WHITE PAPER

Planning an Effective Migration to DOCSIS® 3.0

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Introduction

The DOCSIS 3.0 initiative will allow cable operators to take advantage of the wideband capacity enabled by the initiative's cable bonding technology. Operators will be able to protect their investments in existing assets while deploying next-generation Cable Modem Termination System (CMTS) platforms based on modular or system-based architectures.

The primary challenges for operators in understanding how to use DOCSIS 3.0 are to understand the increased range of high-bandwidth service applications available to them and how they can provide Ultra-Broadband services at distinct time periods during the day to meet customers' unique individual needs. The possibilities are exciting, since cable operators can develop premium-priced, high-speed services that address the demands of multiple market segments, such as higher bandwidth available on nights and weekends to support online gaming for residential subscribers, or higher-speed throughput during business hours to support commercial customers. The first step for operators in addressing these challenges is to create use-case scenarios to leverage the full potential of DOCSIS 3.0.

The ability to design and deploy an end-to-end network that efficiently integrates DOCSIS 3.0 cable modems while allowing cable operators to continue to take advantage of deployed DOCSIS 1.x and 2.0 cable modems is key to developing a migration strategy that allows operators to cost-effectively migrate to DOCSIS 3.0 with minimal disruption while leveraging deployed network assets.

DOCSIS 3.0 is creating opportunities for cable operators to deliver increased bandwidth, enhance security, and efficiently offer voice, data, and video services. By aggressively migrating to DOCSIS 3.0 and deploying CMTS and cable modem solutions that leverage DOCSIS 3.0, cable operators can swiftly deliver over 145 Mbps to a single DOCSIS cable modem and over 200 Mbps to a single EuroDOCSIS cable modem. They can implement a "cap-and-grow" migration strategy that allows them to continue to leverage existing DOCSIS infrastructure while focusing investments in the delivery of Ultra-Broadband services.

This paper addresses the factors driving cable operators toward deployment of DOCSIS 3.0. A brief overview of the major new features in DOCSIS 3.0 are covered next. The importance of channel bonding and multicast services are introduced as well. The paper also explores the migration scenarios from existing networks to DOCSIS 3.0. Finally, the paper concludes with a summary and references.

DOCSIS 3.0 Deployment Drivers

The key drivers for DOCSIS 3.0 are competitive threats, migration planning, and premium services. Cable operators are coming under increasing pressure from competitors in the DSL space. Offerings such as Verizon FiOS are spurring leading-edge trials and investments in pre-DOCSIS 3.0. Several companies have announced aggressive plans to deploy DOCSIS 3.0 devices, as can be seen by recent press releases from Jupiter Communications and Videotron.

These are just a few examples where leadership in DOCSIS 3.0 is being demonstrated in rapidly developing competitive foreign markets. The following table compares the Verizon FiOS service with Videotron's current and planned DOCSIS 3.0 offering.

Tier/Feature	Videotron US Rate (Mb/s)	Videotron DS Rate (Mb/s)	Videotron Annual Cost ($)	Verizon FiOS US Rate (Mb/s)	Verizon FiOS DS Rate (Mb/s)	Verizon FiOS Annual Cost ($)
Basic Internet	0.128	0.600	26.95	N/A	N/A	N/A
High Speed	0.820	7	38.95	2	5	42.99
Extreme High Speed	0.900	10	48.95	2	15	52.00
Extreme Plus	1	20	79.95	15	15	64.99
Ultra 30	1	30	64.95	15	30	139.95
Ultra 50	1	50	79.95	Undisclosed	Undisclosed	Undisclosed

DOCSIS 3.0 provides the infrastructure necessary for cable operators to offer new services to their customers and compete effectively. However, if migration is not pursued by an aggressive deployment of DOCSIS 3.0 devices, then competitors will gain the advantage. For example, Verizon is already aggressively taking steps to deploy downstream services to the consumer at 100 Mbps.

Many cable operators are also facing migration pressures on their existing networks that DOCSIS 3.0 will help alleviate. For example, some operators are seeking to increase the bandwidth, both upstream (US) and downstream (DS), they deliver to the home, which DOCSIS 3.0 channel bonding can solve. Other cable operators are facing difficulties with the IP address space that is addressed by IPv6 in the DOCSIS 3.0 specifications. In addition, operators are seeking ways to offer tiered services and maintain a high level of quality service. All of these needs can be addressed by migration plans, depending on the cable operator's needs. The next section provides a brief overview of DOCSIS 3.0.

DOCSIS 3.0 Overview

DOCSIS 3.0 is a fourth-generation technology that provides high-speed Internet access to business and residential customers. DOCSIS 3.0 brings a core set of new features to the standard that will provide even higher throughput rates to an already fast and stable infrastructure.

Deployment of premium services requires key features that have been introduced in the DOCSIS 3.0 architecture. Two of the key features are:

- Channel Bonding
- Enhanced Multicast

Additional feature enhancements within DOCSIS 3.0 that address other issues with previous DOCSIS deployments are:

- IPv6
- Security Enhancements
- Network Management

Channel bonding and multicast services in DOCSIS 3.0 are key to deploying new, value-added services demanded by the growing markets. Used in conjunction, they provide a tremendous mechanism for offering audio, video, and data services to a large customer base while consuming minimal bandwidth. These services are defined as multicast streams, and devices are configured (either statically or dynamically) to receive and process the multicast streams to which they have been subscribed.

As technology advances, we find a myriad of devices now exist in the everyday consumer household. Devices from set-tops and gaming consoles for video services, PCs receiving data services, and even wired and wireless handheld devices for audio/video services are becoming more commonplace in the connected home. While multicast services provide the mechanism and the transport for these new services, there are still two potential issues that can impact the user experience — jitter/latency and Quality of Service (QoS). Voice and video services are greatly affected by any delays in transmission. These delays can be introduced on multiple layers, including the PHY layer and the MAC/application layers. Channel bonding is one way to address delays introduced by the PHY layer. This is accomplished by offering multiple paths (or channels) on which to transmit data. If too much data is scheduled for transmission at the same time, it can cause delays in the data being sent. At the MAC/application layer, time-sensitive traffic can be assigned a higher priority, thus guaranteeing faster delivery.

As mentioned above, households are beginning to accumulate more and more devices that are capable of accessing the Internet. The number of devices requiring an IP address has outgrown the number of IPv4 addresses that are available. Private address spaces and CIDR (super netting) have provided a short-term fix. The more permanent solution, IPv6, is now available and can offer a seemingly infinite number of IP addresses. To put this in perspective, the IPv6 address space could allocate 2.3x1018 addresses per square meter of the earth's land surface! DOCSIS 3.0 supports a mechanism that allows operators to transition their networks slowly over time to an IPv6 network. Devices are given the option to register using either IPv6 or IPv4, as well as fallback mechanisms in the event one particular mode fails.

Security is always a concern in a DOCSIS network. Early deployments of DOCSIS addressed more simple global issues such as theft of service, data intercept, and even the cloning of devices on a network. DOCSIS devices are required to authenticate themselves with the network, implement the encryption/decryption of data traffic, and validate firmware images before running them. The introduction of more widely used multicast services presents a slightly different possibility for theft of service, so along with the implementation of enhanced multicast services, DOCSIS 3.0 also provides the encryption of multicast traffic.

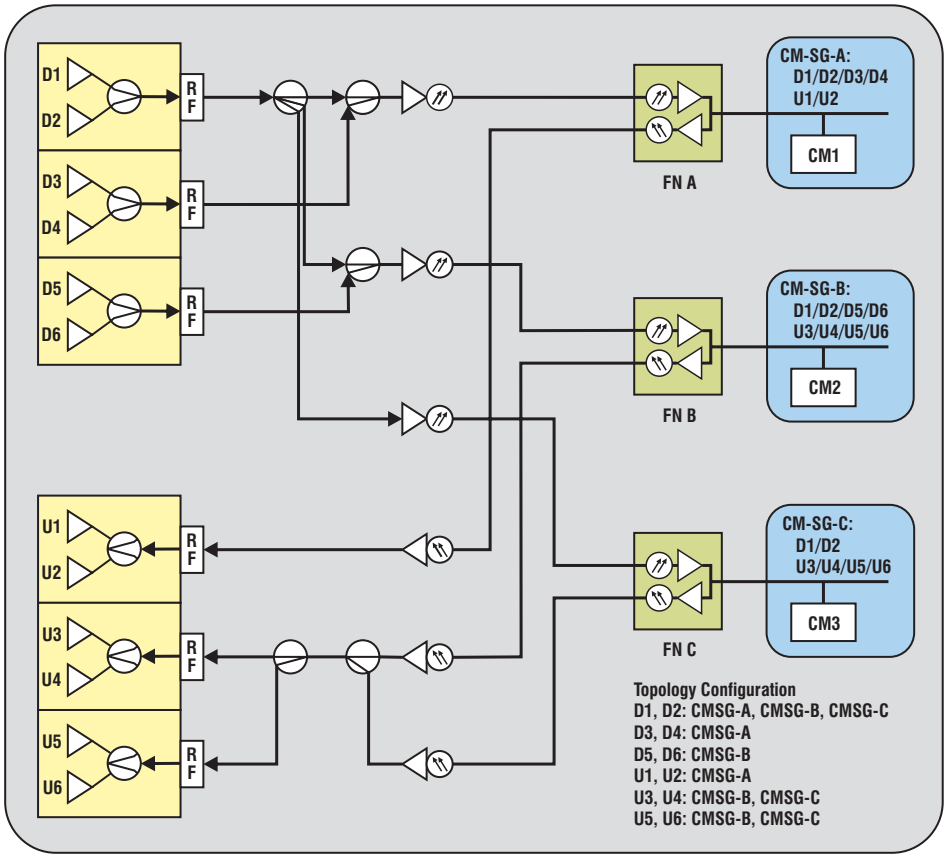
Channel Bonding

At the heart of DOCSIS 3.0 is the channel bonding architecture; channel bonding in the downstream and upstream allows speeds topping 170 Mbps in the downstream and 120 Mbps in the upstream direction. Channel bonding increases the throughput capabilities substantially and offers a competitive solution to the DSL/telco networks.

DOCSIS has not deviated from the model of using an MPEG transport for downstream data delivery and QAM transport for the upstream, and proves to be a stable mechanism even now in DOCSIS 3.0. The early versions of DOCSIS 1.0/1.1 provide, at most, 10 Mbps throughput on a single upstream. DOCSIS 2.0 tripled that capability by offering advanced TDMA channel configurations. With the introduction of channel bonding, DOCSIS 3.0 offers near symmetric data rates on the upstream and downstream. DOCSIS 3.0 specifies a minimum of four bonded channels for both the upstream and downstream. Four downstream bonded channels can achieve an overall PHY throughput of 170 Mbps, while four upstream bonded channels can achieve an overall PHY throughput of 120 Mbps. Voice and video applications are very time-critical traffic flows where latency and jitter can have a great impact on end user experience. Latency and jitter can be minimized with a bonded channel solution by allowing data to be sent on multiple channels, resulting in data being delivered more efficiently. Addressing jitter and latency issues, along with offering greater bandwidth, opens the door to the deployment of multicast services.

The implementation of channel bonding presents an interesting challenge for network operators in terms of defining their infrastructure. Cable operators have to be cognizant of the way their upstream and downstream channels have been distributed. DOCSIS 3.0 offers operators the flexibility to define any set of channels (both upstream and downstream) to be bonded in multiple groupings called Service Groups. A single, discrete downstream/upstream channel can be included in any number of service groups, assuming the physical connections have been established at the fiber nodes and muxes. The following diagram illustrates one example of how a set of downstream and upstream channels can be grouped and allocated to different sets of CM devices.

CM Service Groups



Enhanced Multicast

Support for multicast has become more important as DOCSIS has evolved. DOCSIS 1.0 provided minimal multicast support, and cable modems (CMs) simply forwarded all multicast traffic in the downstream direction (by default). DOCSIS 1.1 and 2.0 allowed clients to join specific multicast sessions and only forward those to which they are a member, but it was also constrained to IGMP-based multicast. Furthermore, there was no way to validate the source of the multicast stream to prevent denial of service (DoS) type attacks. DOCSIS 3.0 incorporates support for IGMPv3 and MLDv2, including support for source-specific multicast (SSM). More responsibility has been placed on the CMTS in dealing with multicast traffic, and the CMTS is more authoritative in terms of notifying the CM which multicast streams are processed by the device.

Cable operators can deliver multicast services to numerous customers and, in doing so, conserve a great deal of bandwidth. DOCSIS 3.0 offers an enhanced set of features that provide the foundation for offering these multicast services. DOCSIS 3.0 multicast functionality is compliant with IGMPv3 (RFC3376) and MLDv3 (RFC3810), which allows Source Specific Multicast (SSM) to be supported. With SSM, the source address of the multicast data stream is part of the criteria for determining membership, which provides an additional layer of security. Within the context of DOCSIS, the CMTS defines a DSID value for each multicast stream; this DSID value is used to define the multicast sessions to which a CM and the CPE attached to that CM are subscribed. DOCSIS 3.0 has put a great deal more responsibility on the CMTS (when managing multicast traffic) and those clients that are joined to the multicast session. While a CM/CPE will still issue a "join" or "leave" message in the traditional multicast definition, the CMTS will be the authoritative entity that specifies those multicast sessions. Furthermore, it defines those specific interfaces on the CPE side to which each multicast session is to be forwarded. Interoperability is ensured by still requiring that IGMPv2 be supported for pre-DOCSIS 3.0 multicast operation.

DOCSIS 3.0 Multicast also incorporates a QoS mechanism, which can be crucial in dealing with the different types of multicast streams/data that can be transmitted in today's networks. DOCSIS 3.0 allows the configuration of a static multicast session using TLV parameters specified in the configuration file via Group Classifier Rules and Group Service Flows; these are defined using the same parameters as standard Classifiers and Service Flows. The CMTS uses these rules to define a level of QoS for the multicast data flow and manages it appropriately based on the devices that are eligible/joined to the multicast session.

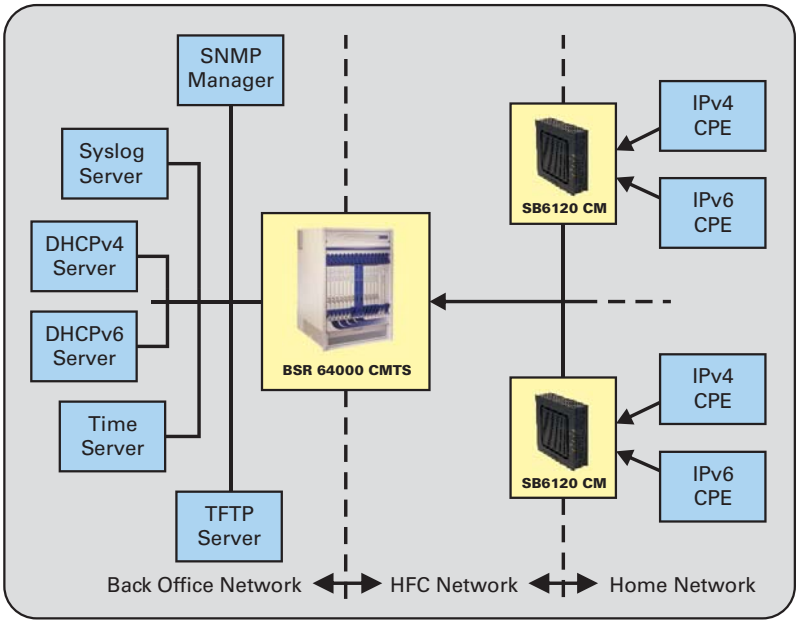
Interoperability can present a bit of a problem for multicast traffic when dealing with a mix of DOCSIS devices on the network. With channel bonding and the ability to support a multicast stream that has been spread over multiple channels in a bonded set, it may not be possible for a pre-DOCSIS 3.0 device to receive that same, exact stream. For this reason, it may be necessary for the CMTS to actually replicate the multicast stream on

multiple downstream channels. The CMTS assigns a DSID to each of the multicast streams, and then directs each CM to only listen to specific DSIDs as a way to manage replicated streams and not to 'confuse' the CM devices. The DSID mechanism was introduced in DOCSIS 3.0, so additional tagging is done to ensure that pre-DOCSIS 3.0 devices don't forward partial multicast data streams that may exist on a downstream channel.

The deployment of video services, and more specifically video on demand (VOD), are dependent on Multicast services being available on the network; the introduction of channel bonding coupled with multicast QoS provides a strong foundation for offering high-quality video services to customers.

IPv6

IPv6 will future-proof the DOCSIS infrastructure and resolve a problem that has begun to impact cable operators' deployments for two reasons: depletion of IPv4 address space and shortcomings surrounding the presence of NAT devices. In recent years, a number of services have been deployed that can create problems when providing data to devices located on a private sub-network within the home and are typically only accessible via Network Address Translation (NAT). IPv6 presents one of the more complicated challenges for DOCSIS 3.0 deployment; however, DOCSIS 3.0 has implemented a common approach to negotiate this support and take advantage of it where possible. DOCSIS 3.0 specifies a "fallback" mechanism where a device is first provisioned to obtain an IPv6 address, and then can revert back to obtaining an IPv4 address if no IPv6 DHCP server is available, or there are problems. Migrating a network to an IPv6 infrastructure is a concern that is independent of DOCSIS; however, the DOCSIS components make it possible to operate in a mixed mode to ease the burden of migration.



The above diagram illustrates a typical back office network configuration capable of supporting both IPv4 and IPv6.

Security

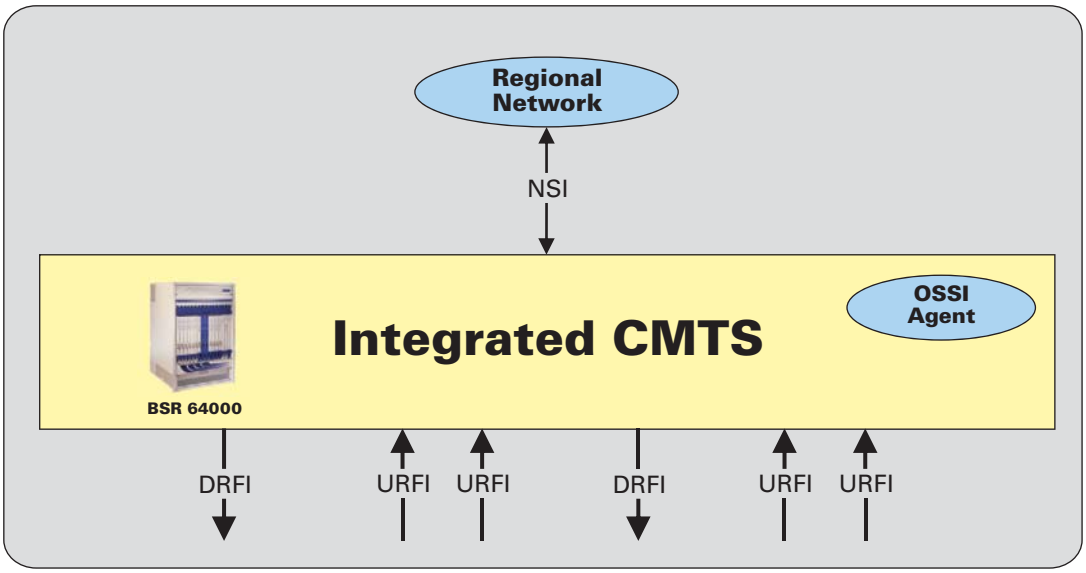
Security has been enhanced in the DOCSIS 3.0 architecture with some minor features. The cable operator can now configure devices to perform Early Authentication and Encryption (EAE), which requires them to authenticate and establish an encrypted channel with the CMTS very early in the registration process. Additionally, with advancements in technology, encryption keys are having to grow larger and larger to combat the ease with which brute force attacks can break down a system's encryption. AES 128-bit encryption is a much more secure encryption method now required within DOCSIS 3.0.

Network Management

DOCSIS 3.0 has added a new method of performing network management of devices called IP Data Record/ Streaming Protocol (IPDR/SP). It is based on an XML-type mechanism that will allow operators to gather more information in a much more efficient manner. The standard SNMP mechanisms are still available; however, operators are requiring more efficient feedback and monitoring mechanisms to allow them to be more proactive in discovering potential problems in their networking, as well as more comprehensive in their troubleshooting. SNMP requires substantial overhead in both management and bandwidth. IPDR/SP allows an operator to manage a large group of devices and receive information in a much more efficient manner with substantially less overhead and a more standardized set of tools. Furthermore, IPDR/SP offloads a number of operations from the CMTS and places them on another device, which can be critical given all the additional responsibilities the CMTS has with channel bonding and multicasting operations.

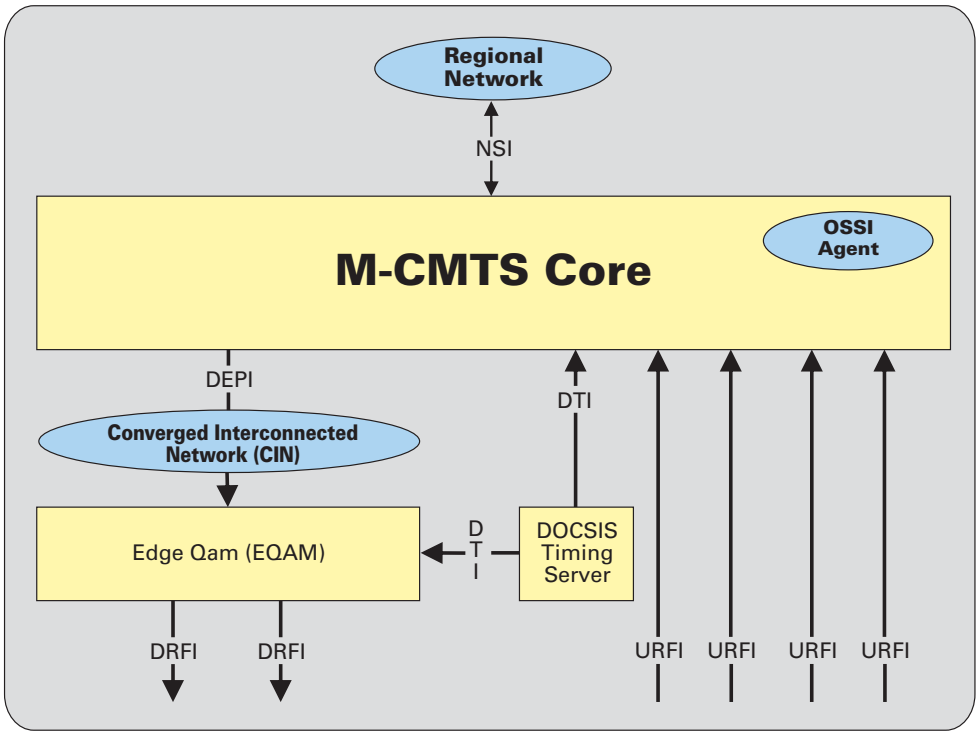
DOCSIS 3.0 Migration

DOCSIS 3.0 is specifically designed with interoperability in mind, so migration to a DOCSIS 3.0 network is not difficult to accomplish. When deploying DOCSIS 3.0 in their network, cable operators can choose either a more simple DOCSIS 3.0 transition, which would involve a simple CMTS "upgrade" to DOCSIS 3.0 (otherwise known as an integrated CMTS, or I-CMTS), or they can implement a more complex upgrade to a modular-CMTS (or M-CMTS), with additional components. The following is a logical diagram of an I-CMTS architecture:



The I-CMTS is a single component/device that manages all aspects of the DOCSIS CMTS specification. Both the upstream and downstream channels are integrated into a single chassis.

The M-CMTS architecture is illustrated below:



The M-CMTS breaks out the functionality into multiple components and provides an architecture that can more easily be expanded in the future. The upstream functionality is still contained within the M-CMTS core device, while the downstream functionality and processing is moved to E-QAM devices. The advantages of the M-CMTS architecture are realized over time as a cable operator's network grows and begins to integrate more services. An M-CMTS deployment will save money in the long run by allowing cable operators to purchase less costly equipment to expand their networks; an M-CMTS core can support multiple E-QAM devices.

A DOCSIS 3.0 CMTS will support any DOCSIS devices, but may result in sacrificing some features and some overall bandwidth as a result of operating in a "mixed" network. The optimal network configuration would obviously be a DOCSIS 3.0 CMTS with strictly DOCSIS 3.0 CMs operating on it, however, it is possible to deploy a DOCSIS 3.0 CMTS with DOCSIS 2.0 and even 1.1 CMs on the network. The channel bonding architecture has been designed in such a way that pre-DOCSIS 3.0 devices can still be provisioned using the same channels that DOCSIS 3.0 devices will use for bonding. This increases the complexity of the system and requires careful network engineering when designing the infrastructure.

Migration to DOCSIS 3.0 can be accomplished by evaluating the key components and addressing the most pressing needs in the operator network in order to deploy devices and compete effectively. A cable operator's infrastructure doesn't require much modification to incorporate DOCSIS 3.0 into their network, although it will require the purchase of new equipment, since DOCSIS 3.0 is not a firmware upgrade.

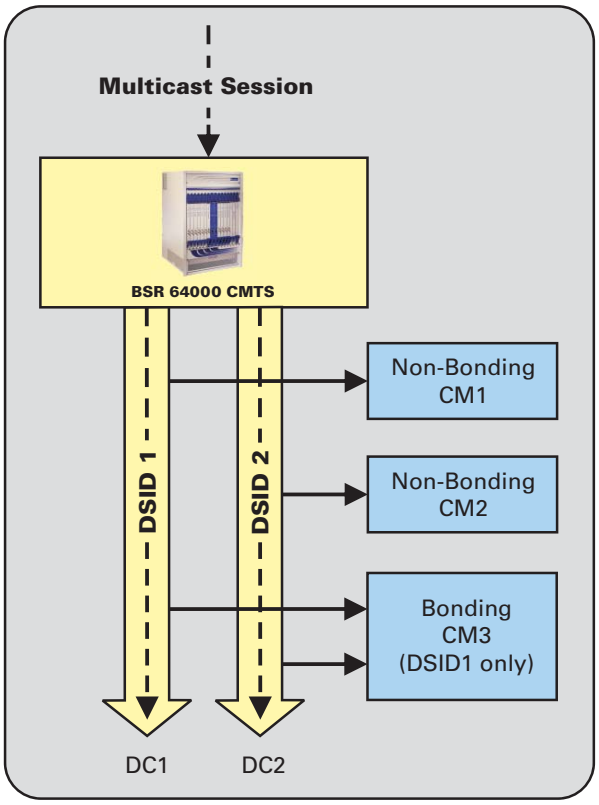
The following subsections discuss some of the more important issues and limitations that cable operators should be aware of when creating a transition plan to DOCSIS 3.0.

Spectrum

DOCSIS 3.0 made some changes to the frequency spectrum that can be supported for the upstream range. Previous versions of DOCSIS supported an upstream frequency range of 5 MHz to 42 MHz and a downstream frequency range from 88 MHz to 860 MHz. DOCSIS 3.0 increases the upstream frequency range to 85 MHz and the downstream to 1008 MHz. There are some potential interoperability issues with overlap and harmonics of the upstream/downstream in the 42 MHz to 88 MHz range, so caution must be taken when defining the spectrum in which a network operates. It is entirely possible to deploy DOCSIS 3.0 in its own spectrum and simply provision DOCSIS 3.0 customers accordingly.

Multicast Replication

DOCSIS 3.0 introduced a new method for managing multicast data streams and the provisioning of multicast for DOCSIS 3.0 devices. DOCSIS devices that co-exist on the same network are not able to process multicast streams in the same manner. As a result, the CMTS may be required to replicate a multicast stream if both DOCSIS 3.0 and pre-DOCSIS 3.0 devices are to receive the same multicast stream. The issue can be best described using the following diagram:



In this example, the CMTS is required to replicate the stream because there are both DOCSIS 3.0 and pre-DOCSIS 3.0 devices on the network that require the multicast stream. It is also possible in a mixed network for a multicast stream to be split over multiple downstream channels for bonding-capable modems, and then replicated on a single downstream for non-bonding capable modems.

IPv6
IPv6 introduces a migration issue even outside the scope of DOCSIS and has to be dealt with in a much more global manner. DOCSIS has provided "dual mode" support for both IPv6 and IPv4 and allows devices to be provisioned in either mode. That also means that a DOCSIS CMTS can pass both IPv6 and IPv4 traffic.

Network Management
DOCSIS 3.0 still supports the SNMP architecture for network management, so there aren't any immediate migration issues here. However, if network operators want to take advantage of the new features and functionality that have been introduced with IPDR/SP, they will need to support additional components and mechanisms.

Summary

DOCSIS 3.0 provides tremendous opportunities for cable operators to increase Average Revenue Per User (ARPU) by delivering innovative, high-performance services. DOCSIS 3.0 is creating opportunities for cable operators to deliver increased bandwidth, enhance security, and efficiently offer voice, data, and video services. By aggressively migrating to DOCSIS 3.0 and deploying CMTS and cable modem solutions that leverage DOCSIS 3.0, cable operators can swiftly deliver over 145 Mbps to a single DOCSIS cable modem and over 200 Mbps to a single EuroDOCSIS cable modem. They can implement a "cap-and-grow" migration strategy that allows them to continue to leverage existing DOCSIS infrastructure while focusing investments in the delivery of Ultra-Broadband services.

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These materials were first presented at SCTE's Cable-Tec Expo® 2008 in Philadelphia, Pennsylvania.

MOTOROLA

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