Timing for DOCSIS Networks

NIST
Keynote Address

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Speaker Introduction

- John T. Chapman, Cisco Distinguished Engineer
  - 50 patents
- Cisco, 17+ years
  - Founder and system architect for Cable BU.
  - Original Inventor of DOCSIS Wideband and M-CMTS Architectures.
  - Inventor of HSSI and Cisco Smart Serial interfaces
- Rolm/IBM/Siemens, 6 years
  - HW designer of analog line and trunks; ISDN interfaces
  - Did timing design for PABX system.

Agenda

- A Day in the Life of a Timing Engineer
- DOCSIS
  - DOCSIS Introduction
  - Modular CMTS Introduction
  - Timing requirements for DOCSIS
- DTI/UTI
  - DOCSIS Timing Interface (DTI)
  - Universal Timing Interface (UTI)

A Day in the Life of a Timing Engineer

A VoIP Story

Once upon a time …

What happens with an irresistible force meets an immovable object?

Irresistible Force
- the Vendor
- logic
- the technically right thing.

Immovable Object
- the Customer
- technology religion
- historical experience

The outcome is often not what is expected

In the beginning …

- Scenario:
  – AT&T buys TCI Cable and wants to do Voice over Cable.
  – AT&T Labs approach Cisco as the lead DOCSIS CMTS vendor with currently deployed DOCSIS 1.0 product.
  – AT&T Labs insists on an ATM solution with full network timing.

The Technical Facts

- Is network timing required for VoIP Services?
  - Voice:

    Clock skew in extreme can cause dropped packets

    VoIP has 100 MIPS DSP processors that run at each end of the link that run a concealment algorithm that uses interpolation to recreates dropped packets.

  - Fax and Analog Modem:

    Faxes calls are short and generally not impacted by clock skew between source and destination clocks.

    Analog Modem data calls are long and are impacted by clock skew.

    Concealment algorithms cannot fix dropped packets.

    Network packet drops are generally the issue.

    Requires G.711 uncompressed Codec.

The Outcome

- What Happens with ATM:
  - We convince them that packets that are pre-scheduled at regular intervals work just as good if not better than ATM cells.

    Beside, DOCSIS does not have ATM.
  - Unsolicited Grant Service (UGS) is introduced into DOCSIS 1.1 by Cisco
  - VoIP is endorsed by AT&T as the way forward for Service Provider voice.

The Outcome

- What happened with timing:
  - The customer was convinced timing was needed because that is the way it always has been.
  - The vendor gives up and builds a clock card.
  - No one buys the clock card because voice works without it.
  - Analog Modem is ignored as the VoIP service typically comes with a high speed data service negating the need for dial-up.
  - The Fax issue is ignored for years as it is broken on paper but works mostly in practice.
  - Eventually, an IP protocol that converts Fax and Analog Modem Relay is defined that converts the analog transmission back into packets, and then those packets are sent with a reliable protocol (actual deployment of this protocol is still TBD).

Lessons Learned & Epilogue

- Lessons Learned
  - Market timing sometimes trumps network.

    Getting to market with half a solution that works can have significant value.
  - Practical solutions sometimes outweigh technically accurate solutions.

    Sometimes everything happens for a different reason.
  - Other unobvious problems may dominate.

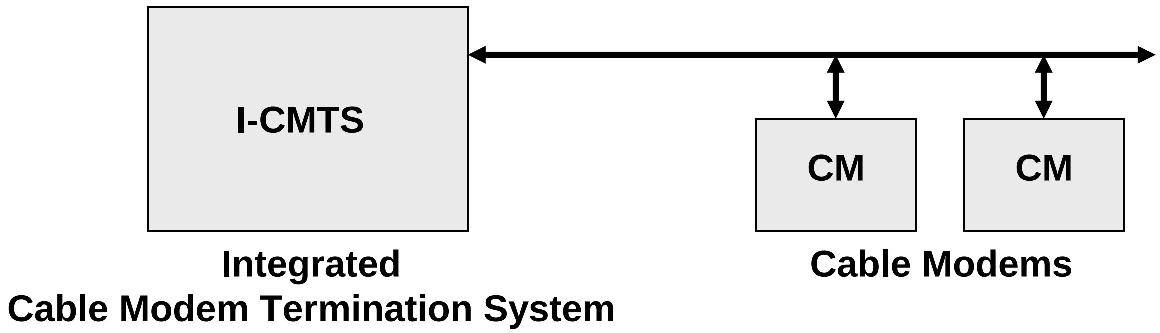
    network packet drops vs. timing for analog modem.

- Epilogue
  - The timing cards in the CMTS became useful many years later for Modular CMTS (M-CMTS) and the DOCSIS Timing Interface (DTI).

DOCSIS & Modular CMTS

Introduction

DOCSIS Intro



- The DOCSIS specification defines how to transport IP Packets over a 100 mile radius Hybrid Fiber Coax (HFC) plant between a CMTS and multiple CM
- DOCSIS is a Point to Multipoint protocol
  - Downstream is one to many and operates much like Ethernet.
  - Upstream is dynamically per packet scheduled bandwidth.

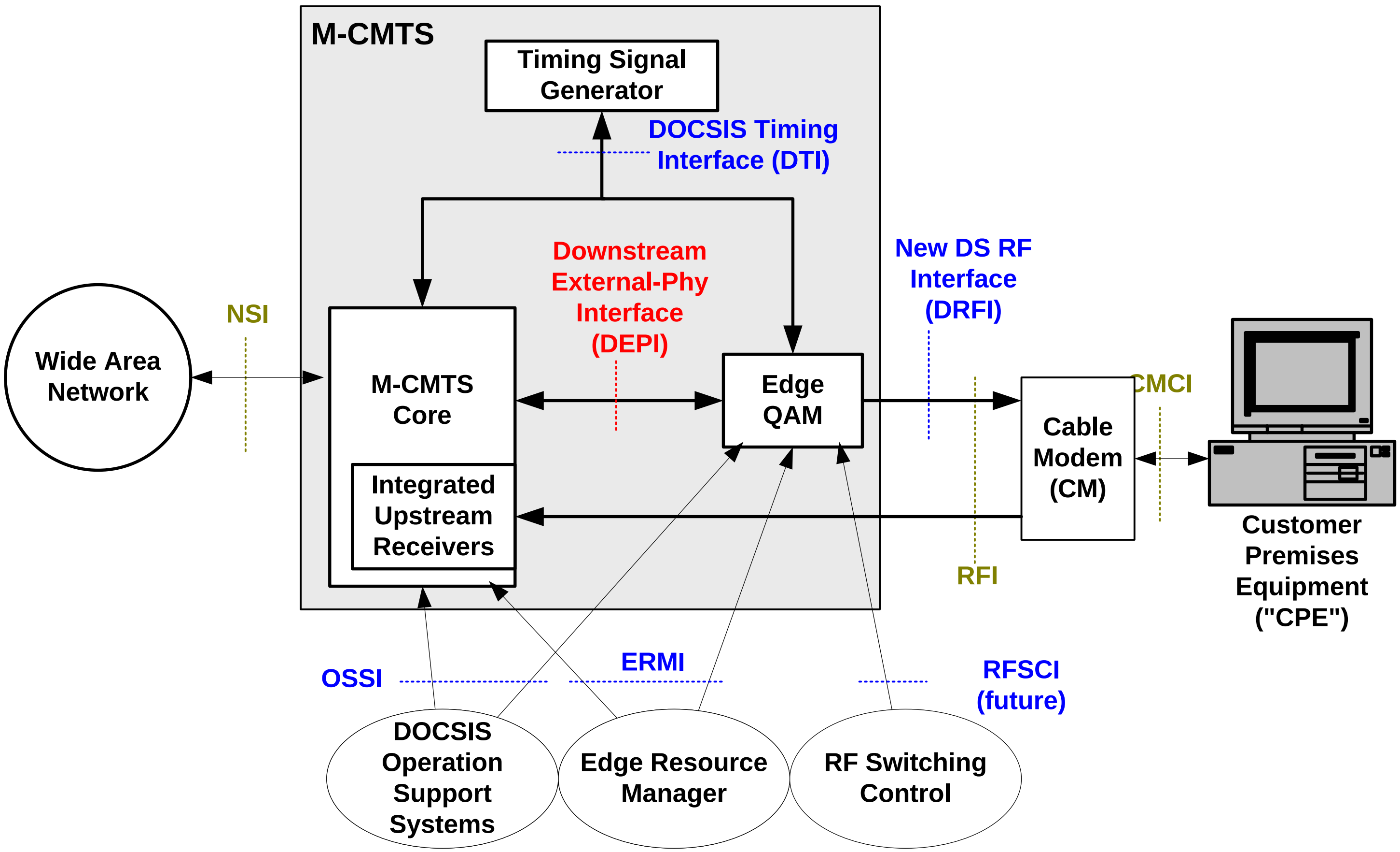
    Contention only occurs on specific control messages, not on data.
- DOCSIS specifies L1, L2, and provisioning.
  - L2 is very IP rich and has QOS
  - Provisioning is key to a Service Provider environment.

M-CMTS Goals & Objectives

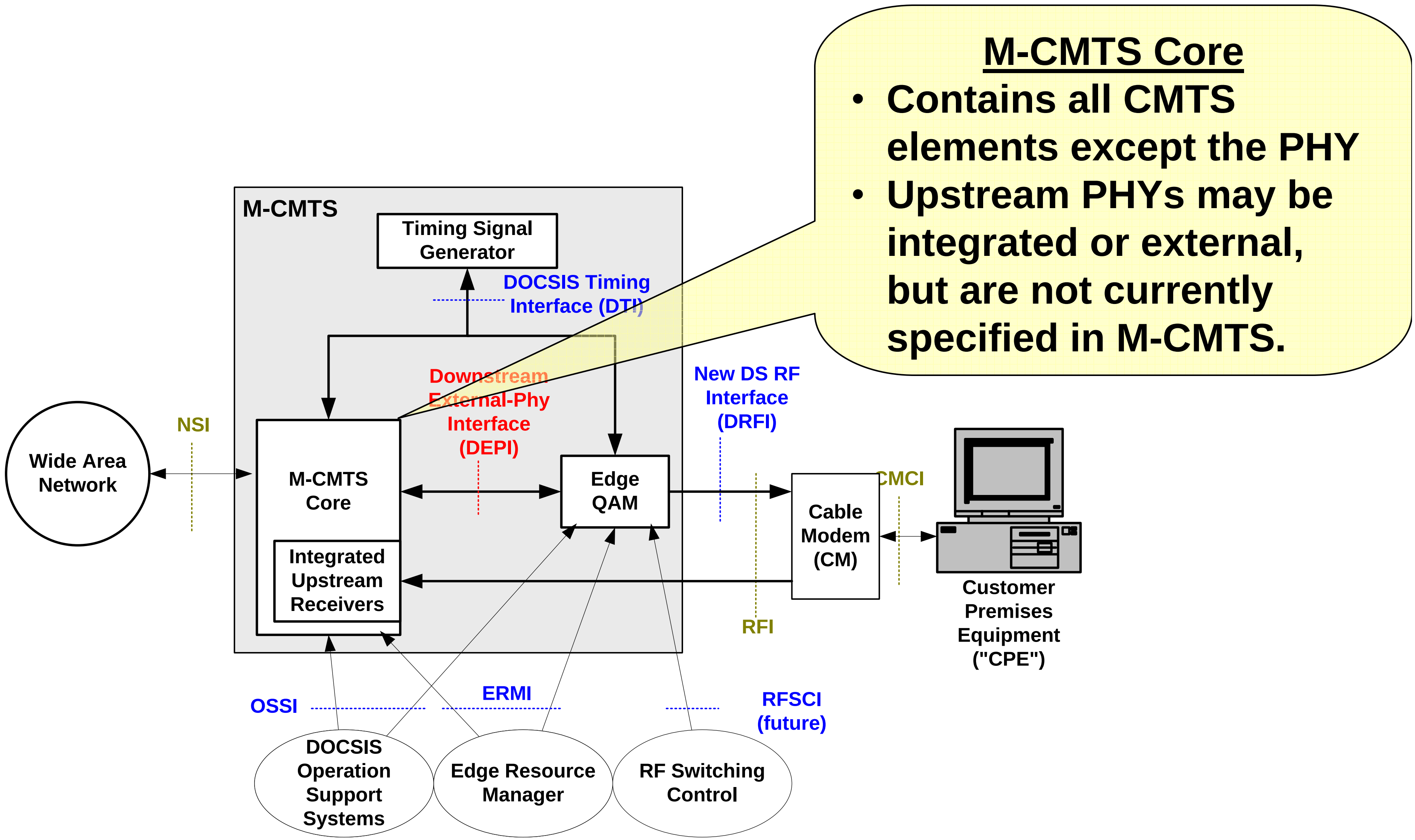
- Goals
  - – Lower cost per downstream for the CMTS
  - – Enable flexible configuration of upstreams and downstreams, thus allowing more downstream capacity.
  - – Share Edge QAM devices between Video and DOCSIS services

- Objectives
  - – Split upstreams from downstreams
  - – Split MAC from PHY

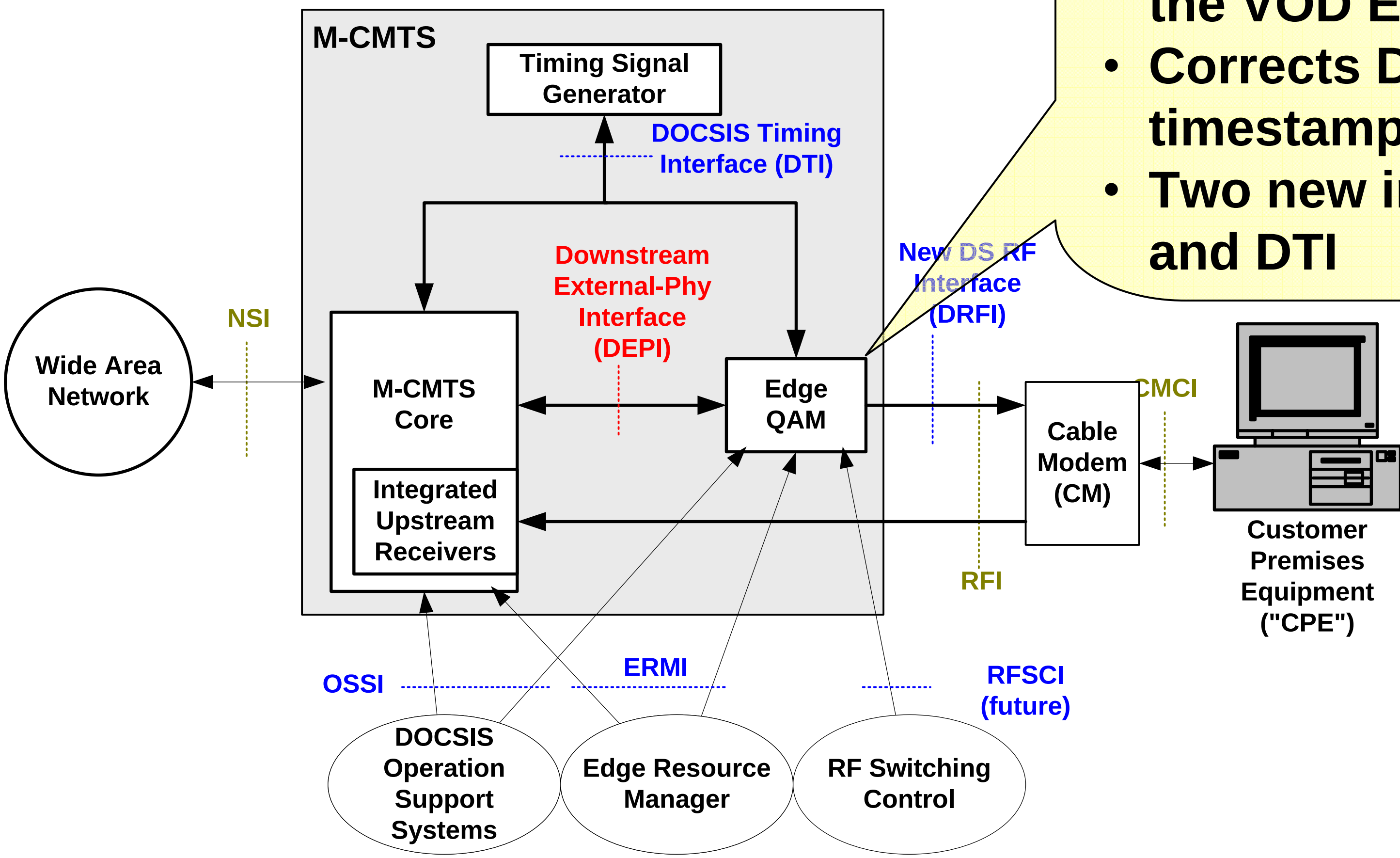
M-CMTS Block Diagram



M-CMTS Block Diagram



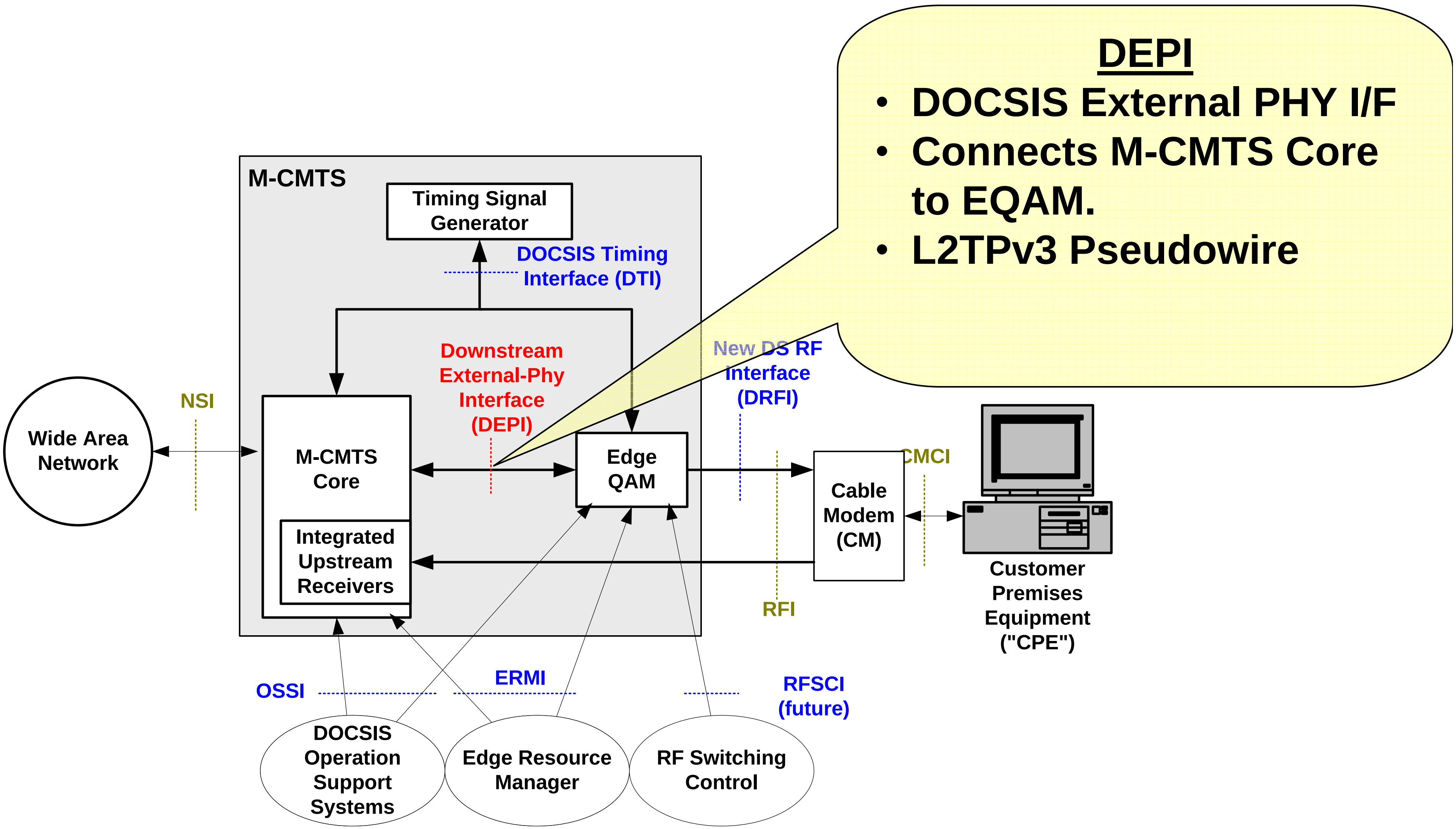
M-CMTS Block Diagram



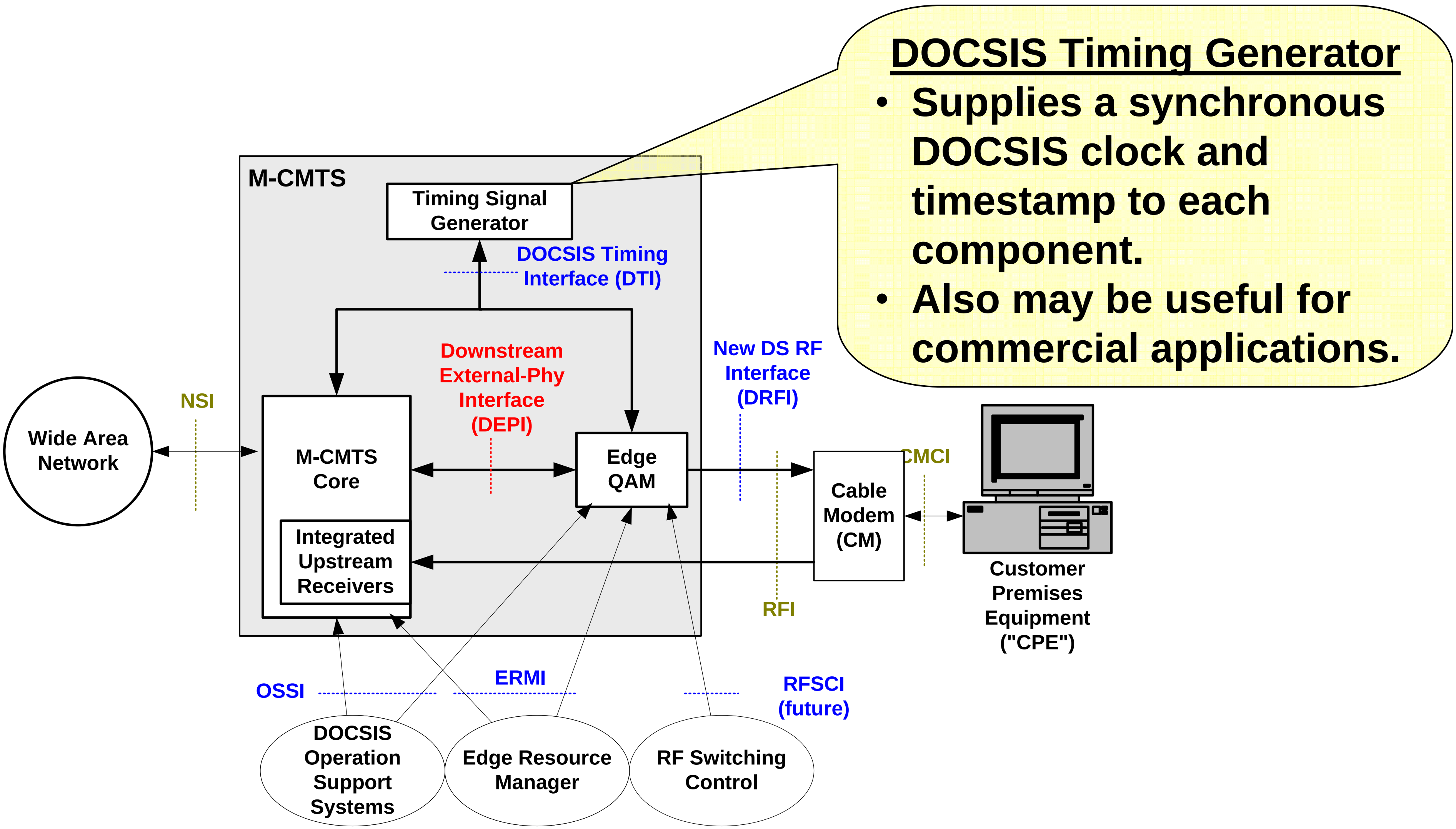
Edge QAM (EQAM)

- Synchronous version of the VOD Edge QAM
- Corrects DOCSIS timestamps
- Two new interfaces: DEPI and DTI

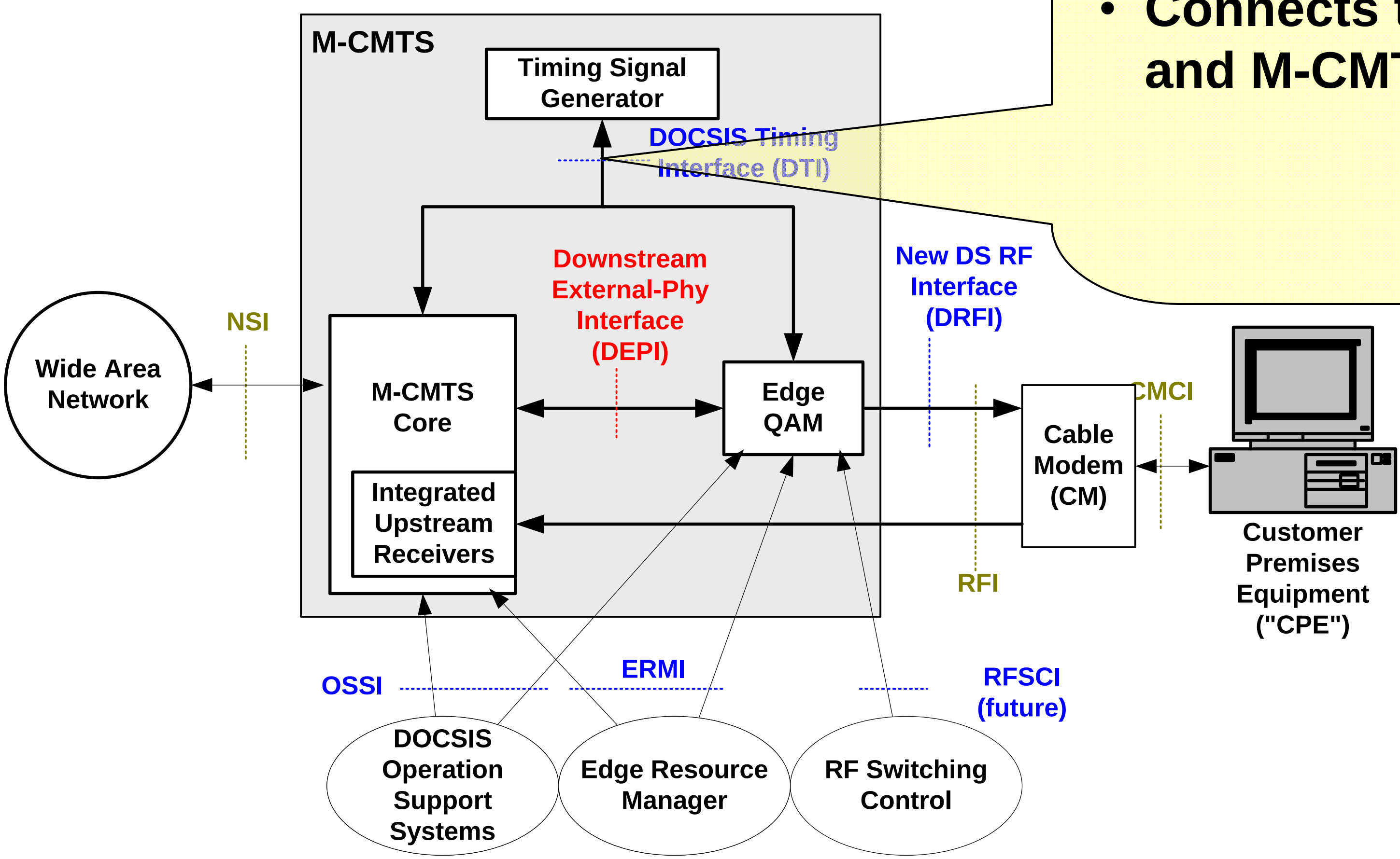
M-CMTS Block Diagram



M-CMTS Block Diagram



M-CMTS Block Diagram



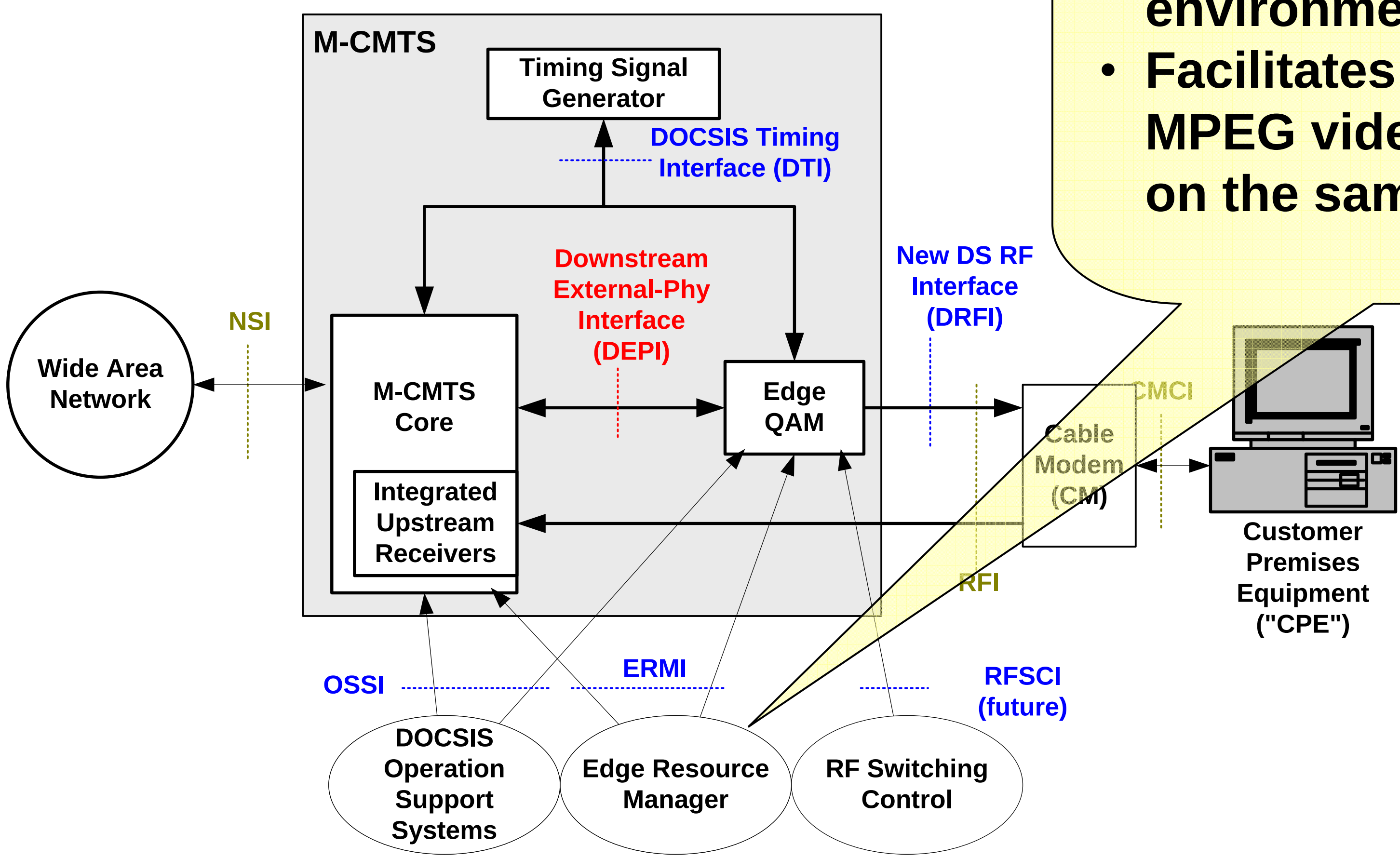
DTI

- DOCSIS Timing Interface
- Connects to both EQAM and M-CMTS Core

M-CMTS Block Diagram

Edge Resource Manager

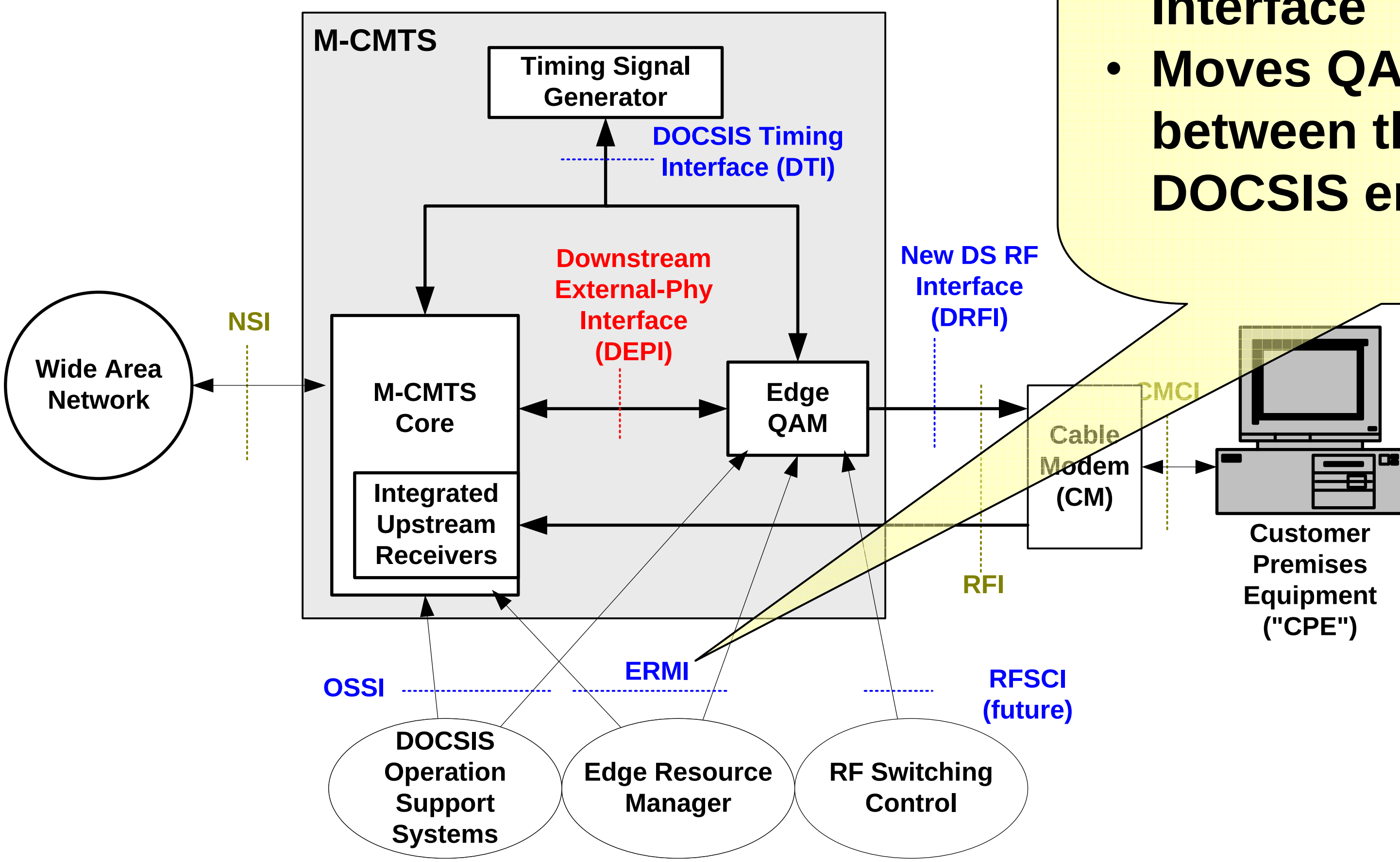
- Part of the VOD environment.
- Facilitates the sharing of MPEG video and DOCSIS on the same QAMs



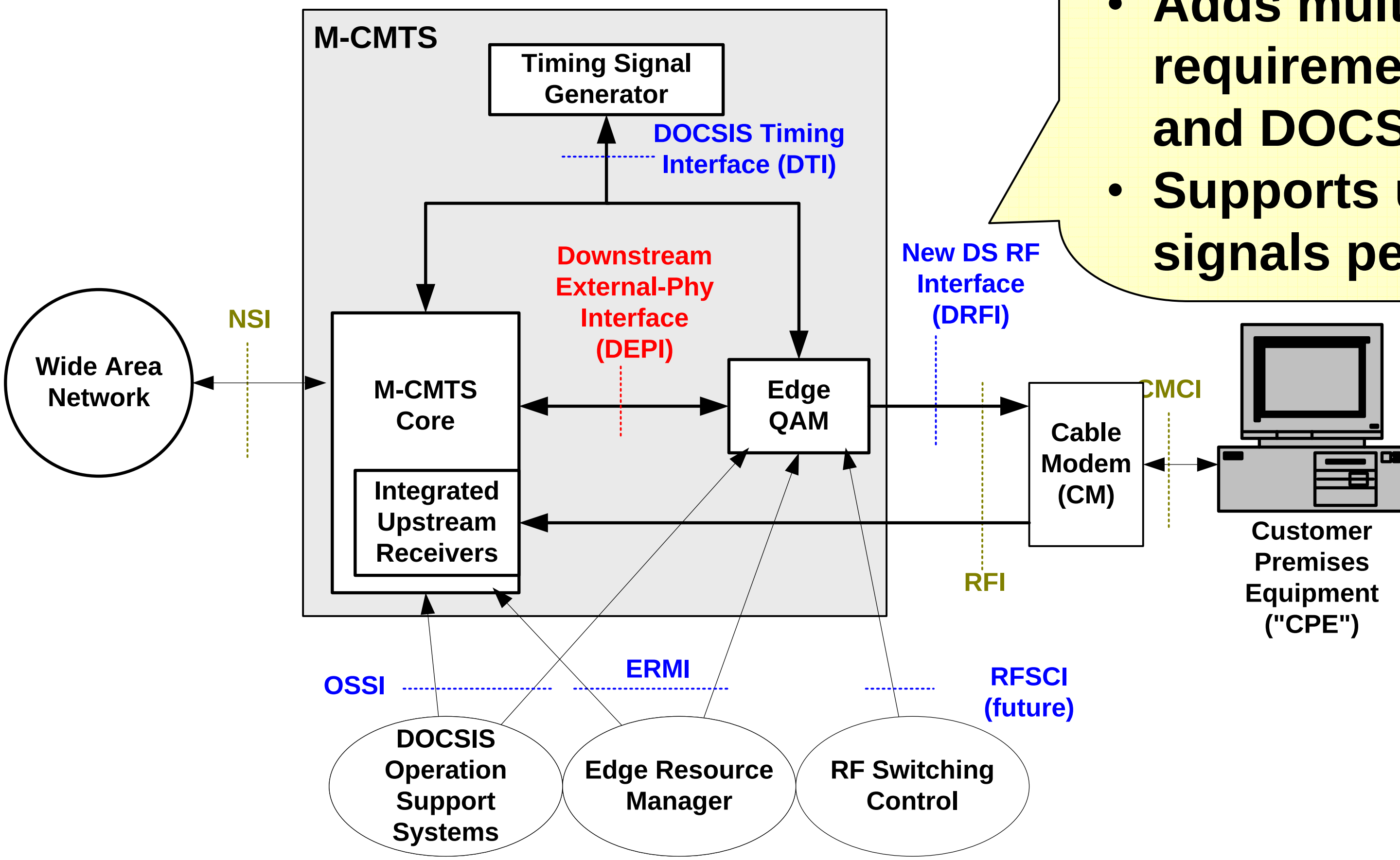
M-CMTS Block Diagram

ERMI

- Edge Resource Manager Interface
- Moves QAM channels between the VOD and DOCSIS environments



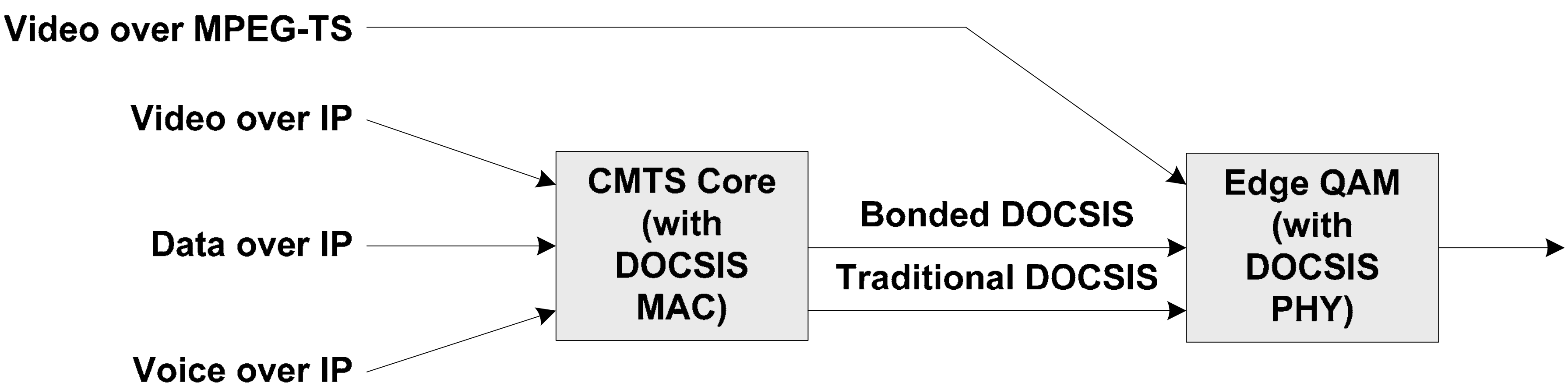
M-CMTS Block Diagram



DRFI

- Downstream RF Interface
- Adds multi-channel RF requirements for Video and DOCSIS
- Supports up to 119 digital signals per spectrum.

M-CMTS and Integrated Services



- The Edge QAM will multiplex legacy MPEG services such as VOD and Switched Broadcast along with the new DOCSIS 2.0 traditional and DOCSIS 3.0 bonded transports.
- Video MPEG-TS has its own completely separate timing requirements.
  – EQAM must handle both native Video and DOCSIS timing.

DOCSIS Timing

- DOCSIS is a synchronous system that carries asynchronous traffic.
  - Transport is synchronous and uses a common clock and time reference.
  - Packet transfer occurs on irregular and random boundaries.
- The CMTS downstream originates a MAC Management message called a SYNC 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.

DOCSIS Timing

- The CMTS and CMs must agree on the same frequency
  – So that bits can be exchanged continuously.
  – So that the CMTS upstream PHY burst receiver can lock quickly to the CM upstream PHY transmitter.
- The CMTS and CMs must agree on the same concept of time.
  – CMs need to be ranged in order to remove transmission delay from the 0-100 mile plant so that the CM upstream bursts can appear arrive at the CMTS back to back.
  – Upstream traffic needs to be scheduled in time (ATDMA and SCDMA) so a common time reference is needed.

DOCSIS Timing

- Timestamp:
  - 500 ns jitter on timestamp delivery to downstream
- Clock:
  - 10.24 MHz. “Clock MUST have frequency accuracy of ≤ ±5 ppm, drift rate ≤ 10-8 per second, and edge jitter of ≤ 10 nsec peak-to-peak (±5 nsec) over a temperature range of 0 to 40 degrees C up to ten years from date of manufacture”
- Coherency:
  - Upstream and downstream clocks must be derived from the same clock source)
- Round trip delay accuracy
  - 2 ns

M-CMTS Specific Timing Requirements

- 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.
- Specifically, frequency and time alignment between
  - EQAM timestamp
  - EQAM baud rate.
  - CM upstream baud rate
  - CMTS upstream burst receiver (even if external to CMTS)
  - CMTS upstream packet scheduler (time only)

DTI

Overview

DOCSIS Timing Interface (DTI)

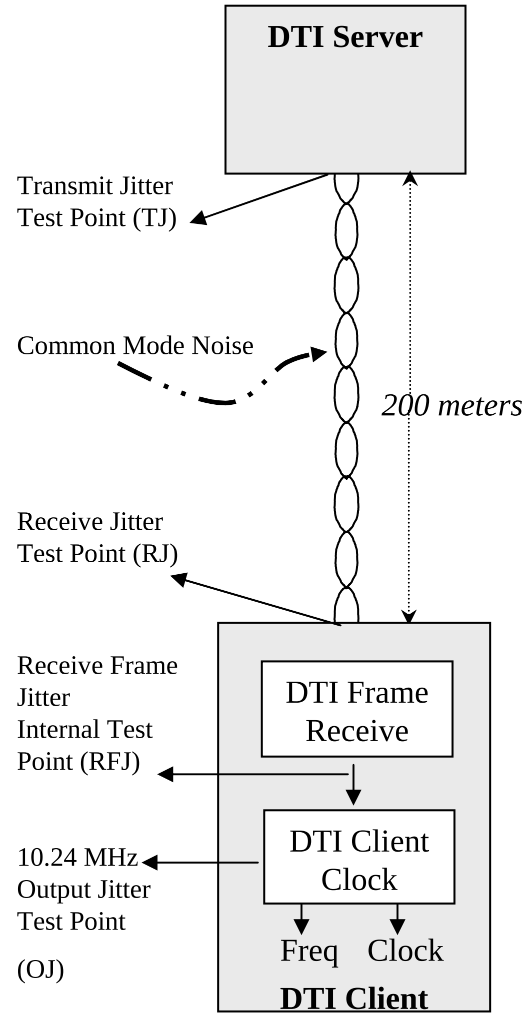
Universal Timing Interface (UTI)

DTI Intro

- DTI is a joint collaboration between Cisco and Symmetricom.
  - Cisco developed the original clocking architecture
  - Cisco partnered with Symmetricom to provide the technical detail and implementation.
- References:
  - 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, 408 428-7835, gzampetti@Symmetricom.com
- A version of DTI is being renamed UTI and being contributed to ITU-T SG9 for telecom use.

DTI Basics

- DTI provides:
  - Out-of-band 32 bit timestamp at each device time aligned to ≤ 5 ns (same site).
  - 10.24 MHz clock.
  - Intelligent multi-port server
  - simple, inexpensive client
- DTI Server with GPS provides:
  - Clock traceable to Stratum 1
  - Multi-site synchronization to an accuracy of 100 ns.
  - TOD (Time of Day) & GPS co-ordinates
- A DTI Server connects point to point with a DTI Client.
  - 5Mbps rate. 200 meters. CAT5.
  - 10 kHz frame rate. Full Duplex.



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.
  - This ensures at least a 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.
- High Availability (HA) achieved by dual homing DTI Clients to redundant DTI Servers.
  - DTI Servers are synced using a master-slave relationship.

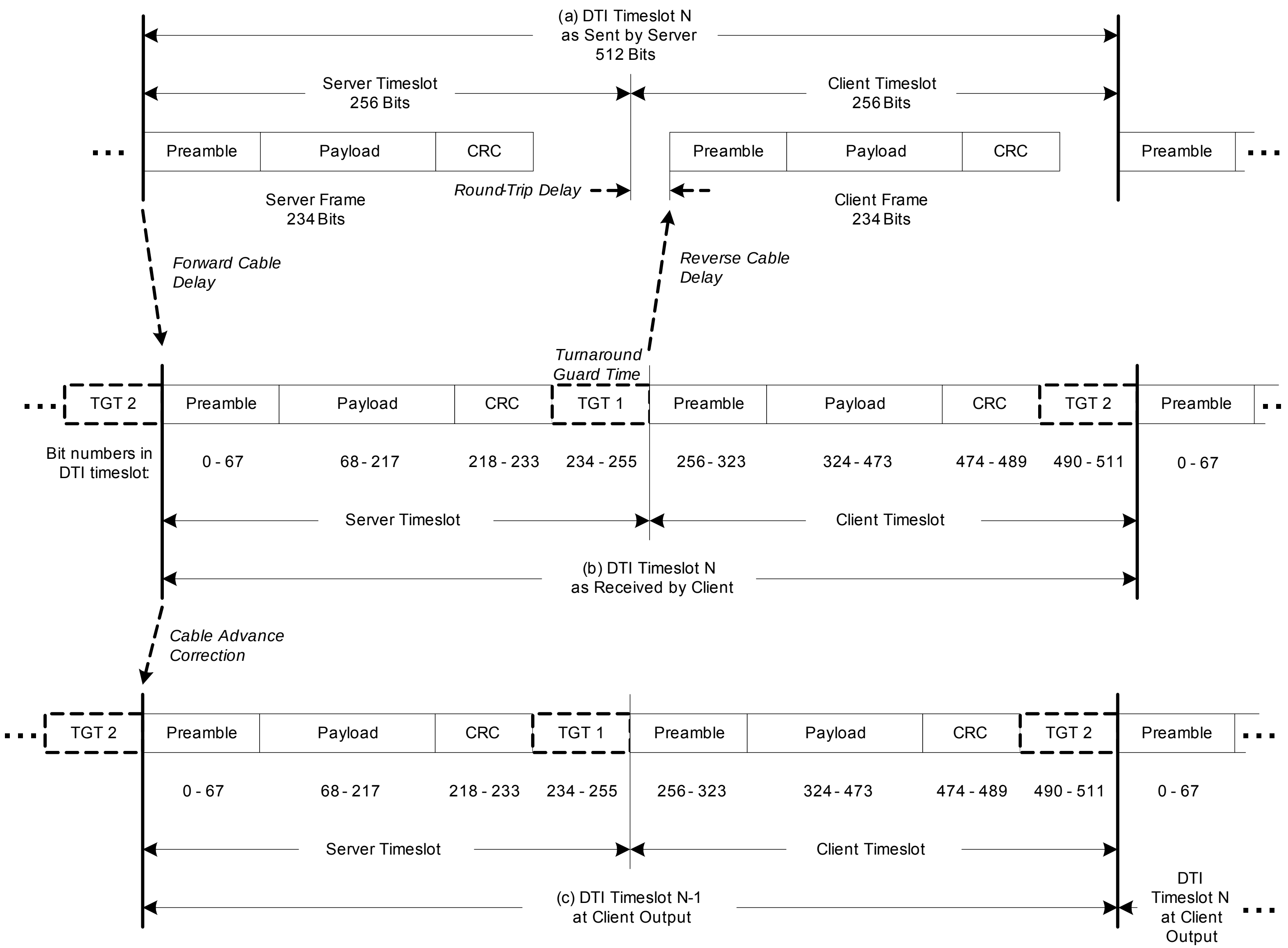
DTI PHY

- 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

DTI Framing



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

- M-CMTS
  – Sync Packet Shelf, DS PHY Shelf, and US PHY Shelf together.
- Business Services over DOCSIS (BSoD)
  – Provide a Stratum 1 traceable clock to a CM which can then provide clocking for T1 pseudowire interface.
- Network Delay Measurements
  – Packet takes a timestamp from location #1, travels to location #2, grabs a timestamp there, and then returns to location #1.

    Location #1 subtracts the time stamps to calculate delay.

  – DOCSIS Latency Measurement (DLM) measures latency from Modular CMTS-Core to EQAM.
  – DOCSIS Path Verify (DPV) measure latency and skew from CMTS to CM.

