SCTE Society of Cable Telecommunications Engineers

30TH ANNIVERSARY

SCTE CABLE-TEC EXPO® '13

OCTOBER 21-24 / ATLANTA, GA

NEXT GENERATION HFC:

THE LOOMING IMPACTS OF DOCSIS® 3.1 AND EPON OVER COAX (EPOC)

John Ulm, ARRIS

Fellow of Technical Staff

Co-authors: Mike Emmendorfer, Rob Howald, Rob Thompson

Tweet about today's session on Twitter #scteExpo

expo.scte.org

DOCSIS® 3.1 or EPoC?

Overview, Key Objectives, Target Markets

What They Share in Common

D3.1 & EPoC: Key Differences

Operator Considerations

Conclusion

DOCSIS® 3.1 or EPoC?

Disclaimer:

DOCSIS® 3.1 and EPoC specifications are both under development and subject to change.

The following are the views of the author and do not represent decisions or positions of either CableLabs or IEEE 802.3.

Overview – What are D3.1 & EPoC?

DOCSIS® 3.1

CableLabs effort

- Strong support from Cable Europe Labs, Euro operators

Defines Next Generation DOCSIS® devices

- Common DOCSIS® specification worldwide
- I.e. No regional variants as today with EuroDOCSIS

EPoC – EPON over Coax

IEEE P802.3bn

- Task Force under IEEE 802.3 Working Group, home of EPON
- Leverages existing EPON MAC and hence EPON technologies

Extends EPON reach over a coax infrastructure

Key Objectives

DOCSIS® 3.1

Efficient support for 10+ Gbps downstream, 1+ Gbps upstream

Significant cost per bit reduction relative to DOCSIS 3.0

Adaptation to different amounts of spectrum and plant conditions

Effective DOCSIS® migration strategy

Operates on existing HFC networks and actives

EPoC – EPON over Coax

At least 1 Gbps in 120MHz for baseline conditions at MAC Interface

- Expanding to 1.6 Gbps in 192MHz

Minimal augmentation to EPON MPCP (MAC) Protocol

Co-exist with legacy HFC services

- FDD support in an Active HFC plant
- TDD or FDD support in Passive HFC

Symmetric or Asymmetric data rates

Target Markets

DOCSIS® 3.1

Expand existing DOCSIS® systems

- Mostly residential today with Fast growing business segment
- Operators already heavily invested in DOCSIS® infrastructure and back office

Support today's "Classic" HFC: Node + 'small': N+3, N+6

- While enabling enhanced capabilities for future Fiber Deep HFC

EPoC – EPON over Coax

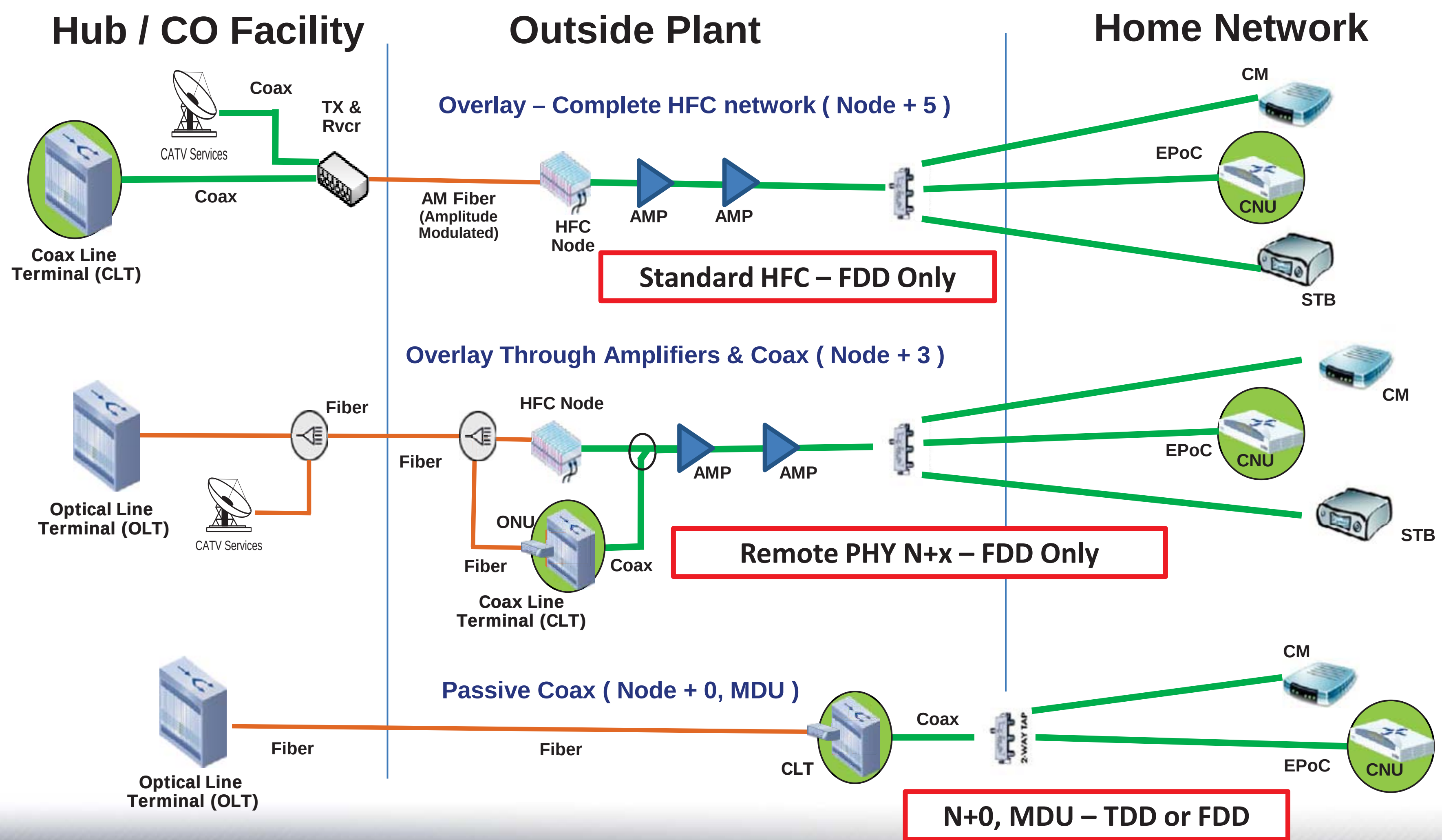
Expand EPON Services Coverage

- Focus on services already deployed on EPON
- Operators that have already invested in OLT's

Asia-Pacific MDU market

- Especially in China
- EPON fiber drop to the building; EPoC inside
  - Next Gen 'EOC' standardized

EPoC – Example Cable Deployment Topologies



Common Channel Characteristics

Channel Model Update Driving System Designs

Downstream Example Snapshot

	#	Parameters	Typical[1]	Limit	Notes/Dependency
Spectrum	1	**Frequency range**	54 MHz - 1 GHz		
	2	**OFDM Bandwidth**	192 MHz		
RF Level	3	**OFDM Power at CPE Input (dBmV)**	15 dBmV, 100 ft, 2-way	10 dBmV, 150 ft, 4-	Notes 2-4
		6 MHz BW	-2	-14	
		24 MHz BW	4	-8	
		96 MHz BW	10	-2	
		192 MHz BW	14	2	Note 5
SNR	4	**SCN Ratio (Signal to Composite Noise Ratio)**	43	40	Note 6
		Variation over 6 MHz BW (dB)	N/A	N/A	Reference Basis 6 MHz
		Variation over 24 MHz BW (dB)	1.5	3.5	
		Variation over 96 MHz BW (dB)	2.5	4.5	
		Variation over 192 MHz BW (dB)	3.0	5.0	
Interference	5	**CTB Interference (20 kHz BW)**			Note 7-8
Narrowband		# of interfered subcarriers @ 30-35 dBc	0%	1%	
		35-40	1%	0%	
		40-45	0%	0%	
		>45	0%	0%	
	6	**CSO Interference (20 kHz BW)**			Note 9
		# of interfered subcarriers @ 30-35 dBc	0%	2%	
		35-40	0%	0%	
		40-45	2%	0%	
		45-50	0%	0%	
		>50	0%	0%	
	7	**LTE Interference**			
	D/S	Bandwidth (MHz)	10	40	
		Level, dBc (PSD)	-30	-30	
	U/S	Bandwidth (MHz)	10	10	
		Level, dBc (PSD)	-40	-5	
	8	**Additive Interference (other)**			Additional bands TBD
		Range of dBc	-41	-29	CL 1997 Report
		Percentage of effected subcarriers	1	1	
Wideband	9	**Burst Interference**			Note 10
		Bandwidth (MHz)	30	TBD	
		Level, dBc (PSD)	-20	-5	
		Duration (usec)	16	25	
		Period (Hz)	Infrequent	10	
	10	**Impulse (white) Noise**			
		Level, dBc (PSD)	-25	-25	Note 11
		Duration (nsec)	0.5	0.5	
		Period (kHz)	10	10	

Industry Cross-Section Channel Model Team

- MSO, OEMs, Chip Manufacturers

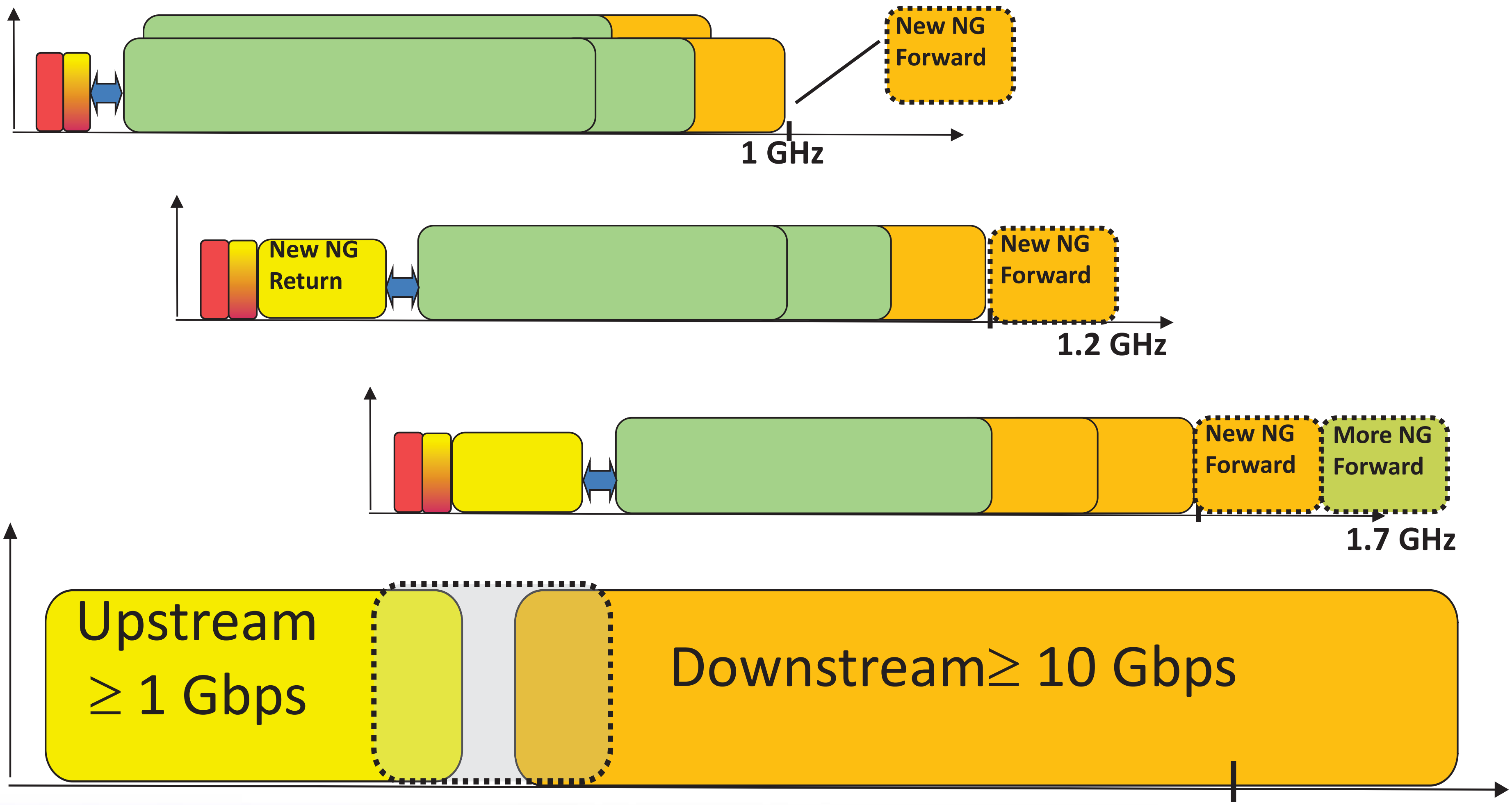
Likely Scenarios for DOCSIS® & EPoC

- Architecture Variants
- Channel Loading Variants
- Spectrum Use Variants
- Downstream & Upstream

Freq Response					
Amplitude	11	**Amplitude Slope**			Note 12
		dB/MHz	0.01	0.02	
	12	**Amplitude Variation**			
		(dB pk-pk/6 MHz)	1.5	6	
		(dB pk-pk/24 MHz)	3.5	8	
		(dB pk-pk/192 MHz)	6	11	
		(dB pk-pk/Total DS BW)	10	15	
Phase	13	**Group Delay Variation, nsec**			
		Over 24 MHz			
		Mid Band	50	100	
		Band Edge (24 MHz)	290	340	
		Over 192 MHz			
		Mid Band	400	800	
		Band Edge (24 MHz)	640	1040	
Echo	14	**Echo Profile, dBc**	99%	SCTE-40	Note 13-14
		.5 usec	-20	-10	
		1 usec	-25	-15	
		1.5 usec	-30	-20	
		2 usec	-35		
		3 usec	-40		
		4.5 usec	-45	-30	
		5 usec	-50		
Spurious Modulation	15	**AM/Carrier hum modulation**	3%	5%	

Reference:
http://www.ieee802.org/3/bn/public/mar13/howald_3bn_01_0313.pdf

Spectrum Evolution Considerations – FDD



Key Shared Technologies

OFDM –

Orthogonal Freq Division Multiplexing

Widely adopted; large pool of expertise

Enables extra wide channels: 24-192MHz

Robust – Adapts to different spectrum and plant conditions

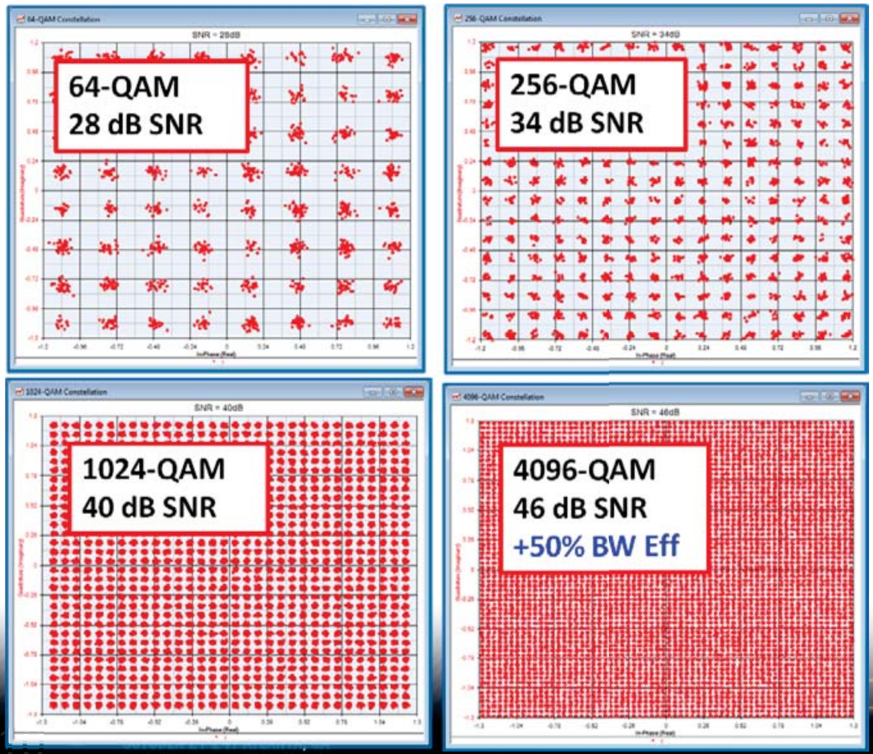
LDPC –

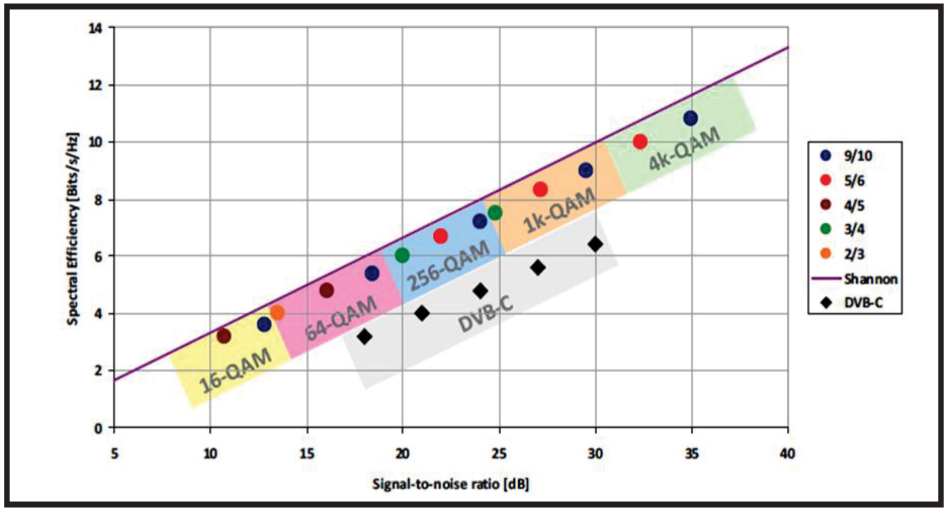
Low Density Parity Check FEC

Pushes us ever closer to Shannon’s Limit

Up to 50% spectral gains

- 4096-QAM down, 1024-QAM up a reality





D3.1 & EPoC – Key Differences

- PHY Layer Considerations
- MAC Layer Considerations
- Architecture Considerations

Key Differences – PHY Layer

FDD/TDD Architecture –

D3.1 only supports FDD: classic HFC

EPoC split: supports FDD *and* TDD

- TDD on passive plant only, MDU oriented

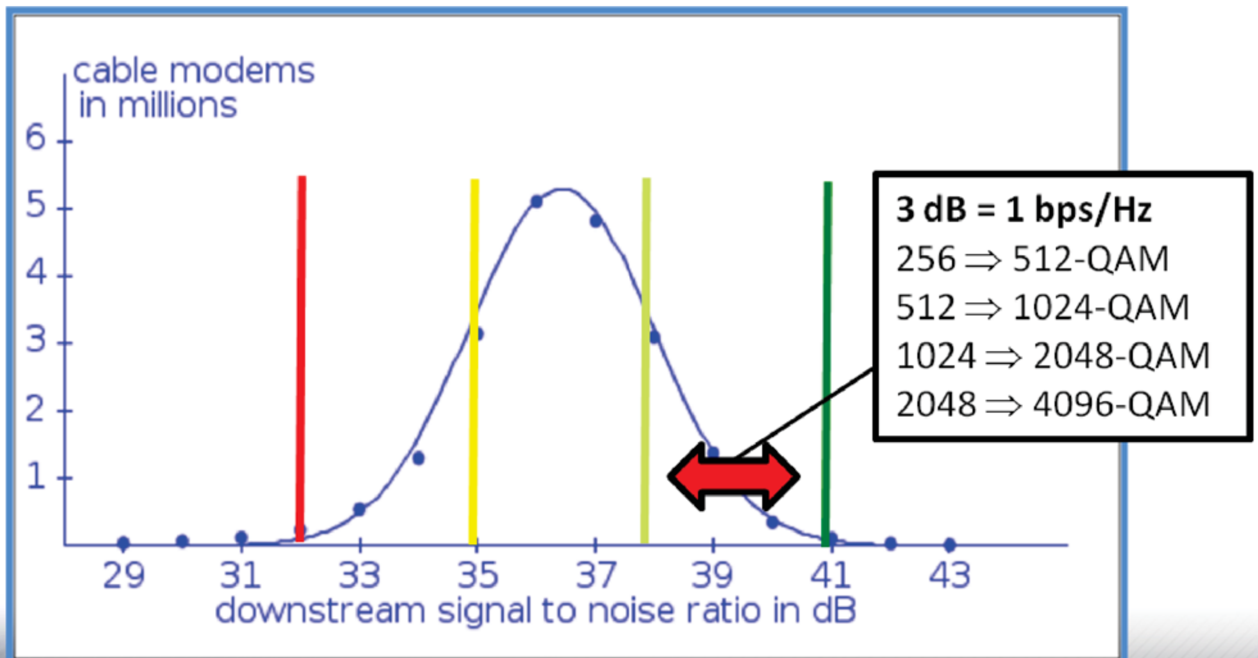
Multiple Modulation Profiles –

~33% capacity gains over single profile

D3.1 supports MMP

EPoC TDD supports MMP

EPoC FDD supports *single* profile



Modem data courtesy of Comcast

Key Differences – PHY Channels

- OFDM Channels (downstream)
  - D3.1: 2 x 192 MHz
  - EPoC: 1 x 192 MHz
- OFDMA Channels (upstream)
  - D3.1: 2 x 96 MHz
  - EPoC: 1 x 192 MHz
- DOCSIS® Backwards Compatibility (D3.1 only)
  - 24 ‘3.0 compatible’ Downstream QAM channels
  - 8 ‘3.0 compatible’ Upstream ATDMA/S-CDMA channels

Operate day one with zero infrastructure changes

Key Differences – MAC

- Channel Bonding – D3.1 Only
  - All combinations: 3.0, 3.0 + 3.1, 3.1 OFDM(A) only
  - D3.1:
    - ~<u>4.5Gbps</u> downstream (2x192 + 24x6 bonded)
    - ~<u>250Mbps</u> upstream in 42MHz with 3.0 <u>spectrum sharing</u>
  - EPoC FDD:
    - ~<u>1.4Gbps</u> downstream (1x192, single profile)
    - ~<u>50Mbps</u> upstream in 42MHz with 3.0 <u>co-existence</u>
  - 10+ Gbps with 5 bonded OFDM channels in 1.2GHz

D3.1 potential capacity ≥ 10G EPON

Key Differences – MAC

- QoS – Rich DOCSIS® Heritage
  - D3.1: H-QoS, 2-D US scheduler, extensive Service Flows
  - EPoC: 1-D US scheduler, Limited LLID resources
    - Needs B-RAS to match DOCSIS® QoS capabilities
- Service Group Sizing (distance, subs)
  - D3.1: 100 miles (160km), 100's to 1000's of subs
  - EPON: 20km, 32 subs typical
    - 256 subs possible, but with shorter distances

Key Differences – Architecture

- CCAP Migration Strategy
  - D3.1 provides CCAP investment protection
    - Dynamic mixing of legacy video & HSD services on 1 RF port
    - Some D3.1 components may even be a soft upgrade
    - Keeps Fiber nodes PHY agnostic

- Remote PHY (Distributed Access) Considerations
  - D3.1: optionally supports distributed architecture when and if MSO needs it (e.g. highly competitive/congested nodes only)
  - EPoC: could force distributed architecture from beginning
    - Requires HFC infrastructure investment before deploying

Key Differences – Spectrum Tax

EPoC –

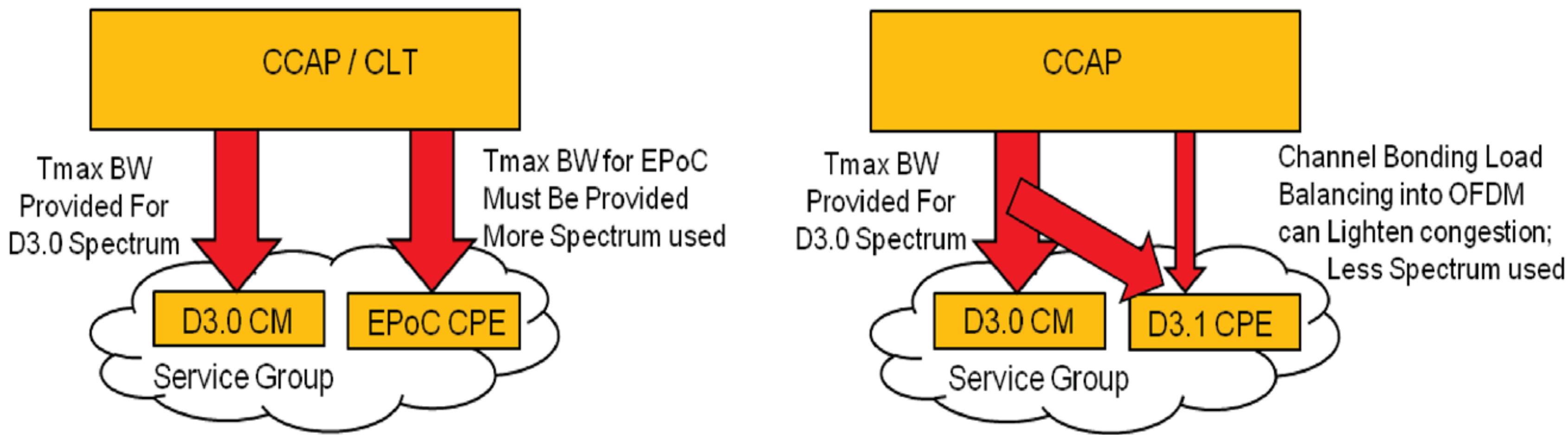
Requires Full spectrum for Services

E.g. 1.8 Gbps rate requires 192MHz

D3.1 –

Shares 3.0 BW; reduced spectrum need

1.8 Gbps rate requires 96MHz OFDM bonded with 24 3.0 channels

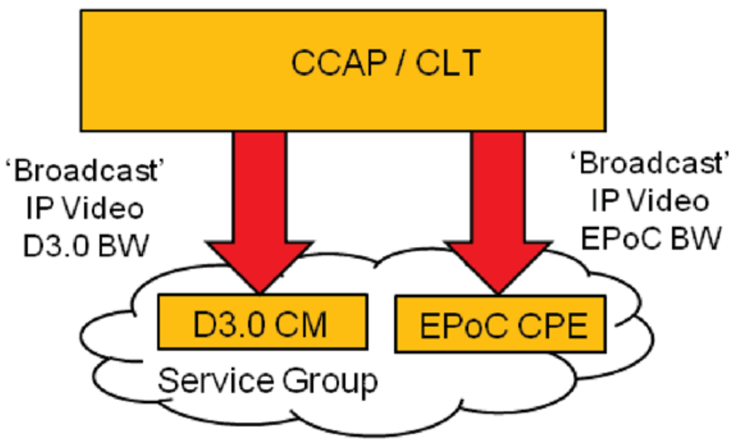


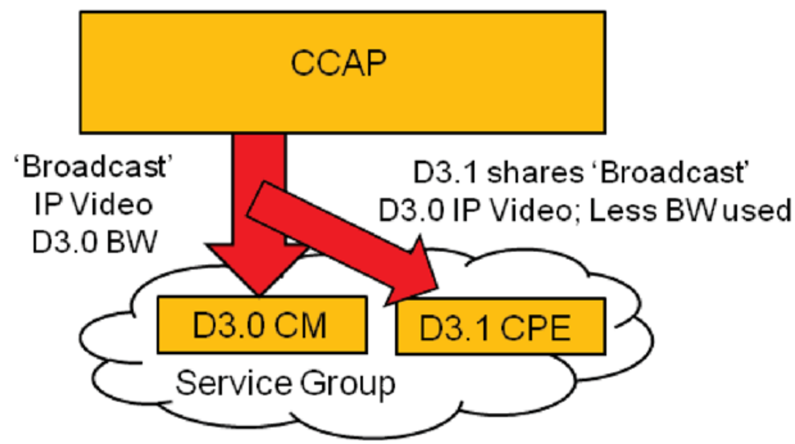
This example: EPoC requires twice as much spectrum (96MHz)

Key Differences – IP Simulcast Tax

EPoC –
Requires Full simulcast
for IP Video Multicast

D3.1 –
Shares IP Video Multicast
from 3.0 channels





This example: EPoC requires IP Simulcast Overhead; D3.1 has none

Operator Perspective – Considerations
What to Choose?

- DOCSIS® Investment Protection
  - 100's of million of modems, CCAP, back office infrastructure
  - Backwards compatibility let's critical mass of D3.1 modems deployed
- Service Tier Offerings
  - Initial D3.1 modems will have almost triple capacity of EPoC
  - Future D3.1 modems can match or exceed 10G/1G EPON
- Spectrum Evolution, HFC Migration Strategies
  - D3.1 defers HFC investments, minimizes spectrum needs
  - D3.1 + CCAP flexibility enables changing legacy video service mix
  - FDD migration, will it ever reach 100% N+0? No need for TDD

Operator Perspective – Considerations
What to Choose?

- Global Market – Economies of Scale
  - Universal D3.1 worldwide
  - EPoC market fractured: FDD/TDD; possible regional variants
- Time to Market
  - D3.1 spec in 2013
  - EPoC spec in 2015, maybe, lots of risk
- Plant Characterization + Maintenance
  - Extensive DOCSIS® tools; InGeNeOs®; new D3.1 hooks
  - EPoC: no tools available today
- Robust Upstream
  - D3.1 2 x 96MHz OFDMA: one optimized for noise, one for thruput

Conclusion – D3.1 or EPoC?

On just about every front, D3.1 wins hands down:

- Migration Path with DOCSIS® Backwards Compatibility
- Investment Protection
- Maximize HFC capacity
- Service Tier Offerings: rates that compete with 10G EPON
- Services: Best in Class QoS
- Efficient Spectrum Evolution strategy
- Global Market, Economies of Scale
- Operations: Tools to manage & maintain HFC plant
- Fastest Time to Market

DOCSIS® 3.1 – the Sensible Choice for Today's Cable Operators

Society of Cable Telecommunications Engineers

30TH ANNIVERSARY

CABLE-TEC EXPO '13

OCTOBER 21-24 / ATLANTA, GA

John Ulm

john.ulm@arrisi.com

ARRIS™

Tweet about today's session on Twitter #scteExpo

expo.scte.org

D3.1 v. EPoC Comparison Summary 1

Attribute	Comment
Backward Compatibility	**DOCSIS 3.1 Yes, seamless migration; EPOC No**
Leverage CCAP Investment	**DOCSIS 3.1 Yes, some SW upgrade; EPOC No**
RF port integration for simplified HE operation	**MPEG-TS & D3.1 share CCAP RF port; EPoC is Overlay**
Spectrum plans: FDD / TDD	**D3.1: FDD only; EPoC market split: TDD, FDD**
Multiple Modulation Profiles	**DOCSIS 3.1 Yes; EPoC** TDD Yes, **FDD No**
Spectral Efficiency (FDD)	Same OFDM/LDPC, but D3.1 uses MMP for **more bits/sec/Hz**
Bandwidth Expansion	**D3.1 bonding ≥ 10G EPON; EPoC 1x192MHz**
Spectrum + Simulcast Tax	**EPOC requires more spectrum for identical services**
Initial Downstream capacity	**D3.1 ~4.5 Gbps; EPoC ~1.5 Gbps**
42MHz US capacity with 3.0	**D3.1 ~250 Mbps; EPoC ~50 Mbps**

D3.1 v. EPoC Comparison Summary 2

Attribute	Comment
Flexibility of MAC, QoS	**DOCSIS® rich QoS, services; EPON 1D scheduler**
Service Flows, SG Size	**D3.1 large SG, many SF; EPoC very limited SG, SF**
HFC Analog Optics	Both compatible with existing AM HFC Optics
Digital Optics, HE to Node	Both D3.1 and EPoC may operate over Digital Optics
Distributed Access Arch	D3.1 optional as needed; EPoC likely Remote PHY from start
Spec Control	**D3.1 CableLabs controlled; IEEE: individuals**
Time To Deployment	**D3.1 is on fast track; EPoC languishing**
Overall Costs	EPoC needs OLT + B-RAS for comparable functions CPE delta small due to Moore's Law, Economy of Scale