DELIVERING ECONOMICAL IP-VIDEO OVER DOCSIS BY BYPASSING THE M-CMTS WITH DIBA

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Abstract

DOCSIS IPTV Bypass Architecture (DIBA) DIBA refers to any of a number of techniques whereby downstream IPTV traffic is directly tunneled from an IPTV source to a downstream Edge QAM, "bypassing" a DOCSIS M-CMTS core. It will allow operators to deliver economic IP video traffic over DOCSIS infrastructure.

INTRODUCTION

MSOs are considering IP-video and IP Television (IPTV) to supplement their current digital video delivery. IP-based video enables new video sources (the Internet) and new video destinations (subscriber IPTV playback devices).

Of course, such a transition to IPTV requires significant additional downstream DOCSIS® bandwidth. In a reasonable 5-7 year "endgame" scenario, VOD is expected to require 26 times the bandwidth of High Speed Data (HSD). What's more, attempting such an increase in downstream bandwidth with a conventional Modular-CMTS (M-CMTS) will be expensive.

As an alternative, we propose that IP-video content travel directly to an Edge QAM, bypassing the M-CMTS core altogether and saving local switch and CMTS core capacity. This technique is called the DOCSIS IPTV Bypass Architecture (DIBA). DIBA refers to any of a number of techniques whereby downstream IPTV traffic is directly tunneled from an IPTV source to a downstream Edge QAM, "bypassing" a DOCSIS M-CMTS core. By bypassing the high-cost components of the CMTS core, DIBA is an architecture for delivery of high-bandwidth entertainment video over DOCSIS to the home for a price per program that matches the cost for conventional video over MPEG2 delivery to set-top-boxes.

DIBA is an innovative bypass architecture in which the conventional Modular-CMTS architecture is replaced by a hybrid architecture consisting of an integrated CMTS and DOCSIS External Physical Interface (DEPI) or MPEG Edge QAMs. This paper/presentation will demonstrate the effectiveness of DIBA, discuss how operators can evolve their infrastructure to implement DIBA, discuss alternative bypass encapsulation protocols to tunnel traffic to either DEPI or MPEG Edge QAMs, and outline the economic advantages of DIBA migration. It will explain how DIBA removes the boundaries of delivering video using a M-CMTS, and how operators can accelerate service velocity by efficiently delivering IPTV services that bypass M-CMTS platforms.

THE CHALLENGE OF DELIVERING IPTV

IP-video and IP Television (IPTV) create opportunities to supplement their current digital video delivery. IP-based video enables new video sources (the Internet) and new video destinations (subscriber IPTV playback devices). It should be considered as a delivery option of Video on Demand (VOD).

The extent to which VOD is delivered as IPTV governs the extent to which additional downstream DOCSIS bandwidth must be provided for IPTV. Consider a hypothetical 5-

7 year "endgame" scenario where each video subscriber can download "What I Want When I Want" (WIWWIW). Assume a fiber node of 750 homes passed has 75% video subscriber penetration, and during the busiest video viewing hour 50% of the video subscribers require an average of 10 Mbps VOD content. The total VOD content required to be delivered to that single fiber node during the busy hour is thus 750 * .75 * .50 * 10 Mbps = 2.8 Gbps, or 73 carriers of 6 MHz QAM 256. What fraction of this "endgame VOD" bandwidth is IPTV over DOCSIS and what fraction is traditional Digital Video to Digital Set-Top Boxes (DSTBs) is anybody's guess.

VOD bandwidth swamps High-Speed Data (HSD) bandwidth. Last year, most MSO deployments offered only 20 Mbps of HSD per 750-household fiber node. A reasonable endgame scenario for HSD would provide 100 Mbps channel bonded service to 50% of households passed with a 0.25% concurrency, for a total HSD fiber node throughput requirement of 750 * 0.5 * .0025 * 100 Mbps = 94 Mbps. Thus, under reasonable hypothetical endgame scenarios, VOD is expected to require 26 times the bandwidth of HSD.

A key goal of the DOCSIS Modular CMTS (M-CMTS) architecture was to define a common Edge QAM (EQAM) architecture that could support a cost-effective transition from Digital Video (DV) VOD delivery to IPTV VOD delivery over DOCSIS. A straightforward strategy of using M-CMTS to provide IPTV VOD would call for deploying M-CMTS EQAMs for DV-VOD first, and adding M-CMTS core capacity as needed to transition the DV-VOD to IPTV-VOD. As we have seen, though, the M-CMTS core capacity used for IPTV-VOD will quickly exceed the CMTS capacity used for HSD. A straightforward implementation of M-CMTS for IPTV, therefore, will require *many times* the cost of M-CMTS core capacity as that currently used for HSD.

AN INTRODUCTION TO DIBA

But there is a simple alternative for IPTV support with a M-CMTS: IPTV should be tunneled directly to the EQAM, bypassing the M-CMTS core altogether.

DIBA refers to any of a number of techniques whereby downstream IPTV traffic is directly tunneled from an IPTV source to a downstream EQAM, "bypassing" a DOCSIS M-CMTS core. By bypassing the high-cost components of the CMTS core, DIBA is an architecture for the delivery of high-bandwidth entertainment video over DOCSIS to the home for a price-per-program that matches the cost for conventional video over MPEG2 delivery to set-top-boxes. IPTV is by definition an IP packet with video content from an IP source to an IP destination address.

In traditional IPTV, an IPTV server sends an IP packet to the destination address of a subscriber playback device, which we call generically an "IP Set-Top Box" (IPSTB). With the M-CMTS architecture forwarding, the IPTV packet is routed through the M-CMTS core. In a conventional M-CMTS architecture without DIBA, therefore, the IPTV content is forced to make two transits through the Converged Interconnect Network (CIN) switch that connects regional networks with the core CMTS.

The video/IP traffic travels to the M-CMTS core, then "hairpins" back through the CIN on a DOCSIS External Physical Interface (DEPI) pseudo-wire to the DEPI EQAM. If-and-when IPTV becomes a significant fraction of overall bandwidth delivered to a fiber node, this hairpin forwarding of IPTV content will require significant expenditures by MSOs for M-CMTS core and CIN switching bandwidth.

In DIBA, rather than pass through the M-CMTS core, the high-bandwidth video/IP content is tunneled from the IPTV server, through the MSO's converged interconnect network directly to the DIBA EQAMs. The IPTV emerges from the DIBA EQAM with full DOCSIS framing, suitable for forwarding through a DOCSIS cable modem to home IP devices. This architecture will deliver high-bandwidth entertainment video/IP/DOCSIS to the home for a price-per-QAM that matches that of the most advanced, cost reduced MPEG2 EQAMs.

REDUCING DELIVERY COSTS

Operators can deploy independently scalable numbers of downstream channels without changing the MAC domain or the number of upstream DOCSIS channels. These downstream channels are available for VOD/IP and switched-digital-video/IP. They can also lower the cost to deliver video over DOCSIS service to be competitive with today's MPEG VOD. DIBA accomplishes the goals of the M-CMTS without the unnecessary expense of the M-CMTS. DIBA avoids the expense of the DOCSIS MAC domain technology for the video/IP traffic by using both synchronized and unsynchronized DOCSIS downstream channels. The synchronized channels pass through the integrated CMTS or the CMTS core and provide the many DOCSIS MAC functions, including:

- Conveying the DOCSIS timestamps
- Managing ranging to provide the proper time-base to the cable modem
- Instructing the cable modems when to transmit upstream
- Delivering other MAC layer messages for cable modem registration, maintenance, etc.

In contrast, the unsynchronized DOCSIS channels are generated by the EQAMs (including installed MPEG EQAMs) for the bypass traffic and omit these functions. With an integrated CMTS and no timestamps in the un-synchronized channels, the DOCSIS Timing Interface which is required in the M-CMTS architecture is not necessary in DIBA.

In DIBA, a DOCSIS 3.0 cable modem requires only one synchronized channel from the existing integrated CMTS to provide timing, control the upstream transmissions, and provide the other MAC functions. The DOCSIS 3.0 cable modem will receive video/IP on additional un-synchronized, inexpensive, DIBA-generated channels, which can even be bonded.

LEVERAGING EXISTING EQAMS

DIBA offers a variety of bypass encapsulations. Using a standard M-CMTS DEPI EQAM, two bypass encapsulations are possible, depending on the video server and MSO network. In either case, the server originates a Layer 2 Tunnel Protocol Version 3 (L2TPv3) tunnel to the DEPI EQAM. The tunnel payload can be:

- The DOCSIS Packet Streaming Protocol (PSP) in which the video/IP is encapsulated into DOCSIS MAC frames. This permits the EQAM to mix both IPTV traffic originated from the IPTV server with non-IPTV (e.g. HSD or VOIP) traffic originated from the M-CMTS core on the same DOCSIS downstream carrier.

- The DOCSIS MPEG Transport (D-MPT) layer which consists of an MPEG-2 Transport Stream of 188 byte packets. All DOCSIS frames, including packet-based frames and MAC management-based frames, are included within the one D-MPT flow. The EQAM searches the D-MPT payload for any DOCSIS SYNC messages and performs SYNC corrections. It then forwards the D-MPT packet to the RF interface. The intent of D-MPT mode is to allow MPEG packets to be received by the EQAM and forwarded directly to the RF interface without having to terminate and regenerate the MPEG framing. The only manipulation of the D-MPT payload is the SYNC correction.

A standard MPEG2-Transport Stream (MPEG2-TS) EQAM can also be used. Here the video server may transmit an IPTV PSP formatted data packet. A PSP/MPT converter, either attached to or embedded within the CIN networking device, then changes the format into an MPEG-2-TS that a conventional MPEG EQAM can process. An alternative is for the VOD server to directly generate IPTV/MPT formatted packets that the MPEG EQAM can process. In the case of non-synchronized DOCSIS channels, a non-DOCSIS Program ID (PID) is used because each D-MPT program would require a separate MPEG-2 PID. A required extension for sending multiple programs streams of D-MPT to the same downstream QAM channel would be for DOCSIS 3.0 cable modems to be programmed to accept D-MPT-formatted packets with other than the standard DOCSIS PID.

TUNNELING BROADCAST IPTV

There are several tunneling options that can be used. One of these is "Interception", in which SPTS/UDP/IP encapsulation is intercepted by a CIN multicast router and encapsulated into PSP tunnel. Another is PSP Tunnels directly from the video server to the DEPI EQAMs. For bonded IP multicast, a "DIBA Distributor" component co-located with a CIN IP multicast router distributes or "stripes" the IP packet to a pre-configured DOCSIS 3.0 Downstream Bonding Group. Switched broadcast IPTV multicast is sent without BPI encryption on non-synchronized downstream channels to DOCSIS 3.0 cable modem IPTV devices.

THE ROLE OF THE CONTROL PLANE

While there is no design yet for the DIBA control plane, there are several other control planes that must be considered in that design. The current MSO switched broadcast architecture is intended to save bandwidth for a moderate-sized optical node, and that feature will have to be retained in any DIBA implementation. The PacketCable Multimedia (PCMM) architecture is intended to provide QoS within a DOCSIS system, and that function will have to be retained. The M-CMTS architecture is intended to provide a scalable number of downstream DOCSIS channels managed by an edge resource manager, and this feature is an essential part of DIBA. IP Multimedia Subsystem (IMS)-based IP services will include entertainment video as well as personalized and on-demand video.

VOD AND SWITCHED BROADCAST

Many cable operators have existing VOD and switched digital video architectures. These two architectures have quite different purposes, but are similar in one major way to conventional digital broadcast video. In all cases the video is brought over the MSO network to the EQAMs as MPEG-2 SPTS/UDP/IP. The EQAM then strips off the UDP/IP encapsulation, multiplexes the material into multi-program MEPG-2 TSs that are transmitted over QAM carriers. The set-top boxes are able to demodulate the MPEG-2 TSs and decode the video. Since the set-tops cannot receive video over an IP stack, they must be instructed which QAM carrier frequency and which Program ID to demodulate. In the case of switched digital video, the objective is to make more video channels available than there is bandwidth for in a typical RF spectrum. All the available video content is carried as a collection of IP multicast sessions, in most cases with all content available within the hub. Only when a set-top within a fiber node requests a particular video title is that title carried to that node.

Statistically, some number of set-tops will be viewing each of the popular video broadcast titles. Other, less popular titles will likely be viewed by only one set-top at a time. Still other less popular titles will not be viewed at all. Thus, the limited bandwidth available to that node will accommodate a great many more available titles than could be carried simultaneously.

When the control plane receives a request from a set-top for a new title, it searches for an EQAM serving that node which has sufficient available bandwidth. This EQAM is instructed to issue an IGMPv3 join to that IP multicast session. In the case of VOD, the control plane must locate a server with the desired title. This server will then send the title as unicast MPEG2-TS/UDP/IP to an appropriate EQAM serving the set-top making the request. In the case of VOD, there can be thousands of available titles.

PACKETCABLE MULTIMEDIA

PacketCable Multimedia will be an important element of the control plane for DIBA. The objective of managing QoS for the myriad of services to be provided over the limited bandwidth of DOCSIS 1.0 and 2.0 networks led to the development of PCMM. PCMM uses such elements as the Application Server, Application Manager, Policy Server, and CMTS. These are all in the headend and under control of the MSO. PCMM is only available for IP-based services. There are several scenarios for the operation of PCMM for IPTV. In one, the client (video viewing) device does not itself support the QoS signaling mechanisms and relies on the Application Server as a proxy. The client sends a service request, and the Application Server sends a service request to the Application Manager. Upon receipt of this request, the Application Manager determines the QoS needs of the requested service and sends a Policy Request to the Policy Server. The Policy Server in turn validates the Policy Request against the MSO-defined policy rules and, if the decision is affirmative, sends a Policy Set message to the CMTS. The CMTS performs admission control on the requested QoS envelope (verifying that adequate resources are available to satisfy this request), installs the policy decision, and establishes the service flow(s) with the requested QoS level.

M-CMTS EDGE RESOURCE MANAGER

The M-CMTS architecture takes the PCMM architecture one step further in terms of granularity. Within the PCMM architecture, it is the CMTS that makes the admission control decision for new flows and assigns then to a suitable DOCSIS channel. In the M-CMTS, the core CMTS must in turn request QAM resources from the edge resource manager.

IP VIDEO AND IMS

There has been much work within the Internet community to use IMS to control video services over IP to offer roaming and two-way features. This has generally not been for entertainment video. However, the current aim of IMS has become the universal deployment of all IP-based services through both fixed and mobile networks, regardless of location. So it is possible that IMS will become a suitable vehicle for the deployment of entertainment video as well, particularly personalized and on-demand video.

This is an aggressive goal, but not an unreasonable one, given the history of and effort that has gone into IMS. IMS began as an effort by telecom carriers in the Third Generation Partnership Project (3GPP) to converge mobile services with VoIP and IP multimedia by using the Session Initiation Protocol (SIP). SIP is an IP-based peer-to-peer protocol used to establish and control two-way flows carrying voice, video, and gaming. The actual flows use Real-Time Protocol (RTP) and UDP/TCP. True to its heritage, non-IP devices such as analog telephones are supported through gateways.

Gradually the range of services and access technologies increased, resulting in a powerful Next Generation Networking (NGN) architecture. The access technologies include any IP/SIP-enabled devices, including phones, PDAs, computers over DSL, DOCSIS, 802.11, etc. The network control plane is built around a Call Server Control Function (CSCF) that comprises the following:

1. Proxy-CSCF, which is an initial control plane element to interact with an IMS device and acts as a proxy in the SIP processing. Beginning with registration, each IMS terminal is assigned to a Proxy-CSCF. The Proxy-CSCF authenticates the IMS device and establishes security. It also authorizes the IMS device to use network bandwidth, and may apply QoS policies to this use. It is in the path of all signaling.
2. Server-CSCF, which is a SIP server and binds the user IP address to its SIP address. It interfaces to the user database (the Home Subscriber Server or HSS) where user information is kept and sees all signaling messages. It also determines which of the application servers to route particular messages to.
3. Interrogating-CSCF is another SIP proxy, this one serving as the interface by which IMS messages from the outside world access the local network. The I-CSCF is able to inspect the user database to determine, for a particular IMS terminal, the correct Server-CSCF to forward signaling messages.

The network also has application servers that are linked to the control plane via the Server-CSCF. In the past, these applications have been call related, such as call-waiting, call-forwarding, conference calls, voicemail, etc. However, it is possible to have these services include such network-oriented tasks as resource management for VOD sessions.

There is an obvious advantage to using IMS and SIP to provide entertainment video services in that the control plane would naturally extend to any IP video sources in the Internet on the one hand, and to a multitude of fixed and wireless video playback devices on the other hand. The roaming ability and the device presence enable handoff between devices, a necessary component of seamless mobility. There are many issues to deal with in integrating the VOD and switched digital video control and data planes with IMS/SIP.

BROADCAST IPTV OVER DIBA

In the typical MSO approach to switched broadcast video, the set-tops are non-IP so it is the MPEG EQAM that joins the IP multicast group. The multicast group is then mapped to a particular QAM and PID, and it is this information that is forwarded to the set-top to enable it to receive the MEPG-2 video transport stream.

In fact, DOCSIS is not generally used to deliver broadcast entertainment video, since the bandwidth is too expensive. However, the intention of DIBA is to bring the cost of DOCSIS bandwidth low enough to make IPTV viable. With DIBA, the IP set-top will be able to join the IP multicast group. The switched broadcast control plane determines which programs are multicast to which fiber node, consistent with the IP set-tops receiving which programs.

BROADCAST IPTV TO DOCSIS 2.0 AND 3.0 MODEMS

Broadcast IPTV is possible with both DOCSIS 2.0 and 3.0 modems. In either case, the IP set-top box sends an IGMP join to an IP multicast session for a particular program. The DOCSIS 2.0 modem will have to use a synchronized DOCSIS downstream channel, while a DOCSIS 3.0 modem can receive on a Bonded Channel Set. It may or may not be necessary to change DOCSIS channels to change to a new IPTV 'channel'. However, any DOCSIS channel changing requires communication from the CMTS to the cable modem in the form of a Dynamic Channel Change (DOCSIS 2.0) or Dynamic Bonding Change (DOCSIS 3.0) to change a tuner of the cable modem to the new channel.

SUMMARY

Cable operators will be able to economically supply IPTV capacity of gigabits per fiber node by bypassing the M-CMTS core and tunneling IPTV directly to the M-CMTS EQAM. DIBA allows operators to avoid the cost of additional M-CMTS core capacity for IPTV. DIBA is proposed as a work item for CableLabs after DOCSIS 3.0 draft specifications. If it is approved, CableLabs would standardize:

- Data Plane operation from IPTV server to DIBA PSP/MPT Converter, DIBA Distributor, and DEPI/MPEQ EQAMs
- NGOD Session Manager control signalling to IPTV server
- CMTS control signaling to DIBA Distributor and PSP Converter functions in CIN
- CMTS control signaling to EQAM

DIBA will remove the boundaries of delivering video using a M-CMTS, and it will allow cable operators to leverage service velocity by efficiently delivering IPTV services that bypass the M-CMTS core.

ABOUT THE AUTHOR

Mike Patrick is a Data Networking Architect, Motorola Connected Home Solutions. In this role, He is responsible for the architecture of Motorola's Cable Modem Termination System products (CMTS). He is currently leading technical development of the DOCSIS® 3.0 feature set for Motorola's BSR 64000 CMTS/Edge Router.

Mike joined Motorola in 1994. Over the last 13 years, Patrick was a Data Networking System Engineer and was a major contributor to the Downstream Channel Bonding and IP Multicast features of DOCSIS 3.0. Mike was a major contributor to version 1.1 of the Data Over Cable System Interface Specification (DOCSIS), which standardized QoS operation for VoIP cable modems.

Before joining Motorola, Mike served in various engineering and management positions at Digital Equipment Corporation, General Computer Corporation, Cryptall Corporation, Ztel, and Texas Instruments. He has 14 U.S. patents granted to date.

Mike earned his bachelor's of science and master's of science, computer science degree from the Massachusetts Institute of Technology in 1980, as well as a Masters in the Management of Technology from MIT Sloan School in 1992. He can be reached at michael.patrick@motorola.com.