IMPROVING CABLE SYSTEM BANDWIDTH MANAGEMENT BY UTILIZING SUSCRIBER-BASED STORAGE RESOURCES

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Abstract

Cable head-end systems supporting on-demand content delivery applications and other key services operate 24 hours a day, seven days a week. Service networks need the ability to scale performance to handle large volumes of subscriber requests during high demand periods without creating unwanted delays or incurring prohibitive costs. Additionally, cable system operators need solutions that are scalable while maintaining efficient bandwidth utilization as workloads increase.

For these reasons, the addition of local client storage in the set-top box presents tremendous benefits to the system operator. One of the many key features of local storage will be the ability to offer customers true video-on-demand: a value-added service already familiar to the customer. This paper will explore the benefits of managing the delivery of content traffic to several client devices with local storage. The result is a video-on-demand service with higher availability, easier manageability, and greater scalability than previous solutions.

The Content on Demand Service

The cable industry has the unique capability of delivering high quality on-demand and targeted content to its customers, thereby delivering a premium service superior to other media delivery systems. The cable customer desires and now can receive true video-on-demand (VOD) services; this includes the ability to start a conditional access program of his or her choice at any time, to pause/rewind/fast-forward the program just like a VCR, and in some cases to view the content multiple times within a given time period. The content on demand concept is already familiar to the consumer because it is similar to the activity of renting programs from videotape rental outlets. Cable-based VOD offers the same service but with an increased level of convenience. The frustration associated with going to a rental outlet only to find that the program you want has been sold out, or is otherwise unavailable ceases to be an issue with client-side enabled VOD. Cable VOD also eliminates the specter of late fees that are incurred when returning media to a rental outlet outside of a given timeframe. Therefore the VOD services provided by cable network operators will offer consumers a familiar premium service where the benefits are immediately obvious to subscribers.

This paper will review some of the technical issues addressed by Keen Personal Media's TV4me™ software and hardware solutions to providing VOD and demonstrate that local storage at the client set-top allows the true VOD experience without using excessive amounts of network bandwidth, implementing major infrastructure changes, or creating excessive deployment costs. Note that we will examine only those technical solutions that provide the consumer with the true VOD experience. Since they do not meet the authors' requirements for true VOD, solutions like certain pay-per-view (PPV) services involving a carousel of staggered start-times and conditional access programs that require the customer to wait for the next start time are not included in this paper. By limiting our examination to the full VOD experience, which removes the delay in start time and enhances the viewing experience with the ability to fast-forward and rewind, we make the assumption that the consumer would be more willing to pay for the premium services that only the full VOD experience can provide.

Technical Solutions for VOD

Clients without local storage

Early trial systems for providing VOD to consumers included two-way, digital set-top boxes capable of decoding MPEG-2 Transport Streams and a network infrastructure to provide direct connections between media servers and set-top boxes. However, the set–top boxes did not include a local storage device sufficient for storing streaming data for any significant length of time. Examples of these early trial systems include the Time Warner Full Service Network (FSN) and the Time Warner Pegasus Phase 2 deployments described by Michael Adams in his book, *Open Cable Architecture*[1]. In these examples, a direct communication link is established between a media server and the consumer's particular set–top box. This link requires at least one dedicated forward digital channel assigned to that customer that is capable of carrying 4 to 6 Mbps of bandwidth without interruption. A secure and persistent back-channel connection was also needed for purchase and control of the stream. In order to provide the consumer the ability to fast-forward and rewind the stream, additional dedicated forward digital channels were sometimes used.

Since dedicated channels must be created in real-time to serve each customer, as they demand content, sophisticated switching and server systems need to be added to the system. For each collection of subscribers, there are several requirements: media servers are required to store and stream the content; forward channel switching systems are needed to establish the dedicated channel to the customer from the media server; and bandwidth must be allocated from a dedicated range of digital channels. Such infrastructure changes affect the head-end, distribution nodes and the set-top box client components of the system.

As illustrated by the Pegasus case study, on average one 6MHz channel can contain 10 digital content streams using QAM modulation. Therefore six dedicated 6 MHz channels (60 streams) were needed to serve 600 customers (where the peak utilization was assumed to be 10%). For a distribution hub with 20,000 homes passed, 2,000 simultaneous streams would need to be served, or 200 digital channels. Due to the limitations of simultaneous streams and media servers that can only handle a finite number of customers, network equipment must be replicated for every group of customers. The true expense for providing VOD to customers in these deployments comes from its inability to scale to serve all customers. Depending on the number of subscribers, the estimated cost of the network changes is $150-$200 per VOD stream in addition to the head-end equipment cost of several million dollars. Note that the upgrade is required for all subscribers on this part of the network, regardless of their subscription to the service. In addition, network upgrades are required to provide the capability to serve customers at peak times like weekend evenings. During off-peak times the network bandwidth is underutilized.

The following table summarizes the use of set-top boxes without local storage to provide VOD to customers:

Set–tops without storage
Advantages
• Reduced cost set-top without storage
• No security risk from local copy

Disadvantages
• Major network infrastructure changes required to support VOD • Bi-directional communication required throughout the session • A dedicated digital stream to each customer using the service. • Poor scalability and bandwidth utilization
Cost Per Stream
• $1,500 - $2,000 cost per VOD stream

Brute Force Method: Store all content at the set-top

Most of the expense and complication of the early systems can be alleviated by using set-top boxes (clients) with local storage (usually in the form of a hard disk drive). Local storage can remove the requirement that a persistent direct connection has to be created between the appropriate media server and each client. In addition, local storage of content can result in more efficient and faster trick-play (fast forward, rewind, etc.) features by removing latency between the user's requests via the remote and the response. In early systems, remote commands had to travel back to the media server in the network. With local storage, the commands are executed locally and therefore without delay. Note that local storage in the set-top provides additional services to the customer in addition to conditional access VOD services. Customers with local storage in their set-top receive all the benefits of personal video recorder (PVR) technology such as pause of live broadcast and EPG-based program recording. PVR devices currently available through retail outlets have already demonstrated that customers are willing to pay for such services. However, the exact value to customers is still to be determined.

We present here a brute-force method of providing true VOD to customers by using local set-top box storage. This model is used only as a comparison to a more efficient system to be described later. In this model, the conditional access content for the VOD service is stored in its entirety at the client set-top box. This content might have been downloaded the night before during off-peak bandwidth times. When the customer requests (and pays for) the content, it is unlocked from the local storage and available for a finite time period to the customer.

This brute-force method would require the least amount of network bandwidth. Each conditional access program is broadcast once during off-peak times and stored on the local set-top. However this system has two major drawbacks that make it less practical. The first is the large storage requirements within the set-top. Assuming that each hour of stored content requires 2 GB of storage, a significant portion of the local storage would be dedicated to storing the available content. Given that less than 10% of that content would ever be accessed, this would be a very inefficient use of the local storage. The second issue is security. Local copies of the content can be protected using existing scrambling schemes, but having persistent copies of the media in the set-top will be a concern to the content owner.

The cost of implementing such a system includes the additional cost of the storage within the set-top unit. Current hard disk drive costs are $2.50 - $3.50 per GB. And, today the most cost efficient capacity is 40 GB. (We can also expect these numbers to continue to drop and capacities to increase over time.) We assume a cost of $150 - $180 for local storage, which is added to the cost of a standard set-top. This cost scales linearly with the number of subscribers to the service. Earlier VOD models scaled with anticipated peak load usage and used a network-storage model versus local storage.

Unlike VOD solutions without local storage, major upgrades to the distribution system are not needed in a local storage solution. There also may be some argument that consumers themselves may be willing to absorb some of the additional cost if the set-top was available at retail. We do not make any such assumptions in this analysis.

The following table summarizes the features of the brute-force method of providing COD using local storage in the set-top client:

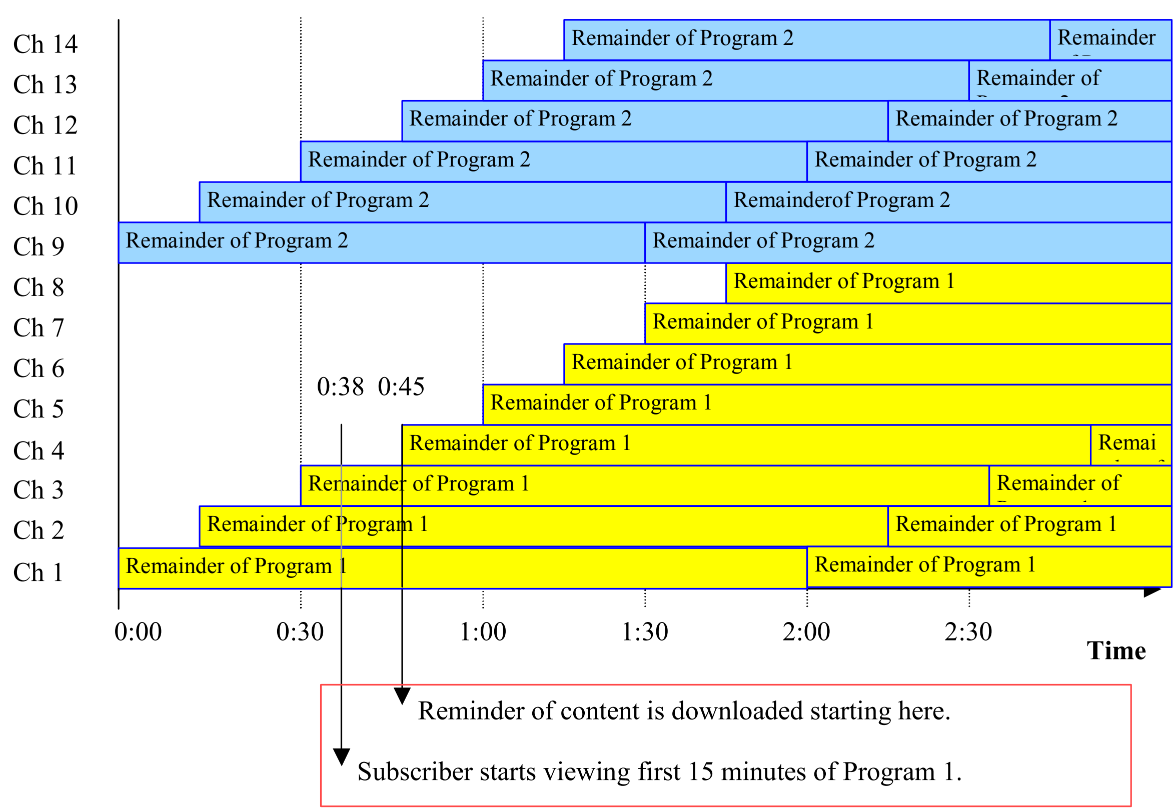
Storing all programs on the set-top
Advantages
• Simpler network infrastructure requirements • Provides PVR services to each customer • Reduced deployment cost
Disadvantages
• Security issues with locally stored content • May use a large percentage of the local storage capacity • Number of on demand titles driven by capacity
Cost Per Subscriber
• $1,500 - $2,000 cost per VOD stream plus $150 - $180 for hard drive in set-top box per home passed

Local Storage of Initial Segments

We present here a more practical method of providing a true VOD service that utilizes local storage and avoids the problems of the brute-force method while maintaining the advantages of a simpler distribution system. In this method only the first few minutes of each premium program is downloaded to the local set top of subscribing customers. In addition, a carousel of the remainder of the program is continuously broadcast on dedicated channels. In this way the system uses existing broadcast infrastructure with a service similar to existing PPV, but provides true VOD features to the customer.

We will show that this method allows true VOD with all trick-play capabilities without storing every program on the local drive, and without requiring dedicated connections between the media server and each customer. Furthermore, by using technology similar to existing PPV systems, this VOD service can be implemented using existing technology.

Assume that the first 15 minutes of each premium access program is downloaded to the local drive in the set-top. The program snippets could be provided via a single dedicated channel that broadcasts during off-peak times. Software on the



set-top would add previews of new programs as they appear on this dedicated preview channel, and the software would remove content when it becomes outdated.

Because the first 15 minutes of every program is available to the customer, they can receive instant, on-demand access to the premium content and begin viewing at any time, therefore providing true VOD. Customers also have the ability to perform full trick-play of the content since it is stored locally.

To provide the remainder of the premium access program (minus the first 15 minutes), a continuous carousel of the remaining portion of each program is broadcast on digital channels. Multiple versions of each program are broadcast on different channels, with each version delayed from the previous one by 15 minutes. For a two hour and 15 minute program (the example shown for Program 1 in the figure), this would require 8 channels to broadcast each version of the program. Once the customer begins viewing the conditional access content (and has completed the purchase transaction), the set-top begins storing the remainder of the content from the start of the next relevant carousel stream. Because the start time of the remaining content is broadcast every 15 minutes, the customer is guaranteed to start receiving the remainder of the content before they exhaust the 15 minutes already stored on their set-top. To the customer it appears as if the content was immediately available without delay.

An example of the system is shown in the figure. In this example two programs are distributed in carousel fashion across 14 channels. The total length of Program 1 is 2:15 and that of Program 2 is 2:00. In the example, a customer begins viewing Program 1 at 8 minutes after the hour. Since the first 15 minutes are already cached on the local hard drive, the customer is viewing the content directly from the local storage in his set-top box. At 15 minutes after the hour, the set-top starts recording the remainder of Program 1 from channel 4. This is appended to the first 15 minutes already on the hard drive and therefore stores the entire program onto the hard drive.

The system uses a distribution method already used in some deployments for PPV or multi-channel conditional access channels (HBO-1, HBO-2, etc.) where multiple versions of the content are displayed at various time offsets. However, unlike PPV the user does not need to wait until the next start time to begin viewing the content. In addition, the user has full trick play control over his viewing.

The storage requirements for a 15-minute preview are only 0.5 GB per program. The top ten preview programs could therefore be stored using about 10% of the drive capacity (assuming that the hard drive capacity is 40 GB). More importantly the distribution system does not require dedicated direct and persistent connections between the media server and each customer. Instead it uses a carousel system similar to existing PPV systems.

Security issues can be minimized in a number of ways. The content stream is encrypted on the hard drive and requires the resident security system for decoding. Since most security systems include keys with finite lifetimes, the content can only be viewed during a finite time period. Set-top software can also automatically delete the content, including the previews, after a finite time. Since the preview material is more accessible to potential hackers, it could be secured with a separate system such that if the preview programming is compromised it does not allow viewing of the entire program.

Storing previews on the set-top
Advantages • Simpler network infrastructure requirements • Uses familiar PPV carousel method. • Provides PVR services to each customer • Compatible with existing VOD infrastructure

Disadvantages
• Some security issues with locally stored content. • Locks up some percentage of the available local storage
Cost Per Subscriber
• $100 - $180 + adder for hard drive • Multimillion dollar VOD infrastructure not required

In summary, cable operators are continually searching for products and solutions that can deliver double digit operating cash flow (OCF) growth. Keen Personal Media has developed an elegant solution available through its TV4me PVR technology that leverages the existing cable system's infrastructure, while providing cost effective software and hardware. The scalability and costs associated with each solution are significantly disparate as the proposed methodology offers a 10 to 1 cost advantage over traditional VOD infrastructure costs. .

This solution essentially moves storage to the edge of the network, with the hard drive residing in customers' homes. From a cost perspective, this solution has significant advantages over the required expenses for transport and storage located in the head-end. The primary difference is the need for peak usage allowances, which require an excess of bandwidth and VOD streams. The proposed schema optimizes load balancing of content transmitted within the cable infrastructure providing the most cost-effective solution for cable operators.

This paper is not intended to suggest that local storage is a direct replacement for current VOD systems, however we do suggest that local storage in conjunction with a VOD system could deliver the optimal solution for full VOD services to a wider population while minimizing head-end infrastructure. A hybrid system consisting of deployed client set-tops with integrated PVR storage and some headend VOD capability would be more scalable and offer the operator a higher degree of flexibility than current systems and have a longer lifespan, ultimately creating a more reasonable solution and potentially greater customer satisfaction with less attrition.

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