THE MODULAR CMTS ARCHITECTURE

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Abstract

The architecture working group of Next-Generation Network Architectures (NGNA) posed the question to the industry if a cable modem termination system (CMTS) architecture could be developed that could leverage edge quadrature amplitude modulation (QAM) devices that have been developed for the video-on-demand (VOD) environment. The author of this paper started working on this problem with a team of engineers in December 2003.

The resulting design was submitted to CableLabs in May 2004 and formally adopted by CableLabs in January 2005 as the baseline design for the Modular CMTS (M-CMTS) specification. The author of this paper is now serving as lead author for the Downstream External PHY Interface (DEPI) working group.

INTRODUCTION

A new architectural concept for building Data Over Cable Service Interface Specification (DOCSIS) CMTSs is underway at CableLabs. It is known as the Modular CMTS (M-CMTS). The concept is to extract the Physical Layer (PHY) out of the CMTS and locate it in a separate network element. That separate PHY network element would be an evolution of the edge QAM network element that has already been developed and deployed for the VOD market.

The motivation for this is several reasons. First, there is the promise of cheaper downstreams. The cost of a downstream on a traditional CMTS is ten to twenty times the cost of a downstream on an edge QAM device. This is mainly due to the fact that the CMTS downstreams come with four to eight upstreams attached to them. It is also due to the fact that the CMTS is a more complex piece of equipment, and the real estate inside the chassis is an expensive place to locate an RF power amplifier.

Another key motivation is to develop a CMTS architecture in which the number of upstream and downstream RF channels can be independently chosen and configured. Today, adding a second downstream to a DOCSIS group typically means that the operator also has to add an extra four to eight upstreams as well—something that is usually not very practical.

This flexibility which will allow CMTSs to increase their downstream bandwidth and lower the cost of the downstream, is required in order for CMTSs to more effectively compete with new high speed competitive services such as newer digital subscriber line (DSL) standards such as the 44 Mbps bonded family of asymmetric digital subscriber line (ADSL) standards—called "ADSL2"—or fiber to the home (FTTH).

Figure 1 on the next page shows a multiservice architecture where the edge QAM device is shared between a DOCSIS network and a VOD network.

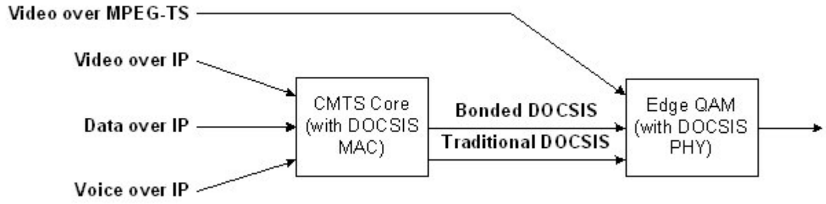

Figure 1: Multi-Service Architecture

The Edge QAM device manages two distinct types of traffic. The first is MPEG 2 (Moving Pictures Group 2) over MPEG-TS (MPEG Transport Stream) video traffic. The second is IP over DOCSIS over MPEG-TS traffic. Typically, an individual QAM channel is only carrying one of these types of traffic, although the edge QAM itself may have QAM channels that are part of either service.

The DOCSIS component provides the "triple play services" of data, voice over IP (VoIP) and video over IP. These services are combined in the CMTS core and transported to the edge QAM device typically over a switched Gigabit Ethernet network.

The data capacity of the DOCSIS downstream can be 40 to 50 Mbps for traditional DOCSIS channels with a 256 QAM downstream on a 6 or 8 MHz RF channel. The data capacity of the DOCSIS downstream can also be on the order of 200 Mbps to 1 Gbps, based upon a new emerging technology referred to in industry as "bonding" or the "wideband protocol for a DOCSIS network" [1].

This new bonding technology is the highest priority for the upcoming DOCSIS 3.0 working groups to address.

REFERENCE ARCHITECTURE

The reference architecture for a M-CMTS system is shown in Figure 2.This architecture contains several pieces of equipment, along with interfaces between those pieces of equipment. This section briefly introduces each device and interface. Subsequent sections will go into more detail.

The edge QAM device, or EQAM for short, has its origins in the VOD environment. It is a chassis that typically has one or more Gigabit Ethernets coming in and multiple QAM modulators and RF upconverters on the output. This EQAM is being adapted for use in a modular CMTS environment.

The outputs of these devices are often referenced as just a "QAM", rather than the full "QAM Modulator and RF Upconverter".

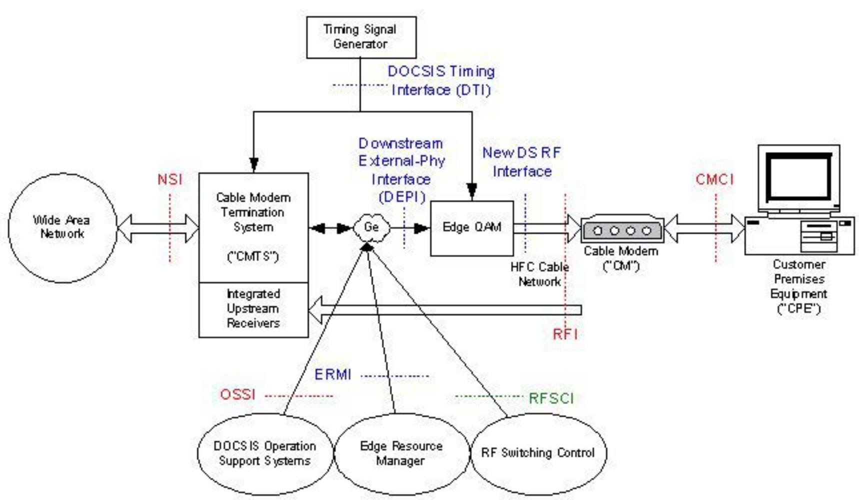

Figure 2: Modular CMTS Reference Architecture

It may be slang, but it has stuck. This paper will use the expression “QAM channel”.

The CMTS core contains everything a traditional CMTS does, except for the downstream PHY. Specifically, the CMTS core contains the downstream media access control (MAC) and all the initialization and operational DOCSIS related software.

Locating the MAC inside the CMTS core has several advantages. First, it permits the maximum reuse of existing DOCSIS software code bases. Second, it provides a local piece of hardware that can rate shape the aggregate flow of all packets to each QAM so that the output queues in the EQAM will not overflow.

This diagram currently shows the RF section of the DOCSIS upstreams internal to the CMTS core. This has been done because at this time, the Modular CMTS specifications only require the use of external downstream QAM channels, mainly because those QAM channels are leveraged off of existing equipment. External upstream QAM channels do not exist. However, there is nothing preventing an implementation of a Modular CMTS from using external QAM channels in the upstream.

The Timing Signal Generator provides a common frequency of 10.24 MHz and a DOCSIS timestamp to all MACs and PHYs.

The Downstream External PHY Interface (DEPI), is the interface between the CMTS core and the edge QAM. More specifically, it is an IP tunnel between the MAC and PHY in a Modular CMTS system which contains both a data path for DOCSIS frames and a control path for setting up, maintaining, and tearing down sessions.

If there was an external QAM burst demodulator device for the upstream direction, then extrapolation of the name DEPI to the upstream results in upstream external PHY interface, or UEPI. UEPI is not currently being defined in the CableLabs' committees, so its definition currently is proprietary.

Downstream Radio Frequency Interface (DRFI) is intended to capture all the current and future RF requirements for the downstream direction for both integrated DOCSIS CMTS systems, modular DOCSIS CMTS systems, and VOD EQAM systems. This is quite the undertaking!

One of the goals of DRFI is to be able to specify a simultaneous system with up to 119 digital carriers and the remainder; analog carriers. Another goal is to define a high density RF connector as it is getting too difficult to use the standard F connector on high density front panels. The specification is also looking at new modulation error rate (MER) and out-of-band (OOB) noise specifications.

DOCSIS Timing Interface (DTI) is an interesting interface. DTI is a point-to-point interface from the Timing Signal Generator to all MAC and PHY components. DTI has the concept of a DTI server and a DTI client. The DTI server is the Timing Signal Generator, while each MAC and PHY has a DTI client. The DTI client is light weight. The DTI server distributes a 10.24 MHz frequency over unshielded twisted pair (UTP) with a timestamp modulated on it. The DTI returns a copy of the timestamp. The DTI server can then measure the difference in the transmitted and received timestamps to measure the round trip delay to each element. It then adjusts the transmitted timestamp to each network element so that they will all have the same sense of time.

Edge Resource Manager Interface (ERMI) is an interface that permits integration with a next generation VoD network. ERMI is used to interface to a Resource Manager. This resource manager then allocates QAM resources to either VOD or DOCSIS applications. ERMI, however, does not directly manage within the DOCSIS QAM, so it is not a required interface on DOCSIS only systems.

Radio Frequency Switching Control Interface (RFSCI), is intended to manage an RF switch which would be used for redundancy. This would allow, for example, a bank of upstream or downstream “working” QAMs to be physically swapped out with a bank of “protect” QAMs in the event there was a failure in the “working” QAMs. This interface is not being defined as part of the first round of definitions at CableLabs.

Operations Support System Interface (OSSI) provides the management interface to each system component. One of the interesting tasks the OSSI system has to define is which DOCSIS device initializes the PHY level parameters of the QAMs such as modulation. Should the EQAM do this since it already has to do this for VOD QAMs? Should the CMTS core do this so that OSSI and CLI structures for the CMTS can be similar to what they are today? Whatever the decision, one device should get configured, and the other device should learn these values over DEPI.

The Network Side Interface (NSI) is unchanged from some nine years ago. It the physical interface the CMTS uses to connect to the backbone network. This is typically 100 Mbps or 1 Gbps Ethernet.

Cable Modem to Customer Premise Equipment Interface (CMCI) is also unchanged and is typically 100 Mbps Ethernet.

DEPI OPERATION

DEPI is an IP tunnel that exists between the DOCSI MAC in the CMTS core and the DOCSIS PHY that exists in the edge QAM. DEPI’s job is to take either formatted DOCSIS frames or MPEG packets and transport them through a Layer 2 or Layer 3 network unharmed.

The base protocol that DEPI has chosen is the Layer 2 Tunneling Protocol Version 3, or L2TPv3 for short [2]. L2TPv3 is an Internet Engineering Task Force (IETF) protocol that is a generic protocol for creating a “psuedowire”. A psuedowire is when a Layer 2 protocol is passed transparently over a Layer 3 network. Examples of protocols supported by L2TPv3 include asynchronous transfer mode (ATM), High-level Data Link Control (HDLC), Ethernet, Frame Relay, and Point to Point Protocol (PPP).

Figure 3 on the next page shows the format of an L2TPv3 packet. There is a bit called the “T” bit in the header of each packet to distinguish between data and control packets. There is also a 32 bit session ID. The UDP header is optional with L2TPv3, but is included to permit addressing of QAM channels with the UDP destination port.

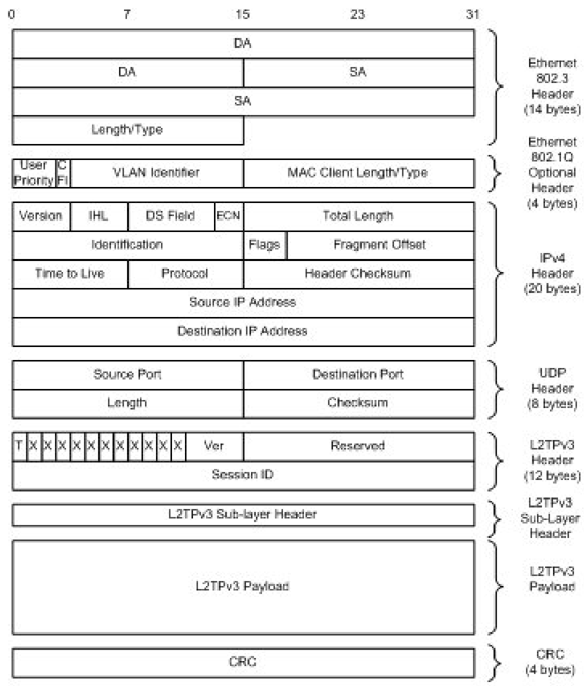

Figure 3: L2TPv3 Data Packet Format

L2TPv3 then permits a sub-header to exist whose definition is specific to the payload being carried. There is a specific sub-header for DOCSIS and MPEG-TS that currently are under definition.

The control channel allows for signaling messages to be sent back and forth between the MAC and PHY. Typical control messages will set up a "control connection" between the MAC and PHY, and then set up multiple sessions. Each session can have a different DiffServ Code Point (DSCP), and/or support a different encapsulation protocol.

There are two basic encapsulation techniques under consideration for DOCSIS. The first is a something called the Packet Streaming Protocol (PSP) and allows DOCSIS frames to be both concatenated to increase network performance, and fragmented, in case the tunneled packets exceed the network MTU size. This encapsulation is intended to carry traditional DOCSIS frames.

The second encapsulation is straight multiple: 188 byte MPEG-TS packets are placed into the L2TPv3 payload with a unique sub-header which contains a sequence number so packet drops can be detected. This encapsulation is intended to carry MPEG-TS based bonding or "traditional DOCSIS" where it is not necessary to send MAPs separately.

One of the technical considerations of the Modular CMTS architecture is its impact on the round trip REQ-GNT delay time. This is the time from when a CM launches an uncontended REQ to when it receives a MAP message with the GNT opportunity in it.

To prevent the MAP from being slowed down by data traffic, the MAP may be sent in an independent L2TPv3 session that has a unique DSCP. This DSCP will have a "per hop behavior (PHB)" that will give MAPs the highest priority and lowest latency service.

EDGE QAM OPERATION

Figure 4 shows a high level block diagram of an edge QAM that is capable of handling either video MPEG traffic or DOCSIS traffic. The expression "MPT"" is an acronym for MPEG Transport.

The next interface supported is DOCSIS MPT. This is similar to Transparent MPT except that edge QAM must search for DOCSIS SYNC messages and correct them based upon the edge QAMs internal timestamp which has been derived from DTI. This mode is intended for DOCSIS frames where the MAP is embedded into the stream and network latency is not a concern. This mode is seen as a transitionary mode which may be more of interest to early implementations.

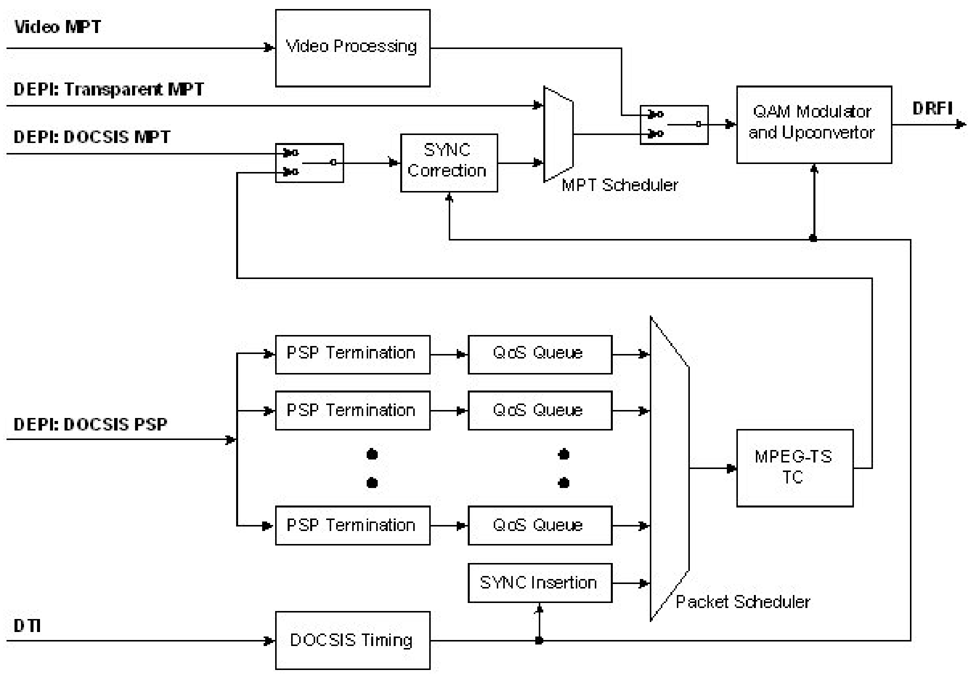

Figure 4: EQAM Block Diagram

The first interface that is shown is the VOD transport. VOD SPTS or MPTS streams are received with a format of MPT over UDP. The video processing functions generally include de-jittering, PID remapping, signaling insertion, and PCR timestamp correction. These functions are not defined in the current round of CableLabs specifications.

The next set of interfaces are the DEPI interfaces. The first one is called "Transparent MPT". This is a simple mode in where the incoming MPT frames are copied directly to the QAM channel without any interpretation or modification. This mode is intended for MPT based bonding algorithms such as described in [1].

The next interface is DOCSIS PSP. Here DOCSIS frames and MAPs are received on different sessions. The DOCSIS frames may have been "streamed together" by PSP into a uniform byte stream. The PSP reassembly engine removes this overhead and recovers the DOCSIS frames. The PSP scheduler then allows MAPs to be placed in order, ahead of data and SYNC messages to be inserted. The output is then fed to a transmission convergence layer which converts the results to a DOCSIS MPT stream.

The last interface is the DTI interface which provides a common frequency and timestamp. The reference frequency is used to synchronize the downstream baud rate for use with DOCSIS 2.0 Synchronous Code Division Multiple Access (SCDMA) cable modems. The timestamp is used for the DOCSIS SYNC correction.

SUMMARY

A new CMTS architecture called the Modular CMTS architecture has been described. This architecture has the DOCSIS MAC and PHY split into two network elements. This allows each network element to be optimized both for performance and cost.

This new Modular CMTS will also provide the foundation for an entirely new class of CMTS which will have much higher data capacities than anything out there today. These new machines will require multiple 1 gigabit or 10 gigabit backhauls rather than the 100 baseT backhauls in use with today's CMTSs.

REFERENCES

1. Chapman, John T., "*The Wideband Protocol for a DOCSIS Network*", Proceedings of the SCTE Emerging Technologies Conference, January 2005
2. Townsley, Mark et. al, RFC 3931, "*Layer Two Tunneling Protocol - Version 3 (L2TPv3)*", IETF, February 2005

ABOUT THE AUTHOR

John T. Chapman is currently a Distinguished Engineer and the Chief Architect for the Cable Business Unit at Cisco Systems in San Jose, California. As a founding member of the Cisco Cable BU, John has made significant contributions to Cisco and the cable industry through his pioneering work in DOCSIS and development of key technologies and concepts critical to the deployment of IP services over HFC plants.

Included in these achievements are being the primary author of significant portions of the DOCSIS and PacketCable specifications as well as the originator of DOCSIS Set-top Gateway (DSG) and evolving specifications for DOCSIS Wideband and Modular CMTS architectures for the industry's Next Generation Network Architecture (NGNA) initiative. John has also published a number of ground breaking whitepapers on Multimedia Traffic Engineering (MMTE), DSG, QoS, and high availability and is a respected and frequently requested speaker at industry events.

John has 18 patents issued and 27 patents pending in a variety of technologies including telephony, VoIP, wide area networking, and broadband access for HFC cable networks. In his spare time, John enjoys spending time with his wife and two daughters. John is a 6th Degree Black Belt Master in Tae Kwon Do and enjoys white water canoeing and skiing.

Previous papers by John may be found at http://www.johntchapman.com