NETWORK PVR VIDEO SERVER ARCHITECTURE

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Abstract

Set-top Personal Video Recording (PVR) at home and network PVR services from cable operators allow consumers to record and watch television programming at their leisure. PVR also gives consumers full VCR-like control (pause, rewind, and fast forward) over live television.

This paper discusses the broadband video server architecture as a platform for network-based PVR services. Network PVR allows cable operators to offer PVR services to digital subscribers using existing digital set-top boxes without local hard disk drives. Instead, network PVR uses video on demand (VOD) systems with video servers and disk storage located in cable headends and hubs.

Network PVR Video Server Architecture describes the technical infrastructure - at the hardware and software level - involved with capturing cable networks into a video server while simultaneously streaming to subscribers and offering full VCR-like control. The paper looks at network PVR architecture in detail, describing the video server requirements and capabilities, as well as the additional equipment and software required for deploying network PVR services. The paper also looks at the Electronic Program Guide (EPG) application integration that is required for consumers to interact with the network PVR service.

WHAT IS NETWORK PVR?

PVR technology, also known as Digital Video Recorder (DVR) technology, is a relatively new product making rapid advances in the interactive television (ITV) marketplace. Consumers can purchase PVR products branded by Tivo, UltimateTV and ReplayTV today in consumer electronics stores and in conjunction with digital broadcast satellite (DBS) services. Today, PVR set tops are installed in the home just like – and alongside – VCRs and DVD players. A set-top PVR is yet another 'box.'

PVR significantly changes the television watching experience. Similar to a VCR, PVR gives consumers the ability to record television programs and watch them at their own convenience. PVRs can often be programmed to automatically record favorite programs. PVR also lets consumers have full VCR-like control (pause, rewind, and fast forward) over a live television broadcast. PVR lets you pause the Super Bowl, rewind and watch thrilling plays over and over again and then fast forward back to real time. You can also fast forward over commercials just like a VCR or jump past them using 'skip ahead' features that instantly advance the program by 30 seconds each time this feature is selected on the remote control.

PVR devices ingest and record programs, and store them on disk drives for playback with full VCR control. Playback can be within a second of the broadcast network feed or much later in time. In summary, PVR is essentially two applications:

- Record TV programs for viewing later with VCR-like controls - Users choose the programs and series they want to record. The PVR records the programs and displays a menu of recorded titles from which the consumer can select any recorded program, any time

- Watch currently broadcast networks with VCR-like controls - Users can pause and rewind live television programs

PVR dramatically changes the way people watch TV: People watch what they want when they want and they watch more TV. A NextResearch study revealed that the vast majority of respondents report changing their viewing habits because of their PVR. Of significant importance to cable operators is that 44 percent of PVR owners report having more premium channels than they had before PVR, and 43 percent have more total channels than before PVR. This is a clear indication that PVR owners seek more television choices than they did before owning a PVR set-top box.

Cable operators are currently exploring how to offer PVR functionality to subscribers, including whether to introduce subscribers to PVR using new, enhanced PVR set-top boxes with hard disk drives in the home or using headend-based video-on-demand systems enabled for network PVR. Everything that can be done with set-top based PVR can be done with a video server.

ADVANTAGES OF NETWORK PVR

Network PVR can be deployed on existing digital set-tops without a trip to digital subscribers homes. Network PVR offers economies of centralization that allow cable operators to extend the PVR offering to more subscribers with less capital and operational expense, in addition to a considerably shorter deployment phase. Because the entire digital subscriber base shares the storage footprint of network PVR, the aggregate storage requirement may be lower and the overall cost per subscriber reduced. Many subscribers can share one copy of each program or network broadcast. The centralization of hardware and operations minimizes staffing and technical support requirements while significantly reducing the investment in PVR-enabling equipment and its operational costs as compared to a PVR set-top box solution.

Consider some of the benefits for cable operators:

- Network PVR – more so than VOD – is the must-have ITV product offering that not only competes with DBS, but exceeds what DBS can offer
- Unlike set-top approaches offered by DBS, network PVR provides unlimited tuners and storage to consumers – all programs can be recorded all the time, so all programs can be available all the time even if subscribers did not remember to record it in advance
- Network PVR increases the number of digital subscribers and reduces churn
- Network PVR drives increased premium channel subscription rates and total channel subscription rates
- One server platform can be used for VOD, SVOD and PVR just by adding storage and streaming capacity
- Network PVR can be rolled out to existing digital subscribers without any truck rolls
- Network PVR operational costs are lower than set-top PVR costs – fewer total disk drives and no truck rolls or home repair calls
- High customer satisfaction – no lost content due to disk failures, no waiting for the cable guy, no recording conflicts

- Incremental revenue through PVR service fees, new digital subscribers and premium package subscriptions, and advanced addressable advertising sales targeted to subscribers

PVR SYSTEM OVERVIEW

With a PVR-enabled Electronic Program Guide (EPG) and a remote control, subscribers can navigate upcoming programs and past programs. Subscribers can then select programs or networks for on-demand viewing. Upcoming programs can be marked for recording, and once the program is recorded, it appears in the subscriber's personal library or "virtual locker," which is accessible through the EPG. Personal libraries for each subscriber are maintained in a PVR preference server, which consists of a database and server-side business logic and is accessible through the programming guide. The preference server can also have applications that track a subscriber's favorite programs and alert them when programs matching their interests are available.

Subscribers can also select programs currently in progress and watch them on demand with VCR-like control. For example, a subscriber surfing through channels could begin watching a broadcast program already in progress, back up to the beginning of the program using the remote control, and then watch the program in its entirety. The subscriber could also channel off the initial PVR session, tune to another channel and enact PVR controls on another program without setting up a new session with the video server. Importantly, subscriber requests to time-shift the broadcast program result in a single video on demand session in which the streaming video content is simply switched on the video server. This single session per subscriber capability significantly decreases session set up and teardown traffic.

When subscribers select content from the server, whether it is for PVR, SVOD, or movies, the server streams the content to the QAM modulators and upconverters and into the hybrid fiber coaxial cable network cable plant. The content then streams into the subscriber homes where the signal is decoded by their set-tops and the programs displayed on their televisions. The QAM modulators and upconverters may be integrated into the video server, collocated with but external to the video server, or located remotely, many miles from the video server. If located remotely, the video streams are output from the server in either Gigabit Ethernet or DVB-ASI format, and then optically transported over fiber optic cable to remote QAM modulators and upconverters.

PVR SYSTEM ARCHITECTURE

There are a number of interdependent hardware and software systems necessary for network PVR, but the video server is the heart of the network PVR system. Understanding video server capabilities is important in deciding the appropriate server platform to choose. Given the massive amount of potential content storage possible with network PVR, storage scalability is a critical video server characteristic that must be fully understood to deploy a network PVR system cost-effectively.

In addition to the video server platform, there are architectural considerations for the deployment, which will affect the overall cost. Video servers can be deployed in either centralized or distributed architectures. In most cases, due to the massive amounts of content storage required for PVR, centralizing will be more economical.

The principal system components in an network PVR service include:

- Video encoders and demultiplexors to receive and format the television networks for ingest by the video server
- Video servers with capacity to ingest, store and stream content to subscribers
- Transport network from video servers to QAM modulators in headends and digital hubs
- Modulation and upconversion equipment to feed the combining networks
- Broadband two-way HFC network with bandwidth for network PVR streams
- Digital set-top boxes with PVR-enabled programming guides
- Subscriber preferences and recorded programming lists integrated with the video server and programming guides
- Billing system and conditional access systems
- Advanced addressable advertising applications

Figure 1 illustrates a typical network PVR implementation.

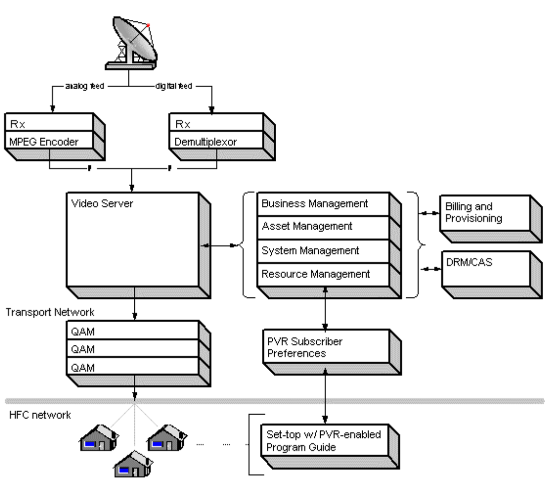

Figure 1: PVR System Architecture

As shown in Figure 1, analog and digital television network feeds are received at headends over satellite or over fiber at digital hubs. Analog signals are MPEG-2 encoded and ingested into the video server. Digital signals are demultiplexed and ingested into the video server. During ingest the fast forward and rewind view data is created, while the television network data is simultaneously written to disk storage. The television network data is then available - almost immediately - to be streamed out to subscribers just like video-on-demand (VOD) content.

Business management and other back-office applications manage the system bandwidth, coordinate video session setup and teardown, monitor system health, and report business and technical performance. During session management, coordination with conditional access and billing systems also occurs. The nCUBE back-office product is the nABLE Interactive Management Platform, and nABLE provides all the aforementioned functionality.

The PVR Video Server

The video server is the cornerstone of the network PVR system. Network PVR requires a video server to capture, store and stream video. The video server's ability to receive video in real time, prepare the visual fast-forward and rewind views, and write the video file to disk is essential. It also needs to identify start and stop record times within a network feed so that it can distinguish recorded programs for playback. In addition to recording and preparing network feeds, the video server will be simultaneously handling requests from the downstream network for streams, fast forward, rewind, pause, skip ahead and skip back on live broadcasts and recorded content.

PVR storage requirements are massive and a video server that cost-effectively scales to accommodate the video data is necessary to keep both capital and operating costs to a minimum. For example, to provide PVR storage for 200 networks for more than one month, the video server must be able to store more than 140,000 hours of unique content.

To scale storage-wise is not sufficient by itself, however. The video server must be able to stream out any of the captured networks and programs to any and all subscribers simultaneously. The goal is to minimize the number of copies of the same content needed to serve the maximum number of subscribers.

When considering PVR and the video server that will stand as the cornerstone of the PVR deployment, cable operators will want to look at several key characteristics of any one particular server platform:

- Storage Capacity
- Streaming Capacity
- Content Buffering and Recording

Capacity to Store Content

To store one cable network for one month requires 1.5 terabytes (TB) of MPEG-2 data ate 3.75 Mbps. A content library of 200 networks stored for one month each requires 300 TB of storage. Video servers that have streaming limitations must replicate content across video servers to satisfy stream requests. Video servers that have storage limitations must shuttle content from one server to the next to satisfy streaming demands. Shuttling content takes up enormous network bandwidth, and while content shuttling may work for movies, it is an impractical and very expensive solution for network PVR. The cost of duplicating content in multiple servers within a single headend or digital hub must be avoided or minimized.

Network PVR storage requirements also influence the deployment architecture in favor of a centralized approach, which avoids replicating content at multiple sites. Duplicating the same cable networks in each cable hub is more expensive than leveraging commodity fiber optic transport technologies and the fiber capacity commonly available in modern HFC cable plants. In particular, Gigabit Ethernet transport is rapidly becoming the most economical transport technology.

Capacity to Stream Content

More content equates to more on-demand use and more digital subscribers. In other words subscribers will watch more content from the video server when more choices are available. In addition, more content will attract more people to subscribe to digital services. PVR services also lower churn. The net effect is more digital subscribers using the system more often, resulting in higher stream concurrency than with VOD or SVOD.

Maximum simultaneous PVR stream capacity can easily vary from 30% to 90% of digital subscribers depending on how many cable networks are available on PVR and depending on whether they are available for record only or for full PVR even for the Super Bowl. For a region with 50,000 digital subscribers the video server may need to support 15,000 to 45,000 streams.

Content Buffering and Recording

The video server must be able to ingest and store a configurable time window for each television network. For instance, the most recent hour, week or months can be maintained. As new content is ingested, old content is deleted. This process is illustrated in Figure 2.

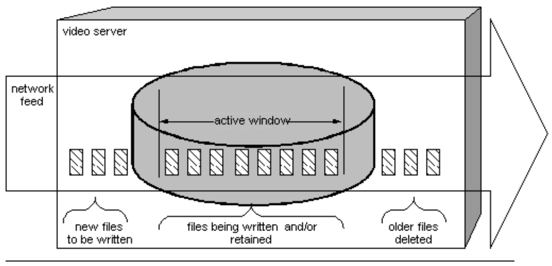

Figure 2: Content Buffering and Recording

Individual programs can be identified with the buffered MPEG-2 data in the window. Any portion of the buffer window that is identified as a recorded program can be stored on the server indefinitely. A program recorded for one subscriber can be made available to every subscriber a single copy of the recorded file.

The buffer window for each cable network and the record start and stop times can be accessed through the PVR system management application, as well as through Record and Play application programming interfaces (APIs).

The n4 Video Server

The current nCUBE video server is the n4. The n4 video server scales from small to large in five rack-unit (RU) building blocks called MediaHUBs. A single n4 video server can consist of anywhere from 1 to 256 MediaHUBs with stream capacity and storage scaling linearly. Table 1 shows the specifications for a fully configured n4 video server built with 256 MediaHUBs, assuming files encoded at 3.75 Mbps. Both the storage and streaming capacities are sufficient for a full PVR offering.

Table 1: n4 Video Server Specifications

Feature	**Specification**
Maximum Output Streams	> 33,000 streams
Maximum Storage in Hours	> 218,000
Maximum Storage in GB	> 368,000

Each MediaHUB can stream approximately 130 streams, assuming 3.75 Mbps. A single video server comprised of 256 MediaHUBs can serve 33,000 streams all from the same MPEG-2 file. The n4 video server provides 218,000 hours of unique storage, assuming 180 GB disk drives, which results in an aggregate of 368,000 GB or 368 TB.

All 218,000 hours of storage is available for unique content. There is no need to replicate content within an n4 server, whether it is configured for 100 streams or 33,000 streams. And 33,000 subscribers can access the same MPEG-2 file. This is very important for PVR because of the massive amount of content possible.

Deploying Network PVR

There are a number of unique characteristics to a PVR offering that operators will need to consider as they move into this advanced stage of interactive television.

Network Bandwidth Considerations

Operators must allocate enough bandwidth in the network to accommodate the PVR streams. Network PVR can easily require 30 to 90 MHz of bandwidth or more, depending on how many networks are available for PVR and whether the networks are available for record only or for record with VCR control.

Return path hardware is also required to accommodate upstream-request traffic; however, most of this hardware should already be in place for existing VOD and SVOD services.

Combining Set-top and Network PVR

If network PVR has an Achilles heel, it is that dramatic simultaneous spikes in bandwidth demand for certain live broadcasts could exceed the bandwidth allocated for on-demand services. This is the "Super Bowl" example where hundreds or even thousands of viewers of a live sporting event simultaneously stop the broadcast feed and rewind to watch a spectacular event. In this example, the system takes a substantial hit due to the large number of simultaneous stream requests.

One solution to the bandwidth spike issue is to combine network PVR with set-top PVR, offering subscribers a standard service of record-only network PVR for all networks and live PVR for a few networks. Disk-based set-tops could then be offered to premium customers paying a higher subscription rate for the full PVR experience for all events and all networks.

CONCLUSION

The subscriber experience defines PVR. Subscribers need to be able to select a program currently in progress and have full VCR-like control over it. They should be able to skip back to the beginning of a program already in progress. They need to be able to record programs in the future or choose to watch past programs. Current implementations and market research data show that PVR is a compelling technology for which consumers are willing to pay. Cable operators have the ability to deliver PVR functionality to their subscribers, driving incremental revenue from their subscriber base while they reduce churn and increase their digital subscriber base.

Because the two-way interactive network is typically already built for VOD and SVOD services, the incremental investment for PVR is primarily in the video server and video server storage. The video server storage and streaming requirements to deliver a compelling PVR offering are significant. Finding the most cost-effective video server solution that is capable of offering the acceptable level of services to subscribers is critical.

As PVR systems scale upward in storage and stream requirements, and as business models increasingly favor centralized architectures, the n4 video server emerges as an economically viable PVR platform. When video servers are integrated with content encoder and demultiplexors, nABLE management applications, PVR-enabled EPGs and subscriber preferences, cable operators can offer complete PVR services from their headends and digital hubs.

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