FLEXIBLE WHOLE-HOME NETWORKING STRATEGIES IN A MULTI-TV ENVIRONTMENT

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Abstract

Intense competition between cable and satellite is becoming the driving force for whole-home digital services such as multi-TV PVR. As service providers deploy customer premise equipment that enables new applications to reach all corners of the digital home, new approaches are required to manage this hardware to ensure ease of installation, quality of experience, and flexibility for different customers' needs.

This paper introduces a powerful architecture for managing distributed hardware resources in the networked home, and describes how a centralized resource manager and a flexible QoS enabled IP LAN can be used with advanced set-top boxes, low-cost clients, and other consumer electronic devices to deliver advanced whole-home digital services today while allowing service providers to maintain control of the consumer experience.

THE NEW DIGITAL HOME

Connected devices targeting the consumer are gaining momentum. Personal computer networking has taken off as broadband connections have driven data gateway sales and Wi-Fi has simplified installs. At present, some 8 million U.S. households have a network to enable Internet sharing[1].

At the same time, new TV-focused consumer applications are driving the need for whole-home connectivity. Personal Video Recording (PVR) technology has become a requirement of advanced set-top boxes as service providers seek to increase revenue and reduce churn. While many providers are taking delivery of single-TV PVR units in 2003, consumers have demonstrated their desire for a multi-TV PVR solution with 43% of PVR households having two or more units, and 74% of them saying they want PVR on all TVs in the home[2].

Adding one PVR box to each television is not only costly, but is confusing and frustrating. Viewers must deal with different recording libraries on every TV, and also coordinate passwords, recording schedules and settings. A less costly and more convenient solution is to use in-home networking with an advanced set-top box providing recording and storage. Additional televisions can access that same content through the use of low-cost media clients delivering content on demand over the home network. Instead of a PVR device on each TV at a cost of $350 to $500, an add-on media client can bring PVR to an additional TV at less than $100 retail.

While today's advanced set tops are one candidate to provide this functionality, CES 2003 saw the commitment of the consumer electronics world to the concept of the media center and media gateway. Panasonic, Philips, Pioneer, Samsung, Sharp, Sony, Thomson, and Yamaha all introduced connected entertainment devices adding networking and hard drives to devices such as PVR, DVD, and CD appliances.

COMPETITIVE FORCES

The trend of network-enabled products is the result of three powerful industry forces converging on the home:

- Cable operator competition with satellite is pushing both to look for ways of extending digital tier services to every TV in the house;
- Cable has recognized the importance of the CE channel with agreements that allow CE manufacturers to build digital cable ready devices; and
- The PC, the set-top and the CE media center suppliers are all trying to be the control center of the home.

For cable operators to prevent disintermediation of their services, they need to embrace an in-home networking platform that installs easily, supplies the quality of service their subscribers are accustomed to, provides extensibility to match evolving customer needs, and delivers a predictable, intuitive user experience.

NETWORKING OPTIONS

As service providers move to embrace whole-home strategies, there are a number of options for the delivery of media throughout the home. The most common options are:

- Analog distribution;
- Legacy MPEG distribution; or
- IP networking

Analog Distribution - One approach to distributing media around the home is modulating video and audio onto the existing coax network in the home. For example, a single advanced set-top box in the living room might provide a PVR session to a TV in the family room by blending the video and applications graphics into a single NTSC signal, and modulating that signal onto an unused or notched-out channel while an IR receiver in the family room communicates received key-presses back to the set-top on a separate channel.

Analog distribution allows a set-top or media gateway solution to distribute content throughout the house without a digital network. Unfortunately, this solution degrades digital cable to analog quality while creating privacy concerns by broadcasting every session “in the clear” to every TV in the house. The analog approach also does not scale well as hardware for every television needs to be added to the advanced set top.

Legacy MPEG Distribution - Another approach to distributing media around the home is to adapt the advanced set-top box to broadcast PVR sessions digitally using HFC modulation standards such as in-band MPEG encapsulation with out-of-band backchannels.

The one advantage of applying the HFC solution to home media distribution is that it allows existing low-end set-top boxes to be repurposed as terminals for additional sets within the home. The repurposed equipment can then utilize the in-band and out-of-band interfaces for communicating with an advanced set-top box media server which becomes a mini-head end.

Drawbacks of this approach include a) the high cost of head-end networking components, and b) the asymmetric communications channel. While the overall cost of this approach is partially mitigated by the reusability of legacy boxes, the high cost of the low-volume, HFC networking chips means that new equipment cannot follow the

same low-cost volume curves of designs using commodity off-the-shelf silicon.

The HFC networking chips also present a problem in that while they allow the home server to act as a mini head-end they recreate the inherently asymmetric communications channel supported by the legacy equipment. The lack of a high-speed back-channel in the legacy equipment eliminates the possibility of pooling networked resources such as tuners and storage. This approach is also not very suitable for IP traffic and hence cuts off an attractive and important array of emerging consumer services and product.

IP Networking - The IP protocol is the most broadly deployed networking solution worldwide and is available in several forms appropriate for whole-home media distribution including wireless and over-coax.

The significant advantage of standards-based IP networking, regardless of the physical layer, is that it leverages commodity hardware available at low-cost. IP networking provides the flexibility of supporting both bursty and streaming high-speed connections over a symmetric channel. With appropriate quality of service and resource management, IP networks support the widest range of applications and efficiently handle video (including trick-play), digital audio, and data networking.

For service providers wishing to pursue the consumer applications and associated revenue opportunities enabled by IP networking, while supporting legacy equipment during the migration, a hybrid approach is possible with intelligent resource management of both legacy and IP-based network resources.

THE DISTRIBUTED HOME

As service providers adopt whole-home networking approaches to digital content, the challenges include ease of installation, quality of service, extensibility, and interoperability of equipment from different vendors. Add to this the desire to have a flexible platform adaptable to different subscribers' needs and competitive market requirements driving time-to-market.

The solution is to deploy network-ready equipment with software components capable of auto-detection and auto-configuration of all devices and resources distributed on a quality of service enabled home network.

Distributed Resources

The Ucentric approach is to employ a centralized resource manager capable of discovering, allocating, and controlling distributed resources. Consider the hardware resources common to the whole-home experience:

Video Tuners – Not long ago, video tuner requirements were straightforward: One TV, one tuner. With PVR, and now whole-home PVR, the right mix of tuners changes depending on the household. Different households will require a different number of tuners depending on the number of simultaneous live-pause and pre-recording sessions needed for their viewing habits.

Service providers must recognize that a whole-home CPE network is not one size fits all. What is required is a means for adding tuners incrementally based on the customer, and allowing the number to change as the customers' needs evolve.

Conditional Access Modules - As with tuners, the conditional access equation of the

past was on a per-TV basis. With a whole-home solution, the number of conditional access modules required is more a function of a family's premium content tier and viewing habits. While the ideal is to have every tuner CA-enabled, the economics of CA-licensing or POD cost suggest that in the short term there may be premium content homes where not all tuners are CA-equipped.

Persistent Storage - The central component to time-shifted media is the hard drive. The problem with storage economics is that it is expensive for a service provider to deploy, and consumers will always want more. The solution to this problem is to leverage traditional and CE channels to allow a consumer to add more storage to their network as their needs evolve. Examples of add-on storage include 1394 drives connected to the primary ASTB or drives located in other CPE on the IP network. A resource management solution needs to be able to discover, configure and control persistent storage located anywhere on the network.

AV Encoders - MPEG-2 is the default AV encoding technology used today for time-shifting and storing analog content. As consumer oriented products evolve, this will migrate to support for more efficient encoding techniques such as MPEG-4 and H.26x. Whole-home PVR solutions today require an MPEG-2 encoder per analog tuner, but in this evolving world, it is important to plan resource management solutions to be advanced codec-ready, and be able to distinguish different encoder capabilities on mixed resource networks.

AV Decoders - As with the AV encoders, there is a migration underway towards multi-codec capable decoders. As these products are deployed, a resource management solution must be able to recognize their capabilities.

Bandwidth - Control of bandwidth is critical to maintaining quality of service in IP networks. A whole-home network may contain a single subnet, such as an 802.11g-over-coax backbone, or it may contain multiple subnets including a wireless network and local IEEE1394 buses. Disk bandwidth management is also critical for time shifting multiple high-def and standard-def streams. A successful resource management solution must be able to reserve and maintain bandwidth throughout the system for all viewing sessions even during trickplay.

Outputs - Not all output interfaces are the same. A resource management solution must be able to distinguish between active high-def and standard-def ports, and track which interfaces are configured to support DRM protected content, and which are not.

Other Resources - In addition to these common AV resources, other devices are converging on the home network. POTS lines provide necessary connections for voicemail and caller-ID information. Broadband connections provide a data link to the Internet. PDAs and cell phones offer alternative GUI opportunities. A resource management solution must remain flexible enough to support new devices and remain extensible to future unforeseen consumer applications.

Centralized Resource Management

Each of the above resources shares the common element that they all operate on streams of media or data content. Some elements, such as tuners, are stream producers. Other elements, such as decoders and their associated display outputs, are stream consumers. There are also elements

that connect producers and consumers. Any of these resources can be chained to form a media pipeline to provide a service, such as live-pause TV.

Standards such as UPnP and HAVi have provided mechanisms for networked devices to broadcast their availability and allow negotiation between devices for control of each other's resources. While this ad hoc negotiating technique works for some lean-forward activities like downloading a video from a camcorder for digital editing, it lacks the level of sophistication needed to provide a single point of control to reserve resources in the future, string together chains of distributed resources, and resolve conflicts in a manner essential for the lean-back experience of whole-home media on demand.

The Ucentric centralized resource manager is capable of discovering resources as they are added to the home network and providing a single point of arbitration for the reservation of these resources among authorized applications. Around each resource is implemented a unified API allowing applications to request and control the resources they need.

HOW IT WORKS

Devices deployed within the Ucentric environment provide a service wrapper around each resource. This service wrapper provides a standard API for stream operations associated with that device. For example, an MPEG-2 decoder provides a streaming media interface supporting the Ucentric Media Protocol (UMP). This API allows other components, such as a disk-stream media server, to deliver trick-play enabled MPEG-2 content to the decoder regardless of whether the two resources are in the same box or in different rooms of the house. When a new device is connected to the network, the device reports its available resources and their interfaces using Simple Service Discovery Protocol. Applications communicate to each other and the resource manager using a networked XML interface.

Each network is required to have at least one resource manager-capable device. In the typical home this is a single advanced set-top box, but in homes that contain more than one ASTB, a negotiation protocol is used to determine which resource manager is active. The active resource manager maintains a table of all available devices, their stream resources and resource interfaces. The resource manager also maintains reservation information allowing resources to be assigned in the present or future.

Applications requiring resources communicate these requests to the resource manager. These requests take the form of a pipeline graph connecting resource requirements. For example, when a new video output is activated on the system, a new session application is instantiated and associated with that display. This session reserves the resources necessary to provide a graphical user interface and pre-recorded MPEG-2 content to that display. If that session later needs additional resources, such as tuner for watching live-pause content, an additional request will be made to the resource manager at that time.

Other applications, such as the EPG, may request resources for a future event. For example, when a user requests that a show be recorded at a future time and date, the application requests the associated resources (e.g. tuner, MPEG-2 encoder, disk capacity) for the time window required.

Example

Consider a typical evening at home with the whole-home enabled network described in Figure 1.

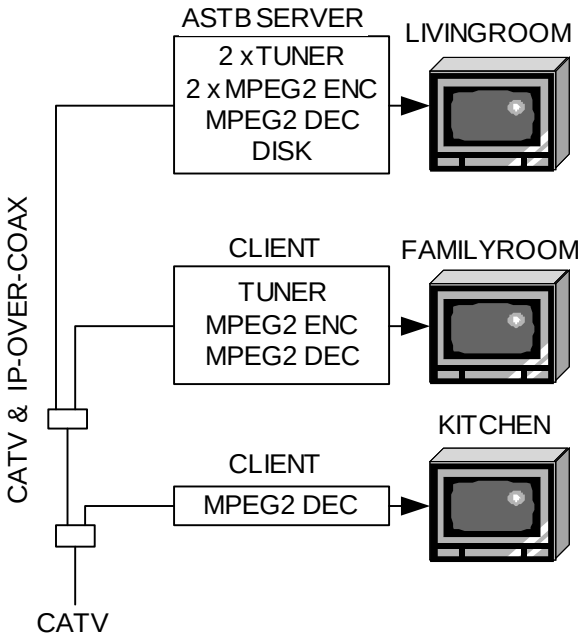

Figure 1 –Typical whole-home network

This diagram illustrates a three-TV household. The living room TV is connected to an advanced set-top box configured to be a media server. The media server contains a number of resources including two analog/digital tuners, two MPEG-2 encoders, and one MPEG-2 decoder. The media server also includes a hard disk with associated media services capable of sending and receiving media streams. The family room TV is connected to a media client with a tuner, MPEG-2 encoder, and MPEG-2 decoder. A third TV in the kitchen is attached to a client with an MPEG-2 decoder. The advanced set-top box and the media clients communicate over a 2.4GHz IP network sharing the same coax as the in-house CATV.

One morning, Dad programs the system to record a hockey game at 8:00pm on digital channel 150 using the EPG on the TV in the kitchen. The EPG scheduling application requests a reservation of an audio-video pipeline with the pipeline in Figure 2:

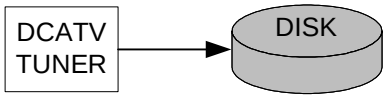

Figure 2 – Digital record pipeline

The requested pipeline includes a digital tuner. If channel 150 had been a premium station, the scheduling application would have made additional requirements on this tuner, such as associated Conditional Access or POD module. The requested pipeline also indicates the required disk bandwidth and storage capacity needed to record the program.

The resource manager searches the resource database for resources that match the request. The network contains one disk and three tuners. All three tuners have the same capabilities, differing only by their location. The resource manager uses a least-cost algorithm to construct a pipeline choosing a tuner in the server to avoid using network resources.

The resource manager checks for disk space both when the user schedules the recording and shortly before the recording begins. If no disk space is available when the user schedules the event, the resource manager checks to see if any “delete-able” files are available for deletion. If all the files on a full disk are marked as “do not delete”, the user will be alerted.

Upon successful reservation of the required resources, the reservation is stored in the resource manager reservation table for use when considering future reservation requests. A successful reservation is

communicated back to the application with a reservation identification.

At 7:30 that evening, the kids want to watch a show in the family room. The show they want to watch is on analog channel 32. When they select this program from the EPG, the application calls the resource manager to request resources. The pipeline in Figure 3 is requested by the application:

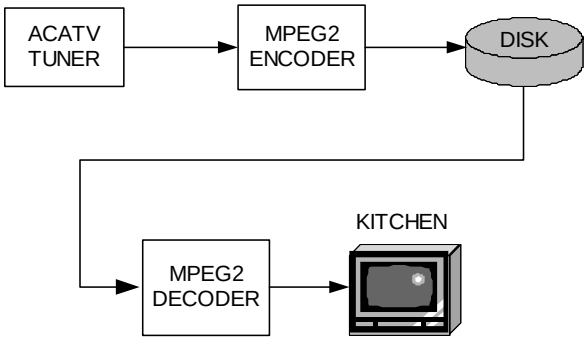

Figure 3 – Requested live-pause pipeline

There are two unassigned tuners on the network, one in the server in the living room and one in the client in the family room. While the tuner in the family room is local to the TV session requesting the tuner, the stream will be written to the disk in the living room for live-pause. The least-cost algorithm leads the resource manager to assign the tuner/encoder pair in the living room to the pipeline, saving a transfer of the encoded data twice across the network. This method preserves more network bandwidth for other uses including best-effort data transfers between PCs sharing the network.

Once the resource manager has successfully mapped the requested pipeline to actual network resources, the instantiated pipeline is returned to the application and the resources are marked as reserved (in this case indefinitely). Note that the resource manager has added one component to the pipeline (Figure 4).

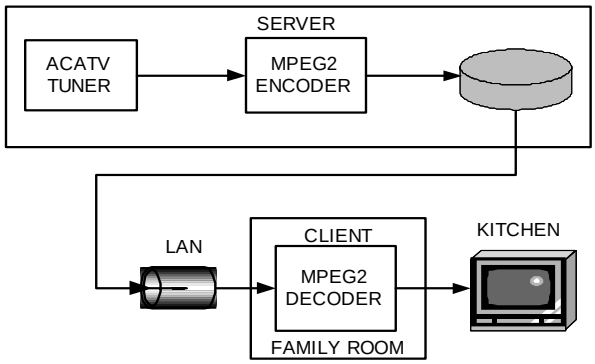

Figure 4 – Granted live-pause pipeline #1

The LAN connection is required to connect the components in the server to the components in the client. The LAN is a managed resource with guaranteed quality of service. Bandwidth allocation is controlled by the resource manager. The resource manager assigns the bandwidth requested to send one MPEG-2 stream.

At 7:45pm, Mom wants to watch a program in the kitchen. The resource manager asks for a pipeline identical to that in Figure 3. In this case, the only tuner remaining on the network is the tuner in the family room. The resource manager completes the graph in Figure 5:

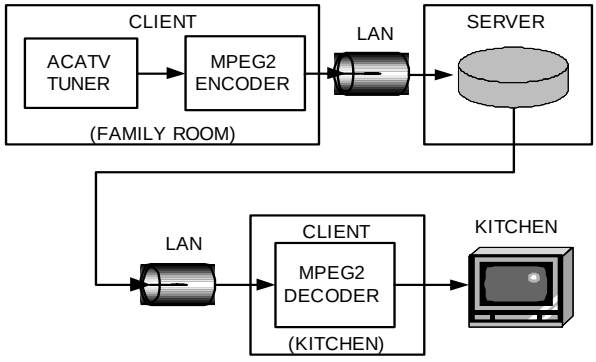

Figure 5 – Granted live-pause pipeline #2

Two network components need to be added to the graph, and twice the bandwidth reserved on the network.

At 7:50pm, the system prepares to record the hockey game, verifying that disk space is available, and removing "delete-able" content or alerting the viewers as needed.

At 8:00pm the recording of the hockey game commences.

At 8:05pm, Dad sits down in the living room to watch a program. He chooses not to watch the game, but to look through the video library, selecting a James Bond movie recorded earlier that week. The system now makes an updated request for resources (Figure 6):

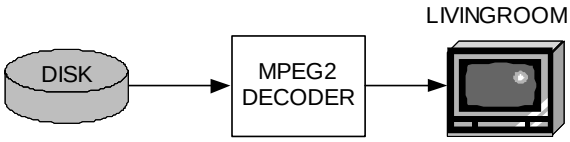

Figure 6 – Play from disk pipeline

The resource manager is able to construct this graph out of resources available in the server in the living room.

Pipelines are torn down when they are no longer needed. For example, the recording resources in Figure 2 are freed when the scheduled recording of the hockey game completes. Typically, a minimal video playback pipeline (**Figure 6**) is maintained to allow every television to have instant access to at least pre-recorded content.

FlexMedia LAN™

The distributed resource model and centralized resource manager discussed here has been implemented in the Ucentric FlexMedia LAN™ software solution. The Ucentric resource manager is capable of managing multiple LAN technologies simultaneously, including hybrid topologies such as wired/wireless or legacy MPEG and IP over coax.

FlexMedia LAN™ also provides control of bandwidth allocation for multiple streams and applications through the Ucentric bandwidth broker. This bandwidth broker provides QoS mechanisms including priority services, dynamic stream management and bandwidth allocation.

The strength of FlexMedia LAN™ stream management over the network is combined with the Ucentric distributed resource manager to pool all tuner, storage and network resources - allowing the number of tuners to be provisioned flexibly in relationship to actual household need. Additional supported services include expandable storage located anywhere on the network providing convenient installation options.

CONCLUSIONS

Cable operator competition with satellite is pushing operators to look for ways of extending digital tier services to every TV in the house. This competition has in part lead cable operators to recognize the importance of the CE channel as a means for making every corner of the home "cable ready". With consumer applications evolving, and PC, set-top and CE media centers all trying to be the control center of the home, cable operators can leverage their quality experience with new CE relationships to deliver a compelling whole-home experience. To accomplish this, service providers need to adopt a flexible network approach to maintain control of the consumer experience.

Successful deployment of new consumer applications requires the flexibility of IP networks. The heterogeneous nature of these networks together with the need for quality of service guarantees requires intelligent resource management. Whole-home applications require a whole-home approach to deployed resources, and this requirement has led Ucentric Systems to adopt a centralized resource manager in the FlexMedia LAN product offering. This approach provides the most flexible, predictable, quality user experience available today.

REFERENCES

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