HFC to IP Overview

- Review
  - DOCSIS & IP
  - DOCSIS registration
  - PacketCable
  - HFC Nodes
- Boxes in the network
  - Modems, MTAs, Nodes, etc
- What’s rolling out today in your network
  - DOCSIS 3.0 “downstream”
  - DOCSIS 2.0 “upstream”
  - Lesson’s learned from other D3.0 rollouts
- What could or will be coming in the future
  - RFoG
  - SCDMA
  - DOCSIS 3.0 devices
  - SIP eMTAs

DOCSIS and PacketCable

DOCSIS

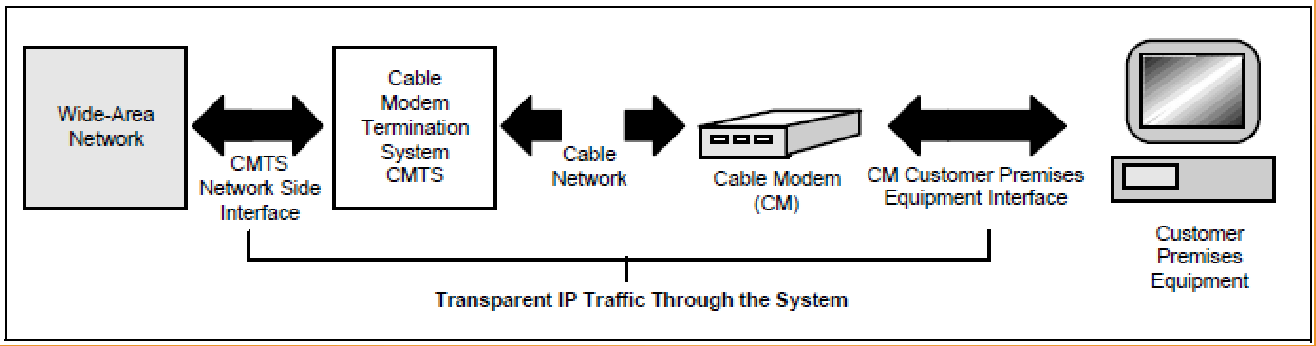
- Interface specifications for IP-based traffic over HFC plants
- The DOCSIS System Consists of:
  - Cable Modem Termination System (CMTS) located at the headed
  - Cable Network
  - Cable Modem (CM) located at the Customer Premise

PacketCable

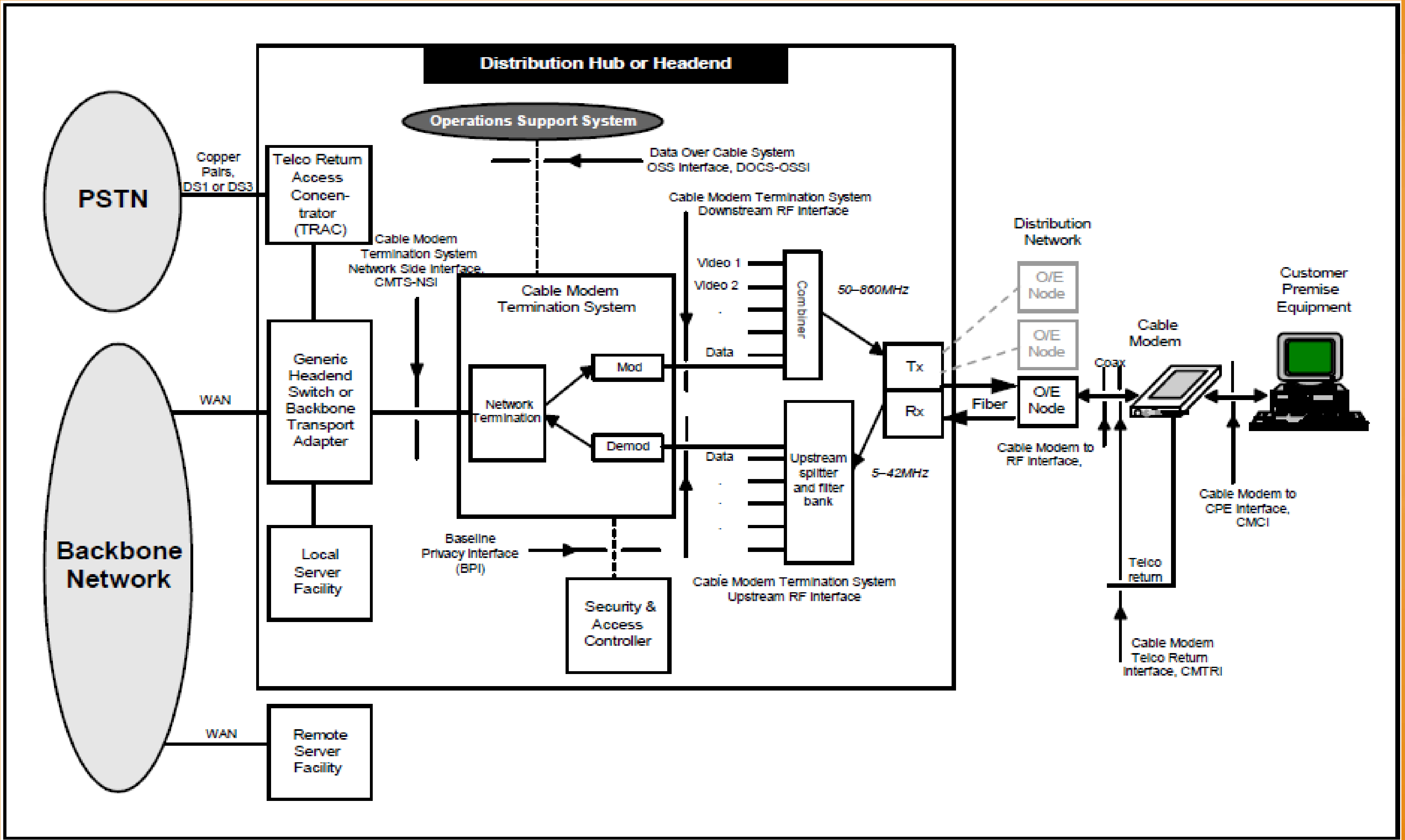
- Interface specifications for real-time multimedia services over HFC plants
- Initial specs address IP telephony and are founded on DOCSIS 1.1/2.0

DOCSIS Service Goal

The service will allow transparent bi-directional transfer of Internet Protocol (IP) traffic, between the cable system head-end and customer locations, over an all-coaxial or hybrid-fiber/coax (HFC) cable network.

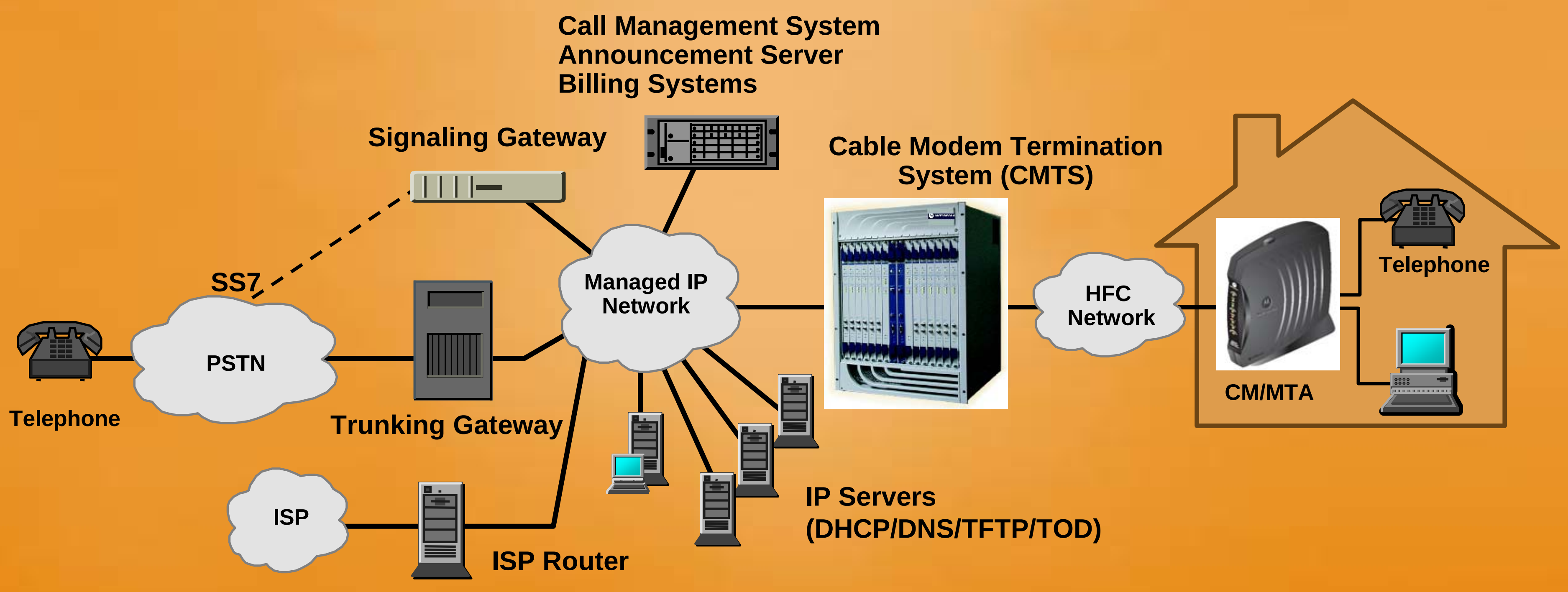


DOCSIS Reference Architecture



Example Network – Data & Voice

- Data and Voice services using IP over DOCSIS infrastructure
- PacketCable Softswitch based approach
- Provisioning via CSR or Subscriber
- IP Services (DHCP/DNS/TFTP/ TOD)



Managed IP Network

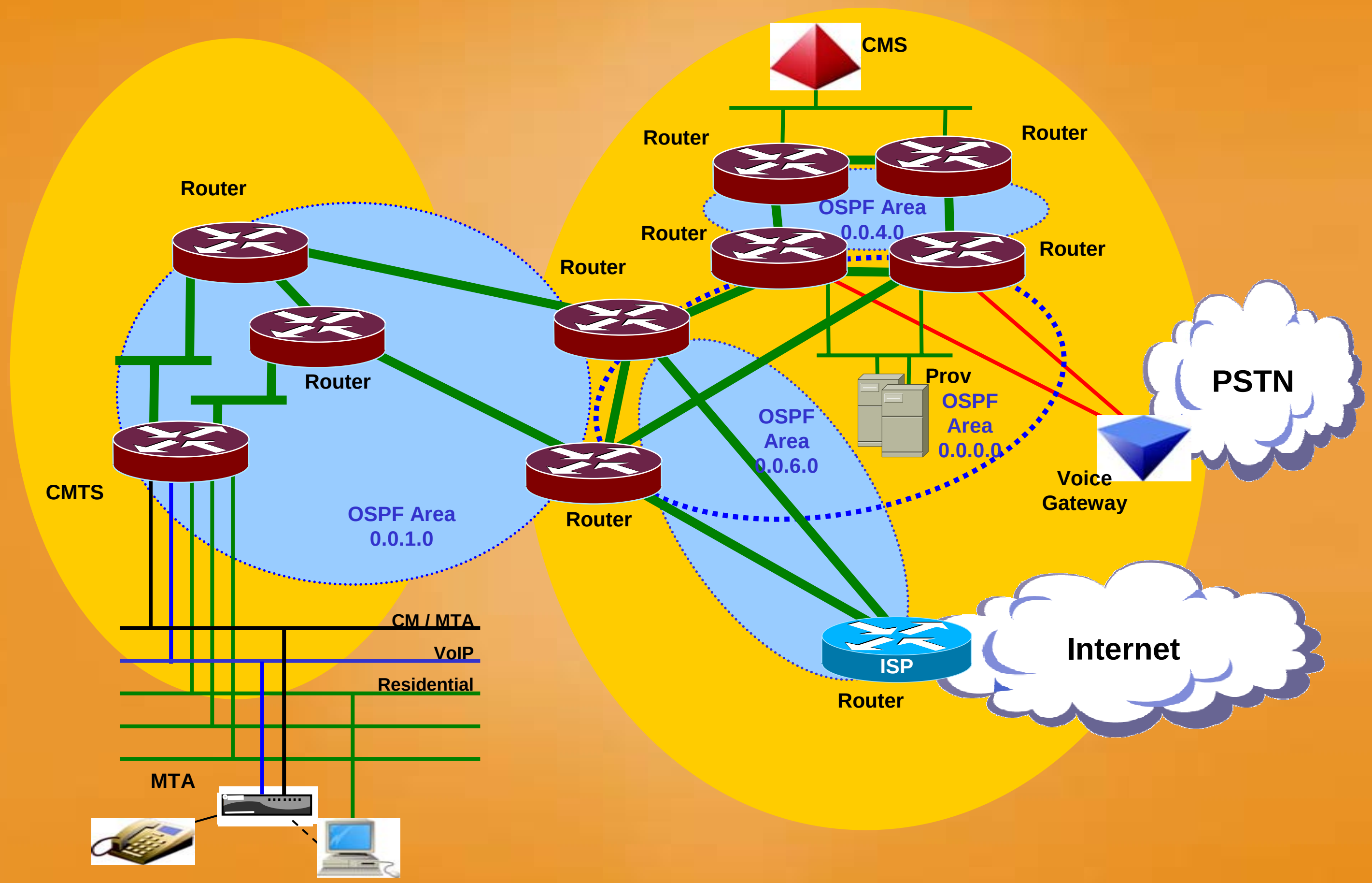


Figure 4.2: Oviedo Logical End-to-End Path

Example IP Address Plan

CMTS	IP Subnet Description	IP Network Prefix	Addresses (approx)
Location A	CM/MTA	10.1.0.0/16	64,000
	VoIP	172.22.0.0/16	64,000
	Residential	81.9.160.0/20	4,000
	Commercial	81.9.240.0/22	1,000
	Backbone VLAN 103	212.89.2.160/29	6
	Backbone VLAN 104	212.89.2.168/29	6
	Interface Loopback0	212.89.2.7/32	1
	Mgmt 10/100 Interface	10.136.0.0/16	64,000

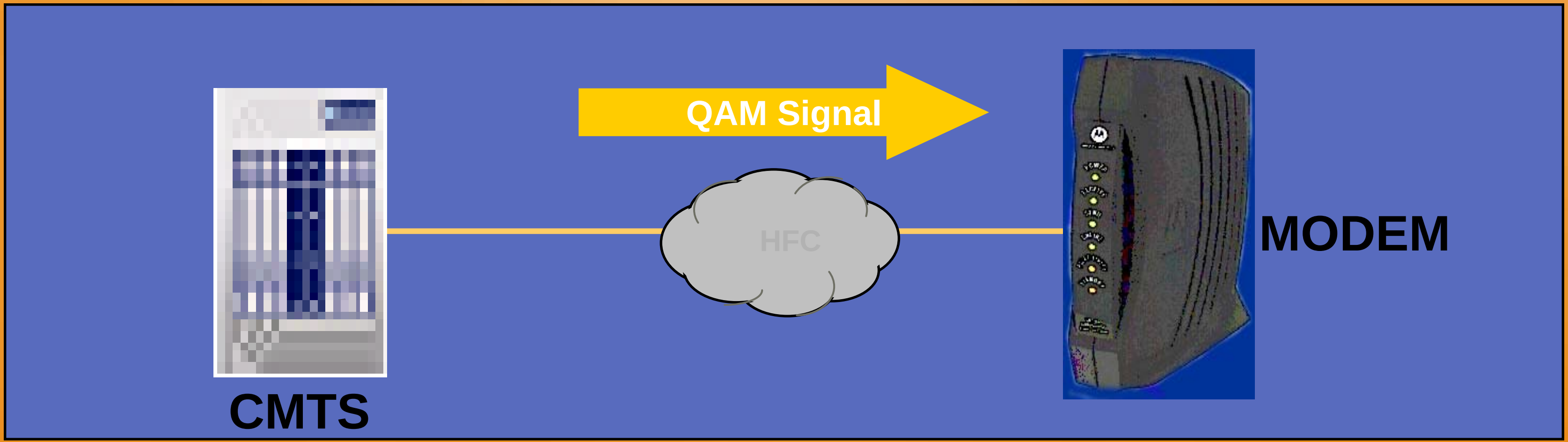
DOCSIS Registration

- **Overview of CMTS and CM Registration Process**
  - Find the Downstream
  - Obtain Upstream Channel Parameters
  - Perform Initial Ranging
  - Establish IP Connectivity
  - Establish TOD
  - Get Configuration Parameters
  - Register
  - Establish Baseline Privacy
  - Periodic Ranging
  - Data Transmission

Downstream Channel Search

CM searches for a downstream data channel

- **Scan downstream channels**
  - Periodically last stored downstream channel
- **Synchronize with QAM**
- **Synchronize with FEC and MPEG**



Monitor for SYNC Message

Periodically transmitted by CMTS (1 per 1.63 msec)

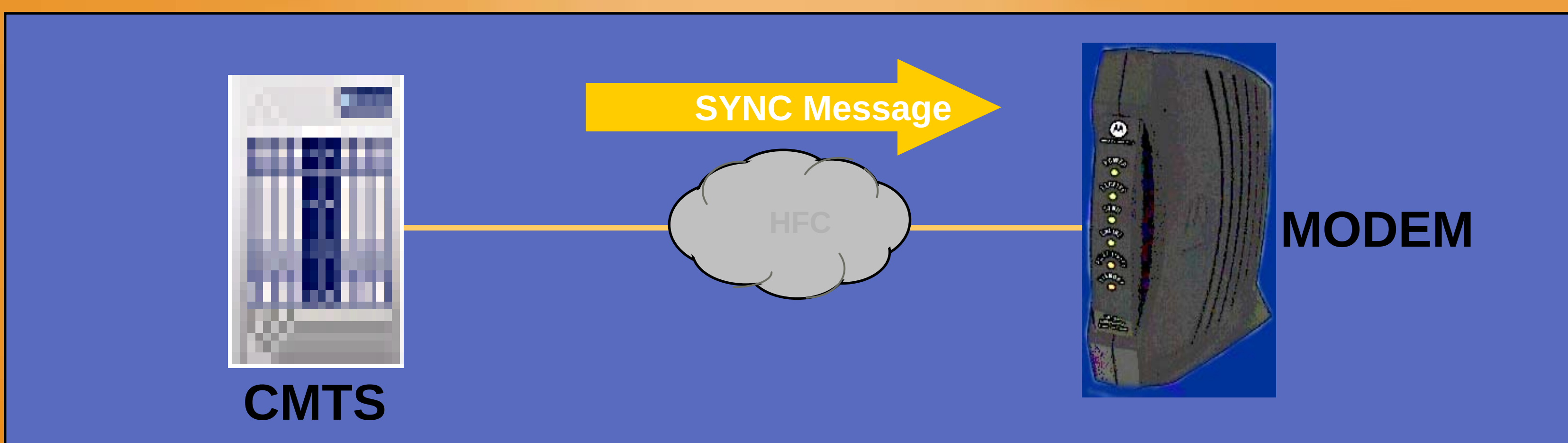
SYNC message contains a time stamp that exactly identifies when the CMTS transmitted the message

CM to synchronize its time-based reference clock so that its transmission on the upstream will fall into the correct mini-slots

To accomplish this, two pieces of information are needed by each cable modem:

- a global timing reference sent downstream from the CMTS to all cable modems (Sync)

- a timing offset, calculated during ranging, for each cable modem.



Obtain Upstream Parameters

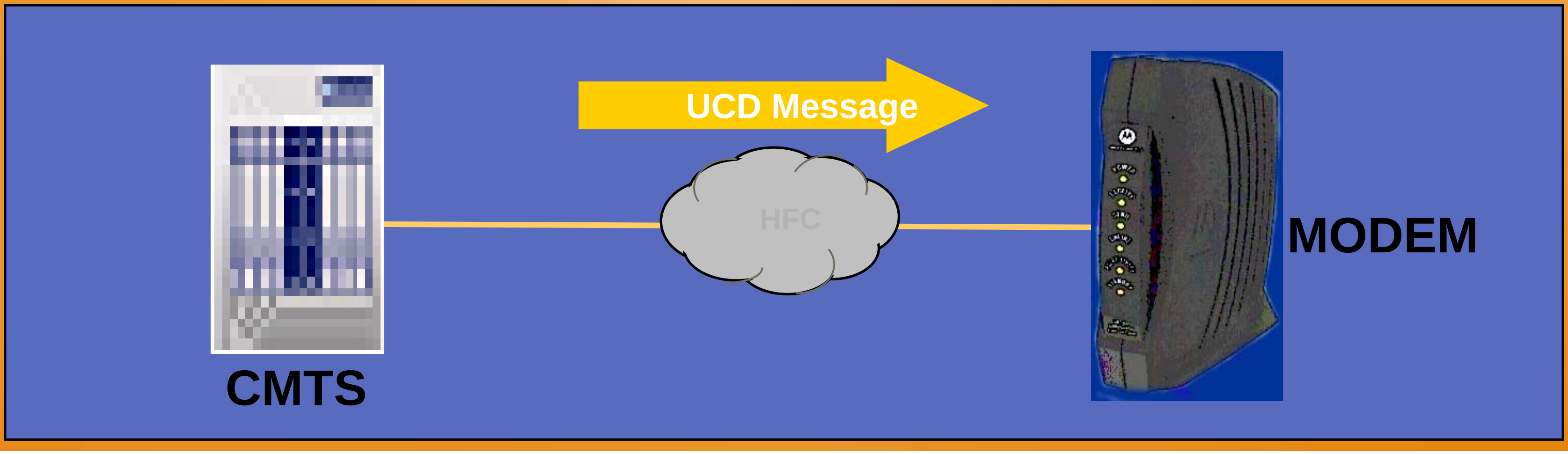
Monitor for UCD message

UCD sent downstream describing each active upstream channel.

Periodically transmitted by the CMTS as a MAC broadcast once per 4 msec per US channel.

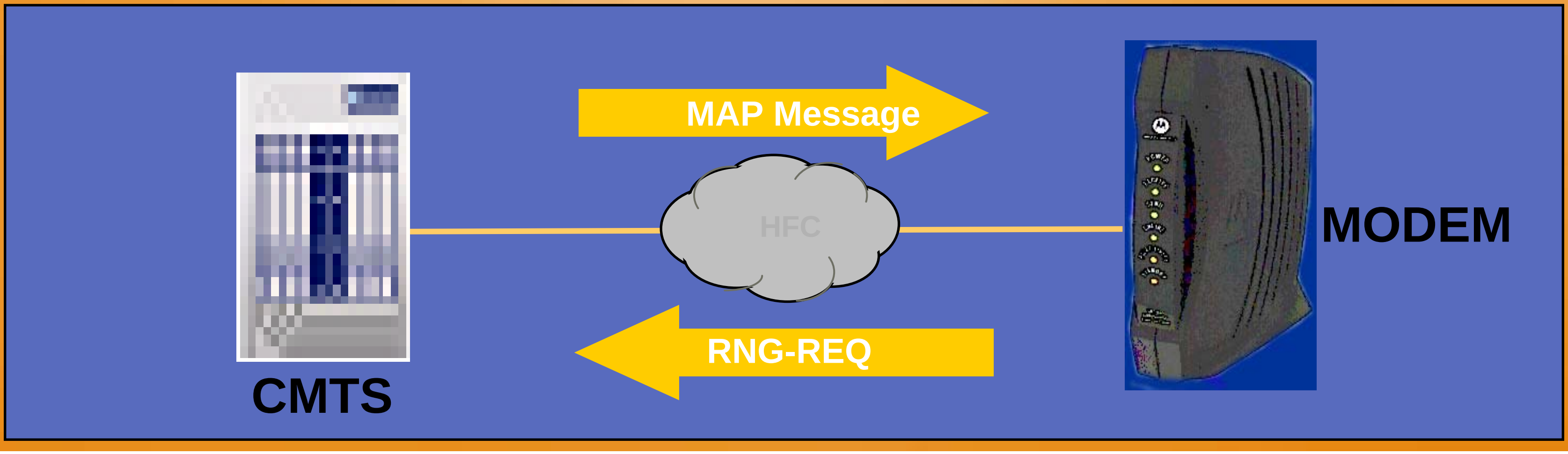
UCDs define characteristics of the upstream channel such as:

- downstream channel ID
- mini-slot size
- upstream channel ID
- upstream channel width
- burst descriptors - modulation type (QAM, QPSK)



Initial Ranging

- CMTS periodically transmits MAP messages
- Upstream Bandwidth Allocation Map (MAP) includes:
  - Initial Maintenance Interval (broadcast interval)
- CM responds with Ranging Request (RNG-REQ)
- CMTS will be able to calculate a timing offset for each CM from the ranging request
- CMTS will then continue ranging (req/rsp) with the individual modem (unicast ranging)
- Cable Modem starts the Ranging function from at 25 dBmV and will increment upwards by 6 dBmV as instructed by the CMTS



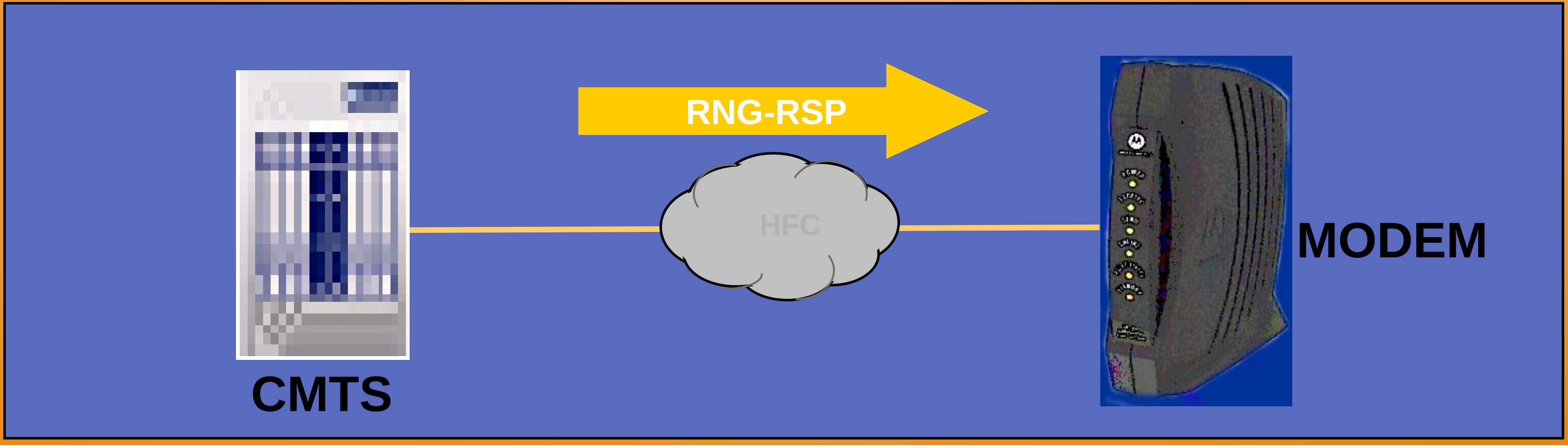
Auto Adjustments

CMTS receives initial Ranging Request from CM

CMTS responds with Ranging Response (unicast)

- assigns a SID and allocates bandwidth to this SID
- adjust power level, timing offset, and frequency

CMTS starts Admission Control



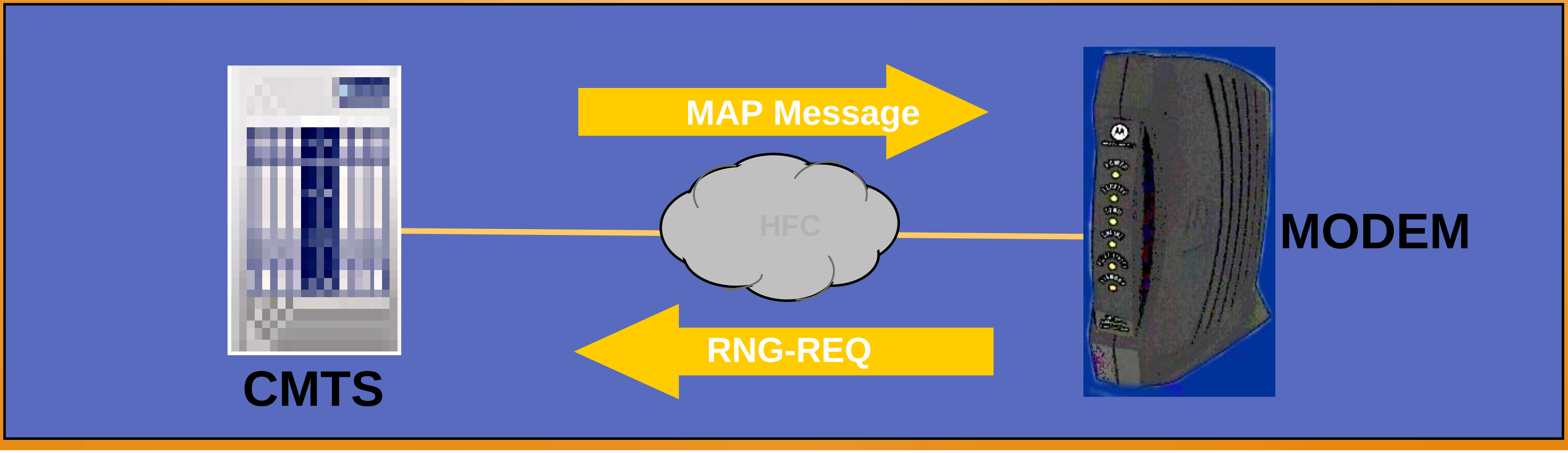
Admission Control

CMTS allocates a Temporary SID for the CM and puts the CM in the Forwarding Tables

CMTS sends MAP with Station Maintenance opportunity for that SID

CM ranges with new settings

CMTS sends RNG-RSP to indicate success or failure of Admission

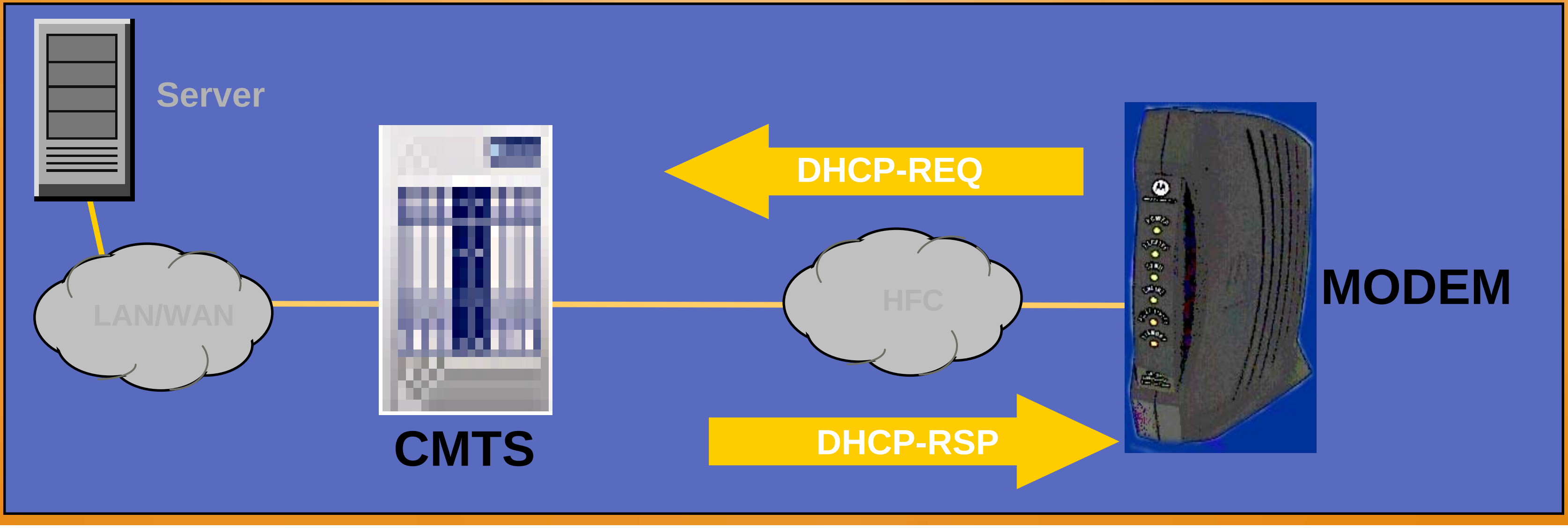


IP Connectivity

CM sends a broadcast DHCP request via the CMTS to the DHCP Server

DHCP server returns:

- **IP address and Subnet Mask**
- **CM configuration file name and IP address of TFTP server**
- **UTC time offset to establish local time**
- **TOD Server IP address**

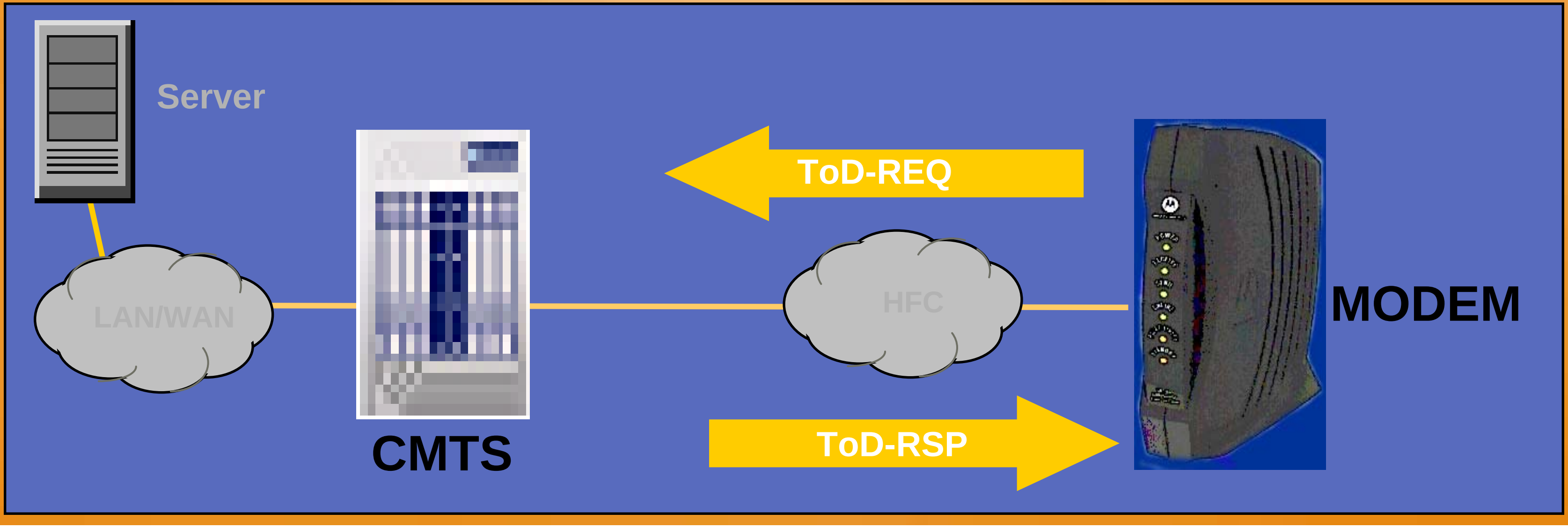


Time of Day

CM sends a request to the ToD Server

ToD Server responds: GMT

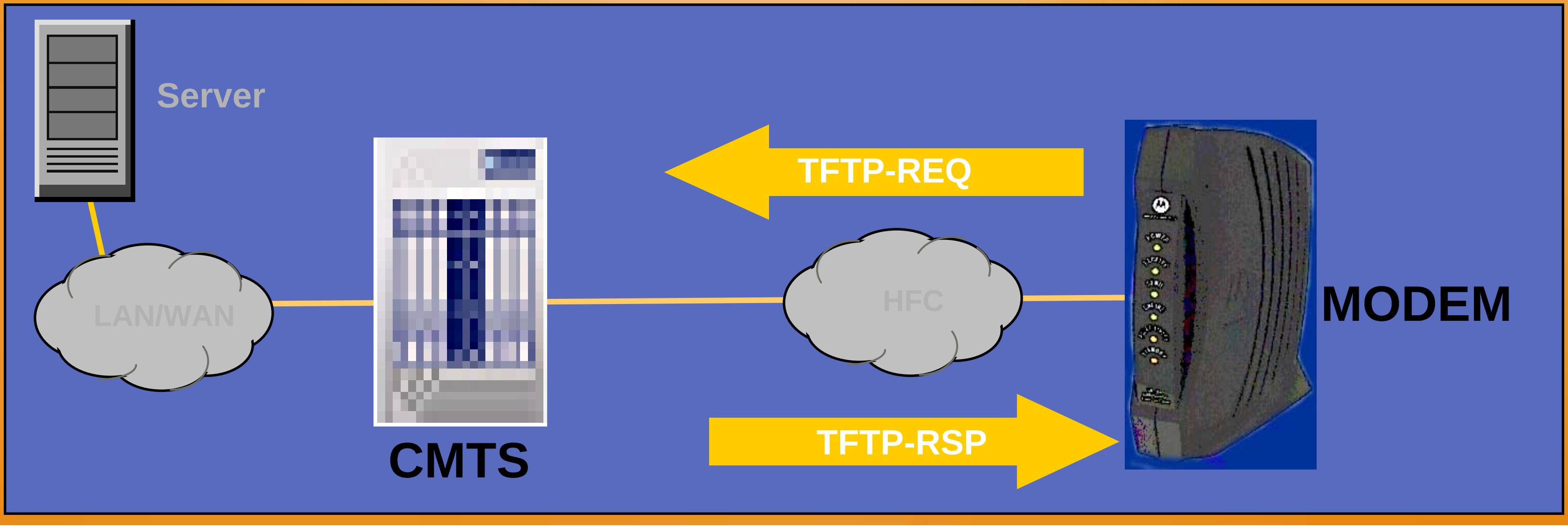
CM sets its clock to GMT +/- offset (from DHCP server)



CM Config File

After DHCP operation, CM must download the configuration file from the TFTP server

Server address is specified in the "siaddr" field of the DHCP response

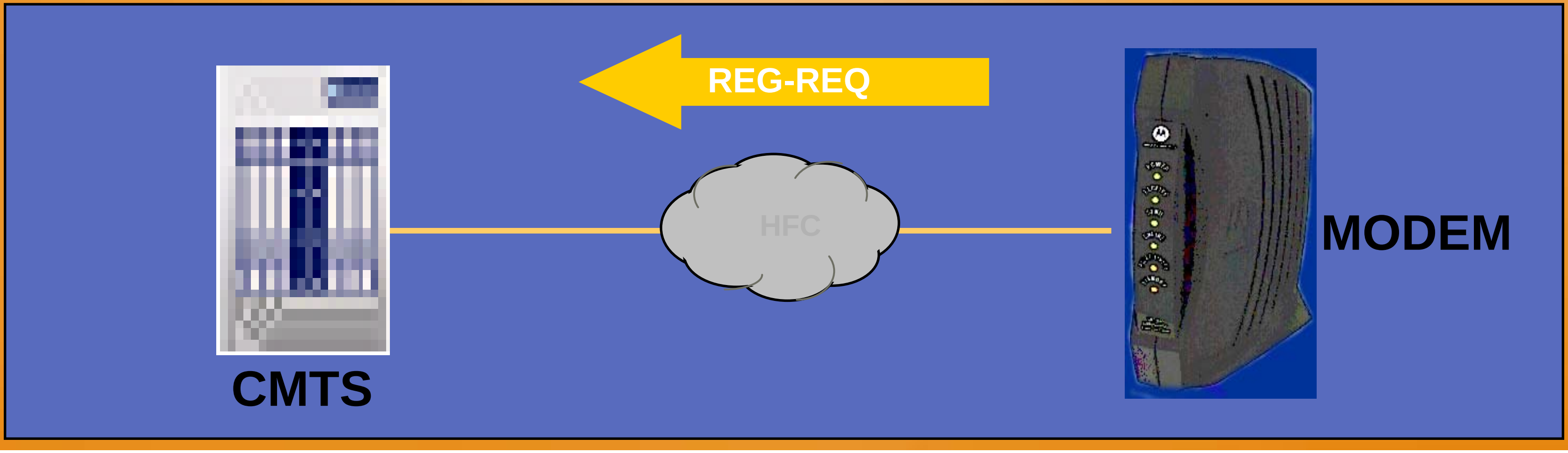


Registration

CM generates a Registration Request (REG-REQ)

Includes configuration parameters received from TFTP configuration file:

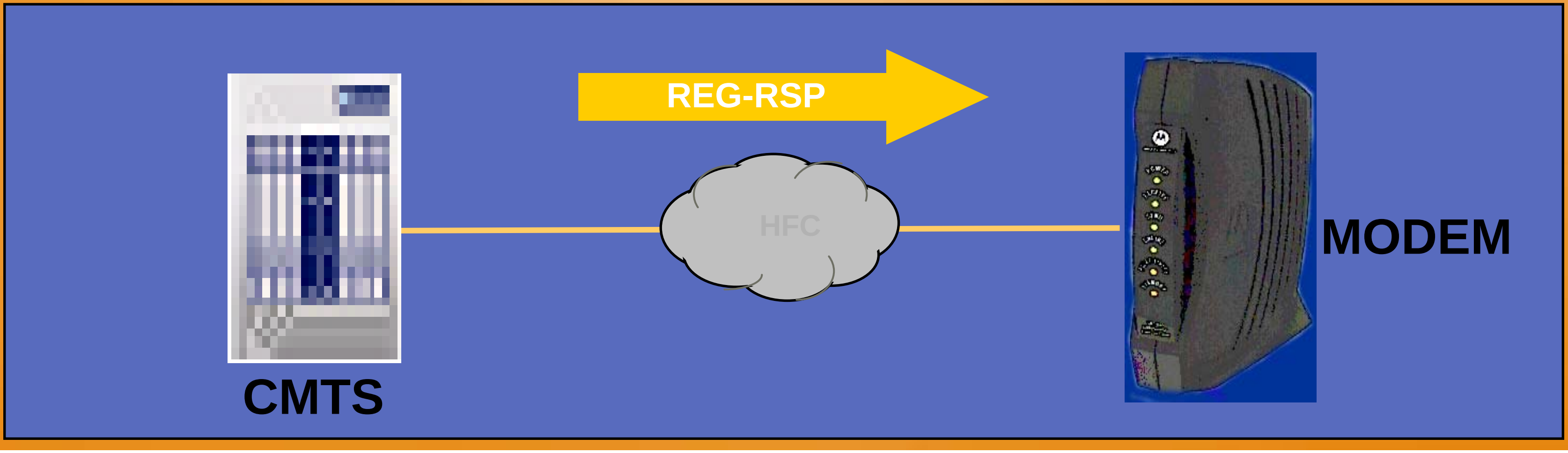
- **Downstream frequency, Upstream channel ID**
- **Network access configuration settings**
- **Service Flows**
- **Modem Capabilities**
- **Modem IP address**



Registration - cont.

CMTS

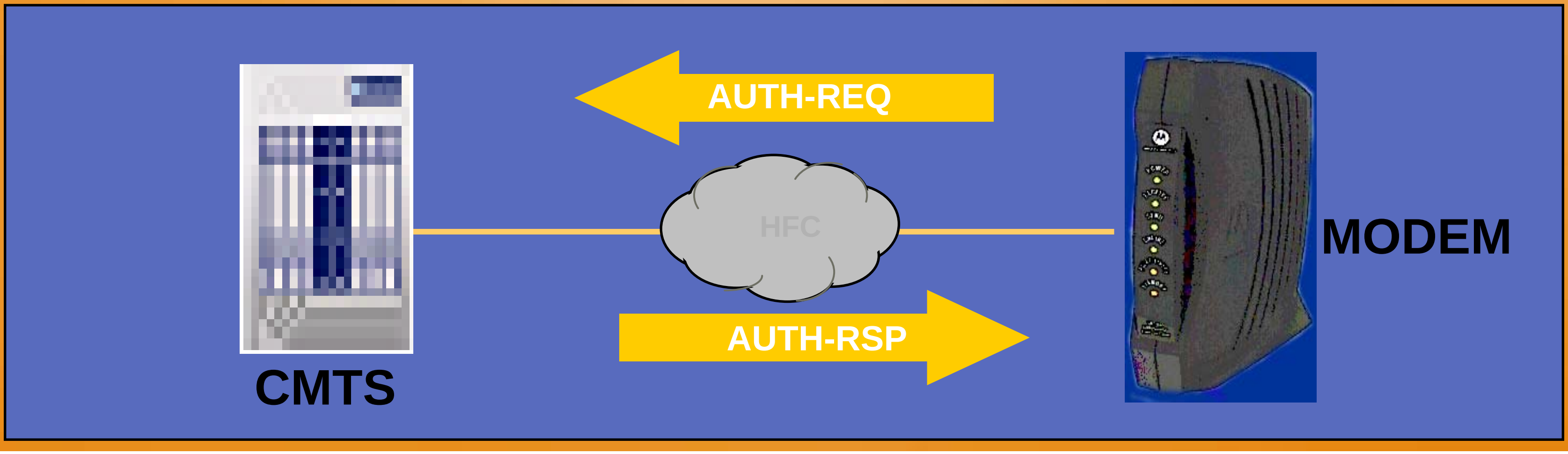
- checks CM’s MAC address and authentication signature on the parameters
- assigns a SID
- provides bandwidth for CM requested service flows
- modifies forwarding table to allow full user data if the modem requested Network Access
- sends REG-RSP to CM (<u>CM can pass unencrypted data</u>)



Security Association

If CM is configured for Baseline Privacy in the modem TFTP configuration file:

- **CM sends Authorization Request**
  - Public key, MAC address, and SID's
- **CMTS responds with an Authorization Response**
  - Authorization Key (encrypted KEK)
  - Key Sequence number and Lifetimes
  - List of SID's (for each requested Class of Service)

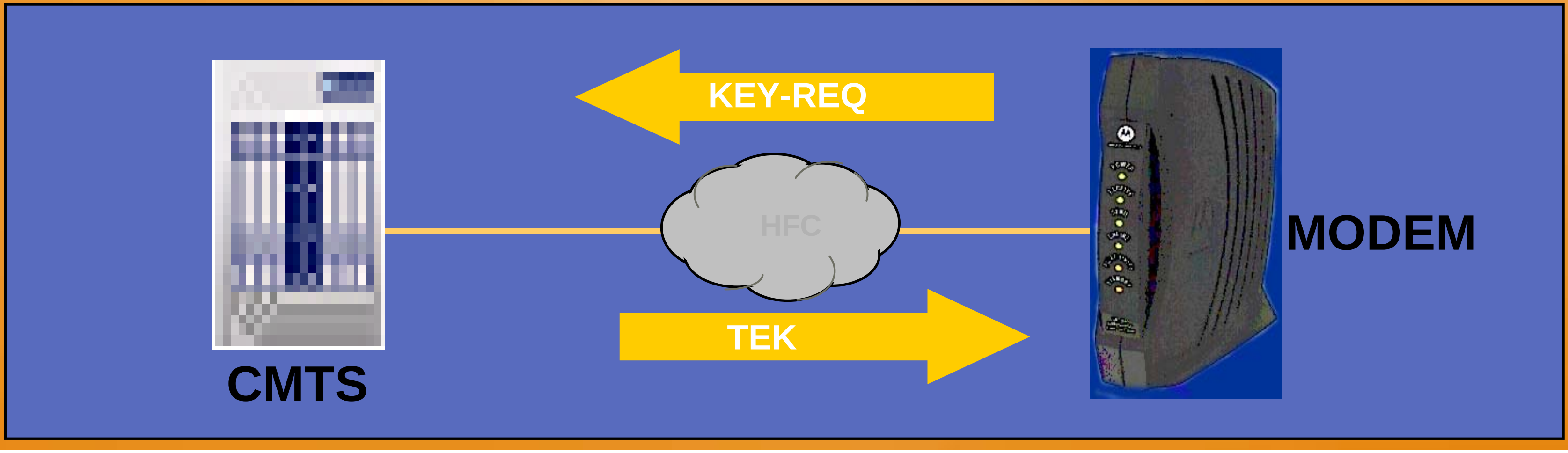


Security Association - cont.

CM requests Key Request for each SID

CMTS responds with DES encrypted TEK for each SID

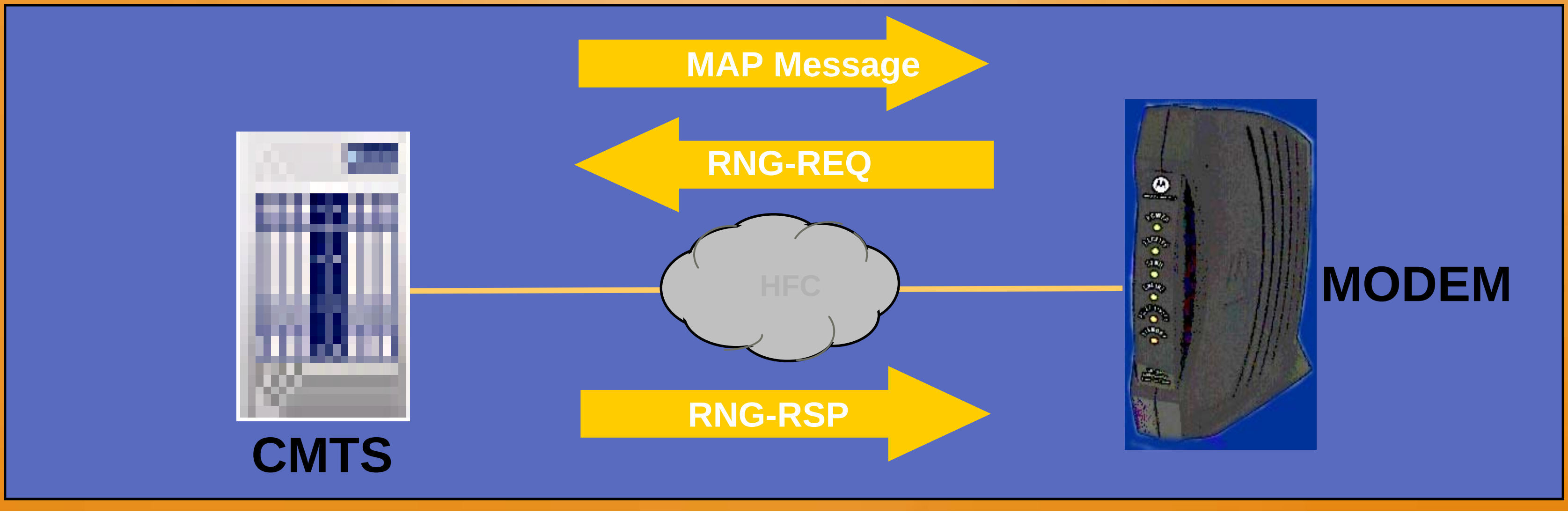
CM can now pass encrypted data



Periodic Ranging

CMTS sends unicast Station Maintenance opportunities to CM

- **Fine tune power and timing**
- **Keep alive (after 16 misses CM deregistered)**



Data Transmission

CM makes requests for bandwidth (transmission opportunities) using a Request IUC or by piggybacking a request to previous data grant

CMTS schedules a long or short data grant(s) to accommodate request after assessing rate limit or bandwidth restrictions along with current load

CMTS sends acknowledgements of data grants received

Contention intervals for data are rarely used

Dynamic flows may receive unsolicited grants on a periodic basis e.g. voice flow

SB5101 Diagnostics - Front Panel LEDs

SB5101 Pocket Guide

LED	Function
POWER	Flashes during the self test and changes to solid green when the self test is successfully complete.
RECEIVE	Flashes while scanning for the receive (downstream) channel and changes to solid green when it is connected.
SEND	Flashes while scanning for the send (upstream) channel and changes to solid green when it is connected.
ONLINE	Flashes while the cable modem downloads configuration data and changes to solid green when the download is complete.
PC/ACTIVITY	Flashes when transmitting or receiving data. A device, such as a computer or hub, is connected to the USB or Ethernet connectors on the back panel.
STANDBY	On when in Standby mode. Internet service is blocked when the Standby button is pressed.

Notes:

- During normal operation the POWER, RECEIVE, SEND and ONLINE lights are ON.
- Receive and Send LEDs flash “toggle” when the unit is downloading a new image.

SB6120 Diagnostics - Front Panel LEDs

LED	Function
POWER	Flashes during the self test and changes to solid green when the self test is successfully complete.
RECEIVE	Flashes while scanning for the receive (downstream) channel and changes to solid green when it is connected. LED changes to solid blue when connected with bonded channels.
SEND	Flashes while scanning for the send (upstream) channel and changes to solid green when it is connected. LED changes to solid blue when connected with bonded channels.
ONLINE	Flashes while the cable modem downloads configuration data and changes to solid green when the download is complete.
LINK	Flashes when transmitting or receiving data. A device, such as a computer or hub, is connected to the USB or Ethernet connectors on the back panel. Amber LED indicates a Fast-Etherent connection to the PC. Blue LED indicates a Gigabit-Ethernet connection to the PC.

Notes:

- During normal operation the POWER, RECEIVE, SEND and ONLINE lights are ON.
- Receive and Send LEDs flash “toggle” when the unit is downloading a new image.

SB6120 Diagnostics - Front Panel LEDs *(continued)*

Light	Off	Flashing	On
POWER	Power is disconnected	This light never flashes	Green: Power is properly connected
RECEIVE	Receive channel not found	Scanning for a receive (downstream) channel connection	Green: Downstream channel is connected Blue: Downstream channel is connected with bonded channels
SEND	Send channel not found	Scanning for a send (upstream) channel connection	Green: Upstream channel is connected Blue: Upstream channel is connected with bonded channels
ONLINE	Internet connection failed	Scanning for network connection	Connected to Internet
LINK	No connection to SB6120 Ethernet port detected	Transmitting or receiving data on Ethernet port	Amber: A device, computer or hub, is connected via the Ethernet (10Base-T) or Fast Ethernet (100Base-T) port Blue: High-speed Gigabit Ethernet connection from SB6120 to your PC

PacketCable Components

Group	Component	Description
DOCSIS	E-MTA	Embedded Multimedia Terminal Adapter
	CMTS	Cable Modem Termination System
CMS	CA	Call Agent
	GC	Gate Controller
	MGC	Media Gateway Controller
	ANC	Announcement Controller
PSTN	SG	Signaling Gateway
	MG	Media Gateway
Media Server	ANP	Announcement Player

Group	Component	Description
OSS	RKS	Record Keeping Server
	DHCP	DHCP Server
	TFTP	TFTP Server
	PROV	Provisioning Server
	DNS	Domain Name Server
	KDC	Key Distribution Center
	SYSLOG	Syslog Server
	TOD	Time of Day Server
Surveillance	DF	Delivery Function

Terminology

MTA - Multimedia Terminal Adapter

Subscriber equipment which provides interface for call signaling and media transport between telephone and networks elements.

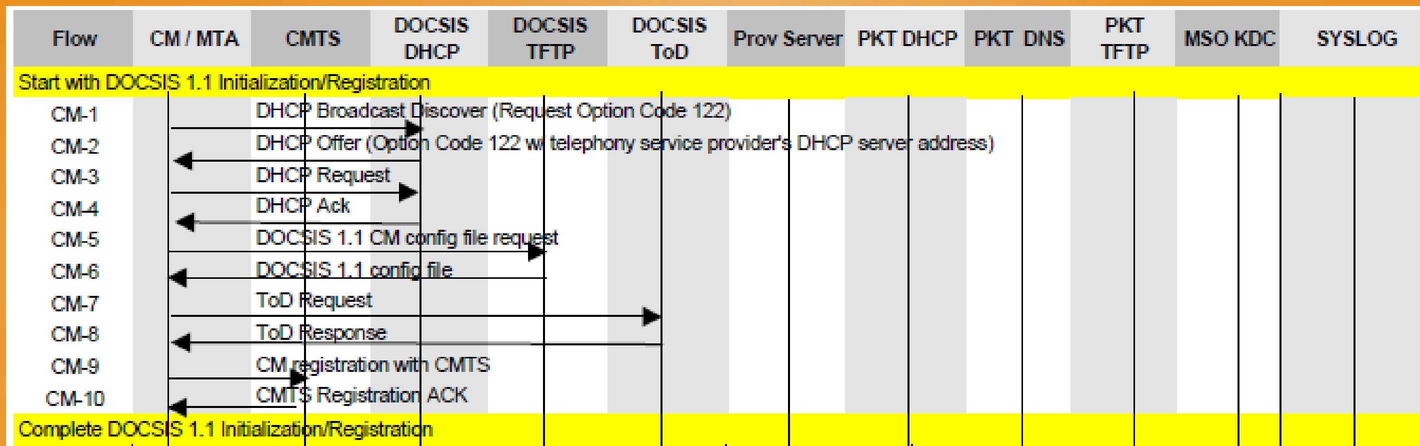
E-MTA - Embedded MTA with a DOCSIS 1.1/2.0 Cable Modem MAC and PHY.

Also called MTA, CM/MTA or DPT "Digital Phone Terminal"

S-MTA - Standalone MTA with a LAN interface to cable modem

PacketCable Provisioning Mode

Basic Mode



The Basic MTA provisioning flow is very similar to the DOCSIS CM provisioning flow.

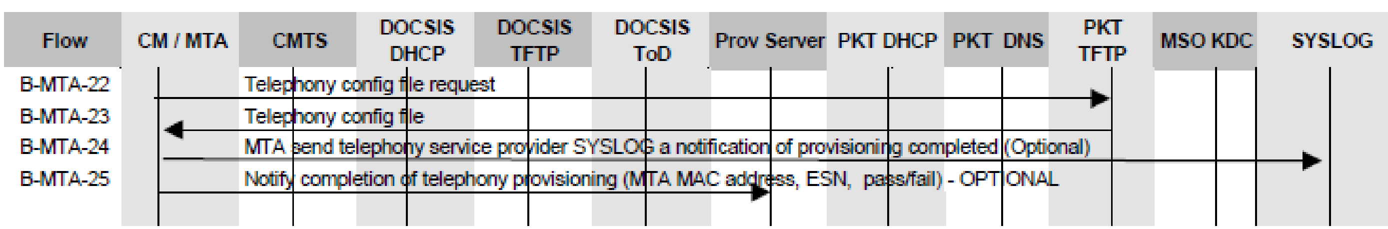
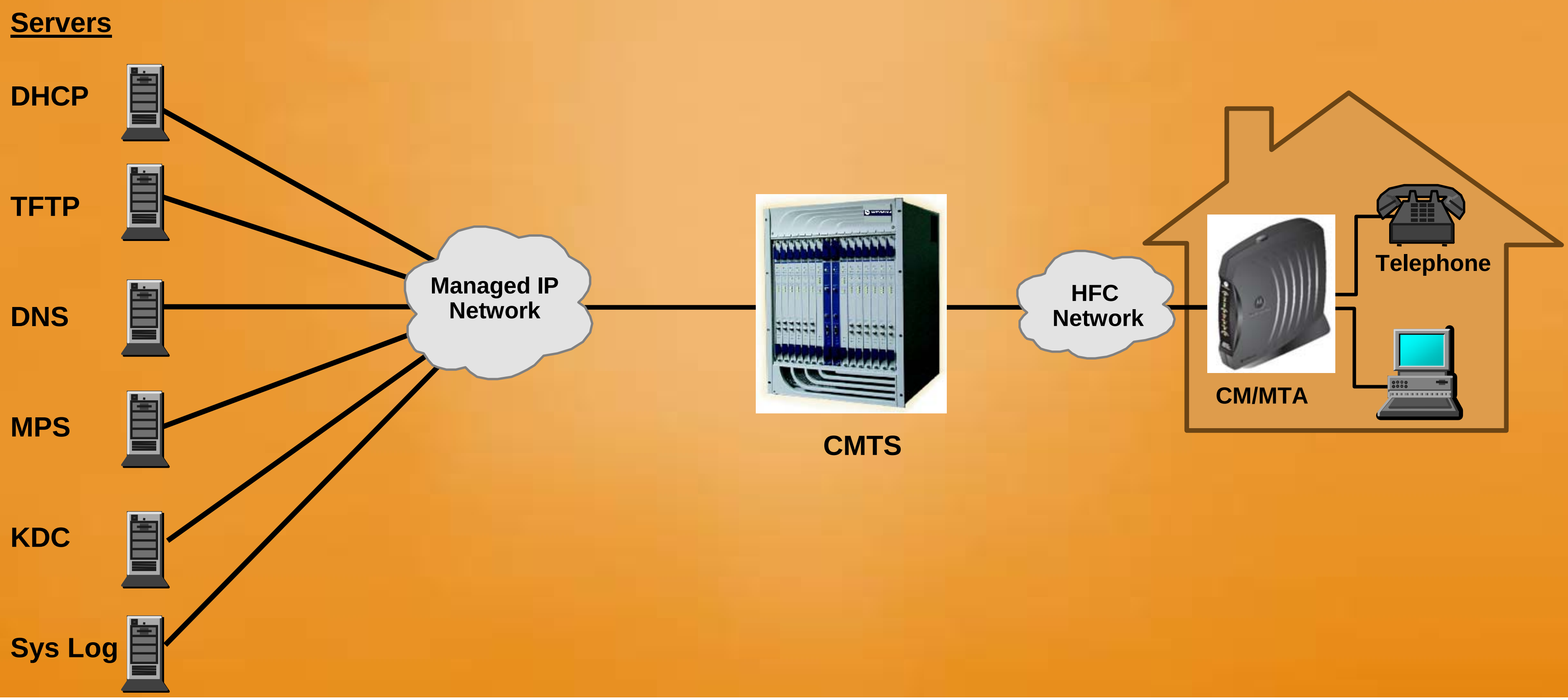


Figure 7. Embedded-MTA Basic Power-on Initialization Flow

Packet Cable Provisioning

Basic Provisioning

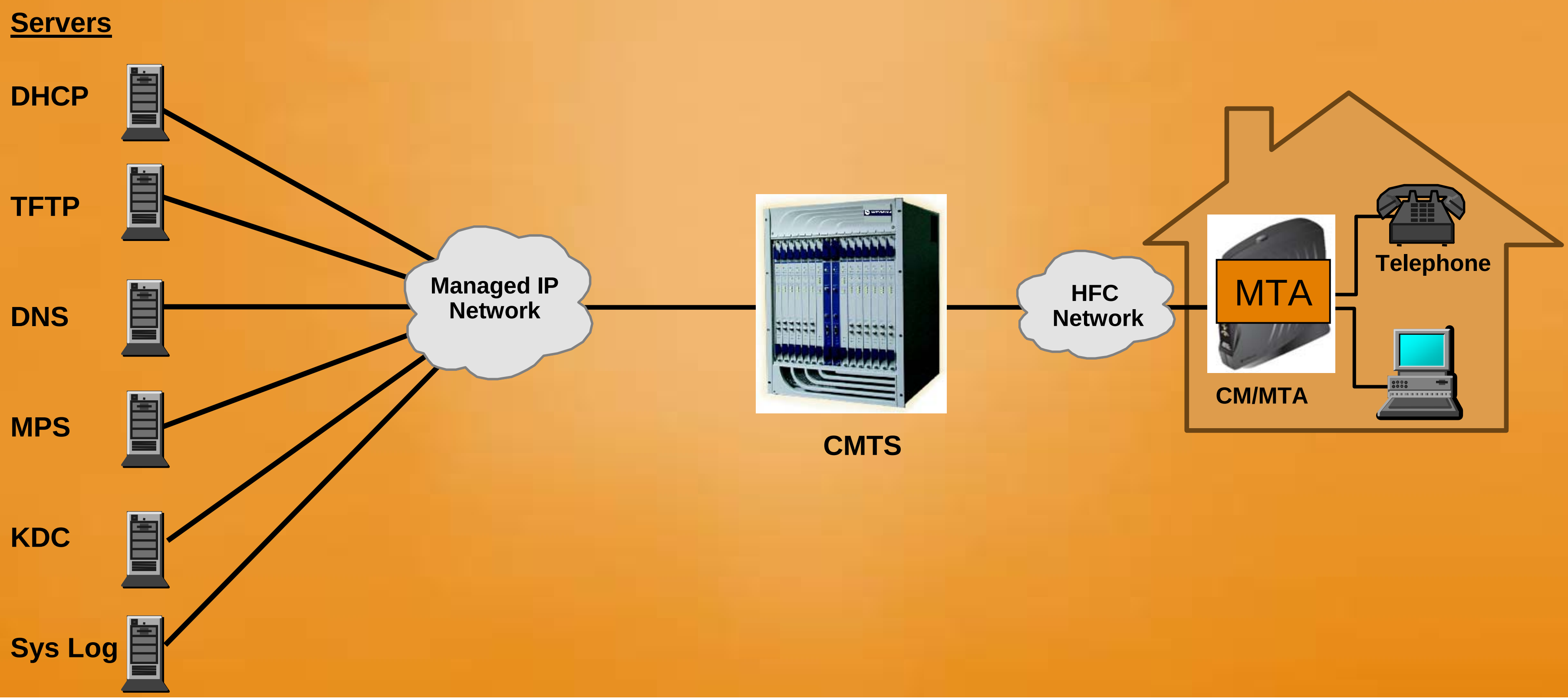
Cable Modem registers with CMTS



Packet Cable Provisioning

Basic Provisioning

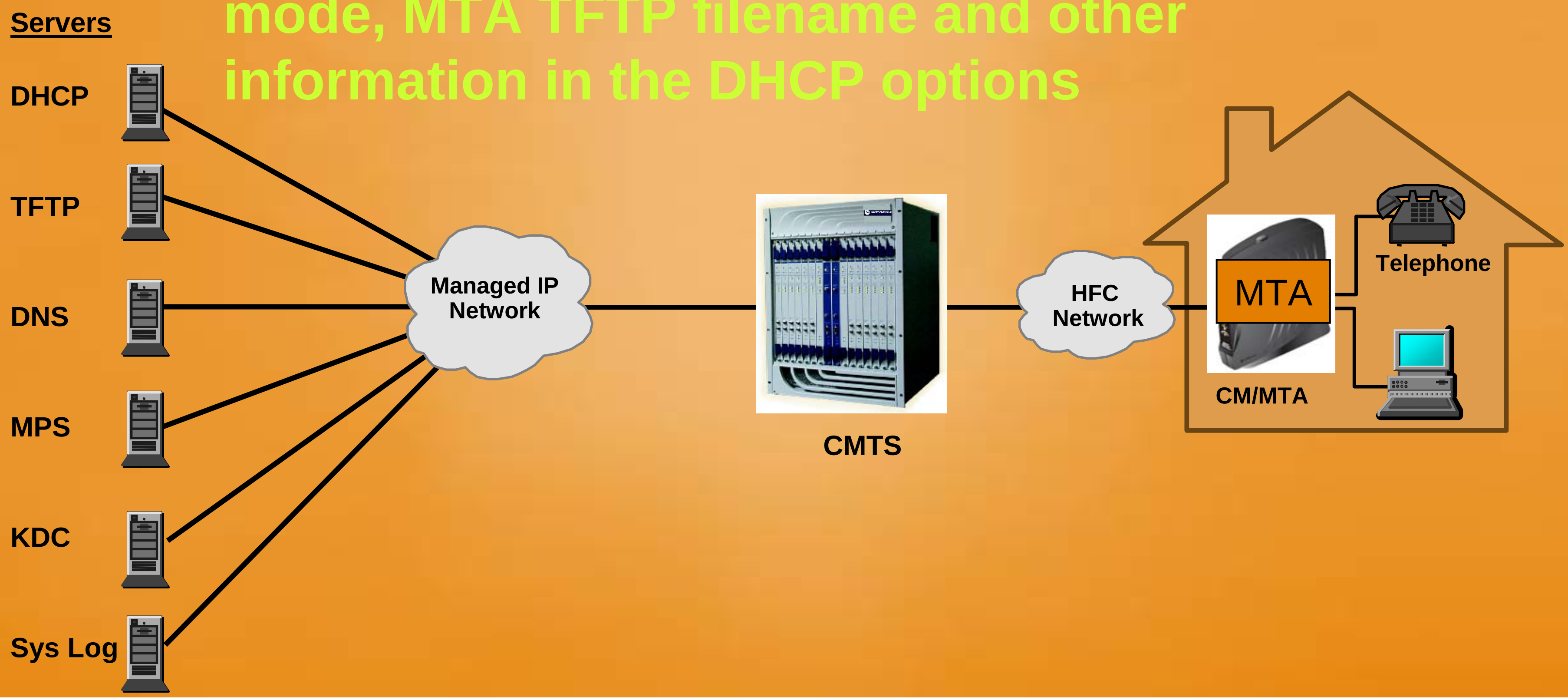
MTA Sends a DHCP Discover



Packet Cable Provisioning

Basic Provisioning

DHCP Send MTA an IP address, provisioning mode, MTA TFTP filename and other information in the DHCP options

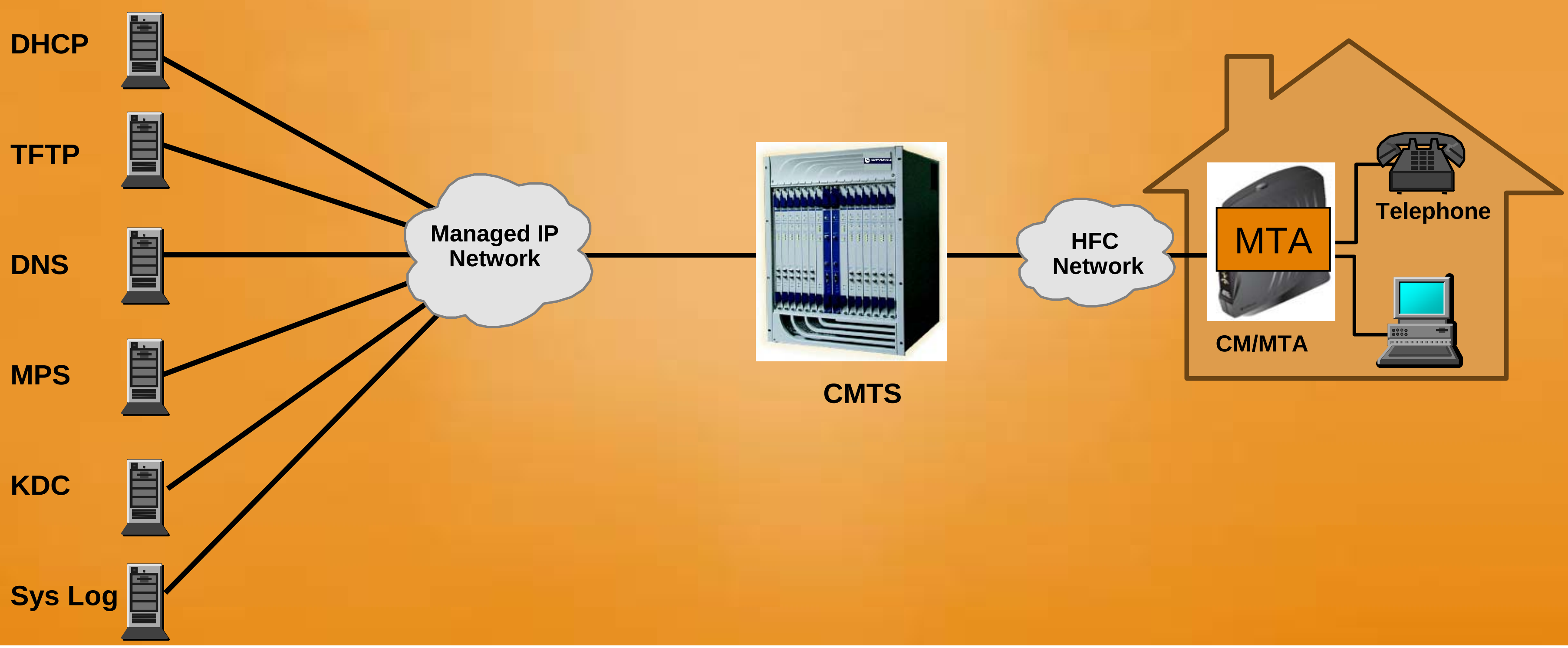


Packet Cable Provisioning

Basic Provisioning

MTA asks DNS to resolve Provisioning Server FQDN

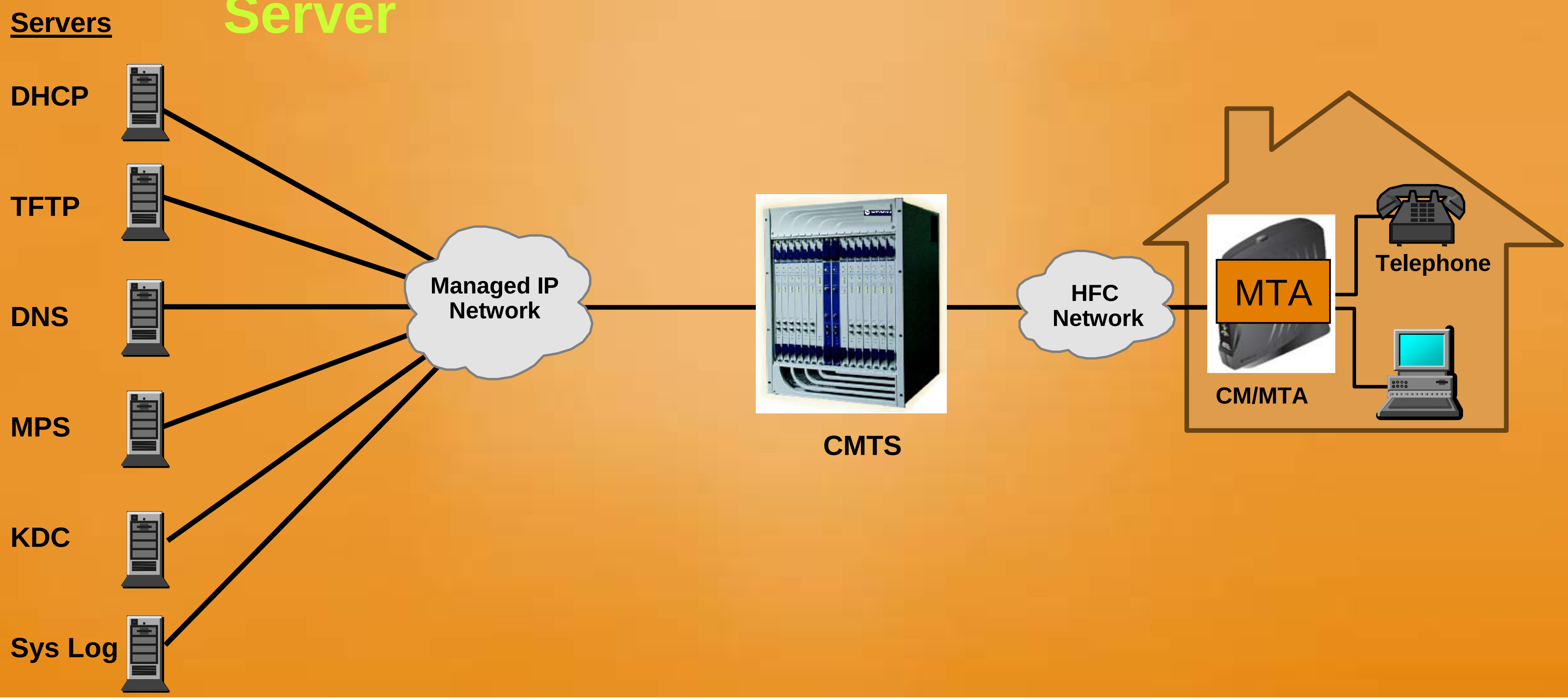
Servers



Packet Cable Provisioning

Basic Provisioning

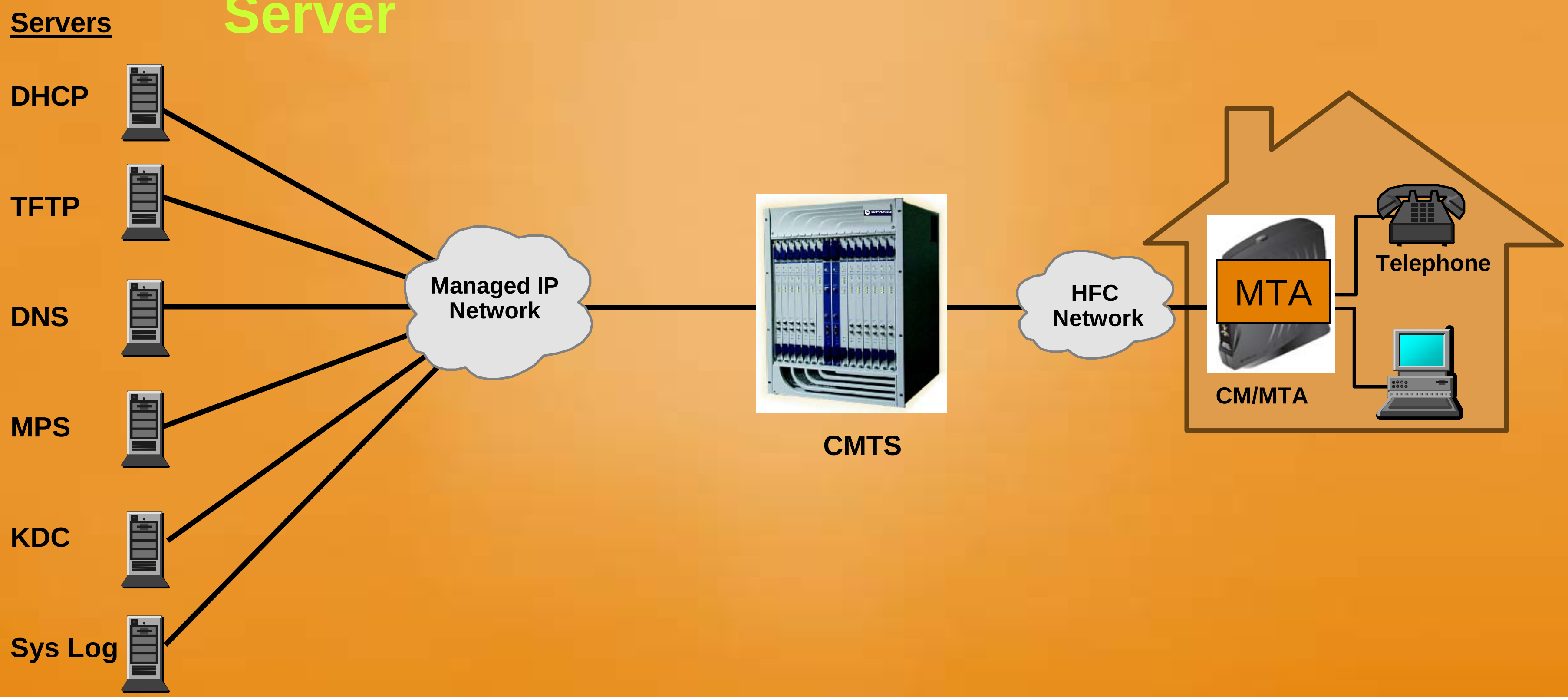
DNS responds with IP address of Provisioning Server



Packet Cable Provisioning

Basic Provisioning

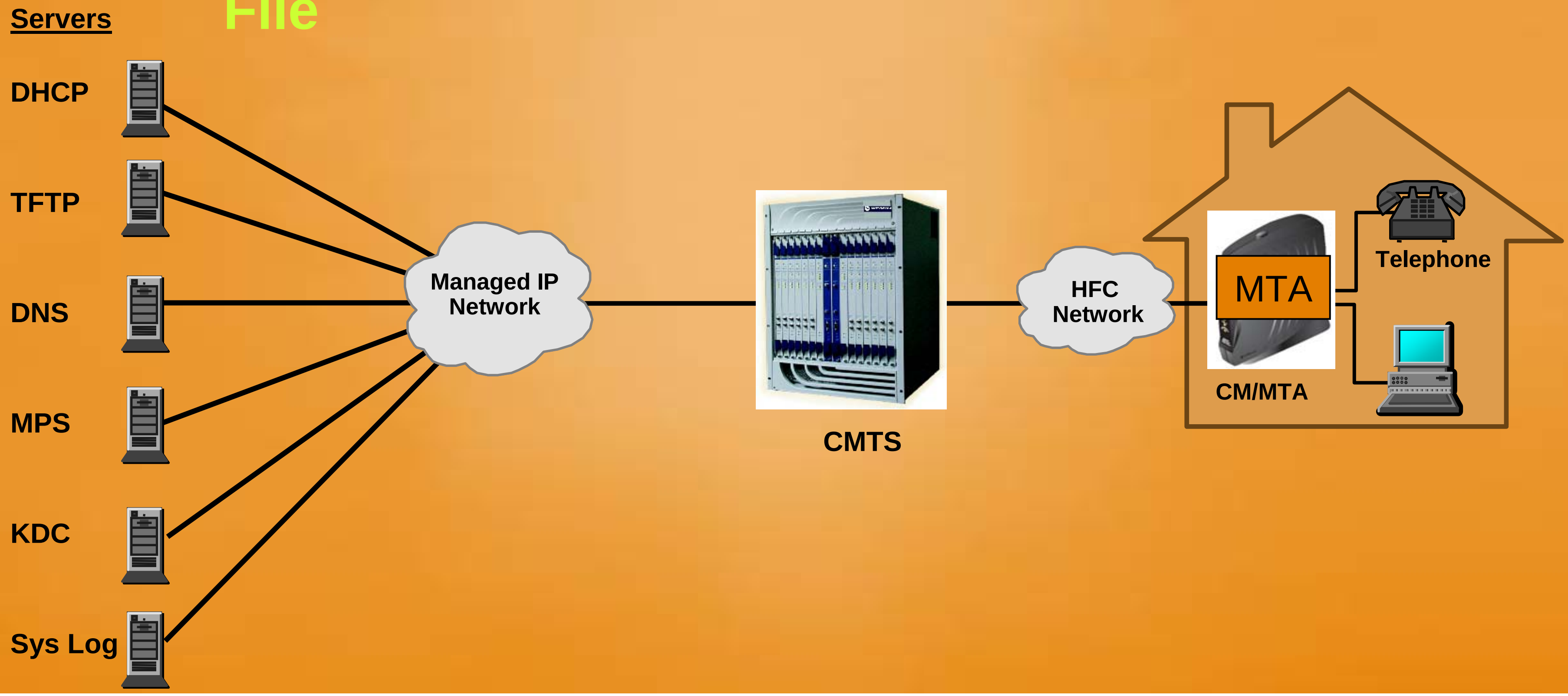
MTA requests its Configuration File from TFTP Server



Packet Cable Provisioning

Basic Provisioning

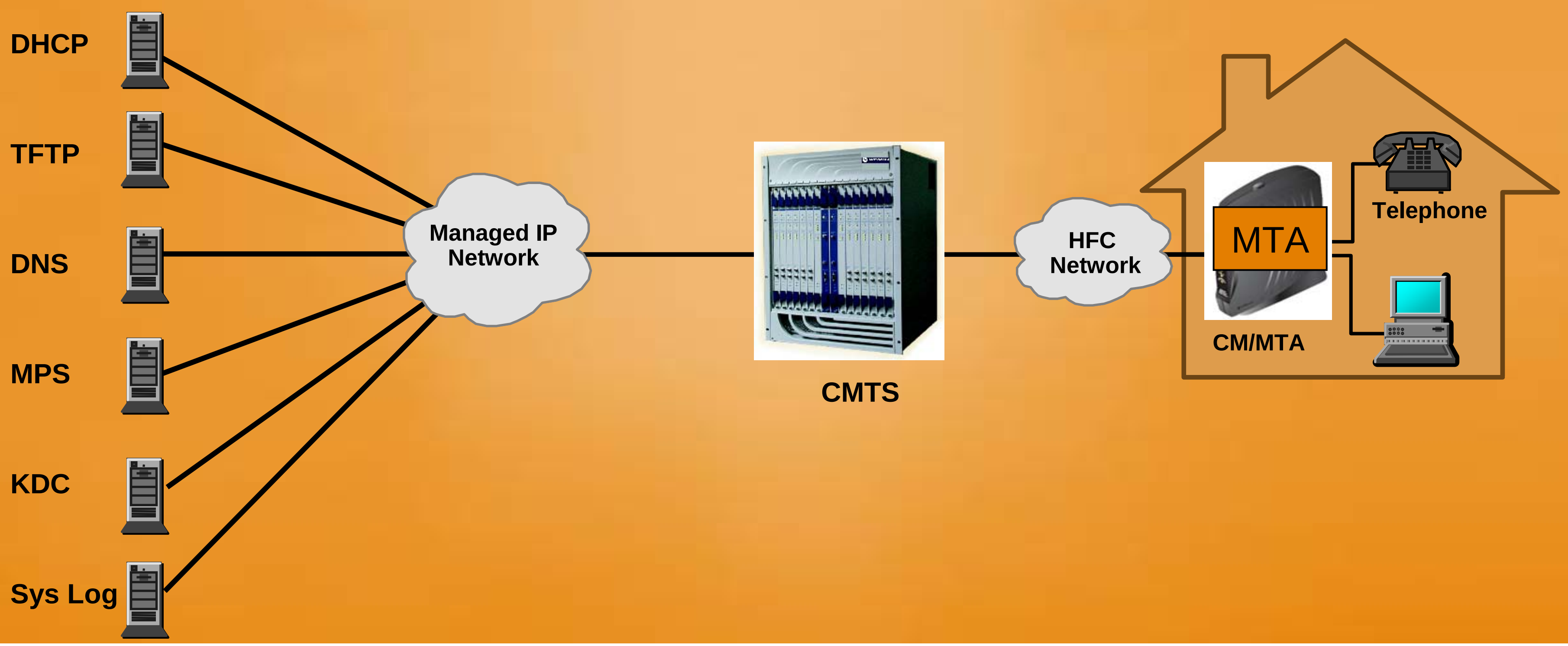
TFTP responds with Telephony Configuration File



Packet Cable Provisioning

Basic Provisioning

MTA sends Sys Log notification of provisioning complete (optional)

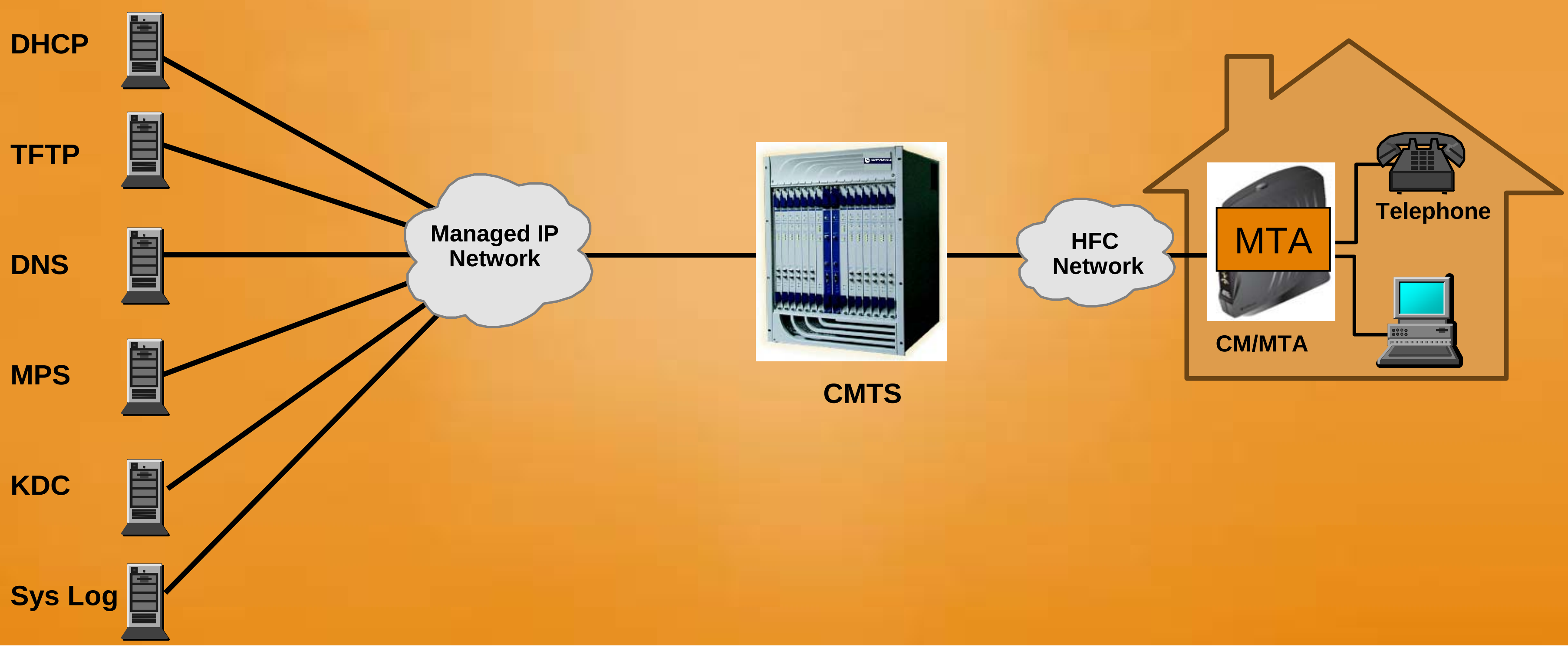


Packet Cable Provisioning

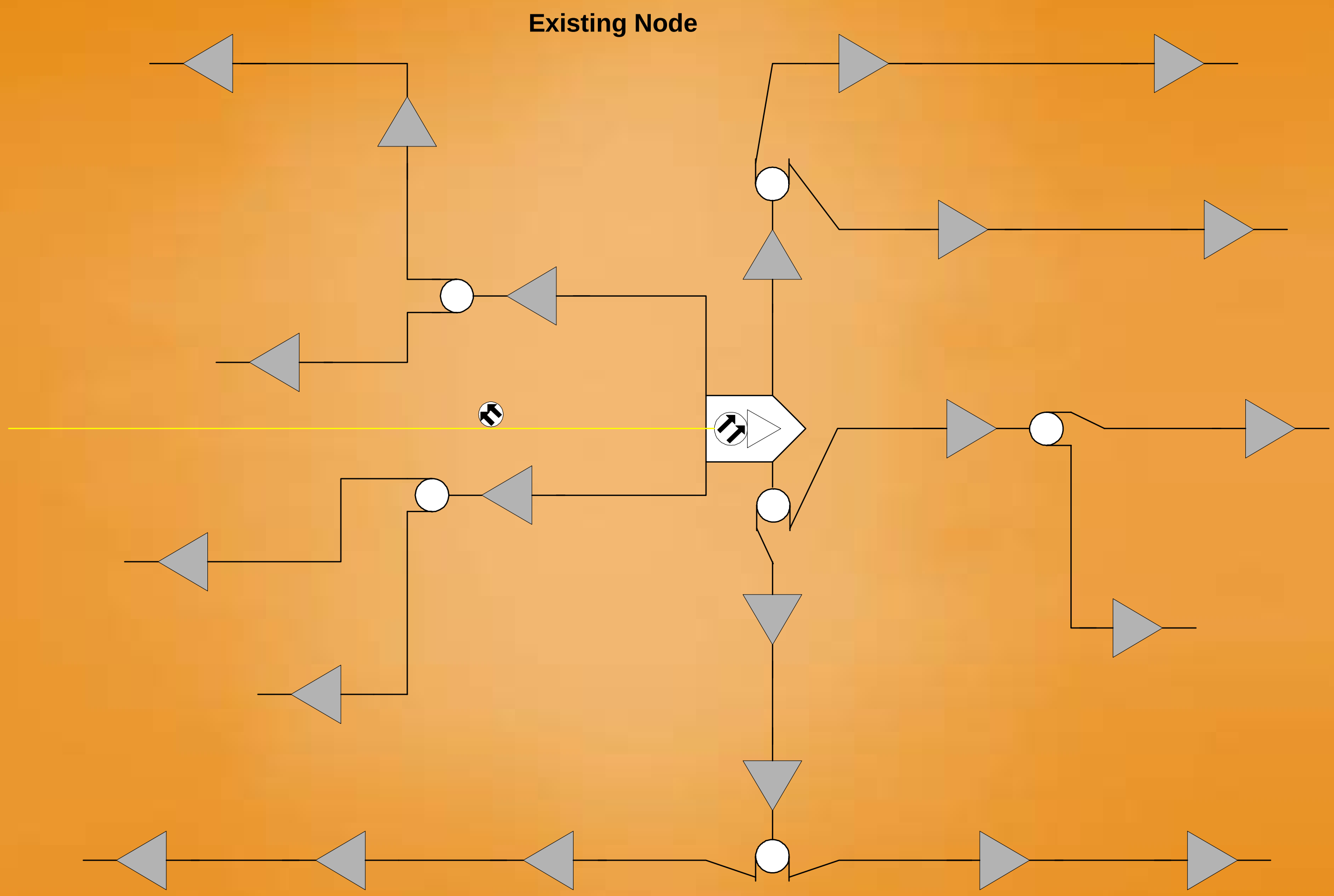
Basic Provisioning

MTA sends SNMP NOTIFY of provisioning complete to Provisioning Server (optional)

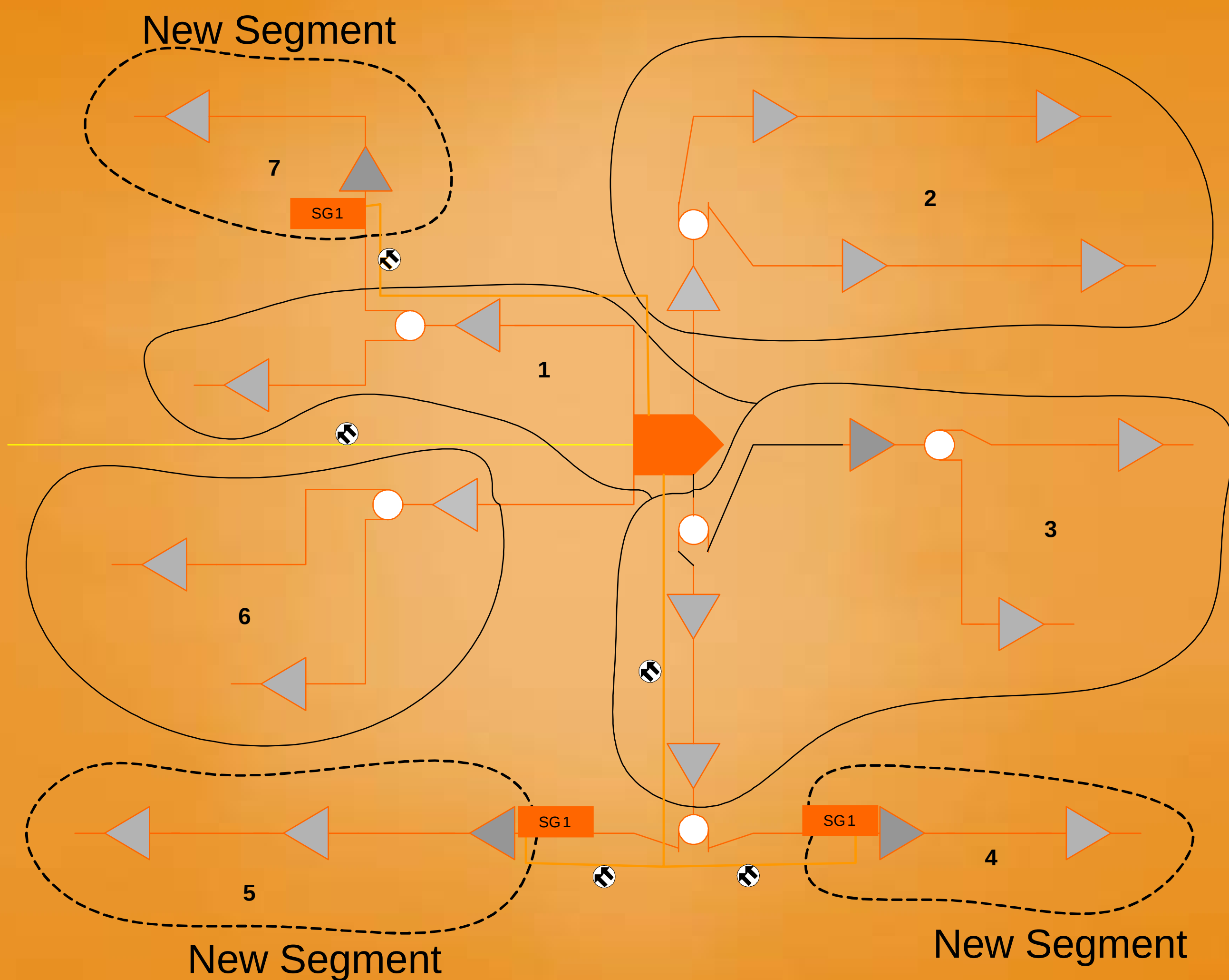
<u>**Servers**</u>



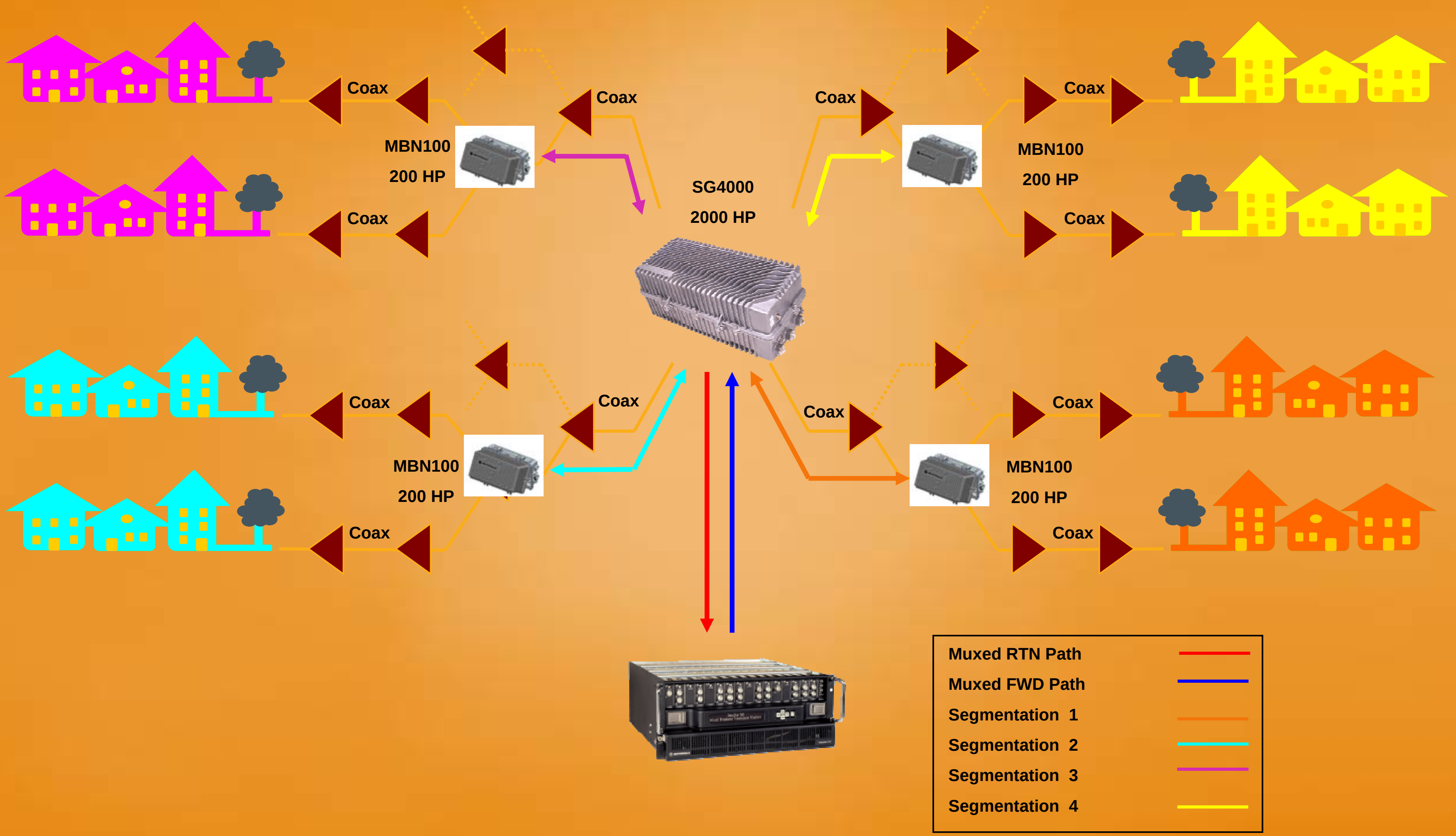
HFC – Node Example



HFC – Node Segmentation



MB Amplifier to Node conversions



Boxes in the network

Modems, MTAs, HFC Equipment, Nodes, etc

SB5101 DOCSIS 2.0 Cable Modem

Value-oriented residential or SOHO cable subscriber who wants a powerful modem capable of providing high-speed data service to their home

Features list

- BCM 3349 based product
- Top-mounted Standby switch for increased security
- Stylish and space saving-enclosure
- MSO or Retail oriented packaging
- 10/100 BaseT Ethernet
- USB 1.1

Enablers

Data Communication:	DOCSIS® and EuroDOCSIS 2.0 certified, interoperable with 1.0 and 1.1 standards
L2VPN:	DUT filtering
Availability:	Available today

SB6120 DOCSIS 3.0 Cable Modem

Designed to provide a cost effective, next generation technology for our MSO customers to offer a high speed residential & commercial service tier

Features list

- User-friendly online diagnostics and bonded channel status page
- Remote management using SNMP and TFTP
- 1 GHz Tuner
- GigE PC connectivity
- IPV6 support
- Up to 160 Mbps downstream, up to 120 Mbps upstream
- Rear panel color coded for ease of installation and troubleshooting
- Front panel, easy to read operational LEDs to indicate status and simplify troubleshooting
- Multi-colored LED option to identify Bonded Channel mode and GigE PC Connectivity

Enablers

Data Communication:

- DOCSIS 3.0 Certified
- TI Puma V Platform
- Channel Bonding:

4 Downstream + 4 Upstream

Certification: DOCSIS 3.0 Certification CW58

Availability: Now

SBG900 Wireless Gateway

Residential or SOHO subscriber who wants the convenience of wireless, high-speed data service and the security of a commercial-grade firewall in a sleek, cost-effective device

Features list

The mobility of a wireless LAN and simplicity of "No New Wires" technology

- Easy-to-use Installation Wizard enables quick connectivity
- BCM 3348 based product
- Top-mounted Standby switch for increased security
- Stylish and space saving-enclosure
- MSO or Retail oriented packaging
- 10/100 BaseT Ethernet
- USB 1.1
- 802.11b/g

Enablers

Data Communication:	wireless access point commercial grade firewall with Denial of Service (DoS) attack prevention, stateful packet inspection, intrusion detection, demilitarized zone
Certification:	DOCSIS® 2.0 certified, CableHome® 1.0 certified
Availability:	Available Today

SBV5220 Digital Voice Modem

For the value-oriented residential or SOHO cable subscriber who wants VoIP telephony and broadband data service with the comfort of battery-backed, uninterrupted, VoIP telephony

Features list

- Up to 2 lines of full featured VoIP telephone service
- Easy to use and simple to setup
- Easy-to-read operational status LEDs
- Automatic fax modem processing
- SNMP and TFTP support for remote configuration and monitoring
- Up to 2 integrated, field-replaceable Lithium-ion batteries; providing uninterrupted power during an outage
- Advanced diagnostics for troubleshooting subscriber line and VoIP network issues

Enablers

Voice Communication: Network Call Signaling (NCS) and Session Initialization Protocol (SIP) support, PacketCable™ 1.5 certified & 2.0 compliant, G.711 and other low-rate codec support, configurable to meet multiple telco market standards

Data Communication: DOCSIS® 2.0 and PacketCable™ 1.0 certified; interoperable with DOCSIS 1.0 and 1.1 and compatible with PacketCable 1.5

Availability: Available today

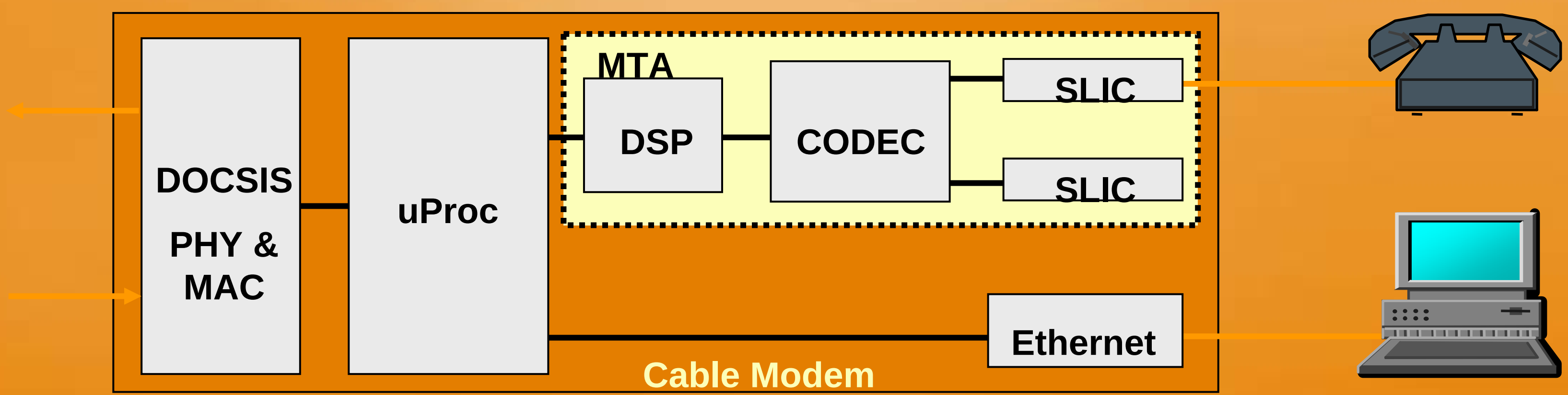
Cable Modem with E-MTA

Multimedia Terminal Adaptor (MTA)

- **Two IP & MAC Addresses**
  - 1 for Cable Modem
  - 1 for MTA
- **For the most part the MTA is treated as a CPE**

Hardware components

- **SLIC: Subscriber Line Circuit - electrical interface: impedance matching, ring generation, and -48 V DC line voltage**
- **CODEC: Coder/Decoder - analog to digital and digital to analog conversion**
- **DSP: Digital Signal Processor - does voice compression/de-compression, jitter buffer, echo cancellation, tone detection, and tone play out**
- **uProc: Microprocessor: Processing the RTP (Real-time Protocol) packets**
- **DOCSIS Chips: Voice and Data packet classification into flows, mod/demod, and RF transmission**



Voice Coders

Voice Code	Rate/BW	MOS
G711	64 Kbps	4.4
G729/A/E	8/8/12 Kbps	3.9-4.2
G728	16 Kbps	4.1
G726	16/24/32/40 Kbps	4.2
G723.1	5.3/6.3 Kbps	3.5/3.9
BV16	16 Kbps	4.2
iLBC	13.3/15.2 Kbps	3.8/3.9

MOS Score: > 4 Toll Quality, 3-4 Good Quality, < 3 Poor Quality

HFC Equipment

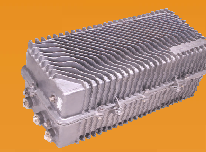
OmniStar GX2

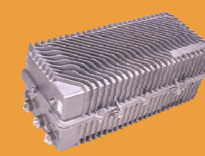
- 1310nm 1GHz Tx
- High-Density Return Rx
- 1550nm Broadcast Tx
- DWDM 1GHz Narrowcast Tx
- Digital Return Rx & Tx

SG4000 C Node

Collector Location

- Optical Switch
  - Optical Amplifier
  - Optical Passives





SG1000/SG4000/MBN100

- 1 GHz
- Broadcast/Narrowcast
- Node segmentation
- Satellite nodes
  - CWDM/DWDM analog return
  - Digital Return

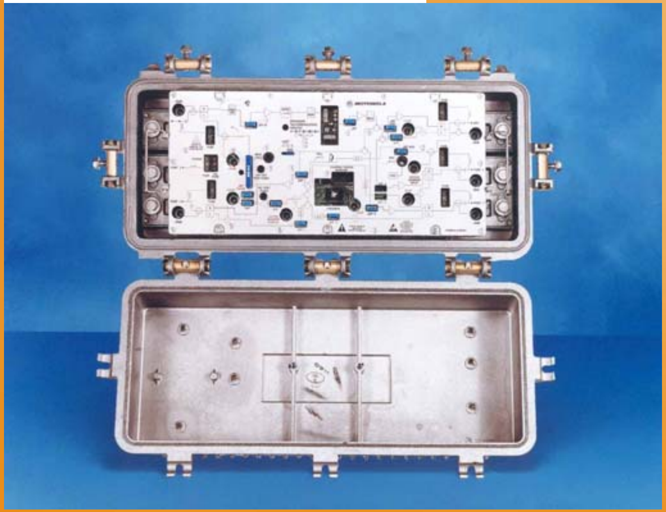
1 GHz STARLINE® Amplifier Series (amplifiers become nodes in the future)

BLE100 Broadband Line Extender

- **1 GHz**
- **Single output**
- **34 dB operational gain**

MB100 MiniBridger Amplifier

- **1 GHz**
- **Single or dual output**
- **42 dB operational gain**
- **Third output user-configurable**



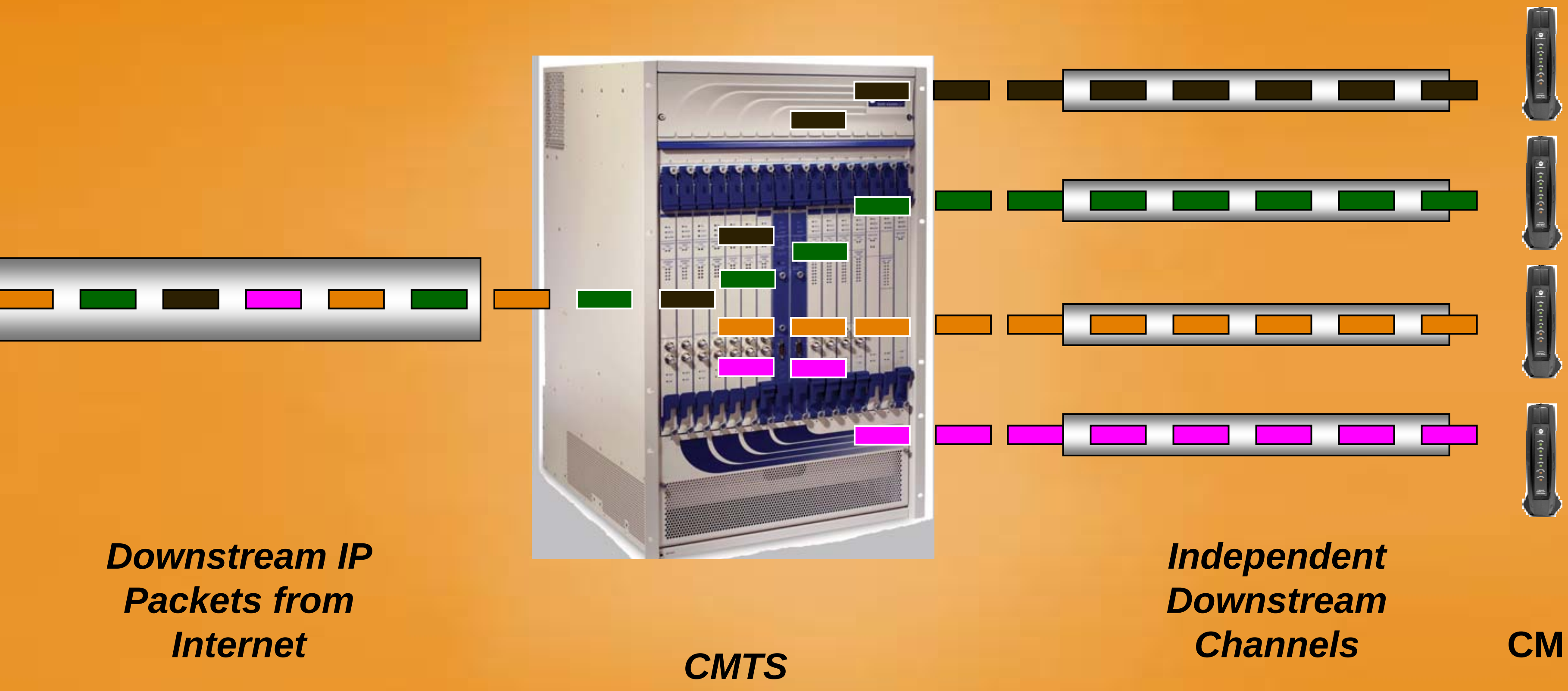
BT100 Broadband Telecommunications Amplifier

- **1 GHz**
- **Three or four bridger outputs**
- **42 dB operational gain**

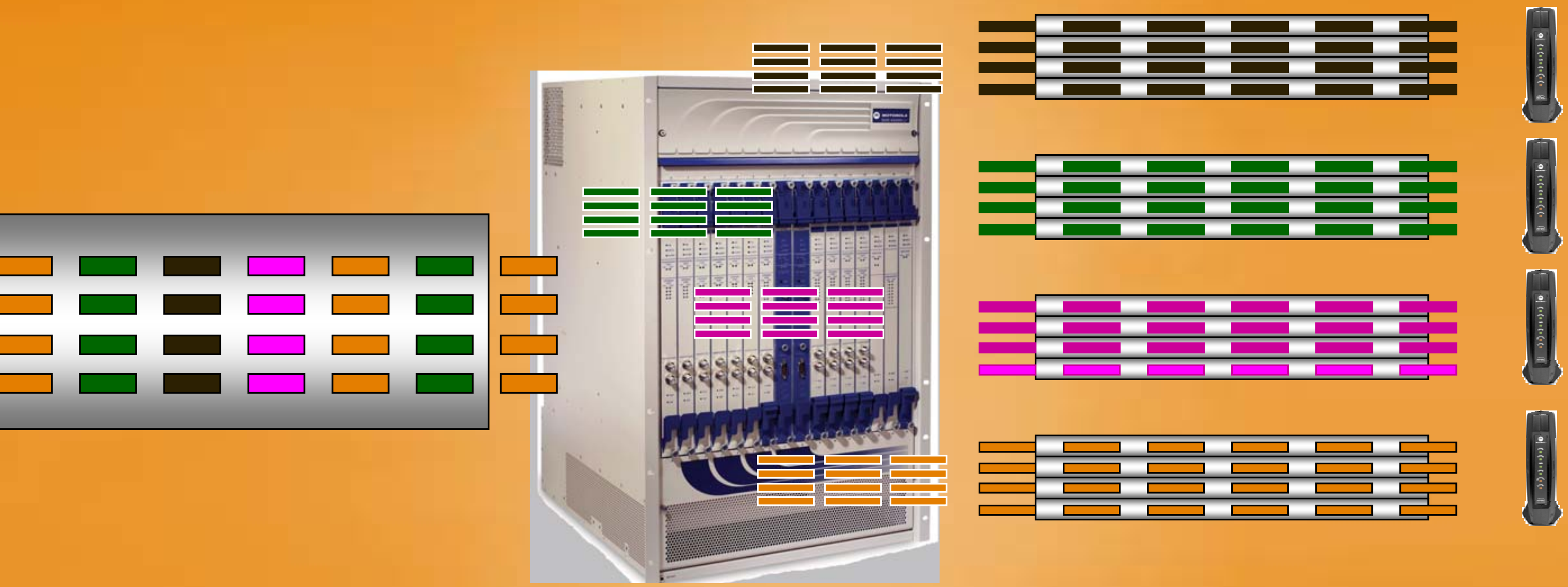
What's rolling out today in your network

– DOCSIS 3.0 "downstream"
– DOCSIS 2.0 "upstream"
– Lesson's learned from other D3.0 rollouts

Current DOCSIS 2.0 Downstream



DOCSIS 3.0 Downstream “Channel Bonding”



Downstream IP Packets from Internet

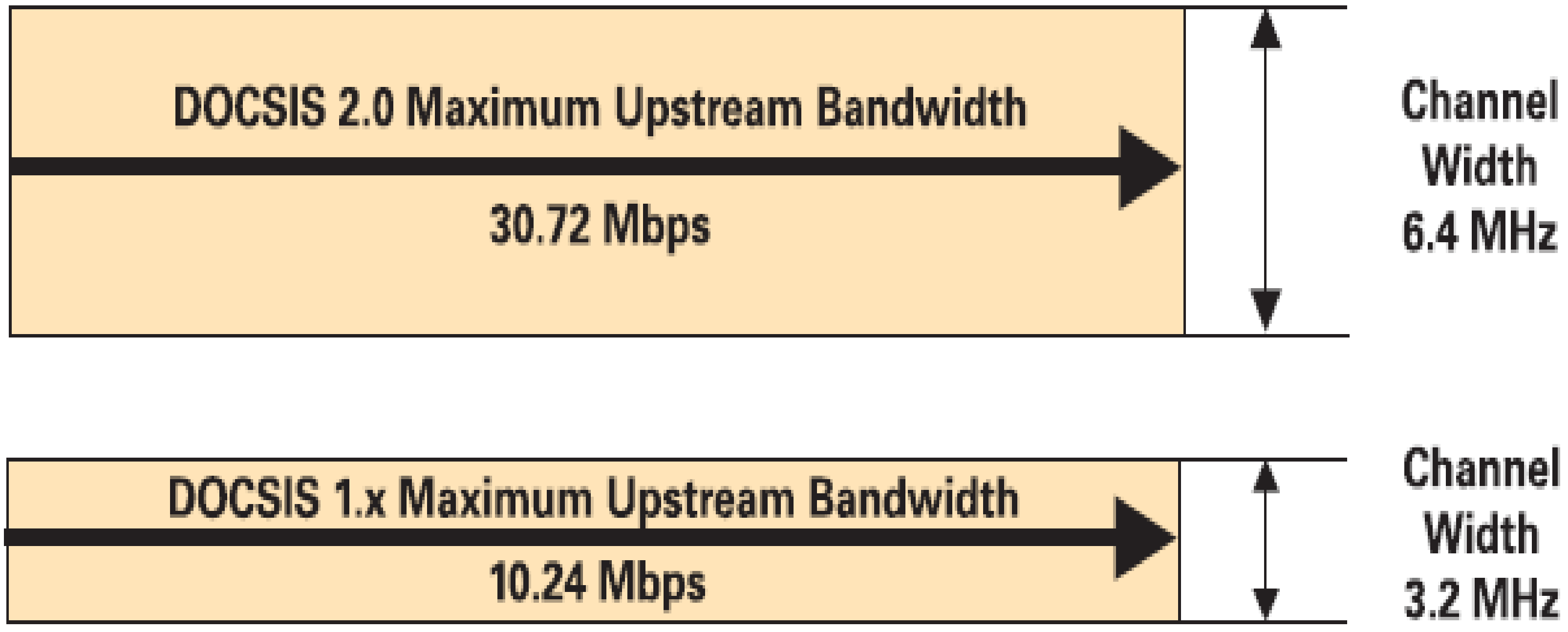
CMTS

Bonded Downstream Channels

CM

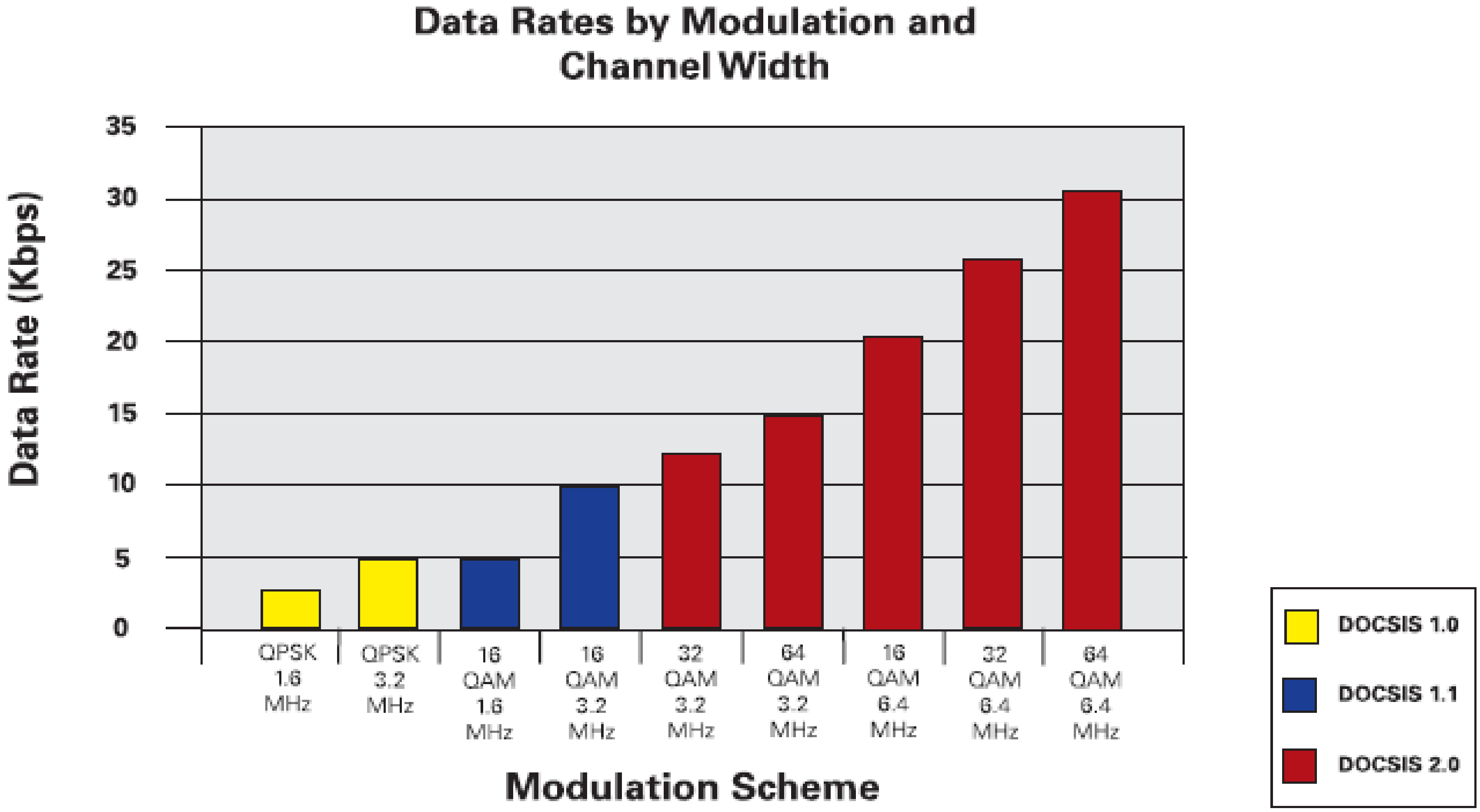
DOCSIS 2.0 "upstream"

DOCSIS 2.0 provides technological alternatives for increasing upstream bandwidth that are rarely implemented fully in practice. A primary advantage enabled by DOCSIS 2.0 is faster upstream performance. DOCSIS 1.X offers a maximum 3.2 MHz upstream channel width and a maximum of 16 QAM modulation, while DOCSIS 2.0 allows cable operators to migrate to 32 QAM or 64 QAM across a channel width of 6.4 MHz.



DOCSIS 2.0 doubles the channel width and triples the upstream peak rate of DOCSIS 1.X

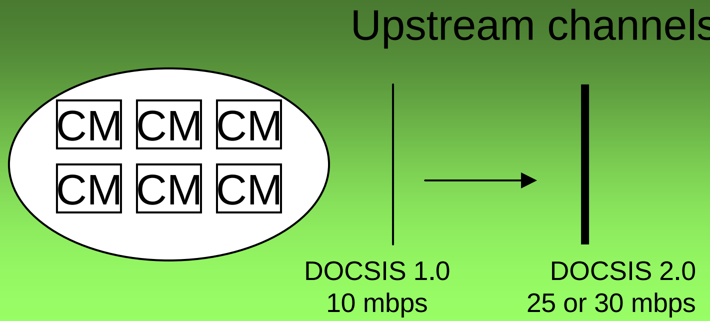
DOCSIS 2.0 "upstream"



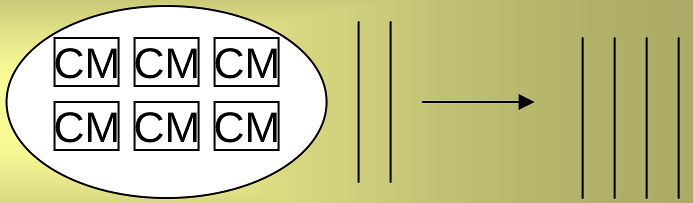
DOCSIS 2.0 enables the use of 32 QAM and 64 QAM and up to 6.4 MHz wide channels

Strategies to Increase Upstream Bandwidth

Increase Data Rate
- Migration to DOCSIS 2.0

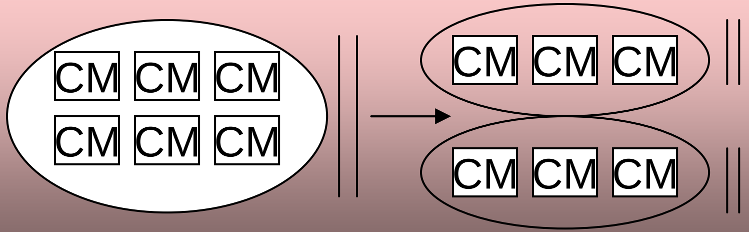


Add Upstream Channels
- More RX ports, SCDMA & DOCSIS 3.0

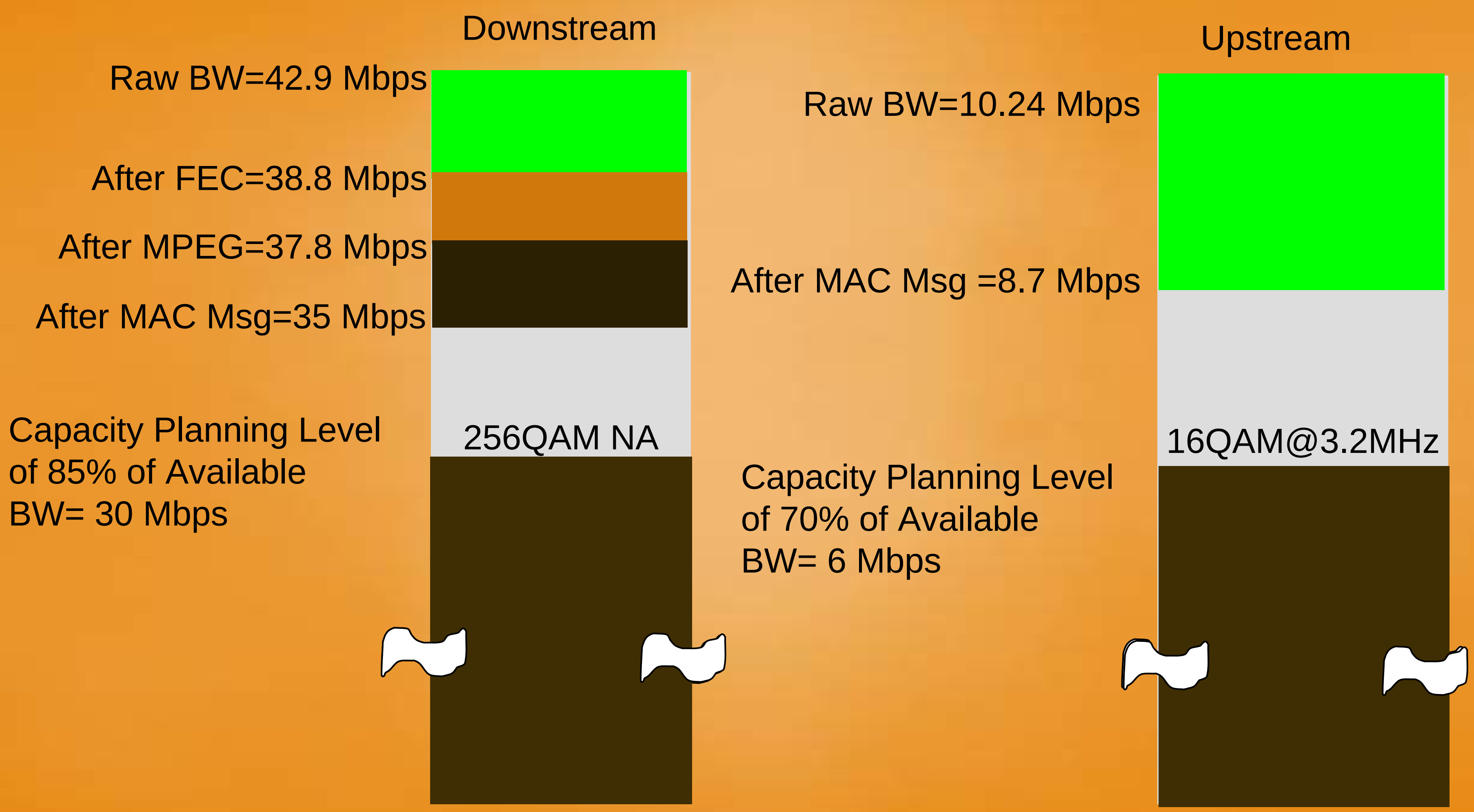


Split Nodes

"Fiber Deeper" – new node with fewer HH/ RF leg
"Segmenting" – same node with separate RF legs per fiber/wavelength. AKA "logical split"



NA DOCSIS Capacity Planning Utilization Levels to Avoid Congestion



Real Life Experiences in Deploying 100 Mbps Service

View **based on working closely with a number of Asia Pac and European Cable Operators**

From lab trials to deployment

What these Cable Operators have in common

Need to deploy a 100+ Mbps service to match or stay ahead of the competition

Not sure what they expect, other than 100 Mbps

Not sure of the applications the subscribers will be using

What Does it Take to Deploy DS Channel Bonding?

Obvious

- Channel Bonding CMTSs and CMs
- Downstream Spectrum

Less obvious

- Upstream Spectrum
- Subscribers’ Education
- Subscribers’ Equipment
  - Re-configuration – at least
  - Upgrade - possibility

Lessons Learned

Performance expectations

- Raw throughput
- UDP Performance
- TCP/FTP Performance

Supporting ‘Legacy’ CMs and ‘Channel Bonding’ CMs

- Overlay Network or Combined Network
- Balancing 100+ Mbps subscribers with “Normal” subscribers
- New sizing concepts are needed
  - Concurrency versus Maximum Sustained Rate
- New tools are needed

Overlay Network Vs. Combined Network

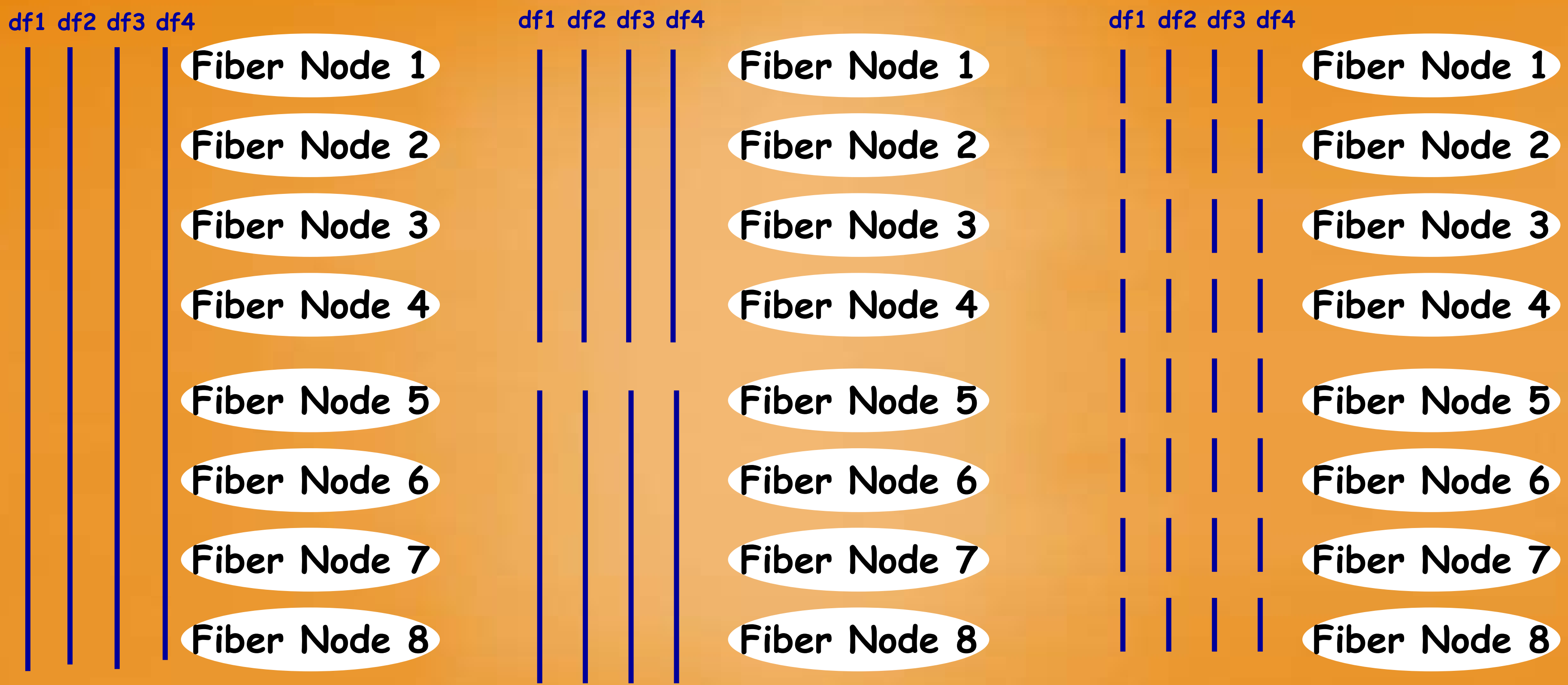
- **In the past, most cable operators selected to offer 100M channel bonded service using an 'overlay' network**
  - **Unsure of 100M service impact on their other subscribers**
  - **Concern about stability of new technology**
- **Now these cable operators are moving to a 'combined network'**
  - **Equipment and technology have proven stable**
  - **Simplified operations**
  - **Reduction in equipment requirements**

Determining Downstream Bandwidth

	DOCSIS (256QAM)	Euro-DOCSIS (256QAM)
RAW BW	42,884,296	55,616,000
After FEC & MPEG	37,778,501	49,890,823
5% DOCSIS OH	35,889,575	47,396,281
2 – Channel BG*	75,557,002	79,781,646
3 – Channel BG*	113,335,502	149,672,468
4 – Channel BG*	151,114,004	199,563,291
2 – Channel BG	71,779,150	94,792,562
3 – Channel BG	107,668,725	142,188,843
4 – Channel BG	143,558,300	189,585,124

* Does not include DOCSIS MAC message overhead

Peak vs. Average Bandwidth



Peak: 144 Mbps/FN
Avg: 18 Mbps/FN

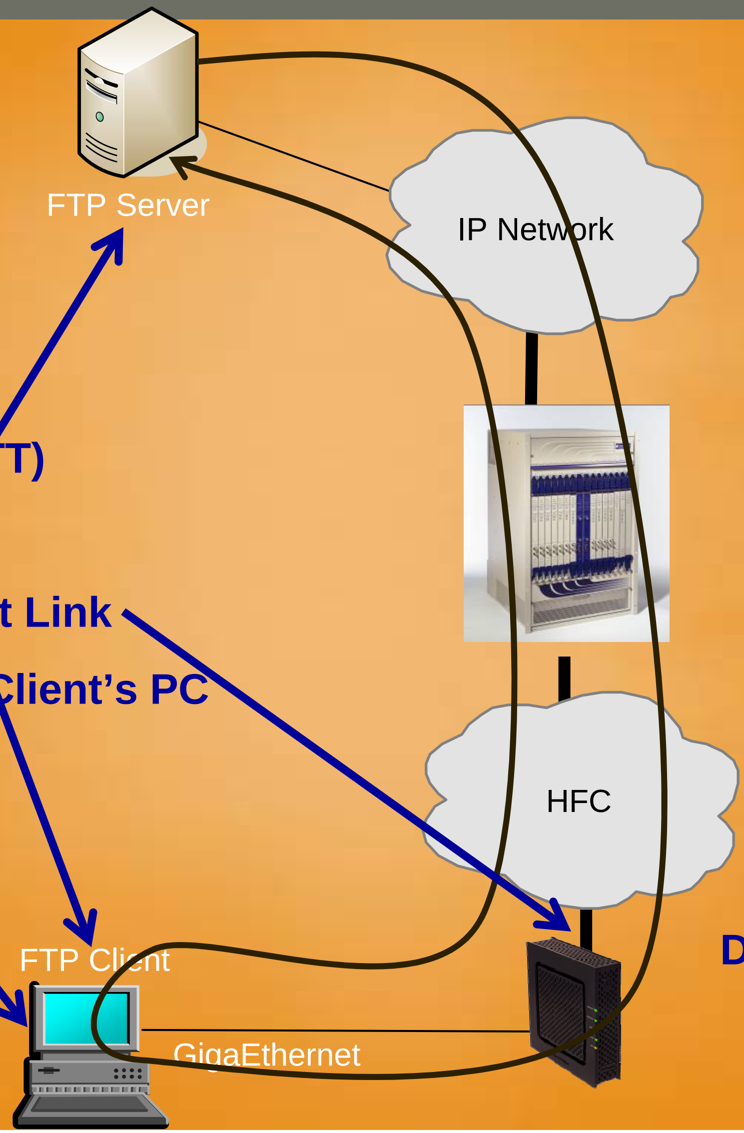
Peak: 144 Mbps/FN
Avg: 36 Mbps/FN

Peak: 144 Mbps/FN
Avg: 144 Mbps/FN

Key Factors for FTP Performance

<u>**Key Factors**</u>

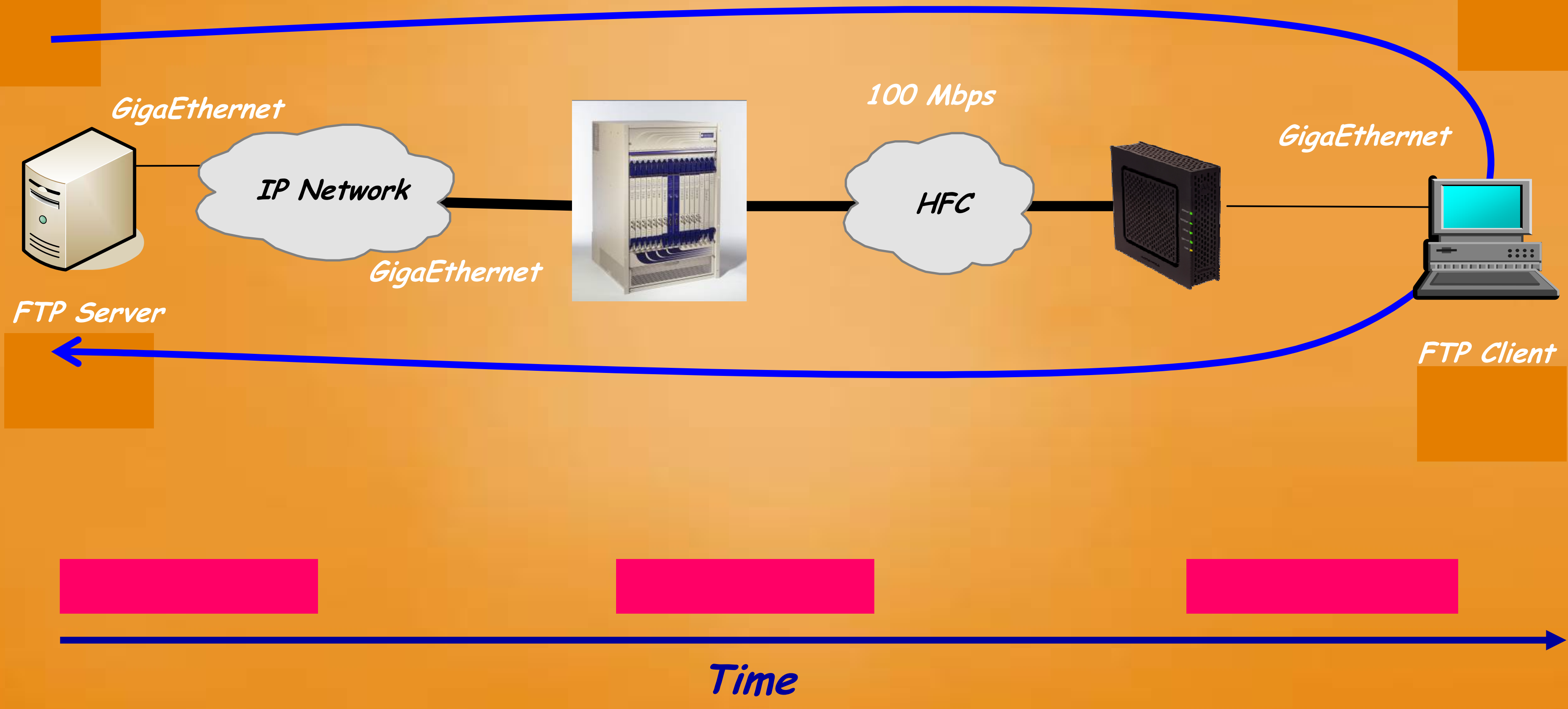
1. **Round Trip Time (RTT)**
2. **TCP Window Size**
3. **Speed of the Slowest Link**
4. **Performance of the Client's PC**



DOCSIS 3.0 Channel Bonding CMTS

DOCSIS 3.0 Channel Bonding CM

RTT and TCP Window Size



FTP Throughput

Max_FTP_Throughput =

((('TCP_window_size' * 8) / 'Link_Speed') / RTT) * 'Link_Speed'

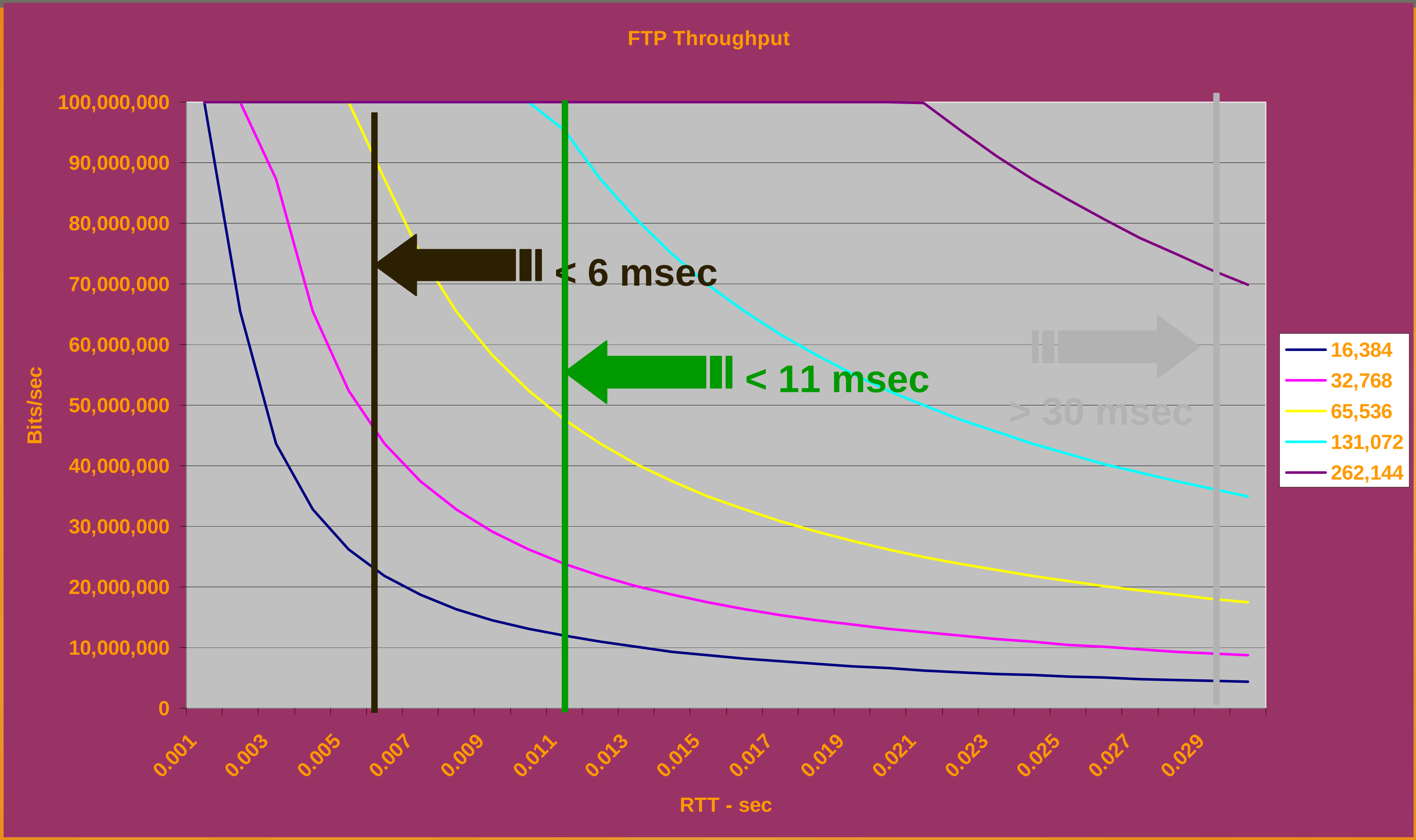
Or

(('TCP_window_size' * 8) / RTT)

Default Window Size

Operating System	Standard RWIN Value (TCP Receive Window Size) in Bytes
Windows 95/98/98SE/NT	8K
Windows ME/2000/XP	16K
Windows XP SP2	64K
Windows Server 2003	64K
Windows Vista	*Receive Window Auto-Tuning*
Macintosh OS X	32K
Linux Redhat 9	32K

FTP Throughput Vs. Round Trip Time (RTT)



Subscriber's PC Configuration

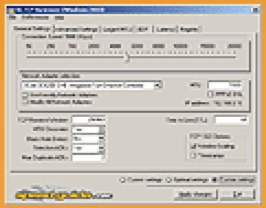
Increase the TCP window size (>= 262,144)

Information and tools available off the WEB

Do a search for "TCP Tuning" on Google

– **Get about 212,000 hits**

TCPOptimizer.exe



Settings -> Control Panel -> System Properties -> Advanced

Performance Setting

Visual Effects ==> "Adjust for Best Performance"

Virtual memory ==> "4096 MBytes"

Processor scheduling ==> "Background Services"

Increase the client PC (and server if possible) performance

Processor speed

RAM size

Disk speed

BUS speed

CMTS Configuration to Consider

1. Increase upstream bandwidth available for Channel Bonded CM
   a) Increase upstream modulation and channel width settings
   b) Increase upstream “Maximum Sustained Rate” and “Burst” settings
2. Reduce downstream and upstream interleave settings
   a) DS interleave = 8, US interleave = 0

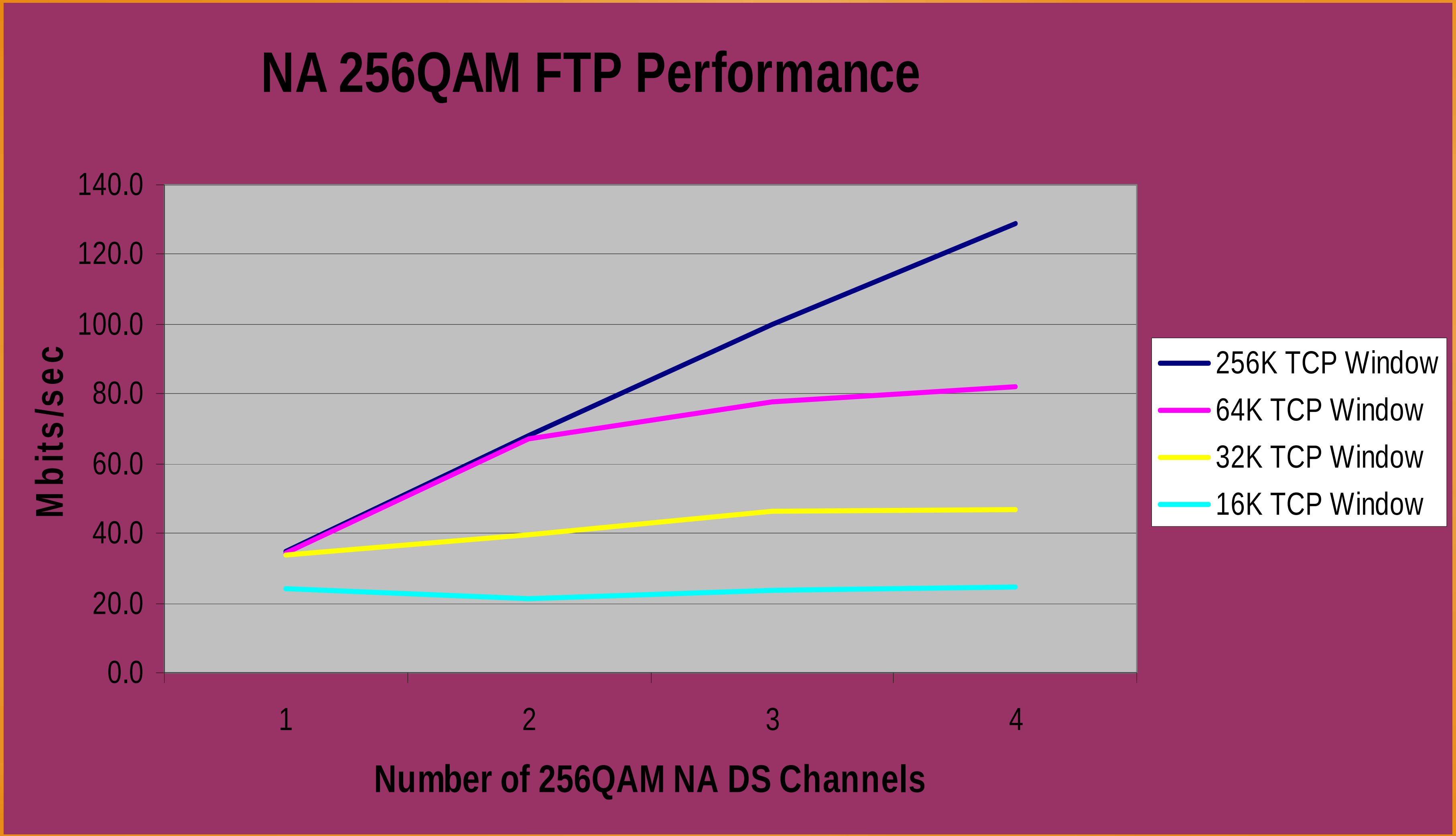
Typical CM's Config File for 100Mbps Deployment

```
24 (Upstream Service Flow Encodings)
   S01  Service Flow Reference          = 11
   S06  QoS Parameter Set Type          = 7
   S08  Max Sustained Traffic Rate      = 3000000
   S09  Max Traffic Burst               = 10000
   S14  Max Concatenated Burst          = 3044 (default)
   S15  Service Flow Scheduling Type    = 2
   S16  Request/Transmission Policy     = 00 00 00 00
25 (Downstream Service Flow Encodings)
   S01  Service Flow Reference          = 21
   S06  QoS Parameter Set Type          = 7
   S08  Max Sustained Traffic Rate      = 110000000
   S09  Max Traffic Burst               = 20000
```

Recommended CM Config File for “Speed Test”

```
24 (Upstream Service Flow Encodings)
   S01  Service Flow Reference          = 11
   S06  QoS Parameter Set Type          = 7
   S08  Max Sustained Traffic Rate
   S09  Max Traffic Burst
   S14  Max Concatenated Burst
   S15  Service Flow Scheduling Type    = 2
   S16  Request/Transmission Policy     = 00 00 00 00
25 (Downstream Service Flow Encodings)
   S01  Service Flow Reference          = 21
   S06  QoS Parameter Set Type          = 7
   S08  Max Sustained Traffic Rate
   S09  Max Traffic Burst
```

FTP Performance vs. TCP Window Size and Number of NA DOCSIS DS Bonded Channels



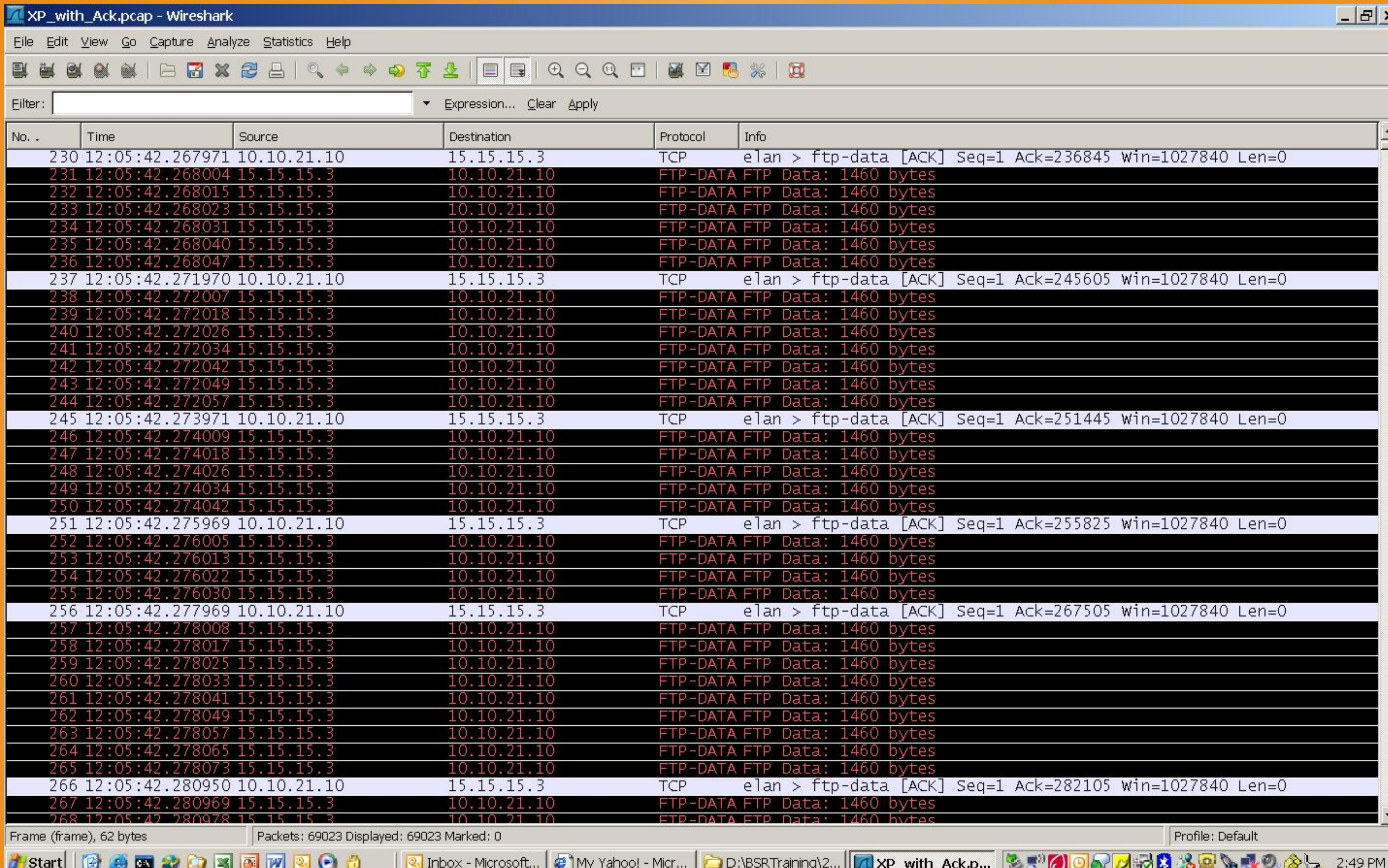
TCP ACK

- **Windows sends a TCP ACK**
  - After two TCP packets received since the last ACK
  - After the “TCP ACK” Timer expires
    - Typically set to 200 msec
- **This has been seen to cause problems with Channel Bonded CMs under certain conditions**
  - Long delay
  - Small TCP window size

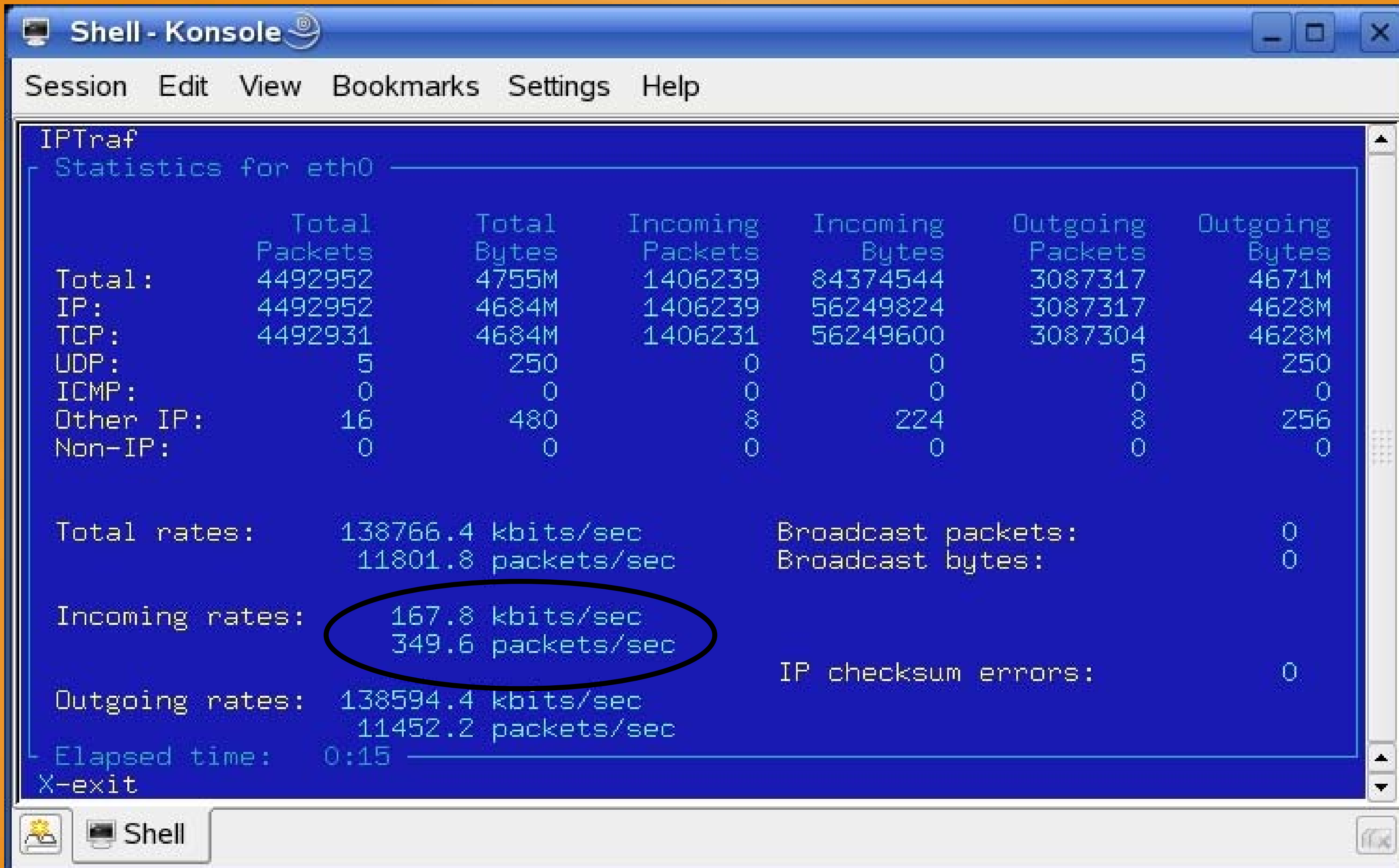
TCP ACK Suppression

- ACK Suppression is a TCP-aware link-layer technique that reduces the number of ACKs sent on the upstream link.
- Each ACK contains an acknowledgement number that corresponds to the byte in the transfer that is being acknowledged. All prior bytes are considered acknowledged.
- A CM only sends the last ACK it receives when its data grant becomes active. Thus, the number of TCP ACKs is fewer, but the number of bytes acknowledged by each TCP ACK is increased
- The benefit that TCP ACK Suppression has is that it not only increases downstream throughput but it also decreases the amount of bandwidth consumed in the upstream.

Windows XP with ACK Suppression



Windows XP with ACK Suppression



Shell - Konsole

Session Edit View Bookmarks Settings Help

IPTraf

Statistics for eth0

	Total Packets	Total Bytes	Incoming Packets	Incoming Bytes	Outgoing Packets	Outgoing Bytes
Total:	4492952	4755M	1406239	84374544	3087317	4671M
IP:	4492952	4684M	1406239	56249824	3087317	4628M
TCP:	4492931	4684M	1406231	56249600	3087304	4628M
UDP:	5	250	0	0	5	250
ICMP:	0	0	0	0	0	0
Other IP:	16	480	8	224	8	256
Non-IP:	0	0	0	0	0	0

Total rates: 138766.4 kbits/sec, 11801.8 packets/sec

Broadcast packets: 0

Broadcast bytes: 0

Incoming rates: 167.8 kbits/sec, 349.6 packets/sec

IP checksum errors: 0

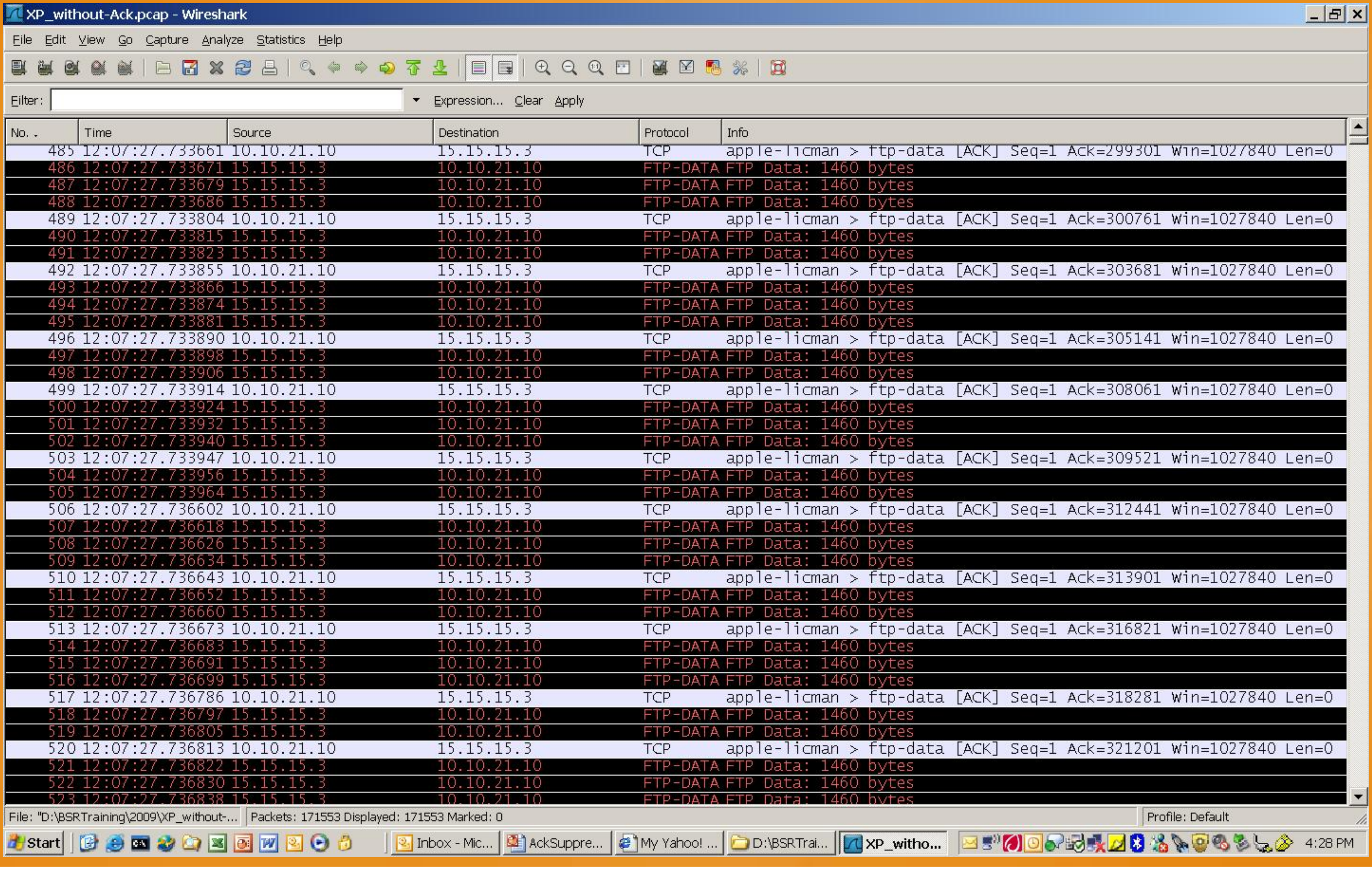
Outgoing rates: 138594.4 kbits/sec, 11452.2 packets/sec

Elapsed time: 0:15

X-exit

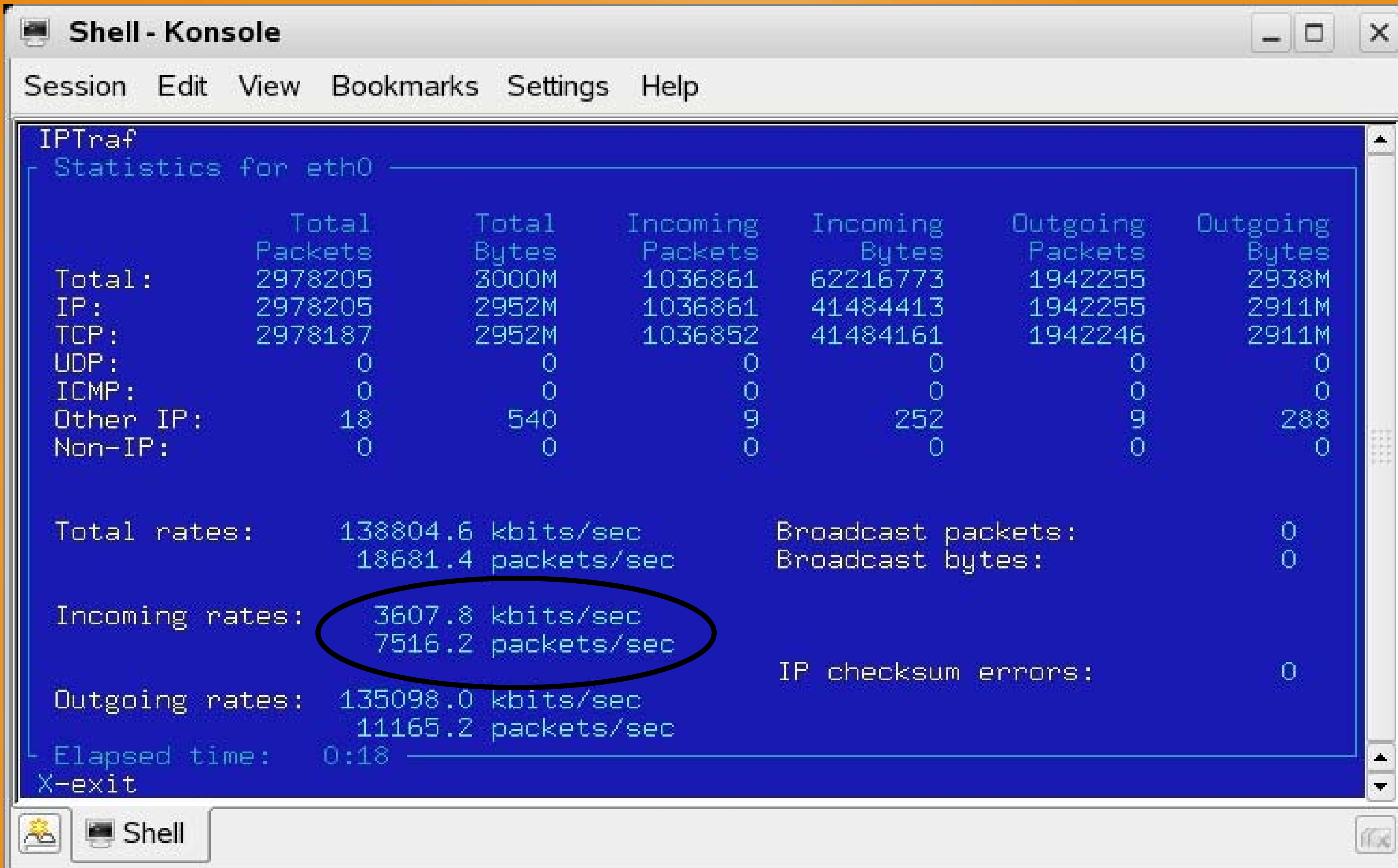
Shell

Windows XP without ACK Suppression



No.	Time	Source	Destination	Protocol	Info
485	12:07:27.733661	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=299301 Win=1027840 Len=0
486	12:07:27.733671	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
487	12:07:27.733679	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
488	12:07:27.733686	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
489	12:07:27.733804	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=300761 Win=1027840 Len=0
490	12:07:27.733815	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
491	12:07:27.733823	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
492	12:07:27.733855	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=303681 Win=1027840 Len=0
493	12:07:27.733866	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
494	12:07:27.733874	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
495	12:07:27.733881	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
496	12:07:27.733890	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=305141 Win=1027840 Len=0
497	12:07:27.733898	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
498	12:07:27.733906	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
499	12:07:27.733914	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=308061 Win=1027840 Len=0
500	12:07:27.733924	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
501	12:07:27.733932	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
502	12:07:27.733940	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
503	12:07:27.733947	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=309521 Win=1027840 Len=0
504	12:07:27.733956	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
505	12:07:27.733964	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
506	12:07:27.736602	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=312441 Win=1027840 Len=0
507	12:07:27.736618	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
508	12:07:27.736626	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
509	12:07:27.736634	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
510	12:07:27.736643	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=313901 Win=1027840 Len=0
511	12:07:27.736652	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
512	12:07:27.736660	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
513	12:07:27.736673	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=316821 Win=1027840 Len=0
514	12:07:27.736683	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
515	12:07:27.736691	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
516	12:07:27.736699	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
517	12:07:27.736786	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=318281 Win=1027840 Len=0
518	12:07:27.736797	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
519	12:07:27.736805	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
520	12:07:27.736813	10.10.21.10	15.15.15.3	TCP	apple-licman > ftp-data [ACK] Seq=1 Ack=321201 Win=1027840 Len=0
521	12:07:27.736822	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
522	12:07:27.736830	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes
523	12:07:27.736838	15.15.15.3	10.10.21.10	FTP-DATA	FTP Data: 1460 bytes

Windows XP without ACK Suppression



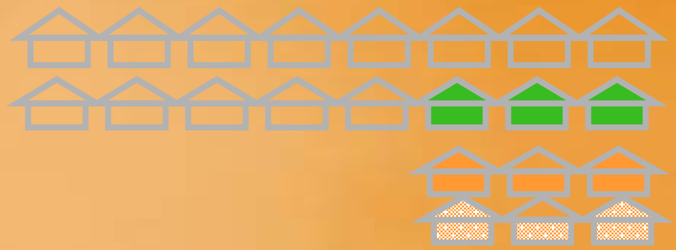
DS FTP Throughput Vs. US Congestion

- **Upstream congestion will affect DS FTP throughput**
  - **FTP throughput depends on the ability of the system to get the “ACKs” upstream as quickly as possible**
- **US congestion factors**
  - **US contention slots**
    - Large number CMs competing for upstream ‘contention slots’
  - **Percentage of US utilization**
    - As link utilization increases the number of available ‘contention slots’ decreases

HPCB – A bandwidth model for all services

The *average* bandwidth requirements to be supplied to a Fiber Node (FN) for any service can be estimated as the product H*P*C*B:

- H = Households Passed
- P = Penetration Ratio
- C = Concurrency Ratio
- B = Bandwidth



The product HPCB is the bandwidth per fiber node for the service:

- H * P * C * B = Bandwidth Requirements

HPCB applies to any service:

- High Speed Data (HSD)
- Voice over IP (VOIP)
- Video On Demand (VOD) [MPEG or IPTV]
- Switched Broadcast (SB) [MPEG or IPTV]

Concurrency C is the inverse of “overbooking”

- 1.0% C means 100-to-1 overbooking
- Worldwide HSD C range: 0.25 to 2.0%;

High Speed Data (HSD) Bandwidth Requirements

2004 Example HSD per FN:

H = 750 HH/FN

P = 20%

C = 1%

B = 4 Mbps

HPCB = 750*0.2*0.01*4 = 6.0 Mbps

Topology:

Split downstream RF port to 6 to 8 fiber nodes

2008 Example HSD per FN:

H = 750 HH/FN

P = 35%

C = 1%

B = 10 Mbps

HPCB = 750*0.35*.01*10 = 26.25 Mbps

Topology:

Split downstream RF port to 1 to 2 fiber nodes

Average increase in DS bandwidth requirement of 4x to 5x

Why 1% HSD Concurrency?

- **The "C-oncurrency" factor for HSD of 1% to 2% was based on observation of the typical HSD supplied in 2002-2008:**
  - **An average of 4 to 10 Mbps maximum rate service.**

- **As DS 'Max Sustained Rate' increases, ahead of applications to use the bandwidth:**
  - **"C-oncurrency" factor is expected to drop**
  - **Expected concurrency for 100 Mbps service today is 0.25%**

Concurrency vs. DS Rate

Observed concurrency data points:

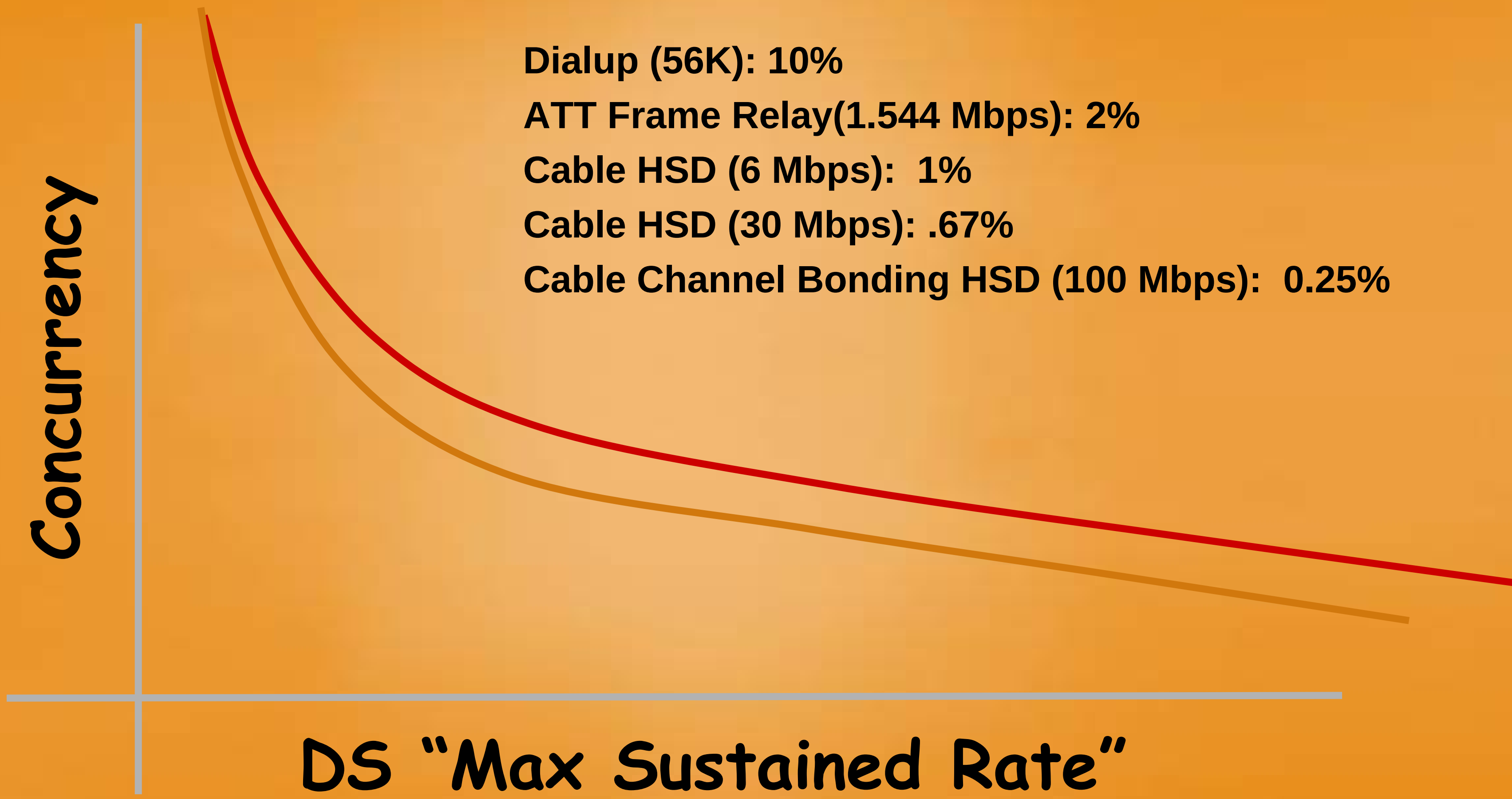
Dialup (56K): 10%

ATT Frame Relay(1.544 Mbps): 2%

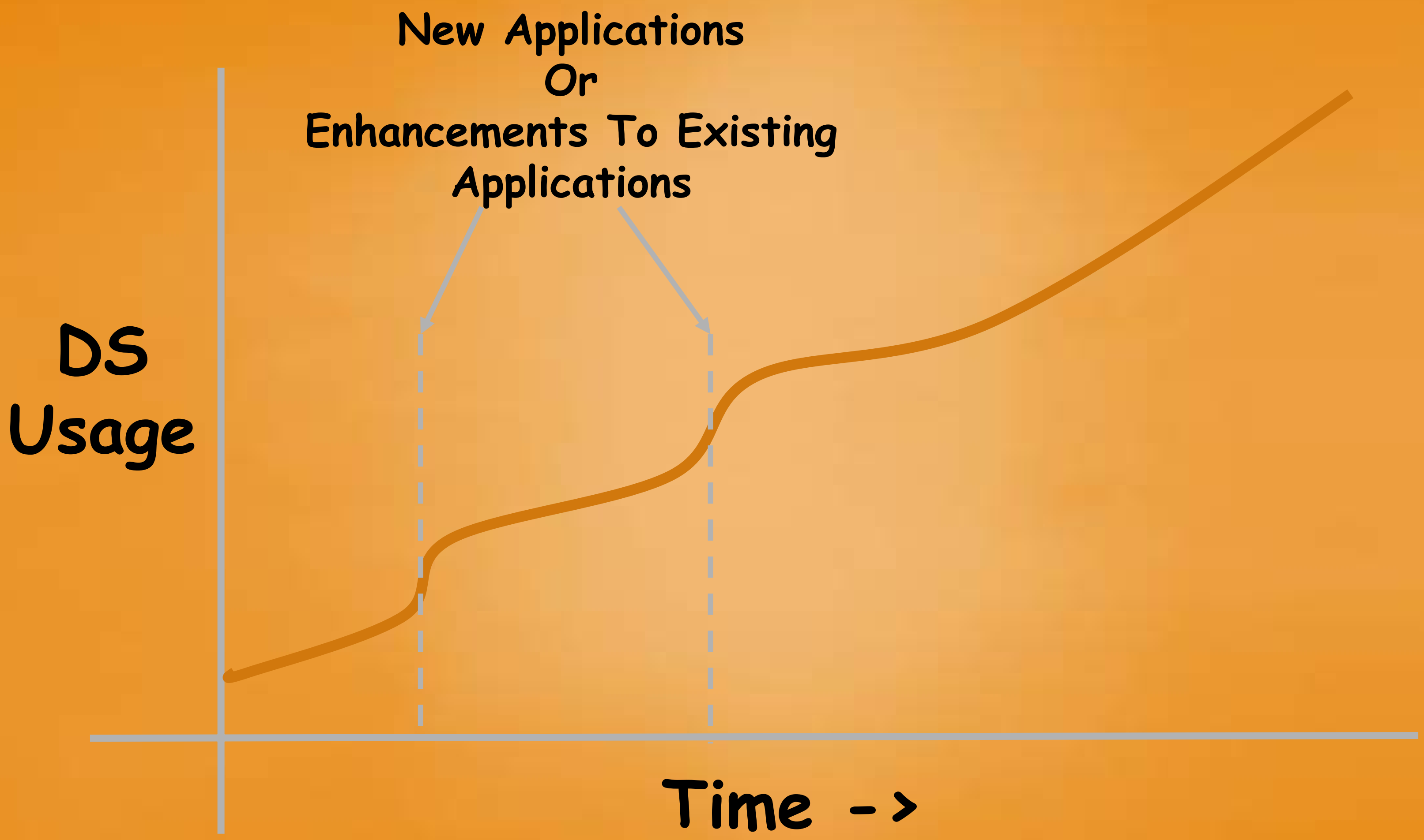
Cable HSD (6 Mbps): 1%

Cable HSD (30 Mbps): .67%

Cable Channel Bonding HSD (100 Mbps): 0.25%



DS Usage Over Time



High Speed Data (HSD) Bandwidth Next Step Requirements

Next Step HSD per FN:

H = 750 HH/FN

P = 50%

C = 0.25%

B = 100 Mbps

HPCB = 750 * 0.5 * .0025 * 100

= 94 Mbps

Topology:

3 NA-DS RF ports per fiber node

Average increase in DS bandwidth requirement of ~ 4x from today

VOIP Bandwidth with HPCB

2004 Model:

H = 750

P = 10%

C = .15 busy hour concurrency

B = 100 kbps

HPCB = 1.3 Mbps DS (and US)

"Next Step" Model:

H = 750

P = 50%

C = .15 busy hour concurrency

B = 100 kbps

HPCB = 5.6 Mbps DS (and US)

- *Voice Bandwidth is increasing*
  - *But it is being over shadowed by other services*
- *Upstream bandwidth requirement is more of a concern*
- *Voice must continue to get PRIORITY over other services*

What could or will be coming in the future

- RFoG
- S-CDMA
- DOCSIS 3.0 devices
- SIP eMTAs

Pulling Fiber Deeper

Pro's

Cascade may be reduced and provide added benefits

Minimizes changeout in the maintenance window.

Design maps can be upgraded quickly and may not require repowering.

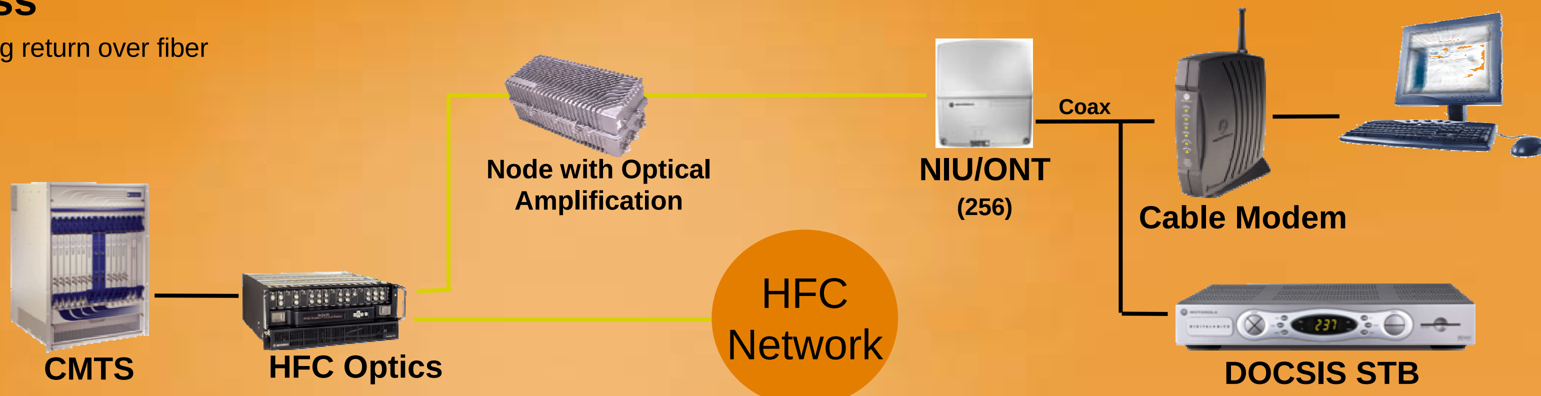
Con's

Must overlash fiber to the new node.

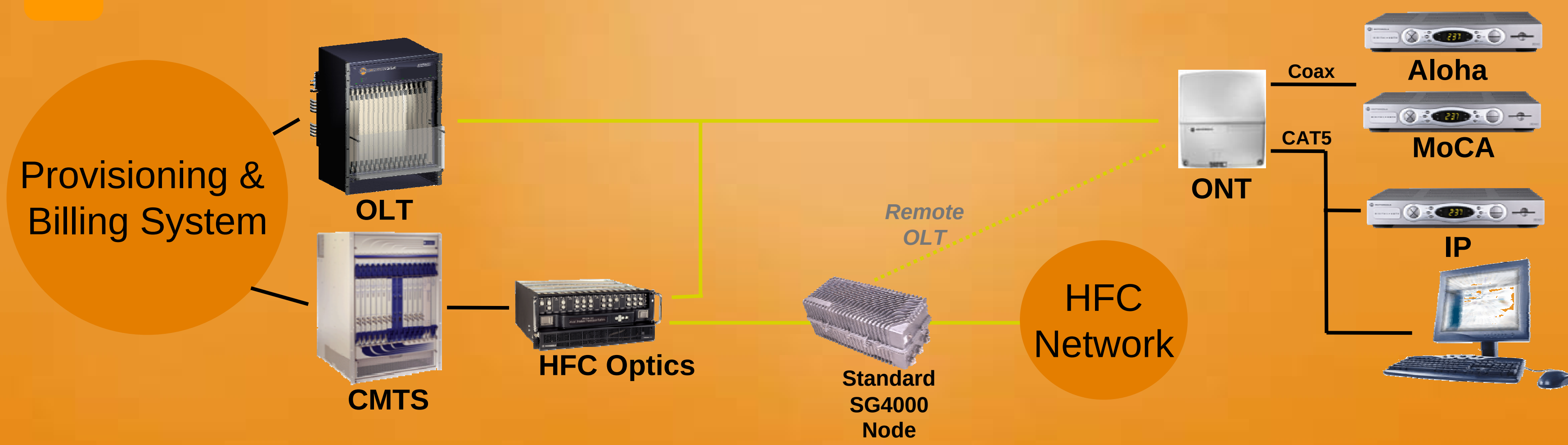
Physical Installation – More sites to visits for segmentation.

Cable PON: 2 directions

1. **Allow cable operators to maintain existing DOCSIS CPE’s and/or set-top boxes. “RF over Glass”**
   - Enable analog return over fiber



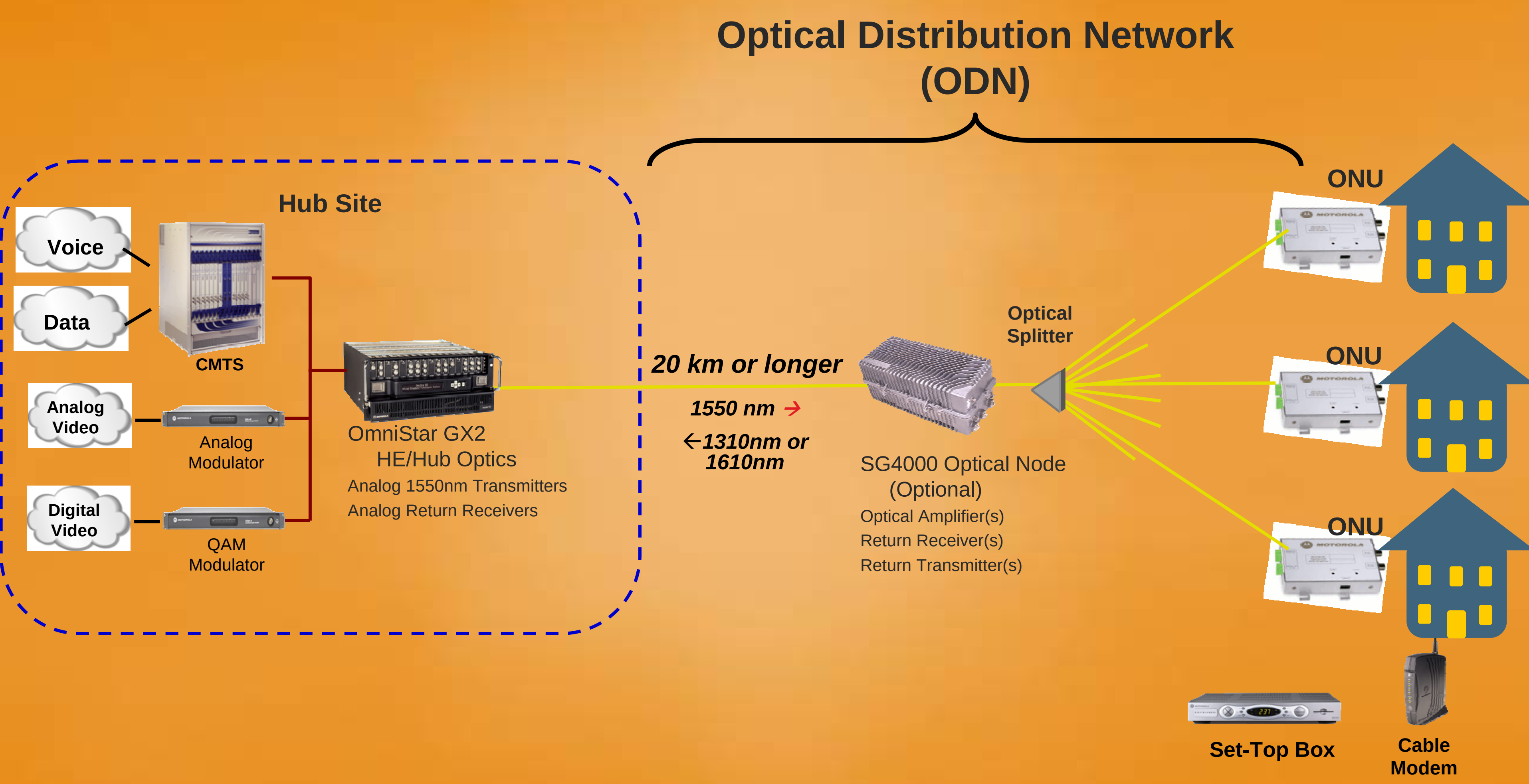
2. **Make GPON look transparent in the current back-office and network.**
   - Provisioning, billing is transparent



What is CablePON?

- Motorola name for suite of FTTx solutions for Cable Operators
- Leverages Motorola's expertise in HFC, PON and DOCSIS architectures and leading platforms
- Accommodate Cable Operators' current deployed base of CPE, infrastructure, and/or Backoffice Systems
- Accommodate Cable Operators current architecture (link budgets, fiber counts, etc.)
- Includes RFoG, ONT with Return Demod, Back-office transparency, and Remote OLT's

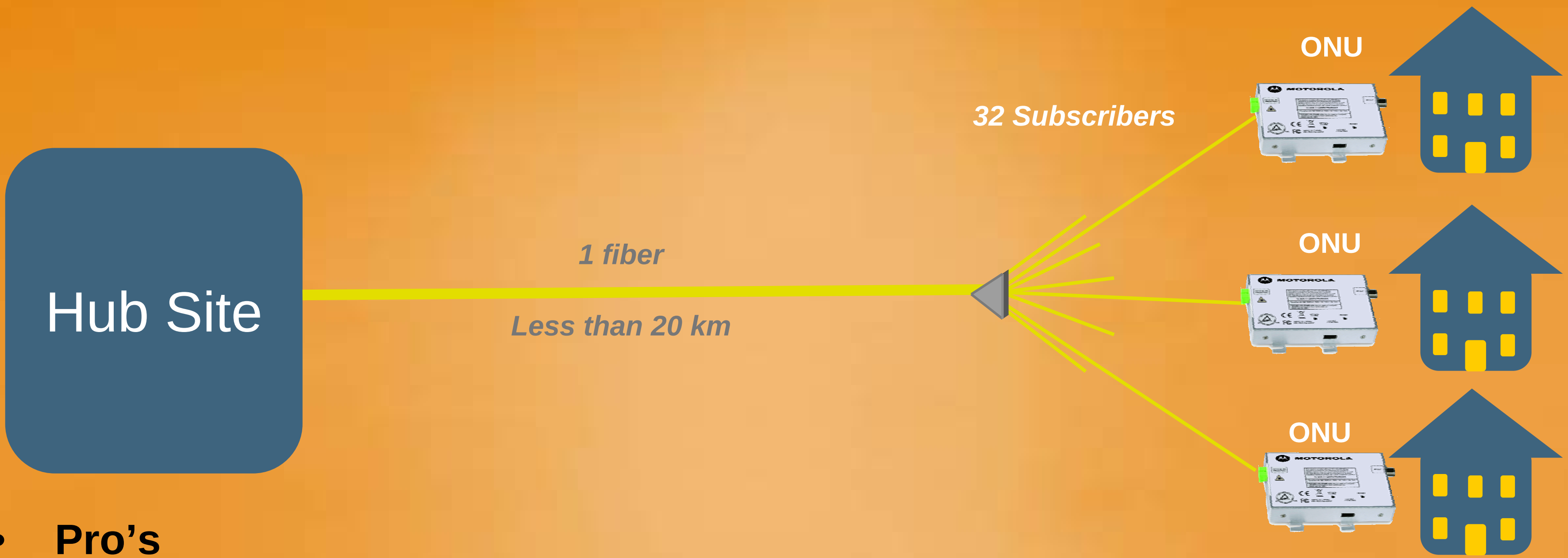
RF-over-Glass (RFoG) Reference Architecture



RFoG Network Description

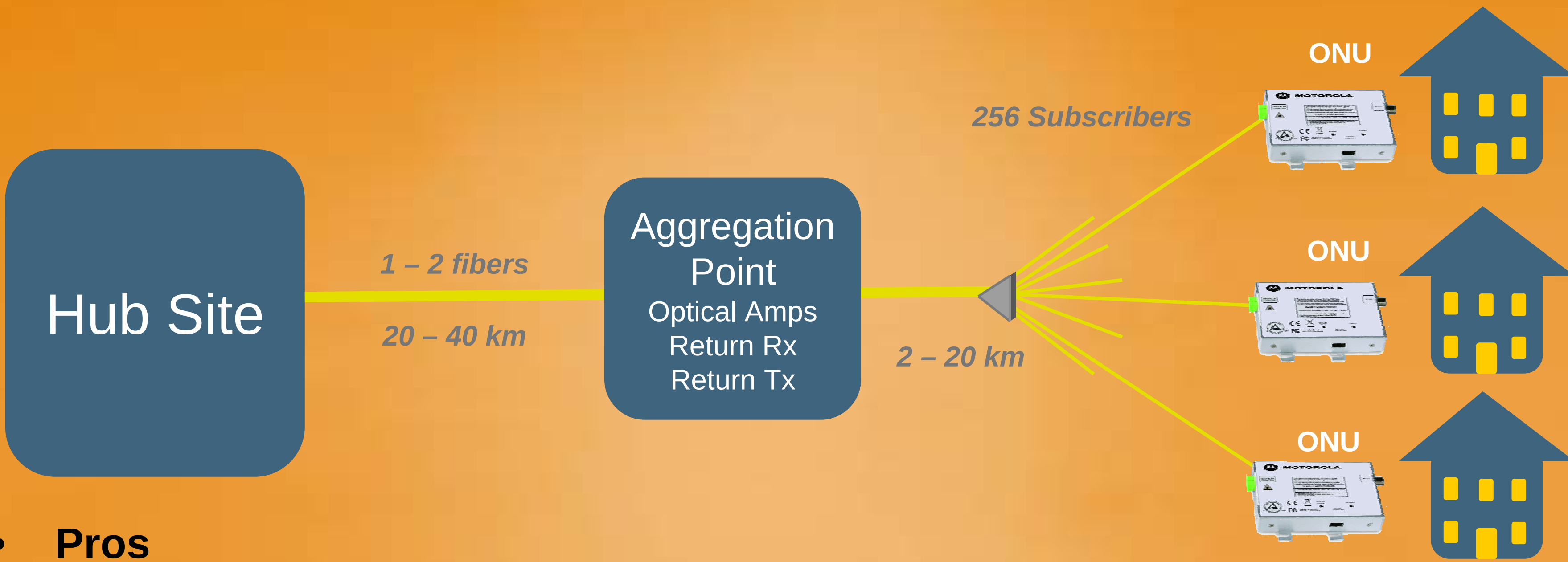
- **Optical-to-Electrical conversion location is moved from Node in the HFC network to the premise for RFoG network**
  - **Optical Network Unit (ONU)**
    - Also called Network Interface Unit, micro-node, house node
  - **RFoG is optical point-to-multipoint instead of optical point-to-point so optical summing required in the return-path – additional challenges**
- **Services are transported over analog RF carriers in both directions, same as HFC networks**
  - **Uses same protocols as HFC network for transporting video (analog + QAM) and data/voice (DOCSIS)**
- **Optional SG4000 all-optical node allows longer distances and aggregation of multiple RFoG service groups onto two fibers between the hub and neighborhood**

Architecture: RFoG Direct Feed



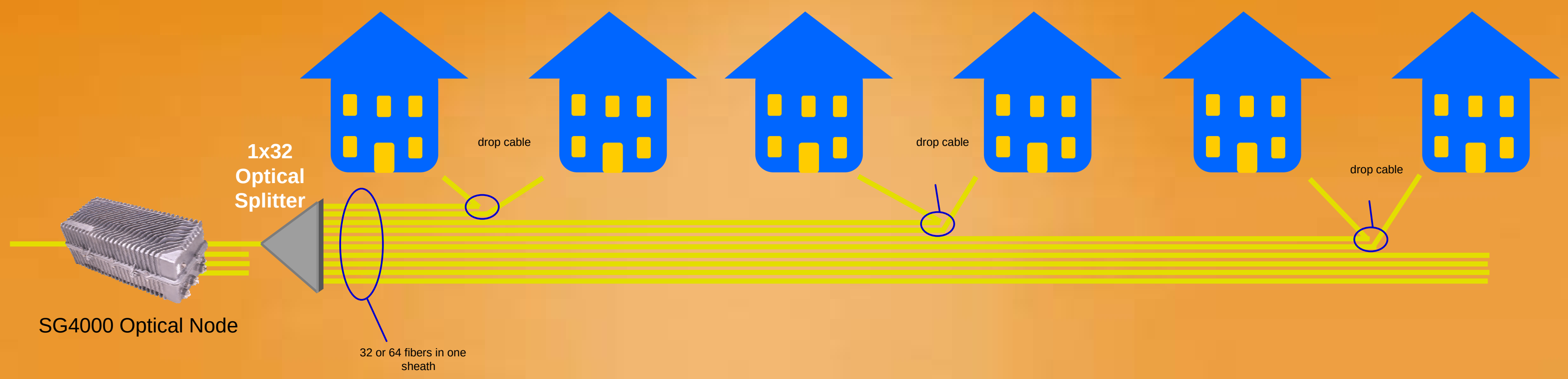
- **Pro's**
  - **No actives in the plant; completely passive**
- **Con's**
  - **Maximum reach is 20km**
  - **Maximum serving size is 32 subscribers per fiber**

Architecture: RFoG Aggregation



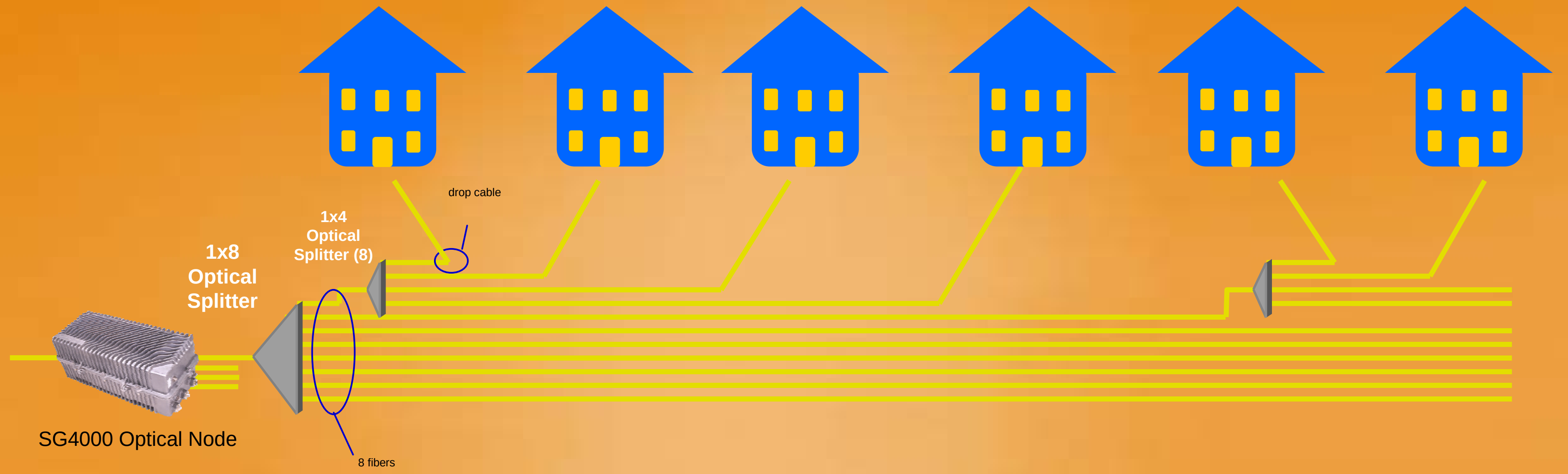
- **Pros**
  - **Capable to deliver RFoG services over longer distances**
  - **Use higher split ratio (1X64 times 4) to serve more subs**
  - **Aggregate multiple returns onto 1 fiber**
- **Cons**
  - **Active equipment in the plant**

RFoG Fiber Architectures: Centralized



- Large splitter - Point-to-Point from node/splitter
- Same fiber architecture being deployed for PON today
  - Leverage technologies and cost curves
- Lends itself well to future migration to PON
- Usually uses optical connectors
  - Only “light” fiber when obtain subscriber – save initial capital costs
  - Some have reliability concerns with connectors
  - Can disconnect service (i.e. analog TV) at fiber enclosure

RFoG Fiber Architectures: Distributed

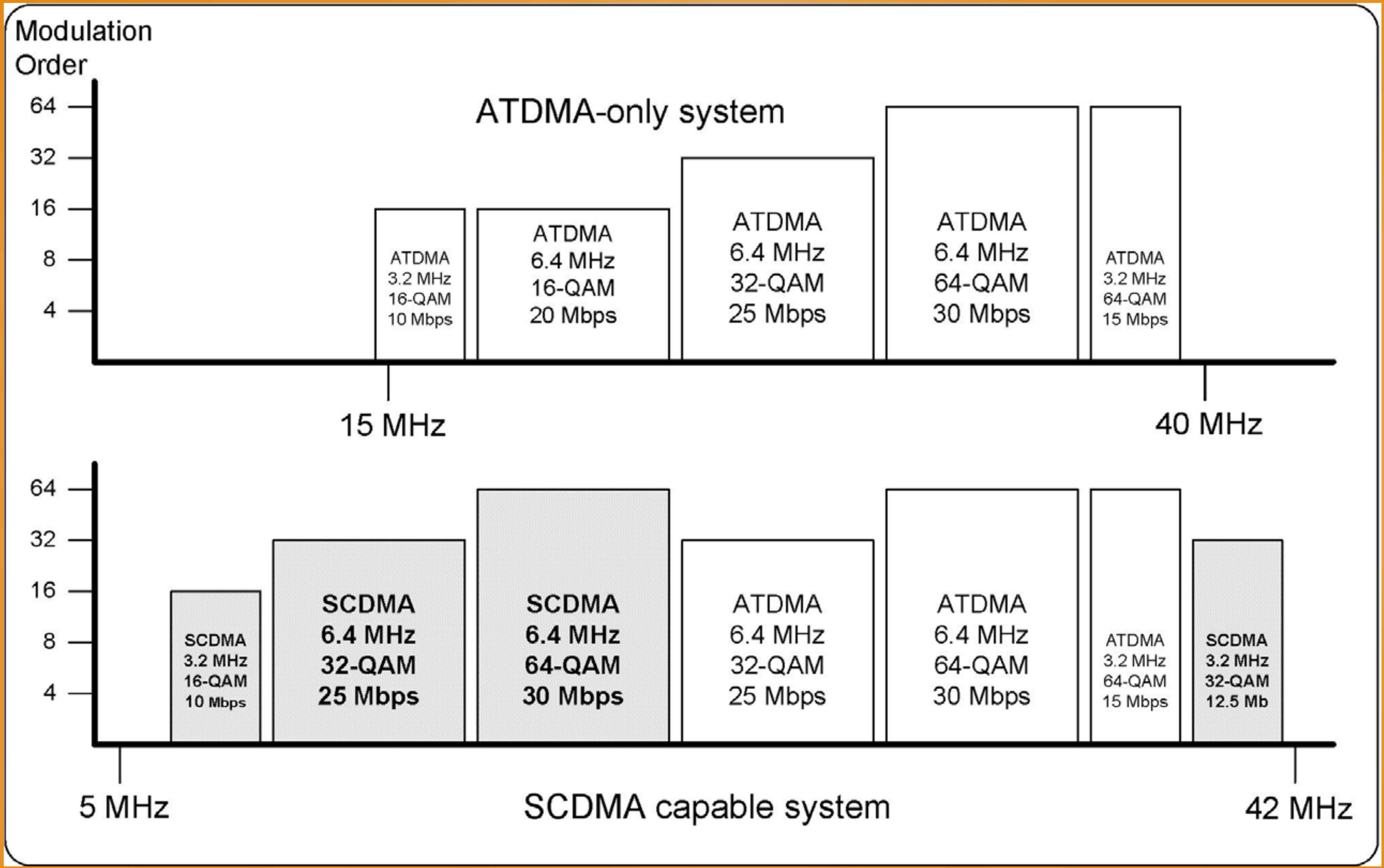


- Low-count splitters cascaded along fiber route to achieve 1X32 or 1X64 split ratio
- Fusion splicing usually used
- Less excess fiber to manage (eliminate snowshoes, etc.)
- A “lit” fiber is usually left for non-subscribers – more capital cost

SCDMA Introduction

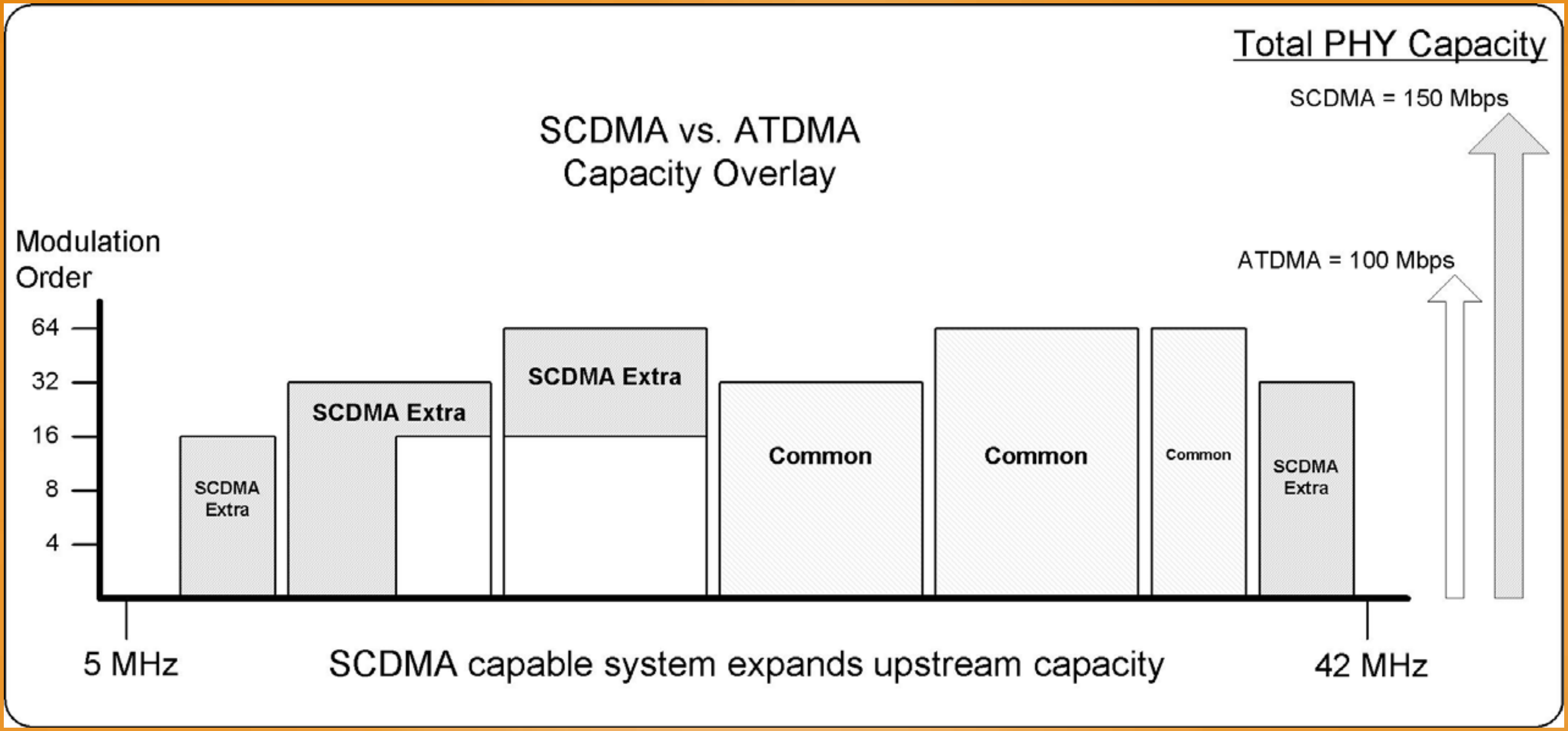
- **What**
  - **Synchronous Code Division Multiple Access (SCDMA) is a DOCSIS upstream PHY technology added in DOCSIS 2.0, and enhanced in 3.0**
    - New modulation and ingress canceller technology
    - Synchronous operation
- **Why**
  - **SCDMA technology is particularly robust against impulse noise**
  - **SCDMA also provides increased power per code feature for higher SNR in the case of highly attenuated upstream signals**
- **How**
  - **SCDMA stretches the symbols out in time by 128 times without decreasing the capacity of the channel**
    - Multiplexes 128 simultaneous transmissions via SCDMA codes

SCDMA vs. ATDMA Capacity Analysis



Assumptions: N+6, substantial ingress + impulse noise

SCDMA vs. A-TDMA Capacity Analysis



- **SCDMA advantages**
  - **SCDMA increase capacity up to ~50%**
  - **Enables 100 Mbps Upstream Service Rates**
  - **Defer Node Splits**

SCDMA: Cost Efficient Upstream Capacity

- **SCDMA is the modulation technique of choice for the "barren land" below 20 MHz**
  - **Deals with dominant Impulse Noise *and* Ingress Noise**
  - **>25% of the return spectrum (5-15 MHz) has been surrendered by MSOs for DOCSIS services**

- **SCDMA vs. ATDMA Capacity Analysis**
  - **SCDMA increases total capacity up to ~50%**
  - **Enables 100 Mbps upstream service rates**
  - **Can defer node splits on many plants**

DOCSIS 2.0 vs 3.0 SCDMA

- **DOCSIS 2.0 SCDMA**
  - **Full impulse immunity (FEC & code domain)**
  - **Basic ingress cancellation**
    - A Few narrowband interferers
    - Should be adequate for most Live Plants (90%+)

- **DOCSIS 3.0 SCDMA**
  - **Improved ingress cancellation**
    - 64 QAM / 6.4 MHz much more feasible at all frequencies
    - Allows 3.2 MHz operation under *severe* levels of ingress
    - Empowered by **Selectable Active Codes (SAC)** feature
  - **Adds Maximum Scheduled Codes (MSC) feature**
    - Granular trading of SNR vs. capacity in code domain

DOCSIS Channel Types

DOCSIS 2.0

Type 1: DOCSIS 1.x upstreams that support no DOCSIS2.0 ATDMA/SCMDA features

Type 2: Mixed upstream that support DOCSIS1.x and DOCSIS 2.0 ATDMA/SCDMA burst

Type 3A: DOCSIS2.0 upstreams to support ATDMA which can not support DOCSIS 1.x modems

Type 3S: DOCSIS2.0 upstreams to support STDMA which can not support DOCSIS 1.x modems

DOCSIS 3.0

Increased flexibility allowing the CMTS to assign a specific IUC to each data transmission by a 3.0 modem

Type 4A: TDMA upstream that support DOCSIS 2.0 modems on IUC 9, 10 and 11 (UCD type 29) and DOCSIS 3.0 modems on IUC 5, 6, 9, 10 and 11 (UCD type 35)

Type 4S: SCDMA upstream that support DOCSIS 2.0 modems on IUC 9,10 and 11 (UCD type 29) and DOCSIS 3.0 modems on IUC 5,6, 9, 10 and 11 (UCD type 35)

Type 4AR: TDMA upstream that only supports DOCSIS 3.0 modems on IUC 5, 6, 9, 10 and 11 (UCD type 35)

Type 4SR: SCDMA upstream that only supports DOCSIS 3.0 modems on IUC 5, 6, 9 10 and 11 (UCD type 35)

Key SCDMA Benefits/Uses

- **Impulse noise robustness for use in bottom of upstream band**
  - **Over 100 times that of TDMA for the same capacity**
    - Effectively due to frame interleaving possible in SCDMA
  - **TDMA impulse robustness can be increased, but at the cost of capacity**
    - Reduce symbol rate to stretch symbol out in time
  - **ATDMA FEC byte interleave only has an impact with large upstream data packets (>768 bytes)**
  - **SCDMA strongly recommended below 20 MHz, may also be required in 20-25 MHz**
    - Depends on order of QAM desired and severity of impulse noise
    - Example: ATDMA 64 QAM/6.4 MHz channel shown to have problems in 20-25 MHz range
    - SCDMA increased power per code can also be required on upper band edge
- **Combined ingress and impulse immunity**
  - **SCDMA in DOCSIS 2.0 ingress canceller performance is lower than ATDMA, but in DOCSIS 3.0, SCDMA ingress canceller can outperform ATDMA for some ingress types/combinations**
- **SNR boost**
  - **Modems on highly attenuated channels**
  - **Modems on networks with available laser margin for higher order QAM**
- **Increased efficiency from synchronous operation**
  - **Lower preamble length improves small packet efficiency**

Tomorrow's Digital Home

Managing the Transition and the Complexity

An all IP home for Voice, Video and Data

DOCSIS 3.0 Cable Modems and eMTAs

CM

eMTA

Standalone

Wireless

Gateways

802.11n
4 port GigE switch
1 GHz capable Tuners
Bonding capability of up to 8 Downstream & 4 Upstream channels

SIP eMTAs

Benefits

- **The intelligence is pushed to the network edge where processing capability is available**
- **Failure recovery is easier when servers do not have to maintain call state**
- **Faster time to market for new features when only edge devices are affected**
- **SIP requires fewer message exchanges between endpoints and network**

NCS vs. SIP

	NCS	SIP
Server	**Call Management Server**	**Proxy Server**
Registration Message	**RSIP (Restart In Progress)**	**REGISTER**
Managing Media Streams	**Create, Modify & Delete Connections**	**INVITE, re-INVITE, BYE**
Subscriber Line Signaling	**CMS handles events & generates signals**	**Intelligent endpoints process locally**
Maintaining Call Context	**Redundant CMSes required for reliability**	**UA maintains state**
Extensibility	**New features are implemented in CMS**	**New applications can be easily introduced**
Popularity	**Specific to Cable Telephony**	**Ubiquitous**