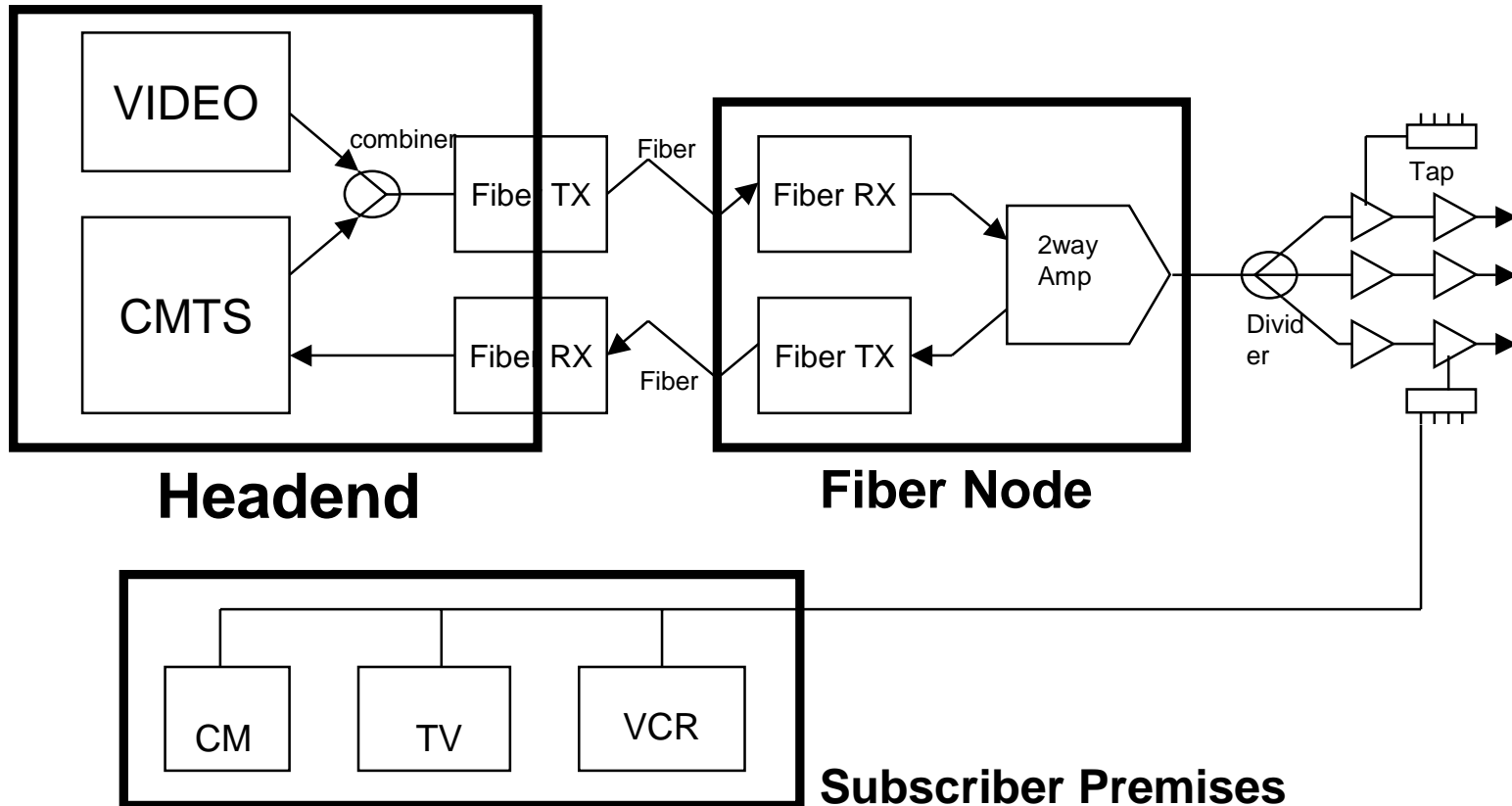

DOCSIS Overview

Ajay Gummalla

Ethernet in the First Mile Study Group

July 2001

HFC Plant Topology

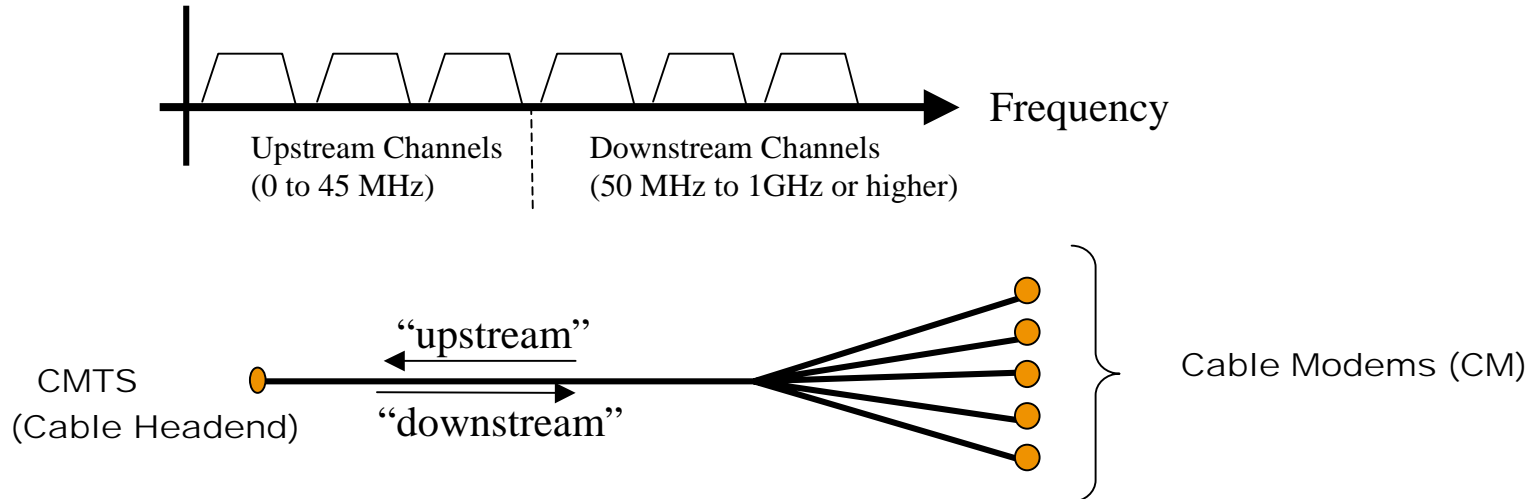


Typical fiber node supports about 2000 subscribers

Terminology

- **DOCSIS: Data over cable service interface specification**
- **CM: Cable Modem**
- **CMTS: Cable Modem Termination System**

Communication Basics



- The DOCSIS system is a **Point to Multipoint** communications system employing a **continuous** signal in the downstream direction and a TDMA **burst** signal in the upstream direction
- **Upstream**
 - TDMA Burst of QPSK or 16QAM signals
 - Supports data rates upto 10 Mbps
 - Supports multiple upstream channels
- **Downstream**
 - TDM Continuous Transmission 64 or 256 QAM signals
 - The downstream uses an MPEG transmission convergence sublayer
 - Data rates upto 100 Mbps

Objective

- **Show DOCSIS solutions for P2MP issues**

- **Link management**

- Upstream synchronization (timing adjustment)
 - Ranging (offset adjustment) (Periodic and Initial)
 - Power adjustment
 - Burst transmission and reception

- **Bandwidth management**

- Bandwidth allocation
 - Contention resolution
 - Prioritization/classification of traffic
 - Supports unsolicited grant service (voice/T1 ckts)

- **Subscriber management**

- Authentication
 - Security
 - Registration
 - MIBs

Overview

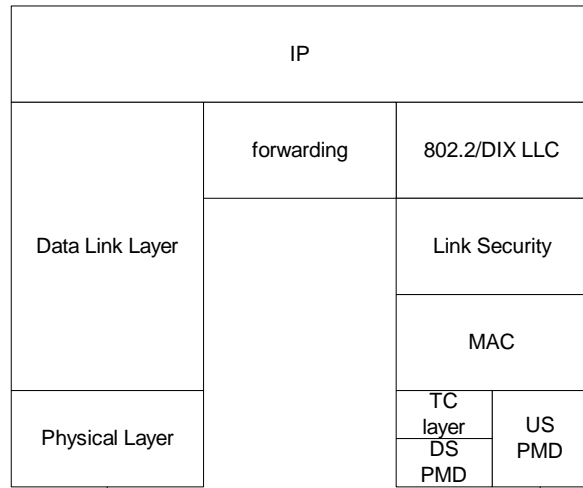
- **DOCSIS1.0**

- Designed for Best Effort Service
- Uses request/grant mechanism for accessing upstream bandwidth
- Single Quality of Service association per modem
- Baseline Privacy provides in-line 56-bit DES encryption/decryption to secure the privacy of the connection

- **DOCSIS1.1: Quality of Service Extensions**

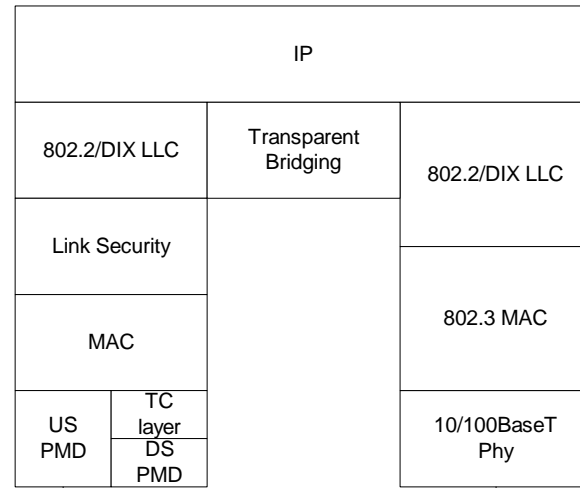
Protocol Layering

CMTS Protocol Stack



CMTS Network Interface

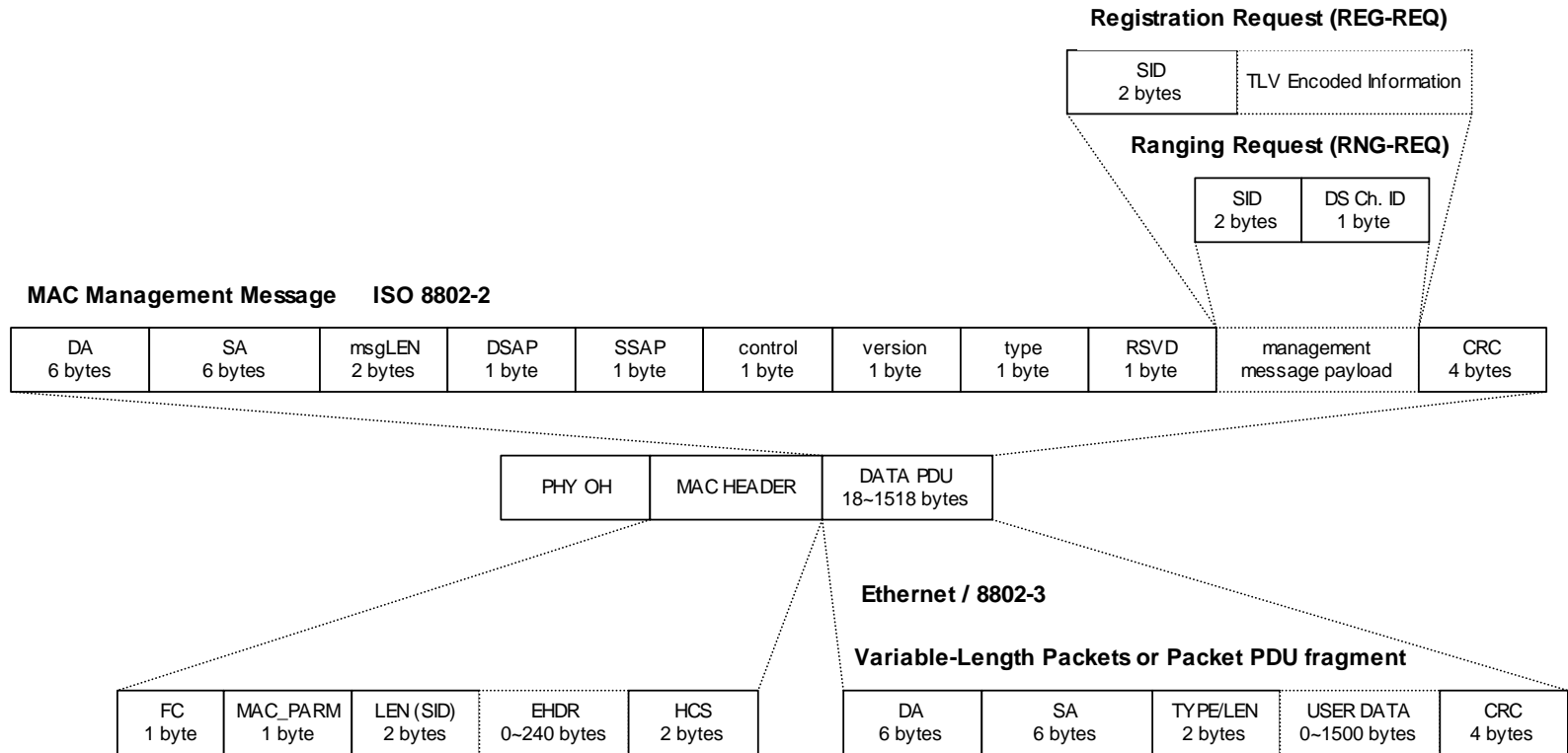
CM Protocol Stack



CM Subscriber Interface

- Conforms to 802.1d forwarding rules
- CMTS reflects all broadcast packets and CMs drop based on SA match

Frame Formats



MAC Management Messages

MAC Management Message ISO 8802-2

DA 6 bytes	SA 6 bytes	msgLEN 2 bytes	DSAP 1 byte	SSAP 1 byte	control 1 byte	version 1 byte	msg type 1 byte	RSVD 1 byte	management message payload	CRC 4 bytes
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Type Value	Version	Message Name	Message Description
1	1	SYNC	Timing Synchronization
2	1	UCD	Upstream Channel Descriptor
3	1	MAP	Upstream Bandwidth Allocation
4	1	RNG-REQ	Ranging Request
5	1	RNG-RSP	Ranging Response
6	1	REG-REQ	Registration Request
7	1	REG-RSP	Registration Response
12	1	BPKM-REQ	Privacy Key Management Request [DOCSIS8]
13	1	BPKM-RSP	Privacy Key Management Response [DOCSIS8]
14	2	REG-ACK	Registration Acknowledge
15	2	DSA-REQ	Dynamic Service Addition Request
16	2	DSA-RSP	Dynamic Service Addition Response
17	2	DSA-ACK	Dynamic Service Addition Acknowledge
18	2	DSD-REQ	Dynamic Service Deletion Request
19	2	DSD-RSP	Dynamic Service Deletion Response
20	2	DSC-REQ	Dynamic Service Change Request
21	2	DSC-RSP	Dynamic Service Change Response
22	2	DSC-ACK	Dynamic Service Change Acknowledge
25-255			Reserved for future use

All management messages are in TLV format and are encapsulated in Ethernet format

CM Initialization

- DS synchronization
- Obtain upstream parameters
- Ranging and automatic adjustments
- Establish IP connectivity
- Establish time of day
- Transfer operational parameters (TFTP download of Configuration parameters)
- Registration
- Baseline privacy initialization

CM Initialization (Details..)

CMTS

CM

..... Upstream Channel Descriptor (<2s)



CM locks on DS channel, acquires time sync for US, sets up modulator for appropriate US channel.

..... MAP (usually 1-10ms)



CM picks random number in ranging backoff window, searches MAPs for appropriate initial ranging slot, and transmits at that time. MAC waits for ranging response message.

..... Ranging Request



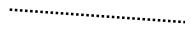
If CM times out on response, CM increases TX power level and signals MAC. MAC increases backoff window and picks a new slot, searches MAPs for appropriate initial ranging slot, and transmits at that time. MAC waits for ranging response message.

CMTS eventually hears modems ranging request and sends ranging response. CMTS then sends station maintenance slots to CM being ranged.

..... Ranging Request



..... Ranging Response

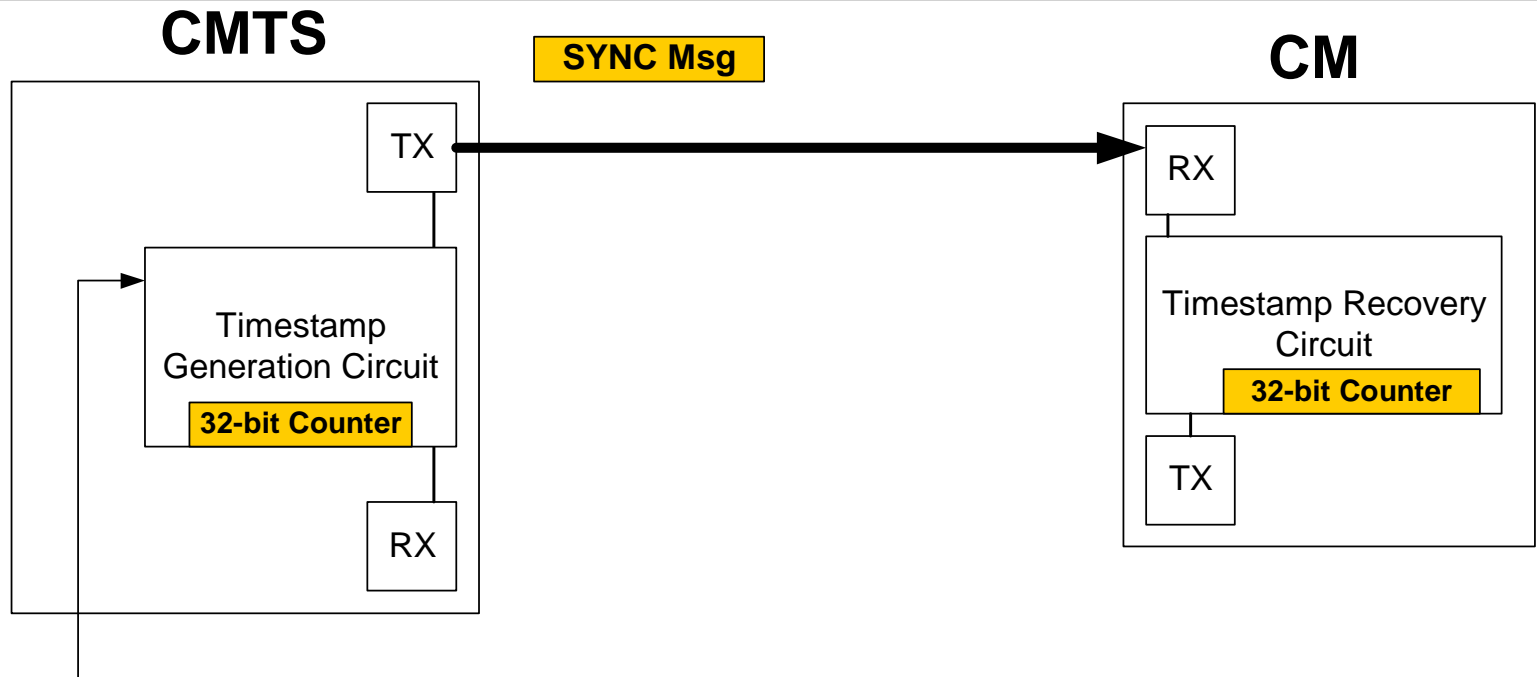


CM tells MAC to switch to station maintenance slots. MAC automatically transmits a ranging request in any station maintenance slot reserved for it. Modem adjusts timing, power level, and frequency offset per ranging response.

..... Ranging Complete Message



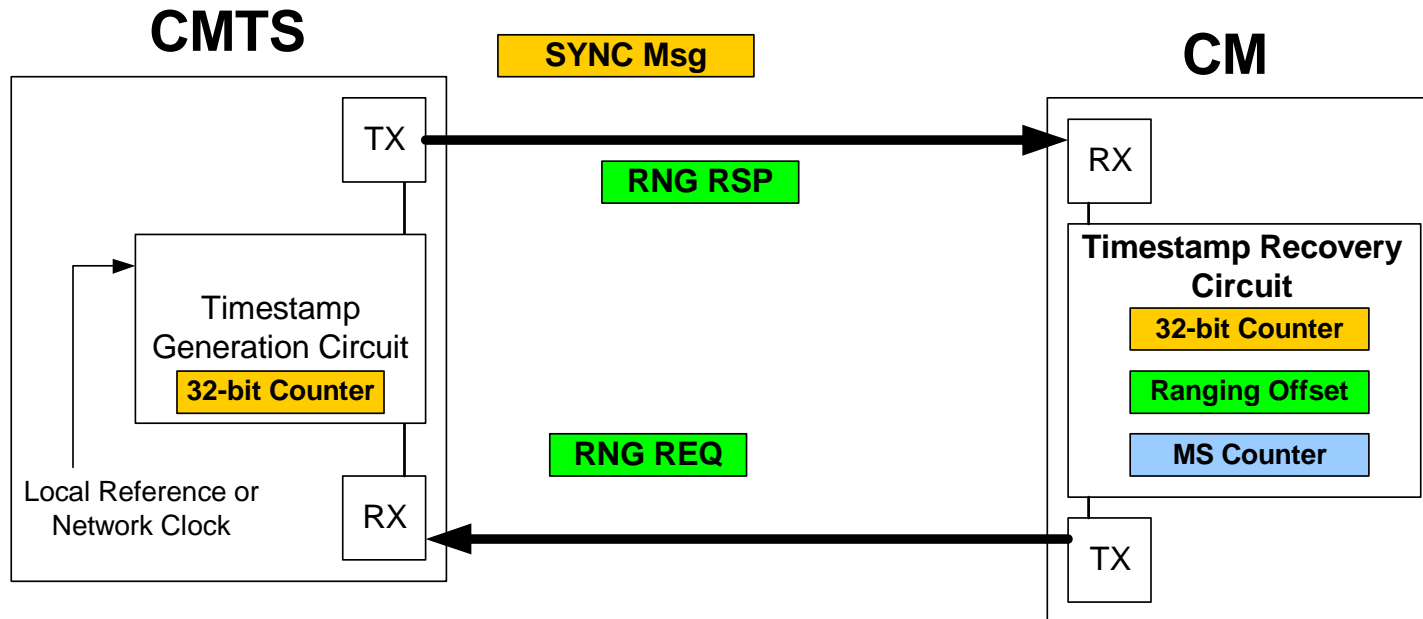
Clock Synchronization



Local Reference or
Network Clock

- CMTS sends out periodic sync messages that contain a 32-bit time stamp of 10.24 MHz clock
- CM receives sync messages and locks the frequency of it's local clock so that it matches the time stamp in the sync messages
- CM now knows frequency of CMTS clock but not the phase because of propagation delays in receiving the sync messages

Ranging Process

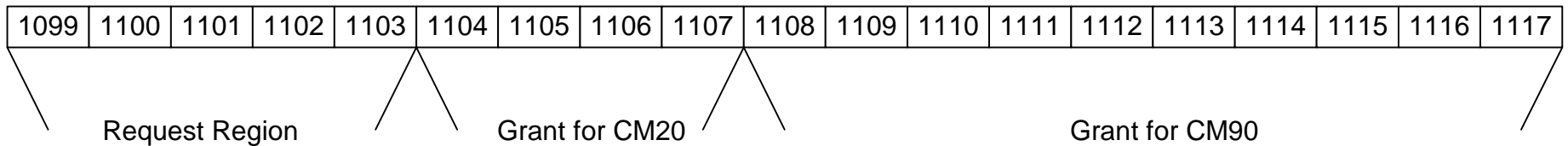


- Before initial transmission, CM loads its ranging offset register with a value to compensate for the known delays (DS interleaver, implementation delays, etc.)
- The CM then adjusts its 32-bit sync counter by the amount in the ranging offset.
- The CM then selects an initial ranging slot and transmits.
- The CMTS measures the difference between the received and expected transmission boundaries and sends that back to the CM as a ranging adjustment. It also communicates the power level, frequency offset and delay adjustment to the CM.

Bandwidth Management

- Request-Grant arbitration mechanism
- CM makes requests to the CMTS
 - Requests can be made in Contention or as Piggybacks
 - Contention is resolved using combination of Binary exponential back off and Ack-Timer
 - Piggyback is a request for additional bandwidth sent in a data transmission
 - Only one unresolved request allowed per priority per CM
- CMTS issues grants using a MAP message
- CM transmits data during its Grant period

TDMA Control



- Upstream time is divided into minislots. Minislot is just a convenient partitioning of time for bandwidth allocation purposes
- An upstream transmission is described by a burst profile
 - A burst profile specifies: Modulation type, Preamble length and value, FEC, Scrambler properties, Maximum burst size, Guard period
 - Burst types: Initial Maintenance, Periodic Maintenance, Request, Short Data and Long Data
- The CMTS serves as the upstream (TDMA) controller.
- The upstream is divided into different regions.
- Downstream messages called MAPs assign upstream regions to CMs.
- Portions of the upstream bandwidth are open to all modems (contention) for requesting upstream bandwidth and for initial ranging.

MAP Information

Upstream Channel ID

UCD Count

(misc.)

MAP start time = 1099

ACK time=0800

Ranging Backoffs

Data Backoffs

Request Region Offset=0

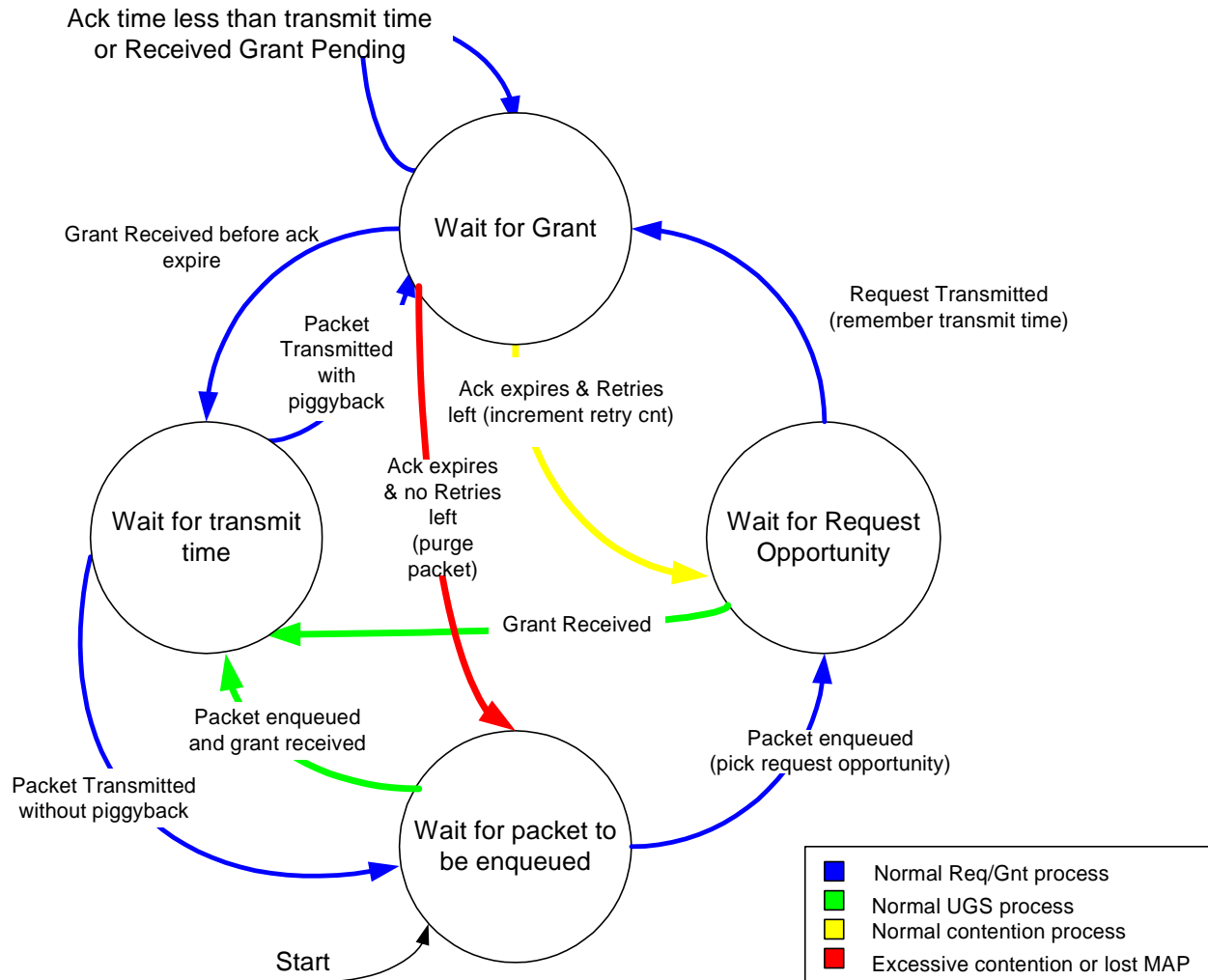
Grant for CM20 Offset=5

Grant for CM90 Offset=9

Null Offset=19

Zero Length Grants (Data Grant Pending)

CM Request Grant Process



Security - Baseline Privacy

- **Two component protocols:**
 - Encapsulation protocol for encrypting packet data across the cable network
 - BPKM (Baseline Privacy Key Management) protocol for providing secure distribution of keying material from the CMTS to the CM
- **Encapsulation protocol defines**
 - the frame format for carrying encrypted data within DOCSIS MAC frames
 - set of supported cryptographic suites (pairings of data encryption and authentication algorithms)
 - Currently employs Cipher based chaining mode of DES
 - rules for applying these algorithms to a DOCSIS frame's packet data
- **DOCSIS frame header is not encrypted to facilitate registration, ranging and normal operation of the DOCSIS MAC sublayer**

Ref:

http://www.cablemodem.com/Security_in_DOCSIS.pdf

BPI has been enhanced in DOCSIS1.1 to add authentication and Multicast support.

http://www.cablemodem.com/BPI+_I06-001215.pdf

DOCSIS 1.1

- Quality of Service: Service flows, classifiers, scheduling types and dynamic service establishment
- Fragmentation - Allows segmentation of large packets simplifying bandwidth allocation for CBR-type services
- Concatenation - Allows bundling of multiple small packets to increase throughput
- Security Enhancements (Authentication) - Baseline Privacy Plus provides authentication as well as in-line DES encryption/decryption
- Encryption support for Multicast Signaling (IGMP-Internet Group Management Protocol)
- Payload Header Suppression- Allows suppression of ethernet/IP header information for improved bandwidth utilization

Summary

- DOCSIS is widely deployed today.
- DOCSIS addresses point to multipoint issues. It has been used in cable and wireless systems.
- All DOCSIS Management and Control is through Ethernet messages.
- DOCSIS specifies all aspects of a complete access system which are relevant to PON in EFM.