Home Networking Cable Television

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Introduction

With the mass market adoption of computer, WiFi and high-speed Internet connections, it may seem that home networking is here. However, most home networks amount to little more than a shared Internet connection. Some homes share networked printers. Some homes may share files stored on networked computers, but this only scratches the surface of the potential of home networking. The basic plumbing is installed. The water is in the pipes. For the most part, however, home users haven't learned how to turn on the faucets or realized the benefits of indoor plumbing.

That is about to change.

The requisite data standards are available and are beginning to show up in mass market products centered on entertainment. They are included in computer operating systems. They are included in dedicated game consoles. They are beginning to show up in televisions and set-top boxes. We are entering a new age of home networking that will change the where, when and how we experience entertainment. This paper explains the philosophies and newly-developed tools that will guide and enable cable television to play a major role in this evolving ecosystem.

Architecture

In order to understand how cable television will factor into the home entertainment network, it is instructive to understand some of the underlying principles that embody the cable television technology strategy.

Principles

Overview

Cable television came into existence motivated by the desire to solve a couple of fundamental problems. The first problem was delivering television programming to people who were otherwise unable to get it. To solve this problem, cable companies built powerful antennas, then distributed the signal via coaxial cable to homes in the area. The second problem was a very limited choice of programming. Cable companies built the infrastructure and made the deals to obtain programming from remote sources and created new content networks to fill the gaps.

In the era of home networked entertainment, these objectives haven't changed all that much. Home networks and their ubiquitous connection to the global Internet have made entertainment programming available to an ever growing number of new devices and new locations. Similarly, this vast network of interconnections has enabled content to be sourced from virtually anywhere by virtually anybody. In other words, the advent of IP-delivered video programming provides an opportunity for cable operators to deliver their products and services to a greater number of people on a wider variety of devices. However, it also presents an opportunity for our competitors to deliver competing services to our customers.

Those familiar with the history of CableLabs may remember the CableHome initiative undertaken several years ago. This project was designed to bring managed home networks to cable customers. Part of the business strategy was based on offering home networking management services and charging a fee for those services. This business model failed to gain traction. Also, the CableHome hardware was designed with so many features that it became prohibitively expensive.

A number of things have changed since CableHome. First, it is clear that our competitors will be delivering video and other services over IP networks to and around the home. Second, standards for home network such as UPnP and DLNA have matured and become available in the marketplace. Finally, the cost of networking components has fallen.

As the cable operators reconsidered their strategy for OpenCable Home Networking (OCHN), they wanted to avoid some of the challenges of CableHome. They established a few principles that could differentiate cable home networking from computer-based home networking and over-the-top video services.

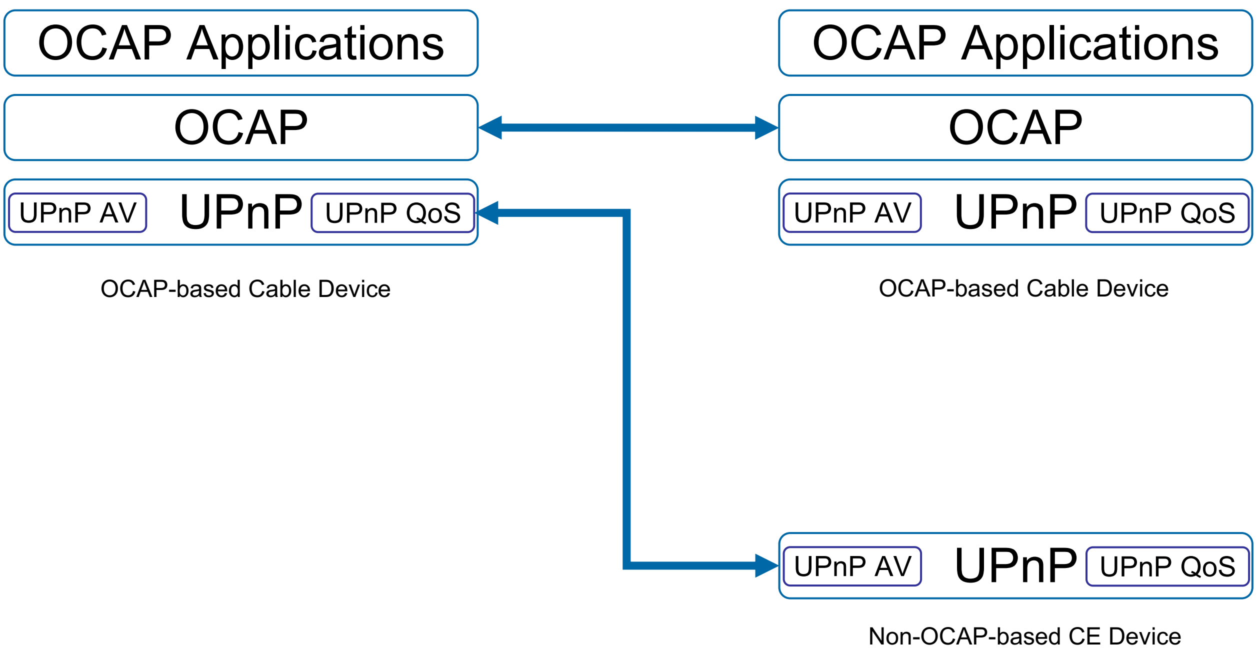

Figure 1. Interoperability layers for OCAP and non-OCAP devices.

High-quality Customer Experience

Cable companies felt that customers would expect a high-quality home networking service that would present video services with equivalent or better quality than they got with regular cable television service. This required bandwidth management services that could ensure that video streams at an adequate bit rate and support multiple video streams on the network simultaneously. It also required a management system that could diagnose and repair problems remotely over the high-speed networks.

Interoperability across different cable providers and with new types of devices was also of key importance. Open and widely adopted standards would enable connections with new platforms and over diverse networks. Interoperability with other OCHN devices is provided at the OCAP layer. Interoperability with non-cable boxes is implemented at the UPnP/DLNA layer (See Figure 1). This enables OCHN-equipped televisions and set-top boxes to source content from Consumer Electronics devices (computers, media servers, etc.) and allows consumer devices (gaming consoles, media players, etc.) to play media content exposed on the network from cable operators. In this sense, OpenCable Home Networking does not compete with networking solutions from the consumer electronics and computer industries. Rather they expand upon each other and provide consumers with the ability to enjoy their content from any source on any connected device.

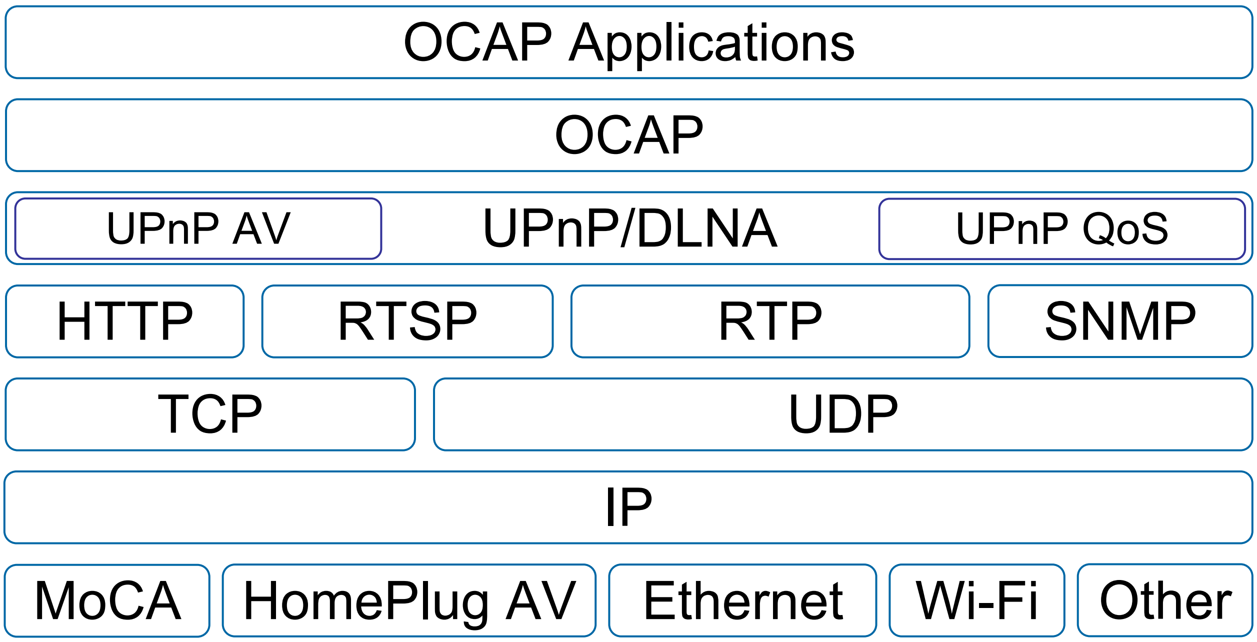

Figure 2. Simplified stack diagram for an OpenCable Home Network.

IP, UPnP, DLNA, CEA

A number of standards were adopted in order to achieve interoperability with cable and third-party devices (See Figure 2). Internet Protocol (IP) was really the only logical choice for transport. This not only enabled a common transport to underlie upper levels of the stack, it also enabled numerous physical layer options that would work across twisted pair, coaxial cable and wireless networks.

UPnP runs over IP and provides support for discovery of network resources, interconnection interfaces for numerous devices and a quality of service (QoS) platform to support both prioritized and parameterized bandwidth management.

DLNA is supported in OCHN (though full certification is not required) as a means of ensuring interoperability with other DLNA devices. OCHN clients, such as televisions and set-top boxes, will be able to play content hosted on DLNA media servers. DLNA players, such as game consoles and DLNA televisions, will be able to play content exposed by cable operators. Various CEA standards (closed captioning, emergency alerts, user interfaces, etc.) are supported for interoperability and to ensure compliance with regulatory requirements.

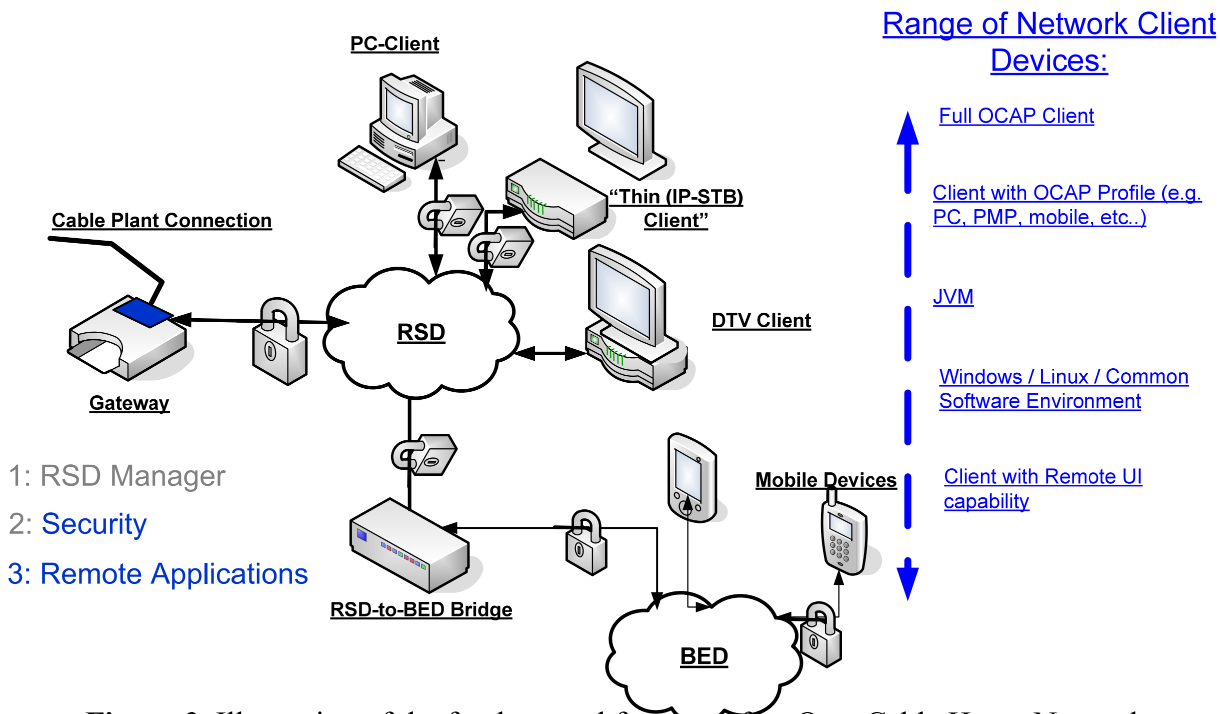

Figure 3. Illustration of the fundamental features of an OpenCable Home Network.

QoS

UPnP QoS version 2.0 provides support for prioritized traffic. This includes packet tagging and prioritization of multiple traffic queues to ensure that the high-priority traffic (such as voice and video) get through the network first. However, cable operators felt that prioritized traffic may not be sufficient. They wanted to be able to reserve traffic paths and ensure that a stream would flow reliability before they started sending it. The recently completed UPnP QoS version 3.0 provides this level of control.

OCHN quality of service is called Reserved Services Domain (RSD) (See Figure 3). It parallels UPnP QoS 3.0 and provides support for QoS Devices, QoS Managers and QoS Policy Holders. QoS Devices are end points and way points on the QoS enabled network. They are servers, clients, bridges and routers that implement QoS policies. QoS Managers are the traffic cops on the network that set up the reserved paths and carry out the policies communicated from the QoS Policy Holders. QoS Policy Holders receive the QoS policies (stream priority handling, preemption, etc.) from the network operator. There is only one QoS Policy Holder active on the network at a time. There can be several QoS Managers and QoS Devices.

In OCHN, the QoS system is enabled by the Reserved Service Domain (RSD) Protocols specification and the RSD Technology Requirements. The first document provides details on how to set up a reserved and QoS-protected path between devices. This path includes the source device (server), the sink device (client), and any devices between these endpoints (bridges, routers, etc.). At each link in the path, a QoS reservation for a specific amount of bandwidth is requested. If all the links have sufficient bandwidth, this process continues until a complete path is reserved between the server and the client.

If there is insufficient bandwidth at any link, the interfering streams will be reported. At this point, the policies of the QoS policy handler are implemented. If the existing streams are higher priority, the newly requested stream will be denied. The user interface can determine how to handle this. It might just notify the user that the request cannot be completed. It might list the interfering streams and allow the user to change priorities. If the newly requested stream is higher priority than existing streams, the situation is different, but the user interface can still handle it in various ways. The new stream could automatically preempt and existing stream. The existing streams might be displayed so the user can determine which stream(s) to terminate. The user interface may also require a password to authorize the user to shut down existing streams.

Regardless of how powerful the QoS system is, it won't do much good if there isn't enough bandwidth to support the services to be delivered. In order to address this problem, CableLabs developed a set of requirements for underlying networks that would meet MSO requirements for service delivery. The primary requirement is that the network must be able to support a sustained bandwidth sufficient for three simultaneous high-definition MPEG-2 video streams. This includes support for networked DVR functionality and trick modes. The minimum bandwidth required is around 100 Mbps. The second requirement is support for scheduled QoS so that UPnP QoS 3.0 will work. Networks that don't meet these requirements, such as Ethernet and WiFi can still be used, to connect to other devices (like computers), but the quality of the video may be impaired. Connections between MSO devices will be based on qualified networks. A couple of PHY/MAC layer networks that appear to be able to meet the RSD Technology requirements include MoCA (over coaxial cable) and HomePlug AV (over AC power lines).

While Wi-Fi networks don't currently support scheduled access, the finalization of the 802.11n standard and new authentication mechanisms such as Extensible Authentication Protocol-Authentication and Key Agreement (EAP-AKA) are making wireless networks faster, more secure, and more easily manageable. EAP-AKA allows a single security identifier to be used as a device transitions between a 3G cellular network and a Wi-Fi network. Different Wi-Fi channels and SSIDs can also be used to provide physical and logical segmentation in a wireless home network. This might be useful for MSOs to support different policies on network segments within a home or business. Wi-Fi is becoming increasingly viable as an alternative to running cables and fits well with an MSO services, IP-based home networking distribution architecture.

Manageability

While unmanaged networks are suitable for many purposes, managed networks can ensure that customers get what they pay for. This is a key requirement for cable operator networks. The manageability of QoS on the home network was described in the previous section. Operators have always been able to manage the delivery networks to the home. OpenCable Home Networking (and CableHome before it) takes manageability into the home. However, while CableHome sought to offer management of home networked devices as a billable service to customers, OCHN view it more as way to minimize service calls and provide a differentiated customer experience with better performance than off-the-shelf consumer networks. The primary service motivating OCHN is multi-room DVR. This service allows any OCHN television or set-top in the home to playback content from any other OCHN server in the home. Every stream is protected by parametric QoS. If the available bandwidth becomes constrained, MSO management policies and user feedback are used to ensure that the customer gets the desired services with the best possible quality. Additionally, if the user encounters poor service (if a poorly behaved consumer device attempts to steal bandwidth, for example) a cable customer service representative can identify the offending device and give the customer options for addressing the problem.

SNMP MIBs, OCAP APIs

Beyond the management of network bandwidth and video streams, the operator also needs the ability to manage MSO devices on the network. This is primarily done through Simple Network Management Protocol (SNMP). Devices that support SNMP implement a Management Information Base (MIB) that exposes various features of the device. Some MIBs are read-only and just enable monitoring of various parameters of the device. Other MIBs can be written in order to set device parameters and execute various device features such as "reset."

There have been MIBs supported on set-top boxes for many years. With OCHN, this set has been expanded and includes several MIBs specifically to support home networking.

More capable and flexible management solutions are currently being investigated as potential extensions beyond SNMP. Among others, UPnP device management and OMA-DM are being evaluated. The goal is to provide more extensive capability for cable operators to remotely diagnose and repair problems, more effectively manage network resources, and provide better customer support at a lower cost.

Few cable customers have the skill or the desire to be network administrators. This is a core competency and a key differentiator for cable operators. Being able to provide this administrative service to customers in a more effective and at a lower cost will keep cable providers relevant as over-the-top application providers attempt to take market share from MSOs.

Security

Security continues to be an important differentiator for cable companies. The existing conditional access systems have been an important lever for obtaining distribution rights for the most valuable content. Security is one of the primary principles underlying OCHN (See Figure 3). It is defined in the CableLabs OCHN Security Specification. Users' rights to premium content and the security of that content as it traverses the network are necessary in order to retain access to the best content. Unfortunately, there are numerous and incompatible security solutions that work over IP networks. OCHN has currently specified DTCP-IP as an approved link security solution. Additional features, such as digital rights management, are currently being negotiated and specified with an objective of having a flexible and consistent security solution that will work for all MSOs and extend to resources beyond the cable networks.

Portability Across Cable Providers

Another goal of cable operators is to provide a common development platform across MSOs. OpenCable Application Platform (OCAP) or the tru2way platform is the basis of this environment. Applications that use OCHN features are developed in OCAP. OCAP provides a set of APIs that provide a programming interface to UPnP functionality. An OpenCable specification called Home Networking Protocol (HNP) maps the OCAP API onto UPnP. It could also be mapped to other protocols if that were to be necessary in the future. ETV Binary Interchange Format (EBIF) is also being used as a common application platform format that runs on a large subset of existing set-top boxes. Although less capable than OCAP, it provides a large addressable footprint for simple applications and advanced advertising features.

OCAP (tru2way)

OCAP is based on Java and MHP and can be implemented on various hardware platforms. Cable operators are currently deploying OCAP across their service areas and shipping OCAP-enabled set-top boxes very aggressively. OCAP-based program guides and other applications will begin showing up on cable networks very soon now.

The cable industry has decided to make tru2way an open-source project and is leveraging the Java development community to create new and innovative applications. There is a tru2way/OCAP section on Sun's JavaOne developer's site.

Enablement of New Products and Services

The days of the standalone set-top are numbered. New set-top boxes coming out now have some sort of networking built in. Set-top boxes and other equipment from cable operators will naturally connect at the highest possible quality, but cable will not build all the devices a user may want to attach to the network. Interoperability is critically important for enabling new services and bringing existing services to new platforms over new networks (See Figure 3).

The use of open and widely adopted standards provides a platform for interoperability. The use of OCAP provides a common application environment on a nationwide footprint. Developer support resources enable an active development community. This all leads to the development of innovative new products and services. Here are a few:

Multi-room DVR, Personal Content, IPTV, Web Integration, etc.

Multi-room DVR is a key operator application. Recordings can be made on any DVR in the home and played back on any set-top in the home. A single DVR can serve the whole household. Multiple DVRs can be used in the home. The content from any DVR in the home can then be played back (with full trick mode) on any other OCHN networked TV or set-top box.

Personal content, such as photos or music, can be played back on OCHN devices. Depending on the particular implementation, OCHN can also be used as a client for web-based video or MSO-provided IPTV. OCHN is not just about connecting home devices together, it's about enabling new integrated services and providing those services to customers anywhere, anytime and on any device.

Implementation

OCHN 2.0 specifications have been publicly issued and are available on the CableLabs web site. Work continues on newer versions. The following sections summarize the capabilities offered by each version of the specifications.

OCHN 1.0

OCHN 1.0 is about accessing personal content. It provides the ability to play unprotected content on OCHN devices. The content may come from any UPnP Digital Media Server (DMS) on the network. Typically, it would discover these resources on a networked computer or dedicated UPnP DMS. OCHN 1.0 does not include QoS. So streams may break up or show artifacts if the network bandwidth is insufficient. Similarly, no provision is made for content security. This version of OCHN is not suitable for distribution of high-quality, high-value MSO content. For these reasons, MSO deployments will be based on OCHN 2.0.

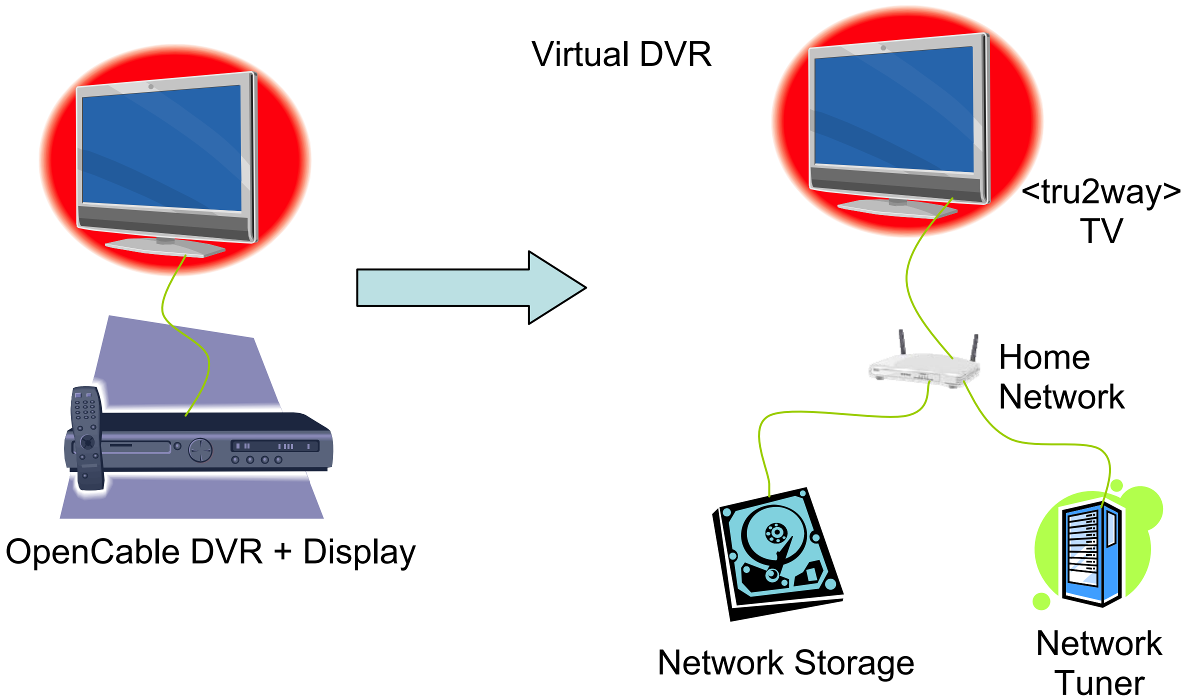

Figure 4. Network-based implementation of a digital video recorder.

OCHN 2.0

OCHN 2.0 adds support for delivery of high-quality, high-value MSO content. First, it defines Reserved Service Domain (RSD). This is based on UPnP QoS version 3.0 and supports parameterized QoS. RSD is optional in OCHN 2.0 but an MSO may choose to limit the release of some content based on support of RSD.

The second major addition in OCHN 2.0 is security. OCHN 2.0 security is based on DTCP-IP. This is a link-based security method that provides a secure path between DTCP-enabled devices. Content is secured during transmission, but there is no DTCP-based method for securing the content once it arrives. Also, since DTCP-IP is a link technology and not a digital rights system, it doesn't specify rules about how the content is presented or the terms of the presentation. For this reason, MSOs may elect to limit the type of content that can be distributed to DTCP devices, or may require additional levels of authentication and authorization. This is currently MSO-specific, but more comprehensive and standardized security systems will be defined in future versions of OCHN.

The other major addition to OCHN 2.0 is support for distributed resources. A framework has been defined to allow networked resources; such has hard drives, time-shift buffers, displays and tuners to be shared over the network. The primary motivation for this was to enable multi-room DVR functionality. Distributed networked resources in conjunction with QoS and network security, can be combined to enable connected and distributed applications. An OCAP-based television with no digital tuner or hard drive can implement a distributed DVR application and use the tuners and hard drives of networked set-top box to enable full DVR functionality from that television (See Figure 4). It is important to note that version 2.0 does not support remote tuning and delivery of a live video stream. The stream must first flow through a time-shift buffer or be played back from long-term storage. This is due to additional complexities associated with the delivery of real-time streams. Live tuning is added in OCHN 2.5.

OCHN 2.5

OCHN version 2.5 is nearing completion. As was mentioned in the previous section, live remote tuning is the major feature added in this version. Using a remote tuner for a live stream introduces increased complexity. Primarily, this is due to the fact that synchronicity between the rate of delivery and the rate of consumption must be tightly managed to prevent buffer underflow (which would result in an interruption of the stream) and buffer overflow (which would result in video artifacts). Additionally, the delivery of live features such as emergency alerts is being considered.

OCHN 2.5 extends to model of distributed resources by allowing remote tuning as an individually addressable resource. It enables new possibilities for home network architectures in which a bank of tuners could be shared across multiple devices. This might allow for less expensive client devices.

Beginning with OCHN 2.0 and extending to OCHN 2.5 operators can build creative architectures that reduce costs and increase functionality through centralized or distributed models. For example, a DVR can be a software application that runs on the television while the tuners and disk storage can be network resources. This can keep the cost of the television low and remove the need for a dedicated set-top at each television.

OCHN 3.0

Requirements are still being developed for OCHN 3.0. Since the requirements are not yet known not much can be said. However, it is anticipated that OCHN 3.0 will extend the original vision of home networking to enable new services, new devices, and new ways for customers to get the content they want, when and where they want it and on an increasingly diverse set of devices.

Strategy

The cable industry recognizes the speed at which technology is moving and in particular the speed at which new means for distributing and viewing video content is moving. In addition to the steps already taken in enabling cable devices to interoperate with other devices based on UPnP and DLNA, cable has taken a strategic step in making its common set-top development system (OCAP) a Java open-source project. This will allow a broad spectrum of developers to enhance the platform and expose significant developer talent to the possibilities of developing applications for cable television.

One of the most enticing opportunities for developers is creating applications that combine the power and scope of the Internet with the entertainment programming possibilities of cable television.

Conclusions

While the possibilities of connected computing devices has stimulated the imagination of engineers for the last few decades, the cable television networks have largely remained the development realm of the cable operators and their vendors. Now this domain is opening up. With CableHome, operators sought to manage consumer networks. With OpenCable Home Networking, this proposition has changed to offering and managing cable services on any network and any device. Alignment with open standards such as UPnP and DLNA allows for connections and interoperability between cable system devices and other consumer electronics. The opening of a common development environment across cable operators allows for a single development platform for cable and economies of scale for aspiring developers. The bridging of networks and the ubiquity of wireless data access reduces barriers imposed by time and location. This gives customers unprecedented abilities to view personal content, cable content and Internet content on any television in the home. Enhanced remote management capabilities allow customers to enjoy a simple but powerful user experience that retains the quality of digital cable experience. At the same time, cable operators can manage their delivery networks and set-top devices with enhanced capabilities and at a lower cost. While many barriers remain to be crossed, the ingredients are quickly becoming available that will enable an ecosystem to support the next generation of connected applications. The notion of consumers getting the applications and entertainment they want, when and where they want them and on any device is becoming a reality.