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Cisco Systems

Advanced Digital Cable Architecture & Technologies

By Greg Thompson

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(Video & Content Networking Business Unit)
Service Provider Video / IPTV Group
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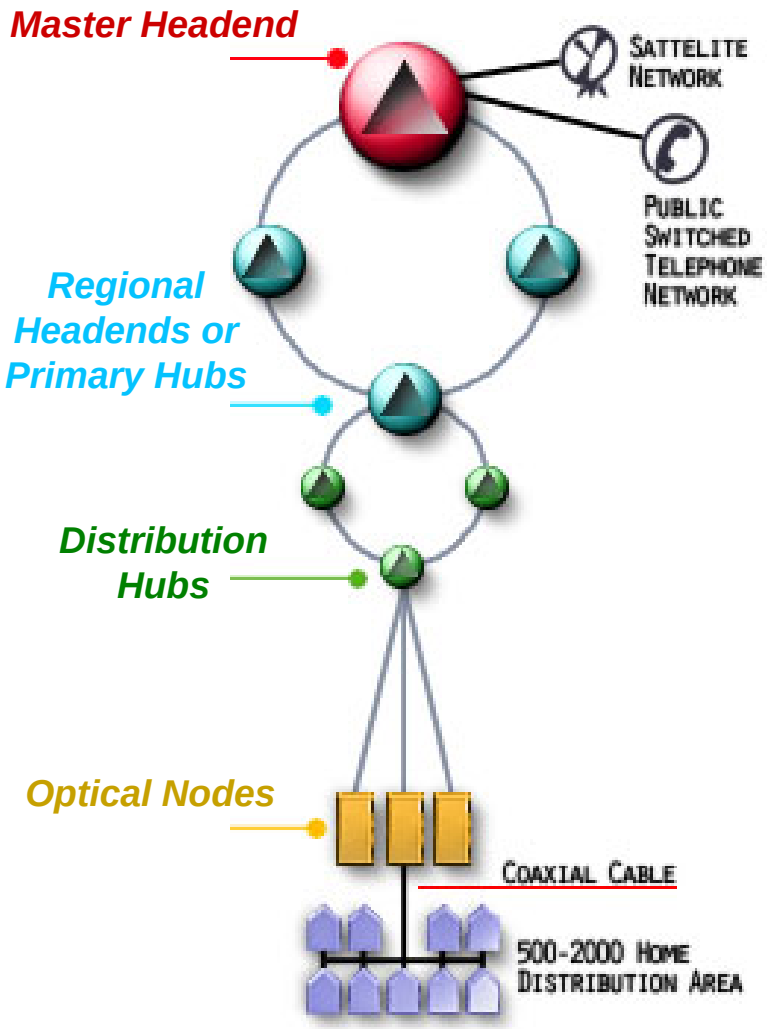
IEEE CES Santa Clara meeting
September 26th 2006

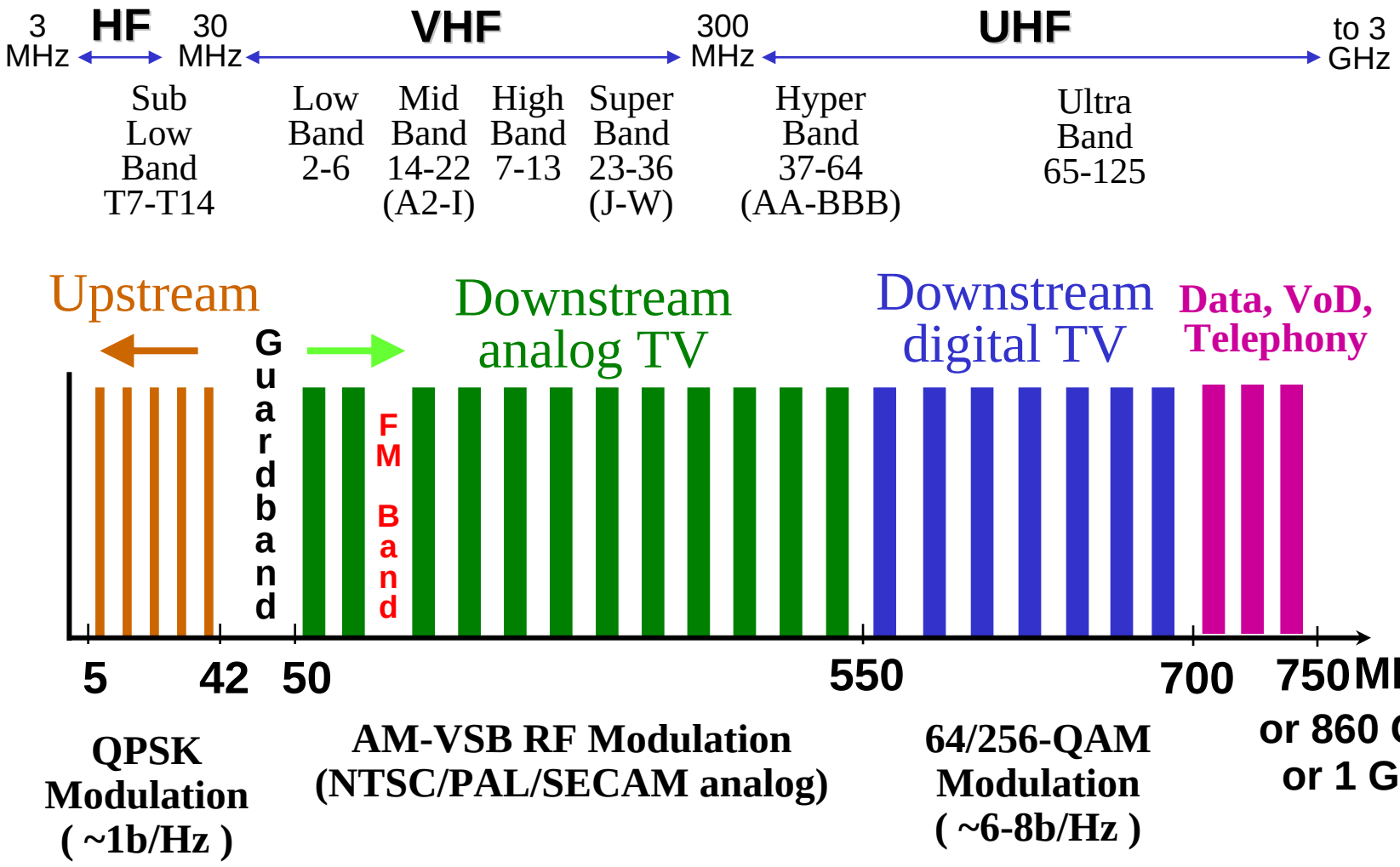
Topics

- Digital Cable Foundation Technology
  - Hybrid Fiber Coax (HFC), Quadrature Amplitude Modulation (QAM)
  - MPEG-2 Transport Streams, CAS Architecture, Video over IP
- Video-on-Demand
  - Forms of Video on Demand (VOD), network PVR (nPVR)
  - VOD delivery architecture to EdgeQAMs
- High Speed Data and Voice
  - DOCSIS STB Gateway (DSG), Modular CMTS
  - DOCSIS 3.0 including Channel Bonding (Wideband)
  - PacketCable 2.0 & PacketCable Multi-Media
- Next Generation Digital Video
  - Digital Simulcast
  - Next Generation Network Architecture (NGNA)
  - Downloadable Conditional Access System (DCAS)
  - OpenCable Application Platform (OCAP)

Digital Cable Foundation Technology

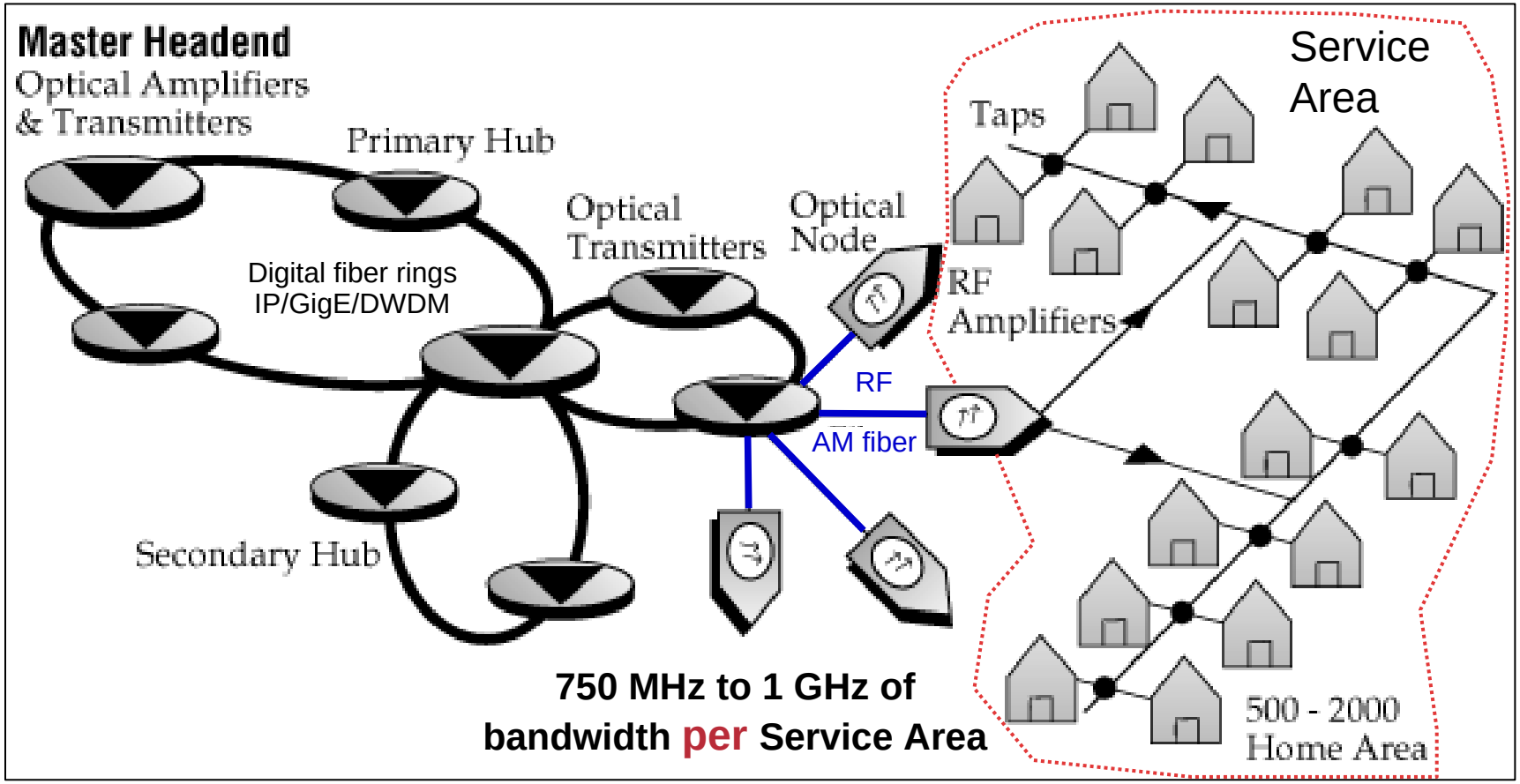


Typical Cable Frequency Allocation



Hybrid Fiber Coax (HFC) Architecture

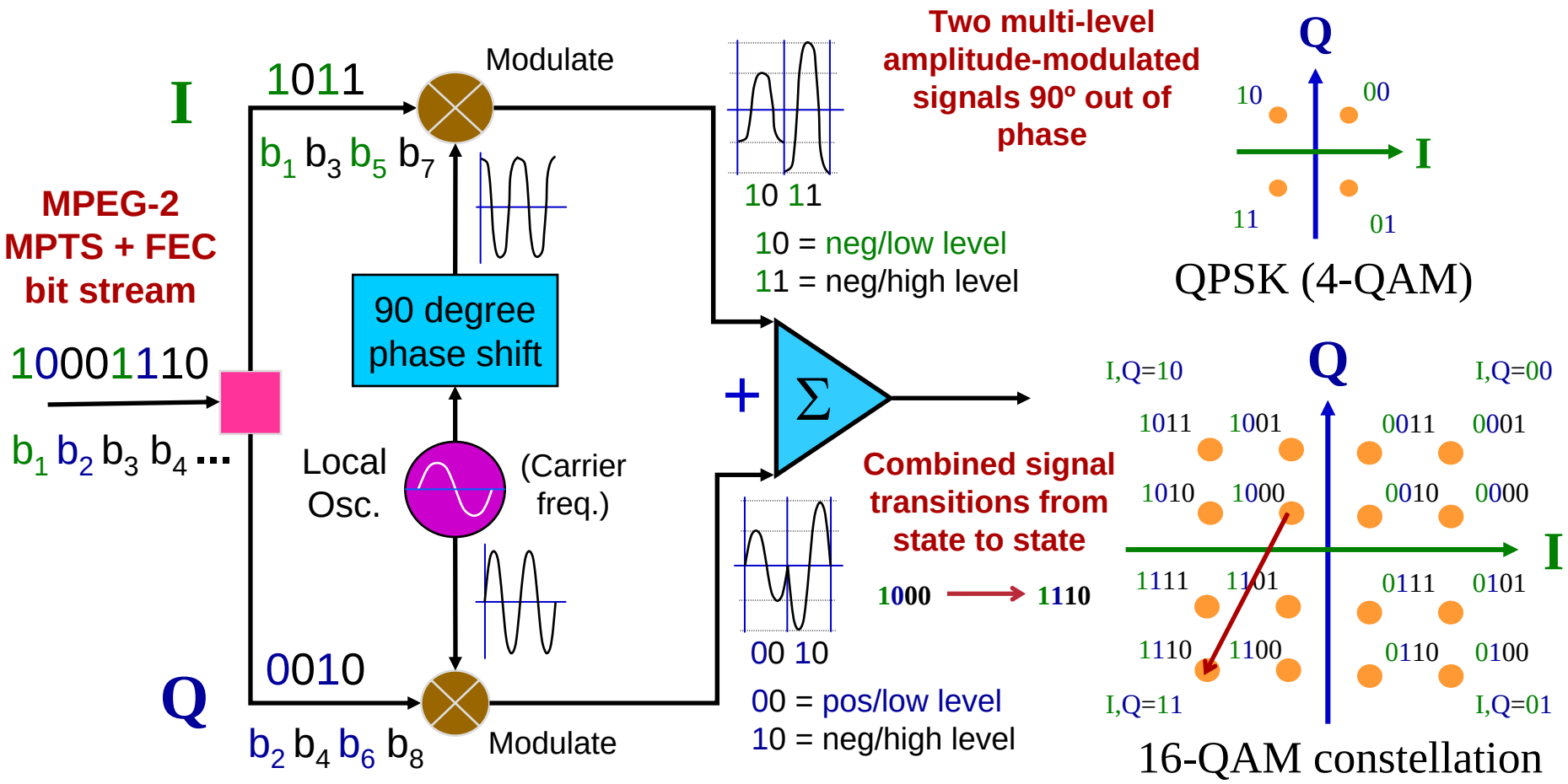
- Amplitude-modulated RF over SM fibers to neighborhoods
- Eliminated many trunk amps, enabled “Spatial Multiplexing”



HFC Arial Optical Nodes in Neighborhoods

Ground Optical Nodes in Neighborhoods

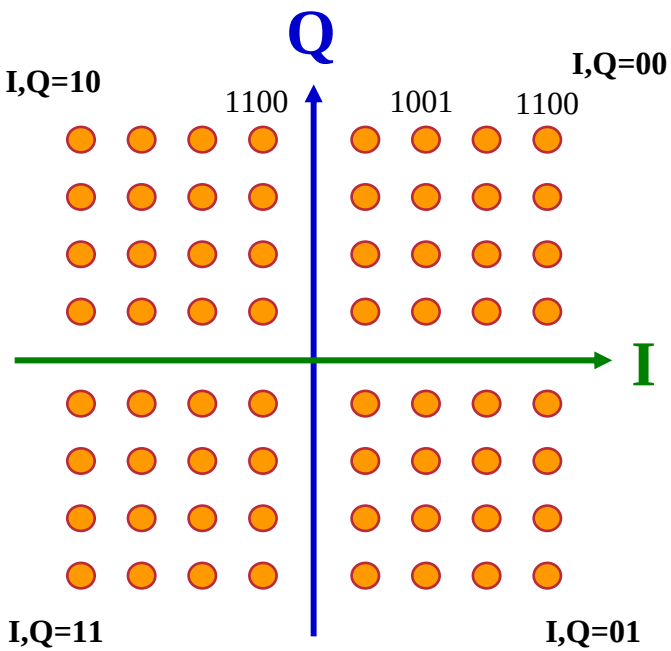
Quadrature Amplitude Modulation (QAM)



QAM Modulation Bandwidth

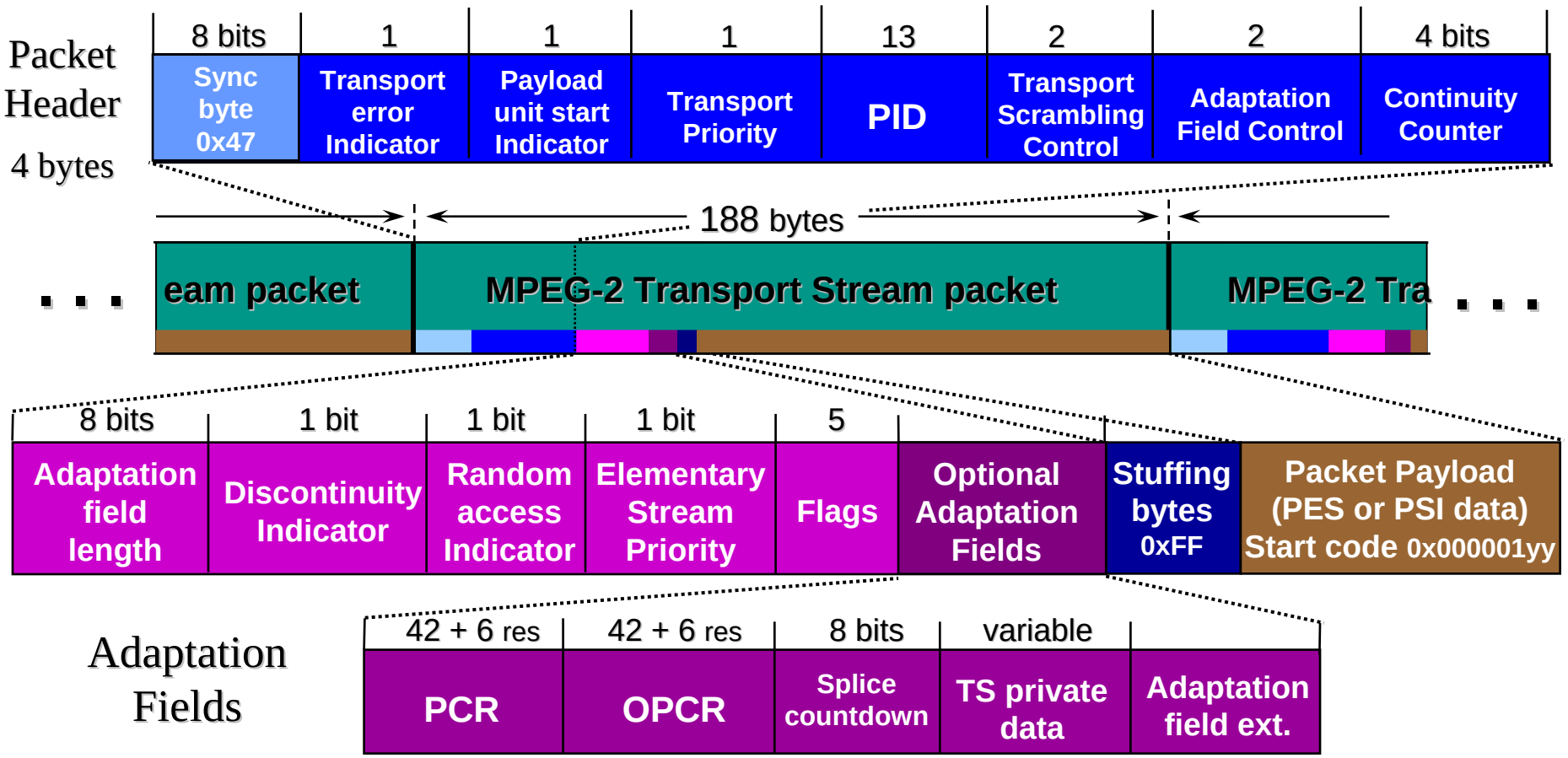
- Quadrature Amplitude Modulation (n-QAM)
  - 5.056941 (64-QAM) or 5.360537 (256-QAM) Mega symbols/sec in 6 MHz, or
  - 6.900 (or 6.875) Msymbols/sec (Mbaud) in 8 MHz channels

Modulation Scheme	MPEG-2 TS Mbit/sec	Total Mbit/sec including FEC	
16-QAM	19.441	21.096	6 MHz channel
64-QAM	26.97035	30.34165	
256-QAM	38.81070	42.88430	
16-QAM	25.435	27.600	8 MHz channel
64-QAM	38.153	41.400	
256-QAM	50.870	55.200	



64-QAM constellation

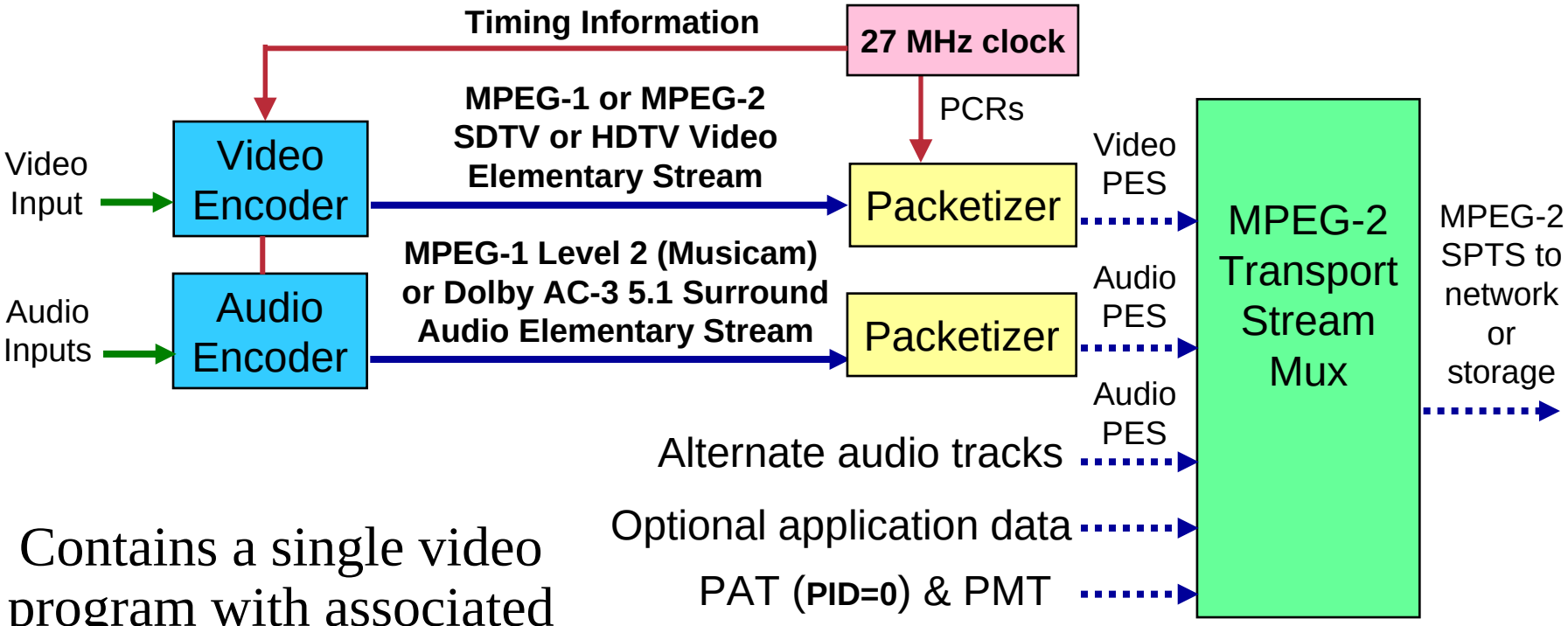
MPEG-2 Transport Stream Details



- Each 188 byte Transport Stream packet contains data from one elementary stream or PSI/SI data as defined by the 13 bit PID value

MPEG-2 Single Program Transport Stream

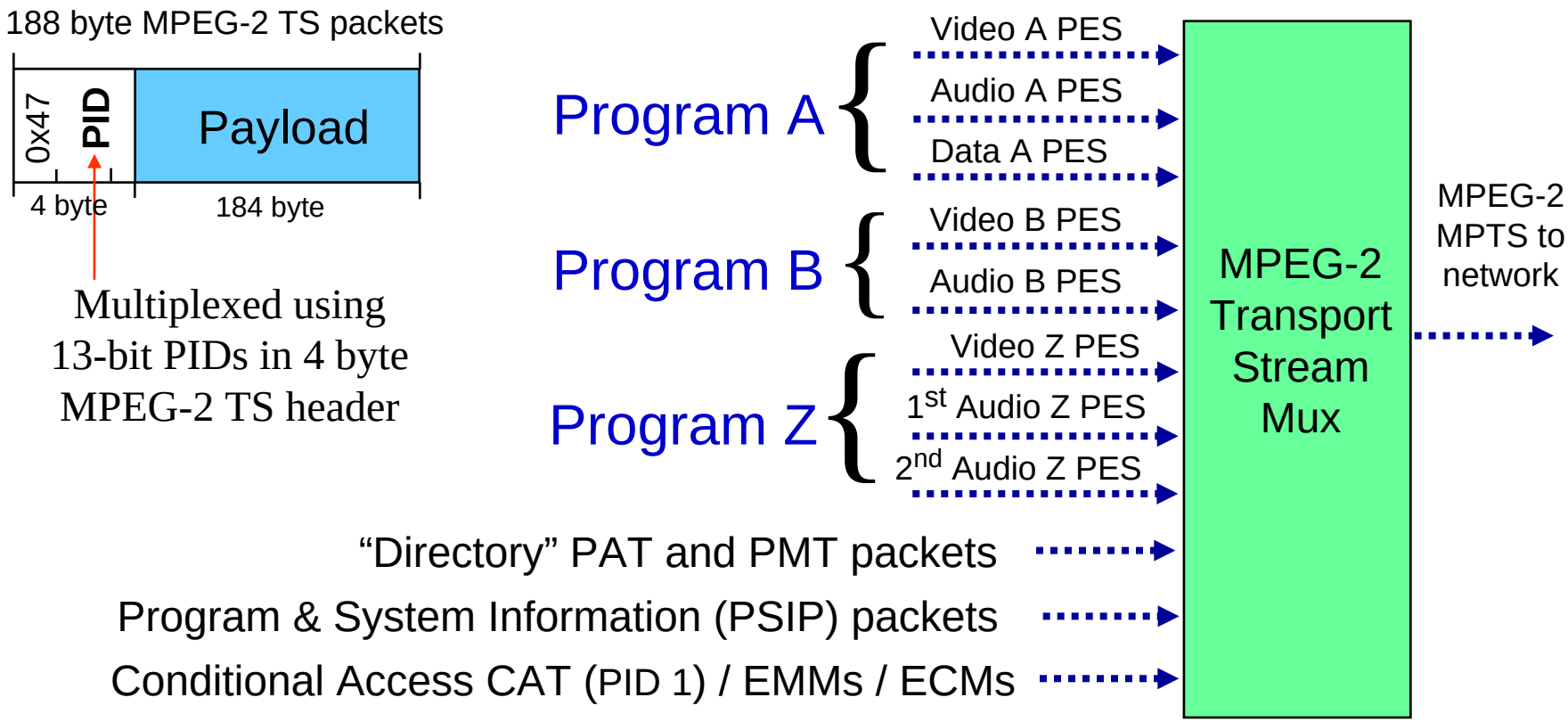
- Transport Stream defined by ISO/IEC 13818-1 or ITU-T H.222.0



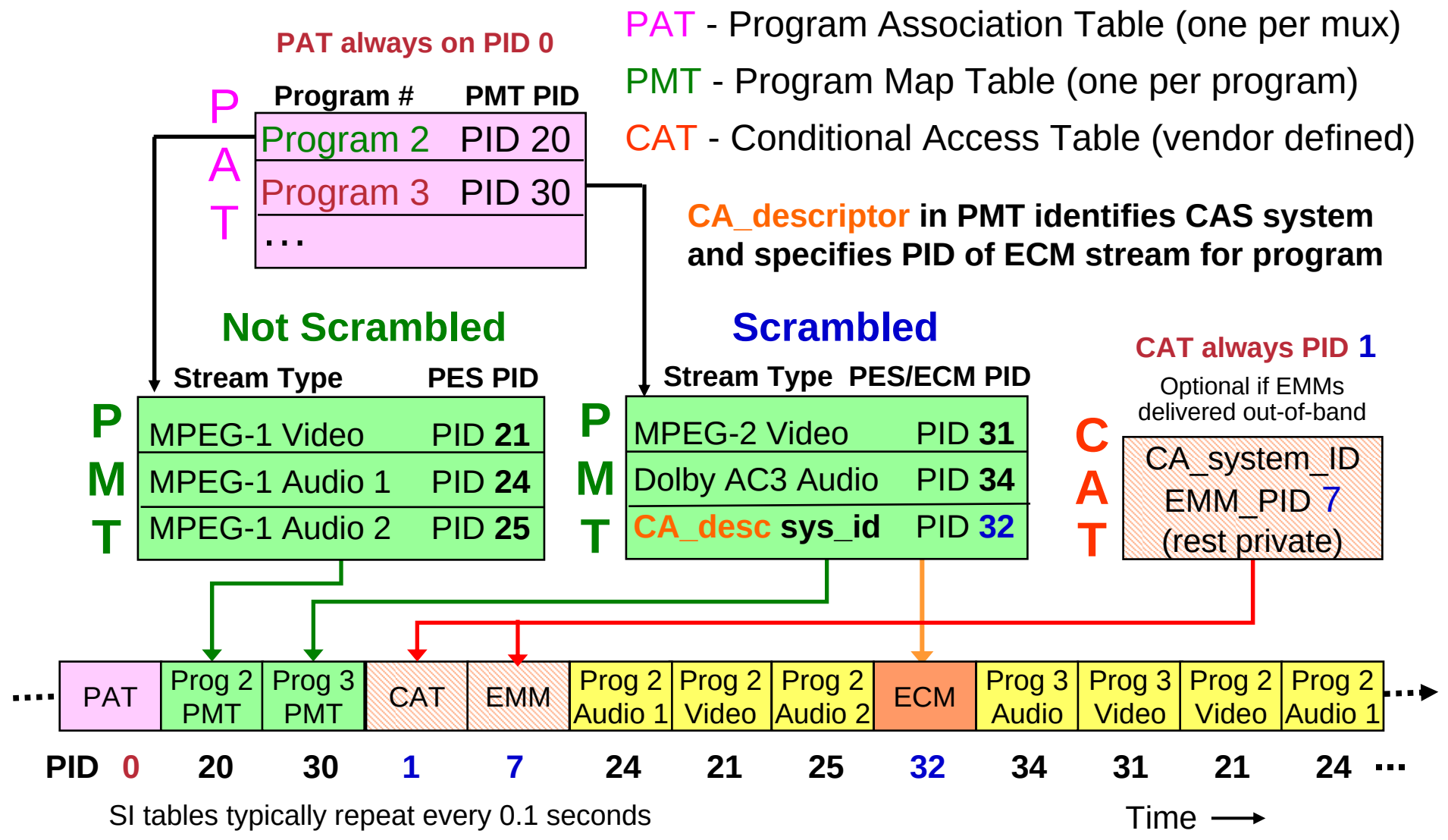
Contains a single video program with associated audio, data, etc.

MPEG-2 Multiple Program Transport Stream

- Multiple programs sharing a single network channel

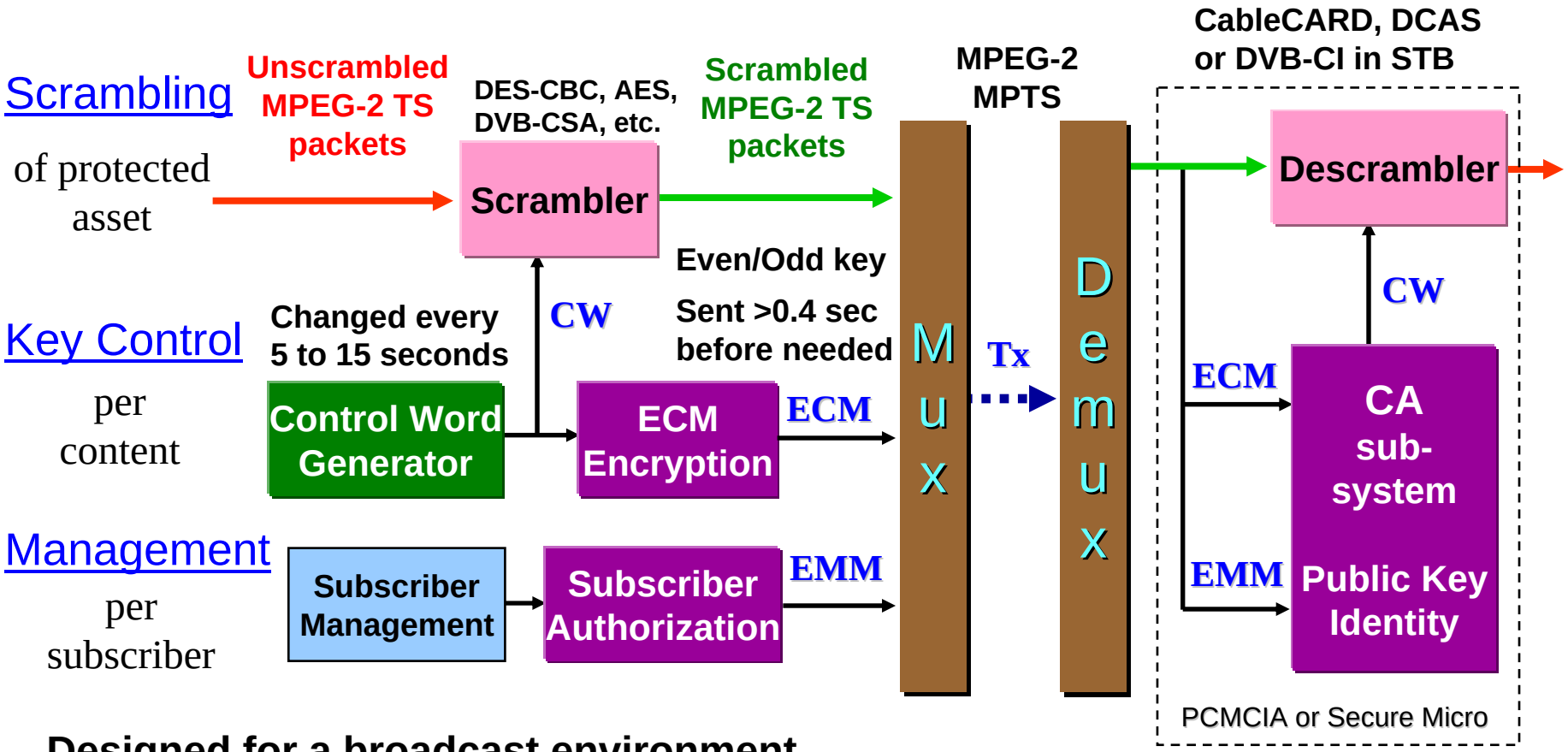


MPEG-2 System Information (SI) Tables



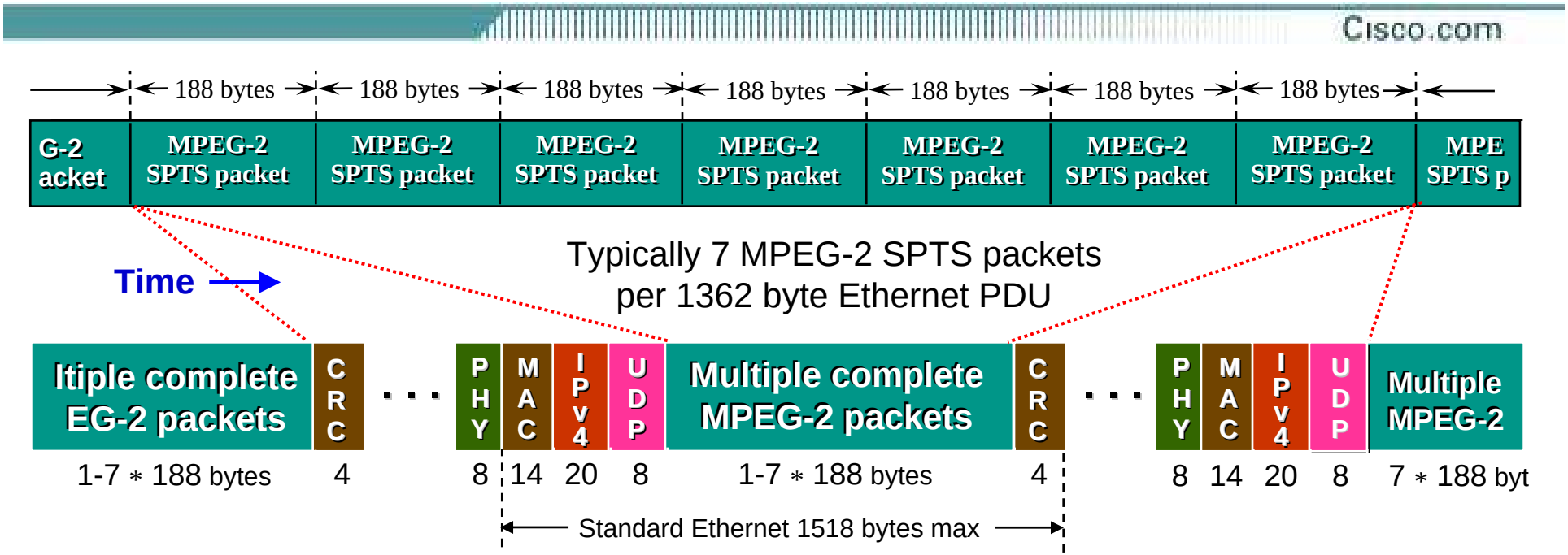
MPEG-2 Conditional Access Architecture

Three nested layers of CAS encryption:



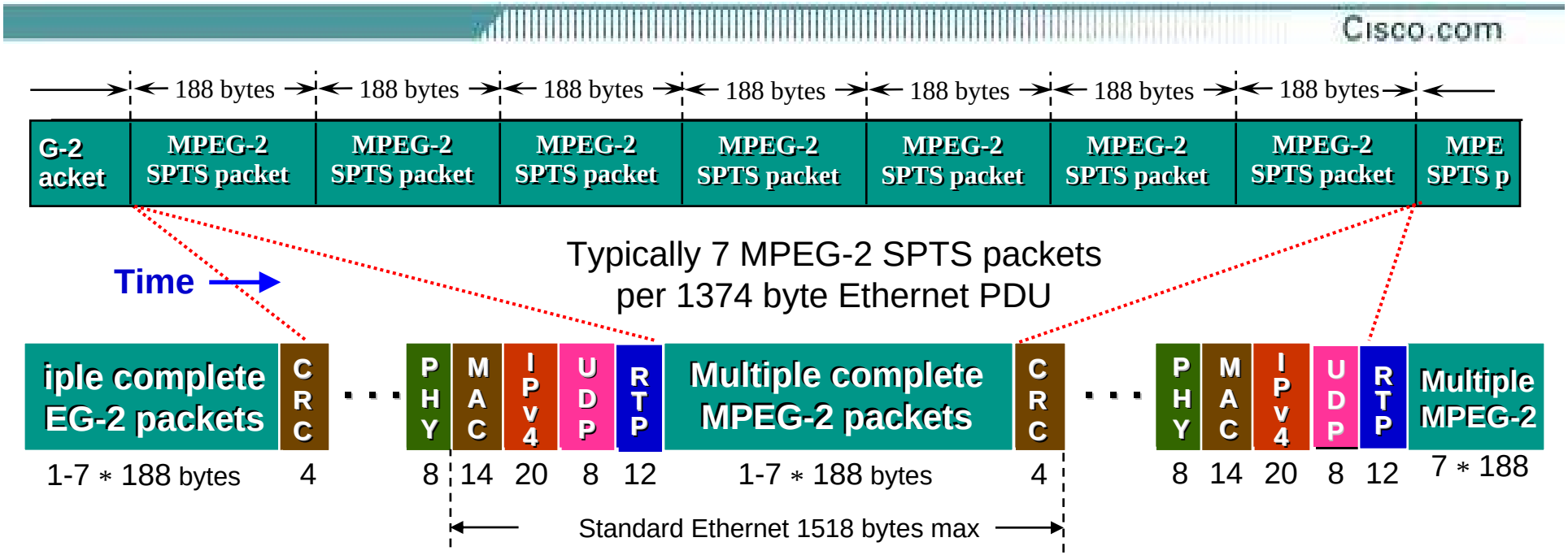
Designed for a broadcast environment

MPEG-2 SPTS over UDP/IP video delivery



- One to seven MPEG-2 Single Program Transport Stream (SPTS) packets per Ethernet frame delivered directly over UDP/IP/Ethernet
  - For each 3.75 Mbps MPEG-2 SD stream, one Ethernet packet every ~2.8 msec
  - For each 15.0 Mbps MPEG-2 HD stream, one Ethernet packet every ~0.7 msec
- Up to 250 streams at 3.75 Mbps/stream per Gigabit Ethernet output
- UDP/IP/GigE delivery overhead is approximately 1 - (7*188/1370) = 4%

MPEG-2 SPTS over RTP/UDP/IP delivery



- Adds RTP-layer time stamp, sequence number, and other capabilities defined by IETF RFC 3550 (RTP) and RFC 2250 (MPEG over RTP)
- Still integral number of MPEG-2 TS packets per RTP message
  - For each 2 Mbps Adv Codec SD stream, one Ethernet packet every 5.264 msec
  - For each 8 Mbps Adv Codec HD stream, one Ethernet packet every 1.316 msec
- RTP/UDP/IP/GigE overhead is approximately 1 - (7*188/1382) = 5%

Video Compression Technology

ISO/IEC JTC1/SC29 WG11 MPEG MOVING PICTURE EXPERTS GROUP

Cisco.com

ISO/IEC-11172 (MPEG-1 ~1988-1996)
ISO/IEC-13818 (MPEG-2 ~1993-2000)
ISO/IEC-14496 (MPEG-4 ~2001-2005)

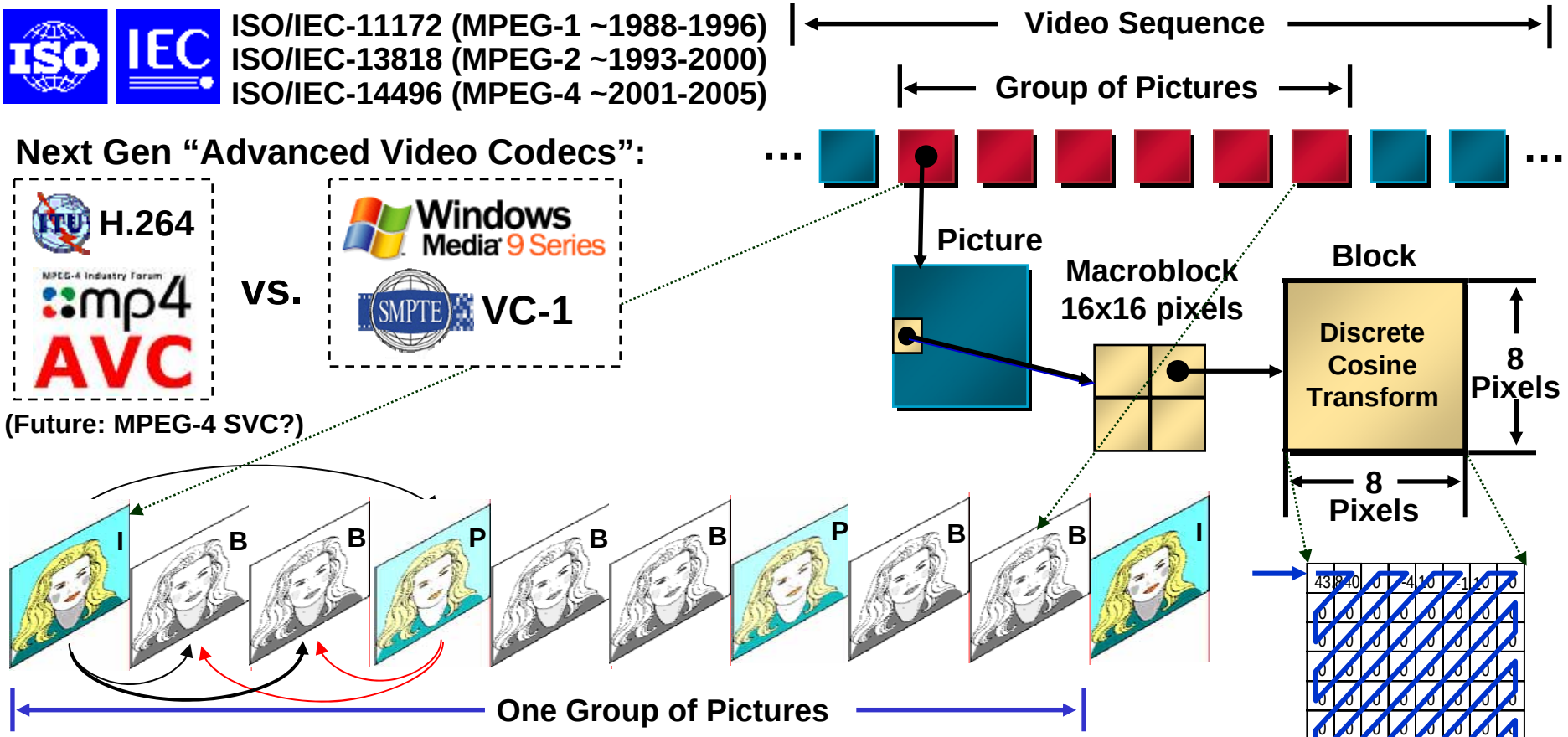
Next Gen "Advanced Video Codecs":

ITU H.264 / MPEG-4 Industry Forum mp4 AVC

vs.

Windows Media 9 Series / SMPTE VC-1

(Future: MPEG-4 SVC?)

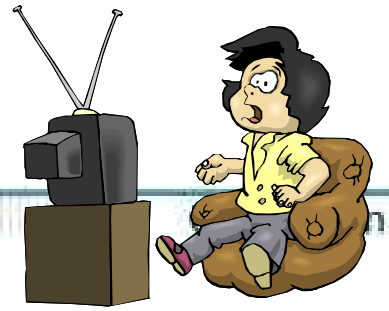


I Frames - Intra-coded only - Reference frame for future prediction.

P Frames - Forward prediction from either previous I or P frames.

B Frames - Bi-directional interpolated prediction from two sources.

PLR Requirements for Video



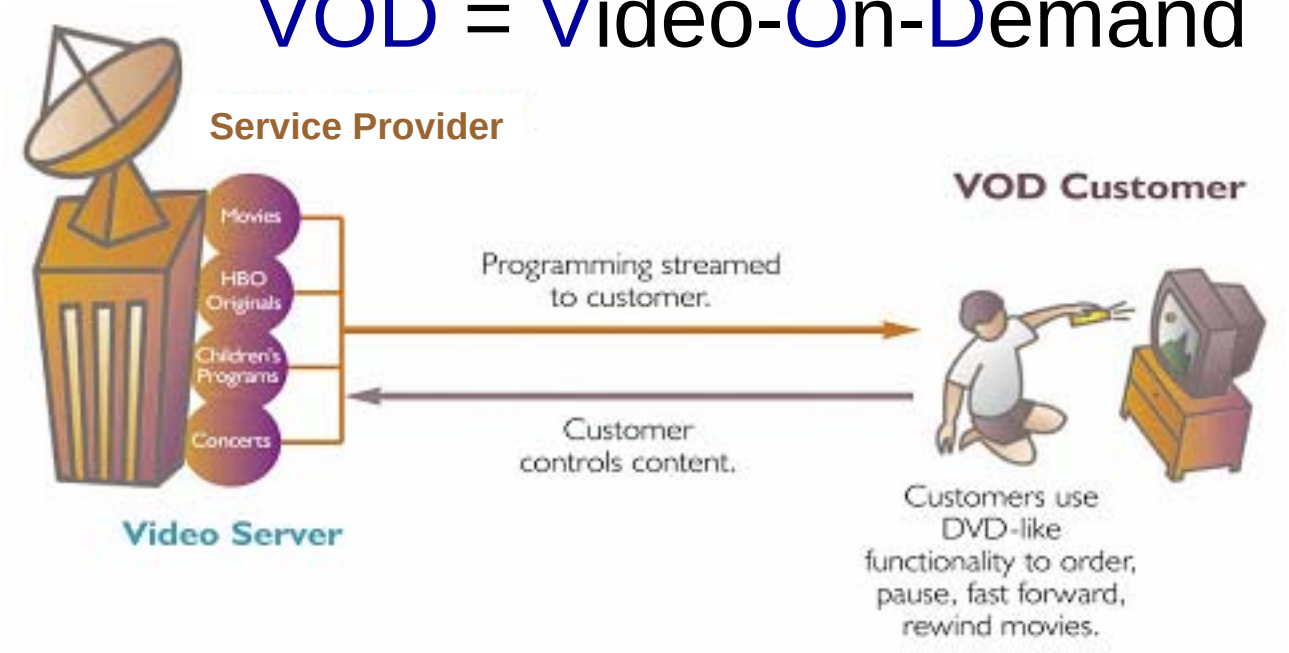
- Most critical: Packet Loss Ratio (PLR)
  - **Video is compressed; Each Packet Carries Multiple Frames**
    Any loss likely causes visible artifact for a varying amount of time
  - **Rule of thumb is no more than one artifact per 2 hour movie**
    For MPEG-2 Standard Definition content @ 3.75 Mbps this translates to a PLR of (7 x 188 x 8) / (3,750,000 x 3600 x 2) = $< 0.390 \times 10^{-6}$
    MPEG-4 AVC or SMPTE VC-1 High Definition requires at least 6 Mbps or PLR of (7 x 188 x 8) / (6,000,000 x 3600 x 2) = $< 0.244 \times 10^{-6}$
  - **Thus packet losses due to congestion MUST be avoided**
    Use Call Admission Control (CAC) + DiffServ prioritization
- Causes for Packet Loss
  - STB Codec Jitter Buffer Overflow or Underflow
  - Router Buffer Overflow
  - Bit Errors on Physical Links
- **Losses due to bit errors on non-fiber links (copper/wireless) may need supplemental Application-level FEC or re-transmissions**
  - A deeper link layer FEC over burdens VoIP and data applications

Video-On-Demand

Putting the Subscriber in Control

Cable's Video-On-Demand initiative

VOD = Video-On-Demand



VOD is about putting the consumer in control in accessing high-quality video-based content

Leverages
Digital Cable or IP
Set Top Boxes (STBs)

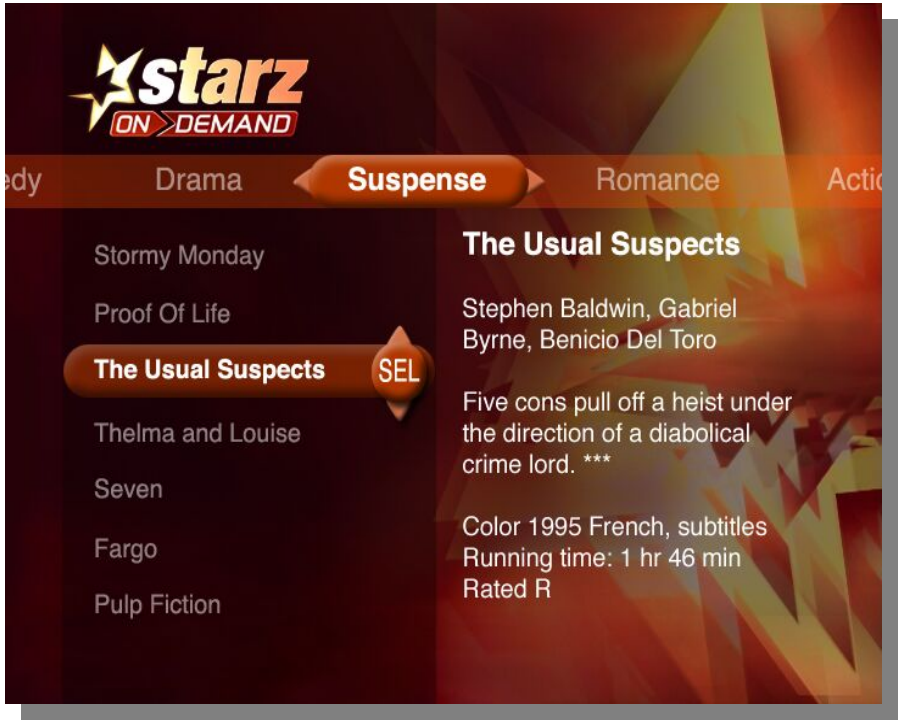
Movies on Demand (MOD)

- Like Pay-Per-View (PPV) except lots of titles available any time the customer wants
- Movies typically rent for a 24 hour period, unlimited views during rental period

- Buy rates 2 to 3 times PPV
- Full visual VCR controls
- No returns or late fees
- No physical tapes or DVDs
- Content can be made available very quickly

Subscription Video-on-Demand (SVOD)

- Fixed monthly charge for unlimited access to a library of content
- Premium Channel (ex. HBO & Starz) SVOD packages with subscription
- New distribution outlet for broadcast and cable network content
- SVOD is popular driving VOD peak utilizations higher
- Average viewing durations much less than 2 hours

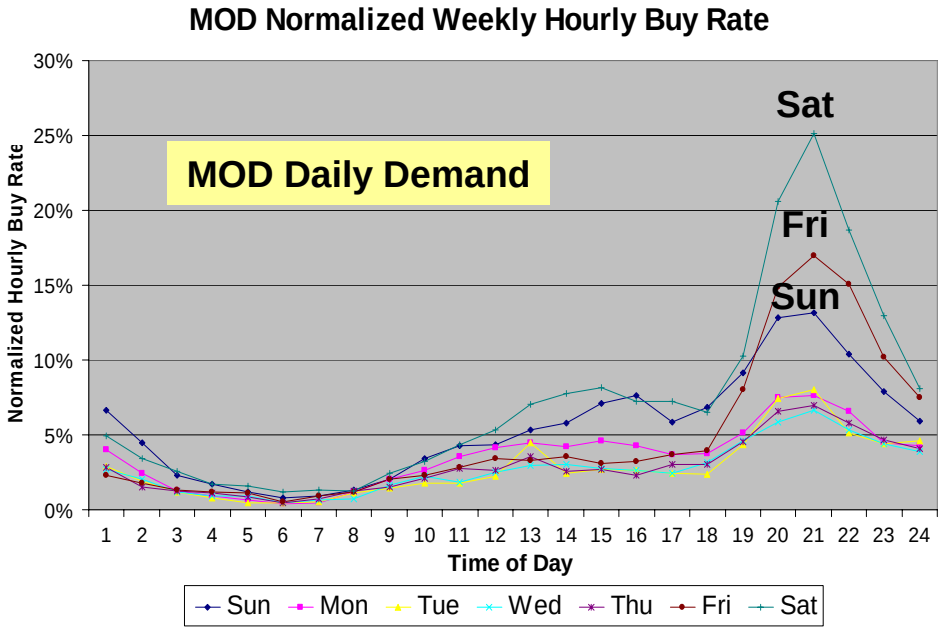


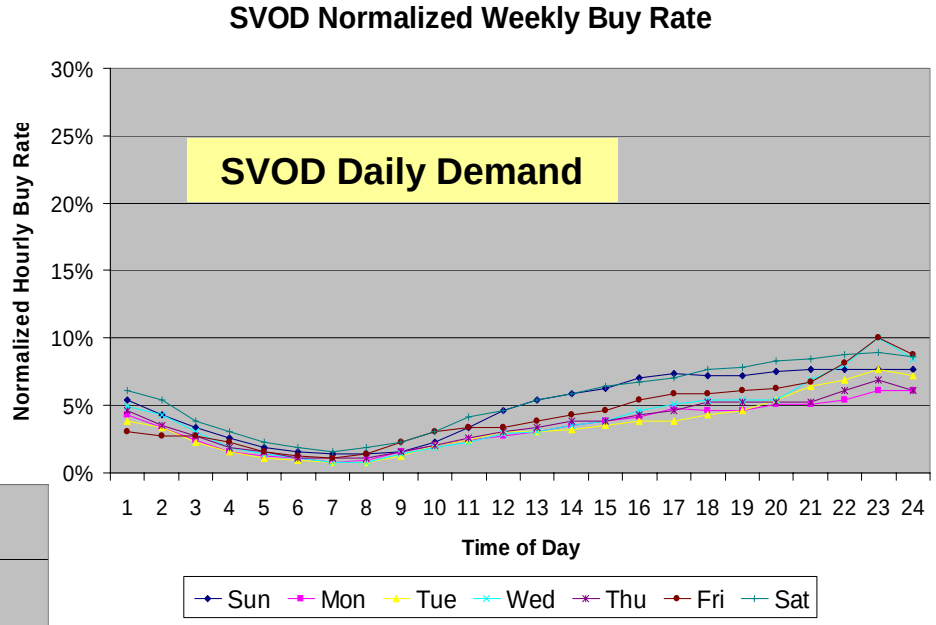
MOD vs. SVOD/FVOD Behavior

MOD Demand is highly peaked on weekends at prime time.

2 Hour Average Session Duration

2 – 6 Hours/Month/Sub





SVOD Demand is “flat” both day-to-day and hour-to-hour

30 Minute Average Session Duration

6 – 10 Hours/Month/Sub

High Definition Video-on-Demand (HDVOD)

- Delivering the promise of Home Theatre
  - Leverages >10M HDTVs already installed in US and >83% annual growth now occurring
- Uses same VOD infrastructure and HD-STBs deployed for broadcast HDTV

- 6 times higher screen resolution
  - HDVOD bit rate is 15 Mbps (4xSD)

- High value content
  - Sporting events, First run movies, Network HD broadcasts, etc.
- Most of the time a VOD system is not at peak capacity
  - Can dynamically decide to accept HDVOD maximizing ROI

Network Personal Video Recorder (nPVR)

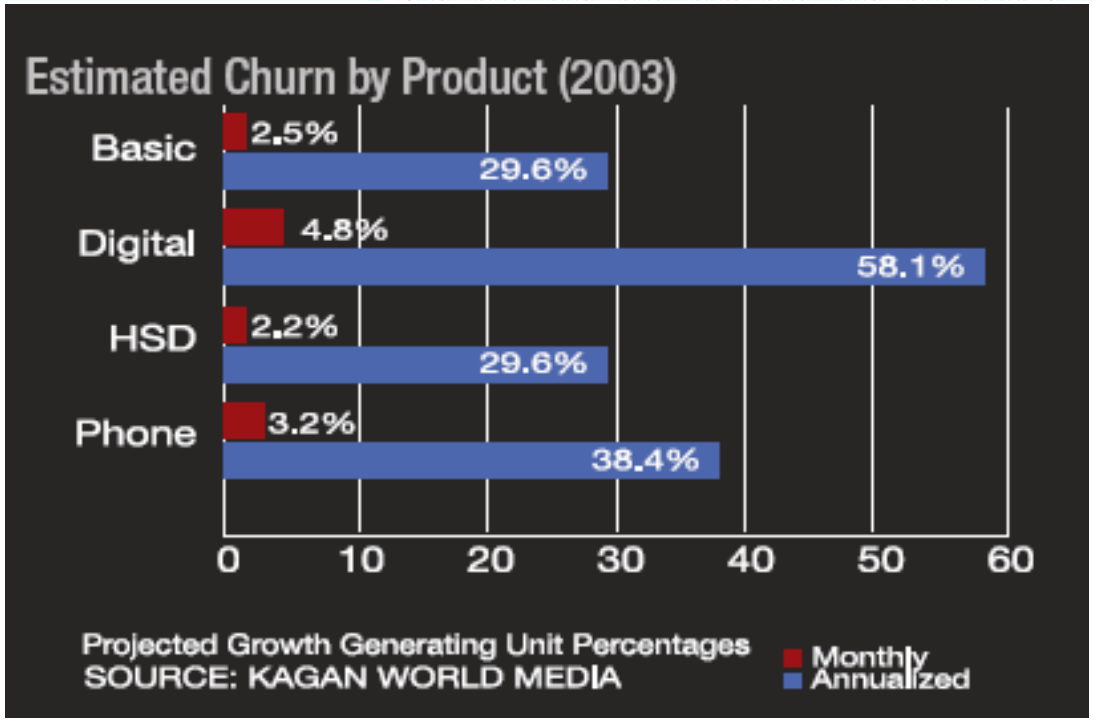
- Broadcast TV whenever you want it
  - One copy of all broadcast content captured and stored on a central headend VOD server
  - Access to broadcast programs via familiar EPG or searching via category, series, episode, actor, etc.
- Without cost or complexity of home PVRs
  - Works with standard digital Set Top Boxes (STBs)
  - Don't have to guess what you might want to watch
  - Don't have to manage limited PVR disk storage
- Headend is most cost-effective place to store broadcasts
  - Much more reliable and less expensive place to store content
  - Headend servers can ensure commercials aren't skipped
- Best solution will be a hybrid of STB & network PVR
  - STB-PVR handles pausing live TV, nPVR enables unlimited content

Examples:
Time Warner Start Over
& Cablevision RS-DVR

Advanced Advertising integrated with VOD

- On-Demand (VOD & PVRs) is devaluing traditional broadcast advertising
  - Can't assume subscriber will see the ads
- New approaches to advertising:
  - More product placement ads within content
  - Spot ads or placement on VOD user interface
  - Long format ads on FreeVOD
  - Targeted or Personalized Advertising
    - Third-party application can select the ads based on a profiles and preferences
    - Spot insertion before, during or after video on demand (VOD) content
    - Video Pump dynamically splices in the ads
  - Interactive Advertising
    - Ads can be delivered based on customer request and even solicit customer input

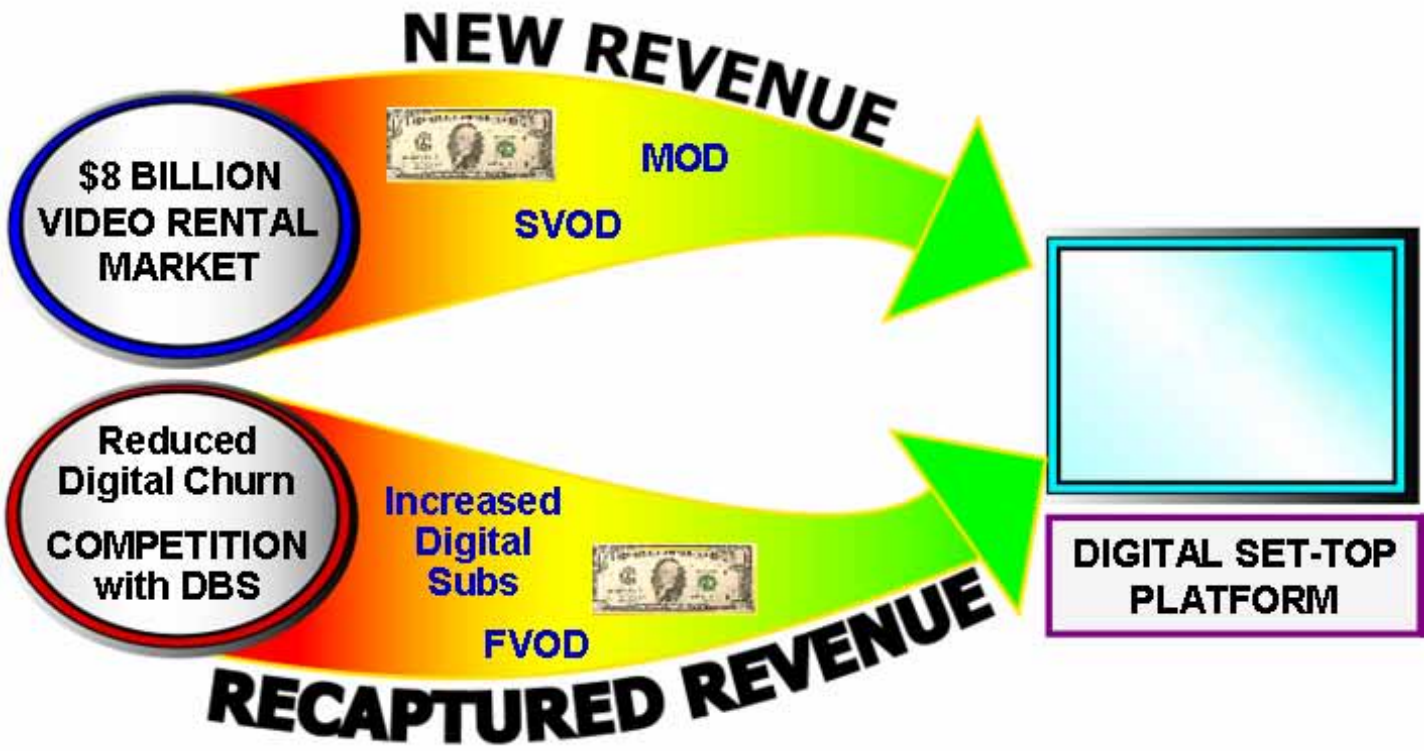
The Big Problem of Subscriber Churn



High cost of installs

- People try but didn't stay with Digital Cable service
  - Digital Cable needed something more to make it unique
- VOD now viewed as a big churn reducer for Digital
  - MOD, SVOD & FreeVOD is today significantly pulling in greater Digital Tier and Premium Channel revenue and reducing churn

Therefore VOD delivers Revenue in 2 ways



- **Directly:** MOD increases PPV revenue, plus new SVOD revenue
  (Since Dec 2003, VOD buys exceeded total PPV buys)
- **Indirectly:** Attracts new subscribers to the Digital TV service
  Reduces subscribers dropping service by 15-25%

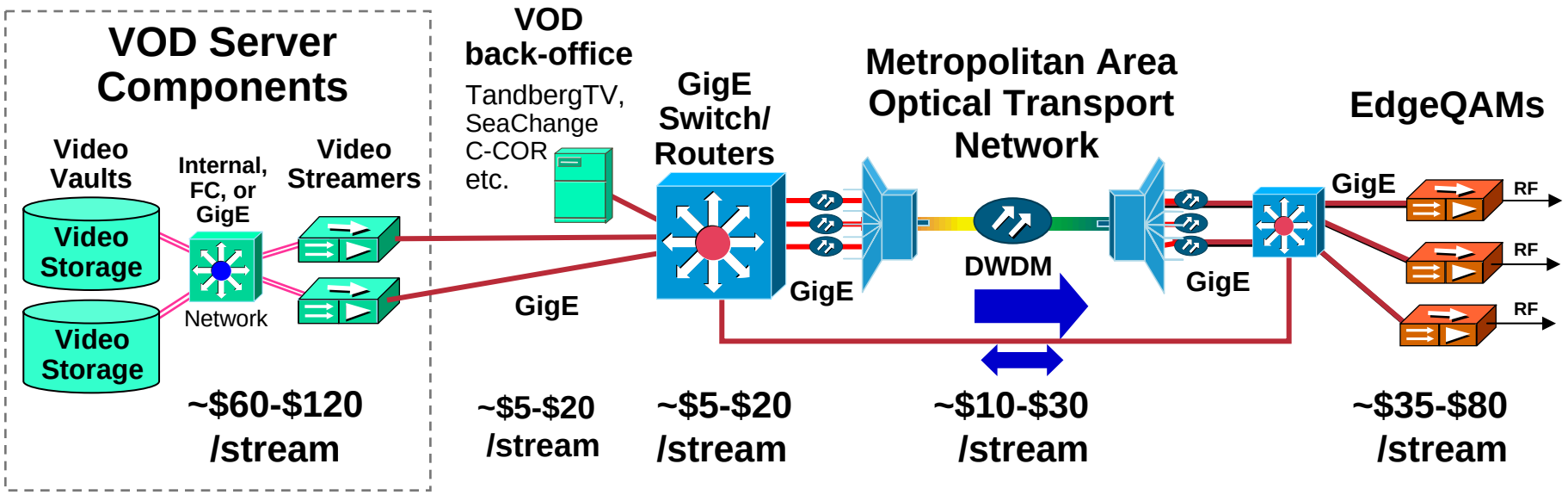
HFC's Targetable Bandwidth enables VOD

- Each "Service Group" gets its own RF Spectrum of channels

Homes passed per node or Service Group	x	% CATV subscribers	x	% Digital subscribers	x	Peak Simultaneous use rate
~ 1000	x	~ 67%	x	~ 40%	x	~ 15%
(typically 500 to 2000)		(common in US)		(and growing)		(6% to 20% today)

x	MPEG-2 Mbps/stream	/	256-QAM Mbps / 6 MHz RF channel	=	RF Channels needed to support VOD service
	~ 3.75	/	~ 38	=	~ 3.95
	(CableLabs standard: 3.75 Mbps for SD 15.00 Mbps for HD)		(50 Mbps/QAM in Europe using 8 MHz channels)		(typically 2 to 8 channels allocated per Service Group)

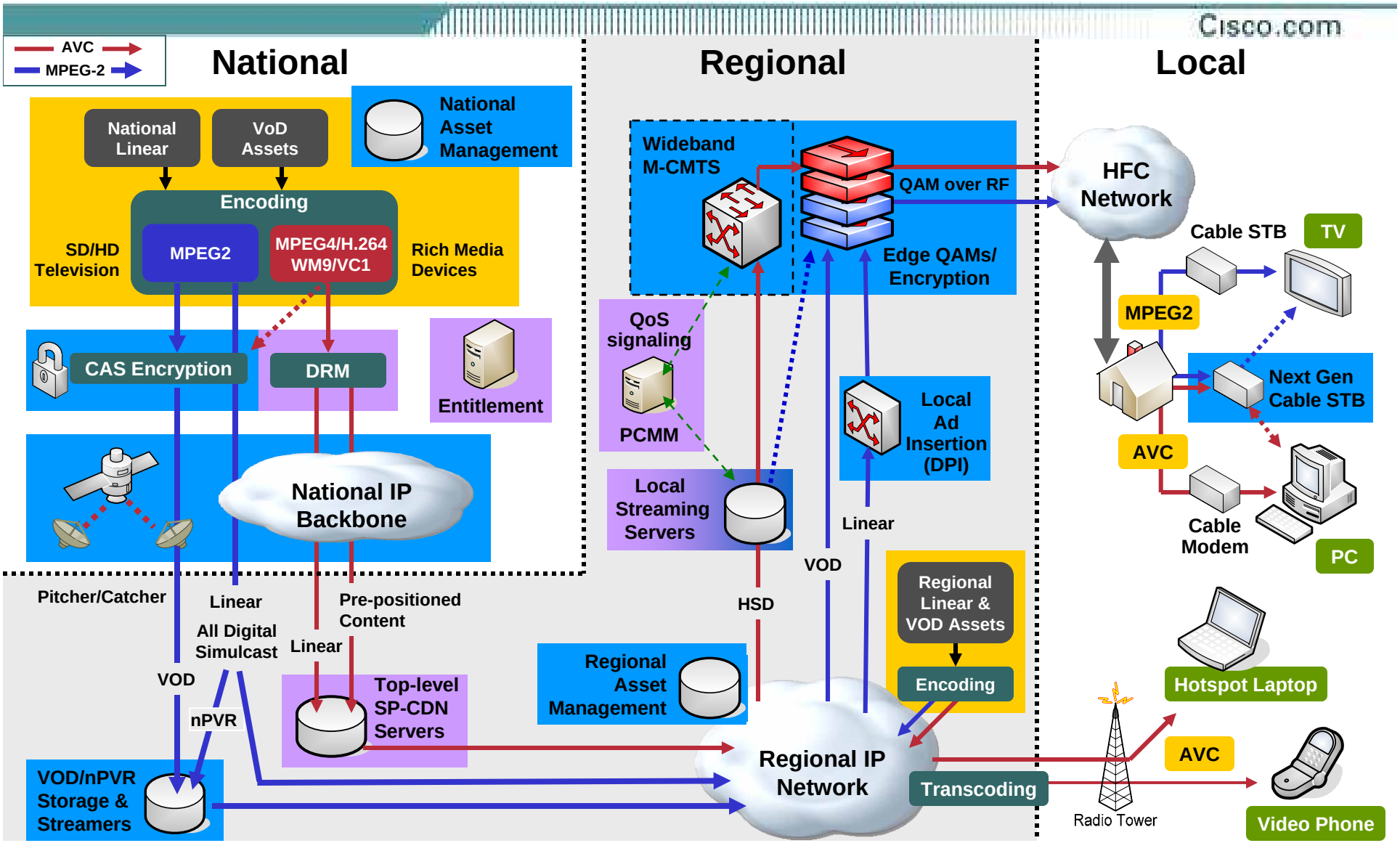
Cable VOD Video Delivery Architecture



(Typical ASP based on 3.75 Mbps CBR MPEG-2 streams)

- Video Server & EdgeQAMs are major portions of per stream cost
  - Currently sized for approximately 10-15% peak concurrency
  - Leverages existing digital cable set top boxes & HFC network
- Video Server consists of video storage, switching, and streaming
  - Market is looking to disaggregate it into its separate components

“Cable” Video Architecture Evolution to IP



High Speed Data and Voice

Building the Cable Infrastructure

CableLabs in Louisville CO

CableLabs®

Cisco.com

- Background
  - Founded in 1988 as a non-profit R & D consortium, financed by MSOs
  - It's charter is to serve the cable industry by:
    1) Researching and identifying new broadband technologies
    2) Authoring specifications
    3) Certifying products
    4) Disseminating information
- Current Projects
  - **DOCSIS**® - cable modem technology
  - **PacketCable**™ - real-time multimedia services over cable
  - **CableHome**™ - extends MSO services into the home
  - **OpenCable**™ - develop "plug-and-play" retail DTV & STB standards
  - **Go2Broadband**™ - web portal to locate MSO services
  - **VOD Metadata** - distribution of VOD content to MSO divisions
  - **Digital Advertising** - develop of Digital Program Insertion standards
- IPTV Investigations
  - CableLabs looking at IPTV internally and via ITU=T SG 9 route to better leverage IP and offer MSO's services to more devices, modes and locations
  - CableLabs monitoring various SDOs (e.g. ITU-T IPTV FG)

www.cablelabs.com

Data **O**ver **C**able **S**ervices **I**nterface **S**pecifications

1999 DOCSIS 1.0 (High Speed Internet Access)

- Drove Modem prices from $300 in 1998 to < $30 in 2004

2001 DOCSIS 1.1 (Voice, Gaming, Streaming)

- "Quality of Service" and dynamic services, a MUST for PacketCable™
- Service Security: CM authentication, secure download; operations tools

2002 DOCSIS 2.0 (Increased Capacity for Symmetric Services)

- More upstream capacity than DOCSIS 1.0 (x6) & DOCSIS 1.1 (x3)
- Improved robustness against interference (A-TDMA and S-CDMA)

2003 eDOCSIS™ (DOCSIS in more than just Cable Modems)

- Embedded DOCSIS in MTA, RG, next gen cable STBs, etc.

2004 DSG (Move from proprietary OOB to DOCSIS)

- **D**OCSIS **S**et-top box **G**ateway supports transition to DOCSIS-based NG STBs

2006 Modular CMTS™ (Separates PHY from MAC in headend CMTS)

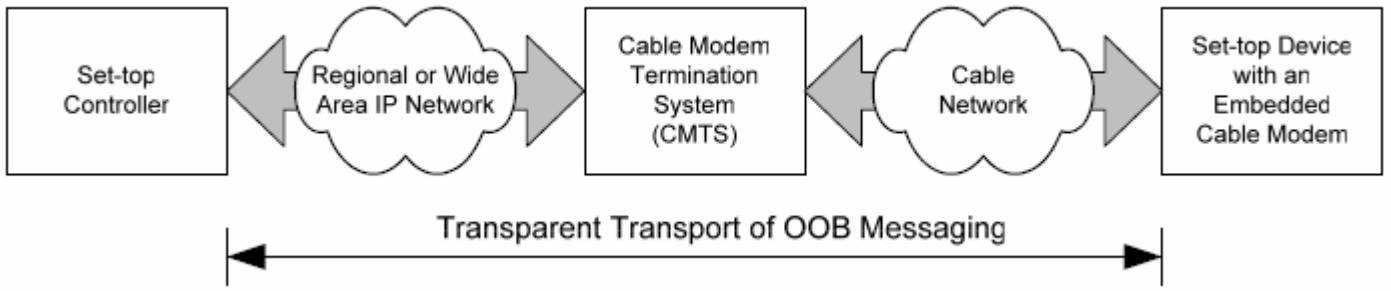
- Leverage cost-effective VOD EdgeQAM technology for CMTS
- Enable transition to common pool of QAM resources for data, voice and video

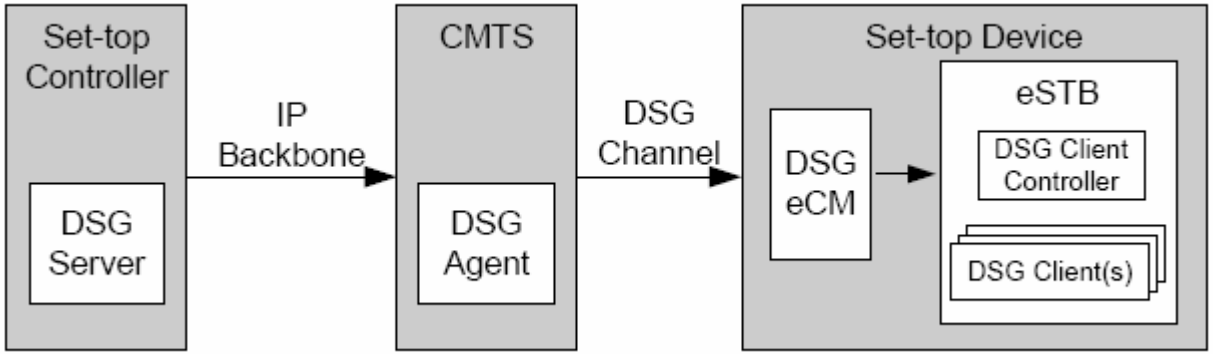
2006 DOCSIS 3.0 (Improve operation in a Broadband IP world)

- Channel Bonding, IPv6 support, enhanced IP Multicast

www.cablemodem.com

DOCSIS Set top box Gateway (DSG)



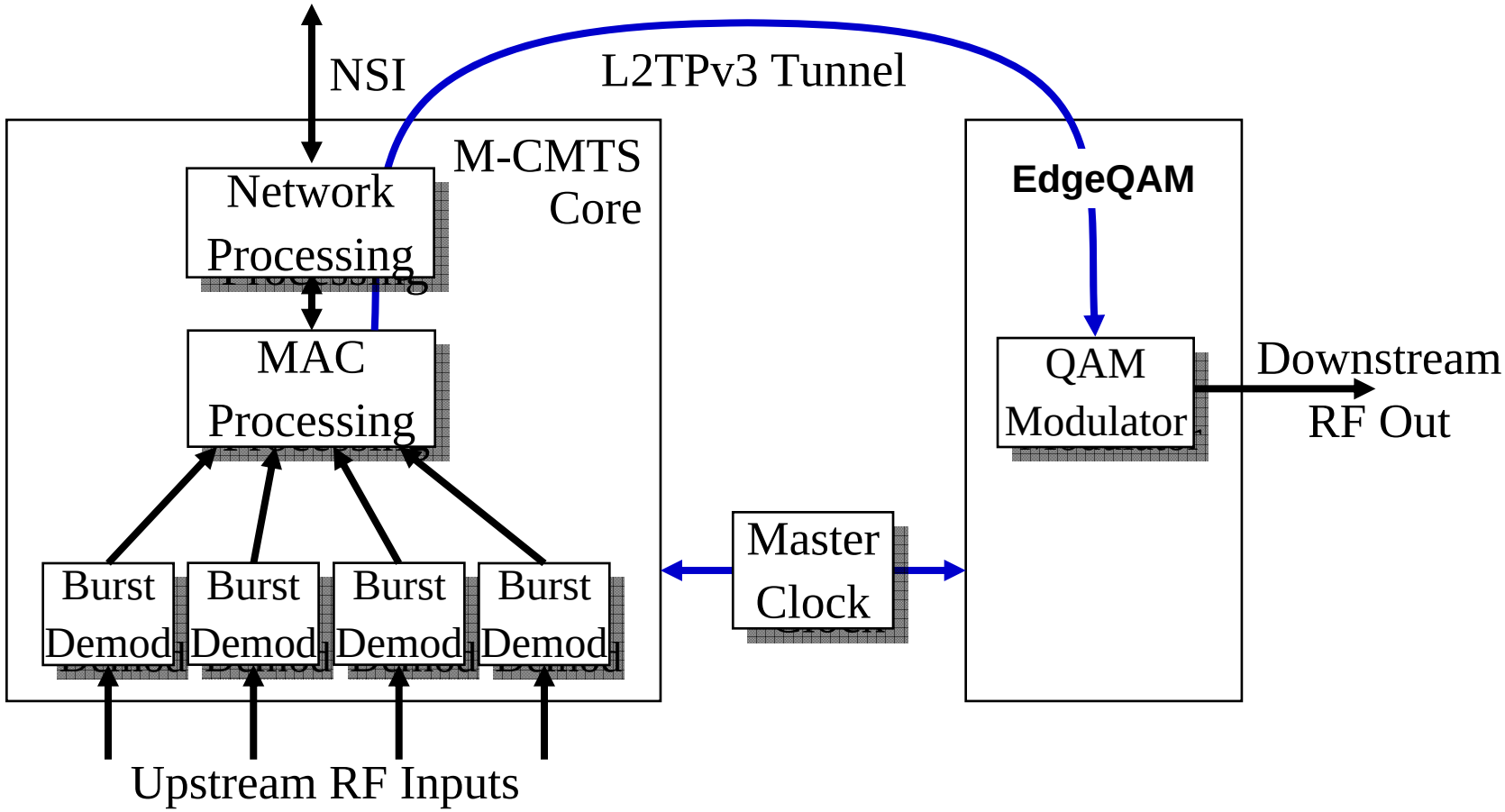


- Supports one-way operation over DOCSIS
  - If DOCSIS upstream is down, traditional broadcast Cable STBs services remain unaffected

www.cablemodem.com/specifications/gateway.html

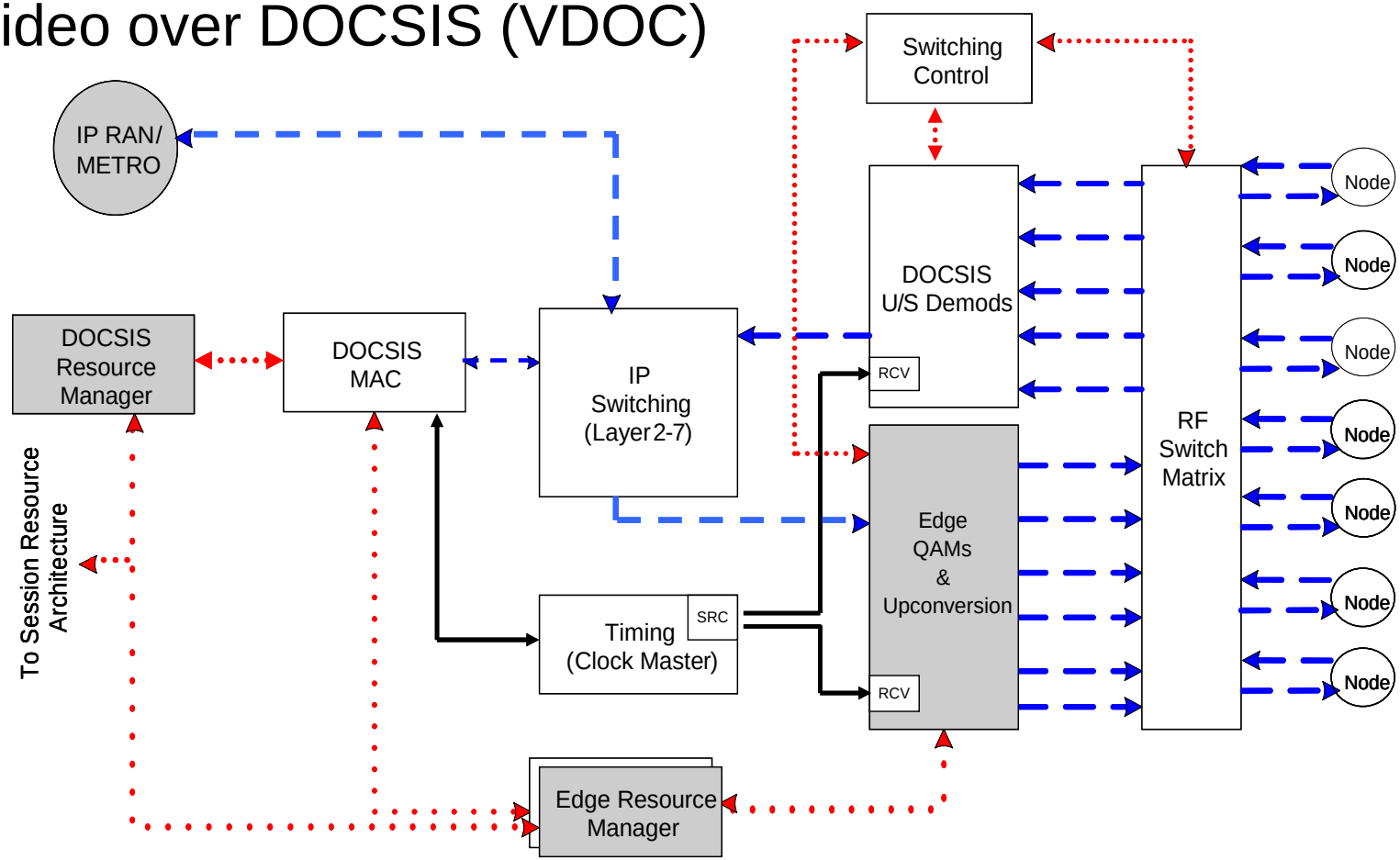
Modular CMTS (M-CMTS)

Tomorrow's CMTS is Modular



Modular CMTS Architecture

- Enabler of cable's movement to IPTV via Video over DOCSIS (VDOC)



www.cablemodem.com/specifications/m-cmts.html

DOCSIS 3.0 Functionality

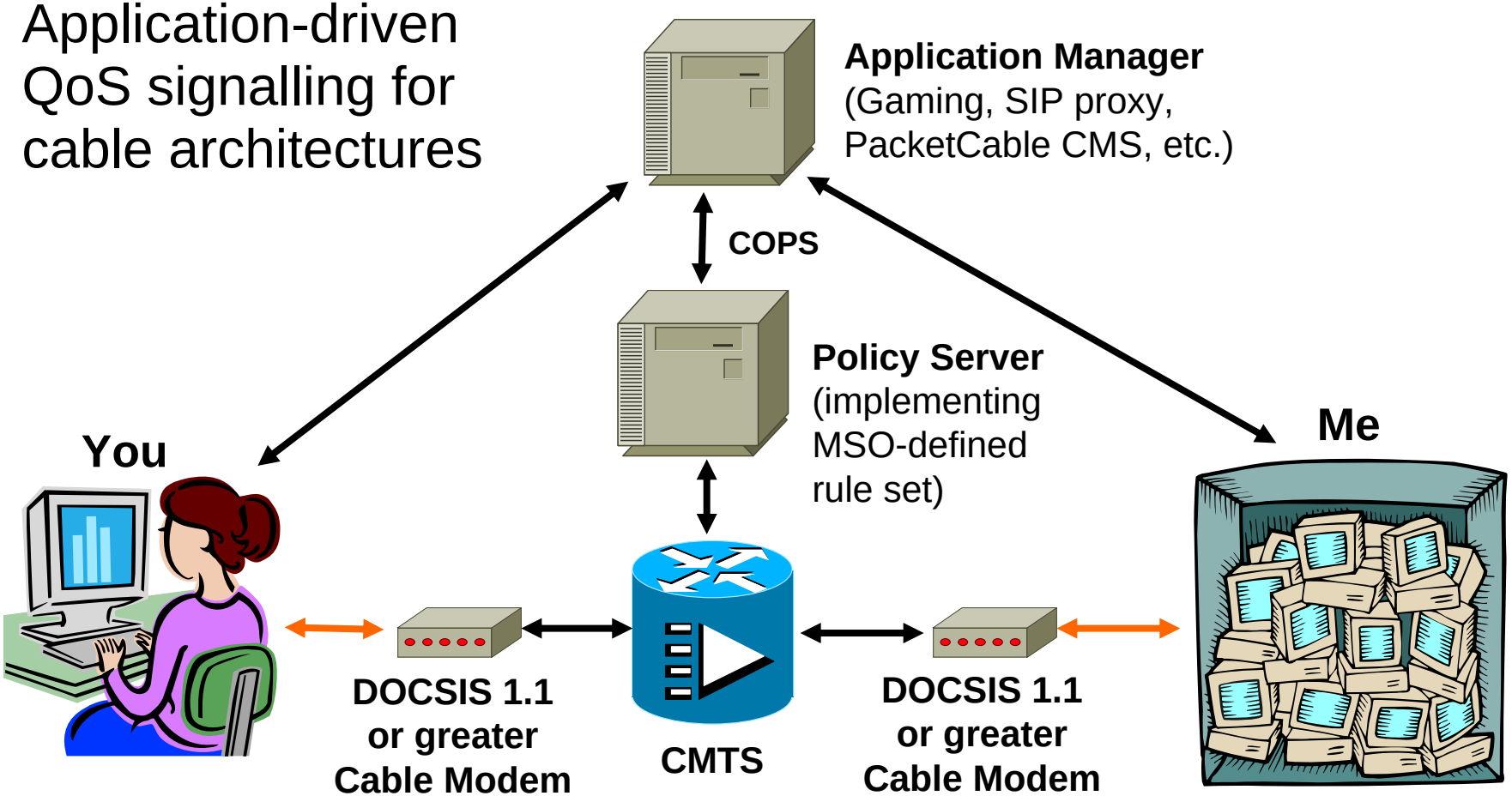
- **MAC Layer**
  - DS Channel Bonding
  - US Channel Bonding
- **Network Layer**
  - IPv6 support
  - IP Multicast Enhancements (SSM, QoS, IGMPv3/MLDv2)
- **Security**
  - Certificate Revocation Mgmt
  - Runtime SW/config validation
  - Enhanced Traffic Encryption
  - Certificate Convergence
  - Secure Provisioning
- **Network Management**
  - Standard Flap List
  - Extension of IPDR
  - Capacity Management
  - Enhanced signal quality monitoring
- **Commercial Services**
  - T1/E1 Circuit Emulation Support
- **Physical Layer**
  - Switchable 5-65MHz US Band
  - S-CDMA Active Code Selection

Specifications were released
August 7, 2006

www.cablemodem.com/specifications/specifications30.html

PacketCable Multi-Media Architecture

- Application-driven QoS signalling for cable architectures



www.packetcable.com/specifications/multimedia.html

PacketCable 2.0 Architecture

CableLabs leveraging 3GPP IMS

Cisco.com

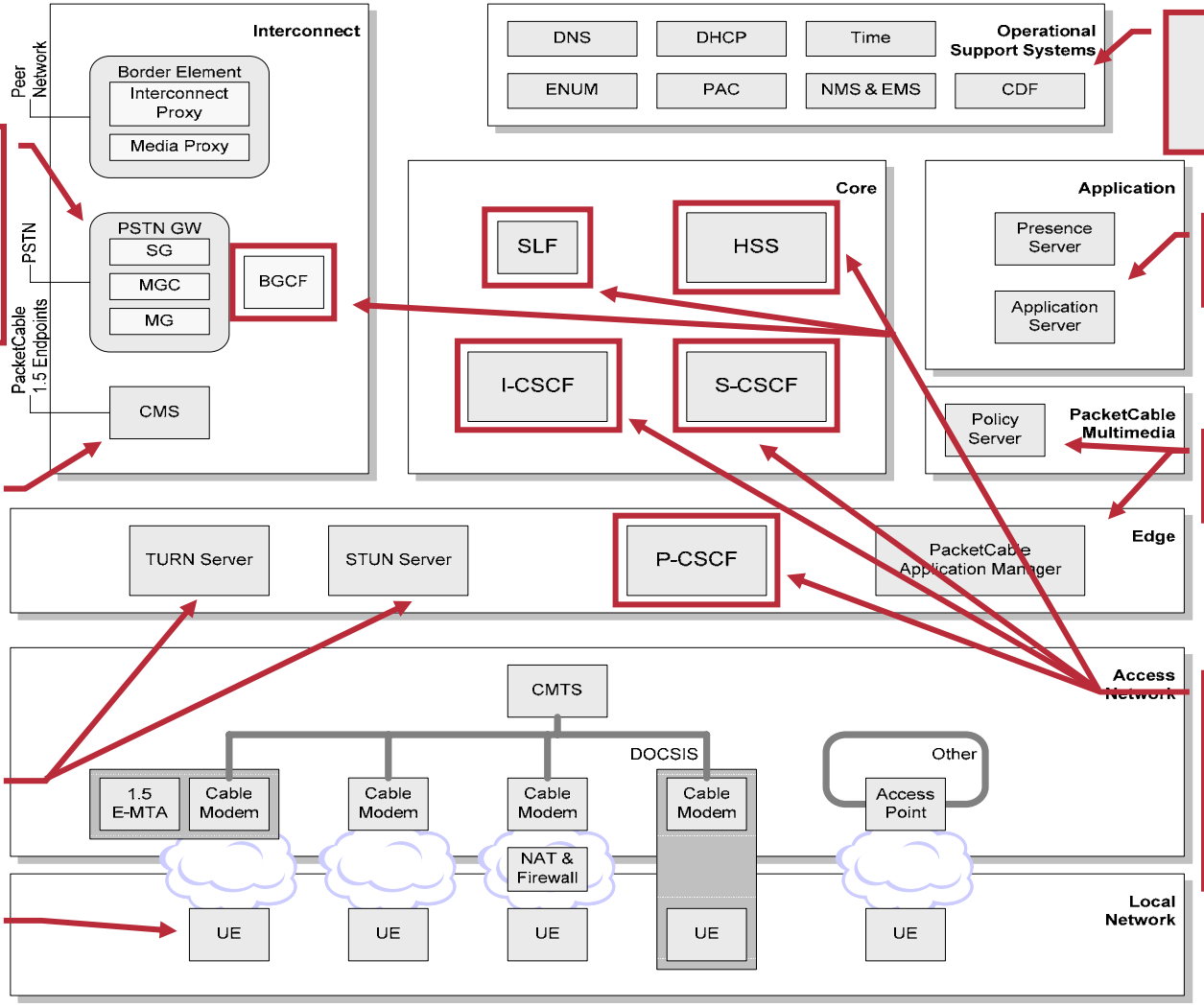
Also now ITU-T IPCablecom2

Re-use PacketCable PSTN gateway components

Compatible with E-MTAs

NAT & Firewall Traversal

Different types of clients



Provisioning, Management, Accounting

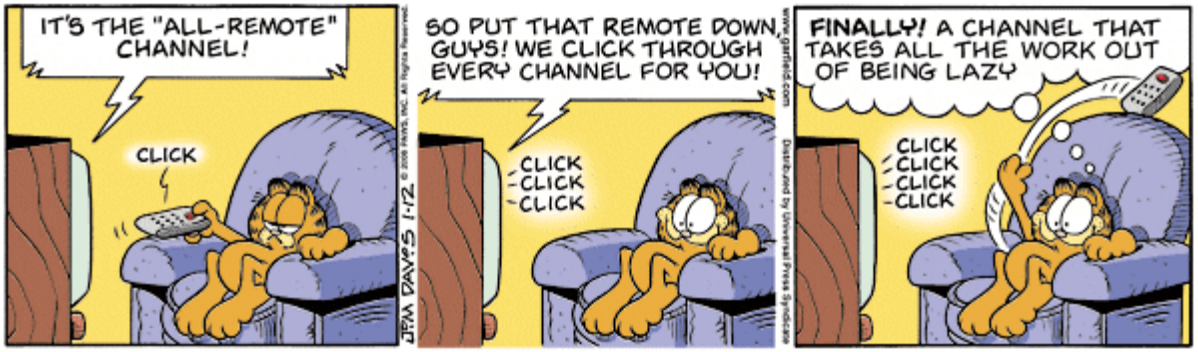
IMS Service Delivery

PacketCable Multimedia

IMS Elements adopted and enhanced for Cable

www.packetcable.com/specifications/specifications20.html

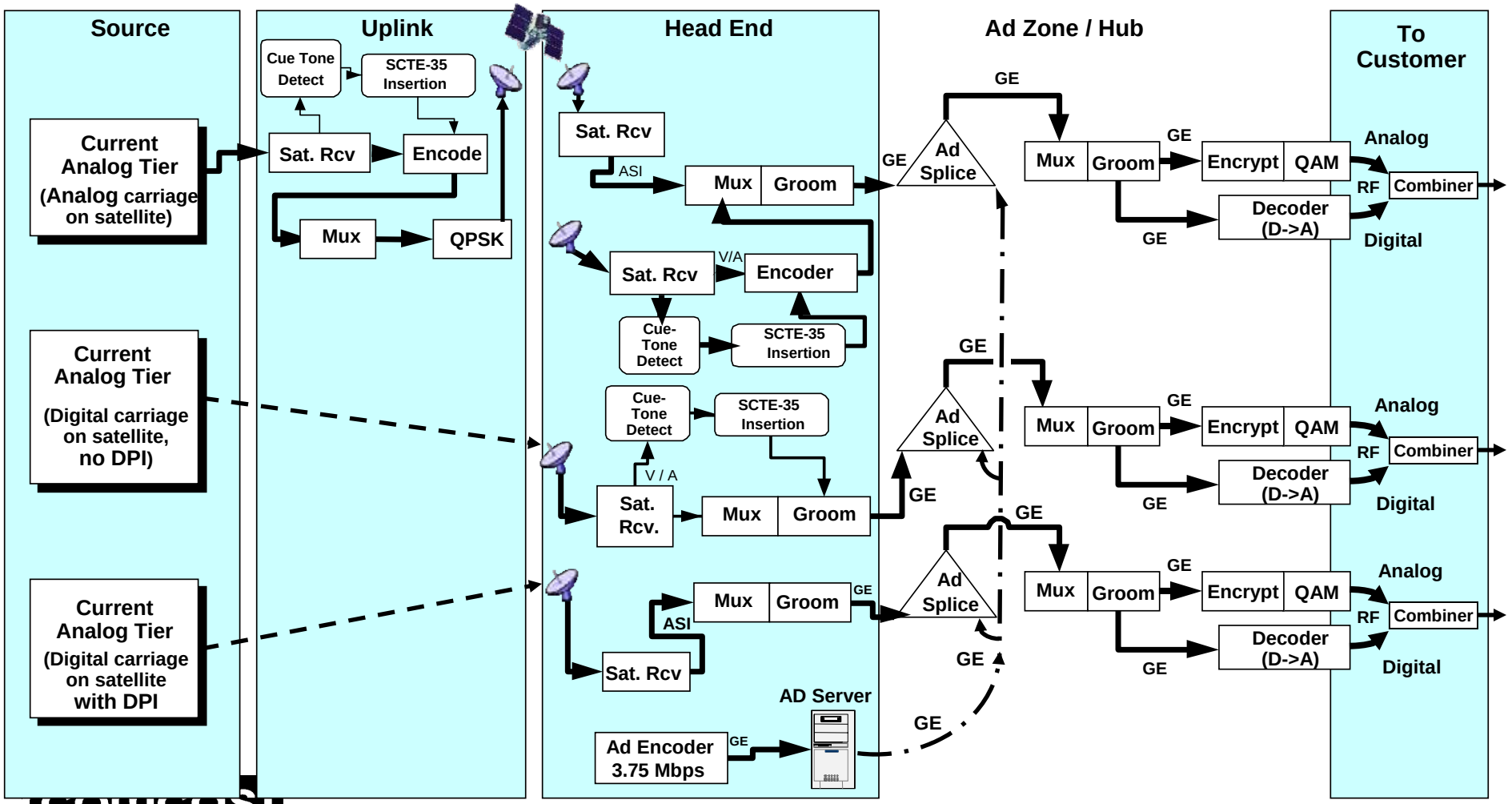
Next Generation Digital Video



Moving beyond Channel Change

Digital Simulcast Architecture

- Video delivery to hub in digital, conversion to analog at edge

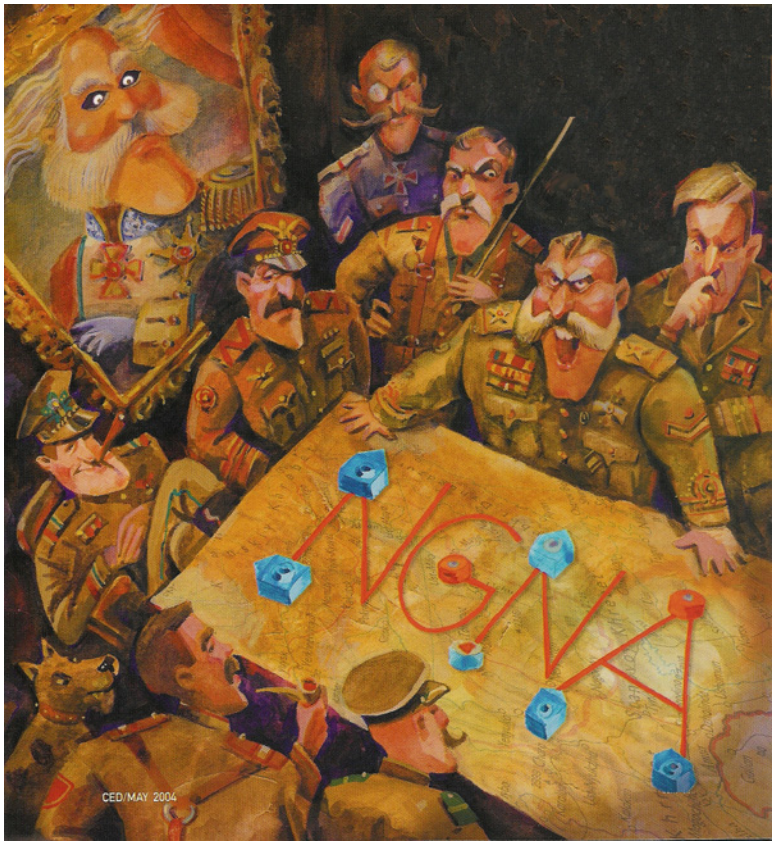


What was NGNA?

- NGNA = Next Generation Network Architecture
  - An LLC & Project initiated by Comcast, Time Warner, and Cox

    114 page RFI was issued
    January 30, 2004
    >80 responses received by
    March 26, 2004
    Going forward plan issued
    July 26, 2004

    Modelled on successful
    1996-8 MCNS/DOCSIS effort
  - Headend arch sent to CableLabs
    STB arch led to Comcast RNG
- Defined a open next generation
  Integrated Multimedia Architecture
  for digital cable going forward



CED cover article May 2004

Goals of NGNA

Cisco.com

- Drive down the cost and enable retail STBs
  - and create a well-defined CPE Application Environment
- Support transition to All-Digital services
  - and eventually a transition to All-IP
- Provide a transition to open cost-effective CAS
  - eliminating the CAS lock optionally without CableCARD
- Provide expanded Capacity and Scalability
  - taking advantage of next-generation codecs, eliminating analog channels, increasing OOB performance, etc.
- Define open and improved resource management and head-end interfaces for advanced services
  - including self and rapid new service provisioning

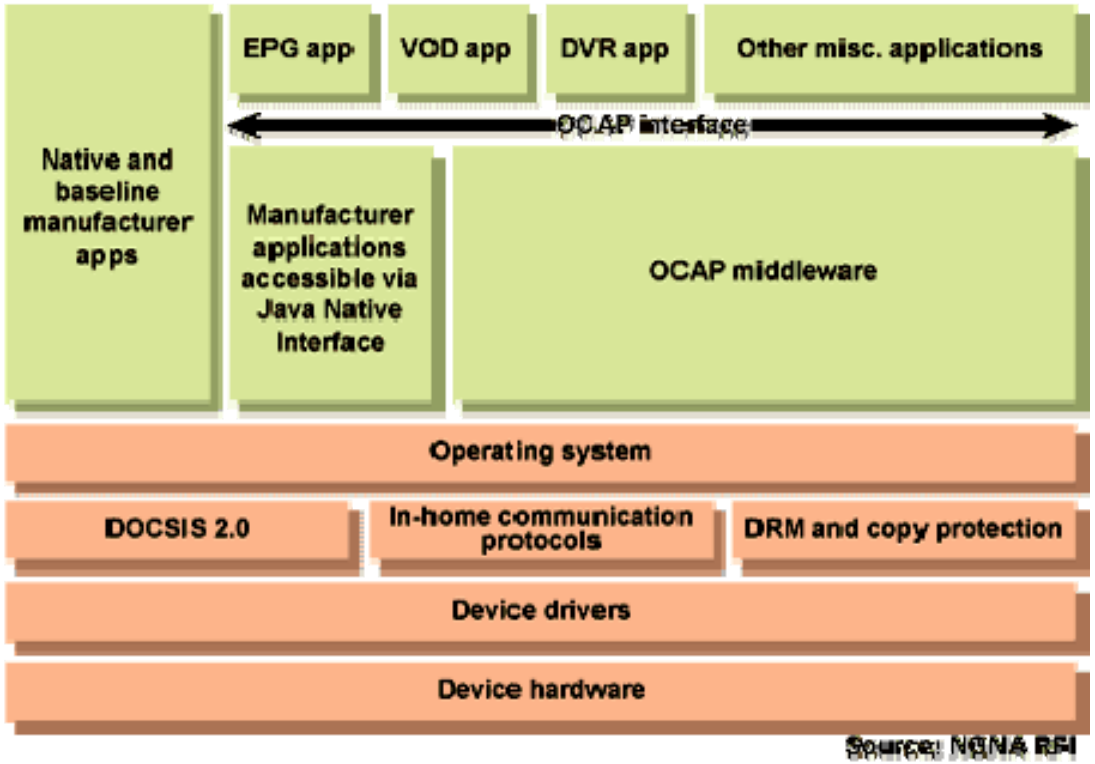
NGNA Architectural Areas

Cisco.com

- Digital Set Top Boxes (dSTB = SVD) for the Home
  - New IP/DOCSIS + MPEG-2 TS interactive SVD architecture
  - Eliminates NTSC analog and proprietary OOB support
  - Drives to low cost, while making VOD and OCAP standard
- Universal Edge (3G CMTS) for the Headend
  - Integrated Data, Voice (VoIP), plus Video support
  - Led to CableLabs M-CMTS and DOCSIS 3.0 efforts
- Next Generation On Demand (NGOD) Architecture
  - Open APIs between VOD architectural components
  - Management of sessions, bandwidth, content location, etc.
  - Auto-discovery and registration of resources
  - Decouples Edge Resource Manager (ERM) and CAS support

NGNA STB Software Architecture

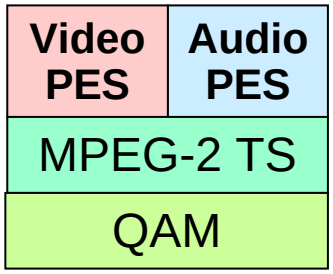
- Middleware Std: Open Cable Applications Platform (OCAP)
  - JAVA & DVB-MHP based, available via OCAP Development LLC
- Comcast (GuideWorks) and Time Warner (MystroTV) developing:
  - OCAP-based EPG+VOD+DVR applications
- Third-party downloadable apps
  - (Games, etc.)
- Self-provisioning, Home Networking, App management



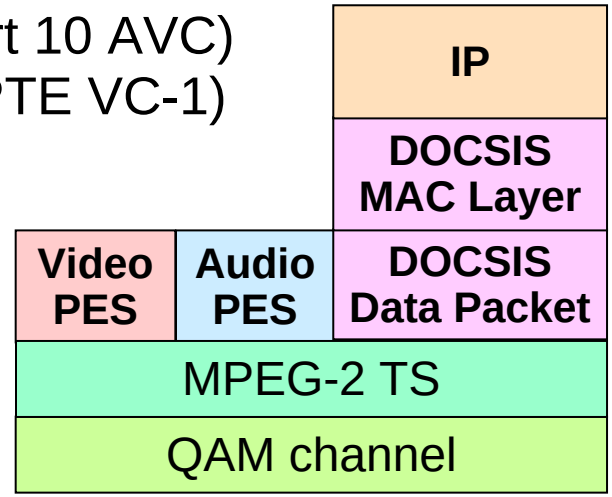
NGNA's video CPE software architecture reference model

NGNA Three Ways to Deliver Video

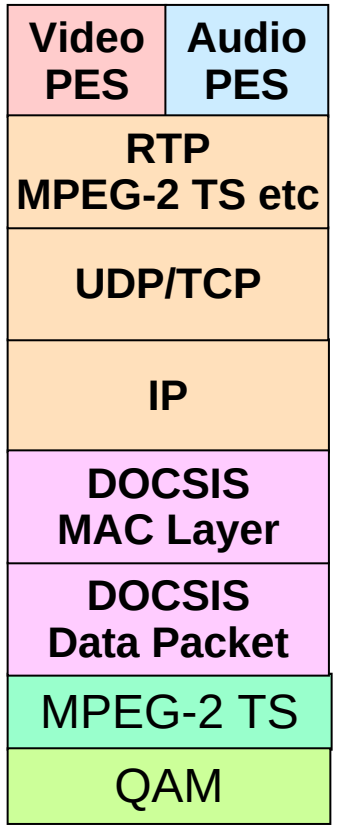
- All STB tuners must support all three
  - Facilitates sharing of QAM resources, IP delivery, & future transition to all IP
- STBs must support MPEG-2 and both advanced codecs (one at a time):
  - H.264 (MPEG-4 part 10 AVC) or WM9 VC-9 (SMPTE VC-1)



Baseline MPEG-2 Transport over QAM



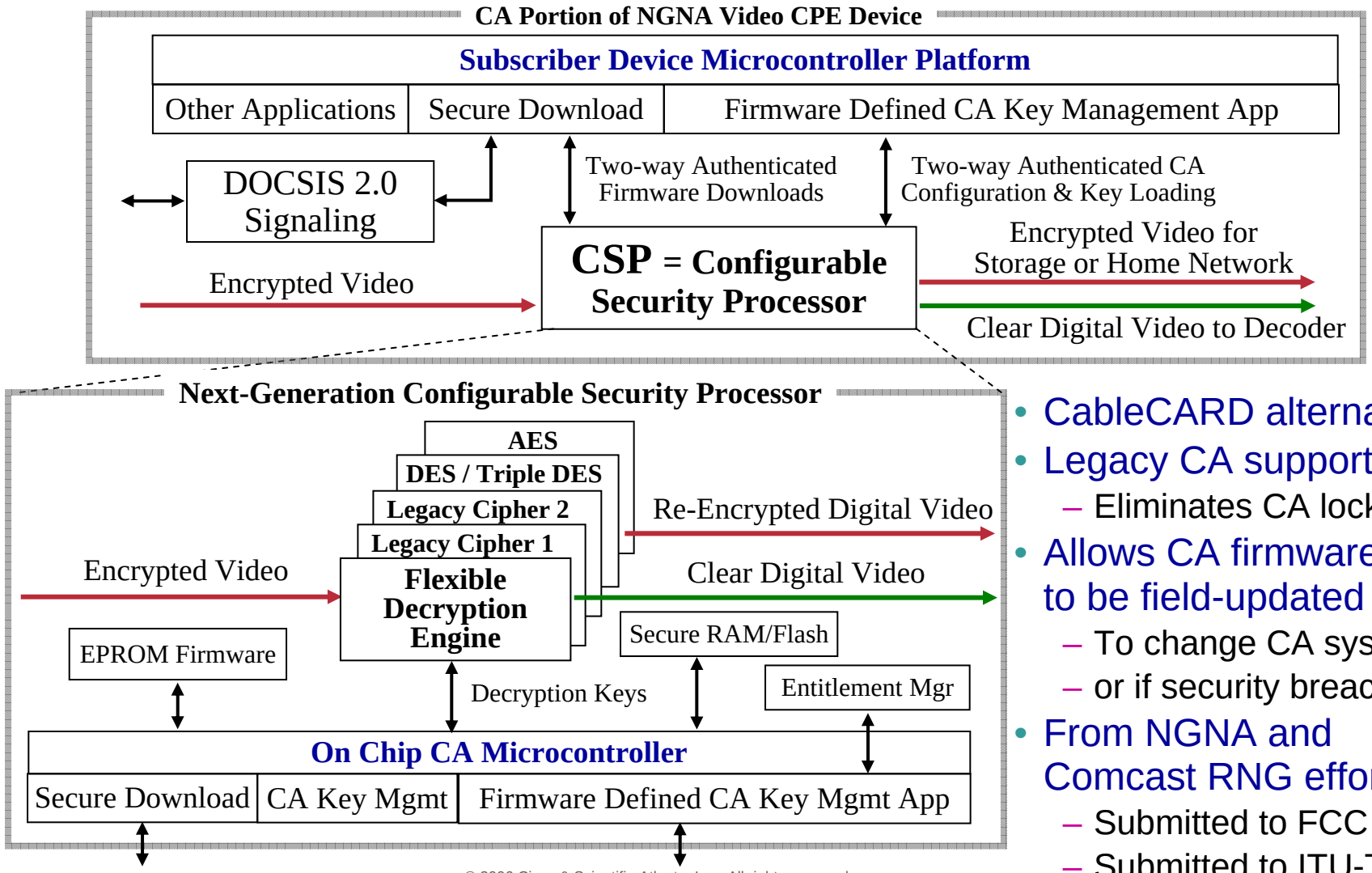
Extended 1 MPEG-2 Transport Multiplexed with DOCSIS Data



Extended 2 Video over IP/DOCSIS

Downloadable CA Support (DCAS)

Security Reference Model



- CableCARD alternative
- Legacy CA support
  - Eliminates CA lock
- Allows CA firmware to be field-updated
  - To change CA system
  - or if security breached
- From NGNA and Comcast RNG efforts
  - Submitted to FCC
  - Submitted to ITU-T SG9

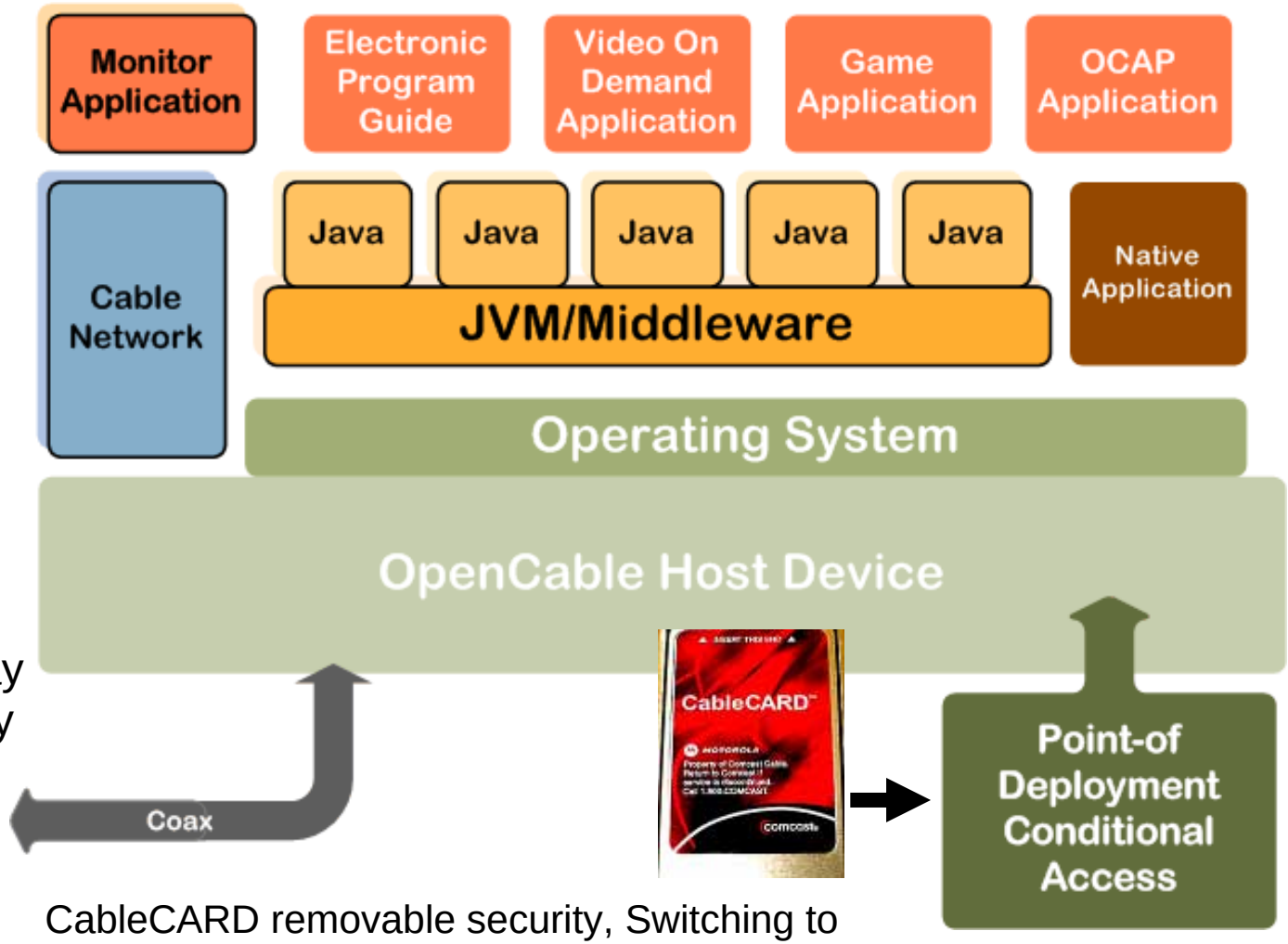
Open Cable Application Platform (OCAP)

- Digital Cable Receiver Software Platform
  - Defines signaling, data formats, and APIs including from head-end servers to support it
- Standard Middleware defined by CableLabs
  - Standardized by ANSI/SCTE and ITU-T
- Java based, Hardware & OS independent
  - Removes hardware dependencies
- Part of retail enabling strategy (driven by the FCC)
  - Create competition in receiver market
  - Drive down cost of hardware, Increase rate of innovation
- Lower cost to deploy services across all cable systems
  - Hardware Portability, Application Interoperability
- Support operator downloaded monitor application
  - Implements STB “Personality, Look, and Feel”

www.opencable.com

OCAP Architecture

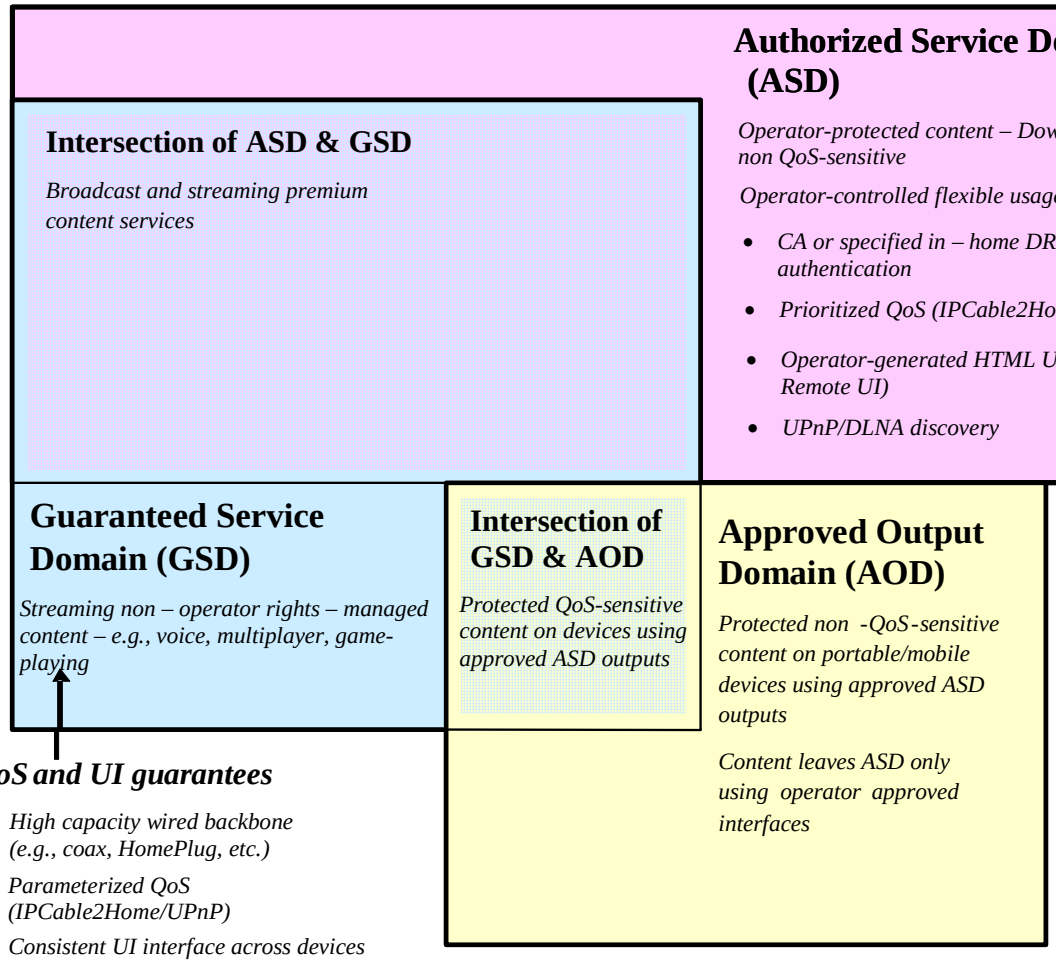
- Cable going with thick via OCAP
- Built on:
  - DVB-MHP
  - JVM, JavaTV
  - HAVi, DSM-CC
  - OpenCable standards and
  - Comcast RNG
- Expected to be foundation for 2-way Digital Cable Ready standard (CHILA license) and



CableCARD removable security, Switching to Downloadable Conditional Access System (DCAS)

ITU-T SG9 Next Gen STB Architecture

- Home Security Domains



From draft ITU-T SG9 Rec. J.stb-core-a defining

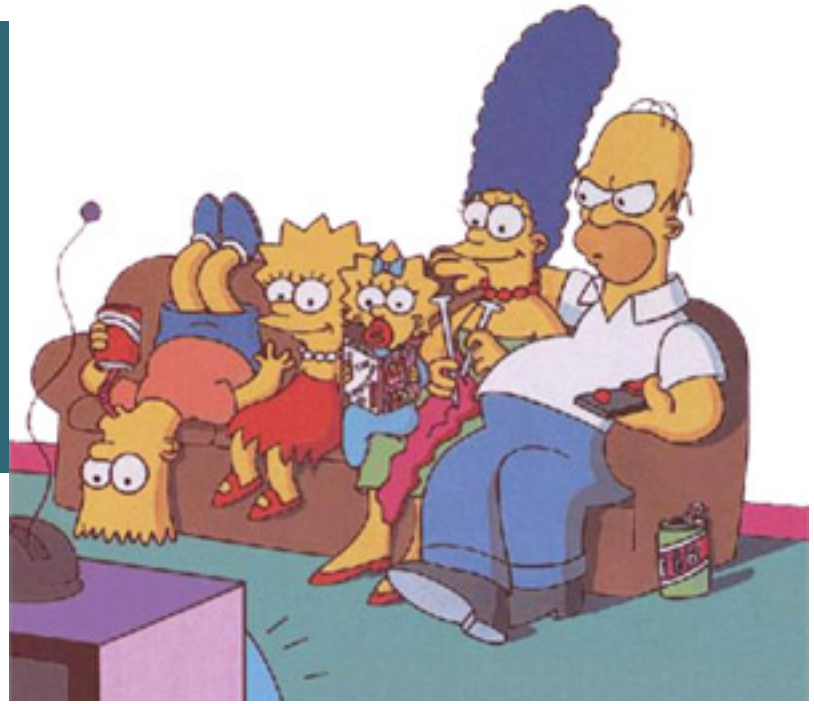
Next Generation Cable Set Top Box architecture

Came out of CableLab's efforts

www.itu.int/ITU-T/studygroups/com09

Summary

So what’s in store for us?



TV is going through its Biggest change since Color

- How many of us see going back to Black & White TV?
- The change to HDTV resolutions is minor compared to TV's change to interactivity via PVRs, VoD, iTV, Quad Play integration, etc.

- Cisco, SA, & Linksys is the perfect team to bring IP and TV worlds together into an IPTV solution for **all** Service Providers

Questions?