EPoC Technical Feasibility

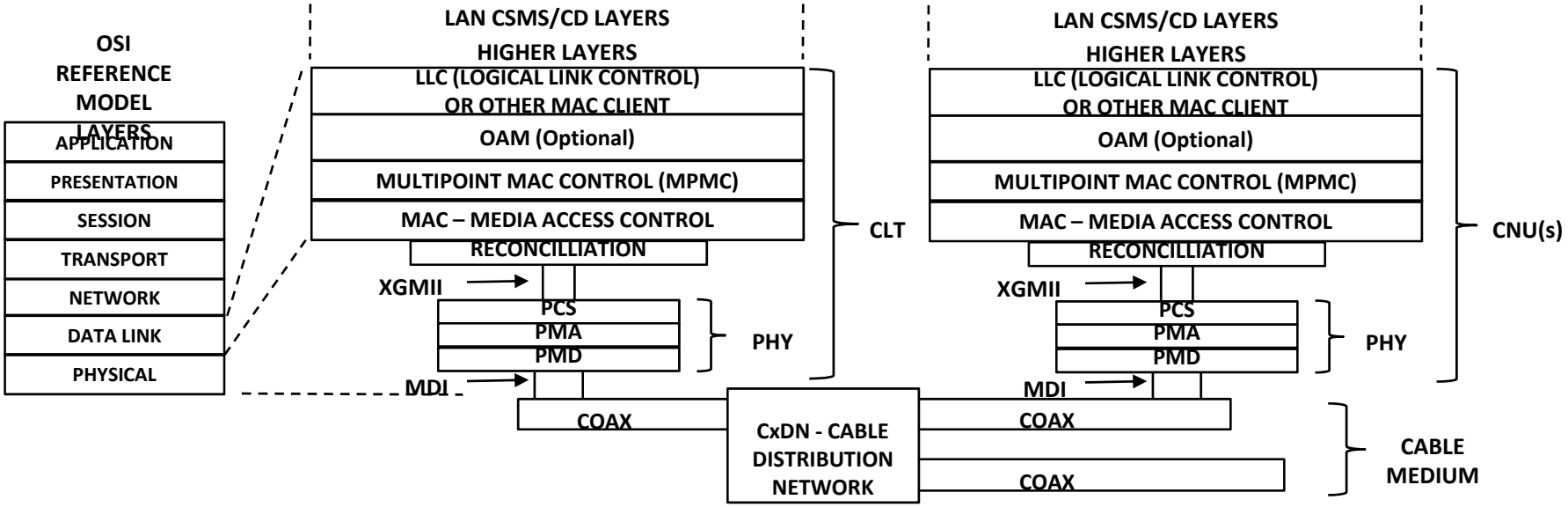
Ed Boyd, Broadcom

Mark Laubach, Broadcom

Disclaimers

- This presentation attempts to show a technically feasible solution for EPoC using the EPON MAC and bonded QAM channels.
- The presentation highlights additional functions required and a possible solution to show that a solution exists.
- The performance of this solution can be used as a baseline for evaluation
- This presentation does not argue that this is the best solution. The merits of this solution versus other solutions will be debated later.

This presentation is not a baseline proposal



Additional Functions Required by EPOC PHY

	Optical PHY	Coax PHY
Wavelength/Frequency	Predetermined	Configured/Search
Upstream Transmit Power	Fixed	Variable
Data Rate	Fixed	Variable
Carriers	One	Multiple
Burst Error Protection	Not Needed	Required
Upstream	Pure TDMA	Multi-Carrier TDMA

- Like other Ethernet Copper PHYs, the EPoC Coax PHY will be required to adjust parameters before the MAC layer can communicate.
- As done in other copper PHYs, I propose that the PHY auto-negotiate the link parameters and data rate.
- The PHY should be configured with capabilities before negotiation begins and exchange PHY layer information.
- Unlike the other Ethernet PHYs, the CLT PHY will be required to auto-negotiate with multiple CNU PHYs.
- Auto-negotiation must work without disrupting CNUs that are linked

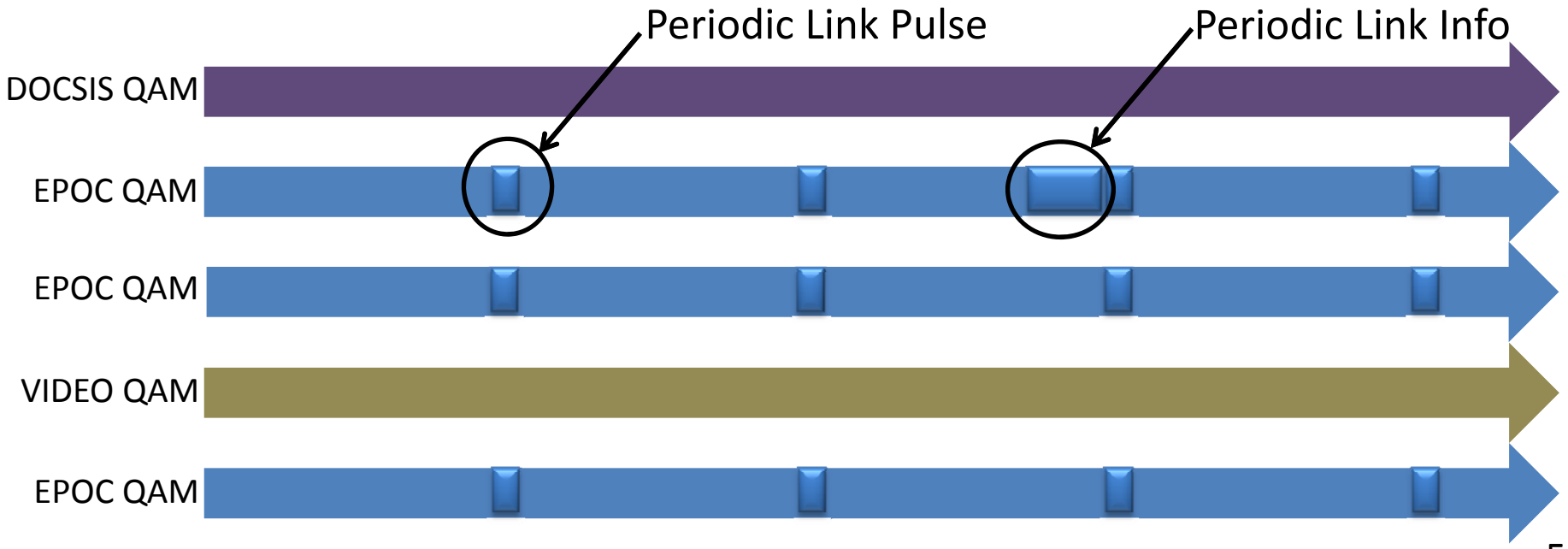
Example PHY Data Path

Basic Upstream & Downstream Data Path

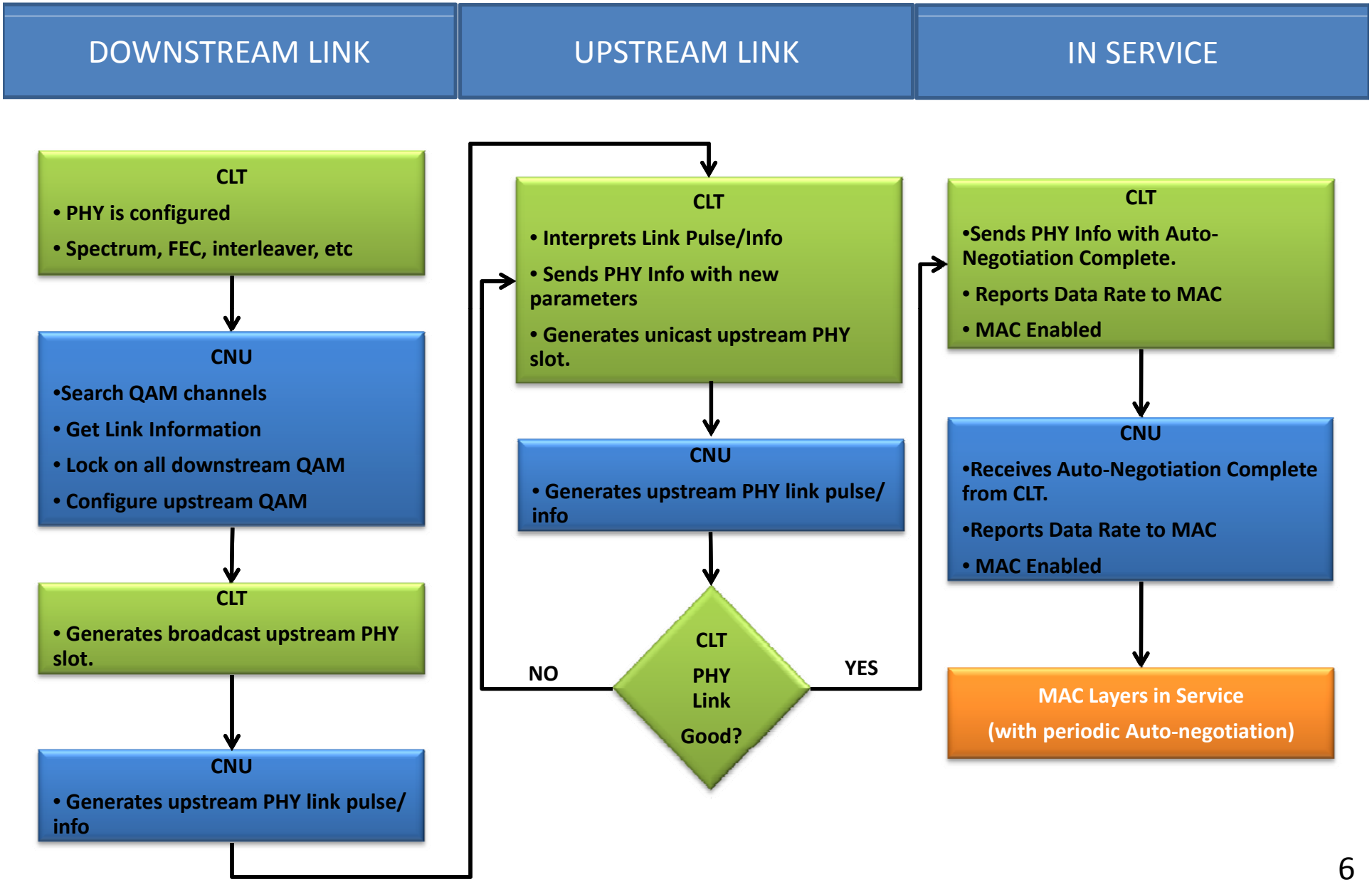
- Encoding
  - 64/66 Encoding of data from 10G could be used
- FEC
  - 10G-EPON RS code (255, 223) has better coding gain than DOCSIS with RS code (255, 239) running with 188 bytes.
  - There are new codes that we should consider
- Interleaver
  - A variable depth convolutional interleaver as defined for DOCSIS could be used. An interleaver is required to handle burst errors
- Multi-Carrier Mapping
  - All QAM carriers will have a common symbol time
  - Data Stream could be mapped into QAM channels across
- PHY LINK SM
  - The EPOC PHY could generate “Link Pulse” like markers
  - PHY Level Information could passed to allow for auto-negotiation of the PHY layer and Link before MAC registration.
- QAM Modulators
  - Many 6 MHz/6.4 MHz wide DOCSIS like QAMs on the current frequency plans could be used for carrying the bits.

Downstream Link

- A Link Byte could be sent periodically to identify and align EPOC QAM Channels.
- Link Information could be sent downstream periodically.
- Link Information could include location of other EPoC QAM channels, modulation information, FEC configuration, interleaver depth, upstream channel locations, upstream transmit power level.
- Link Information will need PHY address to support point-to-multipoint.
- A new CNU PHY could start by searching the downstream for the periodic link pulses and link information.



Point to Multi-Point Auto-Negotiation Example

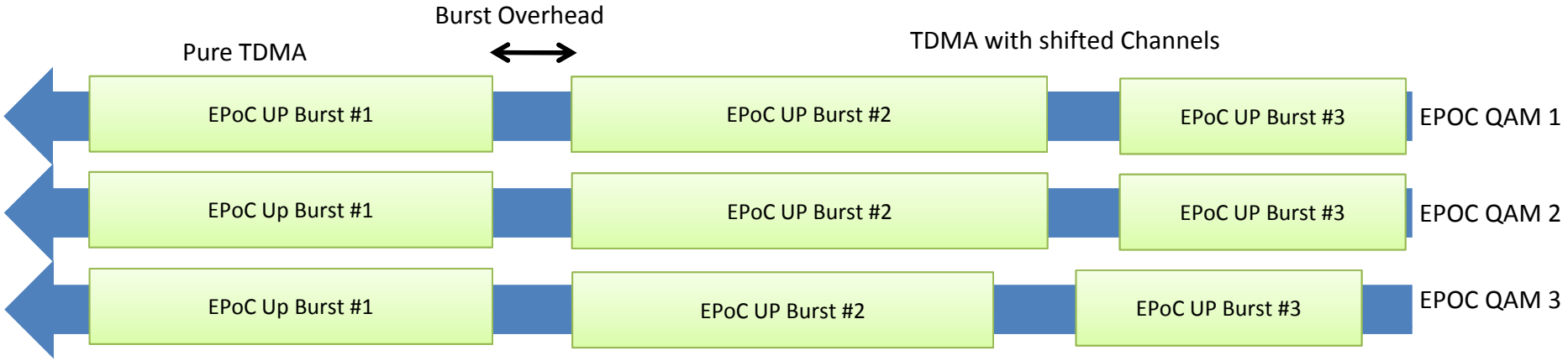


PHY Layer Performance Downstream

- Bonded 6MHz QAM Downstream Channels. (5360 Ksym/s)
  - 256QAM (42.88 Mbps) is defined now
  - 1024QAM (53.6 Mbps) is available in most chips and in testing by operators.
- PHY Rate Needed to Carry 10G EPON
  - 10.3125 Gbps of 10G EPON contains 64/66 and FEC.
  - Add 1% for Link Pulses and Information.
  - 10.5 Gbps Needed.
- 10G-EPON (10.5 Gbps Line)
  - 245 ch of 256QAM (1470 MHz)
  - 196 ch of 1024QAM (1176 MHz)
- 5G [1/2 10G-EPON] (5.25 Gbps Line)
  - 123 ch of 256QAM (738 MHz)
  - 98 ch of 1024QAM (588 MHz)
- 1G-EPON (1Gbps data, 1.15Gbps Line)
  - 27 ch of 256QAM (162 MHz)
  - 22 ch of 1024QAM (132 MHz)

EPON Downstream Speeds over Coax between 1 Gbps and 10 Gbps are possible

PHY Layer Performance Upstream



- Bonded ATDMA 6.4MHz QAM Upstream Channels. (5120 Ksym/s or 195.3125ns symbol)
- 16 symbols of burst overhead required. (16x195.3125ns = 3.125us)
- For pure TDMA upstream granularity (1 symbol time) at 1 Gbps is 195 bits or 24 bytes.
- For TDMA upstream, shifted channels, granularity would be less than 16 bits
- 1 Gbps upstream data would require 1.15 Gbps (FEC & 64/66 overhead)
- 1Gbps in 64 QAM (30.72 Mbps) would require 38 channels (243.2 MHz)
- 1 Gbps in 256 QAM (40.96 Mbps) would require 28 channels (179.2 MHz)

EPON Upstream is possible over Coax but reaching 1Gbps is a challenge

Summary Performance Table

	Bonded QAM	Next Modulation
Down: Spectrum for 1 Gbps Data	162MHz (256Q), 132MHz (1024Q)	
Down: Spectrum for 5G EPON (1/2)	738MHz (256Q), 538MHz (1024Q)	
Down: Spectrum for 10G EPON	1470MHz (256Q), 1176MHz (1024Q)	
Down: Packet Delay @ 1 Gbps	TBD	
Up: Spectrum for 1 Gbps	243MHz (64Q), 179MHz (256Q)	
Up: Burst Overhead	3.125us	
Up: Burst Granularity @ 1 Gbps	24 Bytes	
Up: Packet Delay @ 1 Gbps	TBD	

EPoC Feasibility Summary

- QAM as a baseline
  - 10G EPON PHY and DOCSIS PHY mixture would be technically feasible for EPOC.
  - Pure TDMA upstream is possible
  - Higher orders of modulation are needed to reach higher bandwidths
  - Final EPoC solution will need to out perform the simple QAM solution.
- EPoC Link & Auto-Negotiation
  - EPoC will require a link state machine. (10PASS-TS and many others are examples)
  - Basic concept should apply to any modulation choice.
  - Coax PHY specific functions should stay in the PHY and not change the MAC.
- Areas for Task Force Study
  - Modulations choices
  - FEC options
  - Link and Auto-Negotiation

EPoC is technically feasible but we have lots to cover