APPLICATION BRIEF

Services and Applications Perspective

Synchronization Requirements for High-Performance Cable Networks

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Synchronization: Critical to Network Operation

Synchronization of time and frequency has always been crucial to cable networks since the development of data over cable service interface specification (DOCSIS), the first and still current cable-modem interface standard. Synchronization remains essential to cable networks for two reasons: first, because the physical-transmission medium, in this case coaxial cable, is shared by all cable modems on the network, basic connectivity is likely to cause high levels of transmission interference unless synchronization is precise. In fact, existing DOCSIS systems maintain five-nanosecond time-and-frequency accuracy within a given cable modem termination system (CMTS). Second, various new specifications for flexible CMTS architectures and new services like T1 or E1 circuit emulation require good synchronization in cable networks.

Traditional Cable Modem Termination System Architecture

The long-established CMTS was designed as a single unit to accelerate the development of the first data-over-cable network systems. Various technologies—internet protocol (IP) switching and routing, DOCSIS MAC (media access control), downstream quadrature amplitude modulation (QAM) and radio frequency (RF) upconversion as well as upstream QPSK/QAM demodulation—are all encased in one box.

As shown in Figure 1 below, every cable modem within a network connects to the CMTS. As a cable modem is turned on, it must first go through a ranging process to synchronize its frequency and timing to the CMTS. This process ensures that all cable modems sharing the coax/hybrid fiber coax (HFC) cable and the CMTS do not interfere with each other. In asynchronous time division multiple access (ATDMA) mode, each cable modem gets a specific timeslot to transmit, and all timeslots are aligned among hundreds of cable modems. In synchronous code division multiple access (SCDMA) mode, all cable modems within the network are perfectly aligned to transmit at the same time. Perfect alignment is mandatory to ensure that the CMTS correctly demultiplexes the bursts to determine the data transmitted from the various cable modems. In either mode, if cable modems are not synchronized, transmissions will be completely lost.

Next-Generation Architecture for Advanced Cable Services

Cable operators have made great strides to upgrade and converge their services onto a unified network architecture. The drivers behind this movement are clear—lower prices, higher bandwidth, flexible spectrum management and new services. Today broadband cable operators are in a fierce market battle to innovate their competitive service platform for future success. They are rapidly escalating current services to satisfy hungry consumer demand for high-speed, high-bandwidth networks, and are looking to build secure, fast and cost-effective, state-of-the-art network infrastructures to run these new applications.

CableLabs, the originator of DOCSIS, is accelerating the development of its next-generation platform, aimed at boosting cable modem network speeds much higher and supplying vastly greater bandwidth for other new digital services. The move is on to

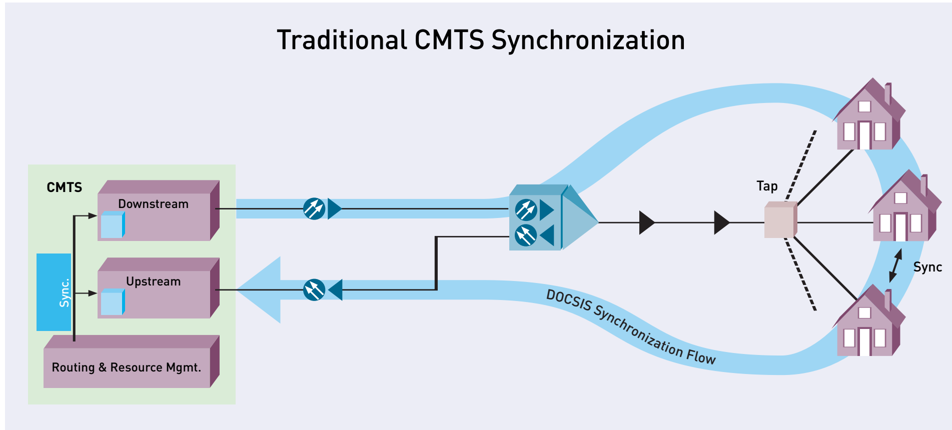

FIG. 1 Cable Modem Termination System Overview

break apart the all-in-one-box architecture of CMTS and craft an advanced DOCSIS platform to allow sharing of network components across multiple services while leveraging economies of scale. Two market dynamics are leading the push: the convergence of video-on-demand (VoD) and DOCSIS architectures; and the deployment of DOCSIS 3.0 residential and Commercial Services including T1 and E1 connections.

Independent scalability enabled by the M-CMTS architecture is crucial to DOCSIS 3.0 deployment.

This next platform, named modular CMTS (M-CMTS), converges DOCSIS and VoD networks. It is one of the latest initiatives to enable the development of a CMTS so different units can be implemented as separated physical entities. The aim of an M-CMTS is to allow sharing of the downstream transmission device, (quadrature amplitude modulation or Edge QAM) for video and data services as well as enabling independent scalability of downstream and upstream capacity.

The ability to scale independently is driven by Commercial Services and DOCSIS 3.0. DOCSIS 3.0 refers to a set of requirements that enhance services and performance capabilities in the DOCSIS network. The highest profile objective of DOCSIS 3.0 is channel bonding, channel bonding, where multiple downstream (or upstream) channels can be aggregated to offer greater bandwidth. With 100 Mpbs or greater burst rates to a single subscriber not only are data services enhanced, the ability to deliver high-definition VOD and other services becomes faster and more efficient. With the greater number of services and changing customer demographics the upstream and downstream bandwidth requirements will be differ from today's deployments and likely change over time. Independent scalability enabled by the M-CMTS architecture is crucial to DOCSIS 3.0 deployment.

Commercial Services, typically T1 or E1, present an $11.9 billion untapped market for cable operators. Unlike residential services, T1 or E1 are symmetric services offering dedicated 1.5 Mbit low delay service point-to-point for data/voice, public voice access or cellular backhaul. Since traditional CMTS cannot scale the upstream and downstream capacity independently and are not synchronized to the core network, Commercial Services historically have not been practical. M-CMTS solves both of these roadblocks.

M-CMTS breaks apart the three functional blocks of CMTS-core, downstream and upstream-so all can be shared by voice-and-data DOCSIS and VOD services. Given the massive downstream capacity and economics found in VoD transmission devices, such as Edge QAM, they will become the standard downstream device. The core and upstream functions from the traditional CMTS will be modularized for their given functions. In this new modular architecture several interfaces that existed on the CMTS backplane must now be distributed across several physically separate devices including management, Ethernet switching and synchronization. In addition, a new radio frequency (RF) specification is needed to blend the requirements of DOCSIS and video.

Why Synchronization?

The synchronization interface, named DOCSIS timing interface (DTI), ensures that the M-CMTS core, Edge QAM and upstream are synchronized to support the existing DOCSIS requirements for frequency and timestamps that existed in the traditional CMTS. In a M-CMTS architecture, shown in Figure 2 below, a cable modem receives its synchronization from the Edge QAM so that it is synchronized to other cable modems to properly transmit to the upstream burst receiver. Additionally, the M-CMTS core is synchronized to the Edge QAM to schedule, correct and insert MPEG timestamps for video.

In an M-CMTS topology a DOCSIS timing interface (DTI) server contains system intelligence; it also controls frequency and time for the head-end or distribution hub. Each M-CMTS device (Edge QAM, upstream burst receiver and M-CMTS core) contains

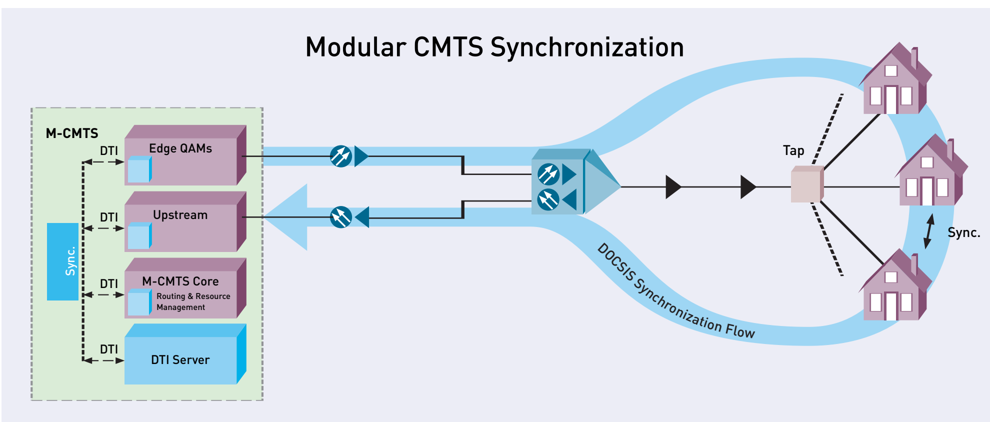

FIG. 2 2 M-CMTS System Flow

an integrated DTI Client required by the specification. The DTI Client is a low-cost digital transceiver of the DTI protocol consisting of a small FPGA, inexpensive oscillator and supporting circuitry. The DTI protocol generated at the DTI Server replicates the precise time and frequency at each DTI Client within two nanoseconds to support the existing ranging requirements. DTI has a robust feature set including automatic cable delay compensation, early fault detection, path traceability and all the DOCSIS 1.0/2.0/3.0 requirements. If desired, the application also enables time-of-day services, hitless protection switching, redundancy, enhanced management and Stratum 1 traceable Commercial Services timing. From a synchronization and timing perspective, the modular devices are on a common, virtual backplane, analogous to the integrated CMTS.

DTI lays a foundation for the existing and future network architectures to converge voice, data and video reliably and economically. The DTI Server is a shared element among the M-CMTS devices making it economical, however potentially a single point of failure. Deployment schemes for redundancy should include protection of power and the active server elements in the DTI Server. Moreover, path protection through dual links from the DTI Client embedded in the M-CMTS devices, to the DTI Server help guard against inadvertent physical disconnection. Dual links can also be configured to originate from redundant DTI Server output cards or redundant DTI Servers for carrier class applications.

Each M-CMTS device contains an integrated DTI client required by the specification.

Summary

Reliable and economic synchronization, provides cable operators the calculated edge in reducing operating costs while increasing network scalability and flexibility for advanced, next-generation services including DOCSIS 3.0 and Commercial Services.

Glossary of Terms and Acronyms

Term	Description
ADTMA	Asynchronous Time Division Multiple Access
Cable modem	A modem designed to operate over cable television lines
Cable head-end	A cable television company's local facility that originates and communicates cable modem and cable television services to its subscribers
CMTS	Cable Modem Termination System-a system of devices located in the cable head-end that allows cable television operators to offer high-speed Internet access to home computers
Coaxial	A type of wire that consists of a center wire surrounded by insulation and then a grounded shield of braided wire. The shield minimizes electrical and radio frequency interference.
DOCSIS	Developed by CableLabs and approved by the ITU in March 1998, Data Over Cable Service Interface Specification defines interface standards for cable modems and supporting equipment.
Downstream	A transmission from a server to an end user is referred to as downstream (see upstream)
DTI	DOCSIS Timing Interface. DOCSIS Timing Interface, CableLabs specification, http://www.cablemodem.com/specifications/m-cmts.html
E1	Similar to the North American T1, E1 is the European format for digital transmission. E1 carries signals at 2 Mbps (32 channels at 64Kbps, with 2 channels reserved for signaling and controlling), versus the T1, which carries signals at 1.544 Mbps (24 channels at 64Kbps).

Edge QAM	A head end or hub device that receives packets of digital video or data. It re-packetizes the video or data into an MPEG transport stream and digitally modulates the digital transport stream onto a downstream RF carrier using quadrature amplitude modulation (QAM).
FPGA	Field Programmable Gate Array-a semiconductor device used to process digital information, similar to a microprocessor. It utilizes gate array technology that can be reprogrammed after it is manufactured, rather than having its programming fixed during the manufacturing
HFC	Hybrid Fiber Coax-a way of delivering video, voice telephony, data and other interactive services over coaxial and fiber-optic cables
IP	Internet Protocol-specifies the format of packets and the addressing scheme
ISP	Internet Service Provider-a company that provides access to the Internet
M-CMTS	Modular Cable Termination System-CableLabs initiative defining the next-generation interfaces for distributed CMTS functions; also referred to as "distributed CMTS"
MAC	Media Access Control-one of two sub layers that make up the data link layer of the OSI model, responsible for moving data packets to and from one NIC to another across a shared channel
QAM	Quadrature Amplitude Modulation-a modulation technique that generates four bits out of one baud (e.g. a 600-baud line-600 shifts in the signal per second-can effectively transmit 2,400 bps using this method). Both phase and amplitude are shaped with each band, resulting in four possible patterns.
QPSK	Quadrature Phase Shift Keying-a digital frequency modulation technique used for sending data over coaxial cable networks.
RF	Radio Frequency-any frequency within the electromagnetic spectrum associated with radio wave propagation
SCDMA	Synchronous Code Division Multiple Access-any frequency within the electromagnetic spectrum associated with radio wave propagation
Upstream	A transmission from an end user to a server that can be in the form of a transmitted signal from a workstation to a server across a network or a signal from a customer to a cable service provider
VOD	Video on Demand-a wide set of technologies that enable individuals to select and stream video from a central server for viewing on a television or computer screen

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