BUILDING LARGE VOD LIBRARIES WITH NEXT GENERATION ON DEMAND ARCHITECTURE

Weidong Mao
Comcast Fellow
Office of the CTO
Comcast Cable

Abstract

The paper presents an integrated Video On Demand (VOD) content library platform that supports virtually an unlimited amount of media content such as movies, TV shows, Internet video, and user generated content. This approach combines the advantages of the existing Managed Network approach and the emerging Over the Top approach in offering VOD services.

Specifically, this paper describes the overall requirements and architectural evolution of Video On Demand (VOD) infrastructures to support large content libraries. The content libraries will enable a large amount of VOD content (SD and HD) as well as Internet Video content. The solution is based on the Comcast Next Generation On Demand (NGOD) architecture with a key extension of the Content Delivery Network (CDN) that utilizes national and regional IP network and library storage.

Several key architectural building blocks and technology options are include content encoding and transcoding, real time and non real time content ingest, asset metadata and rights management, content library and asset propagation management, VOD backoffice integration, streaming server, as well as shared edge resources.

Finally, this paper also discusses content formats, open interfaces, performance, scalability, reliability, and expandability to future on demand services.

MANAGED NETWORK VS OVER THE TOP

Increasingly cable operators are using Video On Demand (VOD) as a key competitive advantage. Alternative video delivery methods such as movie download or video streaming via the Internet are also becoming more practical and feasible as service providers deploy either DOCSIS 3.0 wideband or Fiber to the Home technologies.

Figure 1 illustrates comparisons between the "Managed Network" and the "Over the Top" approaches for providing on demand video to subscribers. In the existing Managed Network approach that is adopted by Cable and Telco network operators, VOD content is usually encoded in MPEG-2 format and distributed along with metadata via a Satellite or IP backbone to the local VOD systems. The content is usually "pushed" and replicated in every local VOD system. The VOD client on the digital set-top box will be able to setup sessions and perform stream control functions such as Play, Pause, Fast Forward and Rewind.

In contrast, the emerging Over the Top approach uses the broadband Internet as the content distribution and streaming platform. Content aggregators / integrators license and

publish movies and TV shows at the Internet website. PC or CE devices such as TV set-tops are able to access the video content via the Internet using the broadband pipe such as cable modem, DSL, or Fiber to the Home network. Content for the Over the Top services is typically encoded using advanced codec such as H.264 with lower resolutions. Content distributions within the Internet are usually driven by the "pull" requests coming from the subscriber.

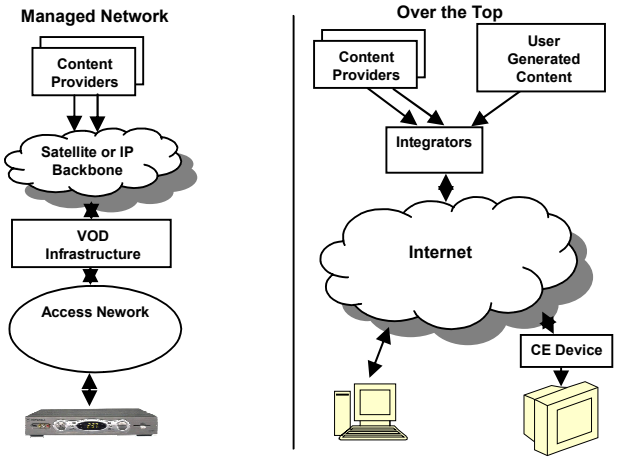

Figure 1 Comparisons of Managed Network and Over the Top VOD Services

The following lists some of the unique features and capabilities of Managed Network and Over the Top VOD services:

Managed Network features and capabilities:

- Extend linear TV programming service with free and premium VOD content
- Utilize managed IP networks for VOD content distribution with better quality of service
- Manage bandwidth expansion at access network to satisfy high concurrency (> 10%) and HD VOD
- Build VOD server streaming infrastructure for streaming capacity
- Leverage existing digital STB at home and digital cable ready TV through tru2way
- Achieve high VOD usage with the large installed subscriber base
- No buffering at the client is required. This enables easy navigation and access of the content.

Over the Top features and capabilities:

- Access to a vast amount of Internet video and user generated video
- Feature rich navigation user interface and search capability using open Web technology
- Benefit from bandwidth competition at access network
- Benefit from advanced codec technology using PC or new CE appliance
- Potential to offer the same VOD service to any device with Internet access

There are several limitations of the Over the Top approach:

- Challenge to achieve high concurrency for HD video streaming
- Utilizes public Internet infrastructure that imposes quality of service constraints (e.g. congestion)
- Lack of end to end network resource management
- Inconsistent premium content offering due to lack of programming agreements with content providers
- Requires subscriber to purchase a separate CE appliance for viewing VOD on TV
- Does not yet have a large subscriber base. Fragmented market with too many players
- Long buffering time at the client may be required

A HYBRID VOD LIBRARY APPROACH

Today's Managed Network VOD system architectures helped network operators bring a compelling product to market. There are significant opportunities for the network operators to expand the current VOD architecture in order to support large VOD content libraries that provide an expansive amount of content including the Internet video. The other opportunity is to provide the VOD offering to devices other than STBs. Most of these are IP enabled devices such as PCs and portable CE devices.

In order to keep and expand the competitive advantages in providing VOD services, network operators are embracing the vision to give customers the ability to watch any movie, television show, user generated content or other video that a content provider wants to make available through Video On Demand. The service would offer the following:

- More HD content:
- More library VOD content
- Time shifted TV (StartOver™)
- Personalized, video rich navigation with better search
- Internet video content
- Cross platform video services (TV, PC, portable devices)
- Extensions for addressable advertising

In order to support these goals of any video content, at any time, to any device, a hybrid approach using VOD content libraries based on the Content Delivery Network (CDN) that will extend the existing Managed Network VOD infrastructure is proposed as shown in Figure 2.

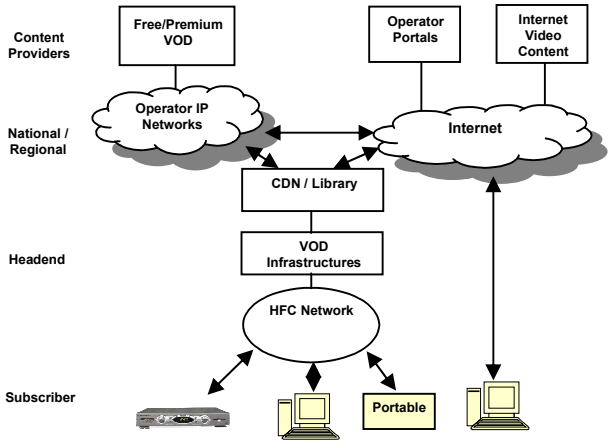

Figure 2 A Hybrid VOD Library Approach

In this approach, the existing Managed Network VOD infrastructure is expanded with the Content Delivery Network (CDN). The large content libraries within CDN are connected via operators' IP backbone and regional networks to both content providers and local headends.

The CDN content library will ingest and store content coming from traditional free or premium VOD sources. The CDN content library will also be able to ingest video content published from an Internet portal and external Internet video content including user generated content.

Typically, all the VOD content is stored in the CDN content library. Popular VOD content can be replicated and propagated ahead of time to the local VOD systems via CDN. Upon a subscriber's request for VOD content, the VOD system can start streaming if the content is already available at the local VOD system. The VOD system will pull the content from CDN content library if it is not available at the local VOD system. The content may be cached at the local VOD system for a period of time to serve other subscribers' requests.

The same CDN content library will serve multiple devices including STBs, PCs, and portable devices. Content may be transcoded to

multiple formats upon ingest to the CDN content library.

The proposed hybrid VOD library approach has several significant advantages, compared with the traditional Managed Network and the emerging Over the Top approaches, they include:

- Content:
  - Free or premium VOD content
  - Offer vast amount of movie and television shows, most in HD
  - Enable access to Internet video such as user generated video
- Infrastructure:
  - Utilize a managed IP backbone and regional networks for VOD content distribution with better quality of service
  - Manage bandwidth expansion at access network for high concurrency of HD VOD
  - Expand existing VOD content distribution, management, entitlement, and streaming platform
- Devices:
  - Leverage existing digital STBs and digital cable ready TVs through tru2way
  - Support PCs and other portable devices with Internet access

ARCHITECTURAL BUILDING BLOCKS

Main Challenges

With the advent of new technologies in IP networking and high performance storage and streaming servers, it becomes feasible to evolve the current VOD architecture to support large scale content libraries. However, there are several challenges that need to be addressed:

- Content Library (CDN)
  - Real time and non real time ingest
  - Performance and scalability of streaming from library storage
  - Asset propagation management
- Streaming Capacity and Bandwidth
  - Additional streaming server capacity is required
  - Increased edge QAM and unicast bandwidth is required
- VOD Navigation User Interface
- Internet Video Model
  - Pull versus push
  - Metadata format
  - Transcoding

Next Generation On Demand (NGOD)

Comcast has developed the Next Generation On Demand (NGOD) architecture framework to address both the feature expansion and capacity expansion of the VOD infrastructure to support multiple on demand services (see [1]).

The Next Generation On Demand architecture will continue to be used as a foundation to support the VOD library expansion based on the following principles:

- Open Interfaces: The reference architecture is developed with logical functional components. Standardized open interfaces between the different components in the architecture are also developed. This will enable multiple vendors to innovate in the areas of their expertise and allow seamless integration among the various components. For example, NGOD has specified key components and interfaces for the Session Manager, On Demand Resource Manager, Edge Resource Manager, and Edge QAM.

- Shared Resources for Multiple Services: Today's architectures are typically customized for a limited set of services.

Unfortunately, a significant re-engineering effort is required to support the addition of new services. The NGOD architecture enables the sharing of storage, streaming, network, and edge resources among multiple services. It is an extensible, on-demand platform that allows multiple services to share the same underlying infrastructure. It will create significant cost efficiencies and make it possible to quickly provide new services more quickly and easily.

- High Performance, Scalability, and Reliability: The NGOD architecture is designed to achieve high performance and scalability by allowing each component to be scaled and optimized independently. In addition, redundancy is built in various sources and components to provide high reliability.

Content Delivery Network (CDN)

One of the key enabling technologies for large VOD content libraries is the next generation Content Delivery Network (CDN). The next generation CDN will support VOD content and other media files. The national and regional IP networks connect multiple VOD content libraries in various locations such as national media center, regional centers, and local VOD systems. The CDN will enable operators to provide a large amount of VOD content cost effectively by serving them from the national and regional libraries instead of replicating all content to the local VOD systems. Intelligent caching can be adapted at the CDN and the local VOD system based on the popularity and actual usage of the content to further reduce the network bandwidth usage and enhance the overall performance.

The overall architectural building blocks for VOD libraries based on the NGOD architecture and its extension to next generation CDN are illustrated in Figure 3.

The architecture is partitioned functionally into a number of logical components. Each component is defined in such a way that the interchangeable module implementing the common interfaces can be introduced to work cooperatively with the rest of the system. It is possible that implementations may integrate several components into a single product or solution.

Each logical entity described in the reference architecture may represent one or many physical entities in an actual implementation.

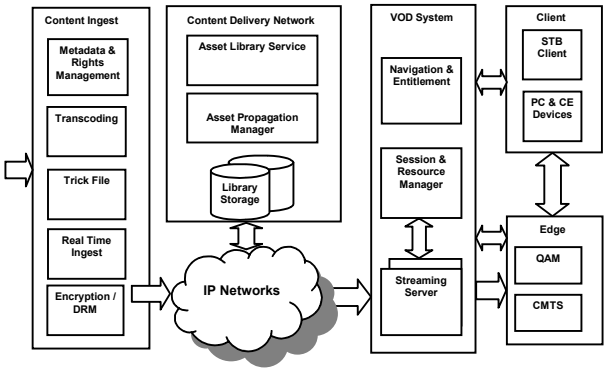

Figure 3 Key Architectural Building Blocks

The key architectural building blocks include:

Metadata & Rights Management – manage the asset metadata and rights for content from various content providers and aggregators, such as licensing windows.

Transcoding – transcode the content into various formats based on codec, resolution, and bitrate.

Trick File – generate fast forward and rewind trick files from the original content.

Real Time Ingest – ingest the real time content streams from content providers and aggregators.

Encryption / DRM – perform encryption and digital rights management packaging on the content.

Asset Library Service – maintain and update a directory of content locations in the CDN / libraries.

Asset Propagation Manager – manage content replication and movement among various library storage locations based on the external business rules and actual content usage.

Library Storage – provide persistent content storage or temporary content caching at various library locations.

IP Networks – provide national and regional IP networks that connect multiple library locations and local VOD systems.

Navigation & Entitlement – provide navigation and entitlement functions to content requested from client devices.

Session & Resource Manager – manage session life cycle and its associated resources for on demand video services requested by subscribers.

Streaming Server – store and outputs content and enables stream control.

Edge QAM – perform re-multiplexing and QAM modulation.

CMTS – Cable Modem Termination System for DOCSIS enabled devices.

STB Client – digital set-top box and its client software that communicate with the VOD system and typically receive video over MPEG-2 transport via an Edge QAM.

PC & CE Devices – PC and CE devices that communicate with the VOD system and typically receive video over IP via CMTS.

OTHER CONSIDERATIONS

Content Formats and Metadata

The content can be realized as various types of media files and real time streams targeting the end devices. Some of the most popular content formats are described in the following Table:

Table 1. List of Content Formats

Format	Resolution / Bit Rate (Typical)	End Device	Delivery	Use Cases
MPEG-2	SD / 3.75 Mbps HD / 15 Mbps	STB	QAM	VOD, StartOver
MPEG-4 / H.264	SD / 2 Mbps HD / 8 Mbps	STB / PC	QAM / IP	VOD, StartOver
VC-1	SD / 2 Mbps HD / 8 Mbps	STB / PC	QAM / IP	VOD, StartOver
Window Media Streaming	800 – 1500 kbps	PC / Portable	IP	Internet
Flash Streaming	400 – 1500 kbps	PC / Portable	IP	Internet
Audio (Dolby AC-3)	192 – 384 kbps	STB	QAM	Music Choice
Audio (Window Media, MP3)	64 – 128 kbps	PC / Portable	IP	Internet
Image (JPEG, PNG, Bitmap)	Various	PC / Portable / STB	IP	Graphics, Photo Sharing
Files	Various	PC / Portable / STB	IP	Application Download

In addition, Advertising content with similar content formats can be delivered via the CDN. SCTE 35 parsing and Ad splicing will be performed at the Streaming Server under the direction of the VOD BackOffice that interfaces with external Ad decision system.

Traditional VOD content is identified using the CableLabs Asset Distribution Interface (ADI) Provider ID and Asset ID. In addition, the metadata for the content is described in the CableLabs ADI 1.1 or ADI 2.0 standard. The content identifier and metadata structure need to be extended to support Internet video that uses Internet media publishing standard such as Really Simple Syndication (RSS).

Content Ingest

The CDN can support ingest of content files from traditional satellite based catchers as well as content files and real time streams via an IP backbone from VOD content providers or Internet Video providers. Content processing may be required upon the content ingest:

- Content may need to be transcoded to a different resolution, bitrate, and codec upon ingest to the CDN
- Trick files (Fast Forward, Rewind) may need to be created upon content ingest into the CDN
- Content with multiple formats (e.g. HD vs. SD) for the same title are treated as different content assets with different content metadata
- The metadata and rights management are performed on the content. This includes content life cycle management such as the licensing window
- Encryption and Digital Rights Management (DRM) are performed on the content upon ingest. It is also possible that tier based or session based encryption can be performed upon streaming

Asset Propagation Management

The CDN contains multiple Content Library nodes connected via national and regional IP networks. The Asset Propagation Manager (APM) is responsible to replicate and/or move the content through the storage nodes of the CDN dynamically based on the content popularity and usage.

The locations for all content within the CDN is maintained and updated by the Asset Library Service (ALS). Upon a session setup request from the subscriber, the VOD session and resource manager will interface with the Streaming Server for the selected content. If the content is already pre-positioned or cached at the Streaming Server, it will stream the content to the subscriber. If the content is not available at the Streaming Server, it will query the ALS for the locations of the requested content within the CDN in order to fetch the content from the content library and stream to the subscriber.

Content Streaming

When the Streaming Server fetches the content from Content Library and streams to the subscriber, it will use the Content Transfer Protocol from Content Library to Streaming Server. The Content Transfer Protocol may be extensions to one of the existing standard protocols such as:

- NFS
- CIFS
- FTP
- HTTP

Open standards, scalability, and performance are some of the key criteria for the selection and design of the Content Transfer Protocol.

Operations and Reporting

An operation model for system monitoring and management is required. Specifically, it will include the following aspects:

- Component level fault monitoring and management
- Content level status monitoring
- Network level monitoring

- Video quality monitoring

In addition, key reporting metrics need to be defined:

- Viewing patterns for content
- Network bandwidth usage
- Storage bandwidth usage
- Peak number of streams and concurrency rate
- Measurement of efficiency of caching algorithm

Scalability, Performance, and Reliability

Scalability, reliability, and performance requirements may include the following:

- Daily hours of content ingest
- Library storage sizing
- Target streaming capacity
- Jitter
- Distribution metrics (delay/latency)
  - Initial Request
  - Peak Utilization
- Caching versus network bandwidth tradeoff
-

VOD for Multiple Devices

It is highly desirable to share the large VOD libraries for multiple end devices such as PCs and other portable media players.

There are several aspects which should be considered when expanding the architecture to support any content to any device.

- Content format transcoding
- Session and resource signaling
- Digital Rights Management (DRM)
- Home networking
- Subscriber and device authentication
- Cross application platform

SUMMARY

This paper describes an architecture framework for large VOD libraries based on the Next Generation On Demand (NGOD) architecture and its extension to the Content Delivery Network (CDN). The architecture combines the benefits of Managed Network and Over the Top approaches. It will enable distribution of any content to any device, at any time. The architectural building blocks are presented and some of the key challenges and design considerations are discussed. On going work includes detailed architecture and interface specifications as well as performance and scalability analysis.

REFERENCES

[1] Evolution of Video On Demand Architectures, Weidong Mao & Kip Compton, May 2004, NCTA Technical Papers

[2] CableLabs Video On Demand Content Specification Version 1.1, August 31, 2006

[3] CableLabs Asset Distribution Interface Specification Version 1.1, May 5, 2006

[4] CableLabs ADI 2.0 Specification Asset Structure, January 5, 2007

[5] ISO/IEC 13818-6: MPEG-2 Digital Storage Media – Command and Control (DSM-CC)

[6] ISO/IEC 13818-1: MPEG-2 System

[7] ISO/IEC 13818-2: MPEG-2 Video

[8] IETF RFC 2326, Real Time Streaming Protocol (RTSP)

[9] ISO/IEC 14496-10, Advanced Video Coding