ARCHITECTURAL ALTERNATIVES FOR CABLE IP VIDEO

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ABSTRACT

A transition to IP Video is being seriously considered by many MSOs and since many different architectural approaches are possible, it seems timely to begin analyzing the advantages and disadvantages of many of the architectural approaches to IP Video. This paper will begin by presenting an overview and brief analysis of the many different architectural approaches that are being considered for IP Video Delivery.

INTRODUCTION

Many Multiple System Operators (MSOs) within the Cable Industry are beginning to plan architectures which will ultimately be used for the deployment and delivery of Internet Protocol (IP) Video services to their subscriber base. Different MSOs will move toward IP Video at different times and at different rates, and different MSOs may also choose slightly different architectures as they unveil these new services. However, the authors believe that once the transition to IP Video begins within any particular MSO network, it will likely occur quite rapidly as MSOs work to offer competitive responses to both traditional video service providers and Over-The-Top (OTT) Video content providers.

By offering this new type of IP Video service to their subscribers, most MSOs are hoping to accomplish several important goals, including:

- Gaining access to a broader audience through all 3 screens in the home (TV, PC, and handheld devices)
- Building a direct conduit to the 15-30 year-old demographic (through their handheld devices)
- Creating new means of further monetizing their high-quality video content with new subscription fees
- Providing an opportunity to enter the growing "Internet advertising market" through directed advertising in IP-based videos
- Allowing themselves to become the "organizers" of all IP Video content (MSO-based and Web-based)
- Reducing the high costs traditionally associated with legacy STBs

The basic goal behind any IP Video Architecture is to deliver a common experience for all video services over a managed or unmanaged broadband access network via Internet Protocol to a consumer's TV/PC/handheld device. For MSOs, this broadband access network is typically DOCSIS over Hybrid-Fiber Coax (HFC) plant. However, MSOs would also like the flexibility to offer IP Video services over the Internet so that their subscribers can access the MSO-managed video content even when they are on the road. The former IP Video delivery service (over the HFC plant) is referred to as an "On-Net" IP Video delivery service by many MSOs, implying that the delivery occurs on the MSO's managed HFC network. The latter IP Video delivery service (over the Internet) is called an "Off-Net" IP Video delivery service (a.k.a. TV Everywhere) by many MSOs, implying that the delivery occurs off of the MSO's managed HFC network.

From a subscriber's point of view, the method of delivering these video services is less important than several other attributes, including:

- The ability to route the video data around the home network to any IP-enabled endpoint using Internet Protocol
- The availability of bandwidth capacity permitting them to access all the video content that they want
- The Quality of Service (QoS) mechanisms to ensure that the video content is delivered reliably without pixilation or halts (which can only be guaranteed for On-Net IP Video delivery services)
- The availability of large quantities of high-quality live and on demand video content, both popular and long tail
- The ability to search through the available video content, regardless of source, in a fast, easy-to-use fashion
- The ability to access the video content at any time and in any format required by any desired endpoint device
- The ability to perform trick modes (pause, rewind, and fast-forward, progress bar) on the viewed video content

This paper will begin by presenting an overview and brief analysis of the many different architectural approaches that are being considered for IP Video Delivery. This paper will not address in detail the market drivers, bandwidth calculations or network cost analysis associated with the cable industries transition to IP technologies for the delivery of video services. Two of these topics (bandwidth and cost analysis) are being covered by papers submitted by Tom Cloonan and Carol Ansley of ARRIS.

IP VIDEO TECHNOLOGY MATURITY BY INDUSTRY

Before addressing architecture details, it would be beneficial to discuss some of the factors that will impact decisions to be made. Technology maturity and standards availability are important factors associated with network architecture decisions. All technologies progress through a basic lifecycle from concept to ubiquitous deployment. Some make it through the entire cycle, while others never make it out of the concept stage. It would be an oversimplification to group all IP Video technologies into a single category. The telecommunications, OTT video providers and cable industry are each at a different point in their evaluation and adoption of IP technologies for video delivery. The OTT provider started with IP but do not own the network. This makes each of their approaches to implementing IP technologies for video delivery unique.

The telecommunications companies in North America began IPTV deployments in 1999[1]. Today there are specifications in development or available from ATIS, Open IPTV Forum, ITU-T, and IEEE for Video delivery over an IP network.

The internet or over-the-top video delivery technology has grown through several streaming technologies since its beginnings in the mid 1990's [2]: progressive download, real time streaming protocol, and most recently adaptive bitrate delivery. Much of this technology was proprietary for the initial deployments. This industry now has a number of standards initiatives underway with a number of standards bodies including W3C, IEEE, ISO/ICE, and Ultraviolet.

The cable industry is just beginning to deliver IP Video to subscribers. They have the advantage of leveraging the available standards and experience from these other industries in developing standards through CableLabs to address their specific needs.

Cable specific IP Video Standards activities include;

CableLabs draft release Multimedia Gateway Device Architecture Technical Report https://www.cablelabs.com/doczone/cross_project_specs/requirements/tech_reports
CableLabs released OCLA (OnLine Content Access) specifications http://www.cablelabs.com/specifications/CL-SP-AUTH1.0-I01-101029.pdf

The TV Everywhere deployments by Cable operators are currently an overlay service that leverages the technologies and suppliers used by the OTT streaming media service providers.

Figure 1 illustrates the typical lifecycle and an estimate of the relative maturity of the technology for each industry.

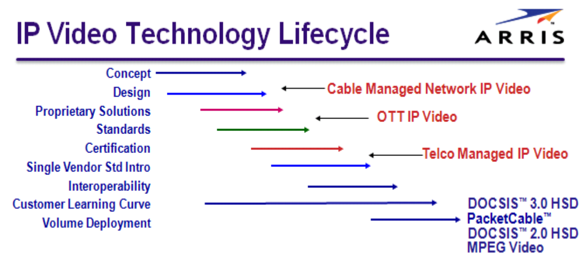

Figure 1: IP Video Technology Lifecycle

TECHNOLOGY TRENDS AND CLASSIFICATIONS AS A GUIDELINE FOR ARCHITECTURAL CHOICES

Before a discussion on the architectural choices and their associated merits, it is important to establish a definition of the various video delivery types and some high level measures to guide the operator in the decision process. These guidelines should be similar to an organization's core values. The guidelines should be non-specific, however if operators stay true to these guiding principles, the end objective will be met.

Proposed Architectural Guiding Principles

1. Open standard solutions are highly preferred to proprietary implementations.

   Open standards allow greater participation by suppliers. This in turn creates competition to reduce costs. Open standards also eliminate the risk of being stranded with a solution from a supplier that fails.

2. Internet Protocol (IP) technologies are preferred over regional or industry segment technologies.

   Selection of IP technologies allow the service provider to take advantage of new developments generated across multiple industry segments versus only those from their single industry segment.

3. Converged networks are preferred when compared to networks segmented by service type or distribution technology.

   Converged networks yield efficiency in utilization of resources throughout a service provider's business. Capital is more efficiently utilized; the statistical gains of convergence increase the utilization of equipment used for processing, storage, and distribution of content. Operations costs are contained; the simplification of the delivery network reduces the variety of equipment needed with cost savings available in spares, service agreements, and support personnel. Most importantly, maintenance and troubleshooting are simplified since a complete view of the network and subscriber is available when a service call is required.

4. Cloud based (centralized) networks are preferred over client based implementations. Much like the statistical gains of a converged network, cloud based systems can reduce the number of devices in the network. However, and possibly more importantly, cloud based networks can reduce the cost and complexity of the end points. For instance, an Operator can put an edge cache device in the network or use Network DVR to reduce the size and type of memory needed in a CPE device. This reduction in complexity of the end point can aid in speeding the deployment of new services without the need to update each CPE device individually. This may in turn extend the useful life of CPE devices capable of operating in this environment.

These four guiding principles will need to be balanced against the realities of today's technology availability, network reach and organizational structure. These realities may present a good reason for not immediately achieving the optimum solution. However, when used as a vision to guide the implementation, the network approaches the optimum over time.

CLASSIFICATION OF VIDEO DELIVERY TYPE

It may be useful to establish a taxonomy of video delivery technologies to measure against the above guiding principles. Figure 2 was developed by ARRIS to assist in the development of an IP video transition plan.

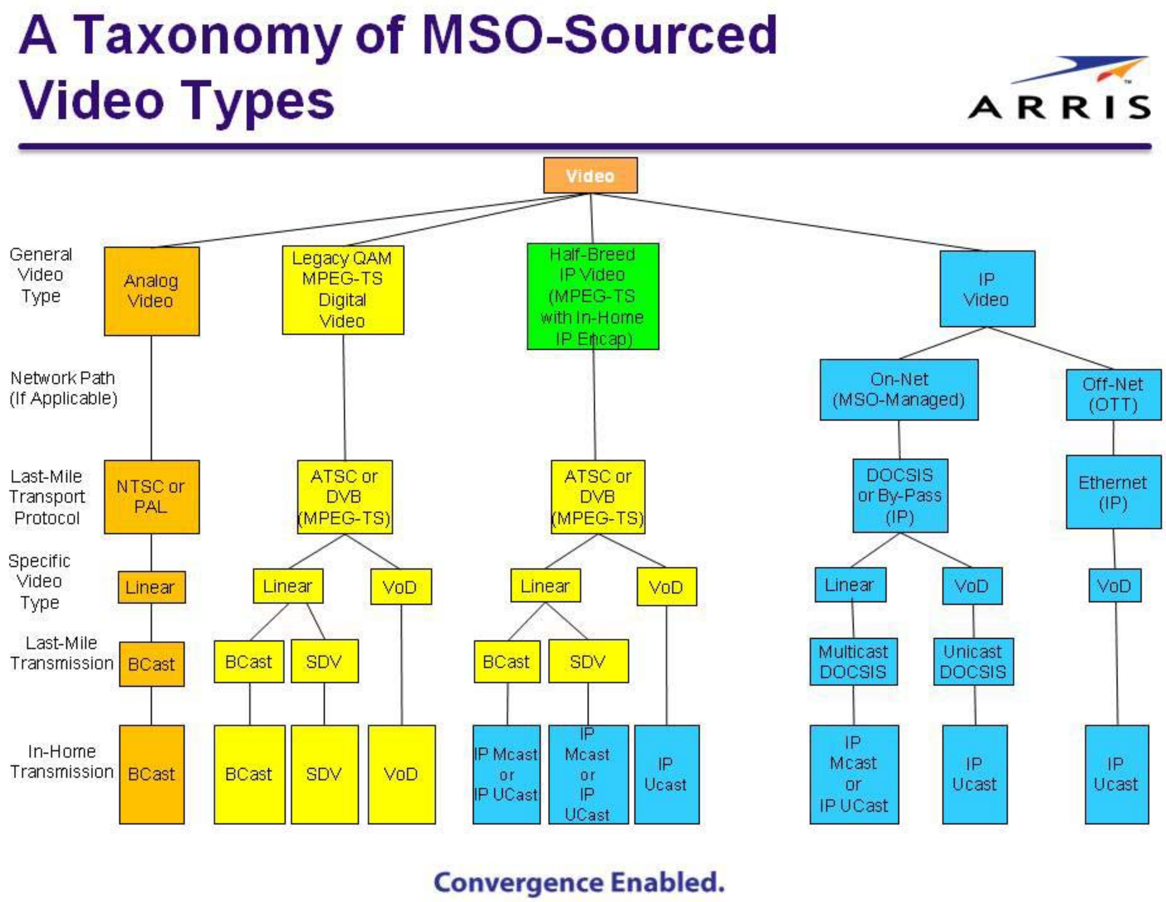

Figure 2: Taxonomy of MSO-Sourced Video Types

The far left side of Figure 2 illustrates analog video. Analog distribution has been in existence for over 50 years and arguably will be around for a few more years. The industry developed digital video delivery to increase the capacity of the infrastructure and improve the security of the content. Video On Demand (VOD) was also developed to extend the service offering. More recently some operators have implemented Switched Digital Video (SDV) to further expand the capacity of the network. For purposes of this discussion, the section on the far left of Figure 2, terminating in the 4 boxes at the bottom left will be named "Digital MPEG Distribution".

While the cable industry was making these service improvements, a host of organizations were developing the technology on the far right of the diagram to deliver video over unmanaged network connections. This will be referred to as "IP Unicast Distribution."

Some cable operators have begun to use IP Unicast Distribution to delivery video to devices other than the TV. This divergence from traditional delivery methods illustrates why it becomes important to look at the long term guiding principles. Do operators simply layer on the new network or do they begin to map a path similar to the center section of the diagram, "Hybrid Distribution", which leads to a converged network? A review against the guiding principles suggests operators should map a path to a "Convereged IP Distribution" network.

OVER-THE-TOP / STREAMING TECHNOLOGIES

In order to develop a plan to convert the networks to an IP transport, we must first understand the differences between the old and new technologies. There are three basic types of internet video/streaming technologies.

- Progressive download - Very robust to network impairments - Relatively long wait before start period - has been used in the past for OTT video delivery.

- Real Time Streaming Protocol (RTSP) with UDP video transport – Very susceptible to network impairments - Little wait time to start - used in today's cable networks to deliver MPEG-TS video to Edge QAMs for transmission.

- Adaptive Streaming (AS) technologies - Robust to network impairments - Some wait time to start - newer streaming technology used to provide additional robustness on congested networks and underpowered hosts.

Much of the cable industry still has analog video in the network. The Internet and mobile industry will support multiple types of streaming for some transition period. However, the race by Microsoft, Adobe, Apple [3, 4, 5, 6, 7, and 8] and others to enhance their adaptive streaming solutions suggest cable should concentrate on the new growing technology.

There are a number of significant differences between today's digital MPEG video distribution technologies and the newer adaptive streaming video technology. There are also similarities from an abstract perspective.

Starting with the similarities: a VOD system and a Content Delivery Network (CDN) perform the same basic network operation of managing servers and the content on those servers to maximize the subscribers' experience and minimize network resources required for distribution. One of the greatest differences, and most difficult paradigms to break, is the difference between MPEG-TS technology and Adaptive Streaming technology. This is partially due to naming conventions.

The Digital MPEG Distribution system uses UDP transport in the routed network and then modulates each stream and places them into an RF carrier over the HFC network and all "streams" are transmitted to the home.

Adaptive Streaming is not actually streaming but is TCP file transfer. A video stream is packaged into small play time fragments. These fragments are then delivered when the client sends a simple "HTTP GET" command. Each fragment of the video sent may also be cached in the network. The repeated requests by the first user, in effect, distribute the content within the network's caches and when the next client requests the same content, the cache closest to the subscriber holding this content may respond to that request. This implementation only transmits the stream that is requested by the home

The above Adaptive Streaming process impacts the processing, storage and delivery resources required in the network. The processing at ingest is much more than the current one MPEG-TS stream for HD and one for SD. It may require as many as 12 different bit rates for each format to be distributed. The encoded content is then packaged based on the devices to be supported and delivered to an origin server. The Tables below provide one example of this process to size this effort for a small cable head end for just the linear programs.

Network Assumptions

- 300 live channels
- MPEG4 encoding (H264)
- HD bit rates; 5.0, 3.0, 2.0, 1.0, 0.5 Mbps
- SD bit rates; 1.5, 1.0, 0.5 Mbps
- 50% HD / 50% SD mix
- Device / Format Supported
    - MPEG 4 Cable STB
        1. HDTV
        2. SDTV
    - Apple HLS
    - Adobe HTTP Dynamic
- Rewind/ Start over window of 15 minutes

Legacy processing for Delivery to MPEG STBs	(300 channels x (50% HD) x (5 Mbps)) + (300 channels x (1.5 Mbps)) = 975 Mbps
Output from video packaging process	2streaming formats x ((300 channels x (50% HD) x 5 bit rates(5.0, 3.0, 2.0, 1.0, 0.5 Mbps)) + (300 channels x (50% SD) x 4 bit rates(1.5, 1.0, 0.5 Mbps))) = 2 x (1755+450) Mbps = 4,350 Mbps
Objects Stored in 15 Minutes	15 min x 60 sec/min / 2 seconds per fragment Apple HLS x (150 channels HD x 5 bitrates / HD + 150 channels SD x 3 bitrates SD) + 15 min x 60 sec/min / 10 seconds per fragment Adobe HTTP Dynamic Streaming x (150 channels HD x 5 bitrates / HD + 150 channels SD x 3 bitrates SD) = 540,000+108,000 = 648,000
Origin/Caching Server Capacity	4350 Mbps x 15 min x 60 sec/min / 8 bit/byte / 1024 = 478 GB

Figure 3: Sample Calculations

	Storage Server (MPEG System) Serving only SD & HD TVs	Origin Server (Adaptive System) Serving HD/SD TV's and mobile devices
Encoder output (Mbps)	975	2,175
Packager Output (Mbps)	n/a	4,350
Objects Saved	300	648,000
Server Capacity Required (GB)	107	478

Table 2: Capacity Requirements

The content is now available for IP Unicast Delivery over any internet connection. A sample calculation to understand how this new service might consume network resources in the cable operators' DOCSIS/HFC is provided only to help the reader understand the scale. A detailed analysis of bandwidth is addressed in the paper entitled "**Architectural Approaches to Help Circumvent the "Simulcast Roadblock" of IP Video Deployments"** authored by T. Cloonan, J. Allen, C. Ansley, R. Arnold, C. Cheevers, T. Cotter, J. Howe, B. Hanks, D. Torbet, & I. Wheelock of ARRIS.

Delivery to portable device Analysis

Network Assumptions

- It is desirable to deliver the best quality video (highest bitrate) to the subscriber. The network should be robust enough that the client shouldn't have to request lower quality segments due to congestion.
- 3.0 mbps to a tablet/pc screen
- 500 Home Passed per Node
- 8 DOCSIS channels per node
- 15% penetration of subscribers
- 25% concurrent use at peak usage hours

Bandwidth Utilization Calculation	(500 HHP x .15 x .25 x 3.0 Mbps) / (8 x ~ 40 Mbps) x 100% = ~ 56 / 320 = ~ 18% of the available DOCSIS capacity

Table 1: Delivery to "Not-The-TV" Analysis Bandwidth Utilization Calculation

If an extreme situation is modeled, the results of the analysis are even more dramatic.

Delivery to HDTV Analysis

Assumptions

- It is desirable to deliver the best quality video (highest bitrate) to the subscriber.
- 8 mbps to an HDTV
- 500 Home Passed per Node
- 8 DOCSIS channels per node
- 60% penetration of subscribers
- 50% concurrent use at peak usage hours

Bandwidth Utilization Calculation	(500 HHP x .6 x .5 x 8 Mbps) / (8 x ~ 40 Mbps) x 100% = 1200 / ~ 320 = ~ 375% of the available DOCSIS capacity

Table 2: Delivery to HDTV Analysis Bandwidth Utilization Calculation

While there will be some statistical gain associated with a large deployment, it will not be enough to fit within an eight channel DOCSIS band. The existing digital network cannot supply the services desired by the subscribers without substantial changes and the existing headend network architecture does not support full adoption of OTT delivery.

THE TRANSITION

An implementation of an overlay architecture for TV Everywhere services results in the addition of a number of new functions/elements in the network and the duplication of some functions due to technical differences. Figure 1 illustrates a Digital MPEG Distribution network that has had an IP Unicast Distribution overlay.

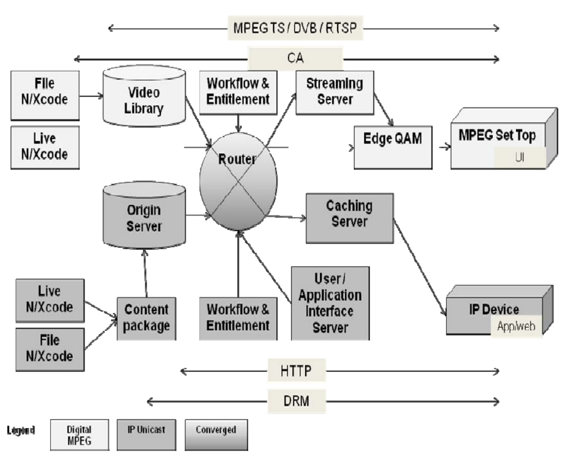

Figure 4: Digital MPEG Distribution network that has had an IP Unicast Distribution overlay

CONSOLIDATION OF WORKFLOW MANAGEMENT

One of the first steps an operator can take toward assuring a smooth transition to IP video services is the implementation of a highly automated asset management system that can serve as a single point of control over content ingestion, processing and distribution. Such a system must, at a minimum, be able to leverage existing operational assets, including back-office components, storage centers, advertising management systems, metadata repositories, and policy servers, while providing the means for operators to efficiently provide multi-screen IP services.

Linear and VOD already require multiple viewing rules along with various modes of capture, distribution and advertising associated with time-shifted content to establish a holistic management approach. Metadata, interactive applications and advanced advertising must be managed across linear and on-demand outlets. TV Everywhere has added still another sphere of operations. With the onset of IP migration, the range of processes to be managed is even greater.

Operators must be able to efficiently manage usage and metadata policies, subscriber and device authentication, multiple encryption, transcoding, streaming, advertising formats, and other processes unique to each IP content category and each IP device. And they must be able to manage all processes essential to assuring accurate billing and payment disbursements to third-party suppliers and advertisers.

These processes start with the ability to maintain an inventory of all the digital copyrights associated with all the assets and to make sure those policies are accurately embodied in the Digital Rights Management System that assigns specific rights to a particular content element going out to a particular outlet. The workflow system must be able to collect and transfer the usage data to the back-office systems that confirm policy enforcement, perform billing processes and orchestrate payments on all contracts.

To do this, the operator has a number of choices including maintaining separate systems, expanding the current MPEG system to address IP deliveries, or expanding the current IP system to address the MPEG requirements, or developing and adopting a new system that meets all of the guiding principles.

The tools and processes in use today for MPEG TS /DVB are not adequate for IP delivery and the systems for IP delivery are not adequate for MPEG TS streams so you are forced into a world where you have to manage the two workflows separately for some period of time during the transition

Alternatively an operator could build application programming interfaces (API) between one of the existing systems and the rest of the network to achieve convergence. Evaluation of each of the existing MPEG and IP systems based on the guiding principles suggests augmenting the IP Unicast Distribution systems to address this network requirement.

CONTENT PROCESSING

The existing content processing requirements for the Digital MPEG Distribution network are simple when compared to the content processing requirements of a network capable of OTT service. A review of processing required, by use cases, will assist in illustrating the processing necessary for each type of network distribution.

The Digital MPEG distribution network must ingest and process "live" content and prepare it for delivery via MPEG Transport Stream (MPEG-TS) for both SD and HD Television consumption. This process was calculated in Table 2. Some operators also ingest this live content and process it for file storage on a library server for use in start over and look back type of service. In addition to the live content ingest, Digital MPEG distribution networks ingest mezzanine files and create compressed files for storage to a library server for delivery of VOD service.

Table 5 depicts the input and output video processing requirements for Digital MPEG. Two (2) types of input Live or Files and six (6) types of output. Two (2) output types for files and four (4) types of output for live content.

Inputs	Outputs			
Live	1.5 Mbps SD MPEG-TS	8 Mbps HD MPEG-TS	1.5 Mbps SD File	8 Mbps HD File
Mezanine File			SD File	HD File

Table 3: Input and output video processing requirements for Digital MPEG

The IP Unicast distribution network must ingest and process "live" content and prepare it for AS delivery for both SD and HD Television consumption and the myriad of other devices an operator chooses to support. Example calculations of this process are shown in Table 6. The first review of this process may appear to simplify the processing as the content is only processed to file. However, the multiple bitrates and formats complicate the output for live content processing. Similar to the MPEG processing above the IP Unicast Distribution network may also ingest mezzanine files and create compressed files for storage to an origin server for delivery of VOD service. In addition to the encoding of the material, the IP Unicast Distribution network requires packaging for each format supported.

Table 6 depicts the input and output video processing requirements for IP Unicast. Two (2) types of input Live or Files and twenty-seven (24) types of output for each live and file input in this example.

Inputs	Outputs		
Live	3 SD bitrates	5 HD bitrates	3 packaging formats
Mezanine File	3 SD bitrates	5 HD bitrates	3 packaging formats

Table 4: Input and output video processing requirements for IP Unicast

Operators must evaluate their current MPEG encoding systems used for live and file ingest to determine if they are capable of the increase in output streams, output resolution and encoding formats. Operators should also consider how they want to group encoding and packaging in the converged network of the future. While it may be possible to serve the IP unicast delivery and the MPEG delivery simultaneously from the encoder output, network transition and component utilization may lead to maintaining separate resources for at least the live feeds processing for the legacy MPEG set tops and the emerging IP Unicast delivery clients.

Operators that have deployed encoders for file processing of IP Unicast Distribution must evaluate the current systems ability to support the real time requirements for live feed processing.

Figure 5 depicts a network that separates the encoding and packaging functions thus allowing the potential for one encoder to feed both the MPEG distribution and IP Unicast distribution requirements. This diagram could have easily been draw with segmented functionality.

CONTENT DELIVERY NETWORK ARCHITECTURE

Operators may be able to rely on the traditional Internet Content Delivery Network (CDN) infrastructure to accommodate the performance requirements of their managed IP video services. However, it is important they also plan their CDN architectures to accommodate legacy VOD service during the transition period.

The new Internet CDN architecture represents a significant departure from the traditional approaches to VOD content distribution. Most CDN solutions, based on commercial off-the-shelf servers and network-attached storage devices, rely on storage sub-systems where CPU speeds and processing modes make it impossible to satisfy new cable operations requirements by merely adding more storage and server capacity. Moreover, there are hidden costs that are incurred as capacity on these traditional solutions is expanded, which requires more load balancers and ESRs (Ethernet switch/routers) along with increases in power consumption and space allocations.

Traditional VOD systems may not yet support adaptive streaming technologies. New scalable CDN solution architectures are required to serve all on-demand content distribution requirements, whether content is ultimately distributed to end users via MPEG or IP transport streams. These new CDNs must fully leverage the capabilities of the cable-managed IP network, affording operators complete flexibility to ingest, store and deliver growing volumes of contents to all types of devices.

Sophisticated simulation methods can be used to determine optimal architectural set-ups for any given operating environment. With expert assistance in this critical design arena, operators will find they can implement CDN architectures that greatly out-perform and out-scale traditional HTTP (Hypertext Transfer) -based approaches.

The above evaluation clearly indicates a move to CDN architectures. Operators that have VoD systems that can support the new functionality of adaptive streaming should look to upgrade instead of wholesale replacement of their installed base.

SECURING CONTENT THROUGH EFFICIENT USE OF DRM TECHNOLOGY

Adding to the complexities of mounting a multi-device premium TV service is the fact that the client software associated with various streaming systems supports different DRM systems. Fortunately, a growing number of backend content management systems are designed to help automate the implementation of different Adaptive Streaming CODEC and DRM combinations. The fact that transcoders as well as other functional components are now available as software engines running on Common off the Shelf (COTS) hardware helps immensely with the flexibility required to keep pace with the changing environment.

There are at least three ways to structure the protection system under discussion within cable industry circles. One is the end-to-end approach, where device-specific DRM encryption is applied at the headend and content is decrypted at the client device.

The other two entail encryption of all traffic using either a single DRM mode or the CMTS-supplied DOCSIS BPI+ protection system between the headend and the home media gateway, where video is decrypted at the gateway, then re-encrypted for distribution over the home network. Typically, these strategies anticipate employing the DTCP-IP (Digital Transmission Content Protection over IP) protocol in conjunction with the use of DLNA (Digital Living Network Alliance) home networking standard to discover and connect devices.

In addition to the three protection schemes used for IP Unicast Distribution, the operator must maintain the current Conditional Access (CA), link layer, protection for the legacy Digital MPEG Distribution portion of their network. The use of CA is an important consideration in Hybrid Distribution. The CA must be terminated somewhere and the content protected in some other acceptable mode for delivery to devices other than MPEG Distribution Set Top Boxes. The options are to bridge the protection to a DRM or terminate the CA in a gateway at the home and use DCTP-IP for protection over the in home network.

It may be required to support multiple content protection schemes simultaneously, prior to standardization of content protection schemes. It may be possible to use content protection frameworks or API’s to minimize the complexity of the client and its interface to the network when this is required.

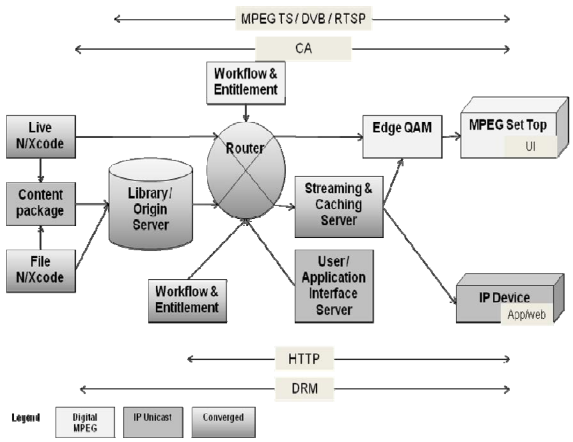

Figure 5: network that has converged the content process, storage, streaming, caching and developed the IP Unicast workflow and entitlement system to interface with the Digital MPEG workflow and entitlement system

Figure 5 illustrates a network that has converged the content process, storage, streaming, caching functions and developed the IP Unicast workflow and entitlement system to interface with the Digital MPEG workflow and entitlement system. This step can facilitate the transition to either a Hybrid Media Gateway or an IP only Media Gateway.

MEDIA GATEWAYS AS A TOOL FOR IP SERVICE MIGRATION

Remembering that neither the IP Unicast Distribution network nor the Digital MPEG Distribution network can meet all demands of today's services, the home media gateway has emerged as a linchpin in IP cable TV migration. It is a major point of intelligence and distribution that can be used to support all video delivery technologies during the migration period.

The gateway serves as the termination point of the operator's network and the primary interface for the home network. It serves as the source for all content entering the home, including legacy MPEG-2 as well as IP video. As a DOCSIS 3.0 sub-system with an embedded modem supporting high-capacity channel bonding, the gateway may also serve as the interface for IP telephony and high-speed data. The gateway is one of the first steps to implement a Hybrid Distribution network.

A gateway can support interfaces to the various home networking platforms required to distribute content to devices in the home, including MoCA, Wi-Fi 802.11n, Ethernet and other standardized physical interfaces suited to premium video transport. The open DLNA protocol stack can support client discovery and connection of all consumer devices. The gateway must be able to interact with all device clients in support of functions such as channel selection, multicast joins, authentication and authorization, distribution of encryption keys, management of AS flow rates and DOCSIS QoS.

Operators must review the functions and features being considered for gateways using the same principles for determining how to transition other elements of the network. Gateways and supporting middleware systems must be flexibly designed to fit virtually any architecture and may need to support:

- IP encapsulation of MPEG transport streams for distributing content to IP devices in the home
- server and proxy functionalities essential to running a common advanced user interface across all devices
- multi-room DVR;
- whole-home media management;
- content protection systems conversions

- conversion of multicast streams to unicast streams
- interactive applications for TVs and companion devices
- dynamic ad insertion
- transcoding of streams to multiple device formats
- value-add services such as energy management and home security

The operators' ability to leverage MPEG and DOCSIS networks and the web based software platform to introduce IP services of all types into the integrated navigational experience represents not only a value-add incentive to introduce gateways, it also allows the transition of the user interface to a cloud based service. Operators can address changing market conditions by offering a branded over-the-top service featuring certain aggregators' offerings, or they can go further by providing consumers a wide-open approach to accessing Web content through the cable branded unified User Interface (UI).

Advanced caching intelligence is another potentially important attribute for gateways. Intelligent algorithms can be employed to manage the video content from the network. Real-time selection of multi-screen streams for gateway storage based on content popularity and local usage patterns can serve to improve channel-change performance and increase bandwidth efficiency. This would present the gateway as an extension of the operator's CDN.

The detailed analysis of each choice within the gateway and the impact to the network architecture is not addressed in this paper, as the author believes the topic should be addressed at some length in a separate stand-alone technical paper.

Figure 6 builds upon Figure 5 with the addition of the Hybrid Distribution Network gateway.

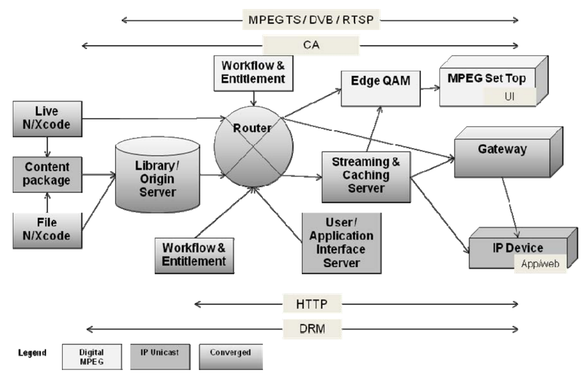

Figure 6: builds upon Figure 5 with the addition of the Hybrid Distribution Network gateway

CONCLUSIONS

This paper has provided a classification of three existing and emerging video distribution technologies. The paper then provided an example comparison of the two corner case distribution methods; Digital MPEG and IP Unicast to a) expose their technical differences and b) propose that neither architecture is capable of meeting all of the operator's requirements for delivery of video services. A framework of guiding principles was then used in the comparison of the various distribution technologies and to evaluate the major functional components of each of the video distribution technologies in an attempt to assist the operator in developing a strategic path to transitioning (or not) their networks to a converged all IP distribution architecture.

Using the distribution technology classifications and guiding principles the authors believe, operators will find it difficult to meet the emerging subscriber service demands through the simple implementation of new technologies on the existing infrastructure. The adoption of the existing solutions for these new services could easily result in a new network overlay. The addition of a new overlay would increase the operators' cost and the complexity of service delivery and support. This outcome is contrary to the ultimate objective.

During the transitional phase operators must take care in the selection of new components that do not limit their ability to achieve their guiding principles. They must also engage with suppliers of their current network elements to determine the ability to upgrade current components to meet new requirements. The use of the guiding principles should allow progress while minimizing the risk of limited flexibility.

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