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# S T A N D A R D S

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**Network Operations Subcommittee**

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**AMERICAN NATIONAL STANDARD**

**ANSI/SCTE 25-2 2017**

**Hybrid Fiber Coax Outside Plant Status Monitoring –  
Media Access Control (MAC) Layer Specification v1.0**

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## Introduction

This document is identical to SCTE 25-2 2008 except for informative components which may have been updated such as the title page, NOTICE text, headers and footers. No normative changes have been made to this document.

The Hybrid Fiber Coax (HFC) Outside Plant (OSP) Media Access Control (MAC) Layer Specification is part of the suite of specifications developed by the Hybrid Management Sub-Layer (HMS) subcommittee under the SCTE. The purpose of the HMS specifications is to support the design and implementation of interoperable management systems for evolving HFC cable networks. The HMS Media Access Control (MAC) Layer Specification describes the messaging and protocols implemented at the Data Link Layer (DLL), Layer 2 in the 7-layer ISO-OSI reference model, that support reliable and efficient communications between HMS-compliant transponders interfacing to managed OSP network elements (NEs) and a centralized headend element (HE).

### 1.1 Scope

This specification describes the MAC layer protocols that must be implemented between all *Type 2* and *Type 3* compliant OSP HMS transponders on the HFC plant and the controlling equipment in the headend to support bandwidth management and reliable communications. Any exceptions to compliance with this specification will be specifically noted in this document as necessary. Refer to **Table 1** for a full definition of the Type Classifications.

### 1.2 Transponder Type Classifications

Transponder type classifications referenced within the HMS suite of specifications are defined in **Table 1**.

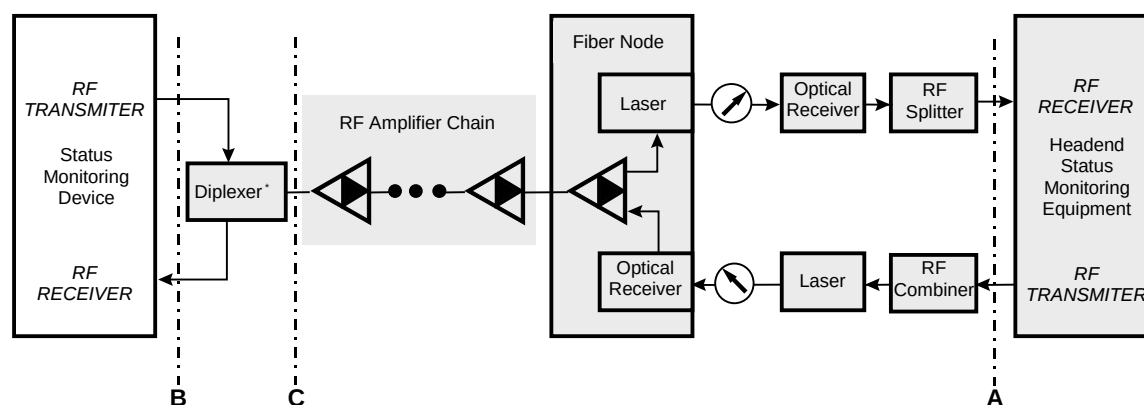
**Table 1: Transponder Type Classifications**

| <b>Type</b>   | <b>Description</b>                                                                                                   | <b>Application</b>                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------|----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Type 0</i> | Refers to legacy transponder equipment which is incapable of supporting the HMS specifications.                      | <ul style="list-style-type: none"> <li>• This transponder interfaces with legacy network equipment through proprietary means.</li> <li>• This transponder could be managed through the same management applications as the other types through proxies or other means at the headend.</li> </ul>                                                                                                                              |
| <i>Type 1</i> | Refers to stand-alone transponder equipment (legacy or new) which can be upgraded to support the HMS specifications. | <ul style="list-style-type: none"> <li>• This transponder interfaces with legacy network equipment through proprietary means.</li> <li>• Type 1 is a standards-compliant transponder (either manufactured to the standard or upgraded) that connects to legacy network equipment via a proprietary interface.</li> </ul>                                                                                                      |
| <i>Type 2</i> | Refers to a stand-alone, HMS-compliant transponder.                                                                  | <ul style="list-style-type: none"> <li>• This transponder interfaces with network equipment designed to support the electrical and physical specifications defined in the HMS standards.</li> <li>• It can be factory or field-installed.</li> <li>• Its RF connection is independent of the monitored NE.</li> </ul>                                                                                                         |
| <i>Type 3</i> | Refers to a stand-alone or embedded, HMS-compliant transponder.                                                      | <ul style="list-style-type: none"> <li>• This transponder interfaces with network equipment designed to support the electrical specifications defined in the HMS standards.</li> <li>• It may or may not support the physical specifications defined in the HMS standards.</li> <li>• It can be factory-installed. It may or may not be field-installed.</li> <li>• Its RF connection is through the monitored NE.</li> </ul> |

### 1.3 HMS Reference Architecture Forward and Return Channel Specifications

The reference architecture for the HMS suite of specifications is illustrated in **Figure 1**.

**Figure 1: HMS Reference Architecture Diagram**



\* The diplexer filter may be included as part of the network element to which the transponder interfaces, or it may be added separately by the network operator.

All quantities relating to forward channel transmission or reverse channel reception are measured at point A in **Figure 1**. All quantities relating to forward channel reception or reverse channel transmission are measured at point B for two-port devices and point C for single-port devices as shown in **Figure 1**.

## 1.4 HMS Specification Documents

A list of documents in the HMS specifications family is provided in **Table 2**.

**Table 2: HMS Document Family**

| HMS Notation           | Title                                                                                                 |
|------------------------|-------------------------------------------------------------------------------------------------------|
| SCTE HMS PHY           | HMS Outside Plant Status Monitoring – Physical (PHY) Layer Specification                              |
| SCTE HMS MAC           | HMS Outside Plant Status Monitoring – Media Access Control (MAC) Layer Specification                  |
| SCTE HMS PSTIB         | HMS Outside Plant Status Monitoring – Power Supply to Transponder Interface Bus (PSTIB) Specification |
| SCTE HMS ALARMS MIB    | HMS Alarms Management Information Base                                                                |
| SCTE HMS COMMON MIB    | HMS Common Management Information Base                                                                |
| SCTE HMS FIBERNODE MIB | HMS Fiber Node Management Information Base                                                            |
| SCTE HMS PROPERTY MIB  | HMS Alarm Property Management Information Base                                                        |
| SCTE HMS PS MIB        | HMS Power Supply Management Information Base                                                          |
| SCTE ROOT MIB          | SCTE Root Management Information Base                                                                 |
| SCTE HMS GEN MIB       | HMS Power Supply Generator Management Information Base                                                |
| SCTE HMS TIB MIB       | HMS Transponder Interface Bus Management Information Base                                             |
| SCTE HMS DOWNLOAD MIB  | HMS Transponder Firmware Download Management Information Base                                         |
| SCTE HMS TREE MIB      | HMS Root Object Identifiers Management Information Base                                               |

## 2 Media Access Control Layer Specification

### 2.1 Introduction

#### 2.1.1 Overview

This section describes version 1.0 of the SCTE HMS MAC protocol. Some of the SCTE HMS MAC protocol features include:

- Support for transaction-based message exchange over the HFC forward and return RF channels. Transactions can be initiated by either the HE or the NE.
- Support for transport of multiple network PDU types over the HFC forward and return RF channels including, but not limited to, IP over Serial and SNMP over Serial.
- Extensions provided to support future transport of other network PDU types.
- Efficient use of HFC forward and return RF spectrum through central HE management of NE transmission opportunities.

#### 2.1.2 Definitions and Conventions

##### 2.1.2.1 Separate Forward and Return Channels

The one-way communication channel from the HE to a managed OSP NE is referred to as the *forward* channel. The one-way communication channel from a managed OSP NE to the HE is referred to as the *return* channel. Both the forward and the return channels are placed on specific center frequencies. The forward and return channels' center frequencies are different. Since the NEs only listen to the forward channel, they cannot listen to return channel transmissions from other NEs. This channel separation is a result of the sub-band split between the forward and return portions of the typical HFC plant spectrum.

##### 2.1.2.2 Single Forward and Return Path Channels per MAC Layer Domain

To keep management of carrier frequencies simple, each HMS-based status monitoring system has a single forward channel and a single return channel. This does not preclude the use of multiple monitoring systems, each with its own individual forward and return RF channels.

A MAC layer domain consists of a single forward RF channel and a single return RF channel over which a single HMS MAC layer bandwidth allocation and management protocol operates. It includes a centralized HE and multiple HMS-compliant transponders interfacing to managed OSP NEs. The centralized HE may support multiple HMS-based status monitoring systems, i.e.: multiple MAC layer domains. Each OSP NE must only access a single forward channel and its associated single return channel; i.e.: it must only operate within a single HMS MAC layer domain.

### 2.1.2.3 Network Element (NE) Term Usage

The HMS MAC layer supports bandwidth management and reliable communications between a HE and multiple HMS-compliant transponders that interface to managed OSP NEs. Throughout this document, the terms “HMS-compliant transponder”, “transponder”, and “NE” are used interchangeably when describing the MAC processes that support the exchange of data or other information between two or more entities at the DLL.

### 2.1.2.4 Packet

A packet is a unit of data exchanged between the HE and any of a number of managed OSP NEs at the DLL. Packets are strings of bytes that can be sent contiguously or be separated by periods of silence. Document SCTE 25-1 *HMS Outside Plant Status Monitoring – Physical (PHY) Layer Specification v1.0* describes specific byte transmission modes that must be implemented in both forward and return channels. A MAC packet consists of a MAC header, a variable-length payload, and a frame check sequence (see Section 2.3).

### 2.1.2.5 Most Significant Byte

Unless otherwise specified, it is assumed throughout this document that the left-most entry in any numeric value is the most significant, i.e.: for the address represented as 12-34-56-78-9A-BC the left-most entry ‘12’ is the most significant value.

### 2.1.2.6 Byte Number Representation

Throughout this document, bits labeled ‘0’ are the least significant bits (LSBs) and bits labeled ‘7’ are the most significant bits (MSBs). The bits in a given byte will be described with bit 7 (MSB) at the left and bit 0 (LSB) at the right. This convention has been adopted for presentation purposes only and has no effect on the actual bit transmission order. Bit transmission order details are provided in Section 2.2 of this specification.

### 2.1.2.7 Reserved Bits

A number of bits are indicated with the word “Reserved” or the abbreviation “RSVD” in the various MAC packets described in this document. Any receiving NE must ignore these bits when implementing this version (1.0) of the HMS MAC protocol.

## 2.2 MAC Packet Transport

### 2.2.1 Byte Transmission Format

Bytes transmitted over both forward and return channels are ten bits in length. They contain one start bit, eight bits of data, and one stop bit. The start bit has binary value '0', and the stop bit has binary value '1.'

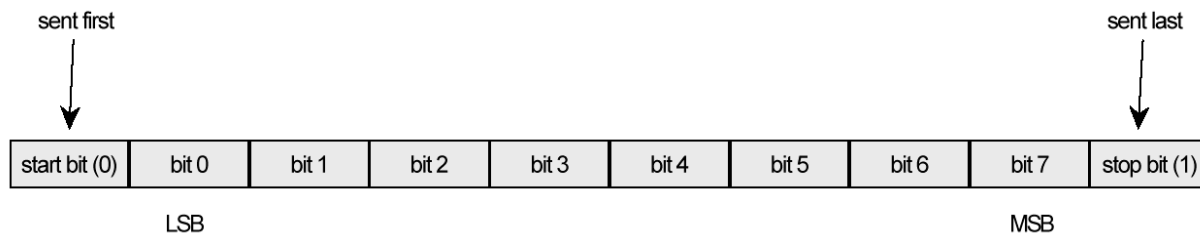
### 2.2.2 Byte Transmission Order

Fields consisting of multiple bytes, i.e.: a MAC address, will have the most significant byte transmitted first. Any exceptions to this rule will be specifically noted in this document as necessary.

### 2.2.3 Bit Transmission Order

The LSB of a single byte, bit 0, is always transmitted first following the start bit. The MSB of a single byte, bit 7, is always transmitted last followed by the stop bit. The transmission order is summarized in **Figure 2**.

**Figure 2: Bit Transmission Order**



### 2.2.4 Transmission Timing

#### 2.2.4.1 Forward Channel Packets

##### 2.2.4.1.1 Timing

Forward channel packets must be transmitted in a manner such that,

1. No two bytes within a packet are separated by more than 3 ms, AND
2. The entire packet must be transmitted within 120% of the *shortest* time for that frame. The shortest time is defined as the time for transmission of the packet with no gaps between bytes.

## 2.2.4.2 Return Channel Packets

### 2.2.4.2.1 Front Porch

NE transmission of the first byte of a message shall begin within a window of two and five byte times after the transmitter power reaches 90% of its final value. Until the first byte is transmitted, the frequency will rest on the 'mark' frequency. This is standard Universal Asynchronous Receiver/Transmitter (UART) transmission. The front porch ensures that the receiving UART can be cleared of all framing errors prior to the start of reception of valid data.

### 2.2.4.2.2 Timing

Return channel packets must be transmitted in a manner such that no two bytes within a packet are separated by more than 260  $\mu$ s (1 byte time). All bits within a single byte shall be immediately contiguous; there shall be no gaps at bit boundaries within a byte.

## 2.3 MAC Packet Structure

MAC packets consist of a MAC header, a variable-length payload, and a two-byte frame check sequence. Packet structure and sizes are identical for both forward and return channel packets. MAC packet structure is illustrated in **Figure 3**.

**Figure 3: MAC Packet Structure**

| Start |         |         |          |        |         |     | End |
|-------|---------|---------|----------|--------|---------|-----|-----|
| Synch | Control | Address | Sequence | Length | Payload | FCS |     |

All MAC packets must have the general format as described in **Table 3**.

**Table 3: Generic MAC Packet Structure**

| Field Name | Length (bits) | Section |
|------------|---------------|---------|
| Synch      | 8             | 2.3.1   |
| Control    | 8             | 2.3.2   |
| Address    | 48            | 2.3.3   |
| Sequence   | 8             | 2.3.4   |
| Length     | 16            | 2.3.5   |
| Payload    | N             | 2.3.6   |
| FCS        | 16            | 2.3.7   |

### 2.3.1 Synch

The Synch field consists of a single byte and identifies the start of the MAC layer packet. It shall be set to 0xA5.

### 2.3.2 Control

The Control field consists of a single byte and defines the type and format of the Payload field. The bit definition of the Control byte is shown in **Figure 4**. The Control field also serves, in conjunction with the Synch, Length and FCS fields, as a packet delimiter as described in Section 2.4.

**Figure 4: MAC Header Control Byte – Bit Definition**

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3    | Bit 2 | Bit 1 | Bit 0 |
|-------|-------|-------|-------|----------|-------|-------|-------|
| RSVD3 | RSVD2 | RSVD1 | RSVD0 | Protocol |       |       |       |

#### 2.3.2.1 Protocol (Bits 3:0)

The four-bit protocol field indicates the type of protocol to be used to interpret the payload field of the MAC layer packet. In addition, the protocol field allows the message service handler to pass messages with alternative protocol values to other upper layer processes without having to unravel the entire message. The value represented by the protocol field shall be as assigned in **Table 4**.

**Table 4: Protocol Field Values**

| Description                       | Binary Value  |
|-----------------------------------|---------------|
| MAC Management Message            | 0000          |
| SNMP over Serial (see note below) | 0001          |
| IP over Serial                    | 0010          |
| SNMP Trap over Serial             | 0011          |
| <i>Available for Future Use</i>   | 0100 to 1111* |

\*Protocol 0101 is not allowed to prevent accidental creation of a Synch byte (0xA5).

#### Note

This is SNMPv1 as defined by RFC 1157. However, the UDP and IP protocols are not used for this implementation. Thus, all references by RFC 1157 to UDP are not relevant. Section 3.2.4 of RFC 1157 explains how the SNMP mechanisms are suitable over different transport protocols. Sections 4 and 4.1 of RFC 1157 explain this further. In fact, in Section 4.1, the RFC states: “Other transport services may be used to support the SNMP.”

#### 2.3.2.2 RSVDx (Bits 7:4)

The bits identified as RSVD are reserved for future use. They must be set to 0.

### 2.3.3 Address

The Address field consists of six bytes. It is used to address devices on a unicast, multicast, or broadcast basis. The address field follows the IEEE Organizationally Unique Identifier (OUI) Std 802 usage for a Universal address. For clarity, this document conforms to the address documentation suggested by the IEEE as follows:

1. Each byte is represented as a two digit hexadecimal numeral (with no radix identification) using leading zeroes where the first (left-most) digit of the pair is the most significant.
2. Each byte is separated by hyphens, with the most significant byte in the left-most position.

An example address is 00-AA-BB-00-43-21.

A Universal address is a sequence of six bytes. The first three take the values of the three bytes of the OUI in order. The last three bytes are administered by the assignee. The binary representation of an address is formed by taking each byte in order and expressing it as a sequence of eight bits, LSB to MSB, left to right. For example, the OUI AC-DE-48 could be used to generate the address

AC-DE-48-00-00-80

Whose binary representation is:

| First Byte<br>of OUI | Second Byte<br>of OUI | Third Byte<br>of OUI |           |           |           |
|----------------------|-----------------------|----------------------|-----------|-----------|-----------|
| 0011 0101            | 0111 1011             | 0001 0010            | 0000 0000 | 0000 0000 | 0000 0001 |
|                      |                       |                      |           |           |           |
| I/G Address Bit      |                       |                      |           |           |           |
|                      |                       |                      |           |           |           |
| LSB MSB              | LSB MSB               | LSB MSB              | LSB MSB   | LSB MSB   | LSB MSB   |
| C A                  | E D                   | 8 4                  | 0 0       | 0 0       | 0 8       |

The first (left-most) bit in the binary representation of the MAC address is the I/G (Individual/Group) Address Bit. This bit is the LSB of the most significant byte. When set to 0 as shown above, it indicates an individual address. It may be set to 1 in an address allocated by the assignee to indicate that that address is a group address. For example, the same OUI above could be used to generate the Group Address

AD-DE-48-00-00-80

| First Octet<br>of OUI | Second Octet<br>of OUI | Third Octet<br>of OUI |           |           |           |
|-----------------------|------------------------|-----------------------|-----------|-----------|-----------|
| 1011 0101             | 0111 1011              | 0001 0010             | 0000 0000 | 0000 0000 | 0000 0001 |
|                       |                        |                       |           |           |           |
| I/G Address Bit       |                        |                       |           |           |           |
|                       |                        |                       |           |           |           |
| LSB MSB               | LSB MSB                | LSB MSB               | LSB MSB   | LSB MSB   | LSB MSB   |
| D A                   | E D                    | 8 4                   | 0 0       | 0 0       | 0 8       |

The address shall be transmitted most significant byte first and least significant byte last.

### 2.3.3.1 Unicast

The Unicast address is the unique address assigned to a particular NE. An NE transmitting a message places its unicast address in the Address field, most significant byte first. This address is completely unique across all manufacturers. By definition, the I/G bit is set to 0.

Each vendor shall obtain an address prefix, or OUI, from the IEEE and assign a unique address using this prefix to each HMS-compliant transponder at time of manufacture. This is the Unicast address for that NE. This document places no restriction on the number of OUIs a single manufacturer may obtain as the IEEE governs that. An OUI assignment allows the assignee to generate approximately 16 million addresses by varying the last three octets.

### 2.3.3.2 Broadcast

A message with a Broadcast address is intended for all NEs that receive it. All NEs must support the Broadcast address. The Broadcast address is FF-FF-FF-FF-FF-FF.

### 2.3.3.3 Multicast

The Multicast address follows the IEEE Std 802 for indicating a Group Address; i.e., the I/G Address Bit is set to 1.

A Multicast address defines a group to which zero, one, or more than one NE has been assigned by a higher level management system. A NE maintains a list of multicast addresses to which it will respond. A NE is a member of a particular multicast group if at least one of its provisioned multicast addresses matches that particular multicast address. The assignment and usage of multicast addresses is out of the scope of this specification. However, examples might be fault isolation, frequency changes, and firmware downloads.

All NEs must support a minimum of four (4) multicast addresses not counting the Broadcast address. This specification places no maximum limit on the number of multicast address groups a NE may support.

Multicast addresses are *not* assigned at manufacture. The network provider provisions multicast addresses into the NE. The method for this provisioning is out of the scope of this specification. To avoid accidental assignment to the wrong multicast address, all multicast addresses held at the NE shall default to the Broadcast address prior to provisioning.

### 2.3.4 Sequence

The HMS MAC protocol is transaction-based; i.e., every originating message from a “requestor” has a corresponding response from the “responder” regardless of which device originated the message. The Sequence field consists of a single byte and defines a message sequence number to ensure message exchanges are synchronized. In order to handle possible loss of messages in either the forward or the return channel, and to avoid duplication of messages at the application

layer, all messages have a sequence number. The bit definition of the Sequence byte is shown in **Figure 5**.

**Figure 5: MAC Header Sequence Byte – Bit Definition**

| Bit 7 | Bit 6  | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|-------|--------|-------|-------|-------|-------|-------|-------|
| SYN   | MSGSEQ |       |       |       |       |       |       |

#### 2.3.4.1 MSGSEQ (Bits 6:0)

The 7-bit MSGSEQ field indicates the message sequence number. Sequence numbers are generated by either the HE or NE. Sequence number generation, modification and elicited behavior must conform to the following rules:

1. HE-originated transactions will have bit 6 of the MSGSEQ field set to 1. Thus, the range for HE-generated sequence numbers is 0x40 through 0x7F with wraparound to 0x40.
2. The HE shall generate and track sequence numbers per unicast address.
3. HE-generated messages directed to broadcast or multicast addresses; i.e., where the I/G bit is set to 1, shall have a sequence number of 0 since this field is ignored by the NE for multicast and broadcast messages. Upon receiving a valid broadcast or multicast message from the HE, the NE shall not change the last received HE sequence number. The NE shall *always* process broadcast or multicast messages regardless of sequence number.
4. NE-originated transactions will have bit 6 of the MSGSEQ field set to 0. Thus, the range for the NE is 0x00 through 0x3F with wraparound to 0x00.
5. As a requestor, the NE can have only a single originating message requiring a response outstanding at any time (see Section 3.8). Thus, the NE only needs to track the sequence number for this single value.
6. The MSGSEQ field is incremented by the originator of the number. The sequence number shall be incremented only:
  - a. When a response is received with a matching sequence number (excluding the SYN bit, see Section 2.3.4.2); or
  - b. When a requestor's maximum allowed number of MAC layer transmission retries has been exceeded. The MSGSEQ shall not change if a message must be retransmitted at the MAC layer, which occurs only when a response or acknowledgement has not been received within a pre-determined timeout window, and the maximum allowed number of MAC layer transmission retries for this message has not been exceeded. See Section 3 of this specification for additional details on MAC protocol operation.