Unicast or Multicast for IP Video? Yes!

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Abstract

Cable operators are leading the industry with innovative cloud-based video solutions such as TV Everywhere and Cloud DVR. These solutions are expected to play a prominent role as operators aim to deliver more content to more devices and ultimately transition to all-IP with full-scale, managed IP Video services. With current-generation IPTV solutions, operators have the choice of using unicast or multicast to deliver Linear TV services, and multicast has proven to be very efficient in existing IPTV deployments. However, cloud-based video solutions currently rely exclusively on unicast delivery, which can have a dramatic impact on the cable access network as the number of subscribers served from the cloud grows. Thus operators need to carefully consider the network impact of migrating to cloud-based video solutions, and look for ways to optimize the network efficiency.

Using example use cases based on field data and our own assumptions, we illustrate the potential for as much as 80% savings in CMTS capacity and HFC spectrum using multicast delivery for real-time viewing and in-home DVR recording. While moving the DVR functionality to the cloud can increase the network capacity required for time-shifted viewing by 40% in our example, it can also significantly decrease the control plane traffic load on the CMTS during prime time. Even with cDVR solutions in place, we expect multicast will continue to be a valuable tool for cable operators in serving non-cDVR subscribers. Hybrid DVR solutions can offer the best of in-home DVR and cDVR solutions if the business case challenges can be overcome.

Many cable operators have deployed TV Everywhere solutions as an overlay to their existing digital cable systems. As operators migrate to all-IP, there are clear benefits to using a common platform for delivering both managed and unmanaged IP Video services to all devices. The TV Everywhere solutions deployed to date can serve as a foundation for the common platform to support all IP Video services in the future. Since these solutions typically employ ABR streaming, the development and deployment of multicast ABR video transport solutions will enable operators to leverage the benefits of multicast as they migrate to a common infrastructure and client for supporting all IP Video services.

While the optimal solution for delivering full-scale, managed IP Video services will be unique to each operator, it will undoubtedly involve both multicast and unicast delivery approaches.

INTRODUCTION

Cable operators are responding to their subscribers' seemingly insatiable appetite for compelling TV programming on their schedule and platform of choice. The proliferation of Set-top Boxes (STB's) with integrated Digital Video Recorder (DVR) functionality and TV Everywhere services are just two examples of the cable industry's innovations. New solutions such as cloud-based DVR (cDVR) promise to keep the cable industry at the forefront of the highly competitive Service Provider market. However, one must carefully compare the impact of in-home and cloud-based solutions on the network infrastructure when choosing between these disparate approaches, and look for ways to leverage the strengths of each approach when deployed together.

In this paper, we will analyze the network requirements for supporting both real-time and time-shifted viewing of Linear TV programming on cable access networks in three scenarios: non-DVR STB, in-home DVR, and cDVR. Our focus is on full-scale, managed IP Video solutions in which all Linear TV programming is delivered via the DOCSIS access network; however, the methodology and results can be applicable in assessing network requirements for traditional QAM-based digital video solutions as well as hybrid QAM + IP Video solutions.

For the purposes of this paper, Linear TV viewing is considered to be either real-time, or time-shifted. Real-time viewing refers to direct playout of the programming from a STB or other rendering device as it is delivered across the cable network, with no user control beyond "tuning" to the TV channel. Time-shifted viewing refers to user-controlled playout from an in-home or network-based storage device, such as a STB with DVR capability, a cDVR system, or a cable operator's service such as Time Warner Cable's Look Back® and Start Over® services. When properly equipped, a user may shift between real-time viewing and time-shifted viewing of the same programming during the broadcast window. Also, note that time-shifted viewing may occur during the broadcast window, or post-broadcast.

An important distinction between real-time and time-shifted viewing in IP Video solutions is that programming viewed in real-time may be delivered via unicast or multicast, while time-shifted programming must be delivered via unicast. Multicast delivery can result in significant savings in the HFC spectrum and CMTS capacity required to support Linear TV services. We will illustrate the savings of multicast and the network impact of offering time-shifted viewing options via in-home DVR and cDVR solutions.

Analyzing the network impact of Linear TV viewership on customer-owned-and-maintained (COAM) devices such as PC/laptops, tablets, game consoles, smart TV's and smartphones, is outside the scope of this paper. However, we will highlight how multicast ABR video transport can enable operators to migrate to a common infrastructure and client to support both STB's and COAM devices.

NON-DVR STB USE CASE

In this scenario, all Linear TV viewership via STB's is in real-time. The percentage of STB's that are receiving Linear TV at a given time is referred to as the STB concurrency. A number of factors affect STB concurrency, including the time of day, day of week, programming choices and popularity, demographics, and even weather and local events. Cable operators must consider the impact of these and any other relevant factors to predict the STB concurrency in each of their cable systems. In a recent study of field data from a cable operator's network (see [1]), we observed STB concurrency in the range of 50–60% during prime time. This is consistent with some prior studies, and we will assume 60% peak concurrency in our illustrative examples below.

Another key factor in estimating the network impact of Linear TV is the efficiency of multicast delivery. As we explained in [1], multicast gain is the average number of viewers per Linear TV channel (i.e. per-channel concurrency) within a service group (SG). The multicast gain that can be achieved depends on a variety of factors, most importantly the number of viewers per

SG, the number of TV channels offered, and the popularity of the programming. In our examples below, we will assume a multicast gain of 5, which is consistent with the gain reported in [1] for service groups of comparable size.

Table 1 provides an illustrative example of the methodology for estimating the HFC spectrum and CMTS downstream (DS) channel capacity required to support multicast delivery of Linear TV services to STB's. This example assumes all Linear TV programming delivered to STB's is encoded as HDTV with a constant bit rate of 8 Mbps. Based on our assumptions, a cable operator would need to allocate 13.7 CMTS DS channels and associated HFC spectrum for each SG to support Linear TV services (assuming an all-switched approach…refer to [1] for more information on all-switched and broadcast approaches).

Parameter	Value
Homes passed per Service Group	500
Cable TV Take Rate	40%
Cable TV Subscribers per SG	200
STB's per Subscriber	2.5
STB's per SG	500
Linear TV STB Concurrency	60%
Linear TV Viewers per SG	300
Multicast Gain	5
Unique Linear TV Streams per SG	60
Linear TV Stream Bit Rate (Mbps)	8
CMTS DS Channel Capacity (Mbps)	35
CMTS DS Channels per SG	13.7

Table 1. Non-DVR STB Use Case

IN-HOME DVR USE CASE

According to the latest Nielsen report on TV viewership [2], roughly 50% of TV households have some type of DVR device. The DVR functionality may be integrated in the STB provided by the service provider, or may be a stand-alone device connected to a STB (or gateway). In either case, the DVR records Linear TV programming received from the network according to the subscriber's input.

From the cable network perspective, the DVR recording appears as real-time viewership. In an IPTV system utilizing IP multicast for delivering the Linear TV programming, the DVR client sends an IGMP (or MLD) Join message to receive the Linear TV program(s) the subscriber has scheduled to be recorded. This is indistinguishable from an IGMP/MLD Join sent by an IPTV STB when a subscriber "tunes" to the same Linear TV program. If the DVR and STB are on the same DOCSIS bonding group, they will receive the same multicast video flow (i.e. the CMTS will send one copy of the Linear TV program on the DOCSIS bonding group).

If the Linear TV programming being recorded by DVR's is the same programming being viewed in real-time by subscribers, then no additional network capacity is required to support the DVR's. In this case, DVR recording increases the multicast gain, since more devices receive a given multicast video flow. However, if the programming being recorded is not the same as that being viewed in real-time, then DVR recording will increase the amount of network capacity required to support the Linear TV services. Although we do not have empirical evidence on the specific programming being recorded during prime time, our presumption is that subscribers with DVR's predominantly record the popular programming that is also viewed in real-time by subscribers without DVR's, and thus there is no material impact on cable network capacity for DVR recording during prime time.

According to a recent study on DVR usage [3], 120% of DVR devices record Linear TV programming during prime time. Exceeding 100% concurrency is possible since most

DVR devices are able to record multiple programs simultaneously. This high level of concurrency is indicative of the tendency for DVR users to record a large volume of content (ED: how full is your DVR?) so they have a wide variety of recorded programming to choose from whenever they watch TV.

Using the DVR penetration and recording concurrency data cited above, we can estimate the number of DVR recordings to be expected during prime time, and the resulting multicast gain, in our example use case. See Table 2 for the methodology and results.

Parameter	Value
Cable TV Subscribers per SG*	200
DVR Take Rate	50%
DVR's per SG	100
DVR Recording Concurrency	120%
DVR Recordings per SG	120
Linear TV Viewers per SG (STB's)*	300
Linear TV Viewers + Recordings per SG	420
Unique Linear TV Streams per SG*	60
Multicast Gain	7

Table 2. In-home DVR Use Case

*See Table 1 for derivation

Assuming the DVR's in our example use case are recording the same Linear TV programming that is being viewed in real-time by subscribers without DVR's, the same number of unique Linear TV streams are required per SG as in the non-DVR STB use case. By dividing the total number of real-time viewers and DVR recordings by the number of unique streams per SG, we can calculate the multicast gain for the in-home DVR case. As shown in Table 2, the multicast gain is 7 when serving both STB's and DVR's, which represents a 40% increase in multicast efficiency compared to the non-DVR STB use case. Figure 1 depicts how in-home DVR recording increases multicast efficiency since more end points are served with each multicast video flow.

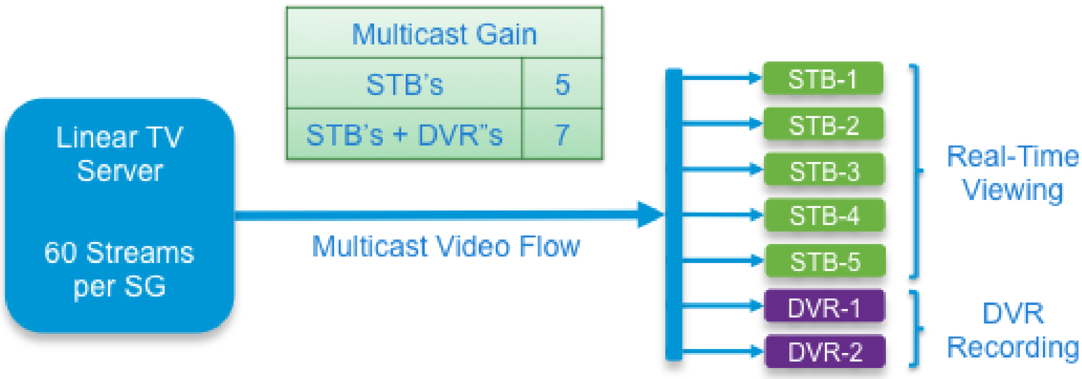

Figure 1: Multicast Gain with STB's and In-Home DVR's

Our example also illustrates the impact that DVR recording can have on Linear TV concurrency. If we assume all DVR's are separate from the STB's, then the overall concurrency of STB+DVR devices in the in-home DVR use case is 70% (420 total viewers + recordings / 600 STB's + DVR's), compared to 60% in the non-DVR STB case. If all DVR's are integrated with the STB, then the overall concurrency is 84% (420 total viewers + recordings / 500 STB's). These examples illustrate that in-home DVR recording can be a significant contributor to the overall Linear TV concurrency.

Although in-home DVR recording may not impact the network capacity required for Linear TV, it does increase the control plane traffic (i.e. IGMP/MLD and DBC messaging) that the CMTS must support, particularly during prime time when a high percentage of DVR's are scheduled to record at the top of the hour. Referring to our example use case, if 10% of the Linear TV viewers using STB's change the channel at the top of the hour, then the CMTS will receive 30 IGMP/MLD Join messages simultaneously. If half of the DVR's that are scheduled to record at the top of the hour initiate a channel change, the CMTS could receive an additional 60 IGMP/MLD Join messages, representing a 200% increase. Clearly the synchronized timing of channel change requests from pre-programmed DVR's can dramatically increase the control plane traffic load on the CMTS during prime time.

CLOUD DVR USE CASE

Cloud DVR solutions move the DVR recording and playout functions to the network, and enable remote access from clients on a variety of platforms. With cDVR, all recording of Linear TV content takes place in the cloud, and thus requires no capacity on the cable access network. However, unlike the in-home DVR case in which all time-shifted viewing is served from the DVR and thus has no impact on the cable network, all time-shifted viewing in the cDVR case is supported from the cloud, and thus requires capacity on the cable access network. Since the cDVR solution utilizes unicast delivery (i.e. a unique video stream per user), the amount of network capacity required is directly proportional to the number of cDVR subscribers viewing time-shifted content at any given time.

In order to estimate the impact of cDVR on the cable network, we refer again to the recent study of DVR usage described in [3]. According to that study, 20% of DVR's are utilized for time-shifted viewing during prime time (not including stream control of Live TV programming). We assume the take rate for the cDVR service is the same as DVR service, since subscribers should not care if the DVR functionality is supported in the home or the cloud as long as the user experience is equivalent. However, given that cDVR service is accessible from any STB in the home (which is not the case with an in-home DVR unless it is a whole-home DVR), we will assume the concurrency of time-shifted viewing among cDVR subscribers is slightly higher than in-home DVR subscribers. Finally, since we are focusing on Linear TV viewership on STB's, we will assume the same encode rate for cDVR service as we did for real-time viewing and DVR recording (8 Mbps). As shown in Table 3, we estimate that 5.7 CMTS DS channels and HFC spectrum is required to support the time-shifted viewing from a cDVR solution in our example use case.

Parameter	Value
Cable TV Subscribers per SG*	200
cDVR Take Rate	50%
cDVR Subscribers per SG	100
cDVR Time-Shifted Viewing Concurrency	25%
cDVR Time-Shifted Viewings per SG	25
Linear TV Stream Bit Rate (Mbps)	8
CMTS DS Channel Capacity (Mbps)	35
CMTS DS Channels per SG	5.7

Table 3. cDVR Use Case

*See Table 1 for derivation

In addition to the time-shifted viewing estimated in Table 3, there is also real-time viewing by non-cDVR subscribers (and cDVR subscribers who choose real-time viewing). Assuming that time-shifted viewing does not materially impact the STB concurrency or multicast gain, we can estimate that 13.7 DS channels are required for real-time viewing (per Table 1). Thus a total of 19.4 CMTS DS channels are required per SG for Linear TV service (13.7 for real-time viewing plus 5.7 for time-shifted viewing). Thus, based on our example use cases, cDVR solutions can increase the network capacity and HFC spectrum required for Linear TV services by roughly 40% compared to in-home DVR solutions.

Since the cDVR solution performs all recording in the cloud, the CMTS does not receive control plane traffic associated with channel changes for DVR recordings. Given the propensity of DVR users to record a large volume of content, especially during prime time, we expect cDVR solutions to offload a significant amount of control plane traffic from the CMTS. While actual results will depend on a number of factors, our illustrative example described previously indicates a 67% reduction in control plane traffic load on the CMTS if the DVR recording function is moved to the cloud.

HYBRID DVR USE CASE

The primary benefit of cDVR solutions when compared to in-home DVR solutions is the avoidance of costly DVR functionality and storage in the STB and the higher maintenance costs of DVR STB's compared to non-DVR STB's. With that in mind, it seems counter-intuitive to consider a "hybrid" DVR use case in which operators deploy both in-home DVR and cDVR solutions. However, two scenarios may merit consideration for such an approach. Both scenarios rely on the assumption that the popular Linear TV programming will be delivered via multicast for real-time viewing by non-DVR subscribers (or by DVR subscribers that choose real-time viewing in some instances). If that is the case, then having an in-home DVR capability that can provide the stream control functionality (for a limited duration) could mitigate the scenario in which a large percentage of subscribers simultaneously access stream control from a cDVR solution, resulting in a large spike in cDVR traffic on the cable network. This in-home DVR capability could be limited to stream control only, with a relatively small cache, and all recording and storage supported by the cDVR solution.

The second scenario is the ability to push the popular Linear TV content to in-home DVR devices with a moderately sized cache, and avoid the cost of storing the popular Linear TV programming in the cloud (i.e. licensing fees and storage capacity). In addition, recording the most popular programming in-home has virtually no impact to the cable network, yet would significantly reduce the network capacity required to support time-shifted viewing of the popular programming from the cloud.

If the hybrid DVR approach is not feasible, a "pseudo-hybrid" solution can be envisioned in which the cDVR service falls back to multicast if the cable network is congested and cannot provide sufficient capacity to support the stream control features from the cDVR solution.

MULTICAST ABR VIDEO TRANSPORT

Many cable operators have deployed TV Everywhere solutions to enable their subscribers to access Linear TV and On-demand services on a variety of customer-owned-and-maintained (COAM) devices such as PC/laptops, tablets, game consoles, smart TV's and smartphones. In most cases, the TV Everywhere platform has been deployed as an overlay to the existing digital cable platform, and designed to deliver unmanaged video services to COAM devices. As operators migrate to all-IP, there are clear benefits to using a common platform for delivering both managed and unmanaged IP Video services to operator-owned STB's as well as COAM devices. The TV Everywhere solutions deployed to date can serve as a foundation for the common platform to support all IP Video services in the future.

The TV Everywhere solutions typically employ Adaptive Bit Rate (ABR) video streaming, which dynamically adapts to network conditions to deliver the best possible user experience without provisioning guaranteed quality of service. The ABR video streams are delivered via IP unicast with a bi-directional TCP/IP connection between the ABR client and server so the client can continually monitor the network throughput and request the appropriate ABR video profile from the server as the throughput fluctuates. As we described in [1], using unicast delivery for all Linear TV services in a full-scale IP Video system is not feasible due to the exorbitant CMTS capacity and HFC spectrum required. Hence, an effort is underway within the cable industry to define and develop a multicast ABR video transport solution to enable operators to utilize multicast delivery for Linear TV services with an ABR-based IP Video system.

To describe the operation of a multicast ABR video transport system, let us first review the operation of multicast delivery in existing IPTV deployments, as depicted in Figure 2. A multicast server receives the Linear TV programming from the source, and outputs a multicast video flow labeled with a unique multicast group address. The multicast client residing on the IPTV STB, which has a priori knowledge of the multicast group address for each Linear TV program available to the user, initiates IGMP or MLD Join/Leave messages to receive the multicast video flow based on user input (or DVR recording activity if so equipped). The CMTS processes the IGMP/MLD messages in accordance with the DOCSIS 3.0 specification, sends PIM messages to receive the specified multicast video flow from the multicast server, and replicates the flow to the downstream interface on which the cable modem/gateway is connected. The CMTS then sends DOCSIS 3.0 (D30) management messages to the cable modem/gateway, instructing it to forward the multicast video flow to the IPTV STB.

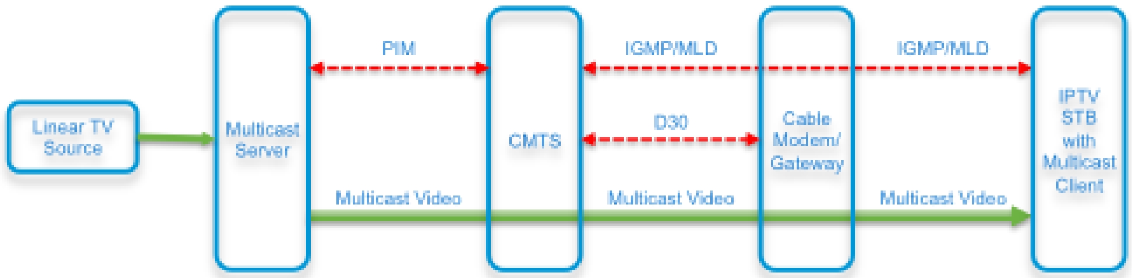

Figure 2: Multicast IPTV System

In a multicast ABR video transport system, an ABR client residing on the IPTV STB or COAM device sends HTTP GET messages to the ABR video server to request a specific Linear TV program (following standard ABR video system operation). However, in this case, a client on the cable modem/gateway intercepts the HTTP GET messages and, with a priori knowledge of the programming available from the multicast server, sends IGMP or MLD Join/Leave messages to receive the requisite multicast ABR video flow from the multicast server. The multicast server is specially equipped to fetch the Linear TV stream from the ABR video server (using HTTP) based on the IGMP/MLD messages received from the client, and encapsulate the ABR video streams into multicast flows. The CMTS follows the same process described above to receive the multicast ABR flows from the multicast server and forward the flow to the cable modem/gateway. The modem/gateway then converts the multicast flow back to unicast for delivery to the IPTV STB or COAM device.

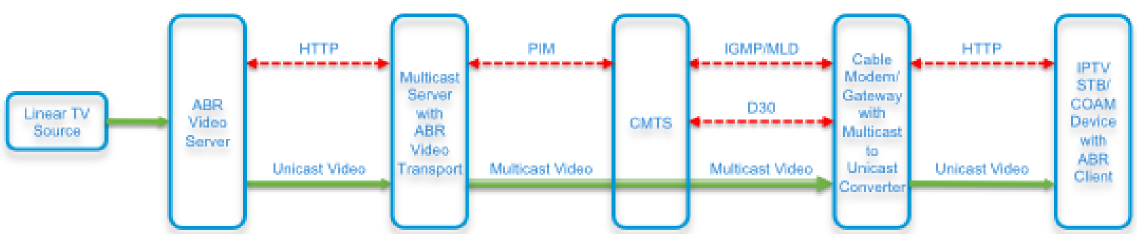

Figure 3: Multicast ABR Video Transport System

The use of multicast delivery in the cable network is transparent to the ABR client and server. If the requested Linear TV program is not available from the multicast server, the system falls back to standard ABR video system operation in which the modem/gateway client simply forwards the HTTP GET from the ABR client, and the

Linear TV service is delivered via unicast. The multicast ABR video transport system is also compatible with in-home DVR and cDVR solutions. Hybrid DVR functionality can also be supported with local caching on the gateway to support stream control, for example.

When deploying a multicast ABR video transport system, cable operators will need to select which Linear TV programs, and which ABR profile(s) for each program, to make available from the multicast server. These choices will affect the multicast efficiency that can be achieved. If the popular Linear TV programming is available from the multicast server, and all STB's and DVR's access the same ABR profile, then the multicast efficiency can match that of standard IPTV multicast systems. In fact, it is possible to achieve even higher efficiency if a multicast flow can serve not only STB's and DVR's, but also COAM devices.

Although not shown in Figure 3, an optional enhancement to the multicast ABR video transport system is the use of a reliable multicast transport protocol. This would enable the multicast server to be notified of lost packets, and re-transmit those packets (within a re-transmit window) in order to improve the quality of experience.

CONCLUSION

Using example use cases, we illustrated a few key takeaways for cable operators to consider in assessing the network requirements for delivering full-scale, managed IP Video services:

1. Multicast is essential for delivering popular Linear TV programming in prime time. Multicast efficiency can reduce the CMTS capacity and HFC spectrum required to support Linear TV services by as much as 80% in our example.
2. In-home DVR scenarios benefit the most from multicast; however, multicast is still a valuable tool in cDVR scenarios where real-time viewing is still prevalent (among non-cDVR subscribers and/or cDVR subscribers who choose real-time viewing in some instances).
3. cDVR increases the network capacity and HFC spectrum required for Linear TV services by 40% in our example; on the other hand, cDVR reduces the multicast control plane traffic load on the CMTS by 67% in our example.
4. Hybrid DVR solutions can enable operators to leverage multicast to record the most popular Linear TV programming in-home with virtually no impact to the network, and record all other programming in the cloud. Hybrid DVR solutions can also avoid the potential for large spikes in cDVR traffic associated with stream control during prime time.
5. Multicast ABR enables operators to continue to leverage the benefits of multicast for Linear TV services as they migrate to a common infrastructure and client for supporting all IP video services across a variety of STB and COAM devices.

The examples provided in this paper are based on field data where available, and on our own assumptions where field data is not available, and thus are for illustrative purposes only. Cable operators are encouraged to adapt the methodology described herein to their own particular environment. While the optimal solution for delivering full-scale, managed IP Video services will be unique to each operator, it will undoubtedly involve both multicast and unicast delivery approaches.

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