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DOCSIS 1.0 / 1.1 / 2.0 / 3.0 migration and planning management

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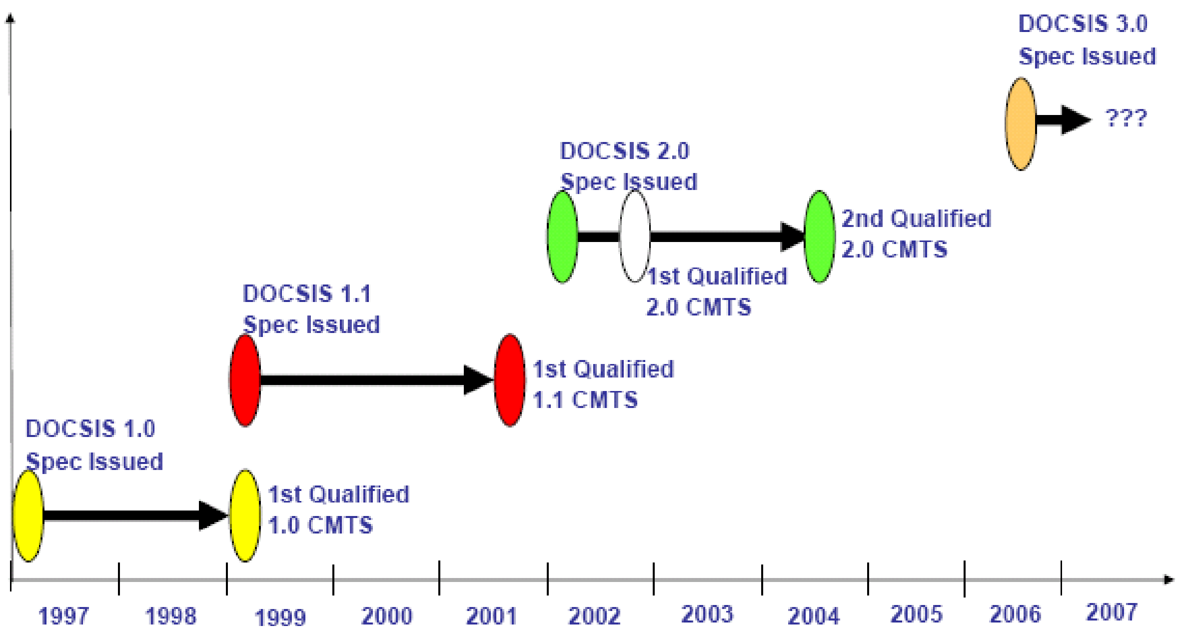
Introduction

Since the inception of the DOCSIS standard there have been two major specification transitions. The first was from DOCSIS 1.0 to DOCSIS 1.1. The second was from DOCSIS 1.1 to DOCSIS 2.0. Each MSO has transitioned to the newer specification of DOCSIS weighing the rewards of the business case versus the risks encountered during the transition. With DOCSIS 3.0 product expected in 2007/2008, soon MSO's will need to make another major DOCSIS transition. A timeline of DOCSIS specification issuance relative to CMTS qualification is displayed below.



Each new DOCSIS specification comes with numerous enhancements. Below is a table which summarizes the enhancements brought about with each DOCSIS specification transition.

DOCSIS specification transitions	Enhancements
DOCSIS 1.0 to DOCSIS 1.1	Upstream quality of service, concatenation, fragmentation, pre-equalization
DOCSIS 1.1 to DOCSIS 2.0	Upstream bandwidth enhancements (noise mitigation and spectral bandwidth efficiencies)
DOCSIS 2.0 to DOCSIS 3.0	Channel bonding (upstream and downstream), IPv6, multicast QoS enhancements, many others…

Before deciding to migrate to a new version of the DOCSIS specification each MSO will analyze product offering business cases which align with the specification. If the benefits outweigh the risk and the return on investment is sufficient… let the transition begin. A migration to the next version of DOCSIS specification comes with definite rewards but the process of achieving those desired enhancement can be challenging.

The best way to plan for future migrations is to analyze the current state of your DOCSIS network and the support systems which utilize it. It is also important to re-examine prior experiences from previous migration to guarantee those issues to do occur again. The major areas in the DOCSIS network which need to be examined include configuration management / provisioning, impacts on the hybrid fiber coax (HFC) network, the upgradeability of existing equipment and the collection of data from DOCSIS devices.

Configuration management

Configuration management systems of a DOCSIS network are important to analyze during a DOCSIS transition for many reasons. For the purposes of this paper, configuration management systems are those systems which create and distribute cable modem, embedded MTA and set-top box configuration files as well as the systems which create and maintain the running configurations for the cable modem termination systems (CMTS). During DOCSIS transition the configuration management systems will be the mechanism through which all needed configuration changes are executed and maintained. The flexibility and scalability of the configuration management systems may be tested given the volume and type of new devices coming onto the network during and after the transition. Different DOCSIS transitions will require different amounts of work with respect to the configuration management systems. The examples below highlight some of the possible issues encountered when transitioning between DOCSIS specifications with respect to the configuration management systems.

DOCSIS 1.0 versus DOCSIS 1.1 QoS and its impact on the cable modem configuration file

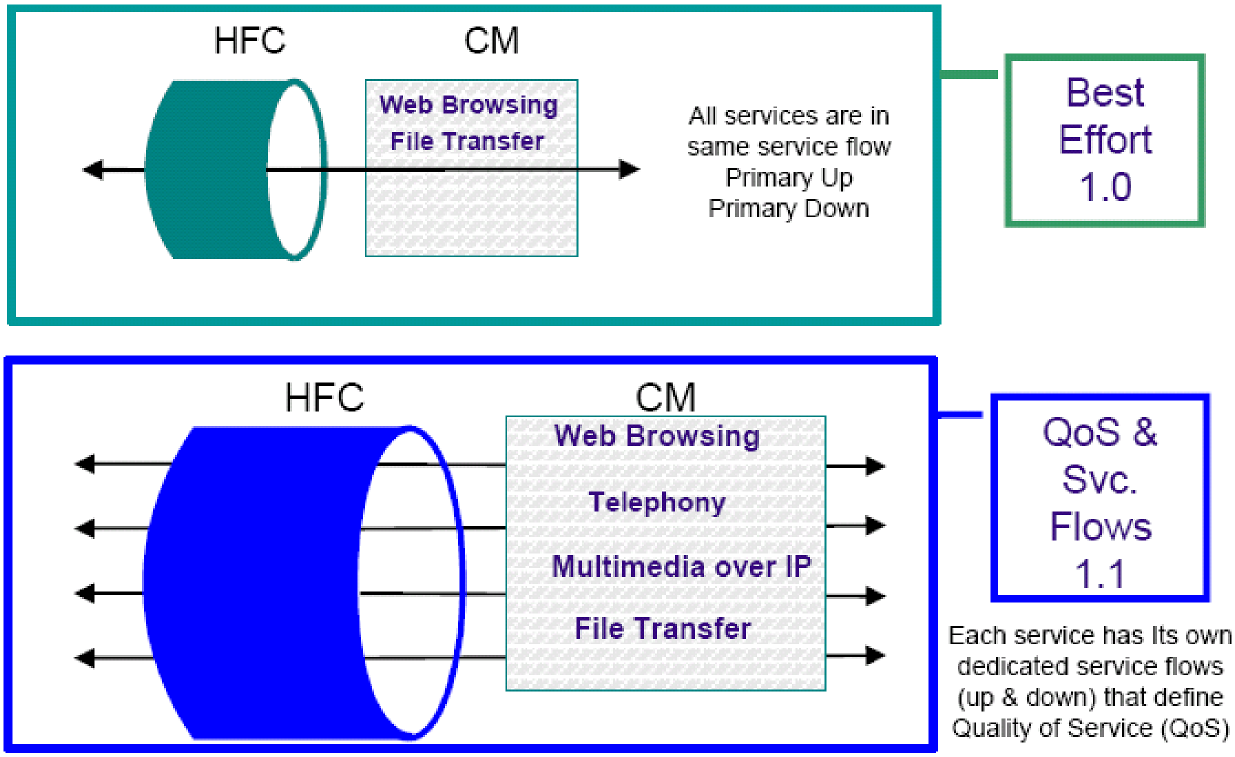
First let's examine a DOCSIS 1.0 cable modem configuration file

```
NetworkAccess true
ClassOfService
        ClassId 1
        MaxDownstreamRate 5000000
        MaxUpstreamRate   512000
        UpstreamChannelPriority 1
        PrivacyEnable false
MaxCpeAllowed 1
```

This cable modem configuration file specifies the downstream and upstream maximum speeds, the upstream channel priority, the ability to enable or disable baseline privacy, the ability to enable or disable network access and the maximum number of customer premise equipment devices which can attach to this device. This configuration was initially sufficient to offer many DOCSIS services, but when expanding past those initial services more configuration of quality of service (QoS) was need.

With the transition to DOCSIS 1.1, the cable modem configuration file undergoes a radical transformation. DOCSIS 1.1 enables the concept of service flow identifiers and their ability to correlate classified downstream and upstream traffic streams to a specific quality of service

(QoS). With this addition to the DOCSIS specification during a transition it enables the MSO to offer a wide array of multi-media services, most notably voice over IP (VoIP).



Another important addition in the DOCSIS 1.1 specification is the ability introduce a layer of abstraction between the amount of data which much be placed in each individual cable modem configuration file and instead have most of that service flow related data in the configuration CMTS. In a DOCSIS network, a chassis based modem termination system can support tens of thousands of DOCSIS devices. By pushing much of this service flow related data up to the CMTS from the cable modem configuration file, it allowed the configuration management of DOCSIS devices to be greatly simplified. By utilizing the ability to place much of the service flow data (example: transmission rate, priority, type of service overwrites, jitter and latency tolerances) in the CMTS, it is possible to simplify a DOCSIS 1.1 configuration file when compared to DOCSIS 1.0. This is true even though the addition of the service flow identifiers has the potential to make the cable modem configuration files much more complicated.

Once the transition to DOCSIS 1.1 has been ‘achieved’, there will be many remaining DOCSIS 1.0 devices on the network. Depending on the CMTS vendor, it maybe possible to allow many of those DOCSIS 1.0 modems to take advantage of service flow like characteristics via manipulation of the ClassId value in the DOCSIS 1.0 cable modem configuration file. This is accomplished by setting the class of service ID (ClassId) in the cable modem configuration file and having that correlate to certain DOCSIS 1.1 service flow characteristics configured in the CMTS running configuration. Taking advantage of this additional feature can enhance the customer experience while maintaining the same level of simplicity in the original DOCSIS 1.0 configuration file.

DOCSIS 1.X1/2.0 to DOCSIS 3.0 CMTS MAC domain deployments

Since the inception of the DOCSIS specification the vast majority of MAC Domains have been deployed with one downstream and multiple up streams. There are many instances where MAC domain properties have been correlated directly to a downstream, because their relationship was normally one-to-one. However in the transition to DOCSIS 3.0 and its ability to perform channel bonding (in the downstream and upstream direction), this one-to-one relationship is no longer valid.

The change in the deployment/definition of a MAC domain is going to impact many areas in the transition to DOCSIS 3.0. The areas which this will impact most include:

- Data collection and interpretation when performing downstream and upstream channel bonding
- Possible CLI changes needed to decouple the previous MAC domain/downstream one-to-one relationship
- Necessary re-cabling in the head end, especially if upstream and/or downstream load balancing is not already in use.

Hybrid-fiber coax (HFC) concerns

The transition to the new DOCSIS specification is not always about new hardware and software on the devices in the head end and the customer's home. In many instances it is about examining and improving the performance of the hybrid fiber coax (HFC) network which connects them. The examples below look at instances where HFC concerns had to be addressed before fully utilizing the feature set available in the transition to the next DOCSIS specification.

DOCSIS 2.0 and the need for a cleaner upstream

DOCSIS 2.0 provided the ability to increase upstream bandwidth efficiencies and an additional set of tools to mitigate noise in the upstream (increased FEC, advanced upstream interleaving (ATDMA) and SCDMA). In order to achieve these upstream bandwidth efficiencies, the cable plant operator must improve the upstream signal to noise ratio on the interfaces which will utilize the DOCSIS 2.0 channel types and high order modulation profiles. These improvements maybe achieved by the following:

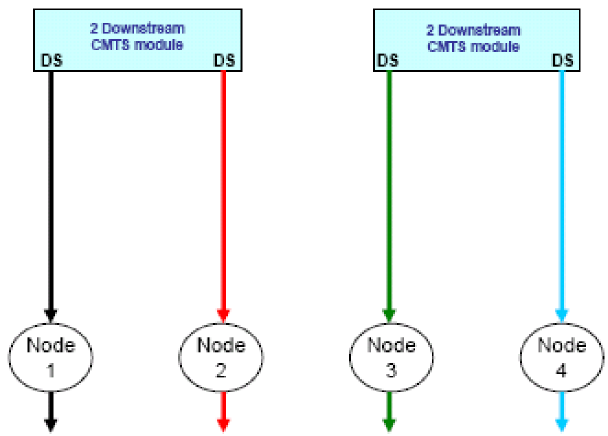
- Utilizing the noise mitigation toolset offered with the additional DOCSIS 2.0 channel types and modulation profile parameters (increased FEC, advanced upstream interleaving (ATDMA) and SCDMA).
- Taking advantage of upstream burst receiver chipset enhancements such as ingress cancellation which will improve upstream signal to noise ratios for all DOCSIS devices
- Directing DOCSIS devices register on a DOCSIS 1.X or a DOCSIS 2.0 MAC domain. This segregation of devices will enable plant improvements to isolated interfaces and not force them plant wide. This may seem extreme initially but this multiple MAC domain deployment can also be exploited to address future capacity concerns by utilizing

upstream and downstream load balancing and upstream and downstream channel bonding when they become available.

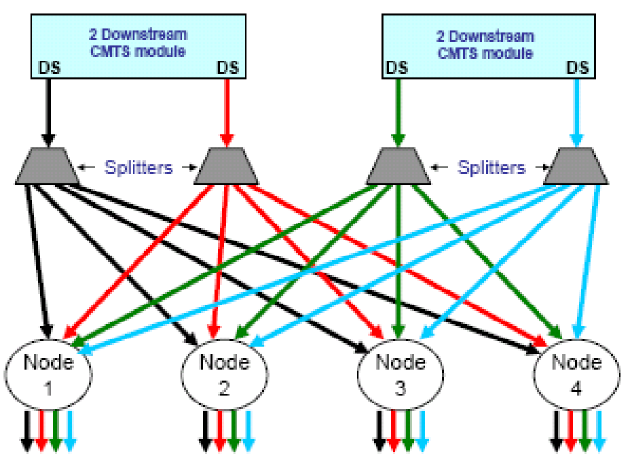
Multiple down streams and multiple up streams per node are needed to achieve the total speed potential available in DOCSIS 3.0

The ability to channel bond in the downstream and upstream is one of the major enhancements included in DOCSIS 3.0. Channel bonding offer's MSO's the ability to provide much higher downstream and upstream speeds to consumers.

To enable downstream channel bonding multiple down streams must be accessible by those nodes which desire this service. These down streams can originate via the original CMTS chassis in an integrated CMTS (I-CMTS) architecture or via an M-CMTS capable edge QAM in a modular CMTS (M-CMTS) architecture. To enable upstream channel bonding multiple up streams must be accessible by those nodes which desire this service.



Currently most HFC plants have only a few downstream and upstream channels dedicated to DOCSIS related services. This will have to change to take full advantages of the speed potential within DOCSIS 3.0. However, it is not necessary to wait until the transition to DOCSIS 3.0 begins to start the process of providing multiple down streams and multiple up streams per node and have immediate benefit. This immediate benefit can be recognized via load balancing of devices across the various interfaces which are accessible. Load balancing achieves it benefits by moving DOCSIS devices between interfaces to accomplish balanced subscriber counts and/or balanced utilization.



Dynamic load balancing has the immediate impact of more efficiently utilizing the allocated DOCSIS bandwidth. The DOCSIS network offers many types of critical services which can be adversely impacted by dynamic load balancing. It is important to make sure that dynamic load balancing does not impact the high availability of those services, such as VoIP.

Upgradeability

When MSO's examine the business cases on whether or not to upgrade to the next version of the DOCSIS specification, capital equipment cost will play an extremely important role. Some equipment which resides in the DOCSIS network can be upgraded to take advantage of the feature enhancements present in the next DOCSIS specification. The ability to identify which CPE and CMTS equipment can be upgraded to the next version is very important in the attempt to keep capital cost as low as possible during the DOCSIS transition.

CPE upgradeability

For CPE devices in the DOCSIS network, upgradeability is a function of being able to upgrade the firmware for that device. In a DOCSIS network which can include millions of CPE devices CPE firmware management becomes very important. When MSO's begin estimating the capital and operational impact of an upgrade to the next DOCSIS specification CPE firmware management will indicate which devices (via the system descriptor) are capable of receiving an upgrade and whether or not they already have the latest firmware. This insight into the DOCSIS network enables every MSO to have a more accurate view of the total cost of going to the next version of DOCSIS and have a realistic expectation of the number of devices which will be able to take advantage of those advanced features.

During and after the upgrade to the next DOCSIS specification, some of the initial problems will be isolated to certain CPE device types. CPE firmware management will enable the MSO to correlate the firmware and hardware version to specific types of CPE devices. In the past these issues have mostly been focused around new DOCSIS messages which all devices are exposed to. An important example of this is the new upstream channel descriptors which were introduced in DOCSIS 2.0 to enable the new channel types and modulation orders. There have been instances where modems were unable to interpret these messages properly initially, but after a firmware upgrade they were able to act on them as expected.

CMTS upgradeability

In prior DOCSIS migrations, the ability to upgrade a chassis based CMTS to the next DOCSIS specification has been a combination of replacing some of the CMTS hardware and new software. For example, with the transition to DOCSIS 2.0, new up stream hardware was needed to comply with the specification. This will continue to be true with the transition to the DOCSIS 3.0. The overall cost of the transition to DOCSIS 3.0 will be greatly impacted by how much of the existing systems can be upgraded with software and not require new hardware purchases. It is important that MSO's understand what is needed to achieve all the DOCSIS 3.0 features and how it relates to the total cost of transition to DOCSIS 3.0.

Overall cost of the DOCSIS transition with respect to upgradeability

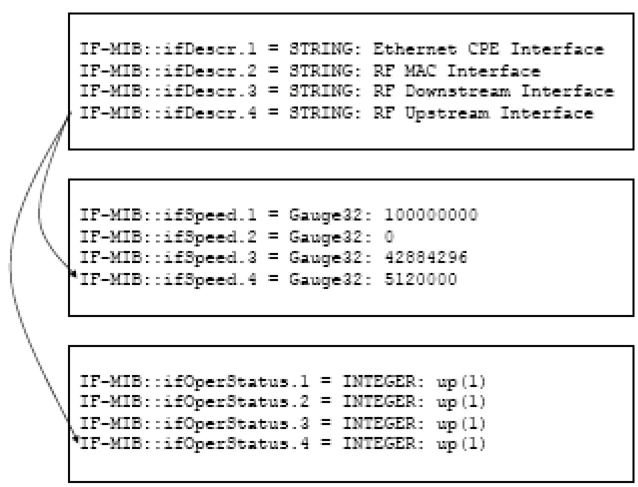
Being able to identify which devices in your network (CPE and/or CMTS) can be upgraded to enable future DOCSIS functionality is extremely important when considering the overall cost of the transition. The ability to upgrade will mean for the MSO: not having to purchase new capital equipment, being able to retain the troubleshooting knowledge attained for that piece of equipment and reducing the overall unknown during the transition process. However, when utilizing the ability to upgrade DOCSIS network equipment (CPE and/or CMTS) it is also very important to thoroughly know the timing of features included in upcoming firmware/software from your vendors such that they properly align the DOCSIS transition needs. Overall the cost of the DOCSIS transition can be greatly reduced with the ability to upgrade to the next version of DOCSIS without the need to purchase new hardware.

<u>Data Collection (OSS systems)</u>

The DOCSIS network is filled with devices from which a large amount of data can be collected. This collection of data is the MSO's insight into the health of the network. Maintaining this insight is extremely important, especially during major changes. The information retrieved from the collection of data can enable the MSO to more efficiently operate and monitor the DOCSIS network. The collection of the data is normally completed by tools which have automated the collection process. At many MSO's, these tools consist of 'in-house' developed tools and 'off-the-shelf' tools. When preparing to transition to the next version of the DOCSIS specification it is very important to plan for time to re-certification the interoperability of 'off-the-shelf' tools. Before the transition to the next version of DOCSIS all the 'in-house' tools must be carefully examined to make sure they deliver the same quality of data prior to the transition.

During initial tool creation these tools are normally developed with respect to the current environment. This development environment may consist of a certain vendor's equipment running a specific version of DOCSIS. When either of these two conditions changes it can have a cascading impact on tools. Below are a few areas which should be examined during the tool development process, whether in-house or off-the-shelf, which can prevent future problems with respect to DOCSIS transitions.

Interface indices

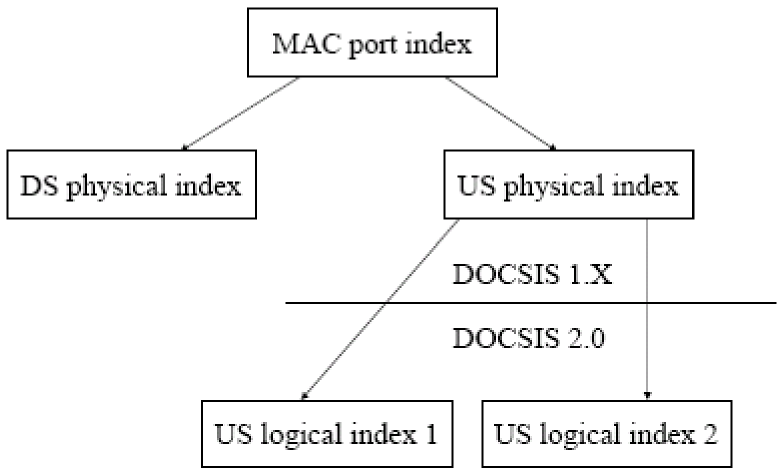


Information contained within a simple network management (SNMP) management information base (MIB) is correlated to an interface on a CPE or CMTS by means of an interface (if) index. An example of how interface indices can be utilized is to correlate the all the interfaces of a cable modem (ethernet, downstream, upstream and MAC) to their associated interface indices. In the example to the right, the .4 index is correlated to the RF Upstream of the cable modem. It has a speed of 5.12Mbps and has an operational status of up. All entries in the IF-MIB which end in .4

are associated to the RF Upstream. By performing an abstraction of association via the ifDescr table, it can enable tools to be more agile during a major change like transitioning to the next version of DOCSIS.

The number of interfaces on a CMTS can be orders of magnitudes higher than that of a CPE. The ability to accurately correlate the index used in a query to the correct interface is very important. This is compounded by the affect that interface indices can change between CMTS vendors.

In the transition from DOCSIS 1.1 to DOCSIS 2.0 a new type of upstream channel was introduced to help ensure backwards compatibility without requiring additional US bandwidth. This type of channel is called a logical channel. Logical channels enable two modulation profiles and/or channel types (TDMA, ATDMA and SCDMA) to exist within the same US spectrum, such that DOCSIS 1.X and DOCSIS 2.0 devices can coexist within the same channel. Since many tools were written with respect to the DOCSIS 1.X environment, when multiple logical channels were activated this had the potential to cause problems. Some of the most notable areas of problems which occurred with respect to multiple logical channels were associated modems to logical up streams and determining the interface utilization of a logical upstream.



Proprietary versus standard MIBS

During the development of tools, a proprietary SNMP MIB maybe utilized because: it more adequately addresses a data query need when compared to a standard SNMP MIB or an equivalent standard SNMP MIB does not exist. While the use of proprietary SNMP MIBs can initially solve a problem they may cause many more problems during a DOCSIS transition if not managed properly. With the transition to the next version of DOCSIS the following events may occur which can have a profound impact on the usability of proprietary SNMP MIBs:

- New equipment vendors are introduced into the DOCSIS environment which do not support proprietary SNMP MIBs of the prior vendors
- New software/firmware is required to upgrade the existing equipment to the next version of DOCSIS and the data reported back from the same SNMP MIB changes its meaning

During the transition to DOCSIS 3.0 many things may change in the DOCSIS network which can impact the collection of data used in monitoring the health of the network. Carefully monitor the following:

- SNMP MIBS
    - Changes to interface indices
    - Proprietary and standard
- Command line interface output
    - Downstream and MAC domain decoupling
    - Channel bonding and its impact on utilization calculations
- Collected data utilization
    - Does the data collected change its meaning with respect to troubleshooting?
    - Does the DOCSIS architecture (I-CMTS or M-CMTS) impact the manner in which the data is utilized?

Conclusion

The first DOCSIS specification was issued approximately 10 years ago. During that time, there have been many transitions from DOCSIS 1.0 to DOCSIS 1.1 and then to DOCSIS 2.0. When planning the upcoming transition to DOCSIS 3.0 it is important to look at the following areas with respect to CPE and head end equipment and its potential impacts:

- The configuration management systems (including provisioning systems)
- Needed HFC changes to achieve the DOCSIS 3.0 feature enhancements
- The impact of DOCSIS device upgradeability and its impact on the total cost of the transition to DOCSIS 3.0
- Data collection by all OSS systems

By applying lessons learned from prior DOCSIS transitions and focusing on areas listed above, the migration to DOCSIS 3.0 can be extremely successful and offer MSO's access to those features which they will need in the years to come.