Moving to the DOCSIS® Set-Top Gateway (DSG)

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By

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Introduction

In today's traditional video network, out-of-band (OOB) traffic, which typically consists of conditional access (CAS), system information (SI), electronic program guide (EPG), and emergency alert system (EAS) data, is sent from the set-top box controller to the set-top box client via proprietary protocols over dedicated RF channels. The DOCSIS Set-Top Gateway specification was developed to utilize a digitally modulated DOCSIS channel as an alternative transport mechanism for this OOB data, which may also combine high speed data and voice traffic from DOCSIS cable modems and PacketCable MTAs onto a shared channel.

The benefit of utilizing the DOCSIS channel for transmission of OOB data will allow for the deployment of more bandwidth intensive interactive video services, and will ultimately free up spectrum formerly used by proprietary OOB transport mechanisms and will eliminate the need for costly proprietary OOB modulation and de-modulation hardware. By eliminating the need for proprietary OOB transport mechanisms, and in conjunction with the ongoing separable security effort, we are paving the way for a true multi-vendor solution in an open standards environment.

The purpose of this white paper is to provide a brief introduction to the DSG specification followed by an overview of the steps necessary for implementing DSG in an existing legacy environment.

DSG Overview

The DSG architecture leverages existing DOCSIS networks to transport OOB data to set-top boxes via DOCSIS based CMTS devices. The DSG tunnels will forward OOB data across the DOCSIS downstream channel and to the set-top box, which will utilize the DOCSIS upstream channel as the return path for interactive video services. The specification was designed in such a way that a DSG enabled set-top box can operate in either a one-way or a two-way DOCSIS environment. In the one-way environment scenario, the set-top box would continue to receive CAS, SI, and EPG data in the downstream channel, however would sacrifice interactive services such as interactive pay-per-view and video-on-demand.

The OOB data is transmitted from the CMTS to the set-top box via IP datagrams over DSG tunnels. The DSG tunnels are uni-directional by definition and are carried over one or more DOCSIS downstream channels on a CMTS. The DSG tunnels are identified by a well-known MAC address (DSG Basic Mode) or a dynamically assigned MAC address (DSG Advanced Mode) provided in a Downstream Channel Descriptor (DCD) message.

DSG Basic Mode was intended as an early deployment option which allowed for the use of unicast MAC addresses for DSG tunnels that prevented the bridging of DSG tunnel traffic across IP filter-less DOCSIS 1.0 based cable modems which bridge all multicast traffic by default. The set-top box identifies the DSG tunnel based solely on the well-known MAC address assigned to DSG tunnel and which is hard-coded into the set-top box by the manufacturer. When the set-top box is booted up for the first time, it will scan through the downstream frequencies for a QAM carrier. Once a QAM carrier is detected and locked, the set-top box will listen for the DSG tunnel with MAC address equal to the well-known MAC address reserved for that particular CA vendor. If the set-top fails to locate a DSG tunnel that contains the reserved MAC address, it will continue scanning downstream frequencies for other QAM carriers.

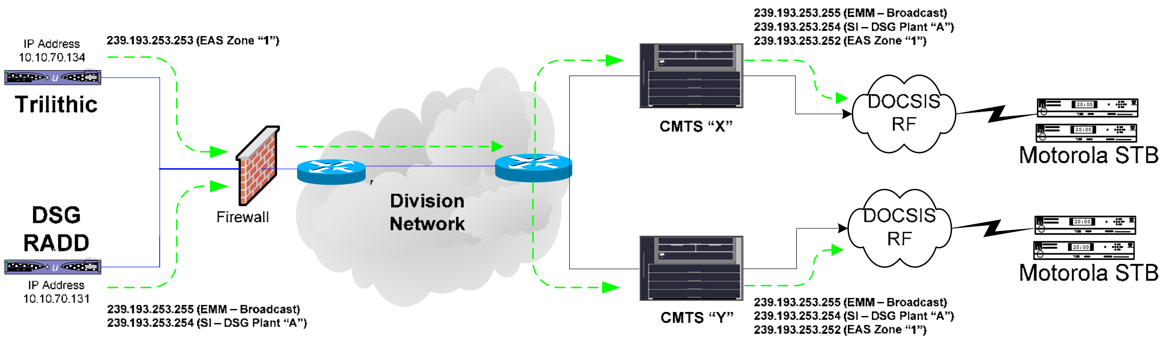
The disadvantages to using DSG Basic Mode are that DSG tunnels must be unique per IP subnet, and in most cases the IP subnets would be bundled across the CMTS limiting the architecture to a single unique DSG tunnel per CMTS for a particular vendor. In other words, in practice, only a single channel lineup and EAS zone would exist for a particular CMTS.

DSG Advanced Mode solves this problem by incorporating a DSG Address Table into a MAC management message called a Downstream Channel Descriptor (DCD), which is periodically (at least once per second) sent to the set-top boxes via the DOCSIS downstream channel. When the set-top box is first booting, it will scan the downstream frequencies for a QAM carrier that contains a valid DCD message. The set-top box will index into the DSG Address Table using either it's well-known MAC address, conditional access ID, application ID, or broadcast ID (or combination) to identify which DSG tunnel address (or addresses) on which to listen. This dynamic assignment of DSG tunnel addresses allows the MSO to incorporate *regionalization* into their DSG architecture. Regionalization provides the flexibility to define unique DSG tunnels per DOCSIS downstream interface on a one-way plant, or per DOCSIS upstream interface on a two-way plant. Therefore, DSG Advanced Mode will permit assigning two distinct channel lineups to two different DOCSIS upstream interfaces on the same DOCSIS downstream interface. EAS zones however must be carried by DSG broadcast tunnels and are therefore limited to a single unique EAS zone per downstream interface.

DSG Example Architecture

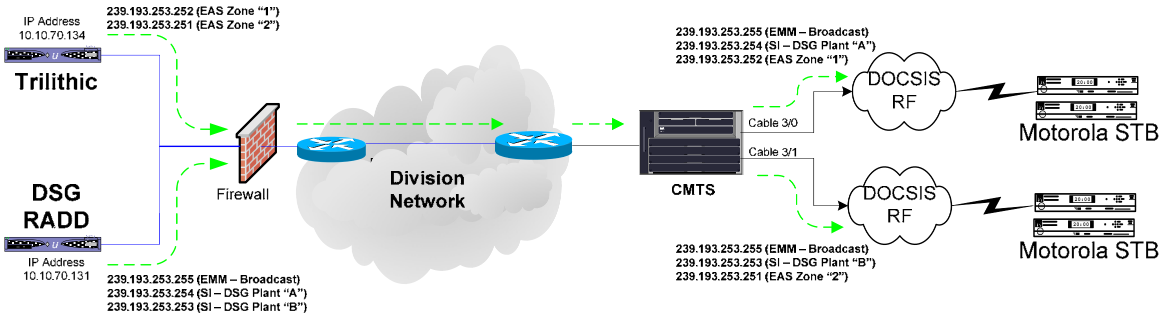
The following three examples depict very basic DSG architectures (using a Motorola environment as an example) and will illustrate the differences between a regionalized configuration and a non-regionalized configuration.

In the first example, we'll take a look at a non-regionalized configuration. There is a single geographic region represented in the DAC/RADD as DSG Plant "A" which contains the channel lineup for that region. In addition, the subscribers assigned to DSG Plant "A" are also located entirely within a single EAS zone, which for this example we'll call state county "1".



Both CMTS "X" and CMTS "Y" services subscribers from the geographic region with a boundary defined as DSG Plant "A" and state county "1". The CMTS configuration for all interfaces on both CMTS "X" and CMTS "Y" will be defined such that three DSG tunnels are available to the STB, the primary CA (or broadcast) tunnel containing the EMM data, the secondary CA (or plant specific) tunnel containing the SI data, and the broadcast tunnel used for SCTE-18 messaging to state county "1".

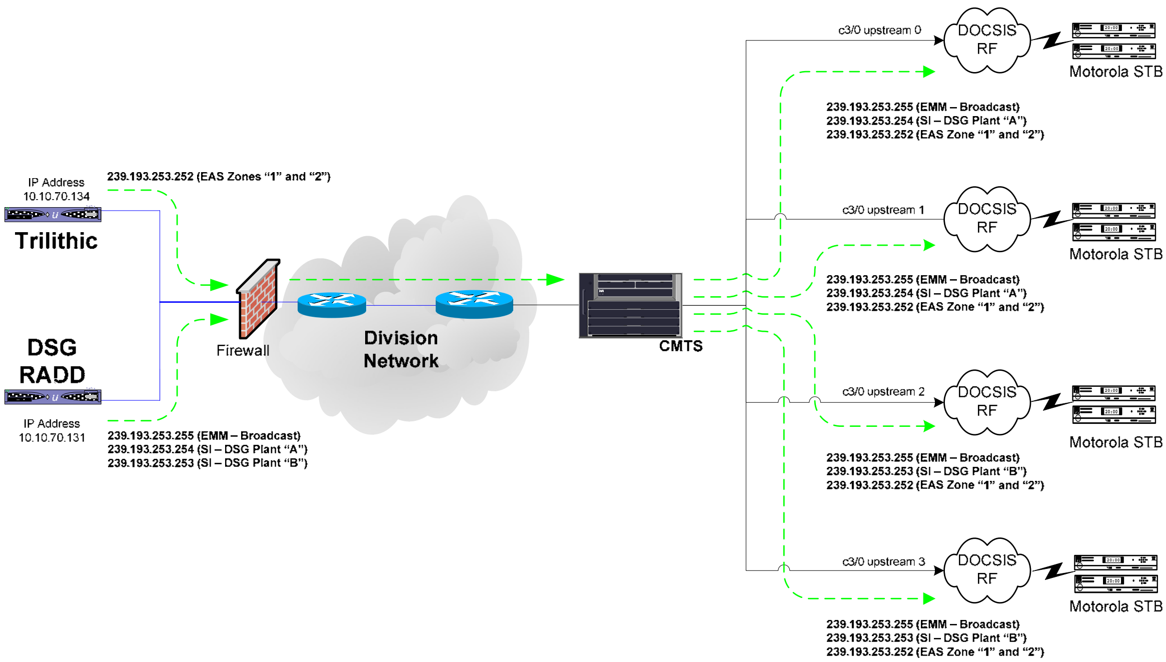
The second example illustrates the scenario where a CMTS provides service to more than one geographic region requiring additional channel maps and EAS zones. However, the geographic boundaries are defined such that each CMTS downstream interface services one, and only one, geographic region. The DSG tunnel MAC addresses can be chosen arbitrarily, but must be unique within the CMTS. There are two geographic regions represented in the DAC/RADD as DSG Plant "A" and DSG Plant "B" with distinct channel lineups. In addition, the subscribers assigned to DSG Plant "A" and DSG Plant "B" are located in different EAS zones, which for this example we'll call state county "1" and state county "2", respectively.



The CMTS cable interface 3/0 only services subscribers from the geographic region with a boundary defined as DSG Plant “A” and state county “1”. The CMTS configuration for this interface will be defined such that three DSG tunnels are available to the STB, the primary CA (or broadcast) tunnel containing the EMM data, the secondary CA (or plant specific) tunnel containing the SI data, and the broadcast tunnel used for SCTE-18 messaging to state county “1”.

Likewise, The CMTS cable interface 3/1 only services subscribers from the geographic region with a boundary defined as DSG Plant “B” and state county “2”. The CMTS configuration for this interface will be defined such that three DSG tunnels are available to the STB, the primary CA (or broadcast) tunnel containing the EMM data, the secondary CA (or plant specific) tunnel containing the SI data, and the broadcast tunnel used for SCTE-18 messaging to state county “2”. Keep in mind that the primary CA tunnel defined on this cable interface is forwarding the same multicast flow as interface 3/0, however, both the secondary CA tunnel and SCTE-18 tunnel are forwarding separate multicast flows than interface 3/0.

The last example illustrates the scenario where a particular CMTS downstream cable interface provides service to more than one geographic region requiring more than one channel map and/or EAS zone to service customers off that single downstream interface. In the following example, there are two geographic regions represented in the DAC/RADD as DSG Plant “A” and DSG Plant “B”, each with a distinct channel lineup. In addition, the subscribers assigned to DSG Plant “A” and DSG Plant “B” are located in different EAS zones, which for this example we’ll call state county “1” and state county “2”, respectively.



The CMTS cable interface 3/0 service subscribes from both of these two geographic regions, with the boundary defined as DSG Plant "A" subscribers reside on upstream interfaces "0" and "1", and DSG Plant "B" subscribers reside on upstream interfaces "2" and "3". This allows us to send the SI data or channel map to the subscriber, based on which upstream interface the STB is registered on. The CMTS configuration for this interface will be defined such that four DSG tunnels are available to the STB, the primary CA (or broadcast) tunnel containing the EMM data, a secondary CA (or plant specific) tunnel containing the SI data for subscribers assigned to DSG Plant "A", another secondary CA (or plant specific) tunnel containing the SI data for subscribers assigned to DSG Plant "B", and the broadcast tunnel used for SCTE-18 messaging to both state county "1" and state county "2".

The DSG specification mandates that the SCTE-18 messages are carried via a DSG broadcast tunnel, therefore when defining the multicast flow SCTE-18 traffic, we must include the FIPS codes for both state county "1" and state county "2". The end result being that customers residing on this particular downstream interface will receive the SCTE-18 broadcasts for both state county "1" and state county "2", regardless of which state county they reside in.

DSG Implementation Systems Requirements

In a Motorola environment, the existing RADDs which provide OOB signaling via the ALOHA protocol cannot concurrently support OOB signaling via DSG tunnels, therefore a separate DSG RADD must be acquired to handle OOB signaling to DSG enable set-top boxes. The RADD and the DAC must be upgraded to support DSG, however the DAC upgrades were already being done as part of the separable security preparations.

In a Scientific Atlanta environment, the DNCS hardware must be upgraded to include support for a fast Ethernet or gigabit Ethernet interface. The DNCS software must also be upgraded to a revision greater than SR4.0 (which is also already being done as part of the separable security preparations), and must include the license for DSG support.

In traditional systems, there is an EAS server configured to send EAS messages to the OOB modulator either via the set top box controller or contact closures directly to the OOB modulator. If those messages are associated with the FIPS codes for the geographic area covered by the Division, then the message is transmitted via the traditional OOB transport. In headends where the only method of communication to the OOB is via contact closures, a hardware upgrade to support an Ethernet NIC card was required. In addition to the NIC card, many EAS systems also required a firmware upgrade to support the transmission of SCTE-18 data via IP multicast.

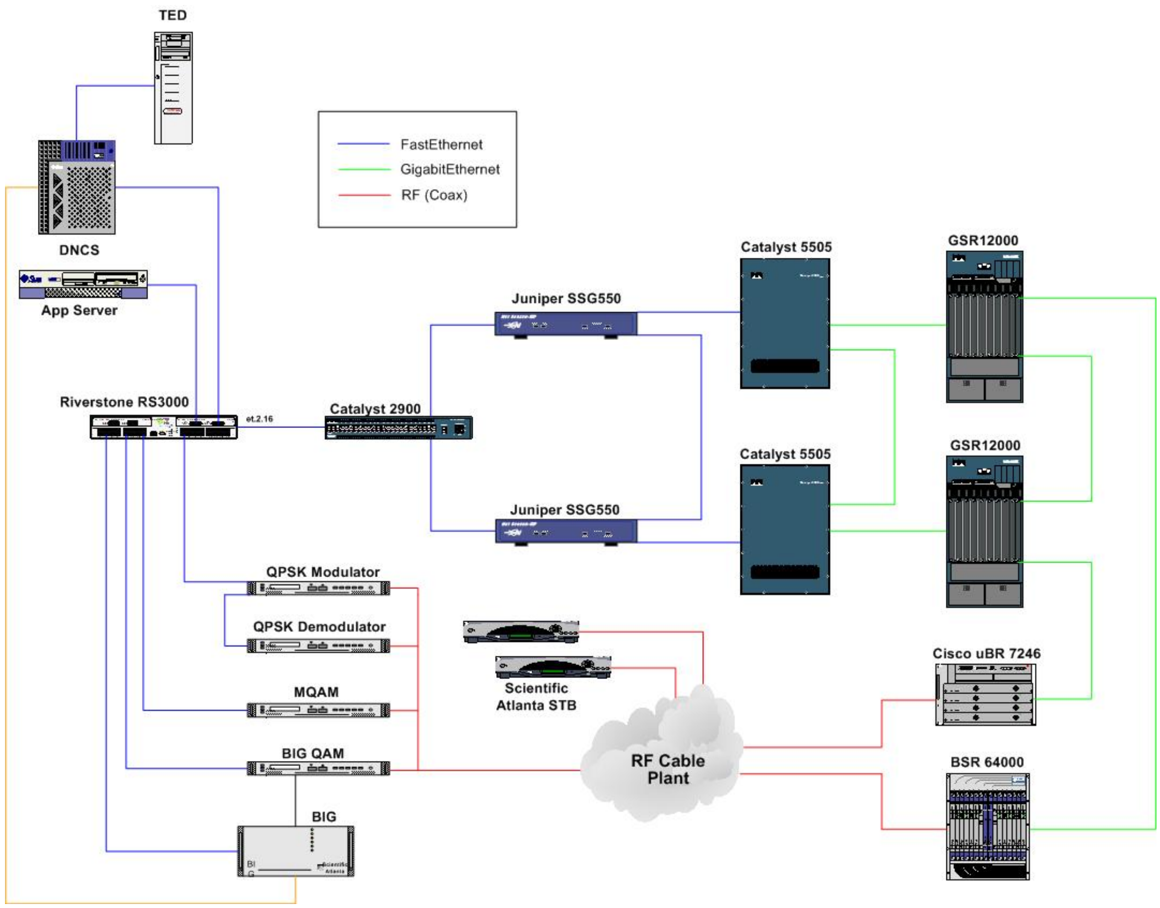
Integration with pre-ISA VOD systems varies by vendor, but all share the same requirement that the set-top box must be able to route to the VOD network. Seachange VOD platforms must enable the autodiscovery feature on its system, while DSG set-top boxes in Concurrent systems must be able to resolve the hardcoded VOD server hostname via the local DNS server. The C-Cor system will send the IP address of the VOD server via in-band signaling and thus only requires the additional routing capability.

We utilized our existing high speed data provisioning system and expanded it to include the addition of DSG enabled set-top boxes. The embedded cable modem will retrieve a DHCP lease from the same private pool of addresses that is used for high speed data cable modems and will also receive a DOCSIS configuration file just high speed data cable modems do. The embedded set-top box however is assigned a private IP address from a separate pool of addresses which was created solely for these DSG enabled set-top boxes. Some re-coding of our DHCP extension scripts were necessary to key in on DHCP option 43 sub-option 3 to identify the device type and to assign the proper scope selection criteria. The selection of IP address ranges for the embedded set-top box are unique between “sister” regional data centers for disaster recovery purposes, but do contain overlap between “non-sister” regional data centers. We also needed to be cognizant of overlap with existing IP address pools assigned to legacy DAVIC or ALOHA set top boxes, and re-assign as necessary.

DSG Implementation Network Requirements

In a traditional headend, there hasn't existed much need for communication between the video and the high speed data networks, therefore they have always been two distinct and separately maintained networks. In a DSG environment, it is a requirement that these two typically exclusive networks be joined together. To protect the critical servers in the video network that must now be exposed to the HSD network, a firewall was implemented to filter out malicious hackers. Firewall policies were defined such that only the IP ranges reserved for the set-top boxes would be allowed to communicate back to the video network.

In some cases it was also necessary to integrate an additional switch or router to sit behind the firewall which supported the necessary multicast routing functionality and to properly tie the various segments of the video network together. To facilitate the routing of the multicast traffic across the networks, we introduced protocol independent multicast (PIM) routing using a static rendezvous point (RP) with MSDP peering along the OOB DSG path. A sample network diagram depicting a Scientific Atlanta environment is shown below.



The CMTS devices throughout our network required a firmware upgrade to support Advanced Mode DSG as well as the PIM routing functionality. The DSG configurations on the CMTS are not necessarily identical across an entire division, and in cases where a large division is involved, there may be several unique configurations depending on how the system is laid out geographically and how many channel maps are in use at the particular division.

Each CMTS downstream interface (and in the cases where upstream regionalization is present, each upstream interface) must be mapped to the DSG plant information present in the set-top controller. An example of the mapping table used to define the DSG tunnels for CAS and SI data follows.

CMTS Name	UBR IP Address	CMTS Interface	Hub name	QPSK	Channel Map	DSG Hub Name	CMTS Bridge Name	CMTS Bridge IP
test-ubr1.hrn.rr.com	10.10.3.4	cable 3/0	Andrews	ANDQPSK1	Georgetown	CLMASCAND	CLMASCAND-01	239.193.253.251
		cable 4/0	Atlas	AtlasMod1	Default	CLMASCATL	CLMASCATL-01	239.193.253.255
		cable 5/0	Atlas	AtlasMod2	Default	CLMASCATL	CLMASCATL-01	239.193.253.255
		cable 6/0	C Forrest	CFQPSK1	Myrtle	CLMASCCFR	CLMASCCFR-01	239.193.253.244

Care must be taken when defining the DSG tunnel on the CMTS. If a DSG tunnel is improperly configured on the CMTS, set-top boxes may receive an incorrect channel lineup, or no channel lineup at all.

The mapping of FIPS codes to multicast addresses and ultimately to CMTS interfaces is also a painstaking process that requires a great deal of care to ensure that the correct groups of set-top boxes will indeed receive to correct EAS broadcast. Thorough testing is required to confirm the correct FIPS codes were included in the multicast stream and that the correct DSG broadcast tunnel was applied to the proper CMTS downstream cable interface. An example of the mapping tables that were used to define the CMTS and EAS server configurations is shown below.

CMTS Name	UBR IP Address	CMTS Interface	EAS System	EAS System IP address	EAS County	EAS Multicast Address	5-digit EAS FIPS	Other FIPS Codes
test-ubr1.hrn.rr.com	10.10.1.1	cable 3/0	Trilithic	10.6.7.8	Horry/Williamsburg	239.193.253.154	45051/45089	545051, 645051, 245051
		cable 4/0	Trilithic	10.6.7.8	Horry/Williamsburg	239.193.253.154	45051/45089	545051, 645051, 245051
		cable 5/0	Trilithic	10.6.7.8	Lexington/Richland	239.193.253.153	45063/45079	545063, 645063, 245063
		cable 6/0	Trilithic	10.6.7.8	Lexington/Richland	239.193.253.153	45063/45079	545063, 645063, 245063

An example DSG configuration of a Cisco CMTS which incorporates regionalization across downstream interfaces as well as upstream interfaces on a Motorola system is depicted below and illustrates how a complicated configuration could be easily susceptible to errors that the CMTS wouldn't detect and would go unnoticed until a set-top box was actually installed on that particular node.

```
cable dsg client-list 1 id-index 1 ca-system-id 700
cable dsg client-list 2 id-index 1 ca-system-id 701
cable dsg client-list 3 id-index 1 broadcast
!
!
cable dsg tg 1 channel 1
cable dsg tg 1 channel 2
cable dsg tg 1 channel 3
cable dsg tg 2 channel 1
cable dsg tg 2 channel 2
cable dsg tg 2 channel 2 ucid 1 2
cable dsg tg 3 channel 1
cable dsg tg 3 channel 1 ucid 3 4
cable dsg tg 3 channel 2
cable dsg tg 4 channel 1
cable dsg tg 5 channel 1
cable dsg tg 6 channel 1
!
!
cable dsg tunnel 1 mac-addr bbbb.bbbb.dcd1 tg 1 clients 1
cable dsg tunnel 2 mac-addr bbbb.bbbb.dcd2 tg 2 clients 2
cable dsg tunnel 3 mac-addr bbbb.bbbb.dcd3 tg 3 clients 2
cable dsg tunnel 4 mac-addr bbbb.bbbb.ea01 tg 4 clients 3
cable dsg tunnel 5 mac-addr bbbb.bbbb.ea02 tg 5 clients 3
cable dsg tunnel 6 mac-addr bbbb.bbbb.ea12 tg 6 clients 3
!
!
```

```
cable dsg cfr 1 dest-ip 239.293.253.255 tunnel 1 priority 0 src-ip 10.10.70.131 in-
dcd yes
cable dsg cfr 2 dest-ip 239.193.253.254 tunnel 2 priority 1 src-ip 10.10.70.131 in-
dcd yes
cable dsg cfr 3 dest-ip 239.193.253.253 tunnel 3 priority 0 src-ip 10.10.70.131 in-
dcd yes
cable dsg cfr 4 dest-ip 239.193.253.252 tunnel 4 priority 0 src-ip 10.10.70.134 in-
dcd yes
cable dsg cfr 5 dest-ip 239.193.253.251 tunnel 5 priority 0 src-ip 10.10.70.134 in-
dcd yes
cable dsg cfr 6 dest-ip 239.193.253.250 tunnel 6 priority 0 src-ip 10.10.70.134 in-
dcd yes
!
!
interface Cable 3/0
  cable downstream dsg tg 1 channel 1
  cable downstream dsg tg 2 channel 1
  cable downstream dsg tg 4 channel 1
!
!
interface Cable 4/0
  cable downstream dsg tg 1 channel 2
  cable downstream dsg tg 2 channel 2
  cable downstream dsg tg 3 channel 1
  cable downstream dsg tg 6 channel 1
!
!
interface Cable 5/0
  cable downstream dsg tg 1 channel 3
  cable downstream dsg tg 3 channel 2
  cable downstream dsg tg 5 channel 1
!
!
```

Warehouse Requirements

Traditionally, set top box staging is done at the warehouse and requires that the STB is provisioned in the STB controller (e.g. DAC or DNCS) and that a cable drop providing the video feed is accessible. To stage a DSG set top, two new requirements are introduced.

With the introduction of the embedded cable modem into the set-top box, it now becomes essential to provision the eCM into the high speed data provisioning system. In a TWC system, and I suspect most other MSO systems, if a cable modem is not defined in the provisioning system, then the cable modem will receive a DOCSIS configuration file with the network access flag disabled. In a DSG enabled set-top box, this would prevent the embedded set-top box from obtaining an IP lease and therefore the warehouse technician could not validate the set-top box functionality. Therefore, the first requirement is that the set-top box not only be provisioned in the STB controller, but also the high speed data provisioning system.

The second requirement is to combine the DOCSIS channel from to CMTS with the video feed drop at the warehouse. Typically, this is done with a spare blade on a CMTS so as to not impact existing subscribers.

Summary

The migration from proprietary OOB transport mechanisms to an open standards based DSG infrastructure is a key step in the OpenCable initiative and a requirement for rapidly approaching technology such as OCAP compliant applications and Downloadable Conditional Access (DCAS). DSG will also make multiple set-top box vendor environments a cost effective solution by removing the dependency on expensive OOB modulators and de-modulators (and rack consuming, all those 1RU units add up!). Also, by utilizing the DOCSIS channel for OOB traffic, the ability to deploy bandwidth intensive interactive applications will be readily available thus potentially providing additional sources of revenue.

Some key points to keep in mind:

OOB data traverses the entire network from set-top box controller to the DSG set-top box, therefore there are many more points of failure along the path than there was with legacy systems, which may require modifications to change management processes. For example, CMTS upgrades which in the past only affected HSD subscribers, now has an impact on video subscribers.

Network engineers, plant engineers, and headend engineers must all be cognizant of how changes they make may have impacts elsewhere in the network. For example, a plant engineer may be planning on doing a node split not knowing that the set-top boxes off the split node may now be receiving an incorrect channel lineup or may not receiving the proper EAS broadcast because the CMTS configuration needed to be updated to reflect the new plant topology. Therefore there is a need for an increased level of communication amongst the division engineering teams.

Good luck!