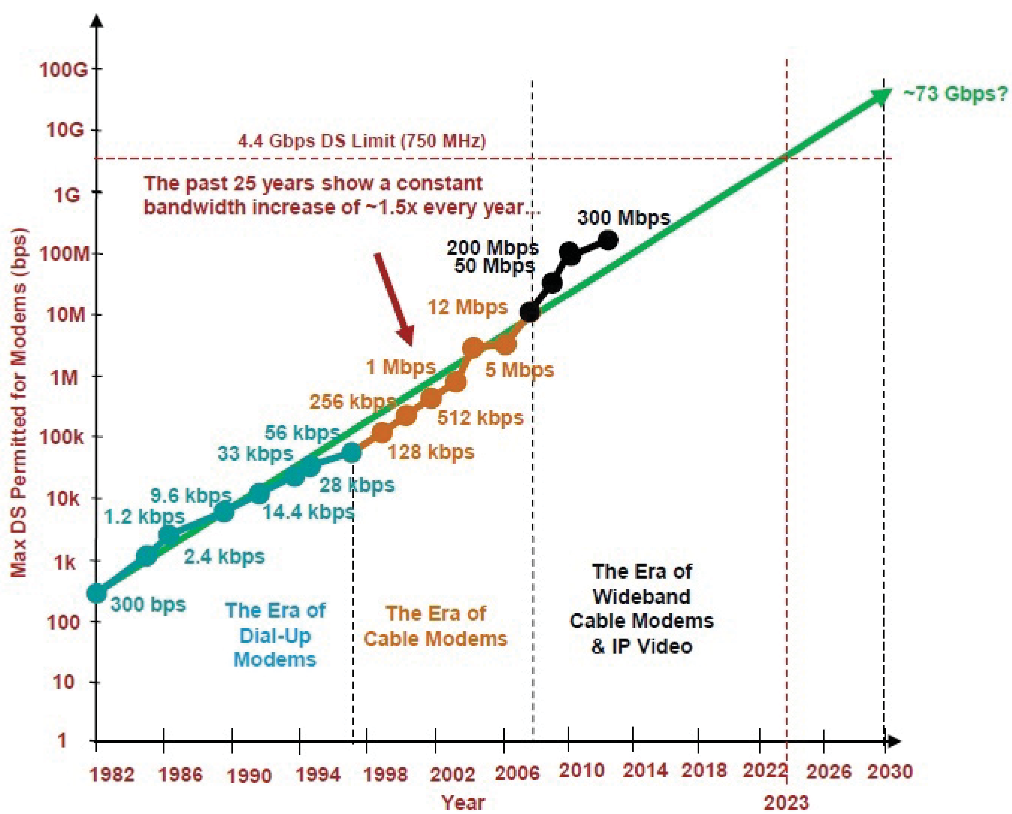

Figure 2: Nielsen Law Bandwidth Curve vs. Actual DS Internet Connection Speeds – Source: Arris, Inc.

The increasing bandwidth needed to accommodate changing TV viewing habits in conjunction with the increasing use of high-speed data are, in turn, driving the capacity required per service group to grow at a rate of greater than 50% year over year.

Since operators cannot just flip a switch and convert from QAM-based to IP-based video, the two technologies will need to co-exist for many years. By the time operators are fully converted to IP-based video, the growth rate of the bandwidth required per service group will likely be even greater.

Figure 3 below shows an estimate of the total number of DS channels (DOCSIS and QAM Video) required during a typical operator's transition from QAM video to IP video. Multiple factors will dictate the timeframe and rate at which DS channels are reallocated from QAM Video to DOCSIS, with penetration of IP set-top boxes (STB) being the most significant one. Therefore, these estimates are neither definitive nor applicable for all operators.

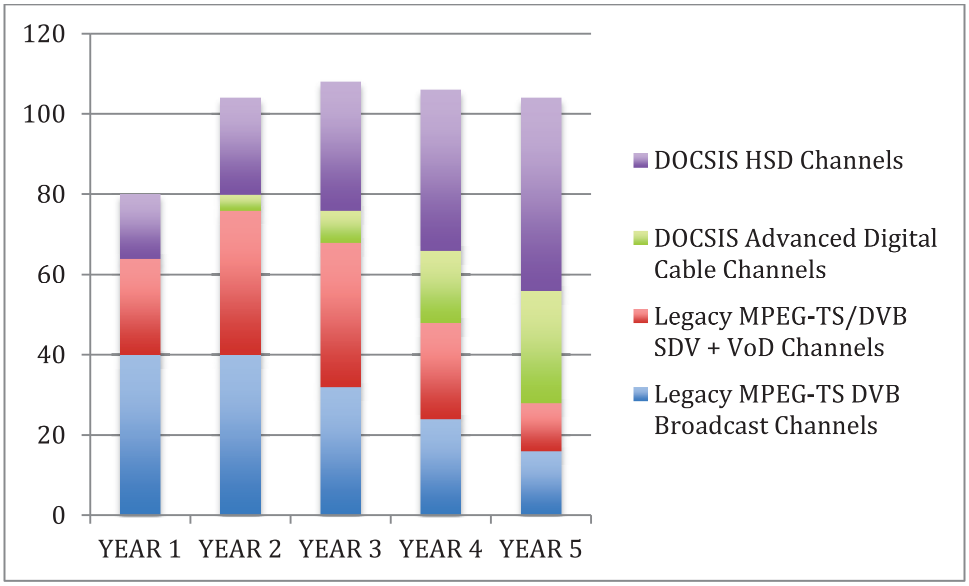

Figure 3: Bandwidth Requirements for Cable IPTV Transition

This scenario assumes a 50% reduction in the number of channels required to carry the same number of video programs due to the increased compression offered by H.264, coupled with the improved statistical multiplexing achieved by delivery over IP. However, the aggregate demand for capacity per SG stays fairly constant as HSD demands consume the channels freed up by the transition to IP Video.

Challenge #3 – Facilities Burden

As operators increase the number of DOCSIS channels per SG and reduce the size of each SG by splitting nodes, they are running into significant headend/hub power, cooling and space issues.

For example, according to a leading North American multiple system operator (MSO), migrating from an N+6 architecture to an N+0 architecture in one of their hubs would scale the number of SGs from 360 to 4,320. That is a 12x increase in the number of SGs! However, it also would require a 12x increase in CMTS, lasers, QAMs and combining rack space, power and cooling, making it impossible to do with today's equipment. Even with the densest CCAP solution, the operator cannot fit all the other required equipment into the existing hub.

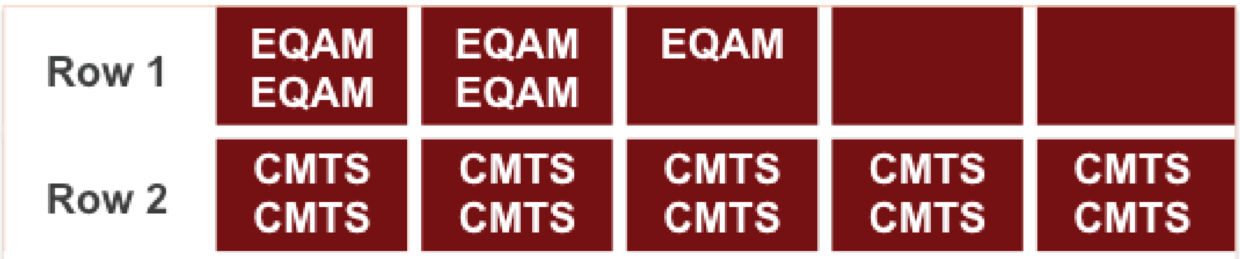

Figure 4: CMTS space requirements for 360 SGs

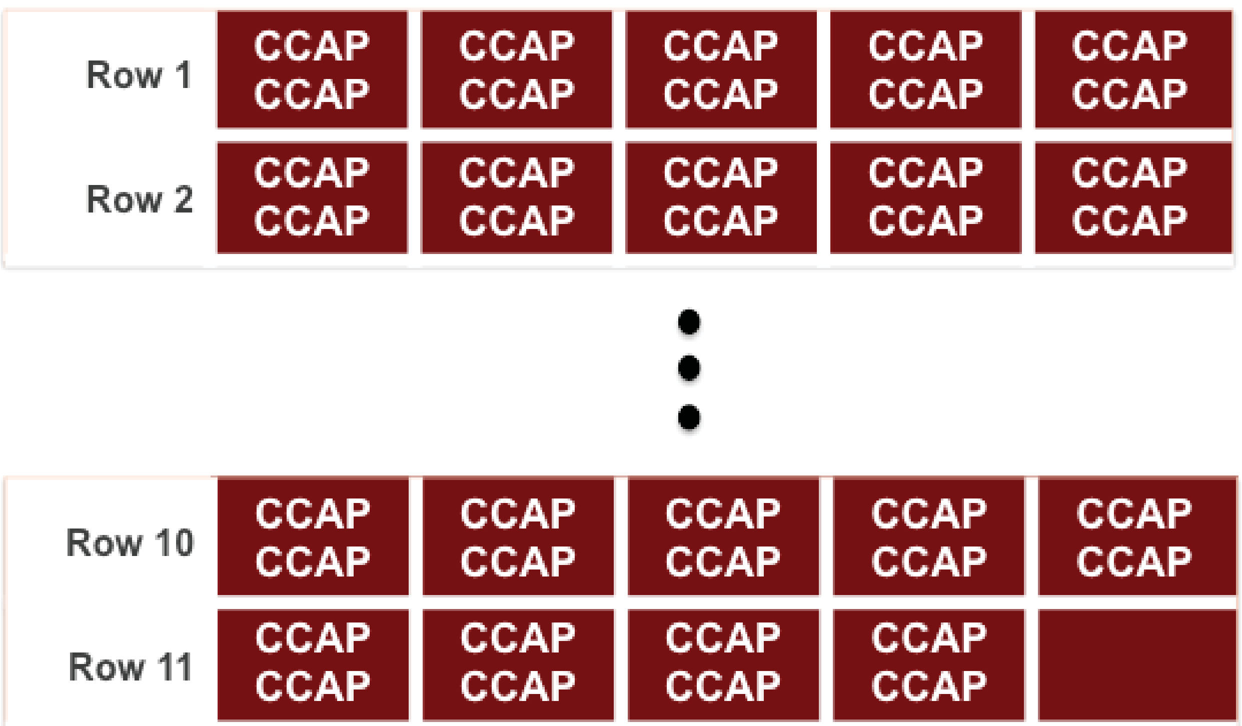

Figure 5: CCAP space requirements for 4,320 SGs

Figure 4 and 5 illustrate the scope of the problem. For 360 SGs in a M-CMTS architecture, an operator would need 8 racks just for the M-CMTS core and associated EQAM platform. Video QAMs, combining, splitting, analog optics, etc would add significantly to the number of required racks. This assumes that each CMTS can be scaled to support 36 SGs each and that 2 CMTS chassis can be fit in a rack (Figure 4). To scale this deployment to 4,320 SGs would require 96 racks just for CMTS and EQAMs! The problem gets worse as more channels are converted from broadcast video to DOCSIS to enable an IPTV deployment.

Fast-forward to CCAP and, assuming 2 CCAP chassis can fit in a rack, and that each CCAP can support 40 SGs and has the specified QAM density per port, it would still require 55 racks (Figure 5)!

The cost for operators to increase the power, cooling and space capacity of a hub makes it unthinkable to move in this direction.

The Solution – The Virtualized CCAP Architecture

In order to meet the growing demand for IP-based services, operators and equipment manufacturers need to re-imagine how HFC networks are built. They must work together to create an architecture that lowers the total infrastructure cost and scales to meet future service requirements.

The Virtualized CCAP architecture accomplishes both of these objectives.

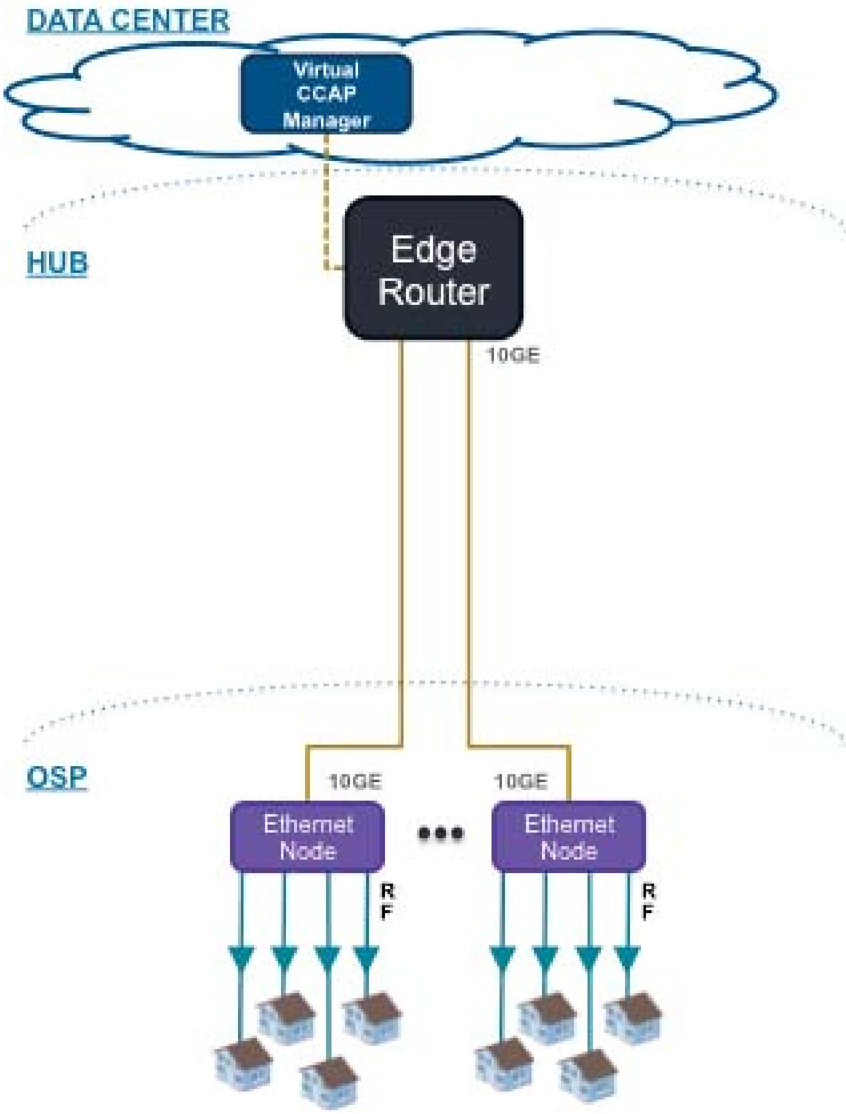

Figure 6: Virtualized CCAP Architecture

Figure 6 illustrates the Virtualized CCAP architecture. The architecture recognizes and takes advantage of the fact that the components and capabilities of a modern-day edge router (ER) and CMTS/CCAP significantly overlap. To be more specific, both ERs and CMTS/CCAPs feature:

1. IP/MPLS Control and Data Plane
2. Subscriber Management
3. QoS
4. 1GE/10GE/40GE/100GE Interfaces
5. Switch Fabric

By identifying and re-thinking where CCAP-specific functions are performed, the edge routers already deployed in headends and hubs around the world can be leveraged to enable a faster and lower cost transition to IP Video. To better understand how this "virtual CCAP" environment works requires a detailed review of the CCAP functions:

1. Cable Control and Management Plane
    - i. IPDR
    - ii. DOCSIS, RF and QAM MIBS
    - iii. Packet Cable 1.5, Multimedia
    - iv. Edge Resource Management – ERMI, NGOD, EDIS/ISA
2. RF Processing
    - i. DS Modulation
    - ii. US De-modulation
3. QAM Video Processing
    - i. MPEG Multiplexing (SPTS to MPTS, MPTS to MPTS, etc.)
    - ii. Conditional Access Scrambling/Encryption
4. DOCSIS Processing
    - i. DOCSIS Subscriber Management
    - ii. US and DS MAC
    - iii. US and DS PHY
    - iv. Scheduler
    - v. DOCSIS QoS

Today, these functions all sit together in the headend. The Virtualized CCAP architecture reimagines and relocates where each of these functions best fit.

Cable Control and Management Plane: This is essentially a collection of software applications and functions. While these functions require detailed knowledge of the CCAP/CMTS data ~~plane ,~~plane, it is not necessary for them to be co-resident with the device. These functions can easily be moved into an application container – the **Virtual CCAP Manager** ~~– which~~– which can run within a virtual machine anywhere in the operator's network, even centralized in the data center.

RF Processing: This function takes IP and Ethernet data that is generated further up the stack in the CCAP/CMTS and "formats" it for the HFC network. The Virtualized CCAP architecture moves this function into a fiber node, deeper within the HFC network. The fiber node is an ideal location for this function as it is the physical demarcation point for the coaxial network in the field. An additional benefit of this move is that signal losses introduced by the linear analog optics are eliminated; improving end-to-end SNR/MER and enabling higher order modulation on the cable plant.

QAM Video Processing: In the long-term, the move to IPTV will eliminate this function. However, as discussed earlier, this transition will take place over a long period. In the interim, with the RF modulation occurring in the fiber node, the rest of the EQAM functions can be easily performed by general purpose servers equipped with acceleration modules for encryption. These servers can either remain in the hub with the ER or be moved into a data center. Bulk encryption devices available on the market today can perform most, if not all, of these functions.

DOCSIS Processing: The function of DOCSIS is to contend with transmission over a shared physical medium – the HFC network. As a result, it is logical to move this function out to the fiber node along with the RF processing. By doing so, all data entering or exiting the hub would move over standard Ethernet (1GE to 100GE).

DOCSIS is the capability that drives the need for a physical CMTS/CCAP device. Without DOCSIS and RF processing taking place in the headend/hub, the functional differences between the CMTS/CCAP and edge router greatly diminish.

Once the Virtual CCAP is in place, not only does the physical CMTS/CCAP disappear, but also gone from the hub are the complex mess of RF combiners and splitters and the expensive cable-specific analog optical transmitters and receivers. This frees up significant physical space and dramatically lowers power and cooling demands.

This new Virtualized CCAP architecture delivers numerous benefits. It:

1. Maximizes scalability
2. Minimizes space requirements
3. Leverages industry-standard computing components
4. Lowers total cost by reducing both capital and operational expense
5. Improves RF performance, thereby increasing overall network capacity

Conclusion

Operators have already made significant strides to enable the transition to IP Video. The access infrastructure is the last piece holding them back. A “business as usual” approach will not get it done. To tackle this problem, operators and their trusted technology partners must work together to re-imagine the fundamental building blocks of the HFC network as it is known today. The technology to accomplish this already exists. It is time to complete the journey.

Bibliography

[MARKET] Infonetics Research, *CMTS and Edge QAM Hardware and Subscribers Quarterly Worldwide and Regional Market Share, Size and Forecasts: 1Q13*, May 29, 2013

[WHITE 2012] The Economics of IP video in a CCAP World
John Ulm & Gerry White, Motorola Mobility
NCTA Spring Forum 2012

[HEVC] High Efficiency Video Coding (HEVC) in a Changing World—What Can MSOs Expect?
Mukta Kar, CableLabs; Yasser Syed, Comcast Cable; Munsi Haque, Consultant
NCTA spring forum 2013

[BW CURVE] http://www.multichannel.com/blogs/bit-rate/chart-week-arris-plots-nielsens-bandwidth-curve

Abbreviations and Acronyms

AVC	Alternative Video Coding
CCAP	Converged Cable Access Platform
CDN	Content Delivery Network
CMTS	DOCSIS Cable Modem Termination System
COTS	Commercial Off The Shelf
CPE	Customer Premise Equipment
DOCSIS	Data over Cable Service Interface Specification
DRM	Digital Rights Management
DS	Downstream
DVR	Digital Video Recorder
DWDM	Dense Wave Division Multiplexing
EAS	Emergency Alert System
EQAM	Edge QAM device
ER	Edge Router

GE	Gigabit Ethernet
Gbps	Gigabit per second
HFC	Hybrid Fiber Coaxial system
HSD	High Speed Data; broadband data service
HSI	High Speed Internet; broadband data service
HEVC	High Efficiency Video Coding
MPLS	Multiprotocol Label Switching
IP	Internet Protocol
IPTV	Internet Protocol based Television Service
MAC	Media Access Control
MIBS	Management Information Base
MSO	Multiple System Operator
nDVR	Network (based) Digital Video Recorder
OTT	Over The Top
PHY	Physical Layer

QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RF	Radio Frequency
SG	Service Group
SDV	Switched Digital Video
STB	Set Top Box
Tbps	Terabit per second
UDP	User Datagram Protocol
US	Upstream
VOD	Video On-Demand