Module 0

CATV, DOCSIS 101, Modem Registration

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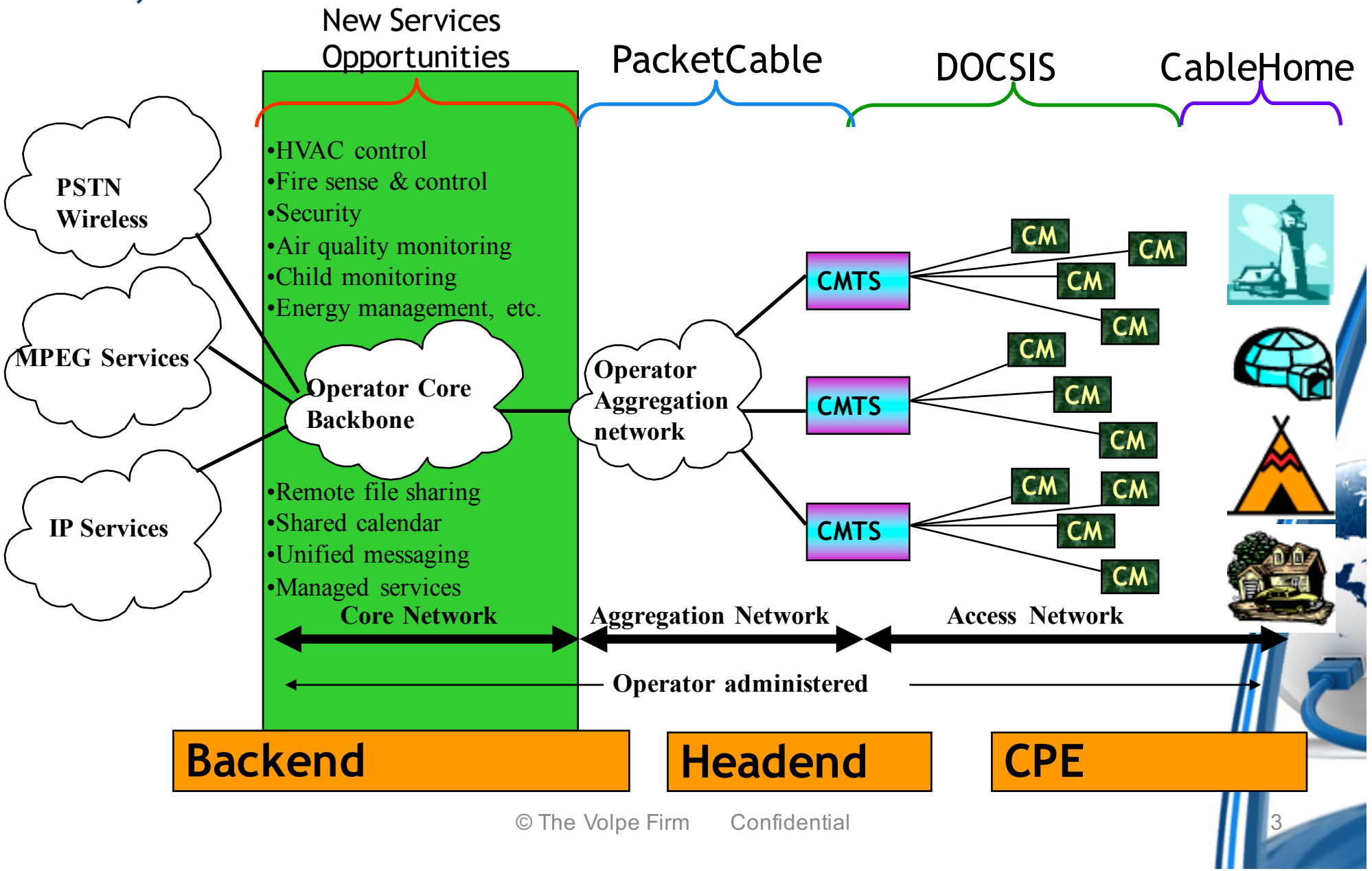
The Volpe Firm

Agenda

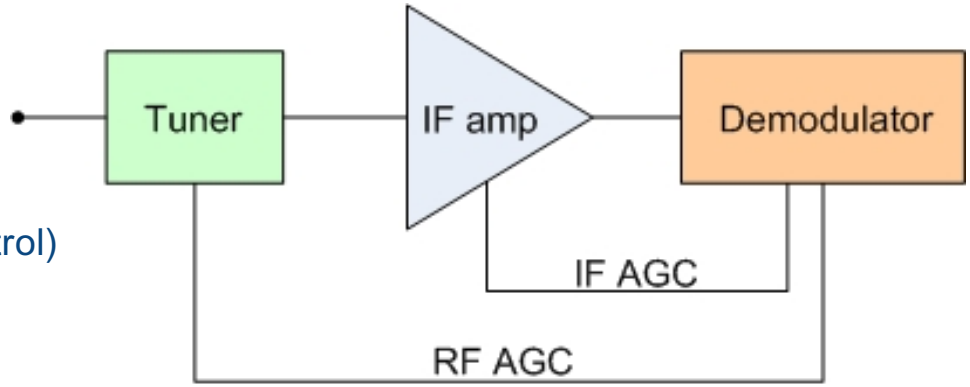
- CATV Architecture & Overview
- DOCSIS Frequency Allocation
- DOCSIS 1.x / 2.0 Cable Modem Registration
- CM Registration Issues
- Brief eMTA Registration Overview
- Summary
- Q&A

50,000 ft - Cable Architecture



Off-The-Air

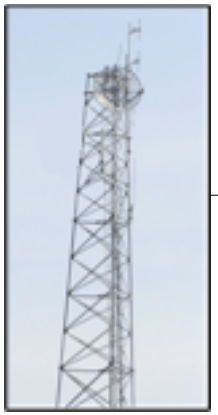
- Reception and distribution on a fairly small coverage (local)
- Objective: TV Sales
- Unregulated
- In 1948 in Montréal, 2 channels are distributed (also WA & PA)
  - Rediffusion
  - American Channel
- Modified Television
  - AGC measurements
    - (Automatic Gain Control)



Measurements

-First measurement: signal level

Off-The-Air – Network Infrastructure



antennas

Signal Combining

Distrib. Amp.

tap

drop

Coax. cable

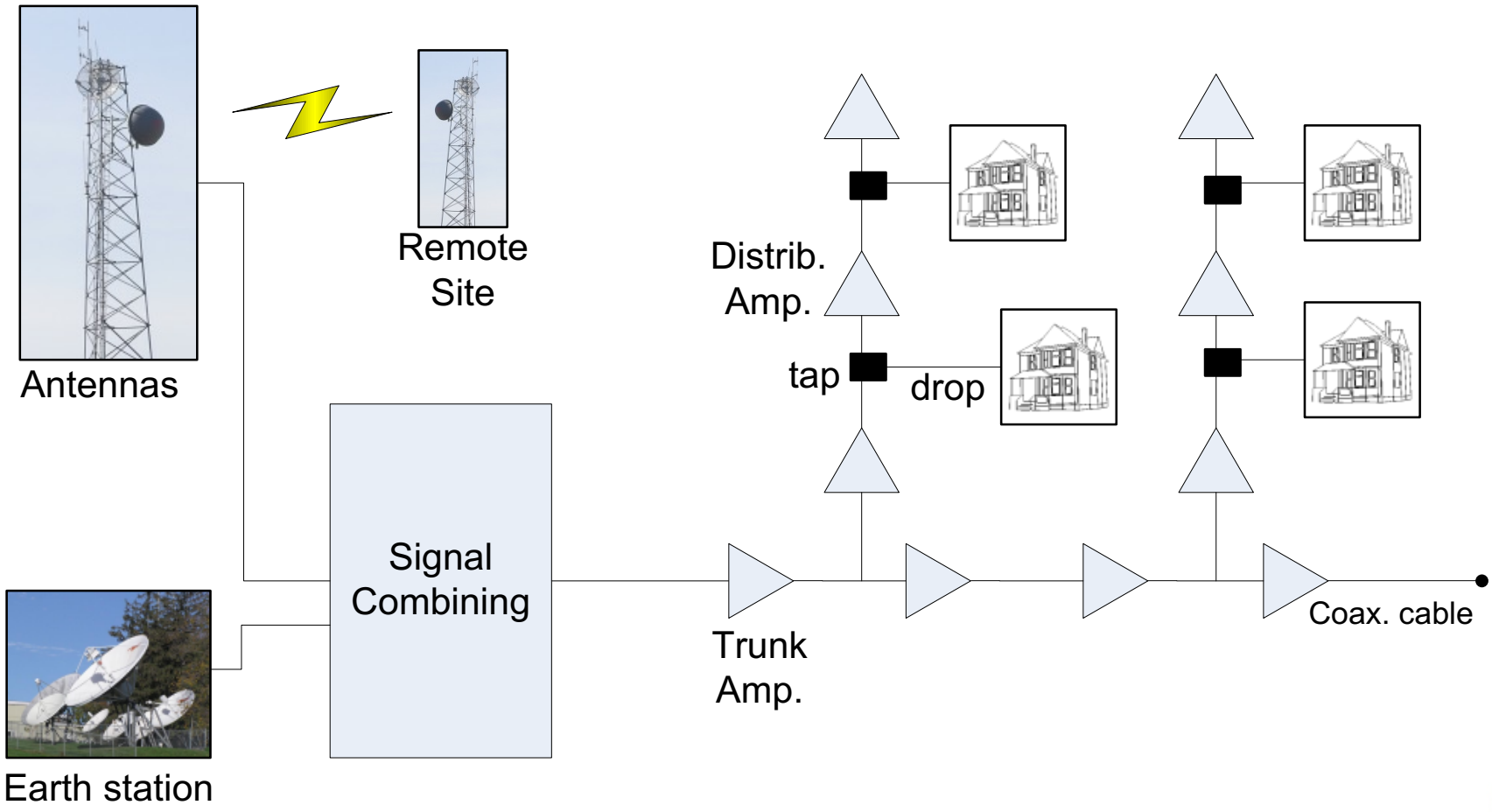
Satellites and Microwaves

- New programming
  - Each city has its own programming
- Wide distribution
  - Local, distant, community-based program
  - The use of satellites is expensive so distribution in suburbs and villages are with long cascading amplifier
- More channels
  - From 21 to 50 channels (Mid-band use, then super band)
- Regulation
  - FCC (in United States)
  - BP-23 (in Canada)
- Long cascades of amplifiers
  - From 10 to 80 amplifiers

Measurements

- Level measurements
- Frequency response measurements
- Carrier to noise measurements
- CTB, CSO and XMOD measurements

Satellites and Microwaves – Network Infrastructure



PAY-TV and Extended Services

- New programming
- Scrambling (and hackers)
- Channel converter
- Channel converter with decoding
- Data transmission toward the channel converter with decoding
- Upstream transmission first try

Measurements

- Need for more accurate measurements (Subscribers pay for a better quality of service)
- Measurement methods standardization to meet FCC standards (NCTA, SCTE)

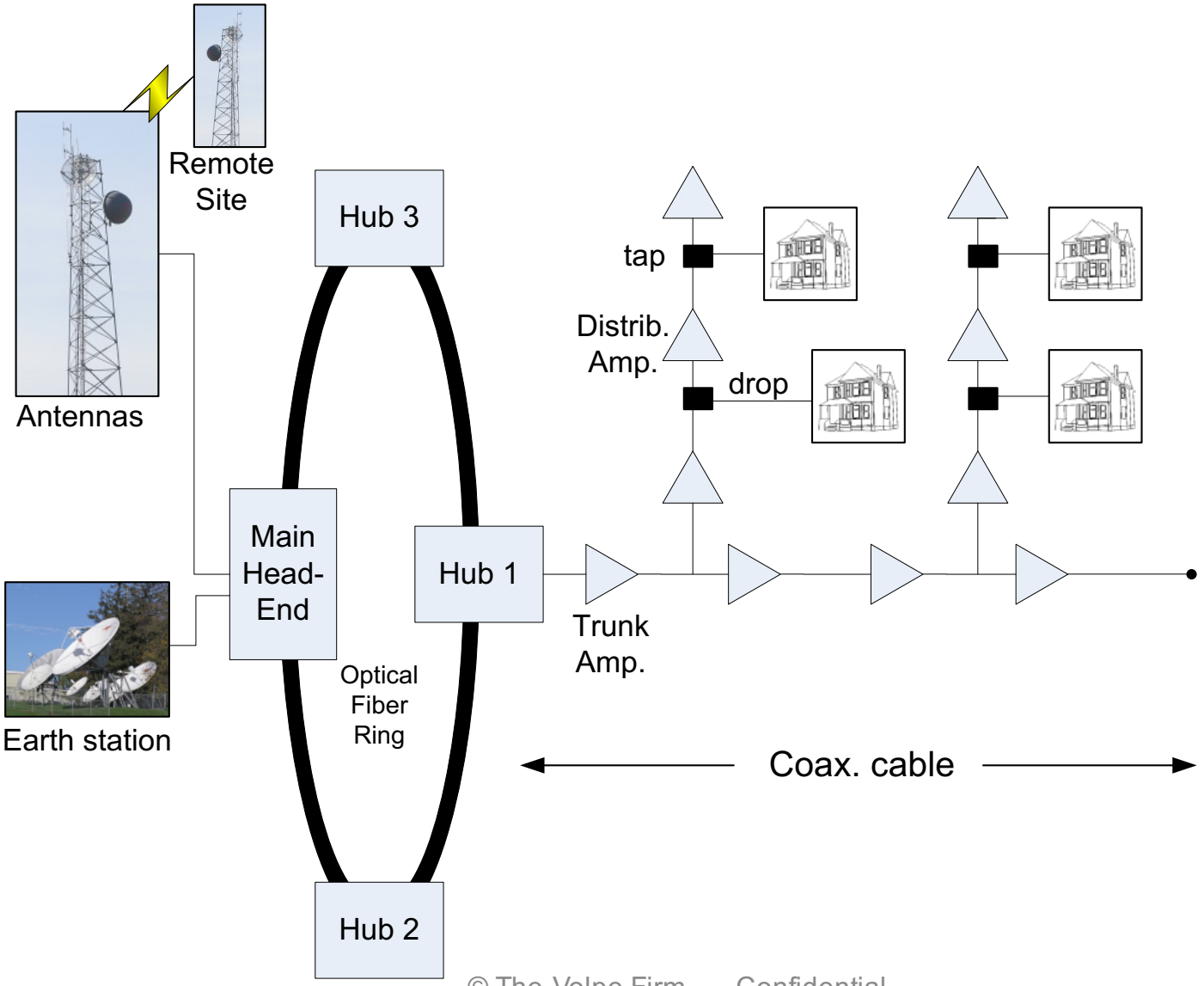
Optical Fiber

- At first: point-to-point
  - FM, a few video channels (to reduce amplifier cascade length)
- Then: SEVERAL channels
  - AM-multiplex
- Then: MANY channels
  - AM-multiplex
- Then: MUCH MORE channels
  - AM
  - Analog TV
  - QAM (Digital TV or data)
- Evolved from primary distribution towards local distribution, shortened coax lengths, reduced amplifier cascading towards passive distribution without amplifiers after the optical node.

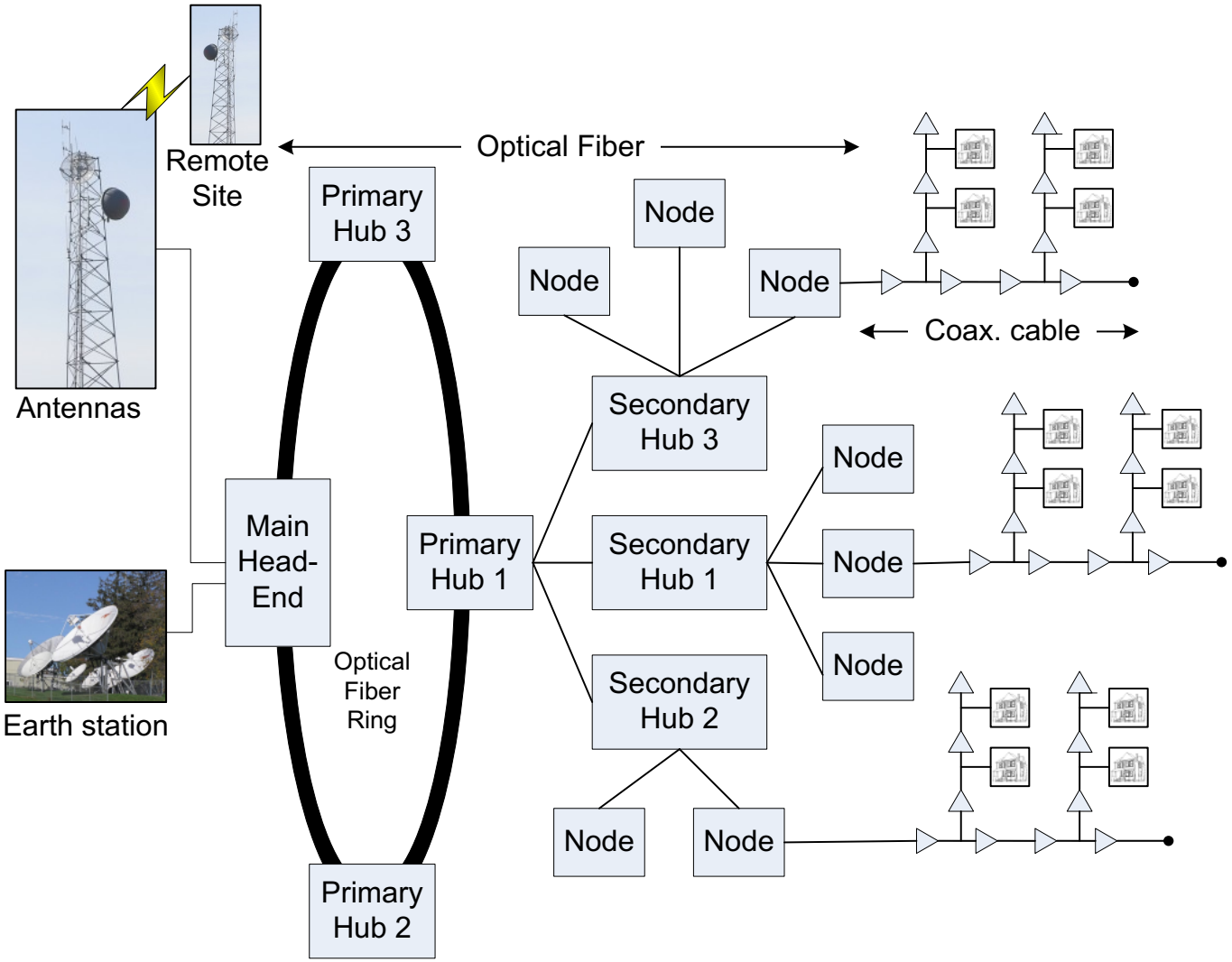
Measurements

- Same RF measurements
- Optical Power
- Optical Receiver
- QAM measurements

Optical Fiber – Network Infrastructure

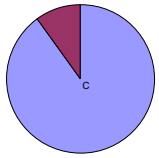


Hybrid Fiber-Coaxial Network Infrastructure

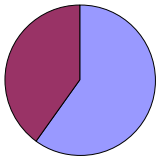


Hybrid Fiber-Coaxial Network

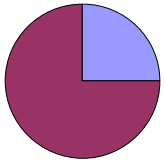
- Fiber in the distribution network
- Core fiber ring, digital
  - TV, data, VOD, IP telephony, IPTV
- Distribution to nodes, AM-multiplex



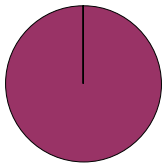
2000
90 % analog TV
10% digital TV



2005
60 % analog TV
40% digital TV



2010
25 % analog TV
75% digital TV



2016
0% analog TV
100% digital TV

- Regulated basic services
  - Available on analog TV (Free STB provided)
- Unregulated additional services

Measurements

- QAM measurements: upstream and downstream
- Ingress Monitoring

Cable Modem and Digital TV

- Cable Modem
  - Several incompatible systems / several manufacturers
  - MSOs regrouping and establishment of a working group MCNS
    - Role: Define buying specifications
  - A normalization group is then formed by CableLabs
    - Allows digital explosion
    - Allows to offer a high-speed service at low price
      - Prices drop from 400$ for a modem to <35$
    - Competition presence
  - DOCSIS flexibility allows adaptation to market
    - $/bandwidth (ex.: bronze, silver, gold)
    - Online service modification (WEB-portal)

This is the digital revolution for the cable industry!

Cable Modem and Digital TV

- Digital TV
  - Analog to digital encoding (MPEG-2, MPEG-2 transport stream)
  - Potential evolution to MPEG-4

TV program	Format	Encoding	Bandwidth
1	SDTV	MPEG-2	3 Mbps
1	HDTV	MPEG-2	19 Mbps
1	SDTV	MPEG-4	1.5 Mbps
1	HDTV	MPEG-4	9.5 Mbps

  - For 1 QAM-256 at 39 Mbps in one 6MHz channel

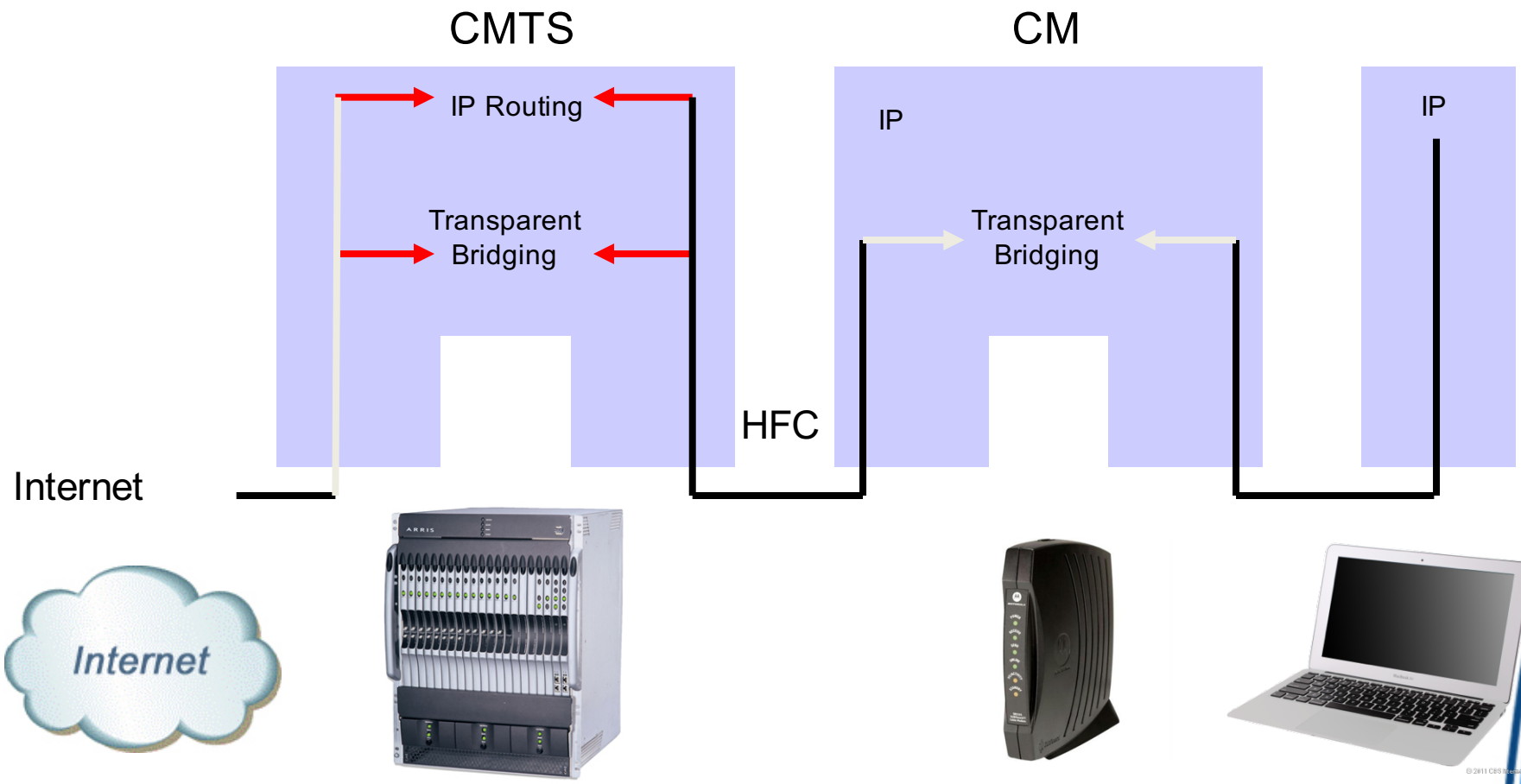
TV programs	Format	Encoding
10 to 12	SDTV	MPEG-2
2	HDTV	MPEG-2
20 to 25	SDTV	MPEG-4
4	HDTV	MPEG-4

CableLabs

- Pre-competitive research and standardization cooperative limited to MSOs
- Manufacturers and others may participate but cannot be members
- Offers certification services
- First accomplishment: DOCSIS
  - This protocol extends over physical, link and network layers of the OSI model
  - Versions
    - Past: 1.0, 1.1, 2.0
    - Current: 3.0/3.1
  - Allows costs diminution and a digital explosion
- OpenCable (« Middleware »)
  - This project aims to define the next-generation digital consumer device.
- VoIP traffic treatment normalisation over broadband networks
- Offers OSS support

What is DOCSIS

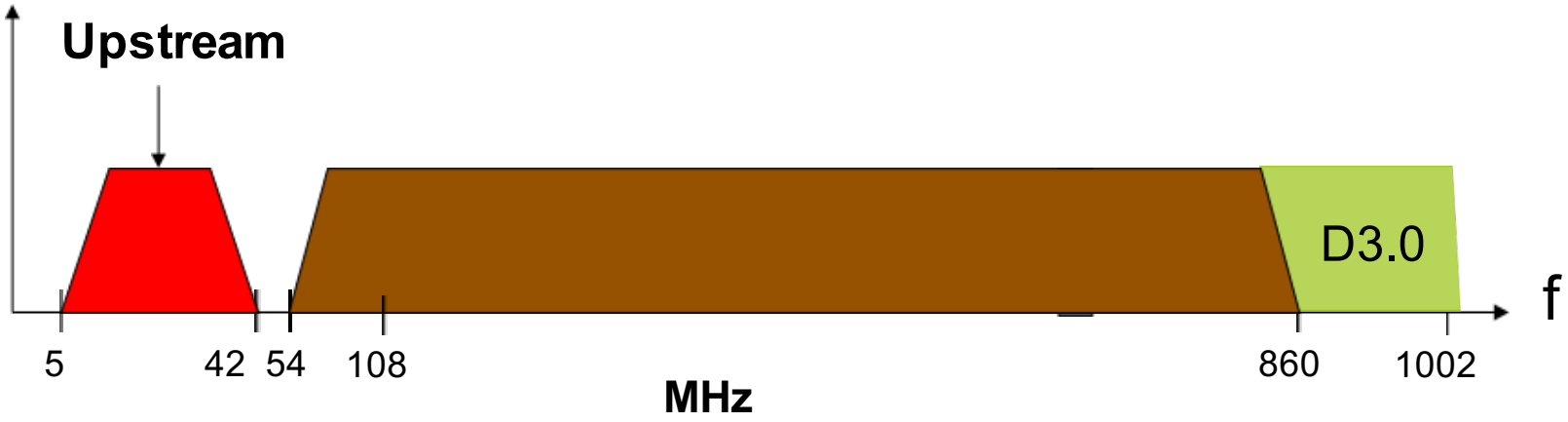
- Data-over-Cable System Interface Specification



DOCSIS 101 & Modem Registration

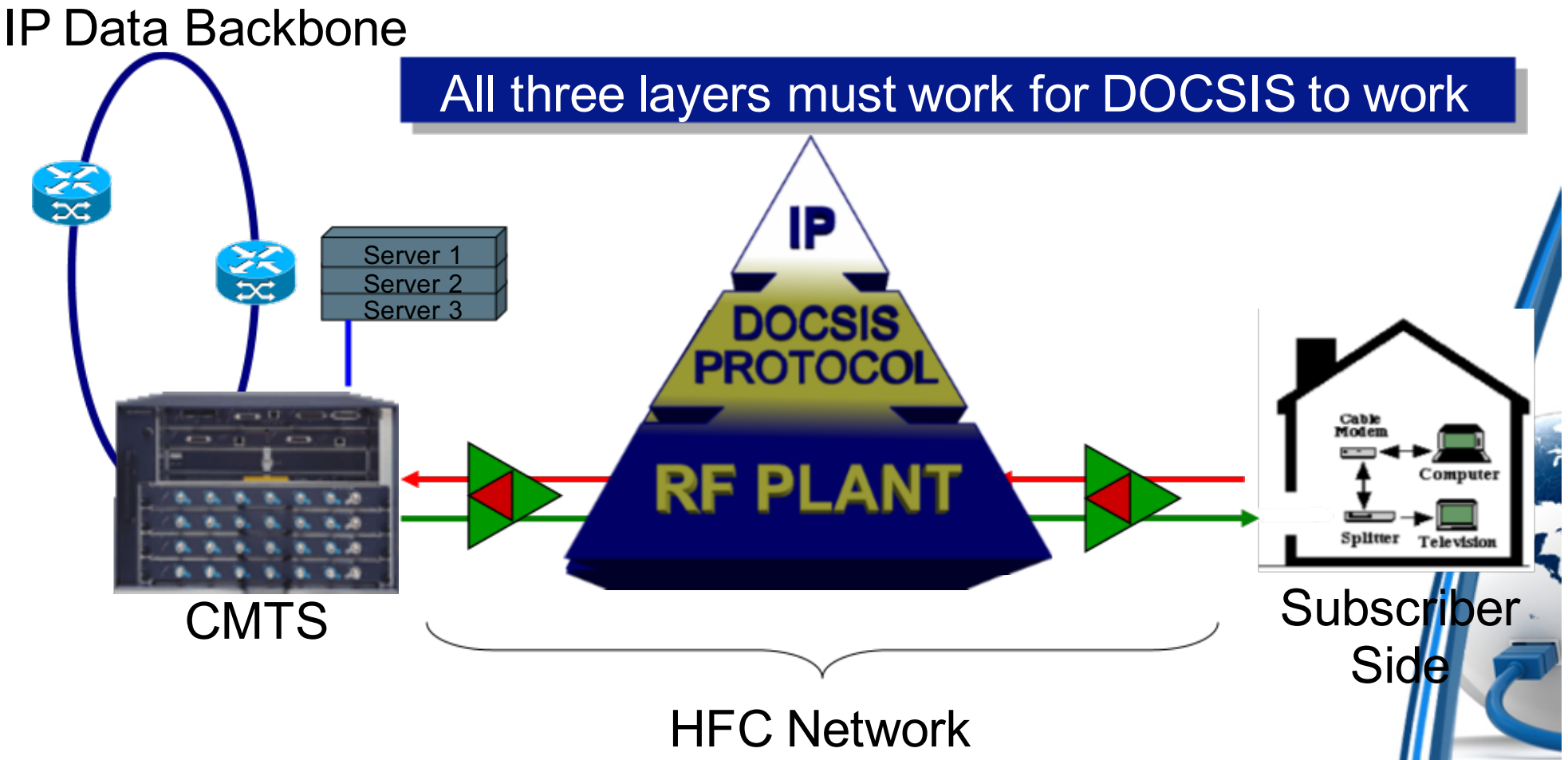
The Volpe Firm

DOCSIS RF – The PHYsical



- The CMTS communicates with the cable modems (CMs) on 6 MHz digitally modulated 64- or 256-QAM RF channels on the downstream between 88-860 MHz (108-1002 MHz D3.0) (1200 /1800 D3.1)
- The CMs communicate with the CMTS on 160 kHz to 6.4 MHz digitally modulated QPSK or 16-QAM RF channels on the upstream between 5-42 MHz [DOCSIS 1.x – DOCSIS 2.0]
  - 5-85 MHz D3.0 / 5-204 D3.1 [1024-QAM UP / 4096-QAM Down]

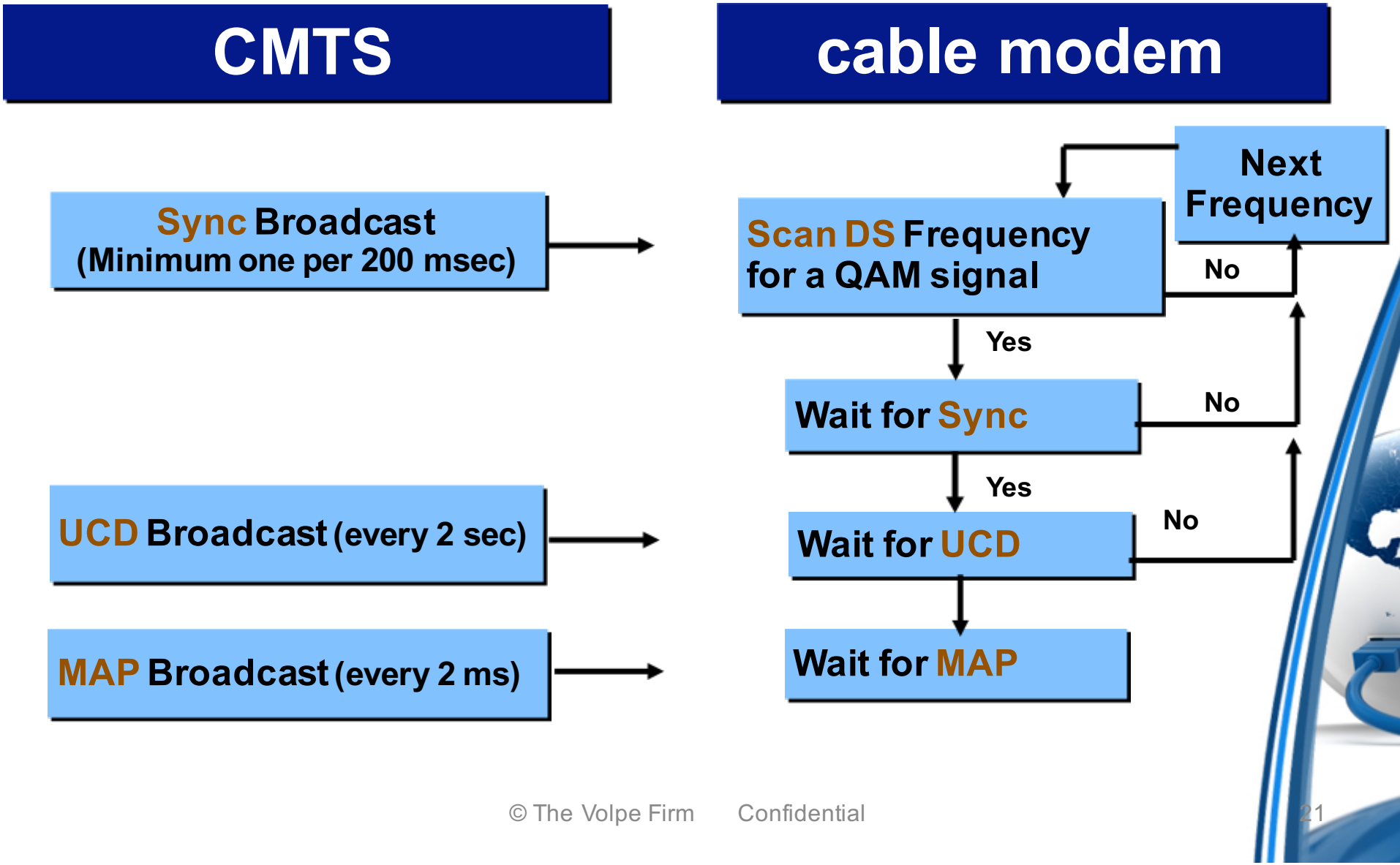
DOCSIS Communications Model



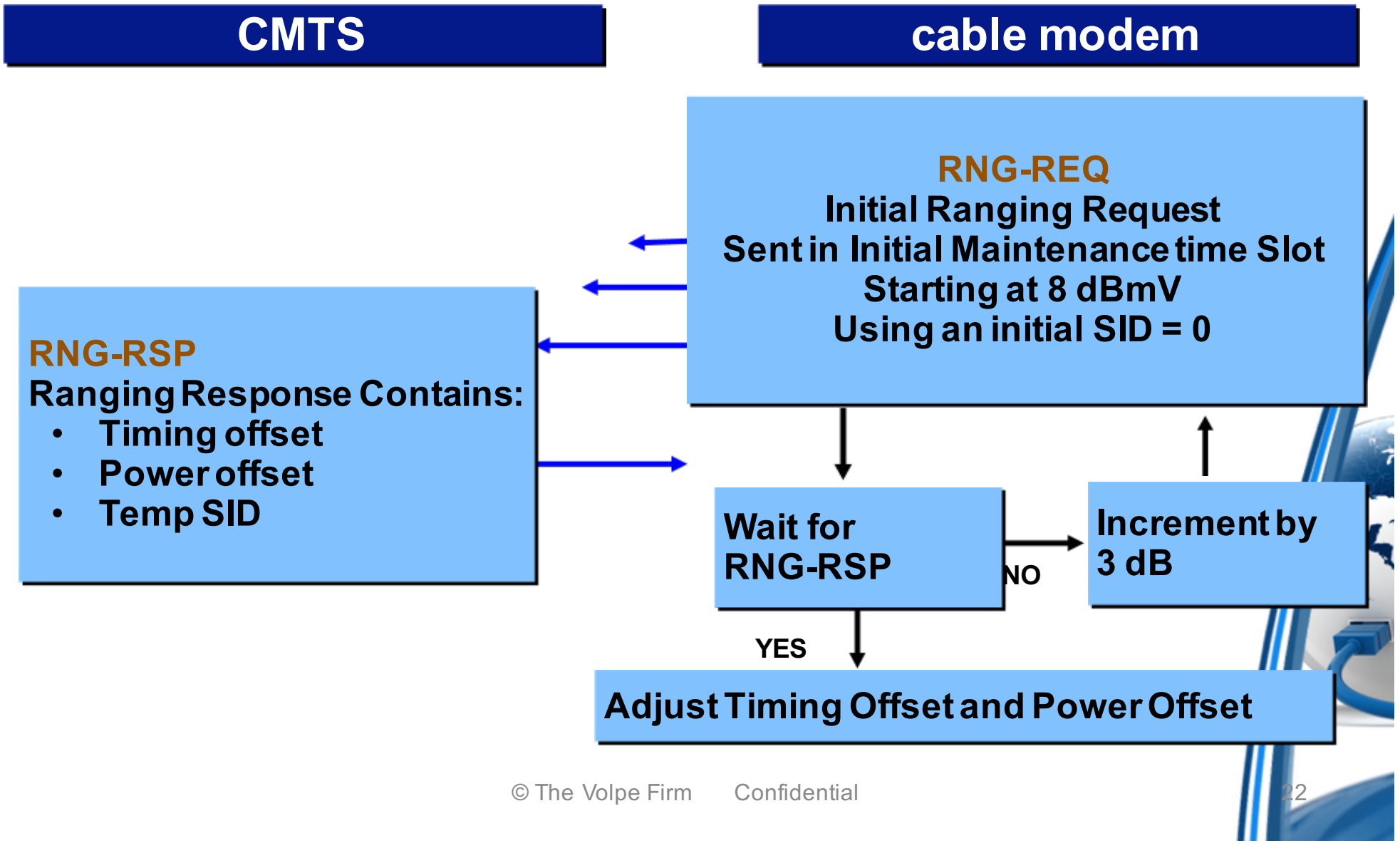
Cable Modem Registration

- CM registration requires the physical layer for signal transport
- DOCSIS and IP protocol layers are necessary to communicate the proper messages for modems to come online
- The next slides illustrate the interaction of these layers

DS Freq. Acquisition



CM Initial Ranging



DHCP Overview

CMTS	cable modem
	Bandwidth Request Use **Temp SID** (Service ID)
MAP Broadcasts →	
DHCP Reply (Offer) DHCP offers an IP address →	
	DHCP Discover
	DHCP Request Acks Initial IP Address and requests Default GW, ToD Server, TOD offset, TFTP Server Addr and TFTP Boot Config File Name
DHCP Ack (Response) Contains **IP Addr**, plus additional information →	
	ToD Request
ToD Response Contains Time of Day per **RFC 868** (Not NTP) →	

TFTP & Registration

CMTS	cable modem
TFTP Boot File Transfer DOCSIS config file which contains Classifiers for QoS and schedule, Baseline Privacy (BPI), etc.	
	TFTP Boot Request For 'Boot File name'
	Validate file MD5 Checksum Implement Config
	Registration Request Send QoS Parameters
Registration Response Contains Assigned SID Modem registered	
	Registration Acknowledge Send QoS Parameters

CM Registration Summary

- Downstream channel search
- Ranging
- DHCP
- ToD
- TFTP
- Registration
- Optional BPI Encryption

- Ranging occurs at least every 30 seconds when online
  - T3 timeout if Range-Request not received within 200 ms (timer in CM)
  - T4 timeout if Range-Response not received after 15 T3 timeouts (timer in CM)
  - More details later…

CM Registration Issues

- Scanning frequencies fixed in CM may not align with MSO channels
  - MSO may ask for custom configuration of scanning tables
- Bootp flag – unicast vs. broadcast, DHCP server can ignore
- CM must adhere exactly to DOCSIS & network spec. on DHCP options or will fail DHCP – stuck in “init(d)”
- Most CM manufactures have custom MIB strings
  - These need to be published and documented
  - Generic config files are often used, will CM work without MIB strings?
- CM support for long (64+ character TFTP file names)
- Do not cash TFTP server IP or any IP address when given a new one
  - Common mistake when TFTP address proxy is used
- You should test registration with every make, model & IOS configuration available – you will fail registration somewhere – fix code

CM Registration Issues (cont.)

- BPI+ key exchange – simple process, but some CMTSs and their configurations will cause issues
  - Make sure to test with different scenarios, models, IOS, mandates
- Modulation profiles – TDMA, A-TDMA, S-CDMA, mixed
  - Include testing with logical channels of above mixes
  - Issues especially occur in 1.x/2.0 mode where QPSK and m-QAM power differs by as much as 6 dB – total RF power should remain constant
    - This will cause laser clipping if you do not follow spec.
- Poor clocks lead to modems who drift out of time slot
  - CMTS cannot correct through station maintenance
  - CM is TX over top of another CM
  - Allowed to stay online up to 499 µsec
  - Have seen 5% of low quality modems do this – **no longer in business**

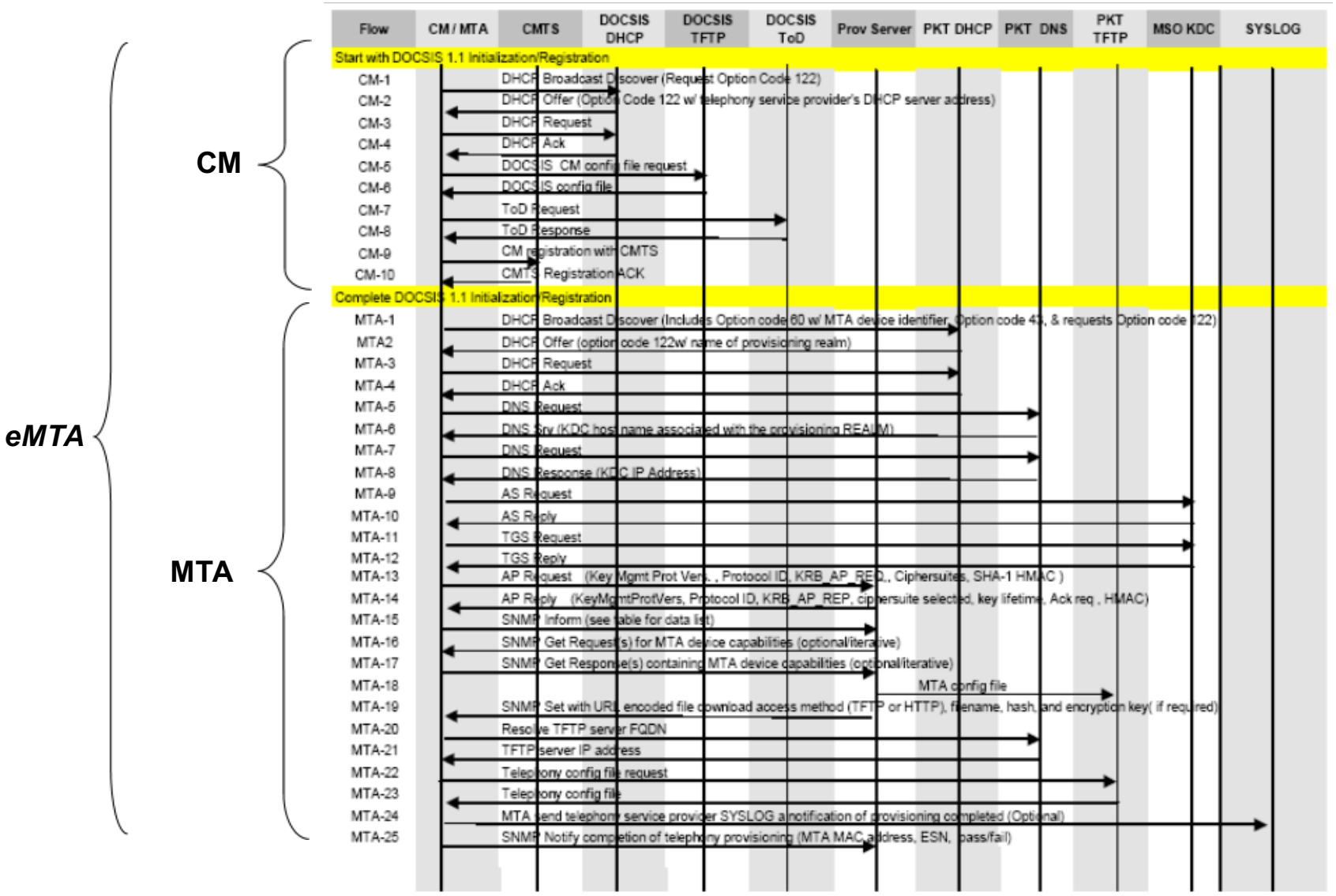
CM Registration Issues (cont.)

- CM must support FW remote upgrade through CVC (BPI+ spec)
  - Failures of upgrade will disable CM and cause truck roll
- CMs lock up at IP layer (can't ping at IP), but stay online at layer 2
  - Can still ping modem using Layer 2 ping (was Cisco proprietary)
  - Some vendors have resolved this problem through watchdog timer to reboot the modem
- ARP storm filtering / immunity
  - Hackers create ARP traffic in DOCSIS IP network, overwhelming CM
  - Your CM must be immune to this and other types of DoS broadcast traffic
- Security – Hackers will try to use your CM for theft of service
  - Bypass BPI+, SNMP, MIBs, etc.
  - Ensure there are no back doors in your CM or you will blacklisted

CM Registration Issues (cont.)

- RF immunity / radiation
  - Your modem must be shielded so that it is not an ingress point
  - It also must not inject noise into the plant
  - Make sure there are no harmonics or spurs during TX periods
  - Look at large sample sizes and subsequent batches of modems

eMTA Registration



DOCSIS 101 Summary

- A DOCSIS network consists of two main components:
  - Cable Modem Termination System (CMTS)
  - Cable Modem (CM)
- The CMTS transmits data on the downstream 54/108 MHz to 1 GHZ
- The CM transmits data on the upstream: 5 MHz to 42/85 MHz
- All three components of DOCSIS must be working well for the network to transport data:
  - The HFC Plant
  - DOCSIS Protocol – CMTS & CM communications
  - The IP Network
- CM registration requires backend servers such as DHCP, TFTP and Time of Day

VOICE OVER IP (VOIP)

Agenda

- Call Quality
- Types of VoIP Impairments
- Troubleshooting
- Cause & Effect
- Q & A

Mean Opinion Score (**MOS**)

- **MOS** is based on a panel of listeners rating a given call on a scale of 1 to 5

User Opinion	MOS Score
Very satisfied (Toll Grade)	4.3 – 5.0
Satisfied	4.0 – 4.3
Some users satisfied	3.6 – 4.0
Many users dissatisfied	3.1 – 3.6
Nearly all users dissatisfied	2.6 – 3.1
Not recommended	1.0 – 2.6

G.711 Bitrate of 64 kb/s → MOS = 4.4
G.729 Bitrate 8 kb/s → MOS = 3.9

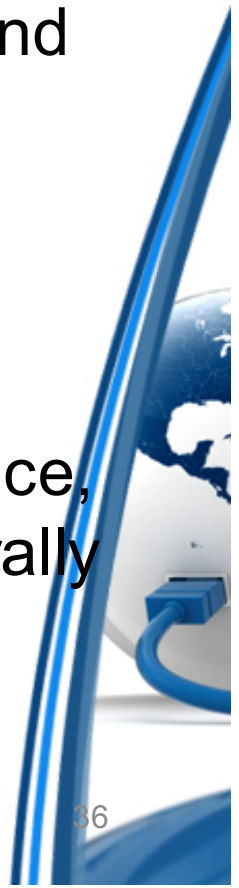
Call Quality – E Model

- **E Model** based on ITU-T G.107 Standard
  - **E Model** is objective in that it applies metrics to various types of impairments
  - The E Model provides for an R factor value

User Opinion	R Factor	MOS Score
Very satisfied (Toll Grade)	90 – 100	4.3 – 5.0
Satisfied	80 – 90	4.0 – 4.3
Some users satisfied	70 – 80	3.6 – 4.0
Many users dissatisfied	60 - 70	3.1 – 3.6
Nearly all users dissatisfied	50 – 60	2.6 – 3.1
Not recommended	0 – 50	1.0 – 2.6

Call Quality – E Model

- **R** Factor = $\mathbf{R_o} - \mathbf{I_s} - \mathbf{I_d} - \mathbf{I_e} + \mathbf{A}$
  - $\mathbf{R_o}$ is a base factor determined from noise levels, loudness, etc.
  - $\mathbf{I_s}$ impairments caused by non-optimum sidetone and quantization distortion
  - $\mathbf{I_d}$ are the end-to-end **delay** impairments
  - $\mathbf{I_e}$ are the distortion impairments introduced by the equipment such as **frame loss** and bit errors
  - **A** is the advantage factor of the network, for instance, cell phones are highly portable (this factor is generally ignored except by marketing analysts)



Defining the Problem

- Often VoIP problems begin with a CSR ticket from a subscriber complaint – a vague description of bad voice quality
- Two days later a truck is rolled
- If the problem still exists, it's a good day!

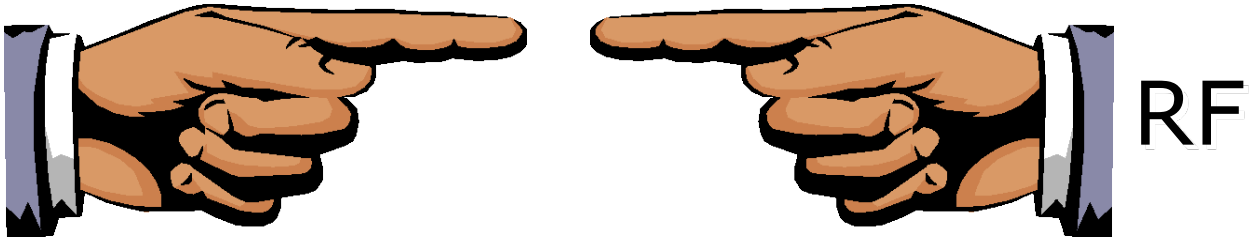
- Often times the problem has gone away

  RF levels are good

  VoIP scores are good

- It may come back several days later
- Another CSR ticket, another truck roll…

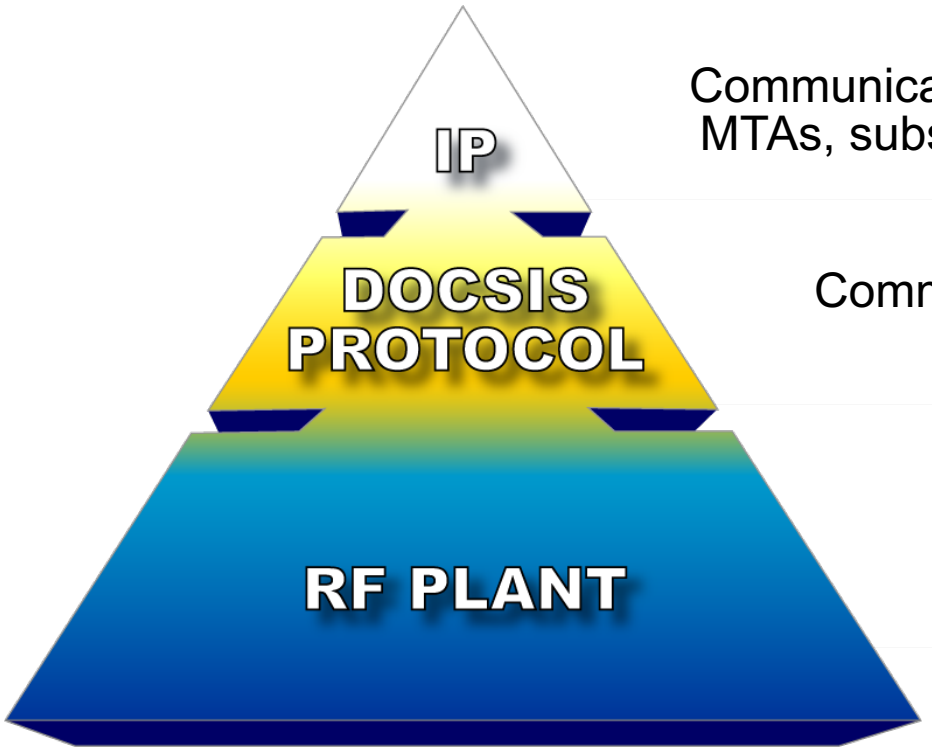
Defining the Problem

DATA  RF

- And the finger pointing begins…
- Determining if a VoIP impairment is caused by RF impairment, by IP data network impairments, or a combination of both is very difficult without collaboration between HFC plant and data network technicians

Troubleshooting Methodology

Troubleshooting any DOCSIS network begins with a **BOTTOM UP** approach coupled with a divide and conquer in the outside plan



Communications between CMs, MTAs, subscribers & IP servers

Communications between CMTS & CMs only

What we fix today

Building Blocks of Troubleshooting

Evolution of RF Troubleshooting

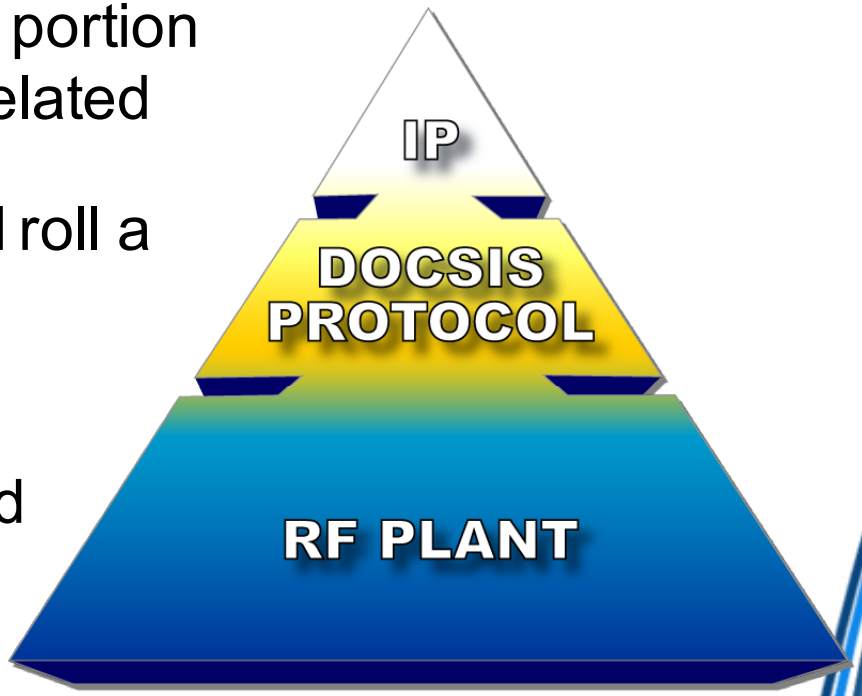
- RF impairments have typically been viewed as the root cause of all network problems in cable networks
- Since two-way data services have been introduced, cable operators have evolved the RF plant to higher and higher standards
- Although RF impairments are still readily present in cable networks, it is important to acknowledge that other impairments exist which must be addressed

DOCSIS & IP Protocols > 20% of Impairments

- DHCP / TFTP / ToD / DNS / CMS / etc. servers
- Modem and MTA configuration files, CMTS configs

RF Plant – Problem Analysis

- Generally speaking a large portion of problems are RF plant-related
- Does this mean you should roll a truck every time there is a DOCSIS or VoIP problem?
- **USE** the tools you have and make smart decisions to minimize troubleshooting



Types of VoIP Impairments

- **Frame Loss** – The complete or partial loss of a frame containing voice payload (packet)
- **Delay** – The time a voice packet takes to go from one caller to another. Delay is created by both physical distance and network routing and switching elements
  - Echo is considered a subset of delay because sufficient delay is required before echo reflections exceed the capacity of the echo canceller
- **Jitter** – The variance of inter-packet arrival time from one transmitted voice packet to the next sequential packet

Frame Loss

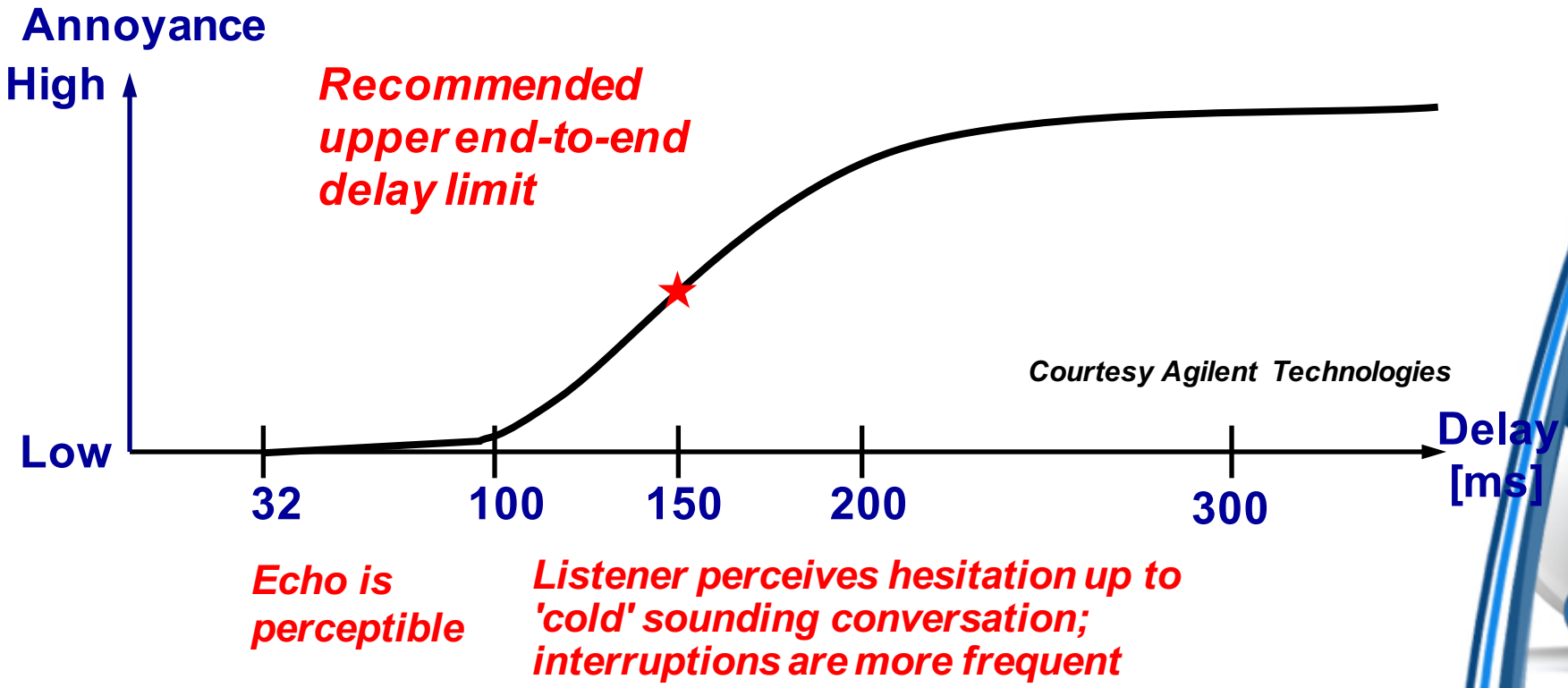
- Frame loss is the Achilles heel of VoIP in a DOCSIS network and WILL be noticeable to your subscribers!
- Unlike HSD, in VoIP there are no re-transmits

Impact of Packet Loss on User Opinion without PLC

Packet Loss	R Factor (G.711 $R_{ideal} = 93$)	User Opinion
0 %	$R = R_{ideal} - Ie = 93 - 0 = 93$	Very Satisfied (Toll Grade)
2 %	$R = R_{ideal} - Ie = 93 - 35 = 58$	Nearly all users dissatisfied
5 %	$R = R_{ideal} - Ie = 93 - 55 = 38$	Not recommended

Delay

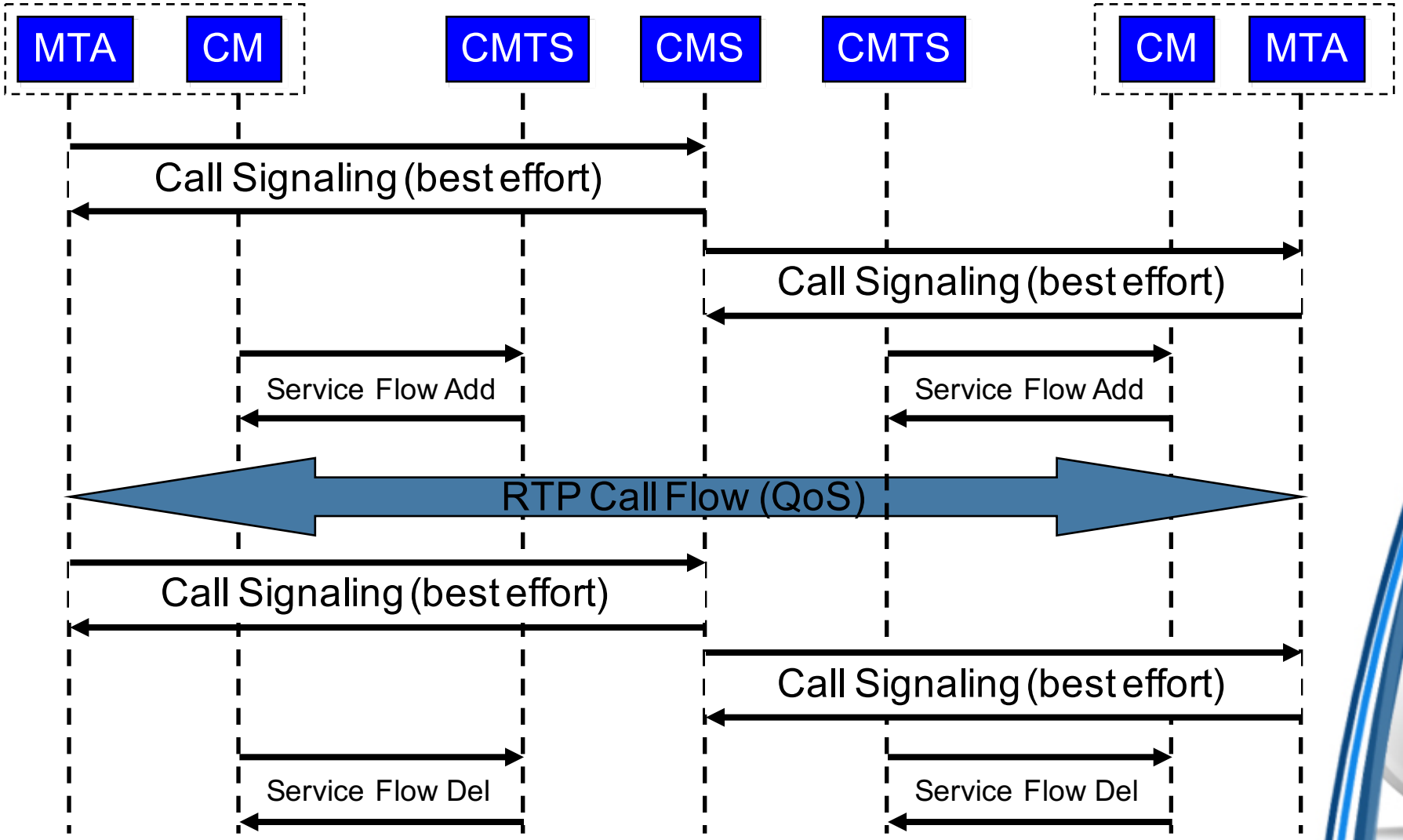
- Delay for a voice packet to be created, traverse the network from source to destination, and be converted back to voice
- Digitization & packetization adds delay - fixed
- Every network routing device, including the CMTS and MTA



Service Flows

- Service Flows guarantee that one traffic flow has a higher priority of service than others
- For instance VoIP or IP Video over traffic has higher precedence than does email, gaming, P2P file sharing, or even non-managed VoIP services such as Vonage
- Static service flows are sometimes used for businesses where T1 equivalent service is desired to be provided continuously
- Dynamic service flows are the typical for VoIP or IP Video – this is the service flow an eMTA creates

High Level Call Flow



DOCSIS Compliant Downstream

- Analog Measurements
  - CNR (≥35 dB per DOCSIS spec)
  - CSO (≥41 dB per DOCSIS spec)
  - CTB (≥41 dB per DOCSIS spec)
- Analog (Digital) Measurements
  - BER (post-FEC 10-8 or less per DOCSIS spec)
  - Modulation Error Ratio (MER)
  - Constellation Analysis
  - Digital Channel Power

1 error in 100 Million bits

10^{e-8}

Downstream Measurements

- **Analog Measurements**
  - CNR (≥35 dB per DOCSIS spec)
  - CSO (≥41 dB per DOCSIS spec)
  - CTB (≥41 dB per DOCSIS spec)
- **Analog (Digital) Measurements**
  - MER
  - BER
  - Constellation Analysis
  - Digital Channel Power

(postFEC 10^{-8} or less per DOCSIS spec)

Modulation Error Ratio

- Modulation Error Ratio (MER) is a measure of the phase and voltage variation, generalized by:

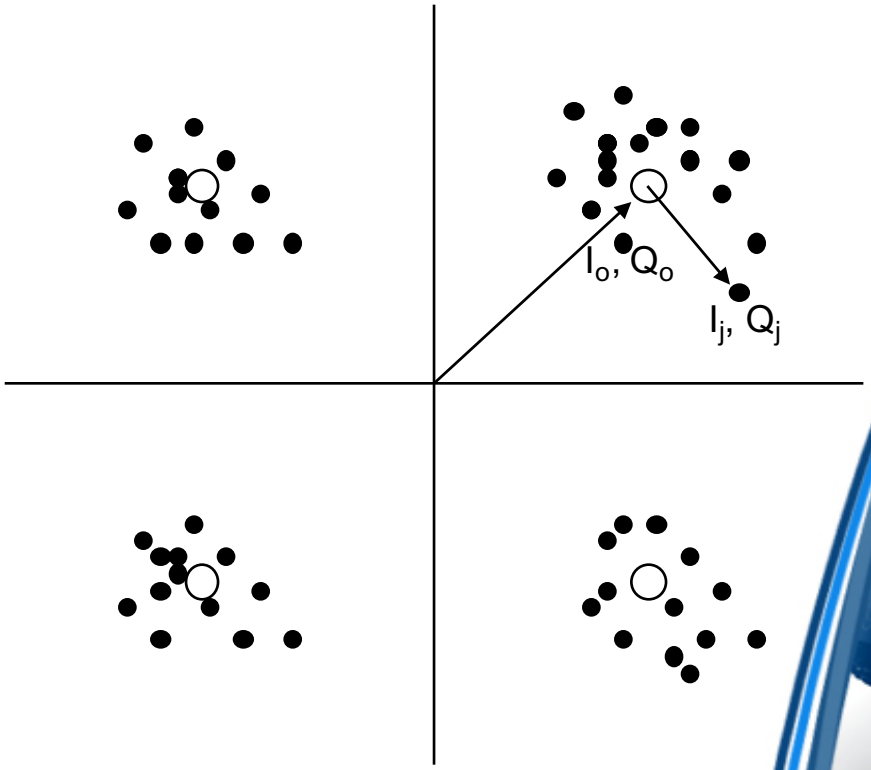
$$MER(dB) = 10\log\left(\frac{\text{RMS error magnitude}}{\text{average symbol magnitude}}\right)$$

- And expressed mathematically by:

$$MER\,(dB) = -10\cdot\log\left\{\frac{\sum_{j=1}^{N}\left(\left(I_j - Io_j\right)^2 + \left(Q_j - Qo_j\right)^2\right)}{\sum_{j=1}^{N}\left(Io_j^2 + Qo_j^2\right)}\right\}dB$$

- Finally, aggregate MER is just the sum of multiple MER measurements:

$$MER_T = -10\cdot\log\left\{\frac{1}{NN}\sum_{i=1}^{NN}10^{MER_i/10}\right\}dB$$



Each point represents one symbol (2-bits) of data or one phase position. The distance from the circle is the error.

Typical BER/MER Results

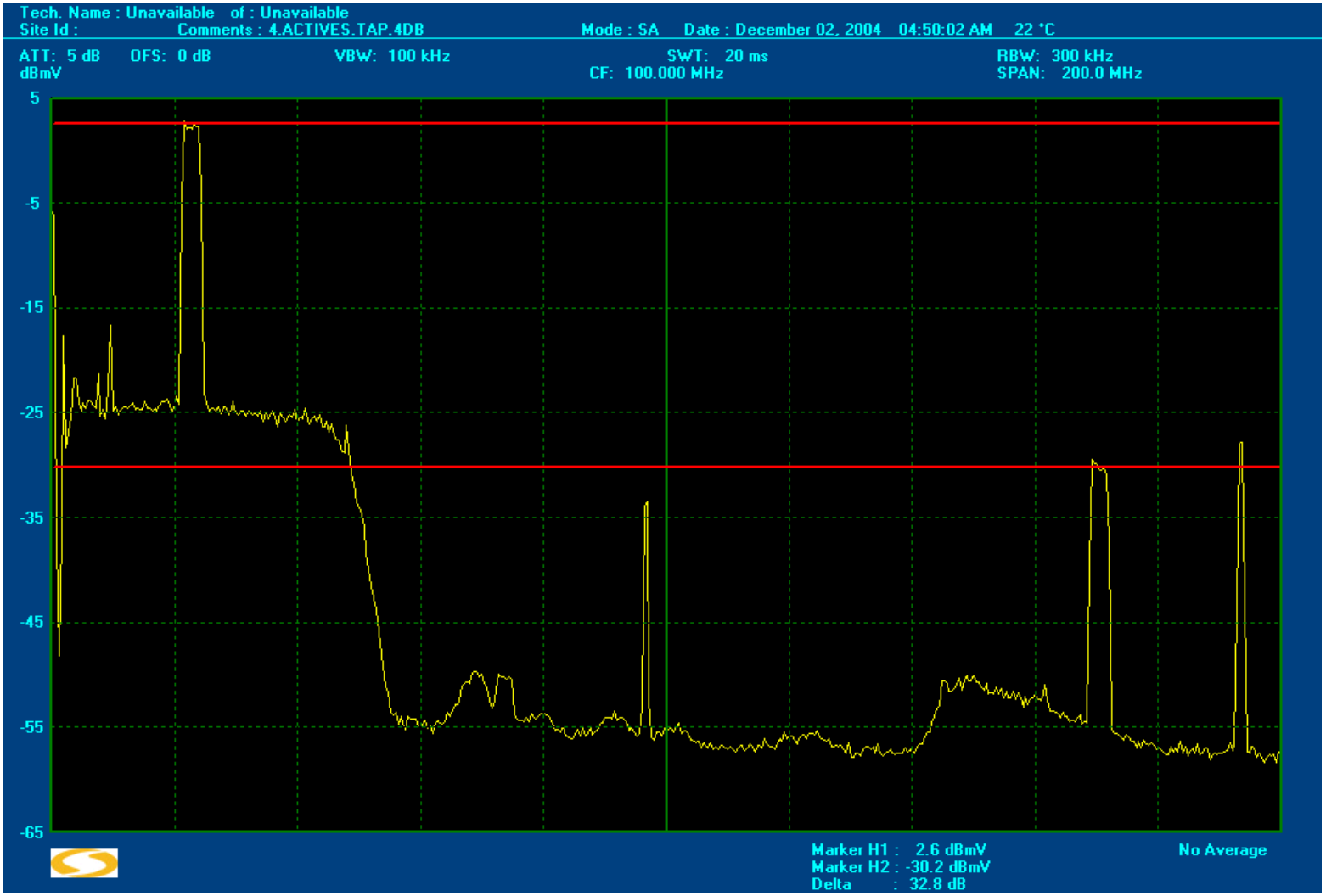
BER	64 QAM MER	256 QAM MER	Quality
10^{-10}	>35	>35	Excellent
10^{-8}	27-34	31-34	Good
10^{-6}	23-26	28-30	Marginal
10^{-5}	<23	<28	Fail

Note: Set-top boxes can tolerate some Post FEC errors, but Cable Modems cannot.

Upstream Measurements

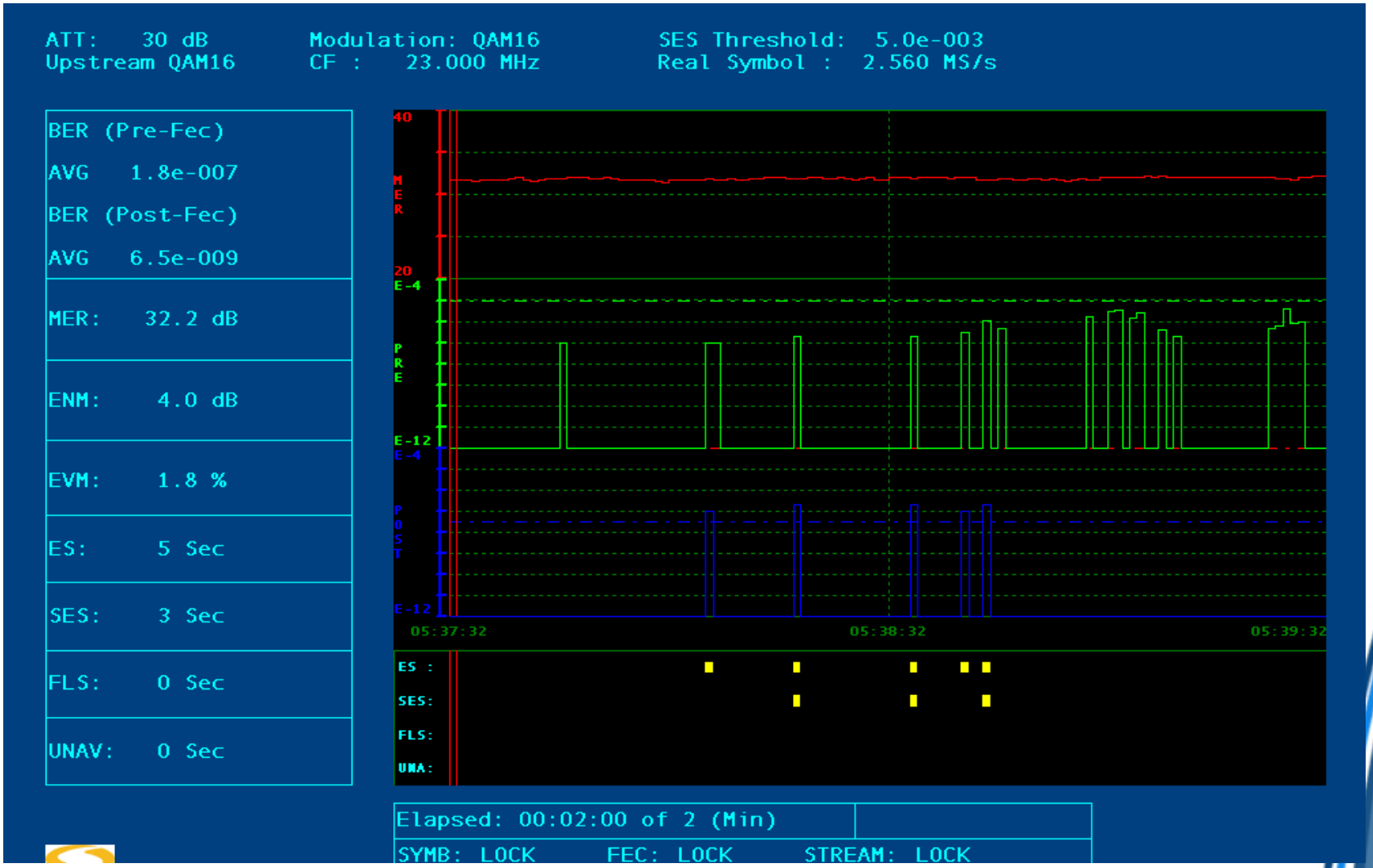
- Linear Impairments such as:
  - Micro-reflections
  - Amplitude & Group Delay
- Non-linear Impairments such as:
  - Common Path Distortion (CPD)
  - Return Laser Clipping
- Transient Impairments such as:
  - Ingress & Impulse Noise

Laser Clipping



Courtesy VeEX

Time Lapsed Measurements

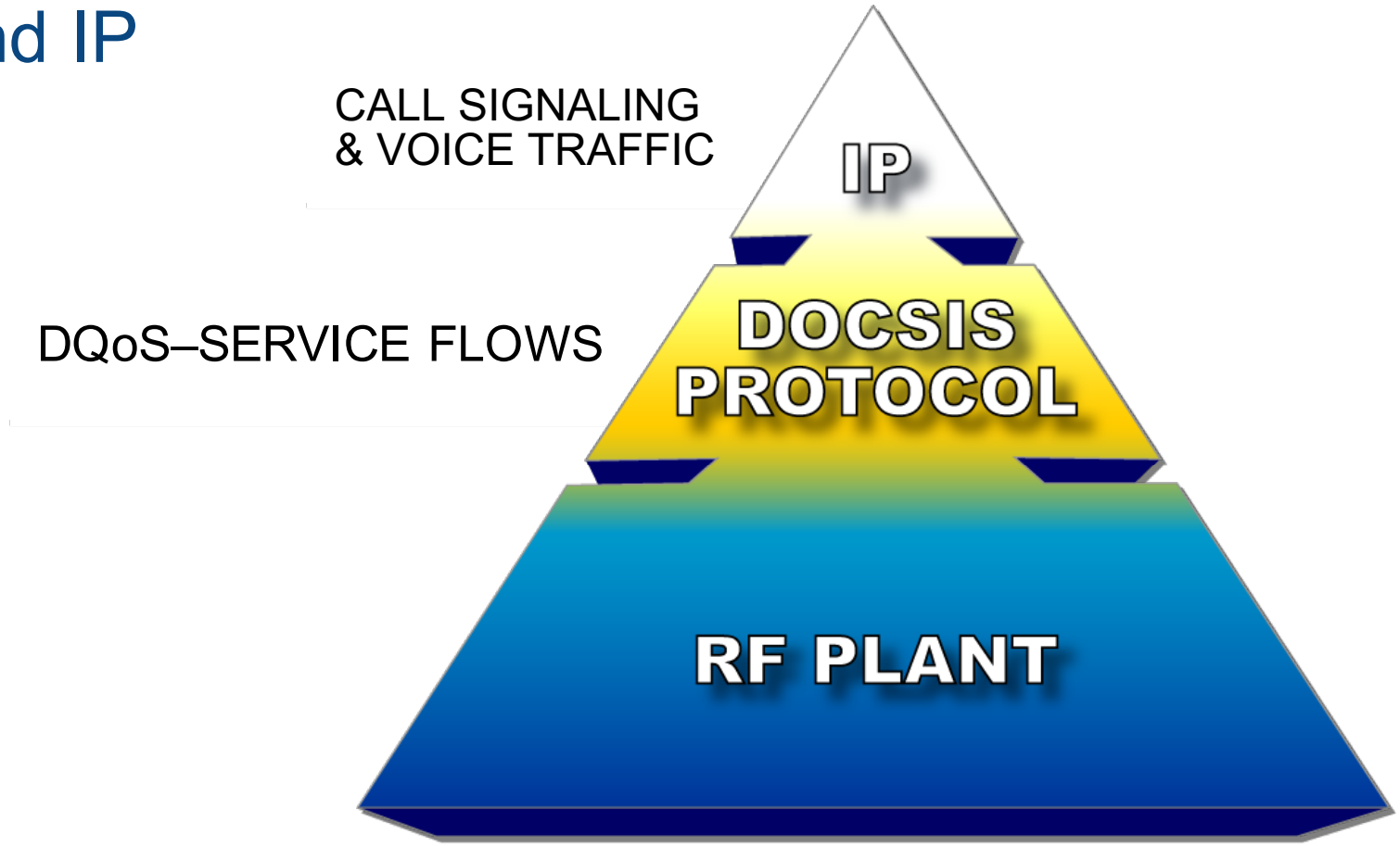


Courtesy VeEX

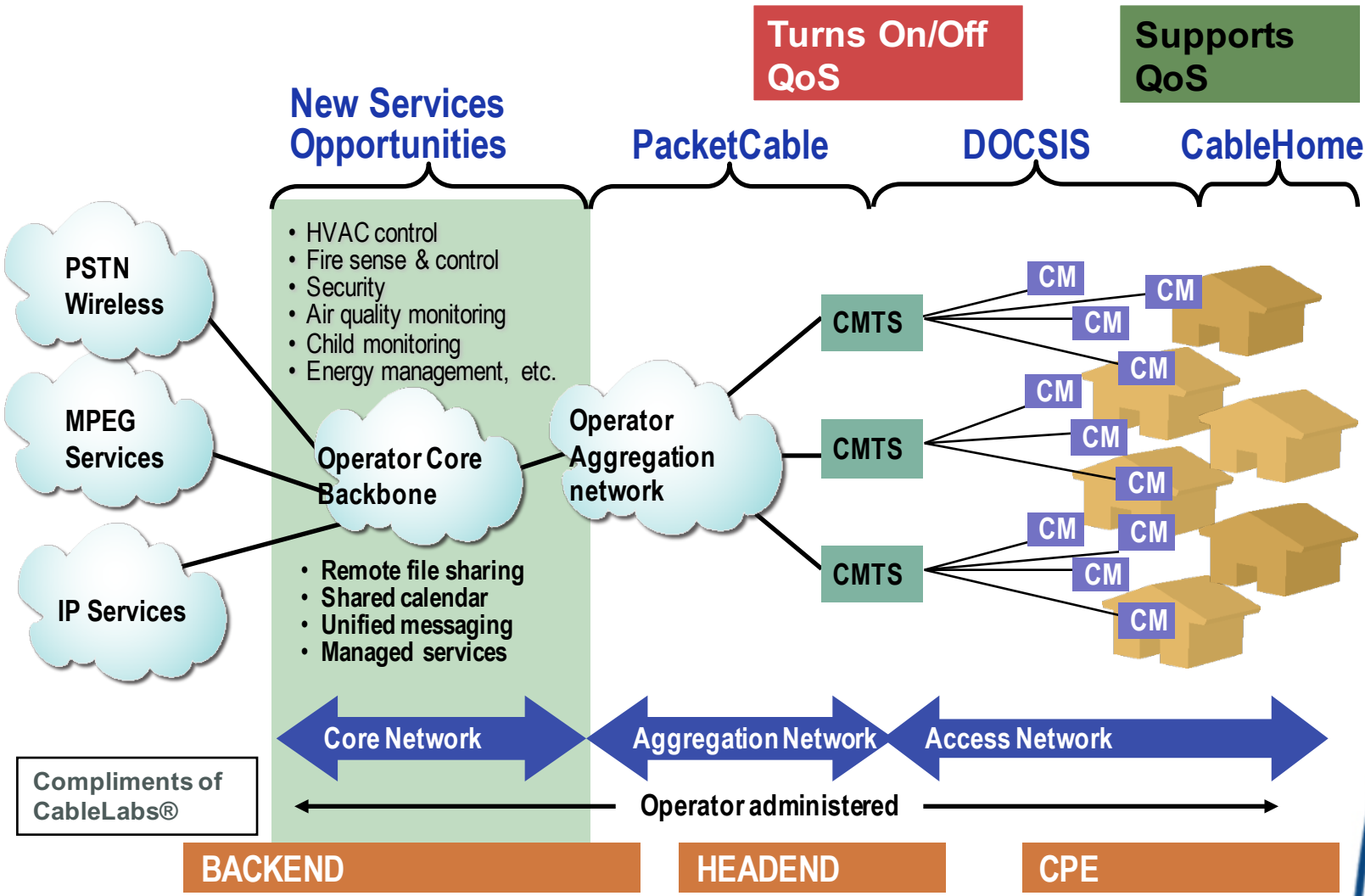
Other US Monitoring Tools

Moving Up the Troubleshooting Pyramid

- Now we can move from RF diagnostics to DOCSIS and IP



Cable Architecture – High Level View



Modulation Profiles

- Optimized Cisco ATDMA mod-profile
  - cab modu 224 request 0 16 0 22 16qam scram 152 no-diff 32 fixed qpsk1 1 2048
  - cab modu 224 initial 5 34 0 48 16qam scram 152 no-diff 384 fixed qpsk1 1 2048
  - cab modu 224 station 5 34 0 48 16qam scram 152 no-diff 384 fixed qpsk1 1 2048
  - cab modu 224 a-short 6 76 6 22 64qam scram 152 no-diff 64 short qpsk1 **0 2048**
  - cab modu 224 a-long 9 232 0 22 64qam scram 152 no-diff 64 short qpsk1 **0 2048**
  - cab modu 224 a-ugs 9 232 0 22 64qam scram 152 no-diff 64 short qpsk1 1 2048
- Voice traffic goes on 16-QAM (a-ugs)
- Normal traffic is on 64-QAM

Concerns

- Verify voice traffic is not on a-short or a-long!
- An eMTA must be at least provisioned as D1.1 or no traffic will go on a-ugs
- If MTA config file is not properly configured, voice traffic will not go on a-ugs
- Many opportunities for failure

Some Common "DOCSIS" Call Preventers?

Call Signaling Fails to Go Through

- "Best Effort Service" competes with other traffic
- Usually TCP/IP signaling will go through, but customer may not wait for dial tone or digits
- CMS receives excessively delayed digits from DOCSIS contention region – REQuest – Grant period used by other best effort services such as Vonage, gamaing, etc.
- Remedy → Establish dedicated QoS for Call Signaling with (10 kbps) per eMTA, drawback is uses US BW

Call Disconnects After Ring

- eMTA and CMTS unable to establish DQoS
  - Bad eMTA, not PacketCable certified or bad PacketCable certificate in eMTA
  - eMTA CODEC or configuration file mis-configured
  - CMTS out of Service Flows – Failure to delete inactive SIDs

Test Best Effort & Service Flow Channels

STEP 1

Test the IP Best Effort Service Flow

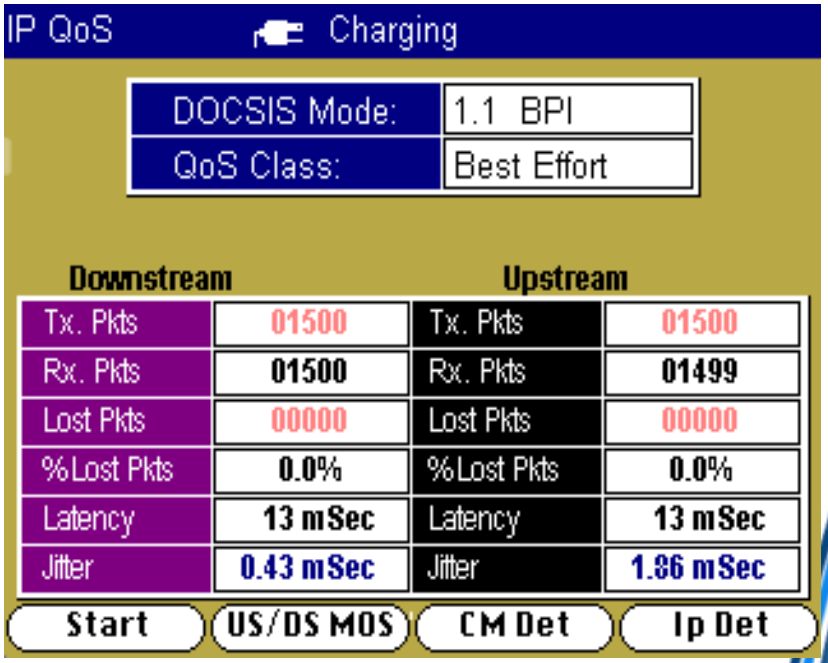
- Packet Loss, Latency & Jitter
- Best Effort Verification for Call Signaling

STEP 2

- Test the Upstream & Downstream Voice Quality
- VoIP MOS & R-Factor tests
- Using DOCSIS Service Flow (QoS)

IP Best Effort Analysis

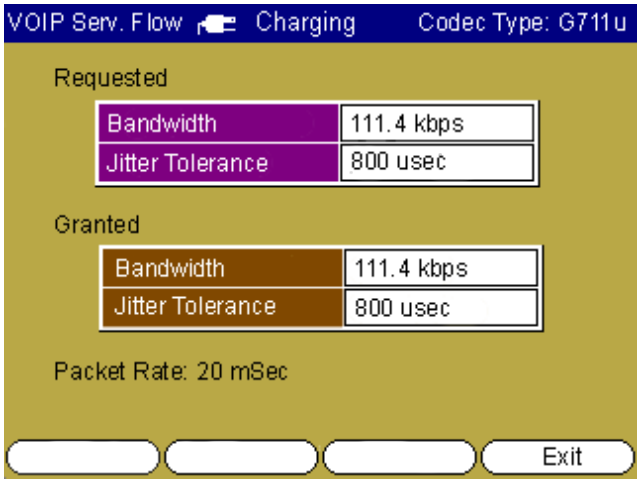
- Test the performance of your systems "Best Effort" services
- Good for testing network performance for call signaling
- **Will your eMTA establish communication with the CMS?**
- Measures
  - Packet loss
  - Latency
  - Jitter
- Does not use QoS (DOCSIS Service Flow)

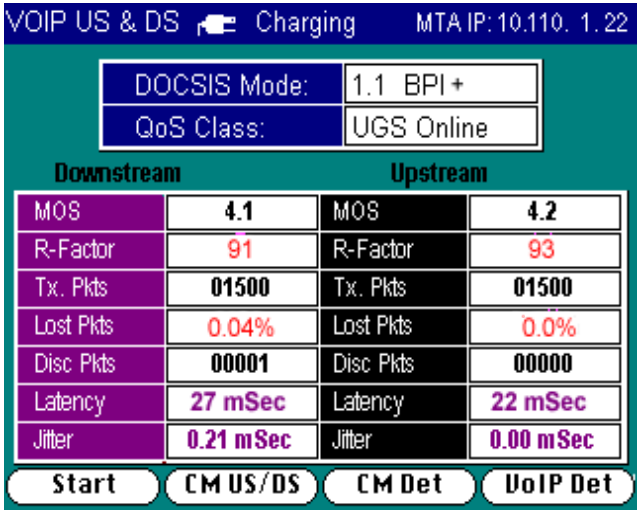


Courtesy VeEX

Upstream & Downstream Voice Quality

- Establishes QoS (DOCSIS Service Flow) with CMTS
- MTA emulator transmits RTP framed VoIP packets to a server at the Headend
- The Server transmits RTP framed VoIP packets back to the MTA emulator
- Latency, Jitter, Lost Packets and MOS measurements are made for Upstream and Downstream service flows





Courtesy VeEX

I've got low MOS scores!

- So your testing your VoIP network and your MOS score is not up to par – what do you do?
  - Lost packets
    - Check RF impairments, CMTS utilization, router utilization, check with PSTN provider, check media gateway utilization
  - Jitter
    - Check CMTS utilization, make sure QoS is working, check router utilization, check with PSTN provider, (BTW, too much jitter will cause packet loss!)
  - Delay
    - CMTS utilization, router utilization, what is packetization size (40 ms is too big, stick with 20 ms in DOCSIS network)
- In most cases, utilization will be mitigated by reducing the number of subscribers per CMTS

Cause and Effect

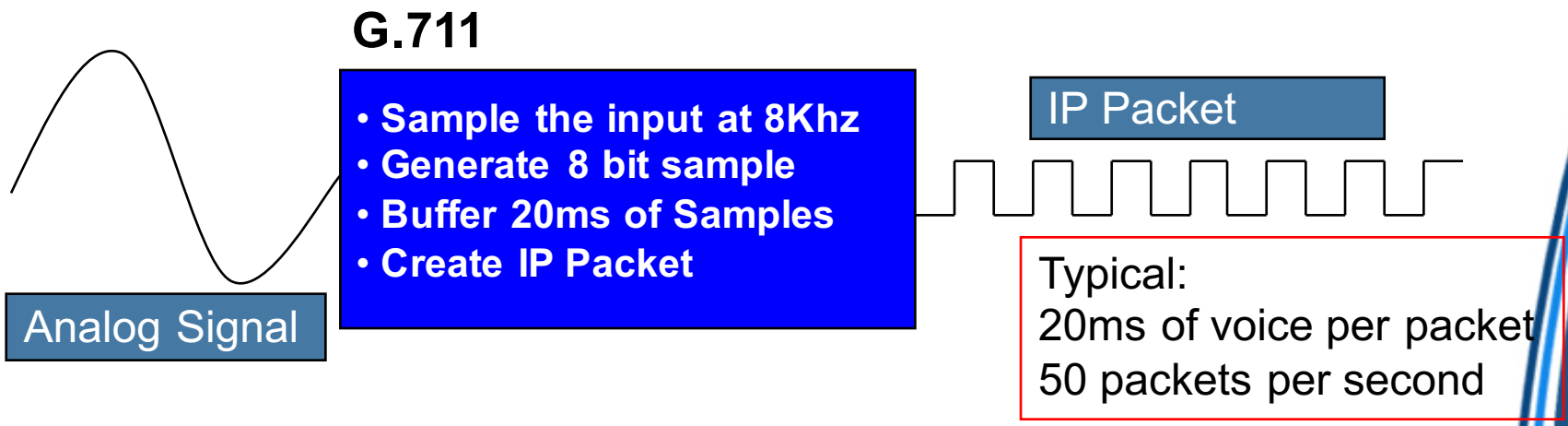
User Complaint	Possible Impairments
No Dial Tone or Delayed Dial Tone	➢Signaling congestion (best effort) ➢CMS configuration or Provisioning eMTA ➢Best Effort congestion - it actually works but takes >6 sec, appears to be a failure to the user
Phone Rings, but no call Established	➢Most frequently Dynamic Service Flow (QoS) unable to be established –Service flows not being deleted after calls –Wrong parameters being requested during setup –Can happen on either end of call
Gaps in speech	➢Frame loss – most likely due to upstream RF impairments, though don't rule out downstream ➢Frame loss can also be caused by over-utilized IP routers, especially the CMTS ➢Bursty packet loss is much more noticeable than short impulse packet loss ➢Frame loss will also be created by excessive jitter in the network. The jitter buffer intelligently discards frames whose jitter is excessive.

Cause and Effect

User Complaint	Possible Impairments
Off-Net Echo (PSTN)	➢VoIP frames converted to analog in the PSTN reflected at the hybrid junction back to originator – usually only a problem when delay exceeds eMTA echo canceller
On-Net Echo	➢VoIP frames converted to analog by the eMTA are reflected by the local phone or in-house wiring into the eMTA and sent back to the originator – this is only problematic when path delay exceeds eMTA echo canceller
Dropped Call	➢VoIP call added during a period of high data usage – Head of Line Blocking – data users traffic is reshaped AFTER traffic has already been transmitted, CMTS blocks traffic, but queues fill up, VoIP frames are dropped then call is dropped. ➢RF performance degrades to point where frame loss disrupts signaling and/or eMTA connectivity ➢Router failure or router update – call is not actually dropped, but fail-over takes up to 40 sec, which is the same as a dropped call to a user

What is VoIP? – Voice Encoding

- **G.711**
  - Similar to T1 PCM Voice
  - 64Kbps - highest Bandwidth – lowest delay – Highest quality
- **G.729A/B/C**
  - 8Kbps - low bandwidth – moderate delay – good quality
  - Commonly deployed across the WAN
- **G.723.1**
  - 5.3 or 6.3Kbps - lowest bandwidth – acceptable quality - longest delay
  - Less commonly deployed



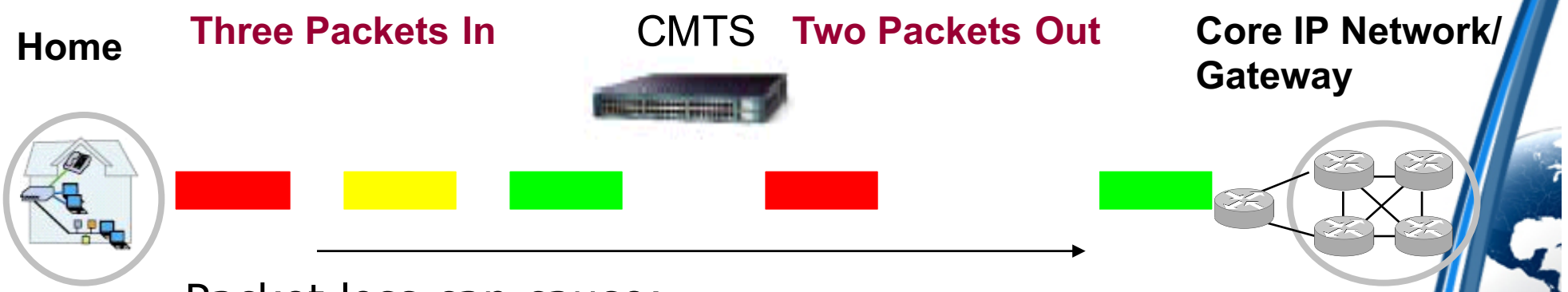
What affects VoIP Quality of Service? (IP)

- (3) Keys VoIP transport parameters that arise due to IP and RF impairments
  - (RTP) Packet Loss
  - (RTP) Packet Jitter
  - (RTP) Packet Delay (Latency)

VoIP Transport Related Issues

Packet Loss

- Packets that are not delivered to the destination
- Caused by RF problems or severe IP congestion



- Packet loss can cause:
  - choppy voice
  - Pops/clicks
  - “Robo-voice”

VoIP Transport Related Issues

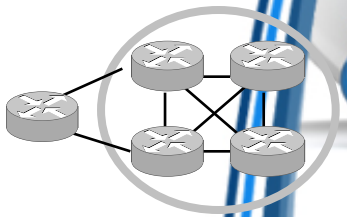
Packet Jitter

- Variations in inter-packet Delay
- Caused by any network element with a buffer

CMTS or
Edge/Core router

Home

Core IP Network/ Gateway



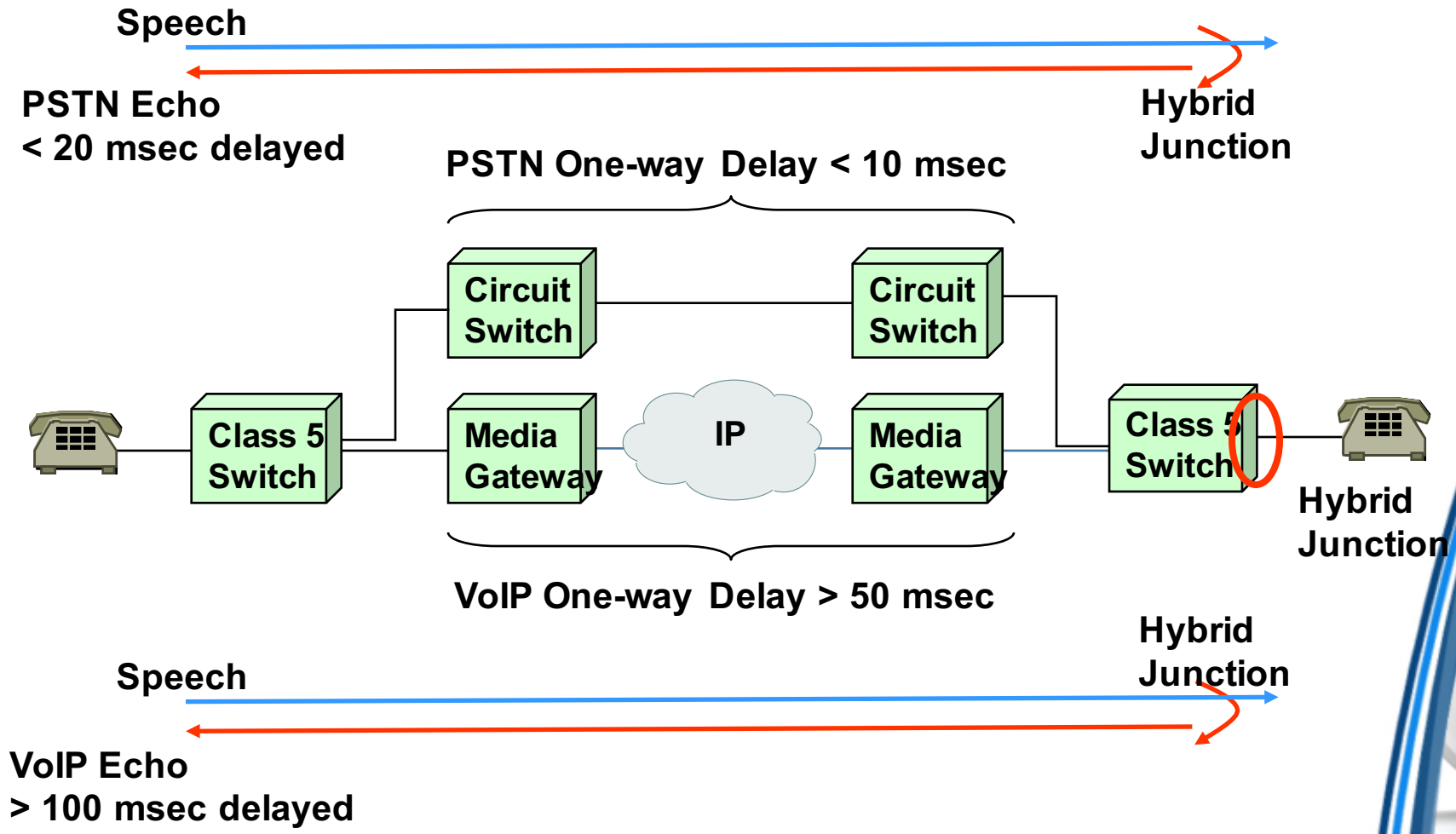
VoIP Transport Related Issues

Packet Delay – Latency

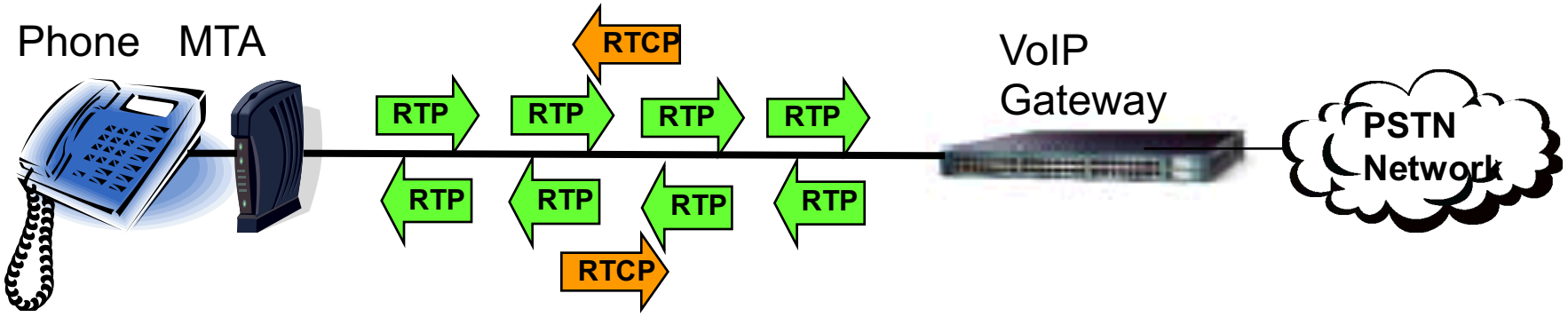
- End-to-End delay from Speaker to Listener
- CODEC has direct effect
- Lower bit rate = higher delay

Toll Quality <150ms

Main Source of Echo in VoIP Networks



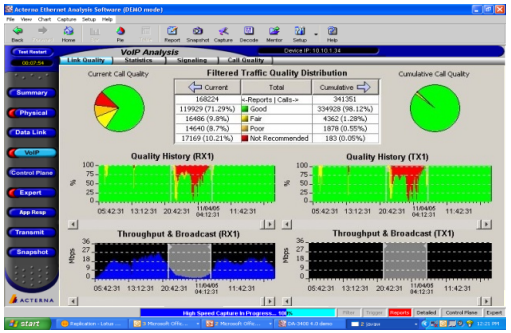
What is VoIP? – Real-time Control Protocol (RTCP)



- RTCP QOS monitoring packets are generated every 3 to 20 seconds
  - Receive Packet counts, Jitter values, packet loss….
- Not all Vendors implement RTCP but it can be useful because:
  - It allows problem isolation and segmentation
  - It allows calculation of Latency (Round Trip Time)
  - It allows single point analysis of end-to-end quality

How do we find impairments?

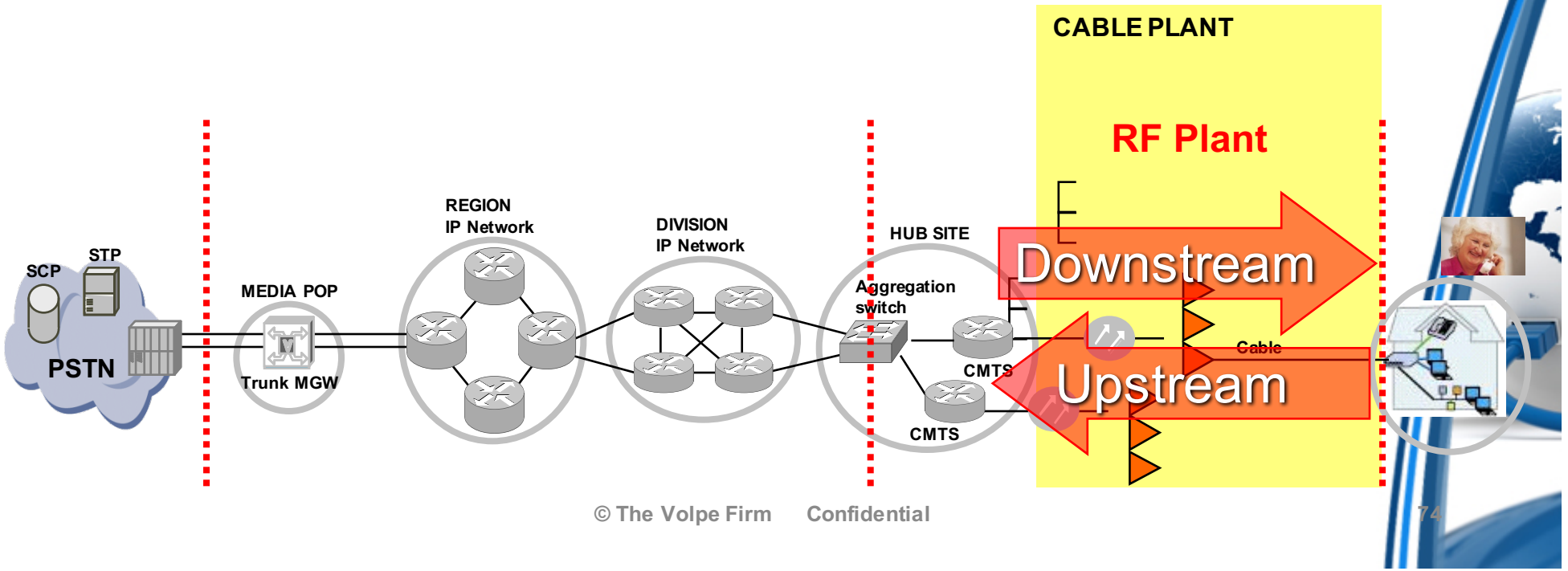
- Signaling issues – usually at turn-up
- Call Quality issues – at turn-up and with monitoring/testing after turn up (via portables & NOC based test equipment)



Voice Call Quality Troubleshooting – Tomorrow 2

Tier 2 CST

- **Further Isolate Problem Area**
  - **Hub Site – RF Plant**
    - **Downstream**
    - **Upstream**
- **Quick Fix or Correct Dispatch**



Summary

- 80% of VoIP problems in a DOCSIS network will be RF impairment related
- 20% are DOCSIS or IP protocol related
- The RF upstream is the Achilles heel of the DOCSIS and VoIP network – frame loss happens here first
- DOCSIS and IP protocol impairments usually impact all subscribers
- Impairments are cumulative

Summary - VoIP Goals

- The following performance parameters are recommended goals for your VoIP network

	Good	Noticeable	Objectionable
MOS	4.0	3.5	3.1
R-Factor	90	80	70
% Lost Packets	0.5 %	1%	2%
Latency	100 mSec	180 mSec	250 mSec
Jitter	20 mSec	40 mSec	50 mSec

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