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Simply DOCSIS

March 21, 2001

presented by:

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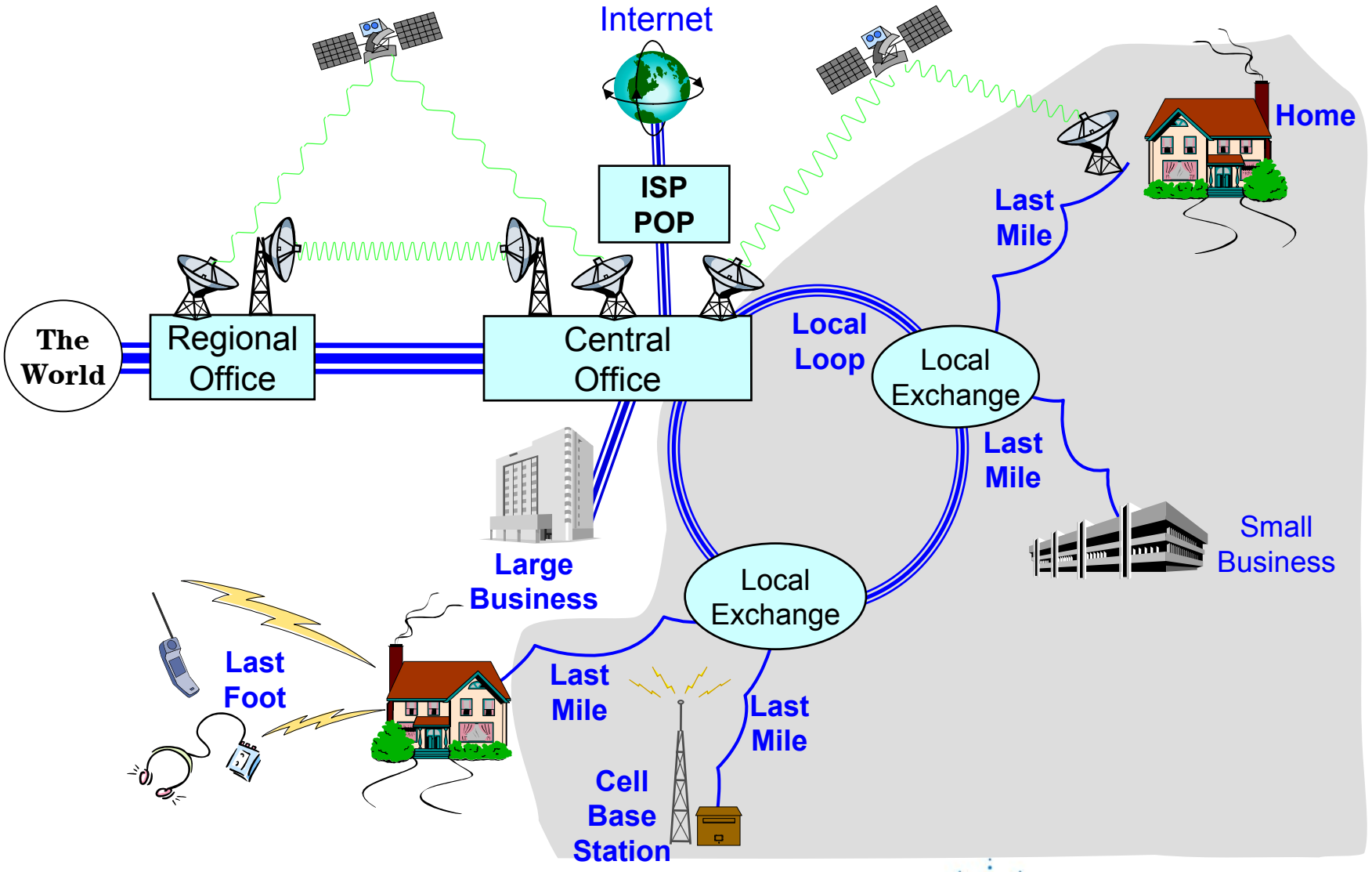
Agenda

- DOCSIS Background
- Cable Plant Description
- DOCSIS Layers
- DOCSIS Operation in Network
- Testing Challenges and Solutions
- Summary

Broadband Access Services

- **Merging communications industries: phone, video, Internet, e-mail, data**
- **Cable-to-home/business provides conduit for multiple services**
- **Broadband vendors provide high-speed, two-way data access equipment**
- **Off-the-shelf cable modems (CM) are available in US and Europe**

The Communication World



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Digital Cable Modem Evolution - 1

- Internet growth created need for faster data transfer
  - 50 - 100 times improvement over 56 kbps phone line modems
  - Service for millions of subscribers
  - Use of existing infrastructure -- broadband CATV plants
- Early cable-system designs provided interim solutions
  - Proprietary cable modems (CM) and headend equipment
  - No standard and no interoperability

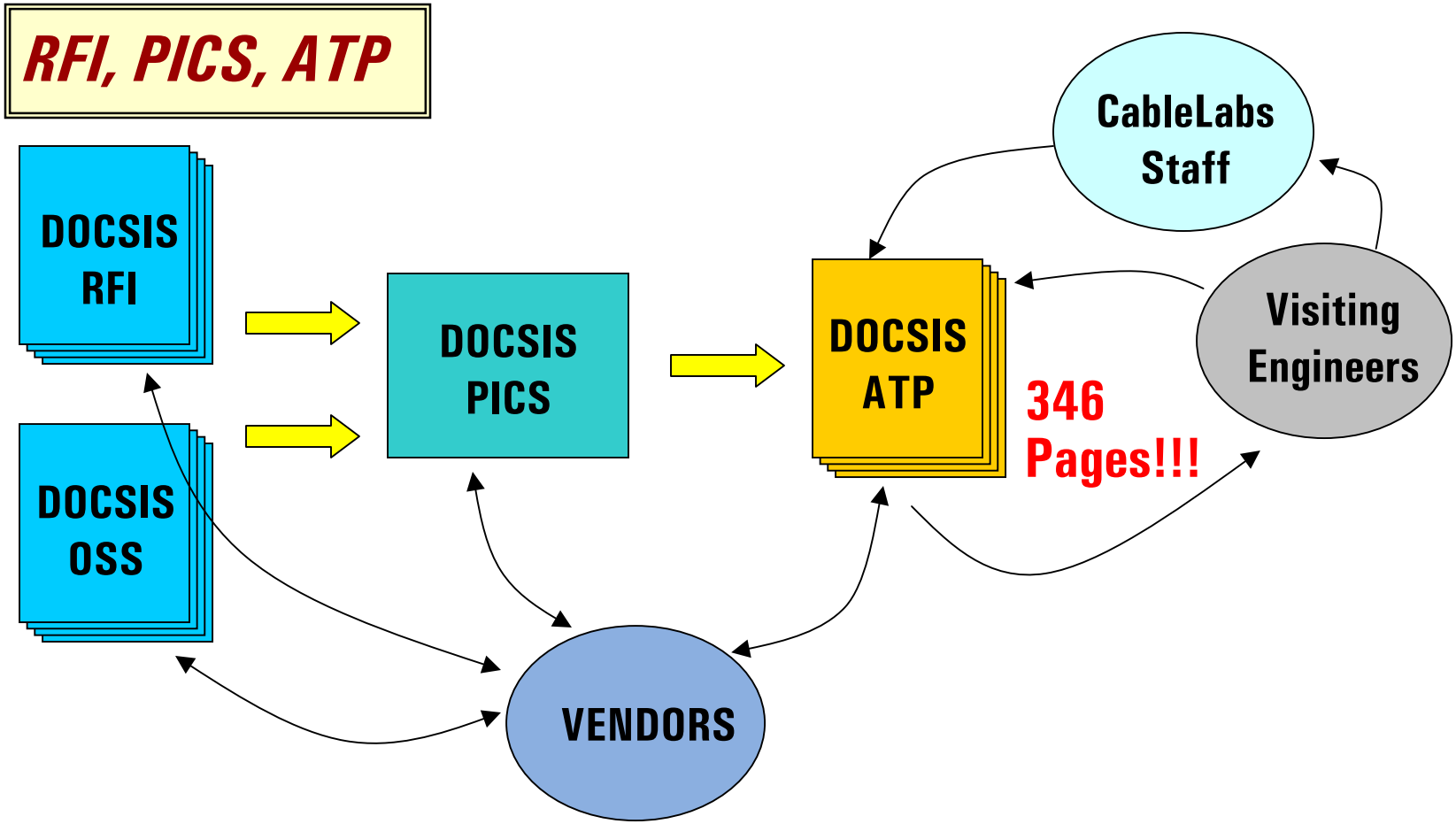
Digital Cable Modem Evolution - 2

- Multimedia Cable Network System Partners (MCNS)
  - Addressed need for interoperability
  - Developed the Data Over Cable Service Interface Specification (DOCSIS)
- DOCSIS Radio Frequency Interface (RFI) published in 1997
  - Defines all interface specifications for CM and headend equipment -- CM Termination System (CMTS)
  - Provides basis for open, non-proprietary, multi-vendor cable systems

Digital Cable Modem Evolution - 3

- Protocol Implementation Conformance Statements (PICS)
  - Industry selected all “must”, “must not”, “should”, and “should not” statements in the RFI
  - PICS document defines CM/CMTS characteristics needed to meet DOCSIS requirements
- Acceptance Test Plan (ATP)
  - Addresses test methods for PICS requirements
  - Joint effort of industry vendors and CableLabs -- 1998 publication
  - CableLabs administers CM certification and CMTS qualification

DOCSIS Background



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DOCSIS Versions

- DOCSIS 1.0 -- North American standard
  - Certifications throughout 2000
- DOCSIS 1.1 -- backward compatible to 1.0
  - Certifications in 2001
  - Adds voice over IP
  - Improves MAC messaging
- Euro-DOCSIS -- European standard
  - Similar to North American standard
  - Certification through tComLabs
  - Different channel BW and US/DS frequencies

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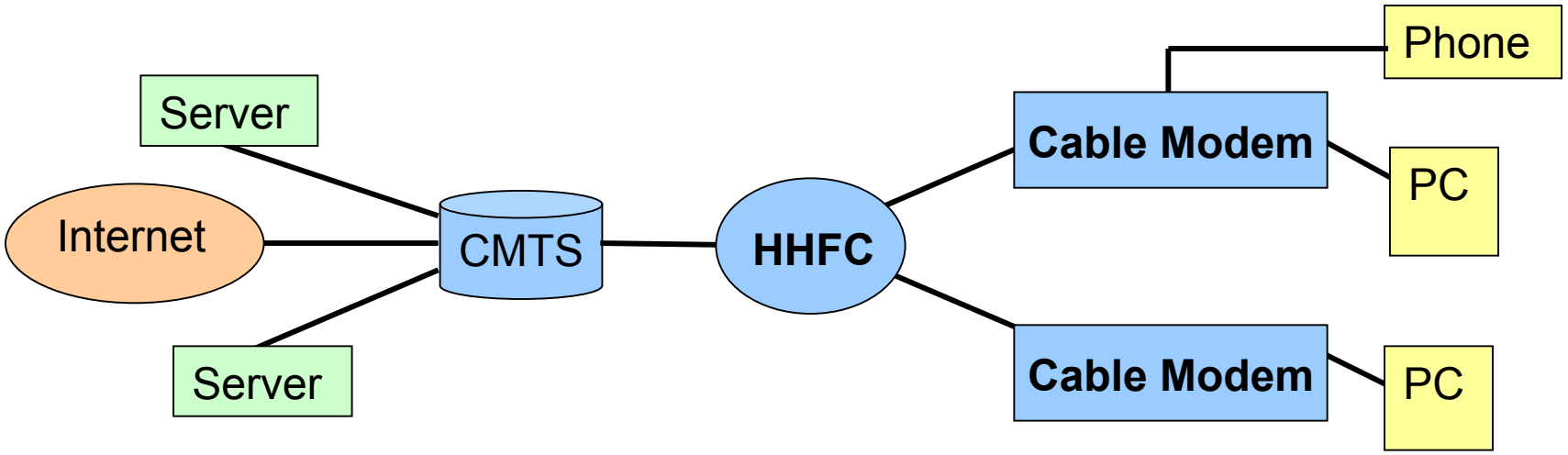
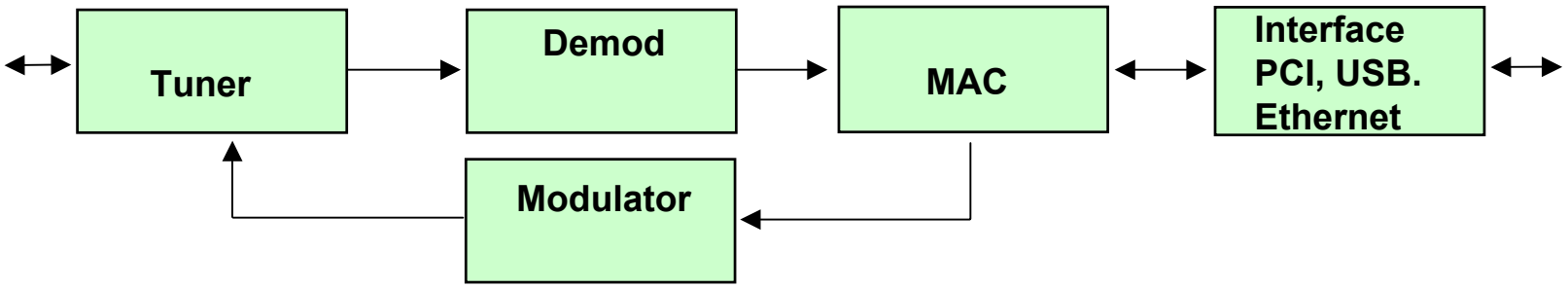
DOCSIS Service



Transfer bi-directional data traffic between service provider's headend (CMTS) and customer's cable modem

CATV tree-and-branch infrastructure provides data conduit: fiber and coax cables with amplifiers -- hybrid-fiber/coax (HFC)

CM Components



- Tuner converts TV channel to a fixed intermediate frequency (IF)
- Demodulator performs A/D, demodulation, error correction and MPEG synchronization
- MAC extracts data from MPEG frames, filters data for other Cable Modems, runs the protocol, times transmission of upstream bursts etc.
- Burst modulator performs R-S encoding, modulation, frequency conversion, D/A conversion etc.
- Interface can be PCI bus, Universal Serial Bus, Ethernet or other?

Downstream (CMTS to CMs)

Downstream Characteristics (North American)

Carrier Frequency: 88-860 MHz

Channel BW: 6 MHz

Power: +50 to +61 dBmV at Transmitter,
-15 to +15 dBmV at Receiver

Multiplex: (1) MPEG Transport + (2) MAC and IP Packets

64 QAM

5.056941 Msym/sec

RRC Filtering: 0.18

256 QAM

5.360537 Msym/sec

RRC Filtering: 0.12

Upstream (CMs to CMTS)

Upstream Characteristics (North American)

Carrier Frequency: 5 - 42 MHz

Channel BW: 0.2 - 3.2 MHz

Power: +8 - +58 dBmV at Transmitter

-16 - +26 dBmV at Receiver

Multiplex: Packet TDMA

QPSK, 16 QAM

160k/s,320k/s,640k/s,1.28M/s,2.56M/s

RRC Filtering: 0.25

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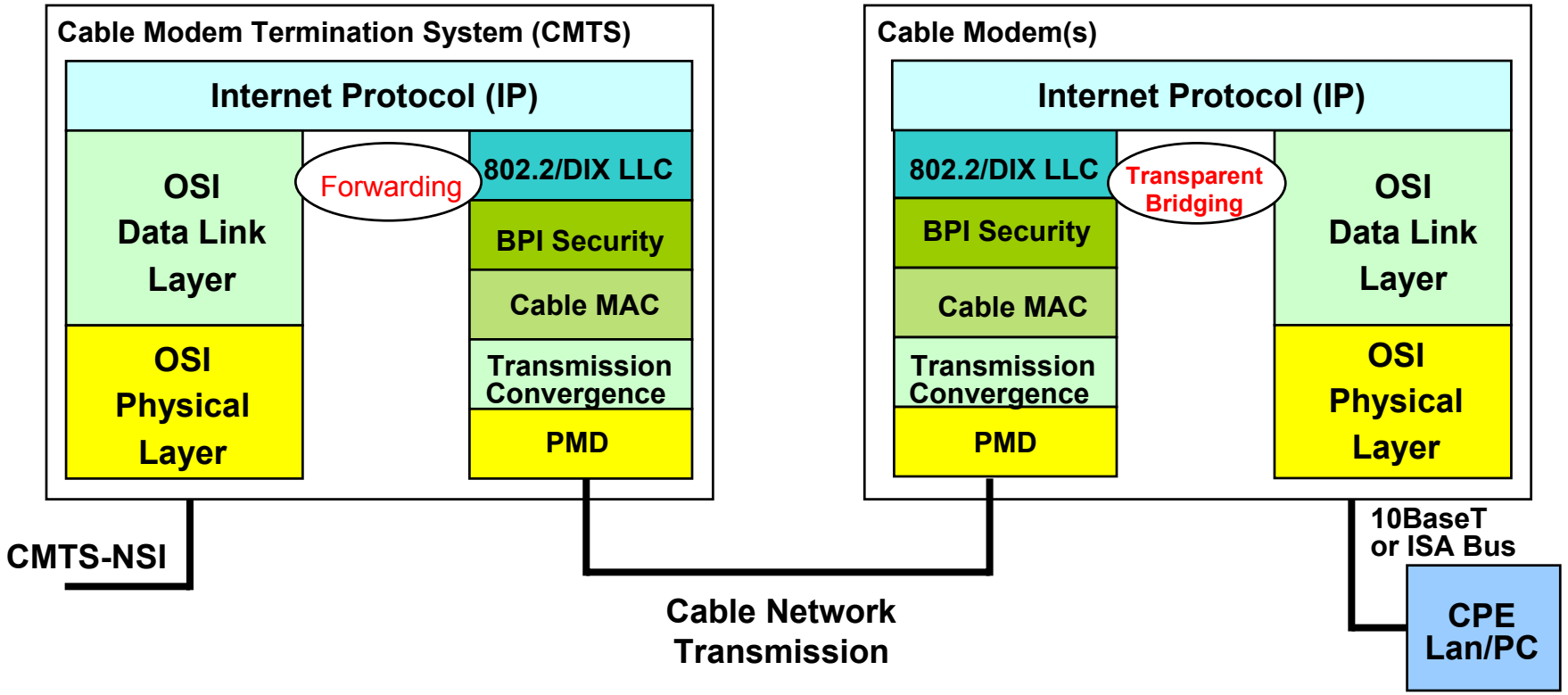
DOCSIS Protocol Layers

- **Physical (PHY): RF and digital protocols for communication between CMTS and CM over coaxial/HFC**
- **Media access control (MAC): management messages for CM and CMTS**
- **Baseline privacy interface (BPI): provides secure communication between CM and CMTS**
- **Operational support system (OSSI): network management control/status interface to CMTS and CMs**

DOCSIS Protocol Stack



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MAC Characteristics

- Implemented in hardware and software
- Performs ranging to calibrate transmitter level, burst timing, carrier frequency and transmit pre-equalization
- Assigns upstream frequency and data rate
- Allocate time slots (upstream bandwidth)
- Runs on both CM and CMTS

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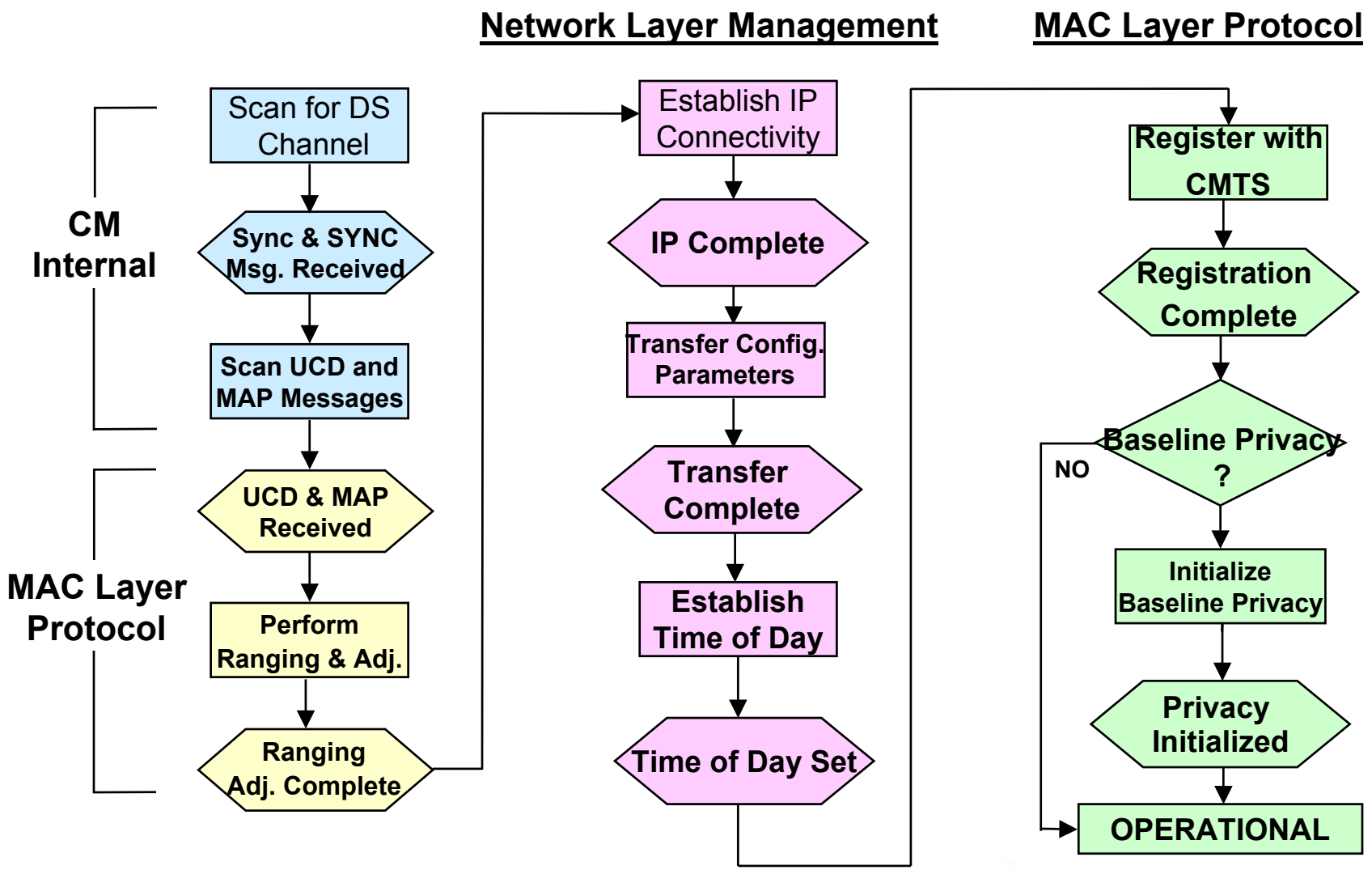
CM Initialization Process



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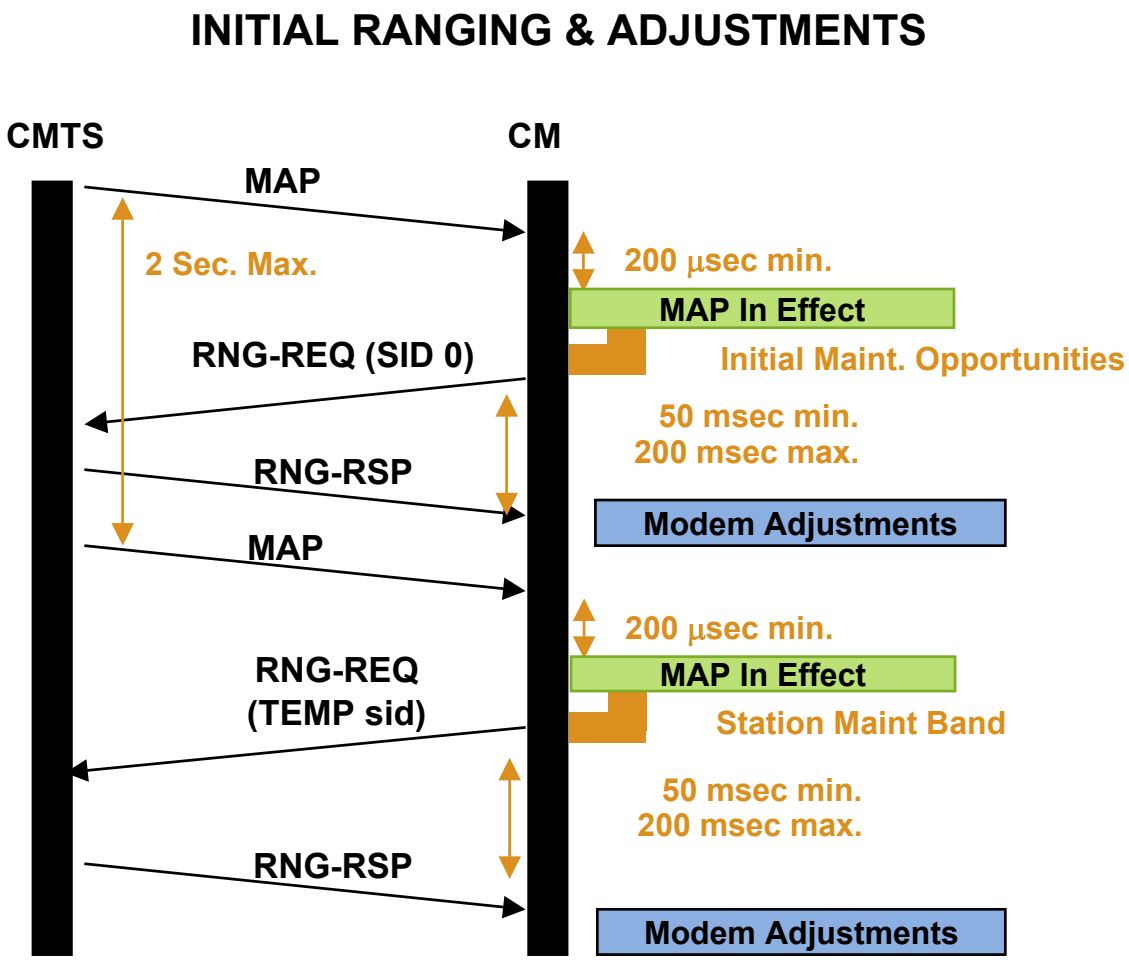
MCNS Protocol



Notes: CM needs a Init. Maint. Opportunity in 10 sec

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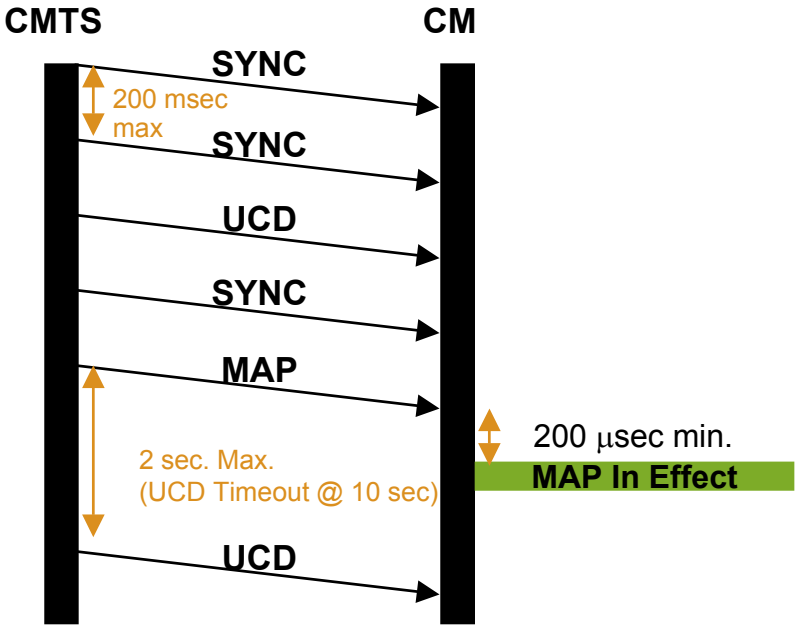
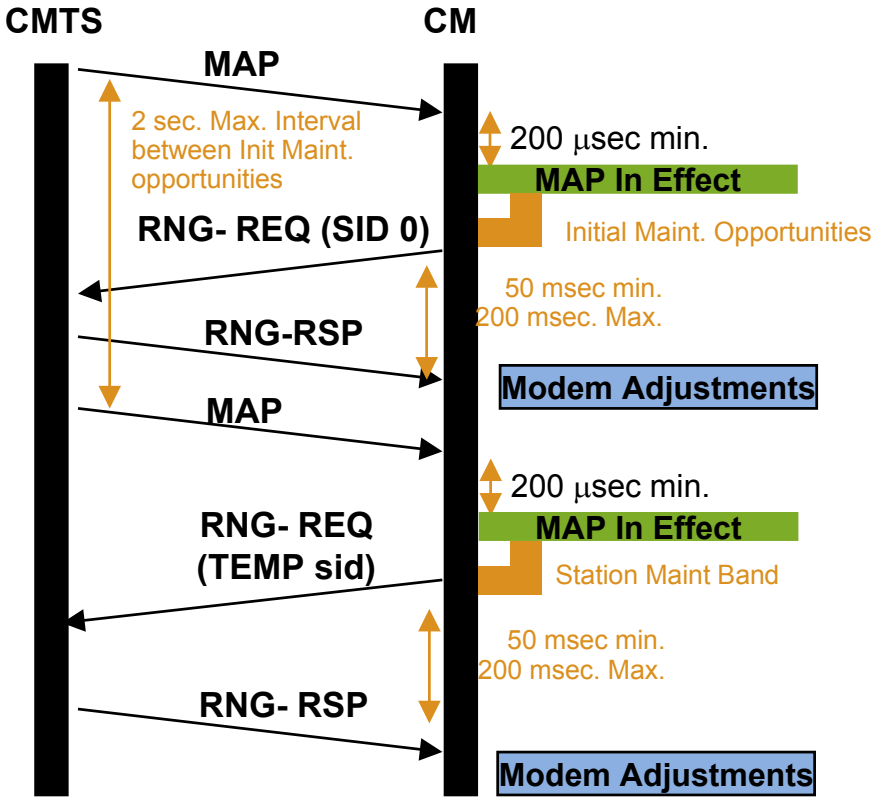
MCNS Protocol

DOWNSTREAM SYNCHRONIZATION



Notes: CM needs a UCD message in 10 sec (T1)

INITIAL RANGING & ADJUSTMENTS



Notes: CM needs a Init. Maint. Opportunity in 10 sec (T2)

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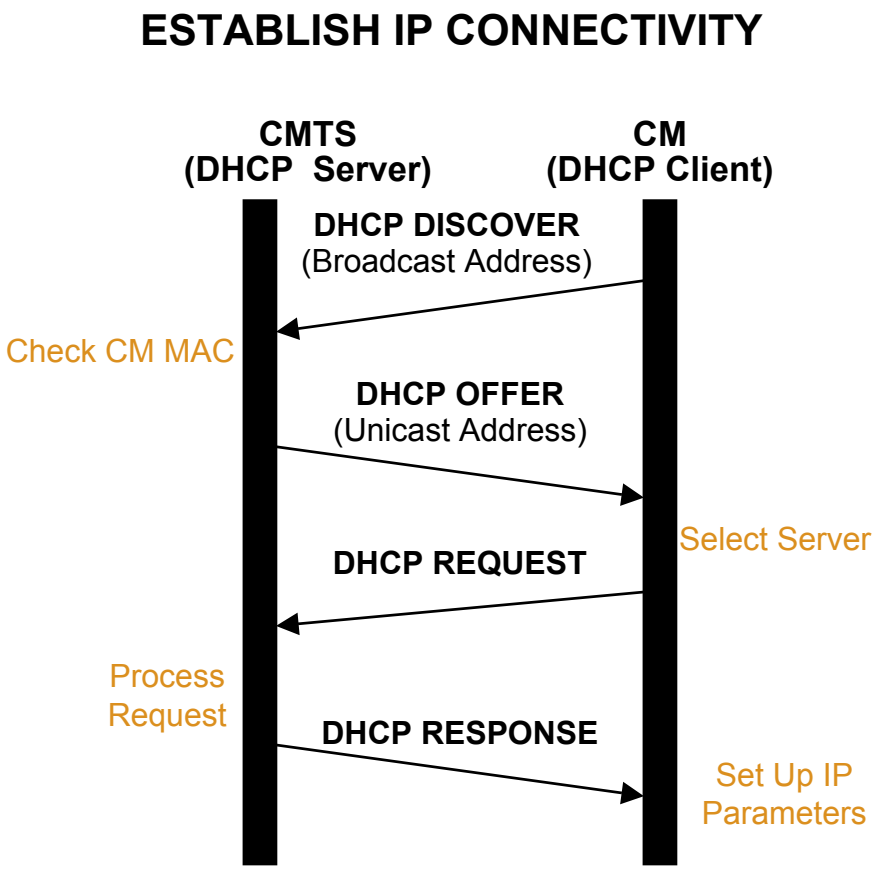
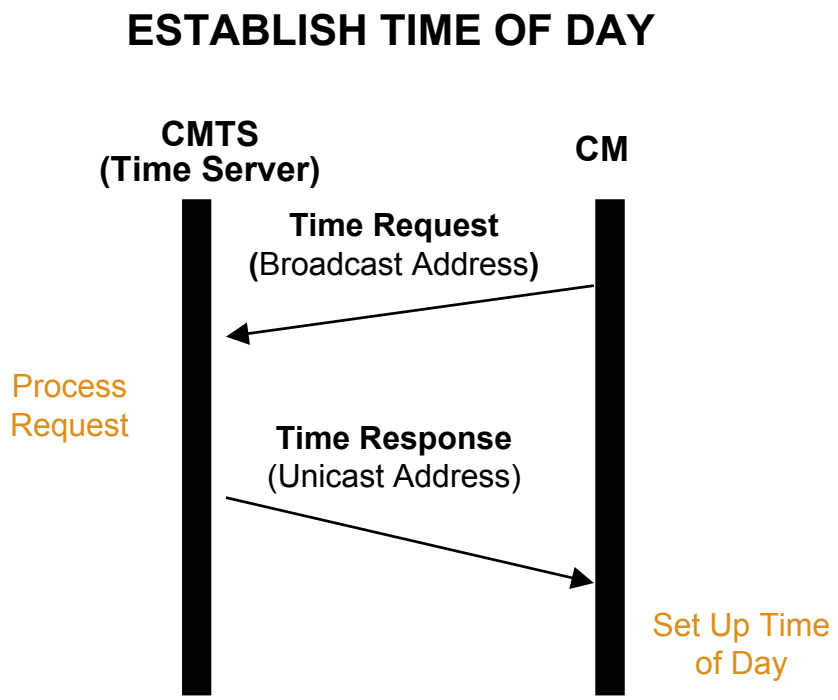
MCNS Message Protocol





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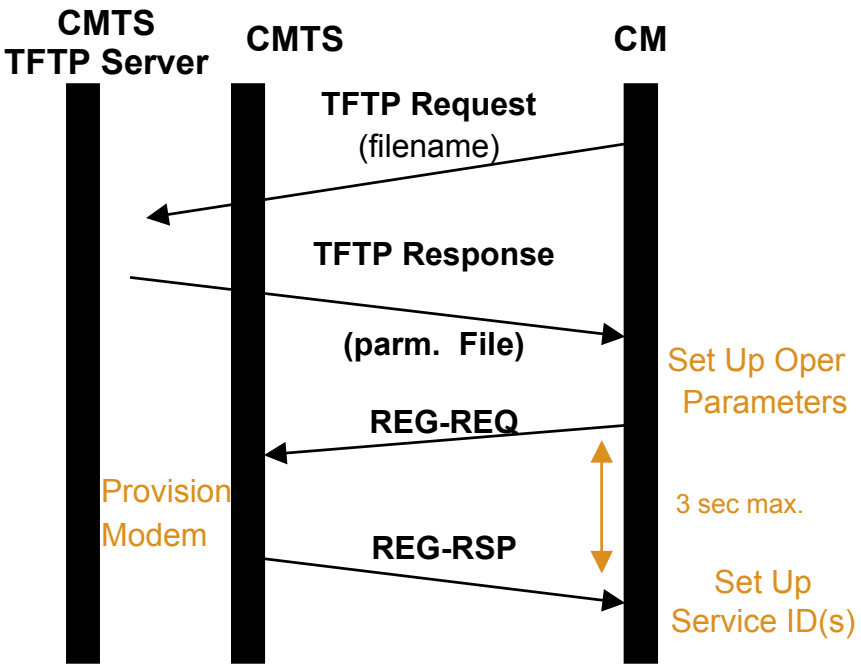
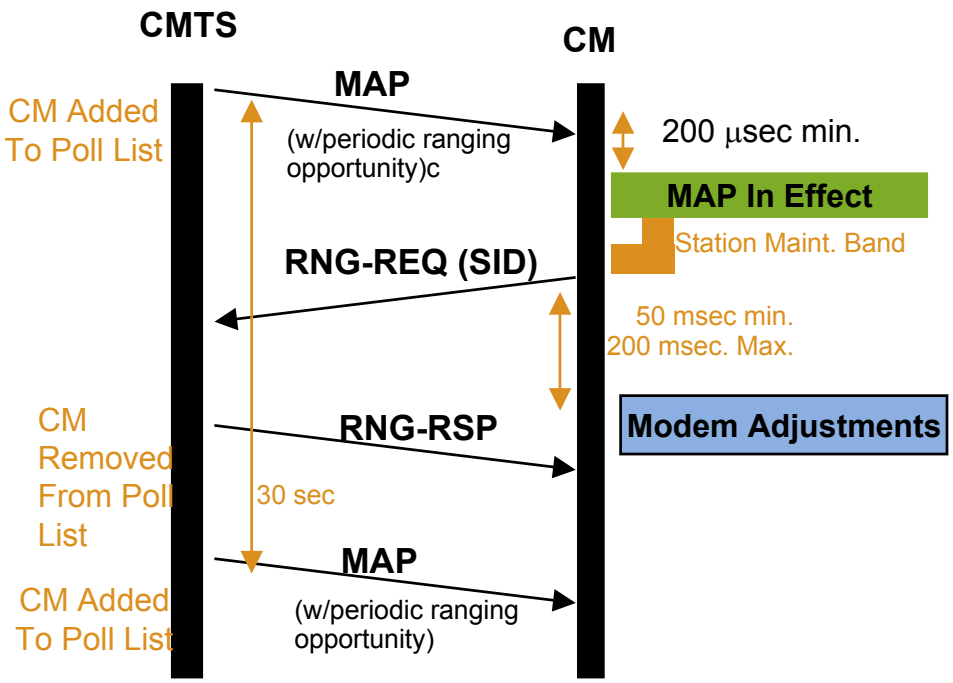
MCNS Message Protocol

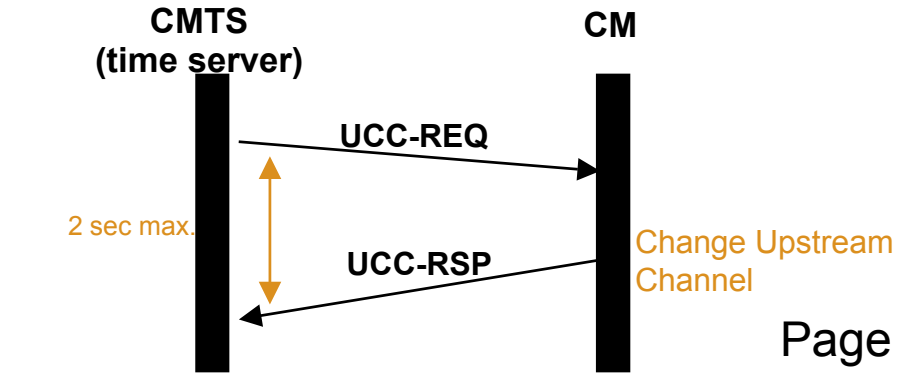
DOWNLOAD PARMs & REGISTER



POLLED (INVITED) RANGING



UPSTREAM CHANNEL CHANGE



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System Data Characteristics

	Modulation	Symbol Rate	Bandwidth	Fltr
Downstream	64 QAM	5.056941 Msym/sec	6 Mhz	0.18
	256 QAM	5.360537 Msym/sec	6 Mhz	0.12
Upstream	QPSK	160 Ksym/sec	200 Khz	0.25
	QPSK	320 Ksym/sec	400 Khz	0.25
	QPSK	640 Ksym/sec	800 Khz	0.25
	QPSK	1280 Ksym/sec	1600 Khz	0.25
	QPSK	2560 Ksym/sec	3200 Khz	0.25
Upstream	16 QAM	160 Ksym/sec	200 Khz	0.25
	16 QAM	320 Ksym/sec	400 Khz	0.25
	16 QAM	640 Ksym/sec	800 Khz	0.25
	16 QAM	1280 Ksym/sec	1600 Khz	0.25
	16 QAM	2560 Ksym/sec	3200 Khz	0.25

Upstream Data Bursts

5 Types of Bursts	Cond/Grant	Purpose	IUC	Indiviual Specify
Req (BW)	C	Asking for Data BW	1	Yes
Initial Maint (Initial Ranging)	C	Cal CM Tx to CMTS Rx	3	Yes
Station Maint (Periodic Ranging)	G	Cal CM Tx to CMTS Rx	4	Yes
Short Data	G	Convey Data and Messages	5	Yes
Long Data	G	Convey Data and Messages	6	Yes

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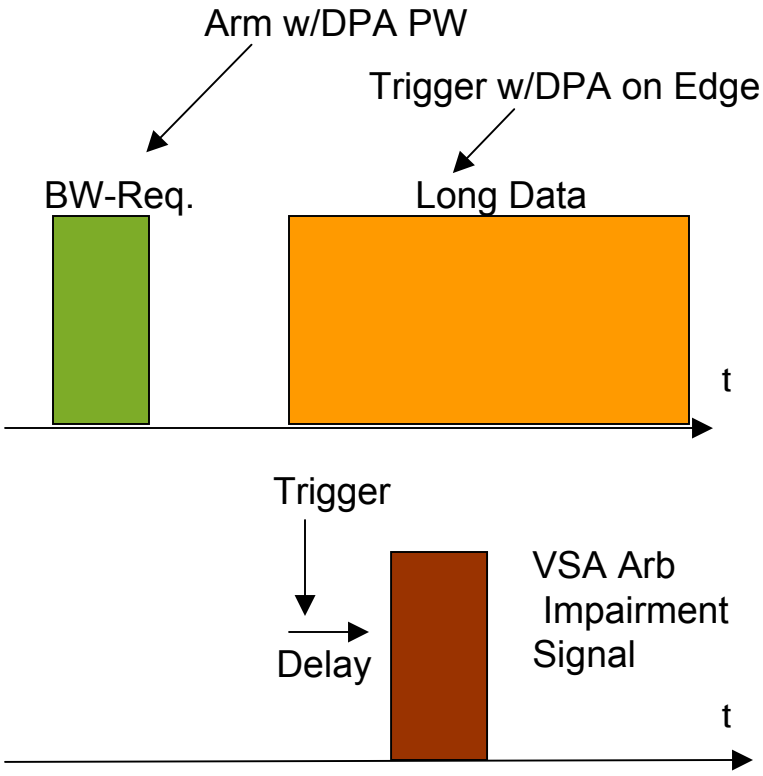
DOCSIS Testing Challenges

- Triggering
- Protocol Analysis
- Measurement Techniques

- Solutions
  - Flexible triggering for upstream burst testing
  - Analysis of MAC protocol layer conformance
  - Calibrated active impairments for CM and CMTS tests

Burst-Selective Trigger Example

- Burst input on DPA
  - RF Trig with level =-33 dBm
- Trigger arm on DPA
  - Pulse Width <500 μsec for BW-Req
- Trigger for RF burst on DPA
  - Rising Edge
- Trigger delay
  - Delay Trigger Out n μsec
  - Adjust trigger into MAC header
  - Adjust trigger into Payload
  - Put Impairment in both MAC and Payload
- VSA source to trigger from DPA



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E7333A DOCSIS Protocol Analyzer

- Features
  - DOCSIS 1.0/1.1 CM and CMTS protocol test solution
  - Downstream and upstream data capture
  - GUI-based software for control and protocol analysis
  - Protocol analysis and statistics, simple SYNC jitter analysis
  - External reference clock inputC

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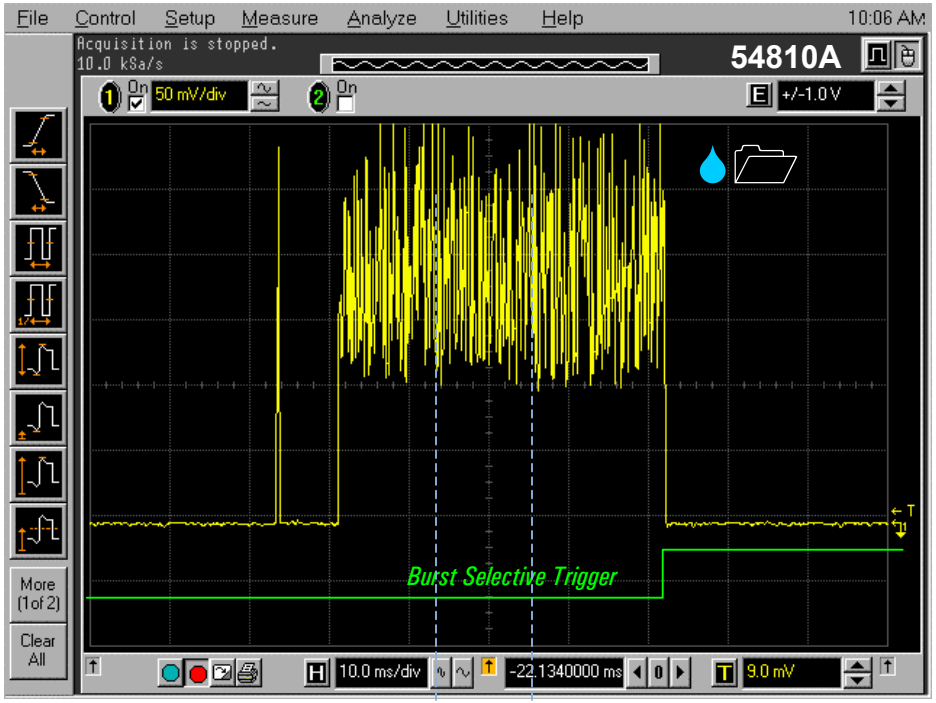
E7333A DOCSIS Protocol Analyzer

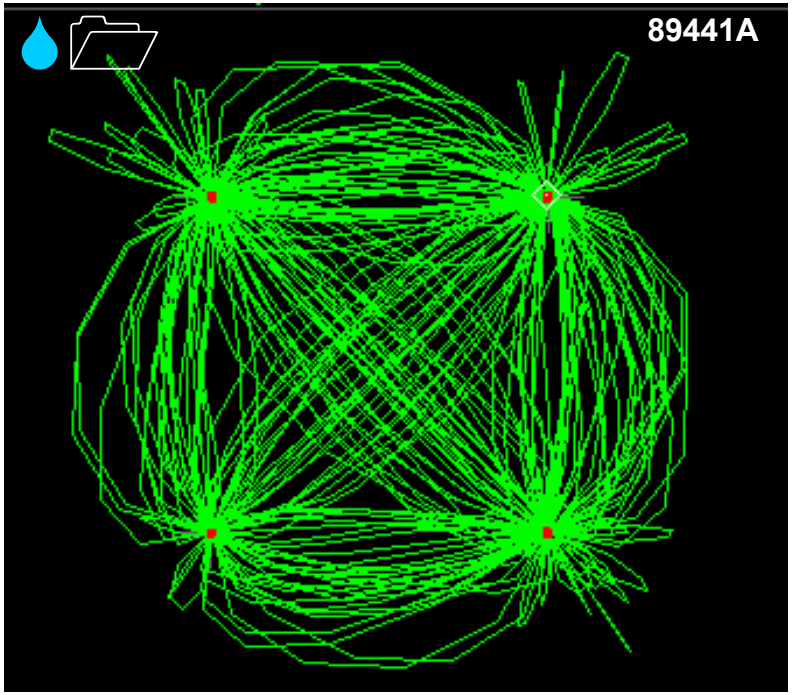
- Downstream Features
  - Raw and filtered MPEG
  - Time-stamped MAC frames
  - MPEG and MAC format and timing analysis
  - Pre and post-triggered acquisitions
  - MAC Protocol Analysis
  - SYNC Timing Analysis
  - Synchronous and Asynchronous Triggering
  - Trigger Depth Control

E7333A DOCSIS Protocol Analyzer

- Upstream Features
  - Synchronous and Asynchronous Capture Modes
  - Time-stamped MAC frames
  - MAC format and timing analysis
  - Trigger Depth Control
  - Burst-width selective triggering
  - Flexible trigger output processing
  - High burst power sensitivity

Upstream Burst and Demodulated Display





Programmable Measurement Window

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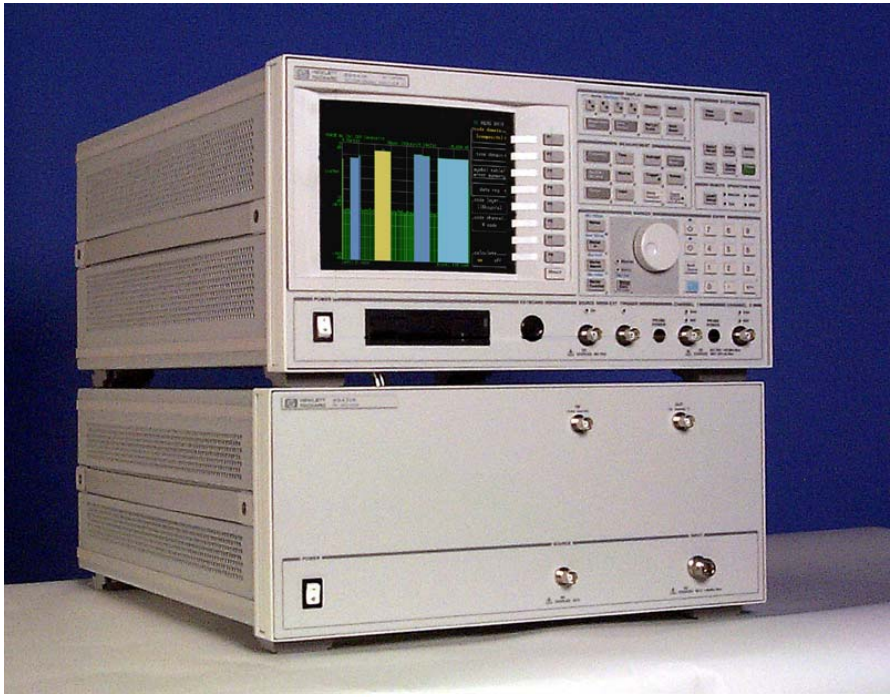
89441A Vector Signal Analyzer (VSA)

- Troubleshoot RF and DSP problems
- Spectrum, time, demod, network measurements
- Error signal analysis
- Adaptive equalization



89441A VSA Measurements

- Setting up correct power range
  - Biggest error that occurs
- Band power marker
  - Measure Power in the signal
  - Integrated Power over a bandwidth
  - Signal is not CW
- Digital demodulation
  - Demodulate signal
  - Used to Measure EVM
  - Constellations / Vector Diagrams

89441A Digital Demodulation

- Digital Demodulation Typical Settings
  - Center Frequency
  - Span to 7 MHz for DS, 0.24 to 3.84 MHz for US
  - Demod set to Video for 64 and 256 QAM
  - Demod set to Digital for QPSK and 16 QAM
  - Input range set to the first range w/o Overload
  - Symbol rate and Alpha set accordingly
  - 800-1600 Symbols for DS, 200-400 Symbols for US
  - Measurement filter set to Root raised cosine
  - Reference filter set to Raised cosine
  - Normalize ON
  - EQ Filter OFF for most strategies

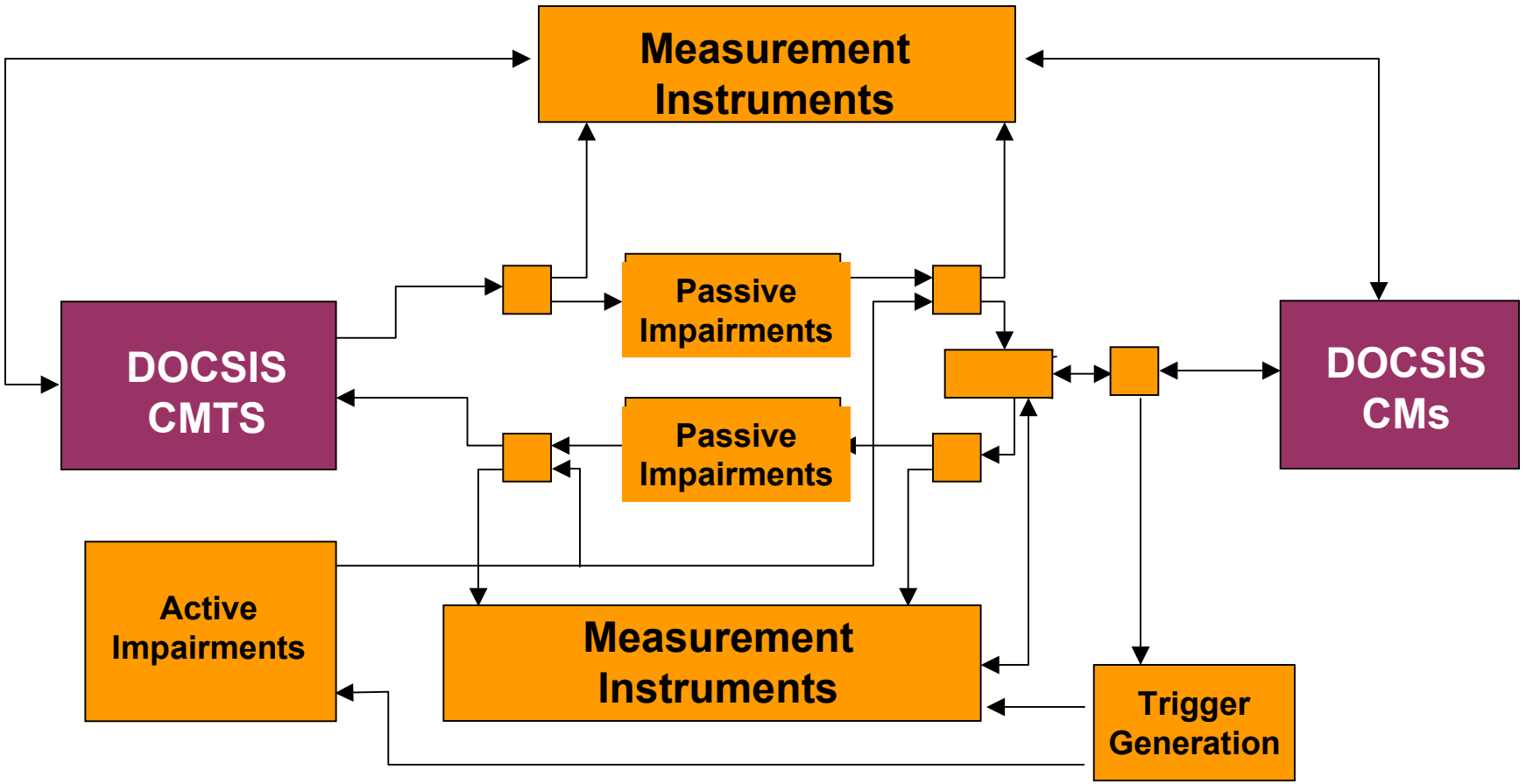
89441A Band Power Measurements

- Band Power Marker Typical Settings
  - Center Frequency
  - Span to 7 MHz for DS, 0.24 to 3.84 MHz for US (20% wider)
  - Vector Mode On
  - Input range set to the first range w/o Overload
  - Change the number of points to 3201
  - Averages to 16
  - Band Power Center to Signal Center Freq
  - Band Power Bandwidth = 6 MHz for DS
    - Use 200Khz, 400Khz, 800Khz, 1.6MHz or 3.2MHz for US

E1371A DOCSIS Test System

- **Provide CM/CMTS DOCSIS 1.0 design verification testing**
  - DOCSIS 1.1 and Euro capable
- **Automated testing for PHY and MAC**
- **Unique protocol analyzer for upstream triggering and downstream data capture and analysis**
  - E7333A offers DOCSIS 1.1 upgrade for upstream data capture and analysis

E1371A Platform Architecture



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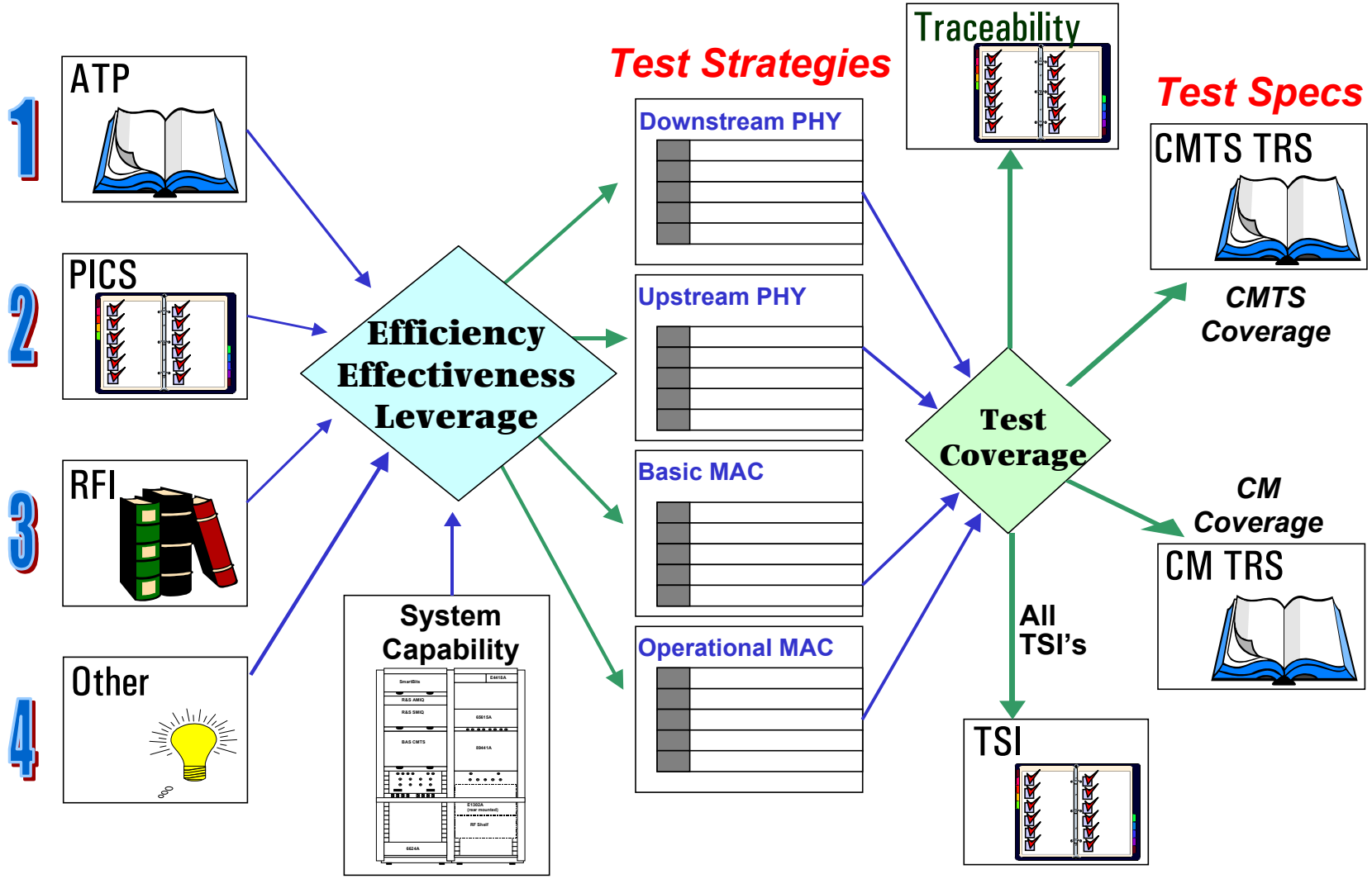
Agilent Test Strategies



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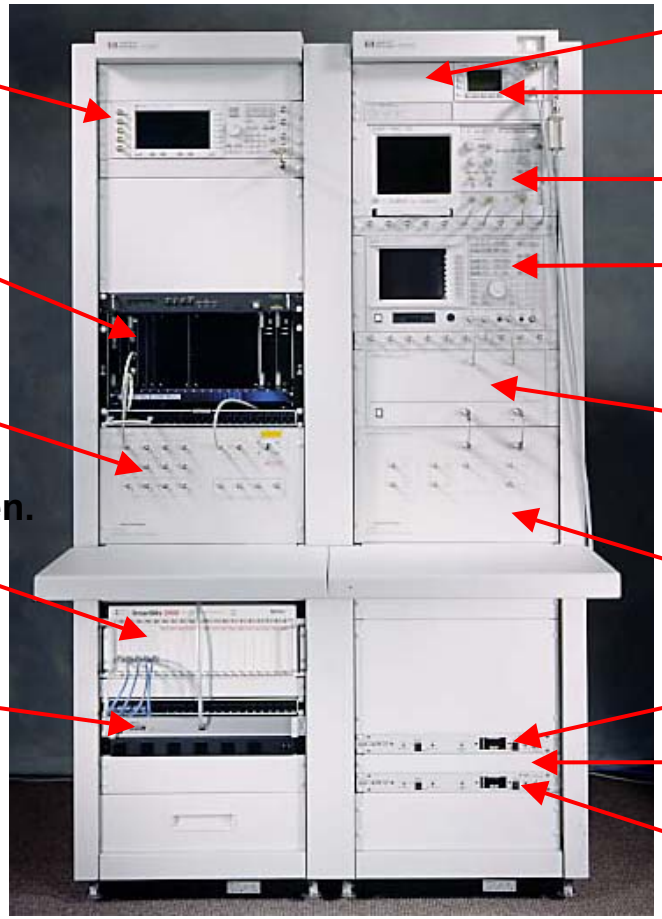
Test Strategy Advantages

- Effective Testing
  - PICS coverage
  - Isolate CMTS vs. CM coverage
  - RFI validation
  - Fully traceable to ATP and PICS
  - Gain insights into design
- Effective Testing
  - Reduce test setups
  - Minimize layer interdependencies
  - Incorporate new technology
  - Incorporate “smarts”
- Leveraged Testing
  - Apply in manufacturing
  - Enable incremental development
  - Leverage tools and test systems

E1371A System Hardware



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E1371A Efficiency

- CM or CMTS testing
  - All PHY testing -- upstream and downstream
  - All MAC testing
- Basic resources
  - Five basic instruments: VSA, ESG, DSO, DS-DPA, Packet Generator
- Automatic test platform
  - System designed for full automation
  - System designed to support Agilent test strategies
- Versatile I/O
  - CMTS: 2 DS and 8 US ports
  - CM: 4 ports
  - Bypass access: aux. impairment, US amplifier, US passive, etc.

Efficient Resource Utilization

ATP Spec.: -12 dBmV per 6MHz

Subtract Path Loss (15 dB) and Margin (10 dB)
Required Measurement Floor: -37 dBmV per 6MHz

89441 Floor (typ.): -165 dBm/Hz = -97.2 dBm/6MHz
= -48.5 dBmV/6MHz

Summary: Measurement Instrument must have at least
-37 dBmV/6MHz noise floor.

Efficient Resource Utilization

CMTS Output: +61 dBmV

= 12.3 dBm

89441 Range Setting: -45 dBm

89441 Dynamic Range: -54 dB (@ -45 dBm)

Required Dynamic Range:

Signal Power:	+61 dBmV
less Test Limit:	-12 dBmV
plus Headroom:	+10 dBmV
	=83 dBmV

Efficient Resource Utilization

DS Channel-Deletion Filters: 93, 459, 855 MHz

Drop In-Band Channel Power by 35 dB
to extend effective dynamic range to
54 dB + 35 dB = 89 dB.

Now, Adjacent-Channel measurements can be made down to -28 dBmV against limit of -12 dBmV.

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DOCSIS Information for Customers

E1371A DOCSIS Test System

Product Overview #5988-1245EN

Press Release:

http://www.agilent.com/about/newsroom/presrel/2000/04dec2000b.html

E7333A DOCSIS Protocol Analyzer

Data Sheet #5980-2143E

Press Release:

http://and.aus.agilent.com/bsts-test-lab/newlook/9/docsis/news/intro-docsis.htm

Agilent Web Site for DOCSIS

http://www.agilent.com/comms/DOCSIS

Agilent Business Contacts

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E7333A DOCSIS Protocol Analyzer

Trevor Dyck -- Product Manager

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E-Mail: **trevor_dyck@agilent.com**

Reference Material

- Digital Basics for Cable Television
  - Jeffery Thomas and Francis Edgington
  - ISBN 0-13-743915-6
- Practical Programming in Tcl and Tk
  - Brent Welch
  - ISBN 0-13-022028-0
- Testing Digital Video
  - Helen Chen
  - Agilent literature number 5965-0964E
  - 1996 Symposium Part 5

Reference Material

- Measuring phase noise with the 89410A and 89440A Vector Signal Analyzer
  - Literature number 5091-7193E
  - Product Note 8944A-2
- Digital modulation in communications systems- an introduction
  - Literature number 5965-7160E
  - Application Note 1298

Additional Websites

- **CableLabs**
  - http://www.cablelabs.com/homenetworks/
  - http://www.cablemodem.com/
- **Society of Cable Telecommunications Engineers (SCTE)**
  - http://www.scte.org/
- **National Cable Television Association (NCTA)**
  - http://www.ncta.com/

Conversion Factors

- dBmV = 20log (V/1mV)
- dBm = 10 log (P/1mW)
- 0 dBm = 1 mW = 274 mV in 75 Ohms
- 0 dBm = 1 mW = 224 mV in 50 Ohms
- dBm to dBmV for 75 ohm = 48.755 dB
  - 0 dBm = 274 mV = 48.755 dBmV
- dBm to dBmV for 50 ohm = 47.005 dB
  - 0 dBm = 224 mV = 47.005 dBmV