DOCSIS Cable Modem MAC

This lecture describes the most commonly used aspects of the basic (version 1.0) DOCSIS cable modem MAC specification. After this lecture you should be able to: list the main purpose for each of the (5) protocol layers used by a DOCSIS CM, explain two reasons for the differences between upstream and downstream MAC protocols, decode the information contained in the MAP frame time allocation information element, and list the PHY parameters adjusted during ranging.

DOCSIS MAC Layers

The DOCSIS Layer 2 (Data Link Layer) and Layer 3 (Network) protocol layers sit above the Physical layer (Layer 1) and are responsible for converting IP frames to/from frames that can be transmitted/received as DOCSIS physical-layer signal.

DOCSIS uses the IEEE 802 L2 and IETF IP L3 protocols. This means that CMs have 48-bit MAC addresses and 32-bit IPv4 addresses and make use of the same bridging and routing algorithms as Ethernet LANs and TCP/IP networks.

The CM acts as a L2 bridge between the cable and Ethernet interfaces. This bridge can be configured with filtering rules by the service provider. For examples these rules would typically prevent forwarding Ethernet traffic that was local to the customer's network.

The following diagram, from the DOCSIS 1.0 specification, shows the various protocol layers involved and that will be discussed in more detail below:

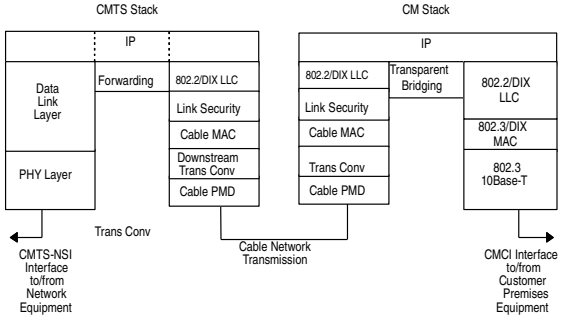

Figure 3-2. Data Forwarding Through the CM and CMTS

- the IP layer is used to interface to customer equipment (CPE) and for CM configuration and management.
- the 802.2/DIX frame format, used internally only, defines a L2 framing format similar to Ethernet (802.3).
- the "Cable MAC" is a DOCSIS-specific protocol layer described below.
- the "Trans Conv" layer represents the MPEG transport stream protocol in the downstream direction.
- the PMD (Physical Medium Dependent) layer is the "PHY" which was described in the previous lecture.

Upstream and downstream are on different frequencies so, unlike Ethernet, CMs do not receive each others' frames. All broadcast communication including coordination to avoid collisions, has to be done by the CMTS.

The description below is a high-level overview of the DOCSIS 1.0 MAC layer functions. Later versions added backwards-compatible features to improve performance, particularly for the upstream and for constant-bit-rate data sources such as cable telephony.

Use of IP

In addition to using IP to interface to the customer's computer (customer premises equipment, CPE), the CM also implements a L3 IP protocol stack which is used for management and configuration of the CM using the SNMP (network management), TFTP (file transfer) and DHCP (host configuration) protocols, all over UDP. For example, the the CM can download firmware or configuration file updates using TFTP and get IP network configuration information using DHCP. The service provider (or user) can read CM status using SNMP.

DOCSIS MAC Framing

In addition to the IP and 802 frames, DOCSIS defines an additional layer of framing. These DOCSIS MAC frames may themselves contain data frames (802 frames, for example) or they may contain DOCSIS-specific frames carrying timing information or management frames. These DOCSIS MAC frames include frames that describe the upstream channel and allow for request/response exchanges for registration, ranging (distance/delay measurement), encryption key distribution, etc. as well as the upstream channel allocation (MAP) frame described below.

Downlink Framing

The downstream has a single transmitter for each channel so there is no contention for media access.

The downstream PHY was originally designed to carry video in an MPEG transport stream consisting of a sequence of 188-byte frames containing a 4-byte header and 184-byte payload. DOCSIS uses frames whose MPEG header has a PID (packet ID) value of 0x1FFE to distinguish DOCSIS frames from video frames that might be transmitted on the same data stream.

DOCSIS MAC frames are split up to fit the fixed-length MPEG frames and may span multiple MPEG frames.

Exercise 1: List the protocol layers (headers) between the PHY and the payload of a downstream SNMP frame. *Hint: Assume SNMP uses UDP.*

Uplink Framing

The upstream has one receiver and multiple transmitters so the upstream channel time is divided into time slots that are allocated to different CMs' uplink transmissions. The CMTS provides timing reference for upstream transmissions and allocates time slots to the CMs.

Some slots are left unallocated for contention-based transmission of requests for upstream channel time. The contention protocol is slotted Aloha – transmissions are aligned to start at mini-slot boundaries. An exponentially-increasing "contention window" size is used – the backoff is chosen randomly within a contention window that doubles for each un-acknowledged transmission.

Various techniques (e.g. "piggybacking" and "concatenation") are used to improve the efficiency of the upstream MAC for various types of traffic. We will not cover these.

Time slots are allocated to 14-bit "Service IDs" (SIDs). A CM may be allocated more than one SIDs. For example, one SIDs may be assigned for constant-bit-rate traffic for cable telephony and another for bursty data.

The upstream time is divided into mini-slots that are powers-of-2 multiples of 6.25μs between 6.25 and 800 (128$\times$).

A DOCSIS MAC "MAP" frame describes the allocation of subsequent uplink channel time. The CMTS may allocate the uplink time for ranging and contention access as well as contention-free time allocations for each SID. The allocation for each SID is encoded as a 32-bit descriptor with a 14-bit SID, a 4-bit "interval usage code" and a 14-bit offset in units of mini-slots.

The following diagram, also from the DOCSIS 1.0 spec, shows the format of the MAP information:

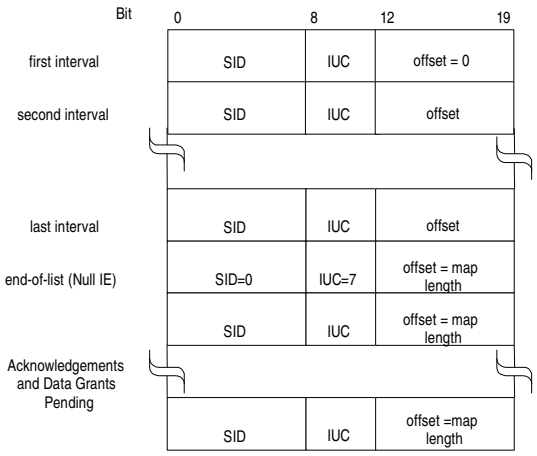

Figure 6-19. MAP Information Element Structure

Exercise 2: Assuming the maximum number of CMs per uplink is determined by available SIDs, each CM is allocated two SIDs and only SIDs from 0x0001 to 0x1FFF are available, how many CMs could be supported per uplink channel? What is the longest time offset that can be specified in a MAP frame assuming the length of a mini-slot is 25μs?

Uplink Ranging

When a CM first starts up it searches for a downstream channel. Once it has found a suitable channel it must measure the delay between it and the CMTS so that upstream transmissions are properly timed and do not interfere with other upstream transmissions.

To do this the CM transmits a Ranging Request frame during a portion of the uplink channel time allocated specifically for these requests. The CMTS measures the arrival time, frequency offset and power level of the ranging request frame. This information is transmitted on the downlink in a Ranging Response frame which also allocates a temporary SID. The CM adjusts its transmit parameters and transmits further Ranging Request frames and uses the received Ranging Response frames to fine-tune the PHY parameters.