# DOCSIS 3.1 Multicast Profile Management Mechanism

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*Abstract*

*DOCSIS 3.1 introduced many new features into the access network, including variable bit loading across a channel and the use of multiple modulations profiles for downstream and upstream channels. For multicast, the CMTS should attempt to maximize the link utilization by only sending packets to a multicast group on a single profile when a CM joins or leaves. Currently, there is no definition about the multicast profile management mechanism.*

*In this paper, the DOCSIS multicast profile management mechanisms based on different implementations were proposed,which can be regarded as the supplement methods of the DOCSIS 3.1 and SDN-Cable TR about the downstream profile management.*

## INTRODUCTIONS

### DOCSIS 3.1 Profile Management

DOCSIS 3.1 [1] introduced many new features into the access network, including variable bit loading across a channel and the use of multiple modulations profiles for downstream and upstream channels. Using multiple profiles can increase throughput per CM, maximize network capacity, and minimize errors. As a new feature, modulation profile management is part of the CMTS but not directly tied to the DOCSIS protocol. This function can be deployed in the CMTS as an internal module or moved out of the CMTS as an external 'Application'. The DOCSIS 3.1 profile management application (PMA), as an external 'APP', was introduced by the SDN Architecture for Cable Access Networks (SDN-Cable) Technical Report [2] firstly and also published in one white paper at SCTE 2015 from Karthik Sundaresan [3], CableLabs. But in these materials, except for the downstream profile management mechanism, there is no definition for the multicast profile management mechanism.

For multicast, based on the description of DOCSIS 3.1 specification [1], the CMTS should attempt to maximize the link utilization by only sending packets to a multicast group on one single profile. The CMTS should use the highest bandwidth profile common to the CMs which are members of the multicast group. When a CM joins a multicast group the CMTS determines if the new CM can support the existing profile in use for the session; if not then the CMTS will have to move the session to a lower common profile which all group members can support or be forced to replicate the multicast on multiple profiles. When a CM leaves a multicast group the CMTS determines if the remaining group members can support a higher bandwidth profile than is currently in use for the session; if yes, then the CMTS MAY move the session to the higher bandwidth profile.

### Internal Profile Management Module

The profile management can be deployed in the CMTS as an internal functionality module, which is used to determine the best modulation profiles for each downstream and upstream channel, given the channel characteristics seen by each CM on the network.

### External Profile Management Application

In the SDN-Cable Technical Report [2], there are two kinds of application that an MSO can create and deploy:

1. Applications that provide service to the end customer;
2. Applications that provide network services to the MSO.

DOCSIS 3.1 Profile Management belongs to the second class of applications that can be enabled by an SDN infrastructure. Some DOCSIS features that are part of the CMTS but are not directly tied to the DOCSIS protocol interface between the CMTS and CM, include variable bit loading, multiple modulations profiles and upstream probes. Refer to the Figure 1, it is the SDN-based DOCSIS 3.1 Profile Management Application architecture, which is not directly tied to the DOCSIS protocol.

The PMA is responsible for gathering the data it needs to make profile decisions. It interacts with the CMTS through the SDN controller to initiate modulation profile tests, provide new or optimized modulation profiles, and provide suggestions or commands to use these modulation profiles. At high level, the PMA makes requests to the CMTS to get information from the CMTS, which in turn sends out MMMs to the CMs to collect the needed information and send it back to the PMA. The PMA also makes recommendations on the profiles to the CMTS, which the CMTS uses to configure CMs to use at an appropriate time.

For the detailed description about PMA please refer to the [2, 3], which is also designed to help Cable Operators determine the best modulation profiles.

In this paper, the authors only focused on the multicast profile management which deployed internally or externally.

## MULTICAST PROFILE (MP) MANAGEMENT

### MP Optimization Trigger condition

Based on the DOCSIS3.1 Specification [1], DOCSIS 3.1 is backward-compatible with some equipment built to the previous specifications. DOCSIS 3.1-compliant CMTS seamlessly support DOCSIS 3.0, DOCSIS 2.0 and DOCSIS 1.1 CMs. Also, DOCSIS 3.1 CM can work as DOCSIS 3.0 mode. So, when a CM joins/leaves a multicast group the CMTS needs to determine its working mode, which is DOCSIS 3.0 mode or DOCSIS 3.1

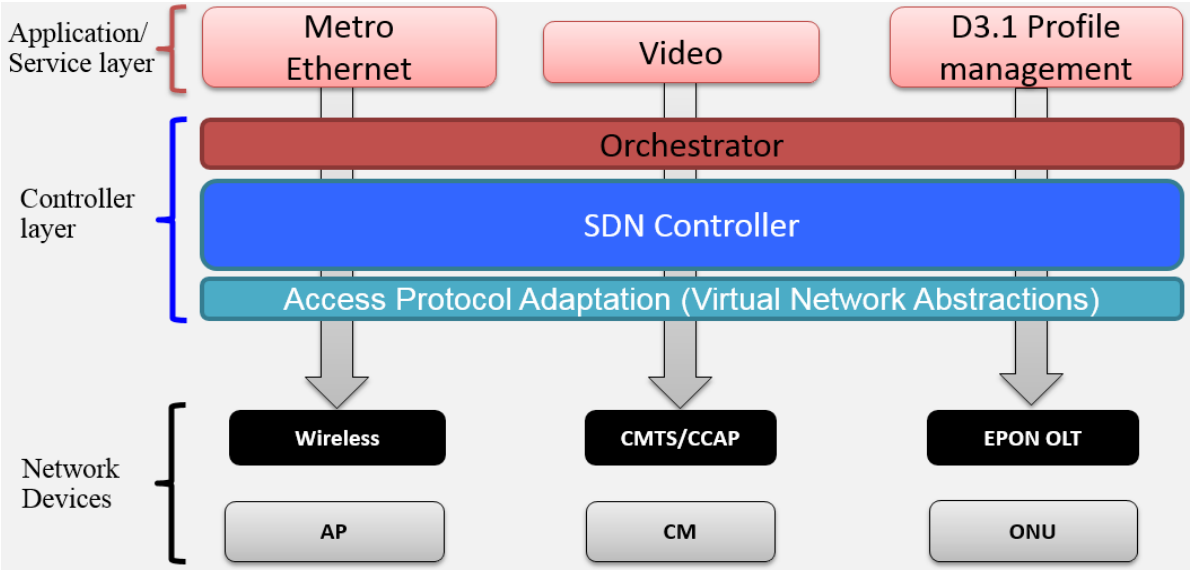


Figure 1. PMA Architecture

mode.

If the CM is working on DOCSIS 3.0 mode, the CMTS will allows it to continue to join/leave the multicast group without doing the profile optimization, otherwise, if the CM is working on the DOCSIS 3.1 mode with OFDM downstream channel, the CMTS needs to determine whether it needs to do multicast profile optimization or not, because each CM can support one or more multicast service which may belong to one or more multicast group, as showed in Figure 2.

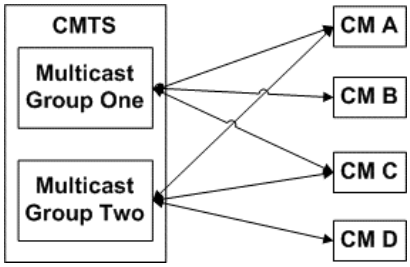


Figure 2. Multicast Groups in CMTS

For the scenario in Figure 2, different multicast groups includes different CMs, CM A, CM B, and CM C belong to multicast group one, and CM A, CM C, and CM D belong to multicast group two, assuming that all the CMs are working on DOCSIS 3.1 mode with the OFDM downstream channel.

Figure 3 shows the case where CM A does not belong to any multicast group.

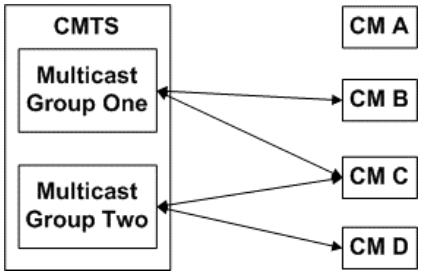


Figure 3. Multicast Groups in CMTS

Now, as shown in Figure 4, client 1 connected to CM A wants to join multicast group one which already includes CM B and CM C using one common multicast modulation profile. At this time, CMTS detects that this is the first client connected to CM A which wants to join multicast group one, then, CMTS will start to do the profile optimization for CM A, CM B, and CM C which belong to the same multicast group.

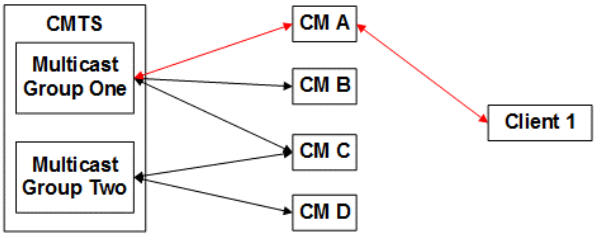


Figure 4. Client Joins Multicast Group

As shown in Figure 5, Client 2 is another client that is connected to CM A and wants to join multicast group one.

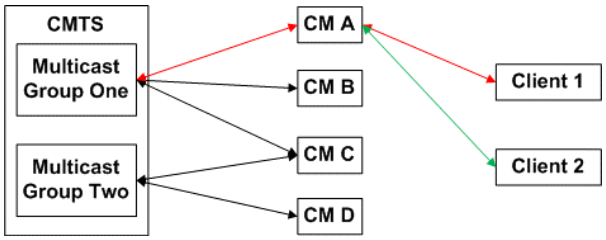


Figure 5. Client Joins Multicast Group

At this time, the CMTS detected that Client 2 connected with CM A wants to join the same multicast group as Client 1, so, the CMTS will not need to do the multicast profile optimization, because the CM A has already joined that multicast group.

In another scenario, if Client 2 wants to join multicast group two, as shown in Figure 6, CMTS detects that this is the first client connected to CM A which wants to join multicast group two, then, CMTS will start to do the multicast profile optimization for CM A, CM C, and CM D which belong to the same multicast group.

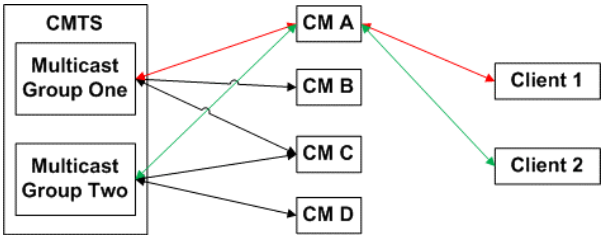


Figure 6. Client Joins Multicast Group

Based on the above analysis, if the CMTS wants to do the multicast profile optimization when a CM joins one multicast group, the following prerequisites need to be satisfied:

1. The CM is working on DOCSIS 3.1 mode with OFDM downstream channel;
2. The CM receives the first join request for the multicast group from one of the clients connected to it.

When a CM leaves a multicast group, the following prerequisites of the multicast profile optimization need to be satisfied:

1. The CM is working on DOCSIS 3.1 mode with OFDM downstream channel;
2. Last Client connected to the CM leaves the multicast group.

Internal Profile Management Mechanism

In this section, the profile management is internally deployed in the CMTS, and assumes that CMTS needs to start to do the multicast profile optimization when a CM joins the multicast group. As showed in the Figure 7, the procedure of the profile management (PM) is as follows:

1. The PM module needs to know the identity of the CM (MAC address, etc.) and the identity of the multicast group. The identity of CM can be obtained from other modules, such as the multicast management module. Using the identity of CM, the PM module can obtain the multicast profiles which the CM supports. And using the identity of the multicast group, the PM module can obtain the multicast profile which is used by current multicast group.

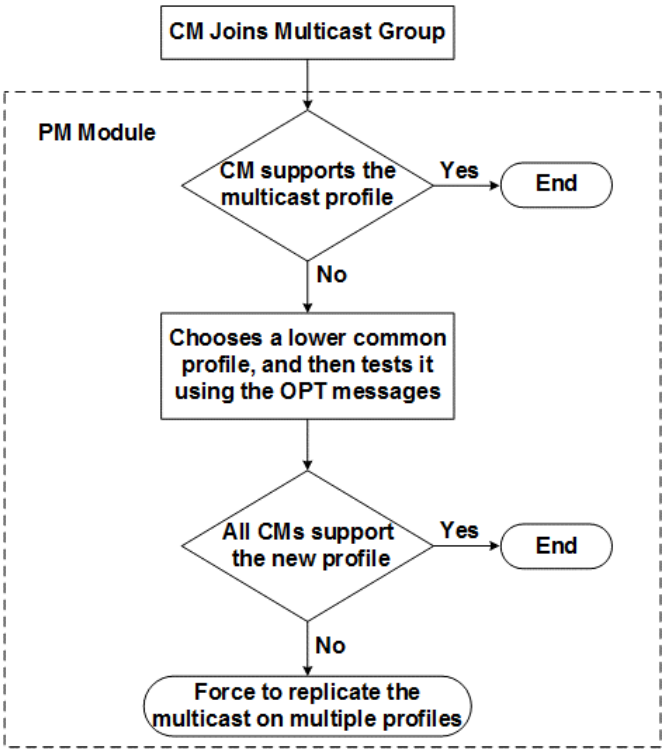


Figure 7. Internal Profile Management (CM Join)

2. Then, the PM module tries to compare the multicast profiles of this CM with the multicast profile which is currently in use by the current multicast group. If this CM can support the current multicast profile, the multicast profile optimization procedure is finished. Otherwise, goes to next step.
3. If this CM cannot support the current multicast profile, the PM module will choose a lower common profile for the multicast group, and then tests it for all CMs in the multicast group using the OPT messages in the DOCSIS 3.1 specification [1]. If all CMs can supports the new profile, the CMTS selects the new profile for the multicast group members, and the multicast profile optimization procedure is finished. Otherwise, goes to next step.
4. If all CMs cannot supports the new profile, the CMTS will force the multicast management module to replicate the multicast on multiple profiles.

When a CM leaves a multicast group, as showed in Figure 8, the PM module determines if the remaining group members can support a higher bandwidth profile than is currently in use; if yes, then the CMTS will want to move the session to the higher bandwidth profile. Based on testing the new profile, if the remaining CMs can support the new higher bandwidth profile, the CMTS will select the new profile for the multicast group members, and the multicast profile optimization procedure is finished. Otherwise, the CMTS will continue to use the profile which is currently in use.

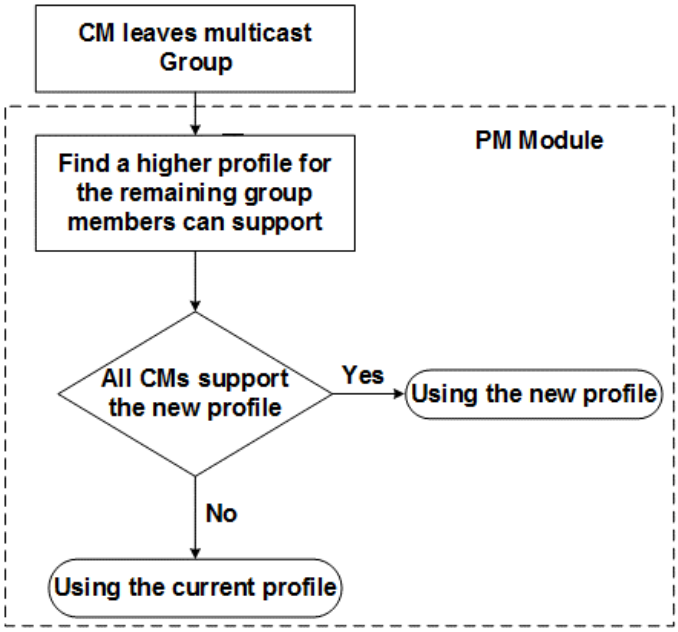


Figure 8. Internal Profile Management (CM Leave)

External Profile Management Application

In [2,3], the profile management functionality is implemented by an external application based on the SDN/NFV cable access architecture. This application can be deployed outside of the CMTS, as shown in Figure 1. But in [2, 3], there is no definition for the multicast profile management.

When one CM wants to joins or leaves one multicast group, if the CMTS wants PMA to do the multicast profile optimization, the CMTS needs to notify the PMA of which CM wants to join or leave the multicast group.

Then, the PMA will work the same way as an internal PM module, to initiate the profile optimization process. After that, PMA will

3) Indicator for whether the CM joins or leaves the multicast group.
4) List of CM MAC address;

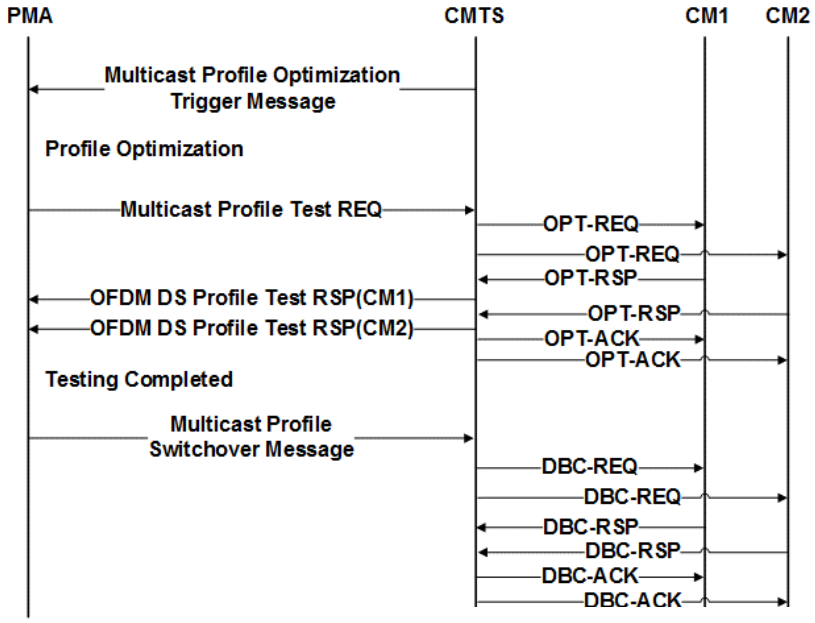


Figure 9. PMA Profile Optimization

send the new profile to the CMTS to it. If the testing results are acceptable, then PMA will ask the CMTS to assign the profile to all CMs in the multicast group, as showed in Figure 9.

In the SDN-Cable TR [2], the downstream modulation profile messages for the PMA-CMTS interface has been defined. As showed in Table 1.

In the Table 1, those messages are not enough for the multicast profile management. Some of them can be reused and some of them need to be modified to accommodate the multicast profile management.

In this section, the high level interactions between a PMA and the CMTS about the multicast profile information were proposed. The interactions messages as follows:

1. CM Join/Leave Descriptor
   includes four elements:
   1) Downstream Channel ID;
   2) Multicast Group ID;
2. This message is sent from CMTS to PMA to indicate whether one CM or a list of CMs have joined or left the multicast group;
3. OFDM Downstream Multicast Profile Test Request.

   This message is for the PMA to request the CMTS send an OPT-REQ messages to the CMs in the multicast group to test a modulation profile. In order to reuse the messages of OFDM Downstream Profile Test Request in Table 1 for the multicast profile testing, some modification and limitation about the CM MAC address and IfIndex need to be satisfied, as follows:
   1) CM MAC address list;
      A Multicast CM MAC Address indicates a request to send the OPT-REQ to all CMs in that multicast group;
   2) IfIndex:
      Needs to be ignored by all CMs in the multicast group;

Table1. PMA-CMTS Downstream Modulation Profile Messages

| Message | Description |
|---|---|
| Downstream OFDM Channel Descriptor | Conveys the configured channel parameters for a downstream DOCSIS 3.1 channel. |
| Downstream Profile Request | Either a request from the CCAP for a new profile or a request from PMA for the details of an existing profile. |
| Downstream Profile Descriptor | Provides the configuration details of a modulation profile. |
| Downstream Spectrum Request | Request from the PMA for the RxMER values for a channel from a given CM. |
| Downstream Spectrum Desciptor | Conveys the per subcarrier RxMER measurements for a channel from a given CM. |
| Downstream Profile Test Request | Request from the PMA for the CCAP to test a specified modulation profile. |
| Downstream Profile Test Response | Conveys the results of the test of a modulation profile on a specified CM. |
| CM-to-Profile Assignment Request | Request for a list of CMs that are assigned a specified modulation profile. |
| CM-to-Profile Assignment Descriptor | Provides a list of CMs that are or are to be associated with a modulation profile. |
| Profile-to-CM Assignment Request | Request for a list of the profiles that are assigned to a CM. |
| Profile-to-CM Assignment Descriptor | Provides a list of channels and modulation profiles that are assigned or should be assigned to a CM |

3) Profile ID;
4) Op code;
5) OPT-REQ TLV;

4. OFDM Downstream Multicast Profile Test Response message can reuse the OFDM Downstream Profile Test Response messages in Table 1.

5. Multicast Group Information Request, includes two elements:
   1) Downstream Channel ID;
   2) Multicast Group ID;

   When sent from the PMA to the CMTS, this message is used by the PMA to request that CMTS send the multicast groups information for a downstream OFDM channel. A Multicast Group ID of 0xFFFF indicates a request for all multicast groups information on the downstream OFDM Channel. A Downstream Channel ID of 0 and a multicast group ID of 0xFFFF, indicate a request for all multicast groups information of all downstream OFDM channels on a given CMTS.

6. Multicast Group Information Descriptor includes three elements:
   1) Downstream Channel ID;
   2) Multicast Group ID;
   3) List of tuples (Multicast Profile ID, CMs Number, CMs MAC Address);

   When sent from the CMTS to the PMA, this message is used to inform the PMA of that multicast group information on the downstream OFDM channel.

   When sent from the PMA to the CMTS, it describes the CMs to multicast profiles assignment as recommended by the PMA. The message may be sent with or without Multicast Group Information Request message.

   In one multicast group, if all the CMs use the same multicast profile, this message only includes one tuple, in which the downstream channel ID could be 0, and the CM MAC address could be the multicast MAC address; if using the

different multicast profiles, this message will include several tuples.

## SUMMARY

In this paper, the DOCSIS multicast profile management mechanisms based on different implementations were proposed, which can be regarded as the supplement methods of the SDN-Cable TR about the DOCSIS 3.1 downstream profile management. For the external case, the authors proposed the multicast profile management interface which is used for the PMA-CMTS profile management interactions.

## REFERENCES

[1] CableLabs, DOCSIS 3.1 MAC and Upper Layer Protocols Interface Specification, CM-SP-MULPIv3.1.

[2] SDN Architecture for Cable Access Networks Technical Report, VNE-TR-SDN-ARCH, 2015.

[3] Karthik Sundaresan, Applications Architecture for DOCSIS 3.1 Deployments – DOCSIS 3.1 Profile Management. EXPO'15, Oct. 13-16, New Orleans.