# Modular CMTS Tutorial

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# Agenda

- **Modular CMTS**
  - **Intro**
- **DEPI: Downstream External PHY Interface**
  - **Intro**
  - **Forwarding Plane**
  - **Control Plane**
- **DTI: DOCSIS Timing Interface**
  - **Intro**
  - **Operation**
- **Summary**

# DEPI Agenda

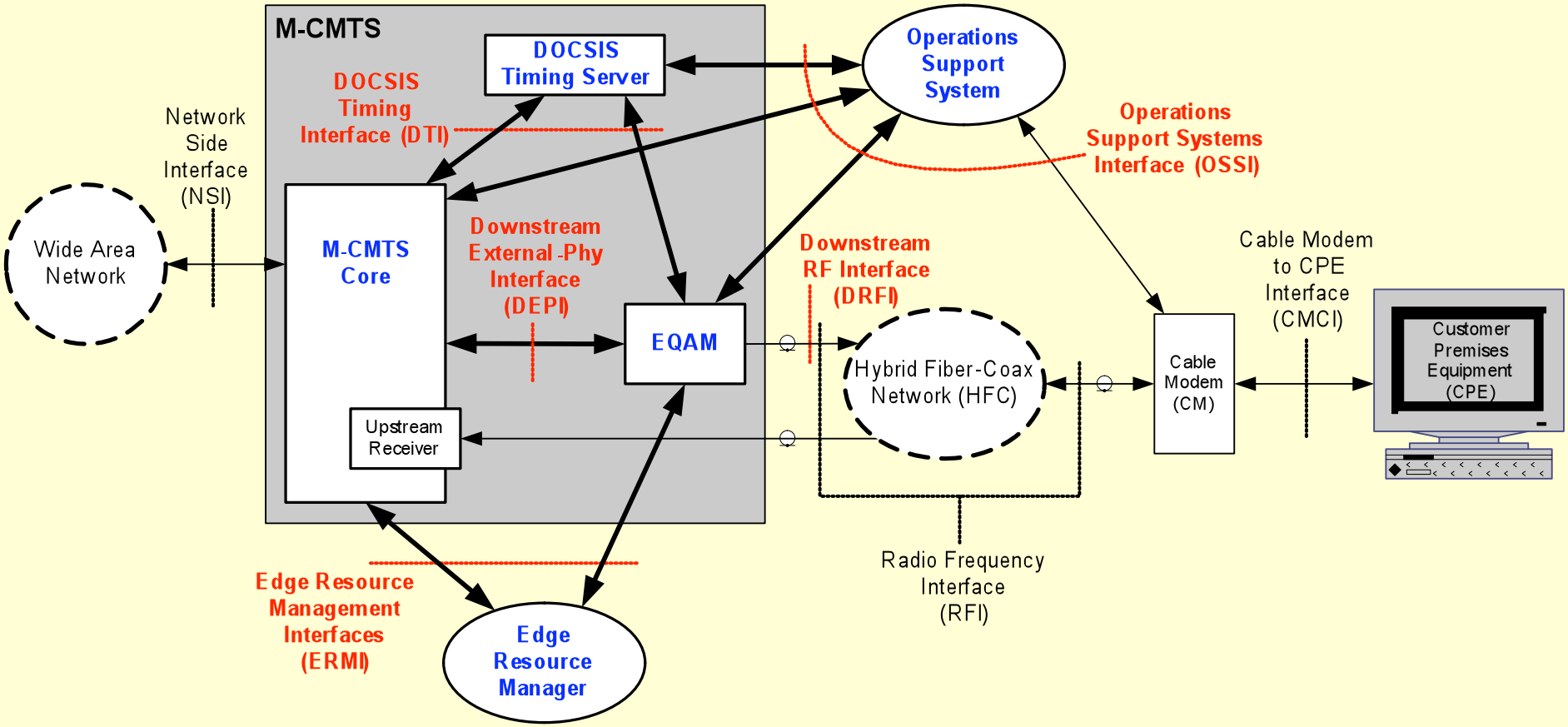
- Quick Intro
- Forwarding Plane
  - Packet Format
  - MPT and PSP Mode
  - DOCSIS SYNC Correction
  - DEPI Latency Measurement (DLM)
- Control Plane
  - Addressing
  - Control Connections, Sessions, and Flows

# Modular CMTS Introduction

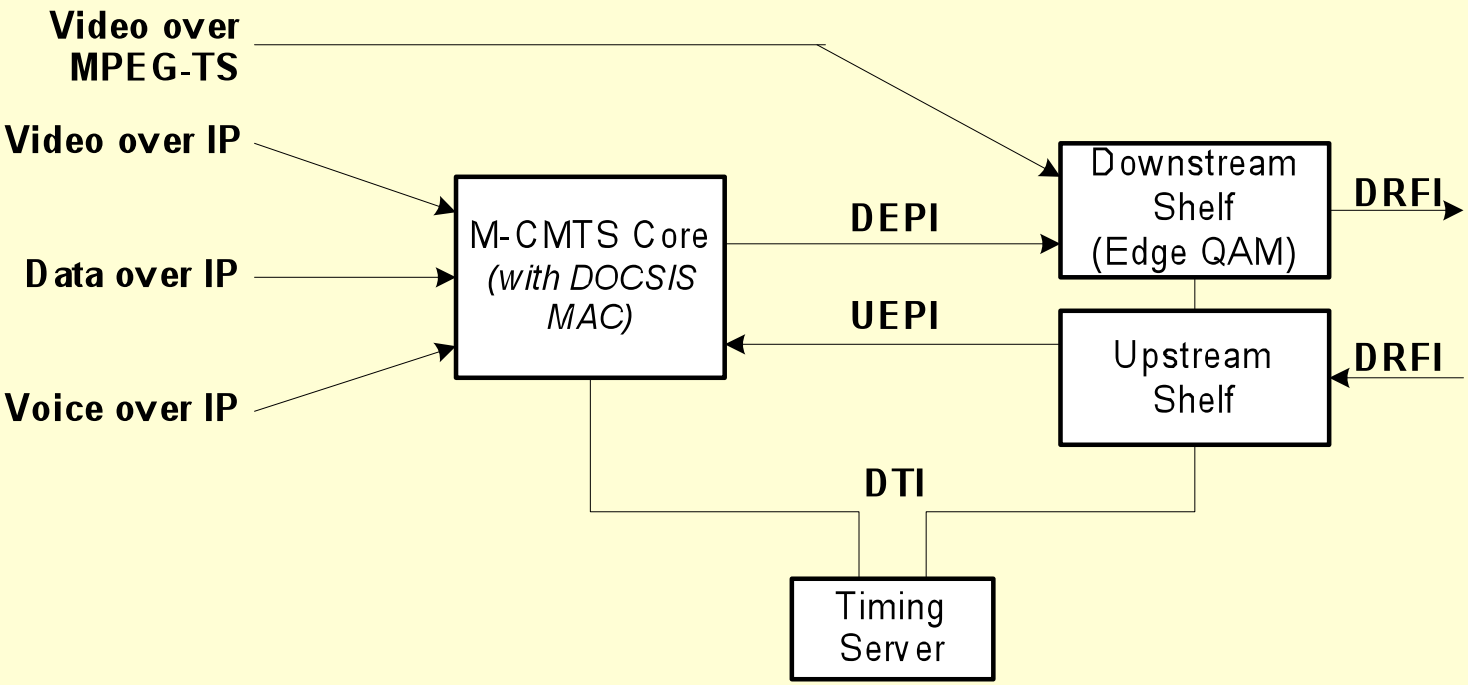
# Origins

- **M-CMTS was primarily architected by Cisco.**
  - **Architectural Lead was John T. Chapman**
  - **The original architecture document is EDCS-376511.**
  - **Current specs are at: http://www.cablemodem.com/specifications/m-cmts.html**
- **Cisco drove the standardization.**
  - **DEPI: Cisco (John) was lead author**
  - **DTI: Symmetricom/Cisco was lead author**
  - **ERMI: Cisco was lead author**
  - **DRFI: Cisco/others**
  - **OSSI: Cisco/others**

# M-CMTS Components and Interfaces



# Basic M-CMTS Block Diagram



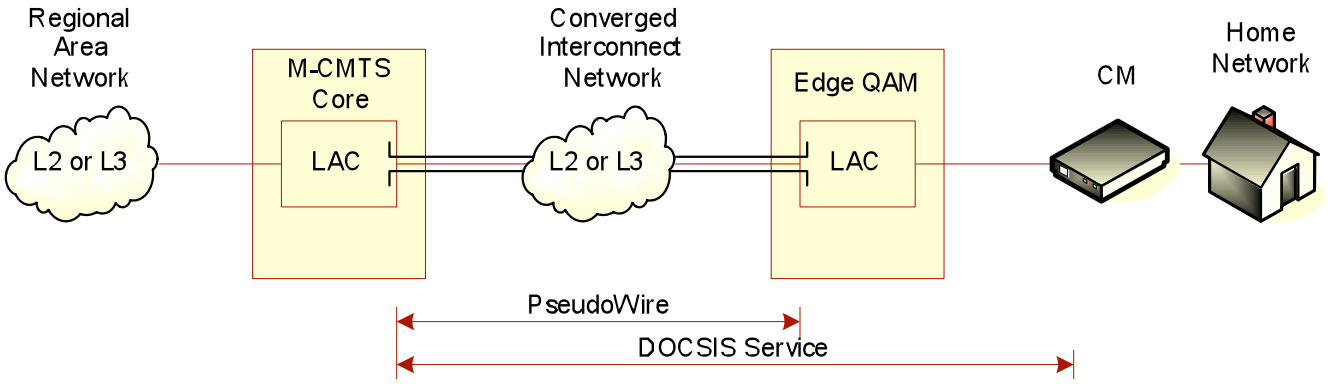

- **UEPI: Upstream is an extension to DEPI and is currently under definition at Cisco.**

# Where to Draw the Line

- **The Modular CMTS architecture separates MAC and PHY into separate chassis. (L2/L1 split)**
  - **In Cisco terms, this is a satellite architecture.**
  - **Primary motivator was to retain current software architecture.**
  - **Secondary motivator was that the Packet Shelf needs hardware to rate shape flows anyway, so it may as well perform framing.**
- **Previously, a L3/L2 split had been tried with the MAC and PHY remote.**
  - **This failed.**
  - **Implementers put entire CMTS design remote as it was too difficult to break up the software model.**

# DEPI Introduction

# DEPI Intro




- **DEPI is an IP Tunnel, known as a pseudowire, that exists in the downstream direction between the DOCSIS MAC in the M-CMTS Core and the DOCSIS PHY that exists in the EQAM.**
- **The CIN (Converged Interconnect Network) may be a Layer 2 or Layer 3 network.**
- **The M-CMTS Core provides the DOCSIS MAC functionality, while the EQAM provides the DOCSIS PHY functionality.**
- **DEPI interfaces the MAC to the PHY.**

# DEPI Intro

- **DEPI uses L2TPv3 (RFC 3931 Layer 2 Tunneling Protocol version 3) as the baseline protocol for the data path and control plane.**
- **DEPI uses two new pseudowire types:**

  **PSP (Packet Streaming Protocol) encapsulates a continuous stream of DOCSIS frames into a DEPI payload.**

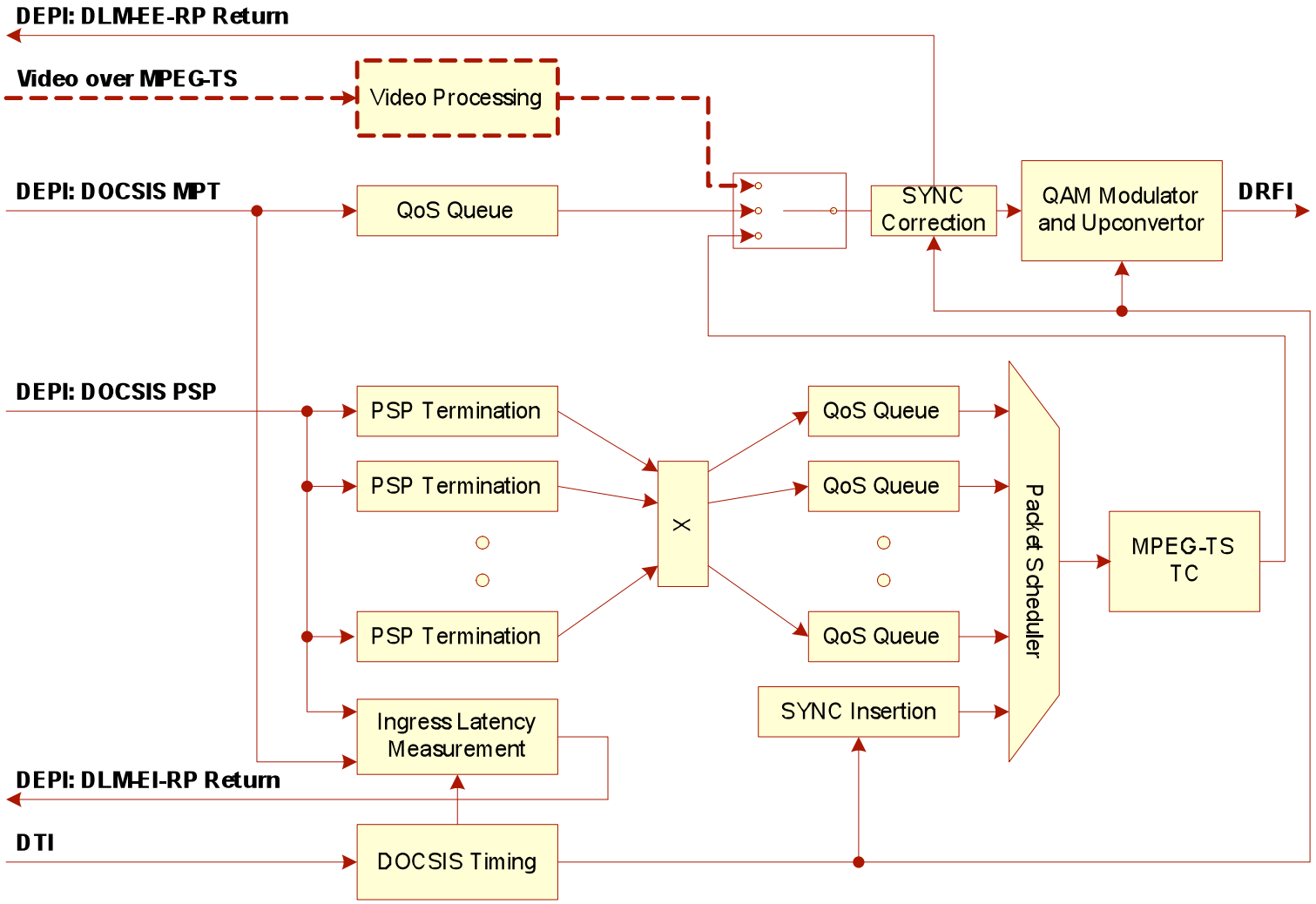
  **MPT (MPEG Transport) encapsulates a group of 188 byte MPEG-TS packets into a DEPI payload.**
- **M-CMTS Core/EQAM must support MPT and/or PSP.**
- **Signaling**

  **DEPI has one (or more) Control Connection between the M-CMTS Core and the EQAM for configuration.**

  **DEPI has one session for each QAM. There are one or more sessions per control connection.**

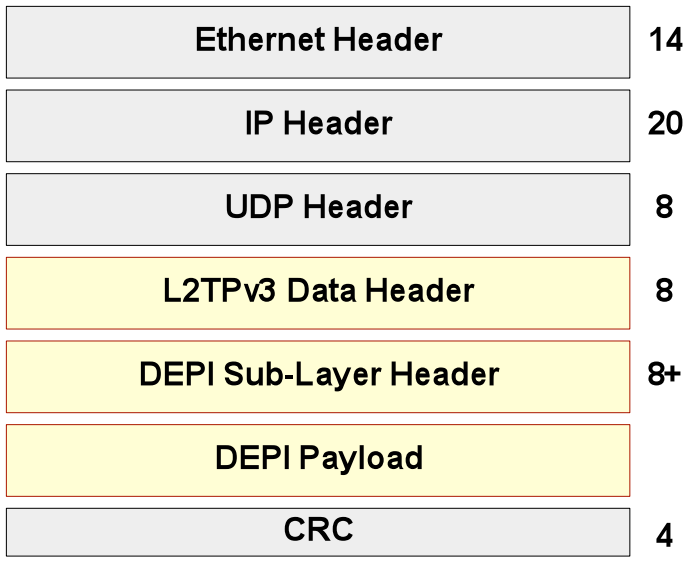
  **DEPI has one or more flows per session for QoS. (Flows are a DEPI specific concept)**

# Edge QAM Block Diagram

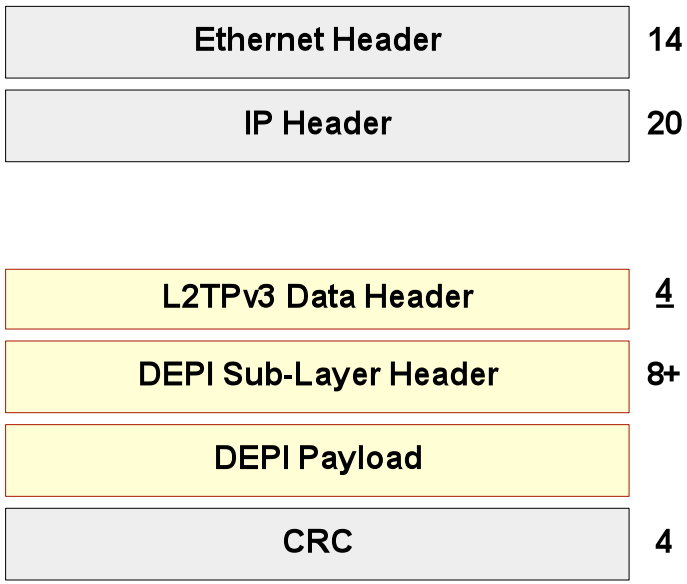


# DEPI Forwarding Plane

# DEPI Data Packet Format



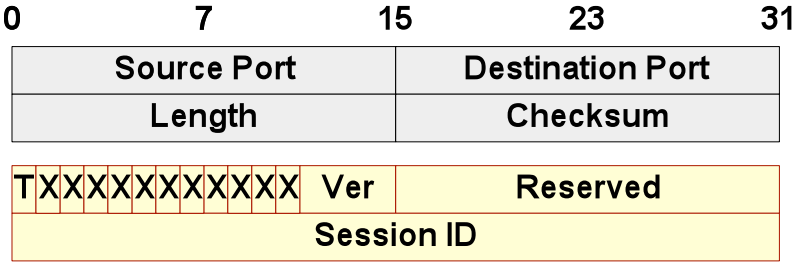

DEPI Data Packet with UDP



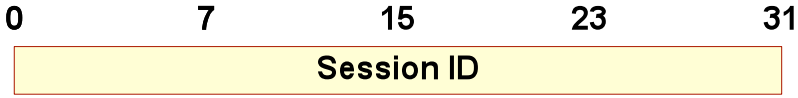

DEPI Data Packet without UDP

- **UDP is optional for DEPI. UDP is allowed for backward compatibility with existing EQAM designs that use UDP port addressing for QAM selection.**
- **L2TPv3 normally does not use UDP.**
- **M-CMTS Core and EQAM are configured (separately from DEPI) whether or not to use a UDP header.**

# L2TPv3 Data Header




L2TP Data Header with UDP Header




L2TP Data Header with no UDP Header

**T** Transport bit. Set to 0 to indicate this is a data message

**Version** Set to 3. (L2TPv3)

**Session ID** This value is negotiated by the L2TPv3 control plane.

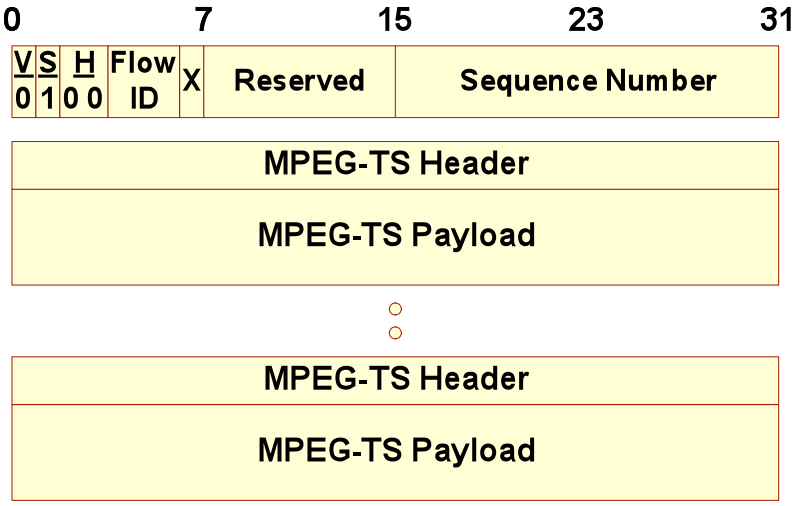
All reserved fields and X bits are set to 0 by M-CMTS Core and ignored by EQAM.

- Note that without UDP, the L2TPv3 Session header is located within the IP packet at the same location as the UDP Source and Destination Port where.
- Eliminating UDP saves 12 bytes and increase QAM addressing from 16 bits to 32 bits.
- The L2TPv3 cookie field is not required to be supported in DEPI.

# DEPI D-MPT Mode

- Similar to MPEG-TS over IP used in video world, except with a L2TP/DEPI header.
- M-CMTS Core and EQAM may allow MPT Mode without a L2TPv3/DEPI header as a pre-standards mode, although this is not a tested or mandatory mode for DEPI.
- One flow per session.

  D-MPT Mode has QoS between the pseudowire and the CIN, but not within the pseudowire.




- 1-7 188 byte MPEG-TS packets per PSP frame for MTU < 1500 bytes.
- Referred to as D-MPT Mode for DOCSIS MPT Mode.

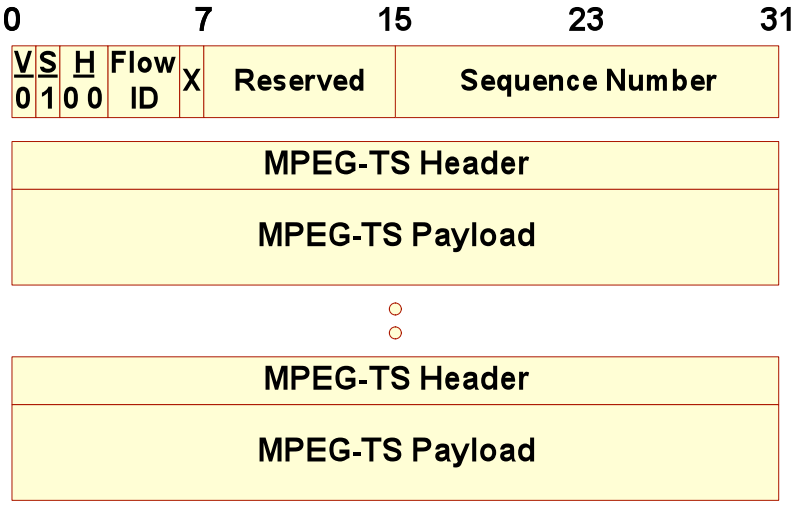
# DEPI MPT Sub-Layer Header

**V** 1 bit. VCCV bit. Set to 0. Reserved for compatibility with the L2TPv3 VCCV protocol.

**S** 1 bit. Sequence bit. Set to 1 to indicate that the sequence number field is valid. Set to 0 to indicate that the sequence field is not valid.

**H** 2 bits. Extended Header bits. Set to '00' to indicate no extended header.

**Flow ID** 3 bits. Flow Identifier.



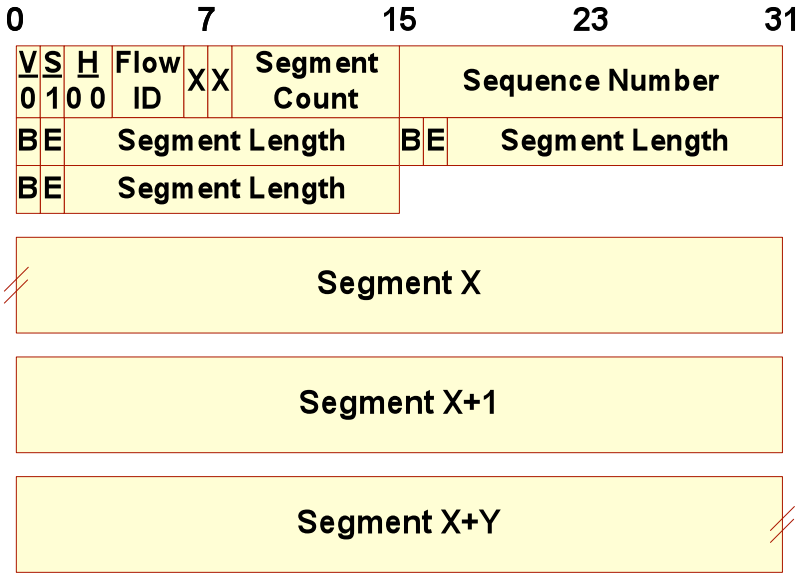

**Sequence Number** 2 bytes. The sequence number increments by one for each data packet sent, and may be used by the receiver to detect packet loss.

**The EQAM does not have to re-sequence packets.**

# DEPI PSP Mode

- Concatenation of DOCSIS frames is done to lower the PPS (packets per second) impact to the intervening network.
- Fragmentation of those concatenation is done to stay within a specified MTU size.
- Multiple Flows allowed per session.

  PSP Mode has QoS between the pseudowire and the CIN and within the pseudowire.
- Packet queuing algorithms (WFQ, DRR, etc) are configured on the EQAM and are not specified by the M-CMTS Core.




- A good mental model for PSP is that DOCSIS frames are placed in a queue, and PSP takes bytes out of that queue.
- PSP is intended to allow MAPs to be sent at a higher priority than data.

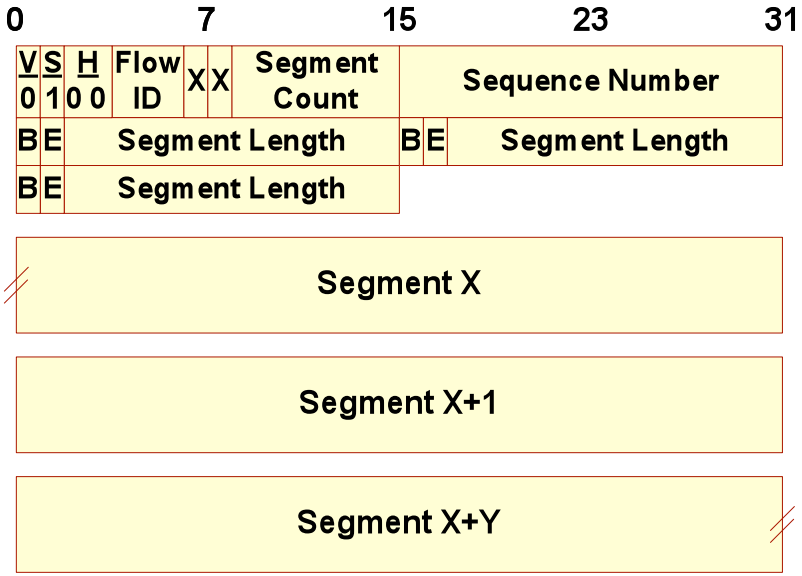
# DEPI PSP Sub-Layer Header

**V, S, H, Flow ID, Sequence Number** Same as MPT Mode.

**Segment Count** 7 bits. This is the number of segments in the DEPI PSP Payload, and this is also the number of 2 byte entries in the PSP Segment Table.

**Segment Length** 14 bits. Length of DEPI segment in bytes.

**B** Begin bit. 1 bit. Set to a 1 to indicate that the PSP Frame contains the beginning of a DOCSIS frame. Otherwise, set to 0.




**E** End bit. 1 bit. Set to a 1 to indicate that the PSP Frame contains the end of a DOCSIS frame. Otherwise, set to 0.

# SYNC Insertion and Correction

- **The SYNC message is a copy of the DOCSIS timestamp. The timestamp is required by the:**
  - **M-CMTS Core MAP Scheduler,**
  - **CM,**
  - **Upstream PHY Receiver,**
  - **and now the EQAM.**
- **CIN jitter can be milliseconds**

  **There is no way that the Core can generate SYNC messages with the required accuracy.**
- **Thus, the EQAM owns the task of generating the SYNC for the DOCSIS downstream.**

  **This is what requires the EQAM to by synchronous. It achieves this synchronization with through DTI.**

# SYNC Insertion and Correction

- **In MPT Mode, the M-CMTS Core provides "dummy" SYNC messages and the EQAM overwrites the with a correct SYNC.**

  **MPT Mode assumes a single stream of MPEG-TS frames generated by the M-CMTS Core and forwarded by the EQAM without interpretation.**

  **This means that the M-CMTS Core sets the DOCSIS SYNC interval.**

- **In PSP Mode, the M-CMTS Core does not generate a SYNC message. The EQAM generates the SYNC.**

  **In practice, it is anticipated the EQAM will generate a dummy SYNC message in the PSP queuing stage, and then correct the SYNC after the TC (Transmission Convergence) stage.**

  **This means that the EQAM sets the DOCSIS SYNC interval.**

# DEPI Latency Measurement (DLM)

**V**, **S**, **Flow ID** as before.

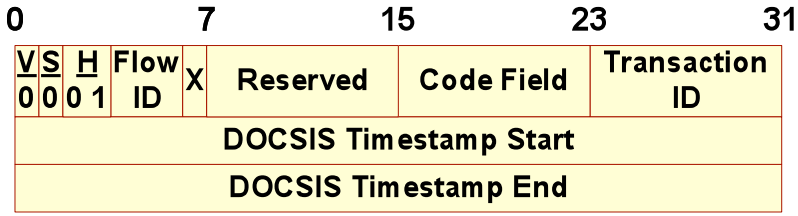
**H** Set to '01' to indicate the presence of the DLM extended header.

**Code Field** DLM Message Type

**Transaction ID** This is a unique ID assigned by the sender and returned by receiver. The transaction ID is unique per session.

**Timestamp Start** Timestamp sent by CMTS Core.

**Timestamp End** Timestamp existing at the EQAM.



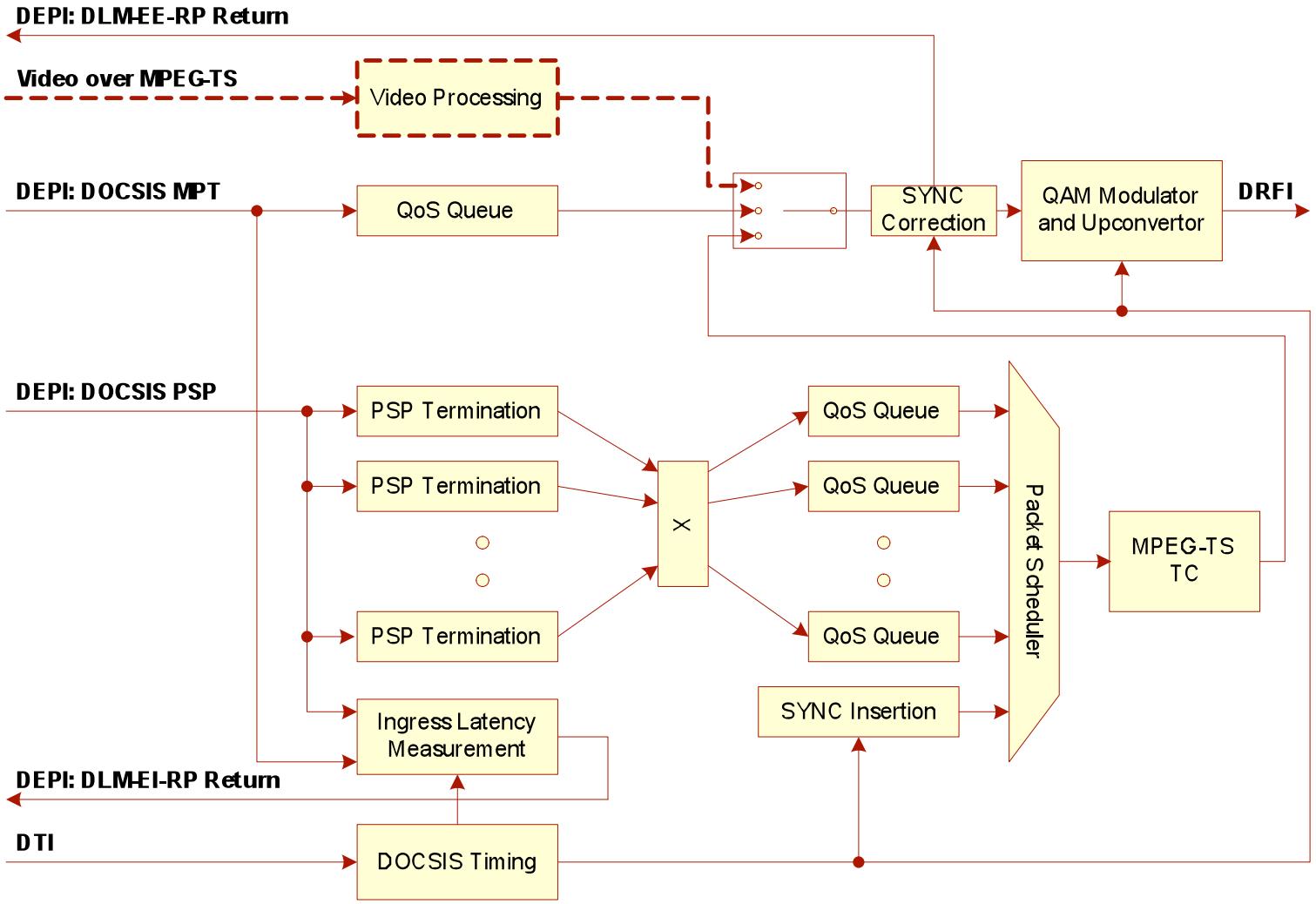

DLM Header

- One-way latency measurement
- Latency can be measured from the M-CMTS Core to either the EQAM ingress or egress.
- M-CMTS performs all analysis and chooses frequency and target of the DLM packet. The EQAM just responds.

# DLM Message Types

- **DLM-EI-RQ (DLM EQAM Ingress Request, type=0). Packet originated by the M-CMTS Core requesting a measurement to be made at reference point adjacent to the DEPI ingress port of the EQAM.**
- **DLM-EI-RP (DLM EQAM Ingress Reply, type=1). Packet originated by the EQAM with a Timestamp End value calculated at reference point adjacent to the DEPI ingress port of the EQAM.**
- **DLM-EE-RQ (DLM EQAM Egress Request, type=2) packet originated by the M-CMTS core requesting a measurement to be made at reference point adjacent to the DEPI egress port of the EQAM.**
- **DLM-EE-RP (DLM EQAM Egress Reply, type=3) packet originated by the EQAM with a Timestamp End value calculated at reference point adjacent to the DEPI egress port of the EQAM.**

# Edge QAM Block Diagram



# Latency and Skew

- **Latency of a QAM Channel**

  **In the absence of higher priority traffic, and regardless of load of lower priority traffic, the EQAM MUST forward isolated packets in each DEPI flow with a latency of less than 500us plus the delay of the interleaver.**

  **Isolated packets are spaced such that, at the nominal downstream data rate, the EQAM would complete transmission of the current packet before the arrival of the next packet.**

- **Skew between QAM Channels**

  **Same as latency requirement.**

# Flow Control

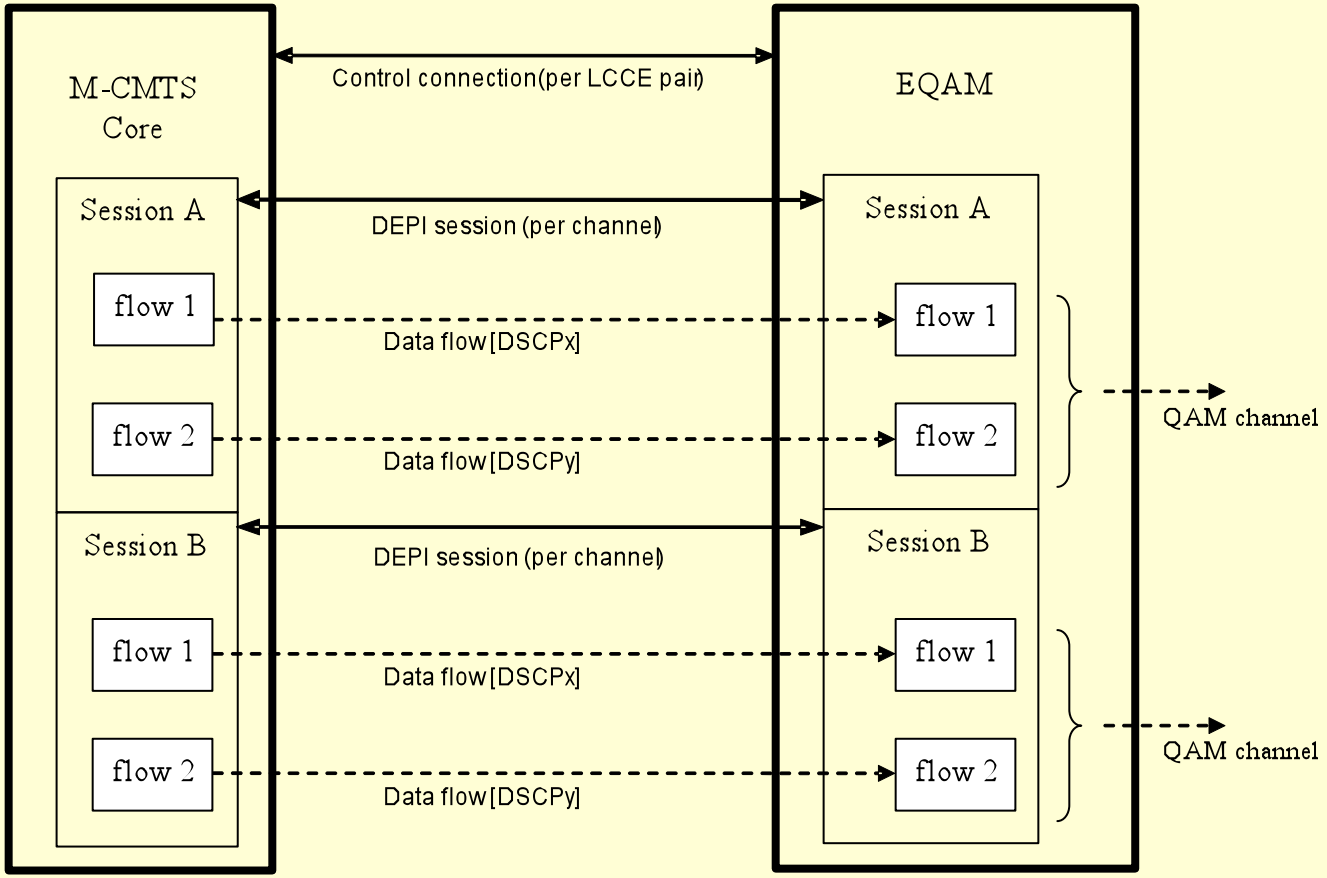
- With potentially a congested multi-hop routing network between the Core and EQAM, there is the possibility for large amounts of jitter on the DEPI flows.
- EQAM will buffer at least 20 ms of data (and perhaps significantly more)
- If the buffer runs dry, the EQAM will insert MPEG Null packets
- To prevent MPEG Nulls from introducing a fixed latency, and to prevent buffer overflow, the Core uses open-loop flow control.

  The MSO configures the Core output rate as a percentage of the RF line rate (e.g. 97%)

# DEPI Control Plane

* Note: more than one image can be used with these segue and Q and A slides, but should never extend past the half grid of the page

# Connection Hierarchy



# Control Connections, Sessions & Flows

- **Control Connections**

  **An M-CMTS Core will establish at most one control connection to an EQAM.**

  **If the UDP Header is used, the control connection SHOULD use UDP port 1701.**

- **Sessions**

  **Underneath each control connection there could be one or more DEPI sessions (pseudowires)**

  **Each DEPI session connects the Core to a single QAM channel.**

  **If the UDP header is used, the UDP destination port generally selects the**

- **Flows – carry the actual data**

  **Each PSP session may have one or more flows**

  **Each MPT session has a single flow**

# Addressing the EQAM

- **The M-CMTS Core SHOULD use the IP Address of the EQAM and the TSID of the QAM Channel to uniquely identify a QAM Channel within an EQAM during initial configuration.**

  **The TSID (Transport Stream ID) is a concept borrowed from the video world. It is a 16 bit tag assigned by the MSO to a QAM Channel.**

  **This allows DEPI to automatically configure sessions/ports/flows, etc.**

- **If UDP is used,**

  **The control connection SHOULD use UDP port 1701. This can be negotiated to a different port. (control packet)**

  **The session typically used the destination port to select a QAM Channel. The EQAM supplies the UDP Destination Port during session setup. (data packet)**

- **If UDP is not used,**

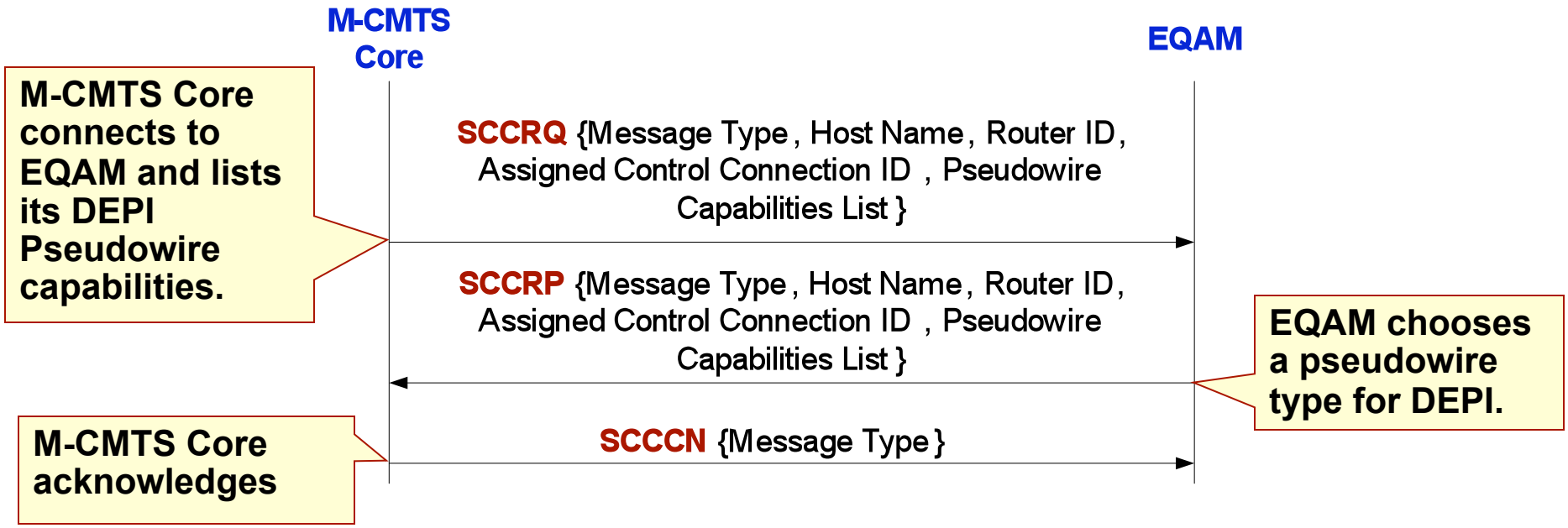
  **The L2TPv3 session ID is used to select a QAM Channel.**

# L2TPv3 Control Connection Messages

| # | Mnemonic | Name |
|---|---|---|
| 1 | SCCRQ | Start-Control-Connection-Request |
| 2 | SCCRP | Start-Control-Connection-Reply |
| 3 | SCCCN | Start-Control-Connection-Connected |
| 4 | StopCCN | Stop-Control-Connection-Notification |
| 6 | HELLO | Hello |
| 20 | ACK | Explicit Acknowledgement |

- Control Connections are setup with SCCRQ, SCCRP, and SCCCN
- Control Connections are torn down with StopCCN
- HELLO is a keep-alive for the Control Connection. (Not for a QAM Channel)
- Since all messages contain embedded acknowledgements, ACK is used only when there is no other messages in the control queue.

# Control Connection Setup




- **Each side announces what Control Connection ID to use. Thus, the CCID is unique per direction.**

# General Signaling Flow

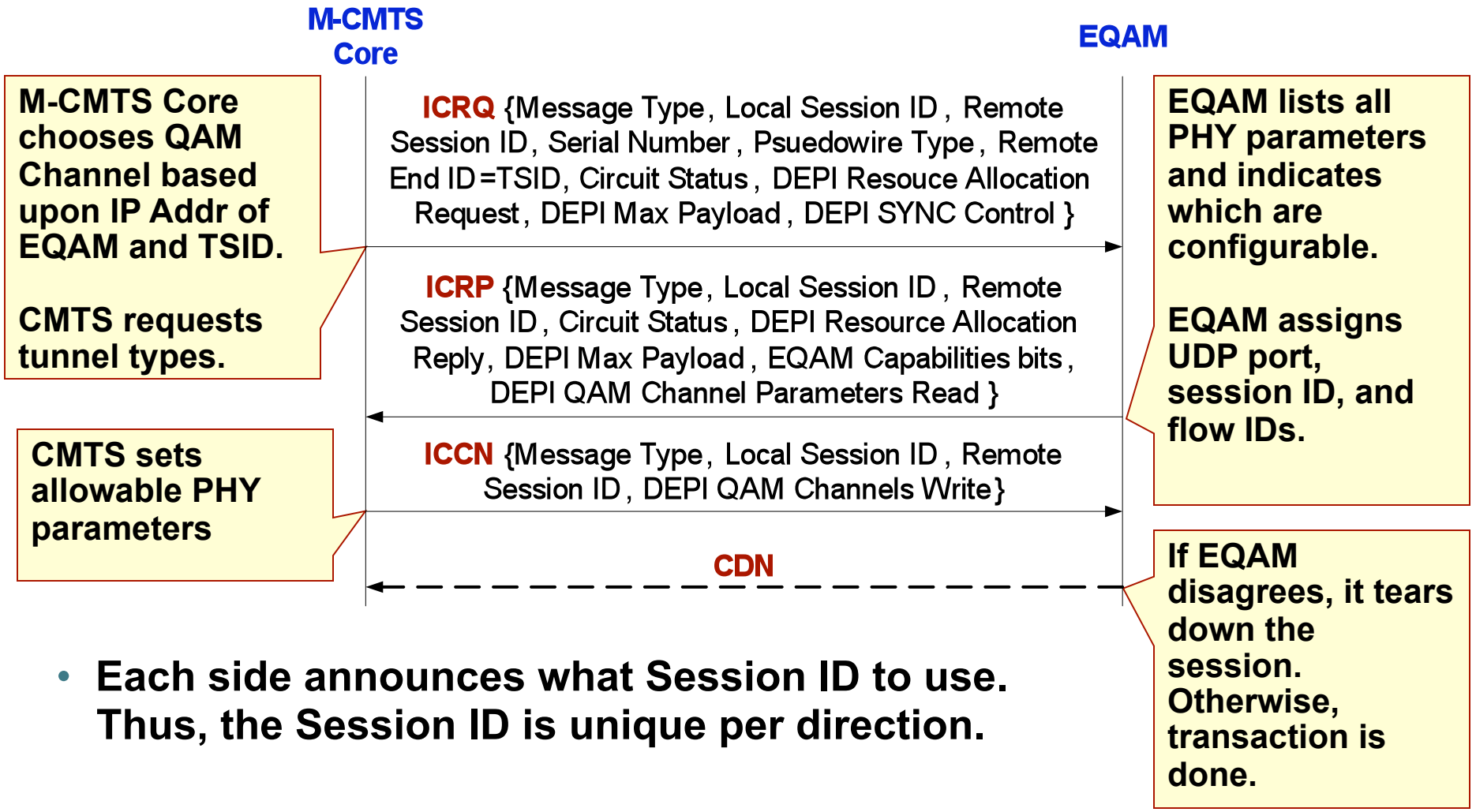
- **L2TPv3 establishes a control connection between the M-CMTS Core and the EQAM**
- **L2TPv3 establishes a session per QAM Channel**
- **Each QAM Channel may have one or more Flows.**
- **If one side disagrees with the setup, it kills the session setup with a CDN – Call-Disconnect-Notify and reports an error code.**

# L2TPv3 Session Messages

| # | Mnemonic | Name |
|---|---|---|
| 10 | ICRQ | Incoming-Call-Request |
| 11 | ICRP | Incoming-Call-Reply |
| 12 | ICCN | Incoming-Call-Connected |
| 14 | CDN | Call-Disconnect-Notify |
| 16 | SLI | Set Link Info |

- L2TPv3 outgoing call messages (OCRQ, OCRP, OCCN) and the WAN-Error-Notify (WEN) message are not required to be supported.

# Session Setup




- **Each side announces what Session ID to use. Thus, the Session ID is unique per direction.**

# Session Operation

- **DEPI uses the Session setup slightly differently than conventional L2TPv3**
- **L2TPv3 presents parameters during ICRQ and accepts/rejects at ICRP. ICCN typically does not have any parameters**
- **DEPI needs M-CMTS Core to initiate the session on ICRQ and then have the parameters presented from the EQAM on ICRP.**

  **The M-CMTS Core then uses ICCN to set parameters.**

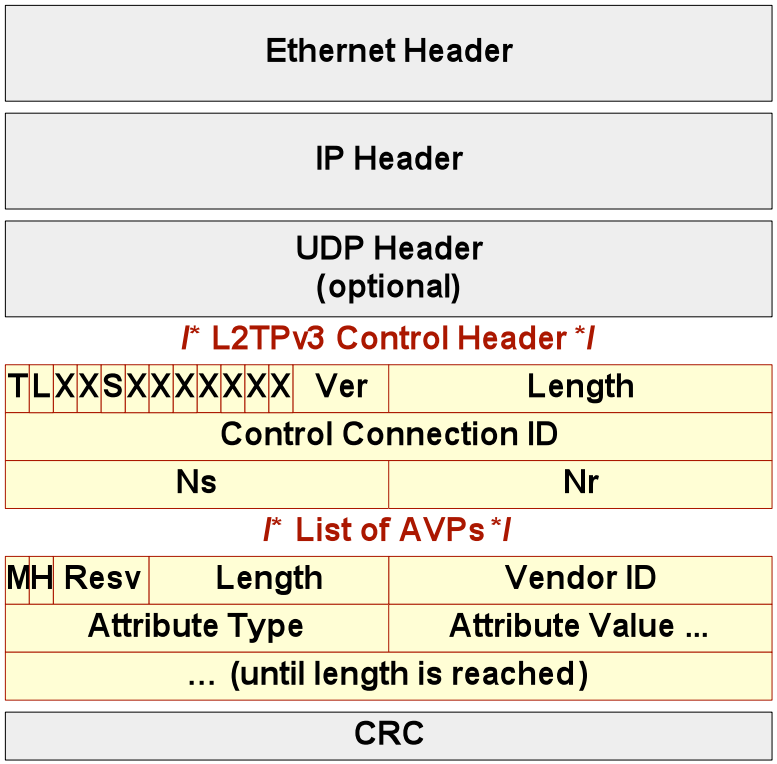
  **Rejection is done with CDN. Acceptance is no CDN.**

# DEPI Control Packets

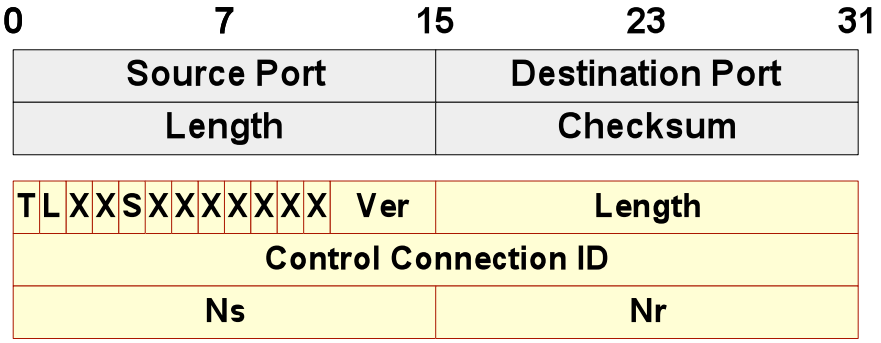
- **UDP Header is optional.**

  **Control messages typically go to port 1701.**

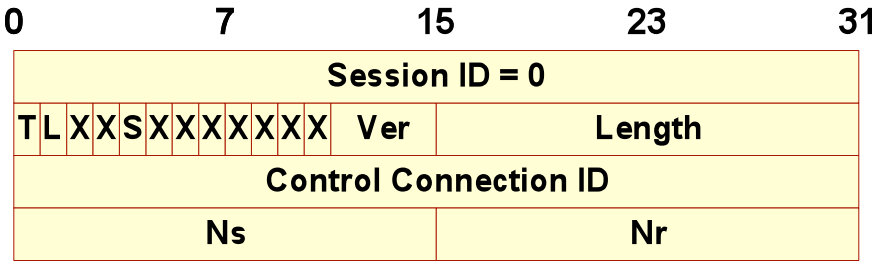
- **Session messages are linked to the Control Connection through an ID.**
- **Each message carries an ACK. The ACK message is control message with no other parameters.**
- **Control messages contain a list of Attribute Value Pairs (AVPs) which contain interface specific details.**



# L2TPv3 Control Message Header




DEPI Control Header with UDP




DEPI Control Header without UDP

**T** Type bit = 1 indicating that this is a control message.

**L** Length bit = 1 indicating that the Length field is present.

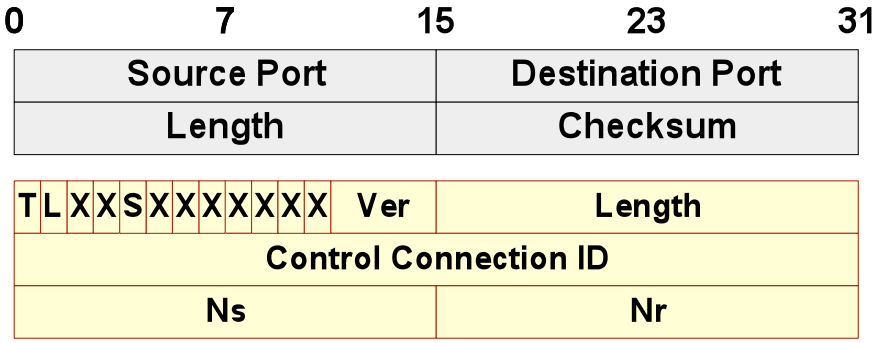
**S** Sequence bit = 1 indicating that sequence numbers (Ns and Nr) are present.

**Version** Set to 3.

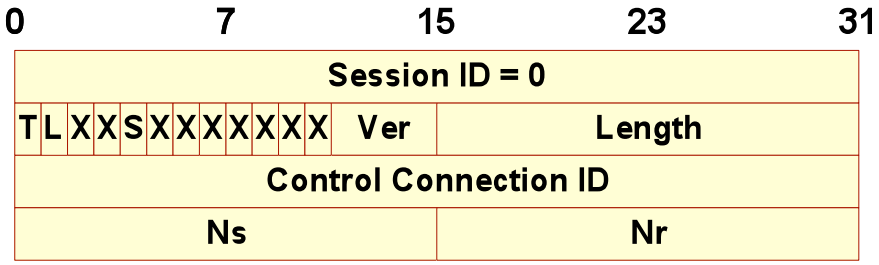
**Length** Indicates the length of the message beginning with the T bit. It does not include the Session ID if present.

**CCID** Control Connection Identifier. Negotiated per control connection.

# L2TPv3 Control Message Header




DEPI Control Header with UDP




DEPI Control Header without UDP

**Ns** Sending Sequence Number. Indicates sending sequence of this control message.

**Nr** Received Sequence Number. Indicates next expected received sequence number.

- Ns and Nr turn every Control Message into an ACK. Ns and Nr create a sliding window for each side indicating Control Messages that have been sent but not acknowledged.
- Thus, delivery of L2TPv3 Control Messages is reliable.

# AVP Format

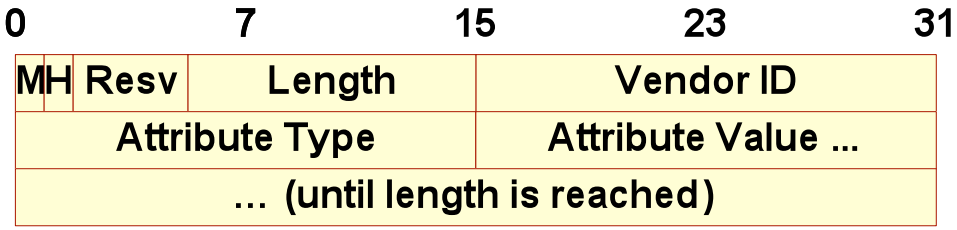
**Mandatory bit**. If this bit is set to a 1 and this AVP is rejected, the control connection or session setup in which the AVP is carried will be torn down.

**Hidden bit**. 1 = encrypted, 0 = not encrypted. Not required for DEPI.

**Length** starting from the M bit.

**Attribute Type** Unique per Vendor ID

**Attribute Value** Defined per AVP




AVP Generic Format

## Vendor ID

- For AVPs defined by L2TPv3, this field is set to 0.
- For AVPs defined by DEPI, this field is set to the CableLabs vendor ID of 4491 (0x118B).
- For AVPs defined outside the scope of DEPI, this may be set to a vendor specific ID.

# AVP Groups

**DEPI has three groups of AVPs**

- **AVPs from conventional L2TPv3 for Control Connection and Session Setup and Tear Down.**

  **Not all L2TPv3 AVPs are required for DEPI, although implementation should be tolerant of other AVPs.**

- **AVPs for DEPI Session Setup**

  **Flow Behaviour**

  **EQAM Capabilities**

- **AVPS for QAM Channel Configuration**

  **Specific to the RF parameters of an EQAM.**

**AVPs are similar in concept to DOCSIS TLVs.**

# L2TPv3 Conventional AVPs

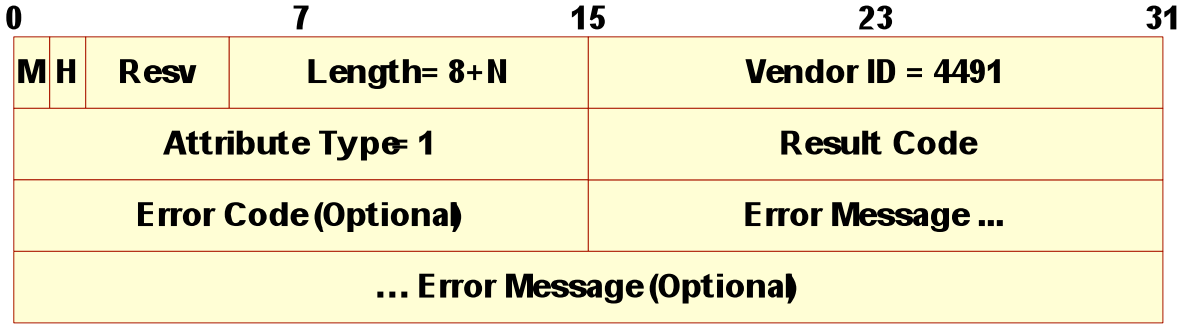
| Attribute Type | Control, Session | Description |
|---|---|---|
| 0 | C, S | Message Type |
| 1 | S | Result Code |
| 7 | C | Host Name |
| 8 | C | Vendor ID |
| 15 | S | Serial Number |
| 60 | C | Router ID |
| 61 | C | Assigned Control Connection ID |
| 62 | C | Pseudowire Capabilities List |
| 63 | S | Local Session ID |
| 64 | S | Remote Session ID |
| 66 | S | Remote End ID |
| 68 | S | Pseudowire Type |
| 69 | S | L2 Specific Sub-Layer * |
| 70 | S | Data Sequencing * |
| 71 | S | Circuit Status |
| 74 | S | Tx Connect Speed * |

# DEPI Session AVPs

| Attribute Type | Description |
|---|---|
| 0 | Reserved |
| 1 | DEPI Result Code |
| 2 | DEPI Resource Allocation Request |
| 3 | DEPI Resource Allocation Reply |
| 4 | DEPI MTU |
| 5 | DOCSIS SYNC Control |
| 6 | EQAM Capabilities Bits |
| 7 | DEPI VLAN ID * |
| 8 | DEPI Tx Connect Speed * |
| 9 | Local UDP Source Port * |

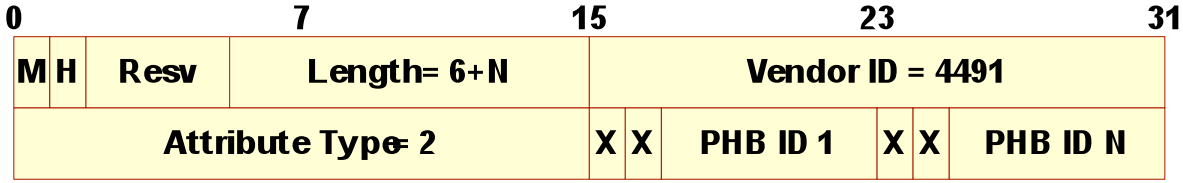
- These AVPs are only used in DEPI session messages.

# DEPI Result Code AVP




- Send by Core or EQAM with CDN or SLI.
- EQAM can tell M-CMTS what when wrong.
- This is in addition to the normal L2TPv3 result code AVP.
- Fields are:
  - Result Code
  - Error Code
  - Error Message
- Very flexible structure. Watch for expansion on this AVP.

# DEPI Resource Allocation Request AVP

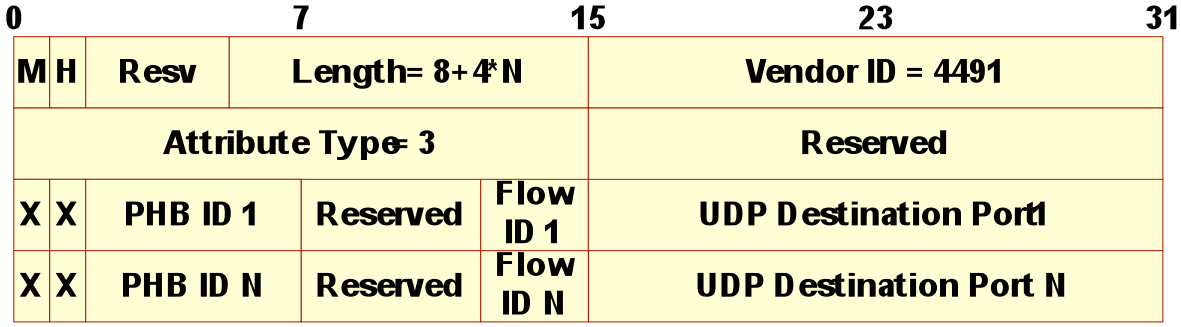



- Sent by M-CMTS Core with ICRQ.
- Each entry represents a request for a flow within a session.
- PHB = Per Hop Behavior.

  Generates a DSCP (DiffServ Code Point)

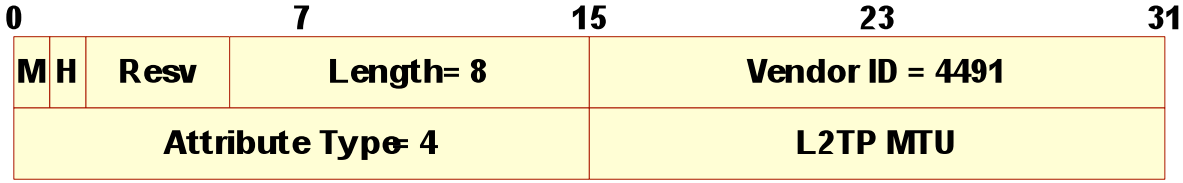
  M-CMTS and EQAM are pre-configured to understand the relevance of PHB and DSCP.
- For example, data PHB = 7, voice PHB = 5, Signaling PHB = 3, MAP PHB = 1

# DEPI Resource Allocation Reply



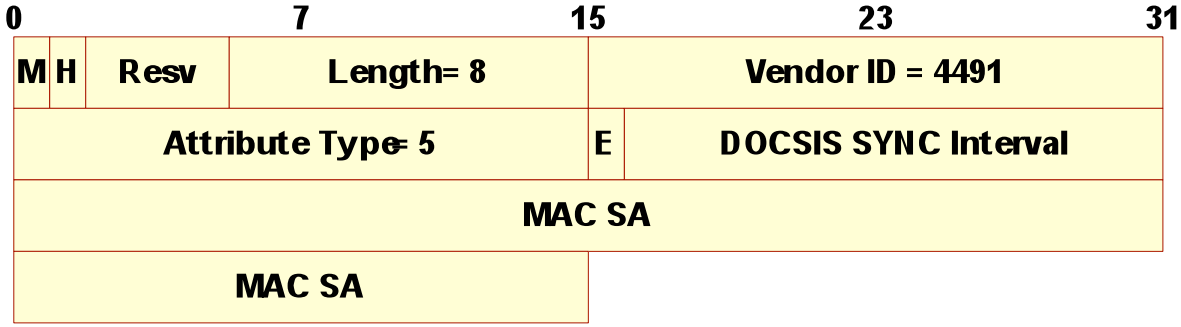

- Send by EQAM with ICRP
- Contains a table with a Flow ID and UDP port assigned to each PHB.
- This is for a particular session which infers a particular QAM Channel.

# DEPI MTU AVP *




- Sent in ICRQ and ICRP.
- Manages MTU of M-CMTS Core and EQAM
  - Sent by Core with ICRQ to request a MTU for DEPU
  - Sent by EQAM with ICRP to indicate the MTU to be used for DEPI.
- Network MTU handled by MTU Discovery

# DOCSIS SYNC Control AVP




- Sent by M-CMTS Core with ICRQ or SLI.
- MPT Mode

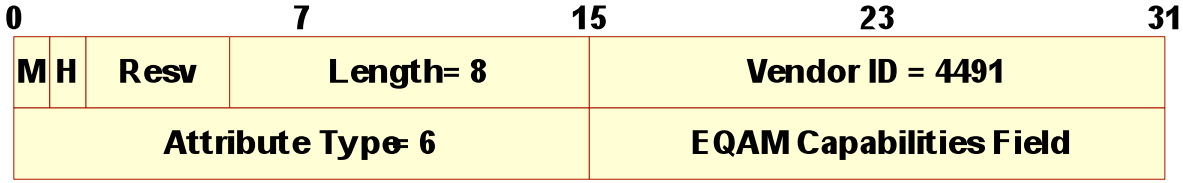
  If E=0, then the EQAM MUST NOT correct the SYNC messages. If E=1, then the EQAM MUST correct the SYNC messages.

  The DOCSIS SYNC Interval and MAC SA field are not used.
- PSP Mode

  Uses MAC SA from Core to create SYNC message rather than a local SA.

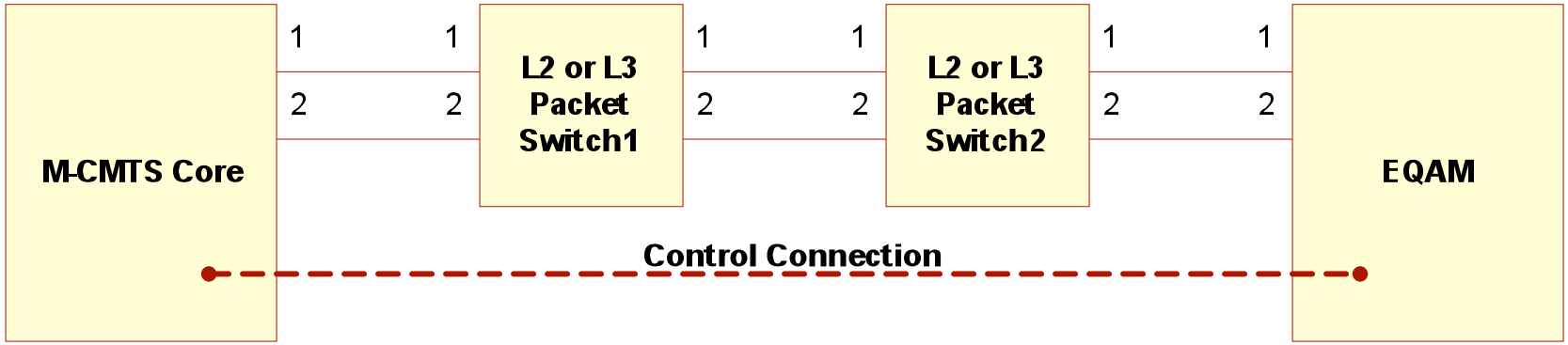
  Generates a SYNC message at or near the specified interval

# EQAM Capabilities Bits AVP



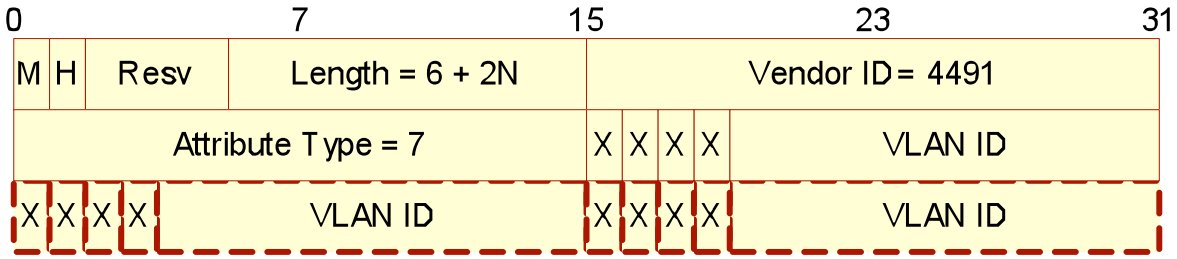

- Sent by EQAM with ICRP
- Current the only capability bit defined is the support of DLM at the EQAM egress.
- Watch for expansion on this AVP.

# CIN Resource Reservation & Admission Control *



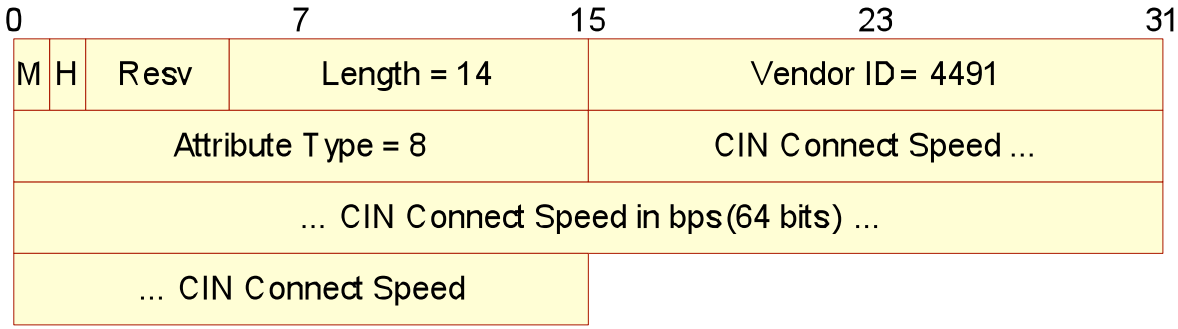

- **Routing and Bridging, without load balancing, will choose one of the two links in the middle of the CIN.**
- **Network load balancing may not provide an even load**
- **In a bridged network, one Control Connection needs to manage multiple GE links. There is no way in L2TPv3 to do that.**
- **DEPI solves these problems by allowing sessions to be associated with 802.1Q VLAN IDs.**

# VLAN ID AVP *




- **Sent in ICRQ and ICRP**
- **M-CMTS Core lists VLANs it owns and has bandwidth available. (M-CMTS Core should reserve bandwidth on each VLAN it places in the list)**
- **EQAM picks one of the VLANs and in doing so, chooses a GE port and reserves the bandwidth. (Core releases reservation on VLAN not chosen.)**
- **This is admission control and resource reservation.**
- **CIN reservations can be achieved by sending RSVP down the VLAN. RSVP does not support VLAN selection.**

# CIN Connection Speed AVP *

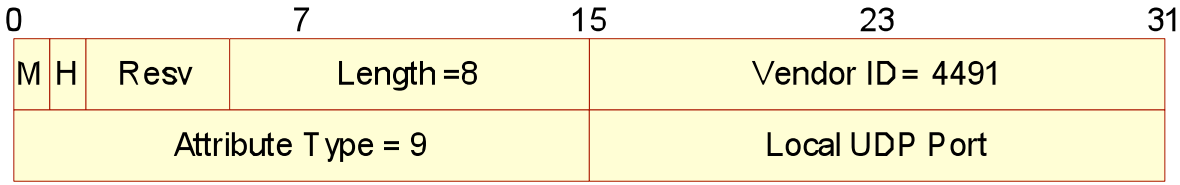



- **Send by M-CMTS Core in ICRQ**
- **This is the commitment by the Core as to the maximum bandwidth it will use on the CIN.**

  **The maximum bandwidth that it will use on the QAM Channel is encoded in the L2TPv3 Tx Connect Speed AVP.**
- **Used for admission control by EQAM.**

  **The EQAM may choose to discount the max burst rate knowing that all flows are PSP with QoS.**

# Local UDP Port AVP *



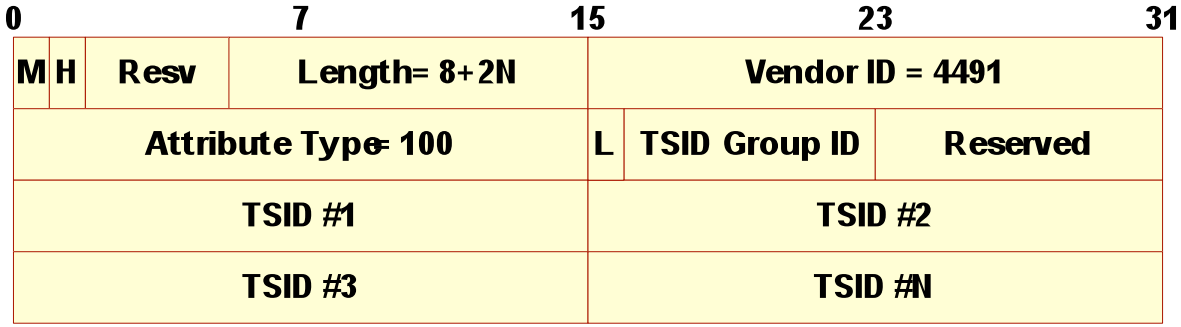

- **Sent in ICRQ (optional in ICRP)**
- **If UDP is enabled, and if the Core wants to receive session packets on a different UDP ort than the Control Connection, it indicates the desired port with this AVP.**
- **The only packet this currently impacts is DLM.**

# DEPI QAM Channel AVPs

| Attribute Type | Description |
|---|---|
| 100 | Downstream QAM Channel TSID Group |
| 101 | Downstream QAM Channel Frequency |
| 102 | Downstream QAM Channel Power |
| 103 | Downstream QAM Channel Modulation |
| 104 | Downstream QAM Channel J.83 Annex |
| 105 | Downstream QAM Channel Symbol Rate |
| 106 | Downstream QAM Channel Interleaver Depth |
| 107 | Downstream QAM Channel RF Mute |

- M-CMTS Core programs EQAM PHY parameters
- The RF Mute allows the M-CMTS core to disable the QAM Channel output without tearing down the session.
- TSID Groups and Lock bits are unique to this group of AVPs.

# TSID Groups

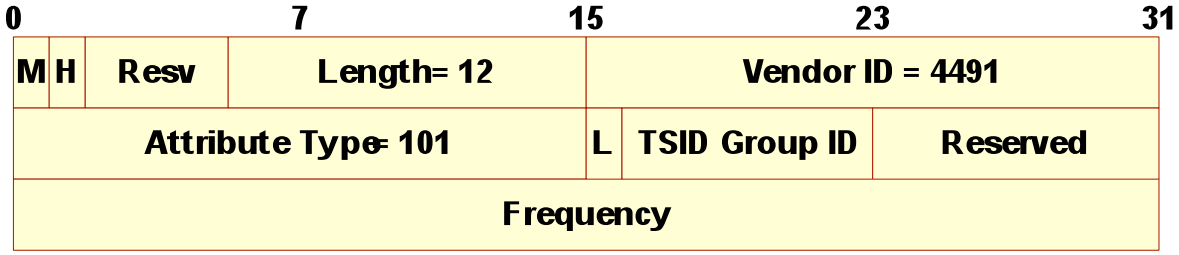



- Multiple channels on an EQAM may have certain PHY parameters linked together.

  For example, a 4 channel QAM modulator that shares a common power amp, would share the same power level and the frequencies may be adjacent.

- The EQAM informs the M-CMTS of this dependency by creating TSID groups, and then linking the TSID group into each QAM Channel AVP.
- Different QAM Channel AVPs may have different TSID groups.

# Lock Bit




- **Each QAM Channel AVP has a Lock bit (L).**

  **The EQAM sends all QAM Channel AVPs to the M-CMTS Core and indicates if the parameter can be changed or not.**

  **The allows read access to all QAM Channel parameters, and configurable write access.**

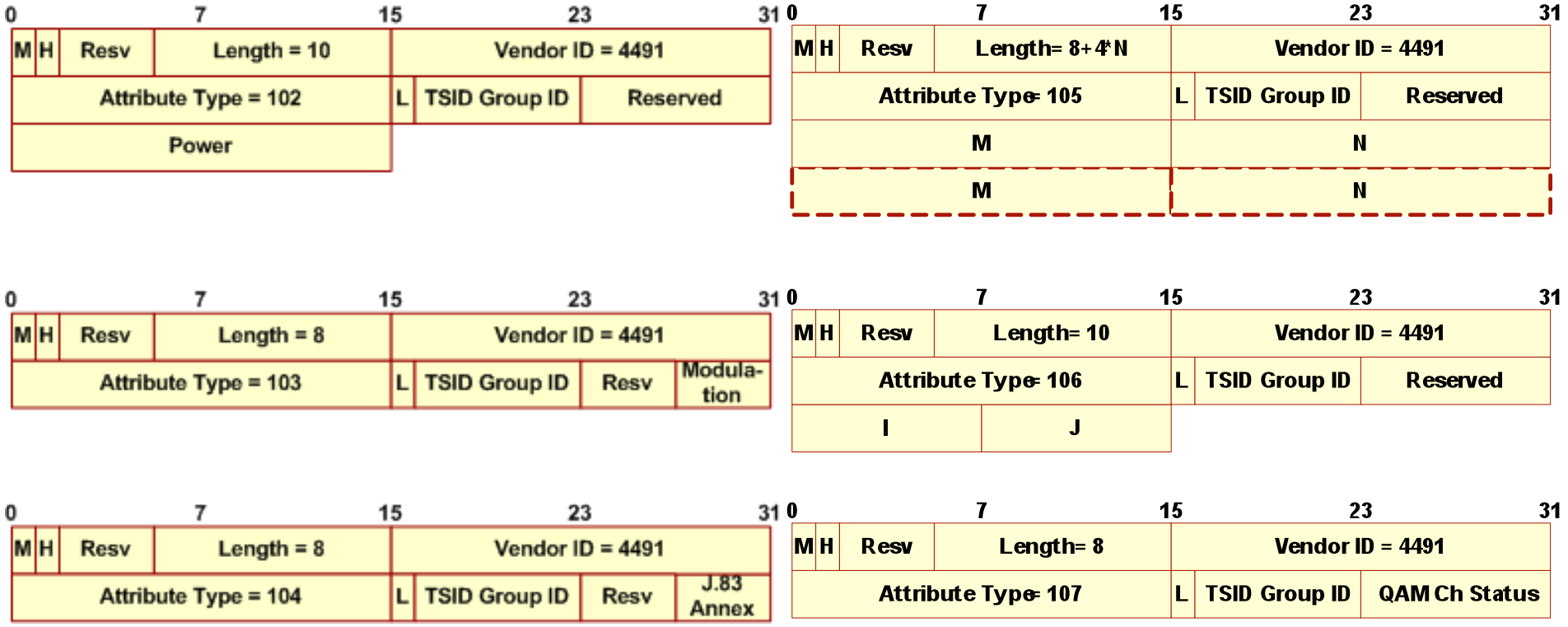
- **Example**

  **The EQAM may want to own the power and frequency settings as part of the HFC configuration.**

  **The M-CMTS may want to own the Modulation format as part of the DOCSIS configuration.**

- **Note the linkage to the TSID group.**

# QAM Channel AVPs

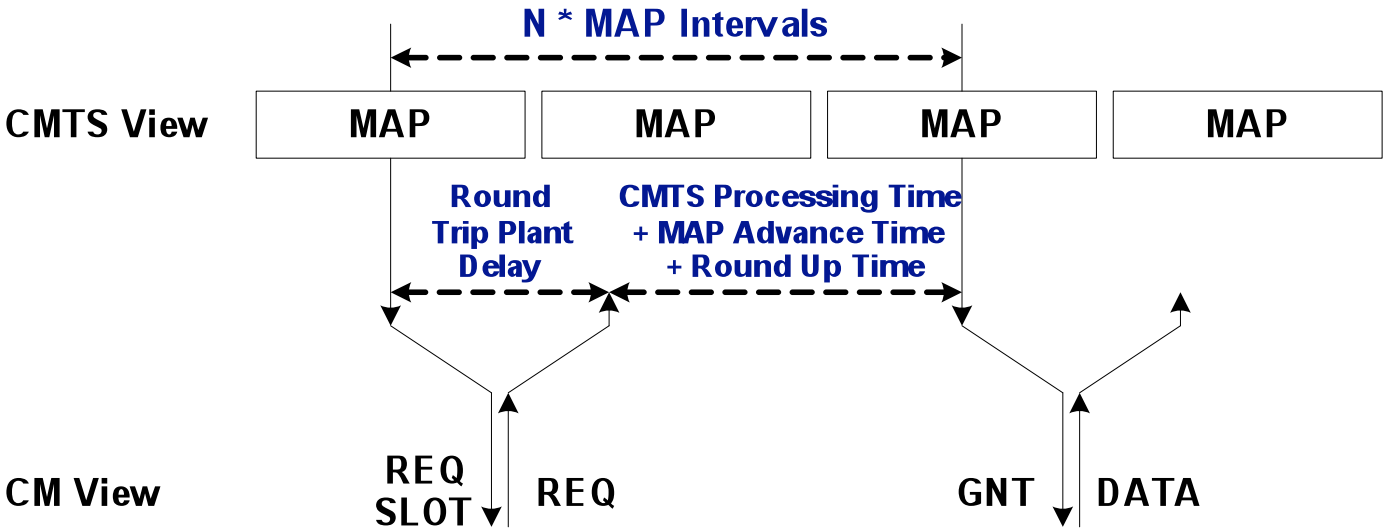



- **TSID Group AVP and Frequency AVP shown on previous slide.**

# Backup Slides

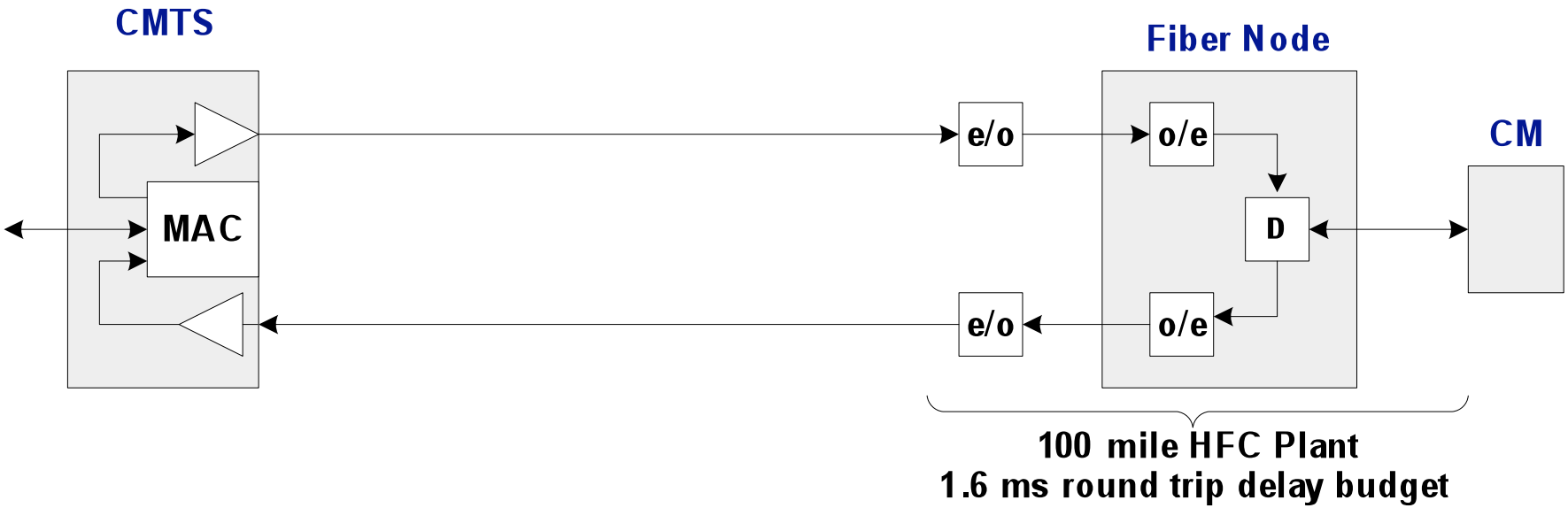
* Note: more than one image can be used with these segue and Q and A slides, but should never extend past the half grid of the page

# DOCSIS REQ-GNT Delay



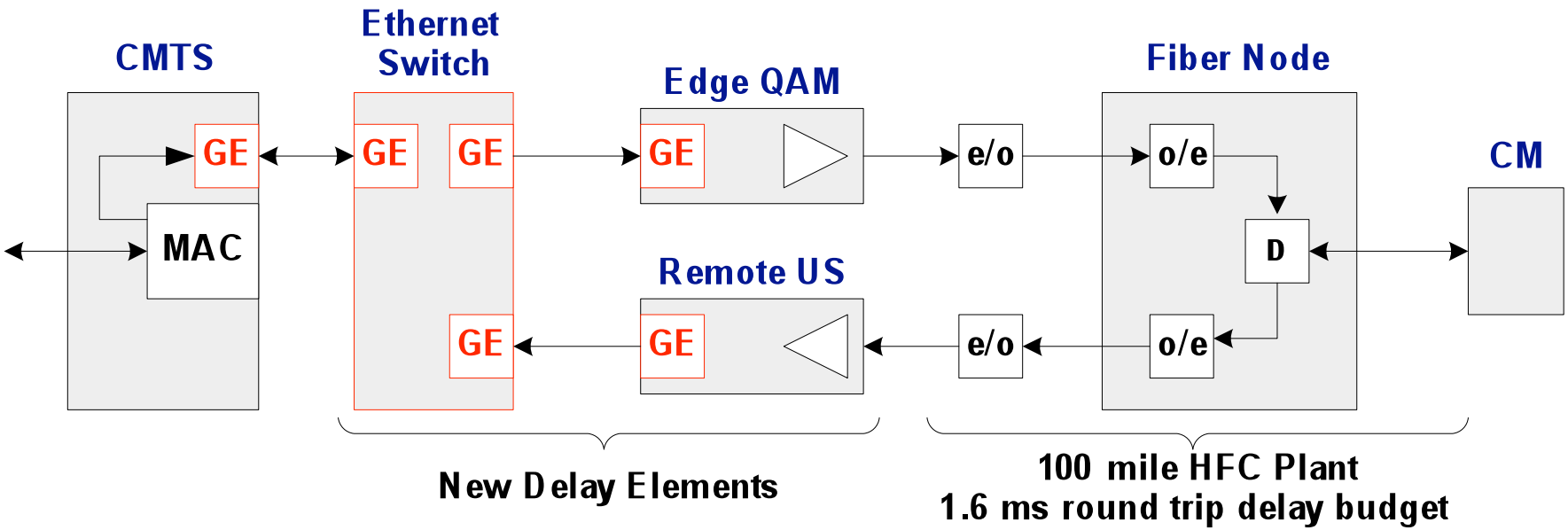

- One of the biggest design concerns for the M-CMTS was the impact on the REQ-GNT delay.
- Typical MAPs today are a minimum of 2 ms. With a GNT occuring a maximum of every other MAP, this allows a maximum of 250 PPS (packets per second) in the upstream.

# HFC Plant Delay with Integrated DOCSIS




- The current DOCSIS specification allows a 100 mile plant which has a round trip delay of 1.6 ms
- CMTSs usually round this up to 1.8 or 2 ms for initial ranging opportunities
- Impact of actual delays are rounded off to MAP boundaries

# HFC Plant Delay with Modular DOCSIS




- **Additional delay elements add about 10% - 15% more delay.**

  **This reduces the peak transfer rate from about 25 Mbps to 22 Mbps. This is still above normal usage.**

- **It is generally agreed that this effect is not noticed and that this cost is outweighed by the gain of the architecture.**

# DEPI Summary

- **The Modular CMTS will provide the foundation for the next generation CMTS which will provide:**
  - **significantly more flexibility in configuration**
  - **significantly lower transport cost per bit**
  - **significantly higher data capacities than anything out there today.**
    - **These new machines will require multiple 1 gigabit or 10 gigabit backhauls rather than the 100 baseT backhauls in use with today's CMTS.**
- **The Modular CMTS architecture will allow DOCSIS to competitively provide the triple-play services of data, voice and video over IP.**

# DOCSIS Timing Interface (DTI)

# Universal Timing Interface (UTI)

* Note: more than one image can be used with these segue and Q and A slides, but should never extend past the half grid of the page

# Intro

- **DTI is a joint collaboration between Cisco and Symmetricom.**
- **References:**

  **Cisco: EDCS-376511 by John T. Chapman**

  **Current specs are at:**
  **http://www.cablemodem.com/specifications/m-cmts.html**

- **Symmetricom contacts:**

  **Jerry Bennington, BizDev / Marketing, 408 433-0910, JBennington@symmetricom.com**

  **George Zampetti, Chief Scientist, 1-408-428-7835, gzampetti@Symmetricom.com**

- **A version of DTI is being renamed UTI and being contributed to ITU-T SG9 for telecom use.**

# Background

- **DOCSIS is a synchronous system.**
- **The CMTS emits a SYNC MAC Management message that contains a 32 bit timestamp derived from a 10.24 MHz clock.**

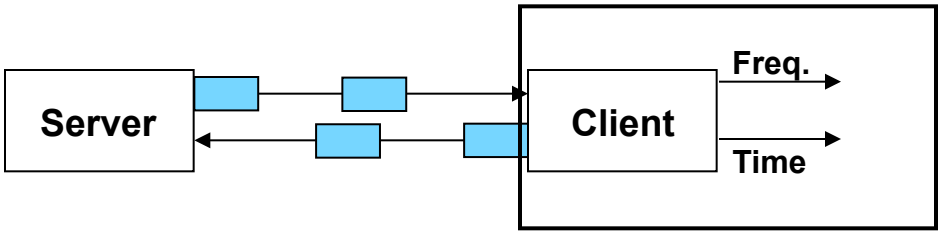
  **In DOCSIS 1.1, the CM derives time and frequency info from the SYNC message.**

  **In DOCSIS 2.0, the CM derives frequency from the QAM baud clock, and time info from the SYNC.**
- **In M-CMTS, the EQAM must produce the SYNC message.**

  **The M-CMTS Core and EQAM need the same time and frequency info.**

  **This is accomplished with DTI.**

# DTI




- **DTI provides:**
  - **Time aligned 32 bit timestamp at each device**
  - **10.24 MHz clock traceable to Stratum 1 when used with a GPS**
  - **TOD (Time of Day)**
  - **GPS co-ordinates (not in spec yet)**
- **Intelligent DTI Server. Multiport.**
- **Simple inexpensive DTI Client**

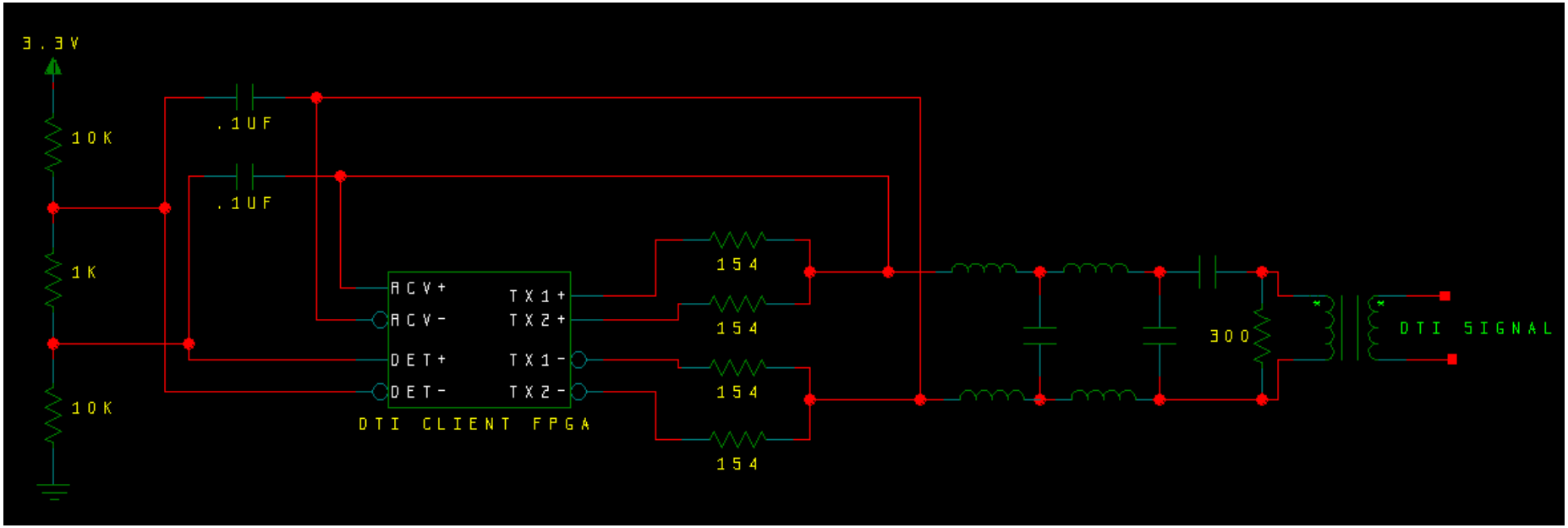
# DTI Operation

- **Uses a two-way ping pong protocol.**
  - **Message rate is 10K a second. 512 bit Frame**
  - **Server transmits then Client responds.**
  - **Upper 22 bits of timestamp are presented serially at 10KHz frame rate**
  - **Lower 10 bits of counter are all zeros at rising edge of 10KHz frame clock.**
- **DTI Servers measures cable delay and provides an offset adjustment to the DTI Client.**
  - **5 ns spec accuracy across all DTI Clients.**
  - **Symmetricom implementation provides 425 ps peak-to-peak error.**
- **DTI Client can operate stand-alone (free running) with no CPU.**

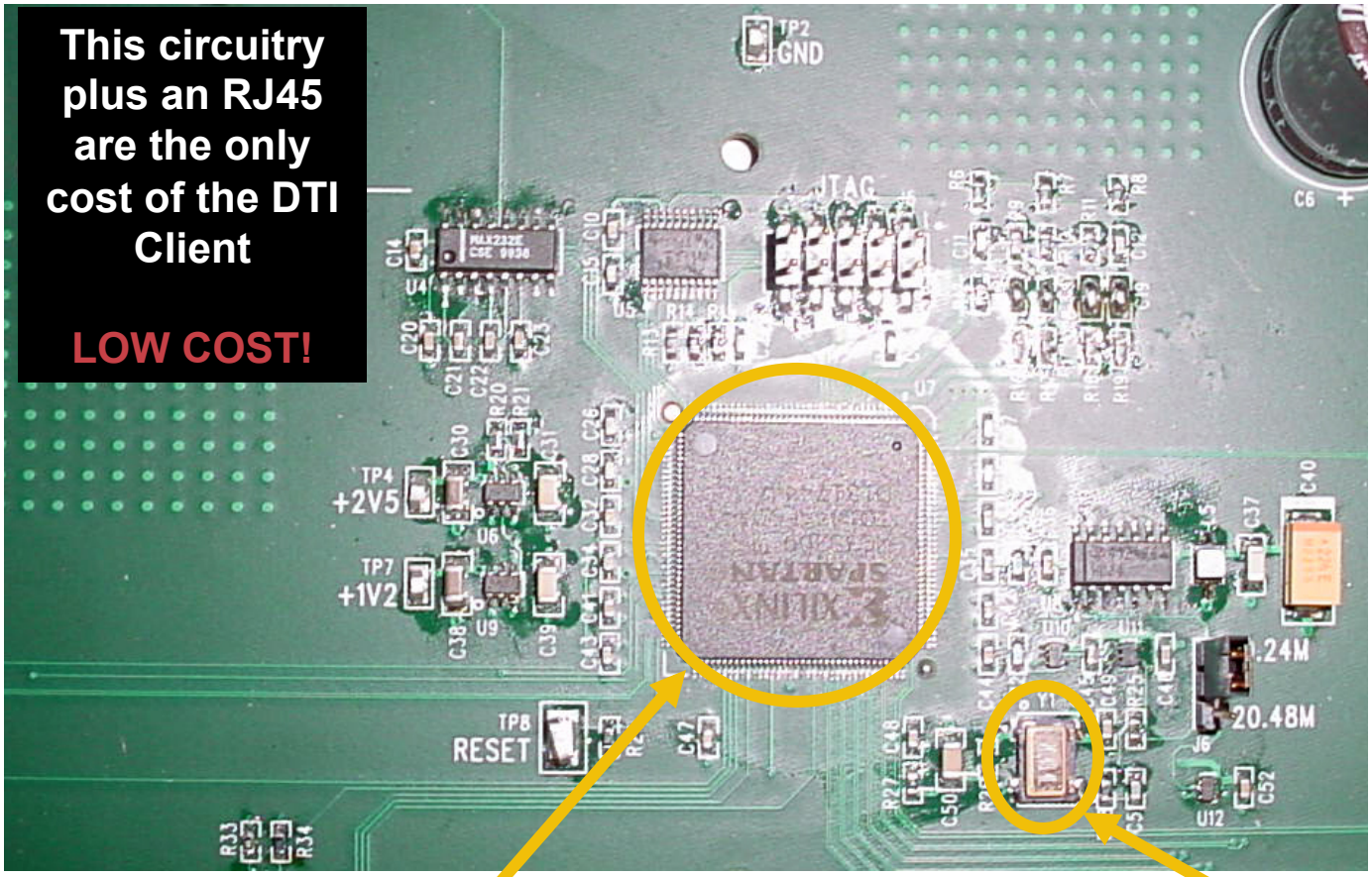
# DTI PHY

- **Cable (DTI):**
  - **5.12 Mbps Half Duplex signal**
    - **Half Duplex signal uses same cable and filters in both directions allowing for highest accuracy cable delay calculations**
  - **Manchester encoded signal**
  - **Uses 10/100BaseT transformer**
  - **10 MHz 5 pole Butterworth filter**
  - **Runs up to 200 meters on CAT5 cable**
  - **100 Ohm Impedance**
- **Telco (UTI)**
  - **G.703 compliant, 1.024 or 2.048 MHz**
  - **2 level Manchester**
  - **Cat5 or Coax**

# CAT5 Physical Layer Schematic

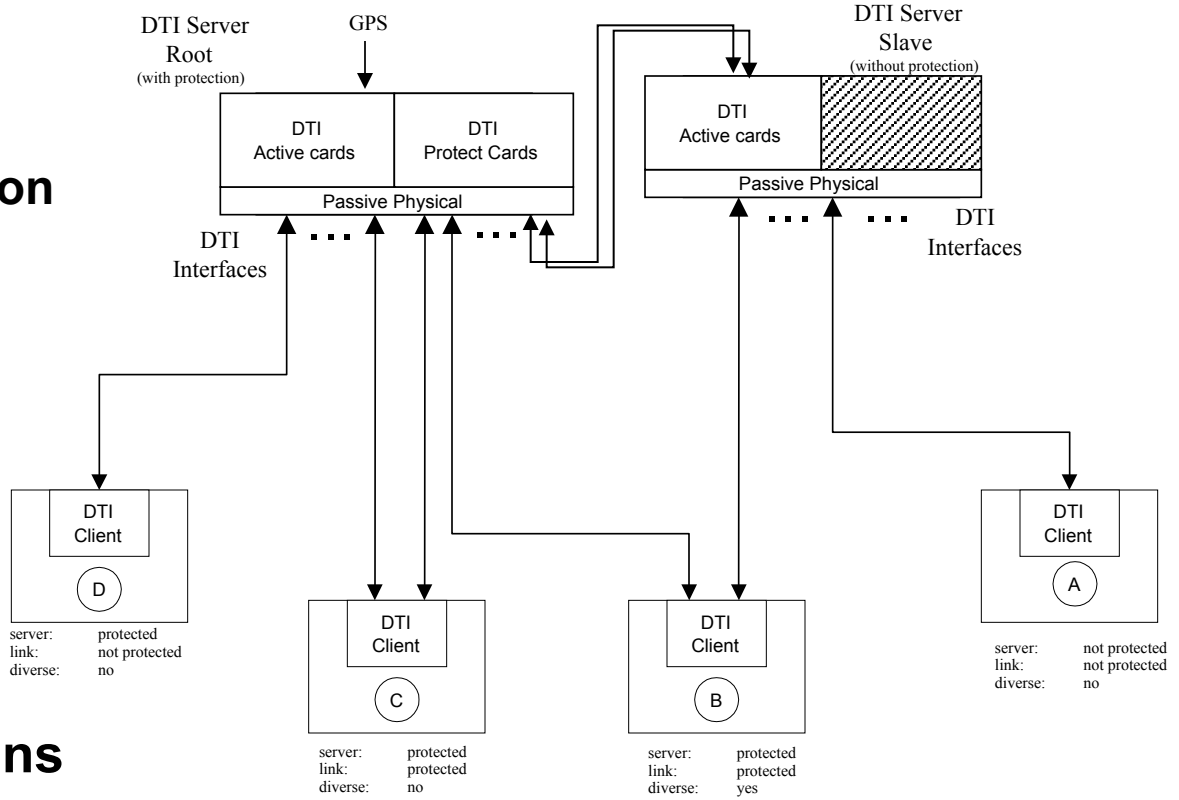


# First DTI Evaluation Board



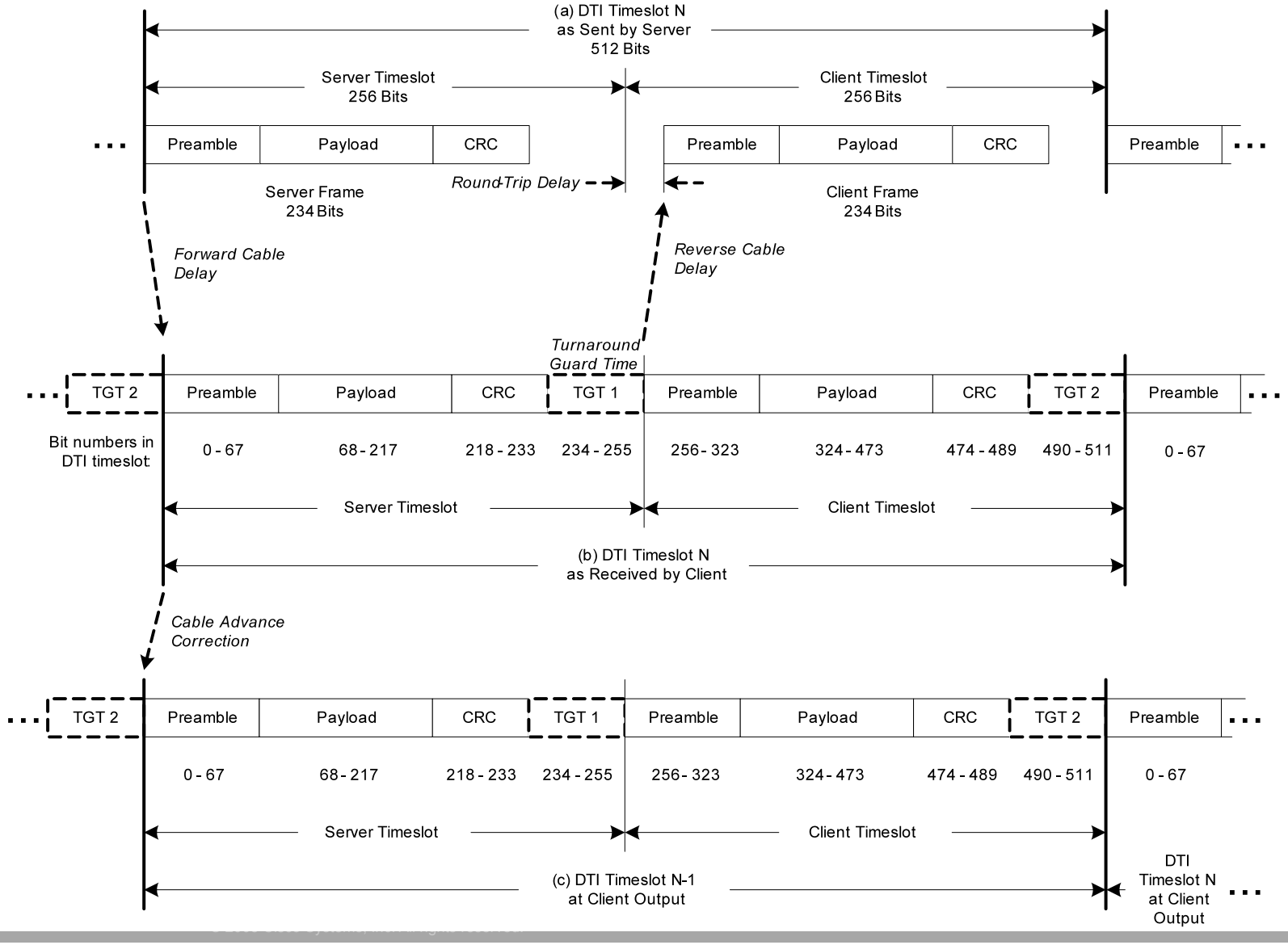
# Deployment & Management

- **Deployment considerations**
  - **DTI is essential to operation of M-CMTS devices**
  - **Path Redundancy**
  - **Power Protection**
  - **Server Protection**
  - **Diversity**
  - **GPS Considerations**




- **Management considerations**
  - **DTI Server continuously monitors each DTI Clients' performance & health**
  - **The DTI Server can report a DTI client that is going off-line**
    - **Traffic can be re-routed. Redundant devices can be enabled**
    - **The faulty device can be taken off-line for maintenance**

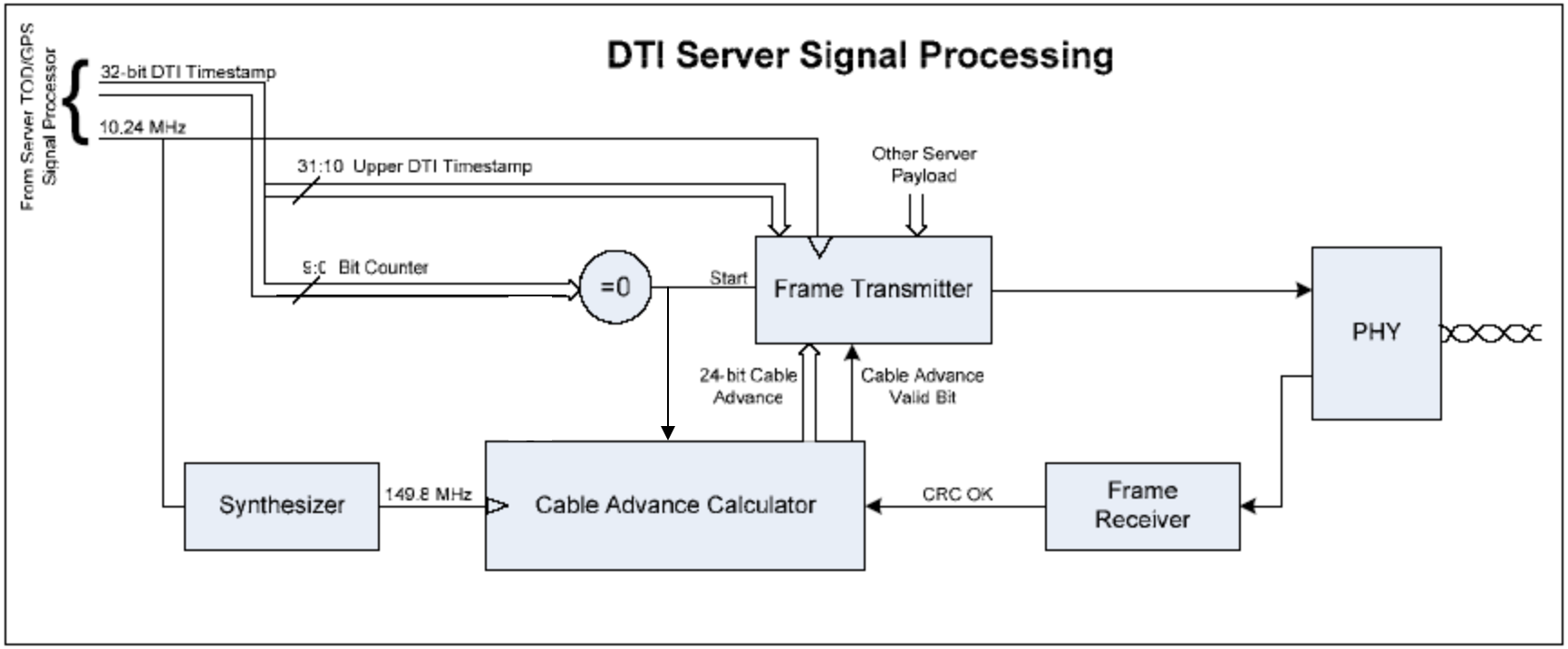
# DTI Framing


(a) DTI Timeslot N
as Sent by Server
512 Bits
Server Timeslot
256 Bits
Client Timeslot
256 Bits
Preamble
Payload
CRC
Preamble
Payload
CRC
Preamble
Server Frame
234 Bits
Round-Trip Delay
Client Frame
234 Bits
Forward Cable
Delay
Reverse Cable
Delay
Turnaround
Guard Time
TGT 2
Preamble
Payload
CRC
TGT 1
Preamble
Payload
CRC
TGT 2
Preamble
Bit numbers in
DTI timeslot
0 - 67
68 - 217
218 - 233
234 - 255
256 - 323
324 - 473
474 - 489
490 - 511
0 - 67
Server Timeslot
Client Timeslot
(b) DTI Timeslot N
as Received by Client
Cable Advance
Correction
TGT 2
Preamble
Payload
CRC
TGT 1
Preamble
Payload
CRC
TGT 2
Preamble
0 - 67
68 - 217
218 - 233
234 - 255
256 - 323
324 - 473
474 - 489
490 - 511
0 - 67
Server Timeslot
Client Timeslot
(c) DTI Timeslot N-1
at Client Output
DTI
Timeslot N
at Client
Output

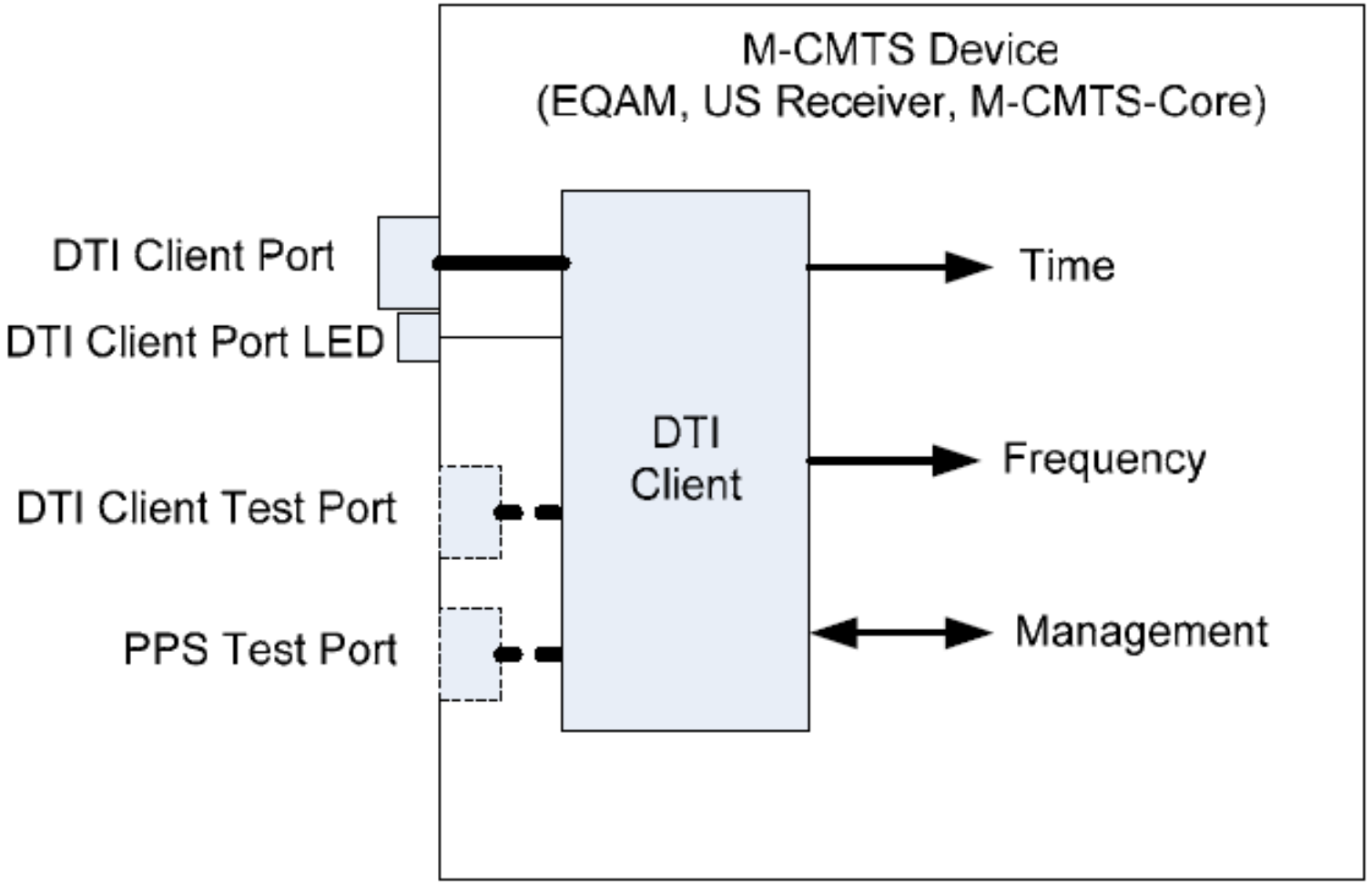
# DTI Frame Structure

| DTI Server Frame Structure | | | |
|---|---|---|---|
| **FIELD** | **NAME** | **SIZE (Bits)** | **DESCRIPTION** |
| 1 | PREAMBLE | 68 | Preamble of 0xAAAA AAAA AAAA AAAA 9 |
| 2 | DEVICE TYPE | 8 | Byte describing type of server |
| 3 | SERVER STATUS FLAGS | 8 | 8 flag bits identifying server status |
| 4 | DOCSIS UPPER TIMESTAMP | 22 | 22 Most Significant Bits of the DTS |
| 5 | TIME OF DAY | 10 | Field supports serial TOD message over multiple frames. |
| 6 | CABLE ADVANCE | 24 | Integer and Fractional Cable Advance |
| 7 | PATH TRACEABLILITY FIELD | 10 | Field supports serial Path Traceability Message over multiple frames. |
| 8 | RESERVED | 68 | All bits set to one |
| 9 | CRC16 | 16 | 16 bit CRC which covers all bits except preamble |
| | **Total Payload Bits** | **234** | |

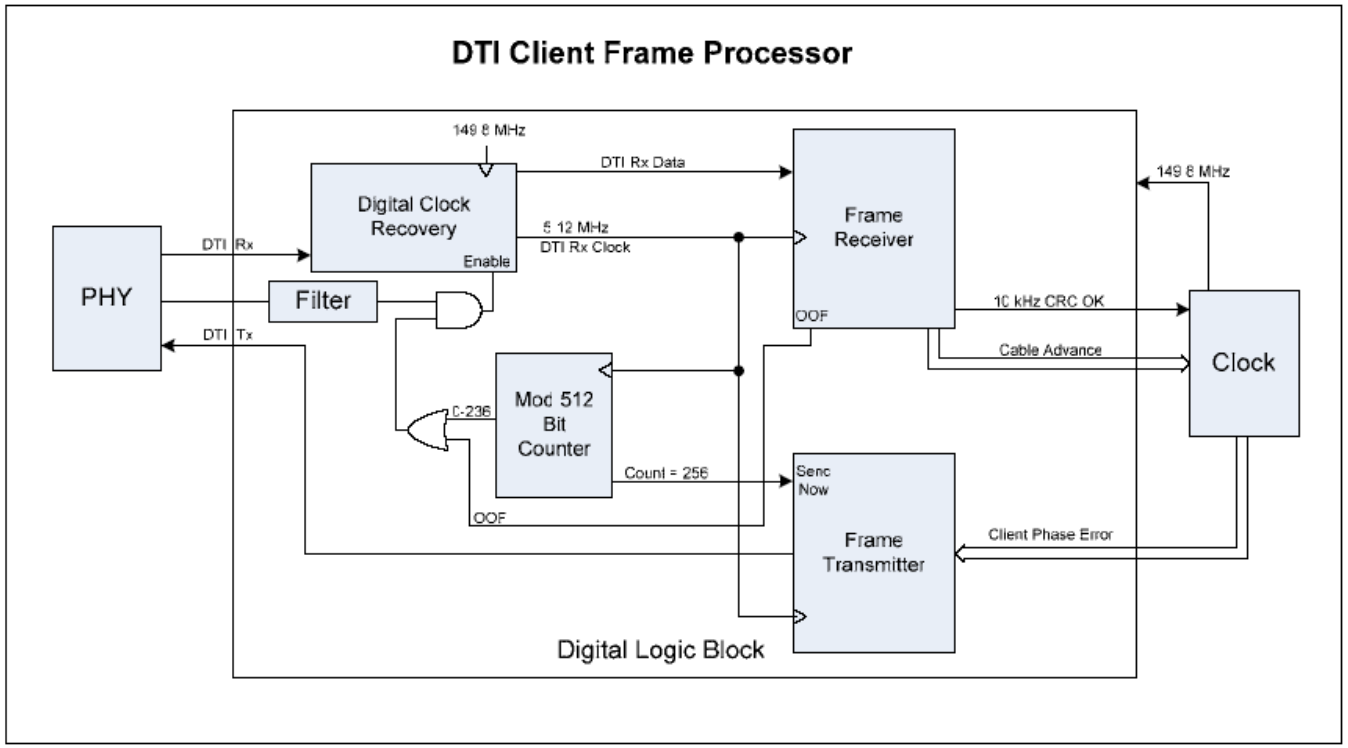
# DTI Server Signal Processing



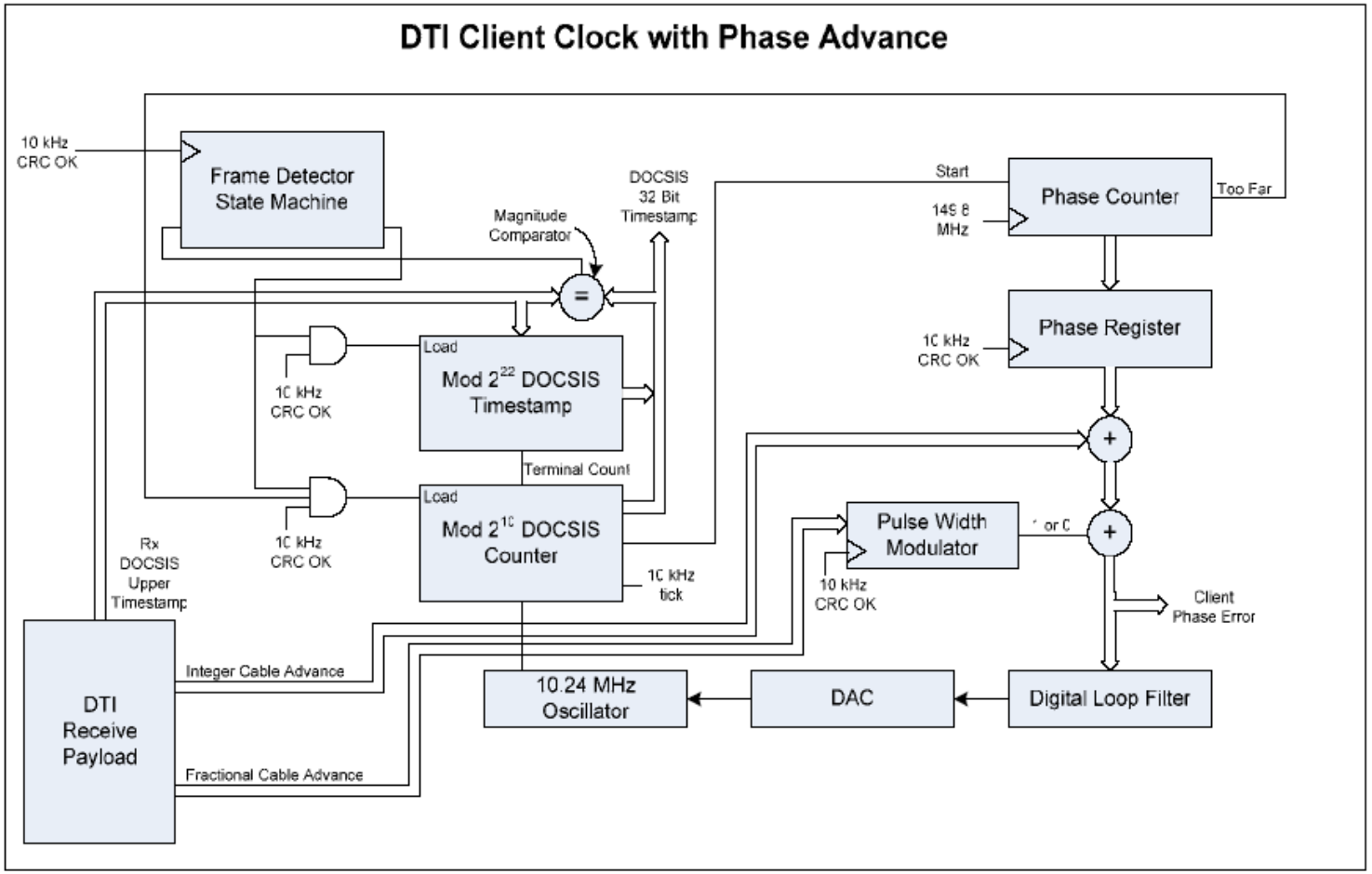
# Client block diagram



# DTI Client Frame Processor

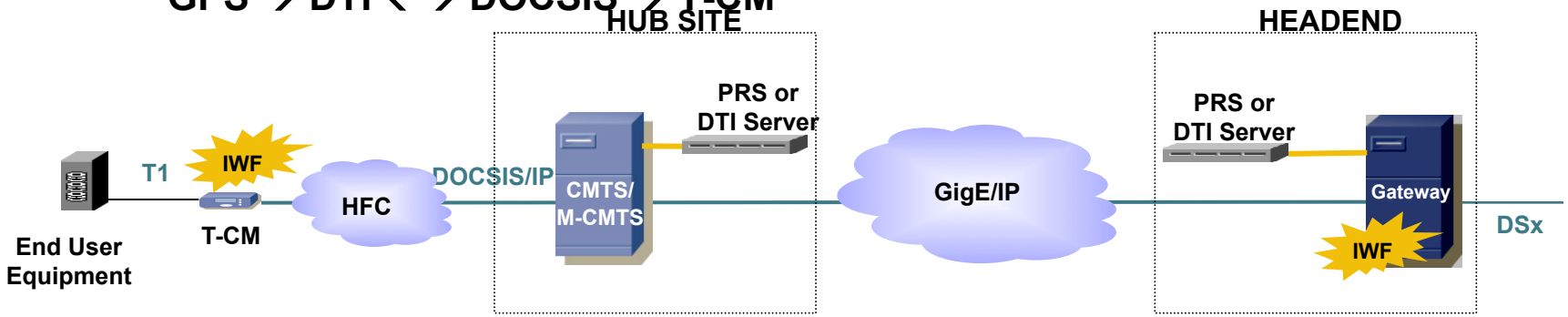


# DTI Client Clock



# DTI Applications

- **M-CMTS**
  - **DTI is required**
- **Commercial Services over DOCSIS (CSoD)**
  - **T1/E1/J1 over DOCSIS**
  - **IP encapsulation**
  - **G.823/G.824 Traffic & Sync. bearing quality**
  - **GPS → DTI ←→ DOCSIS → T-CM**




* Other topologies with IWF in the CMTS or end-to-end T-CM to T-CM are possible

# Conclusions

# Summary

- **M-CMTS is a satellite architecture designed by Cisco that will be deployed in the 2006 (pre-DEPI) and 2007 (DEPI) timeframe.**
  - **Separation was done between MAC and PHY.**
- **M-CMTS, when combined with Cisco's Wideband architecture for DOCSIS will provide:**
  - **significantly more flexibility in configuration**
  - **significantly lower transport cost per bit**
  - **significantly higher data capacities than anything out there today.**
- **The Modular CMTS architecture and Wideband will allow DOCSIS to competitively provide the triple-play services of data, voice and video over IP.**
  - **500+ Mbps downstream channels**
  - **100 Mbps Downstream, 10 Mbps upstream Cable Modems.**
  - **10x the bandwidth at 1/10 the cost**