EPoC

IEEE P802.3bn Tutorial Part 1

EPON Protocol Over Coax “EPoC”

Monday, 3 November 2014

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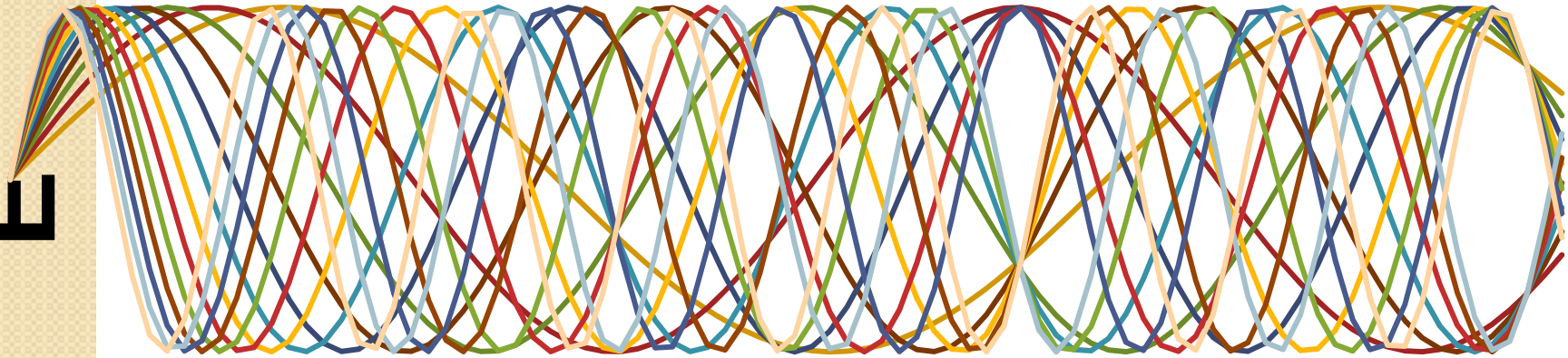

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Agenda

- Introduction
  - Motivation for EPoC
  - P802.3bn overview
  - EPoC Application
  - Overview of Challenges
- Cable Network Requirements
  - Terms
  - EPoC Topologies
  - RF Spectrum availability and flexibility
  - Common component architecture elements
- PHY Link Channel
  - What it is, why we need it
  - DS PHY Link
  - US PHY Link
  - CNU bring up
  - PHY Link Tasks
- Summary
- Q&A

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Introduction

- EPoC -> EPON Protocol Over Coax
- This tutorial overview can be viewed as a Part 1. We can do go into more into technical depth for next plenary – if needed
- National Cable Television Association 2014 conference technical paper:
  - Publicly available
  - IEEE P802.3bn EPoC Status Overview

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Motivation for EPoC

- Cable operator IP / data services deployment:
  - DOCSIS®
    - Residential and business
    - Refer to CableLabs ® site: www.cablelabs.com/specs/
  - EPON
    - Business, cellular backhaul, some residential
    - Fiber typically runs “next to” coaxial trunk cable
      - Fiber only to customers where cost effective
    - DOCSIS Provisioning of EPON (DPoE™) managed
- Opportunity expressed both in China and U.S.:
    - Extend EPON over coax – extend life of coax network
      - Opportunistic, instead of $’s for fiber all the way
      - Unified management and Quality of Service
    - Increase the number of choices for providing gigabit services

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IEEE 802.3 Course of Events

- Call for Interest (CFI) and Study Group November 2011
  - Reference: EPoC www.ieee802.org/3/epoc/
- P802.3bn project approved, Task Force chartered August 2012
  - Project Authorization Request, 5 Criteria, Objectives: www.ieee802.org/3/bn
  - Addendum to IEEE 802.3-2012 Ethernet Standard
- IEEE P802.3bn EPoC PHY Task Force face-to-face meetings:
  - Sep 2012, Geneva, Switzerland
  - Oct 2012 Hangzhou, China
  - Nov 2012, San Antonio, Texas
  - Jan 2013, Phoenix, Arizona
  - Mar 2013, Orlando, Florida
  - May 2013, Victoria, BC, Canada
  - Jul 2013, Geneva, Switzerland
  - Sep 2013, York, England, UK
  - Nov 2013, Dallas, Texas
  - Jan 2014, Indian Wells, California
  - Mar 2014, Beijing, China
  - May 2014, Norfolk, Virginia
  - Sep 2014, Kanata, Ottawa, Canada
  - Nov 2014, San Antonio, Texas

Task Force Status

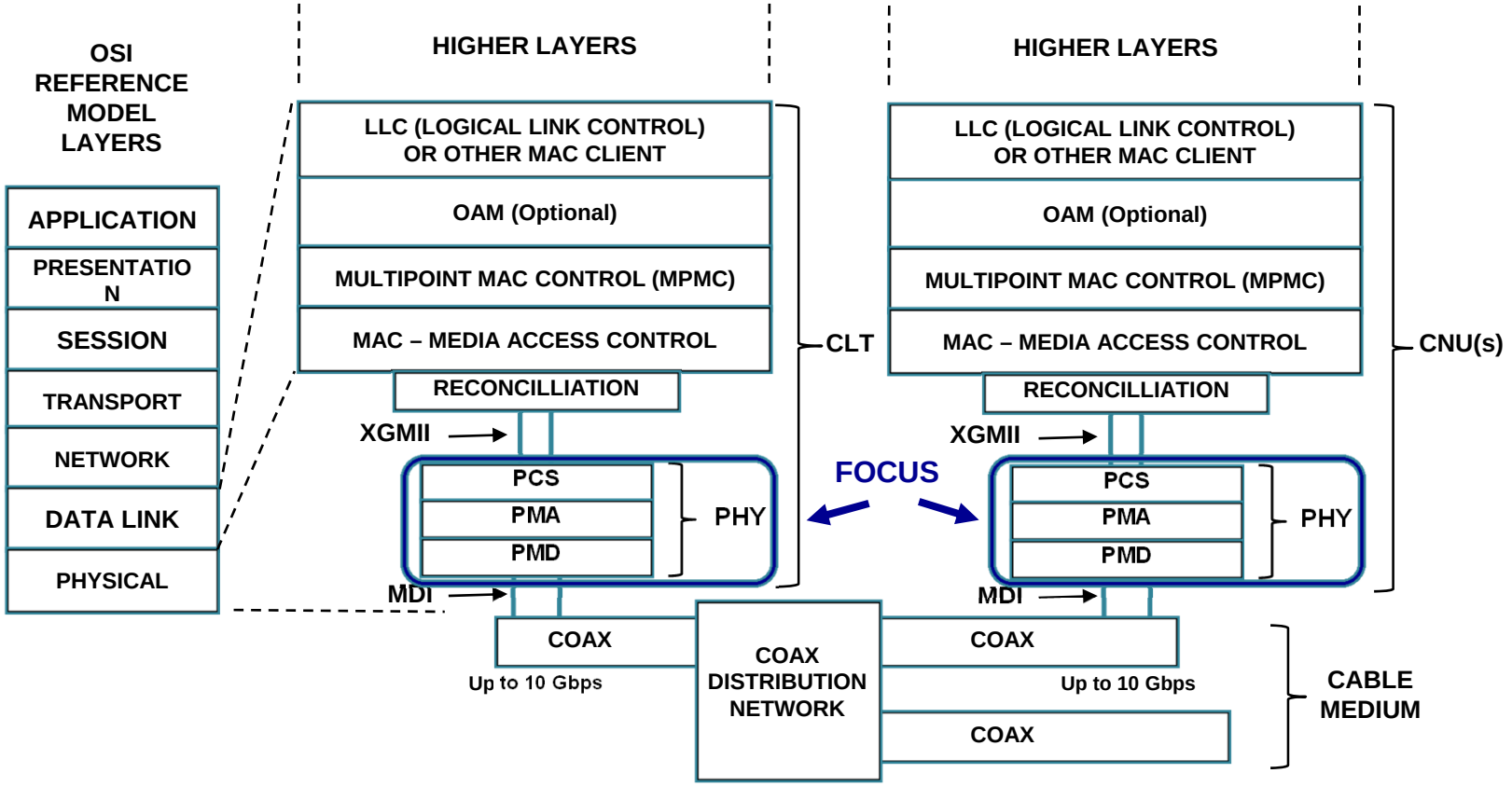
- Draft 1.1 comment resolution this meeting
- Task Force Status: www.ieee802.org/3/bn/
  - 143 Technical Decisions (updated 9/16/14)
  - Task Force Timeline (updated 7/16/14)
    - Targeting March 2014 for Working Group ballot
  - Current Work Items list

Objectives Overview

- Detailed objectives at http://www.ieee802.org/3/bn/
- Major points:
  - Compatibility with 10G-EPON
  - High modulation rate on coaxial cable networks
    - Downstream: to 12 bits / sec / Hz: 4096-QAM
    - Upstream: to 10 bits / sec / Hz: 1024-QAM
  - Up to 10 Gbps (downstream)
  - Symmetric and asymmetric configurations
  - Efficiency and error performance goals for cable services and for Ethernet
  - Operation without causing harmful interference to any signals or services carried in the remainder of the cable spectrum.
- Other
  - Minimal augmentation to EPON MPCP and OAM
  - Consider of common component architecture with DOCSIS 3.1 (D3.1) PHY where it makes sense; CableLabs copyright permission for P802.3bn

EPOC

Project Focus



CLT – COAX LINE TERMINAL
CNU – COAX NETWORK UNIT
MDI – MEDIUM DEPENDENT INTERFACE
OAM – OPERATIONS, ADMINISTRATION, & MAINTENANCE

PCS – PHYSICAL CODING SUBLAYER
PHY – PHYSICAL LAYER DEVICE
PMA – PHYSICAL MEDIUM ATTACHMENT
PMD – PHYSICAL MEDIUM DEPENDENT
XGMII – GIGABIT MEDIA INDEPENDENT INTERFACE

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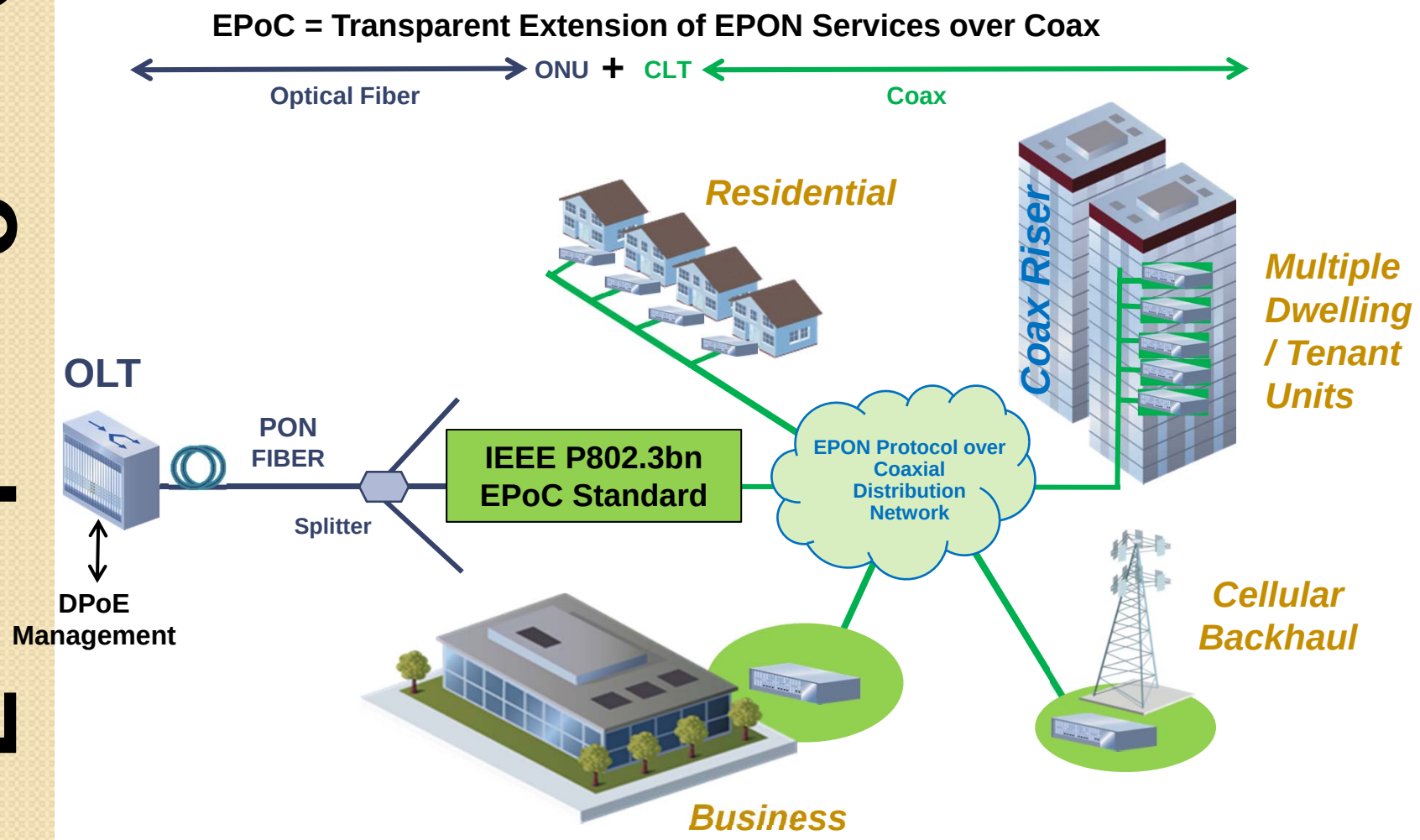
EPoC Application



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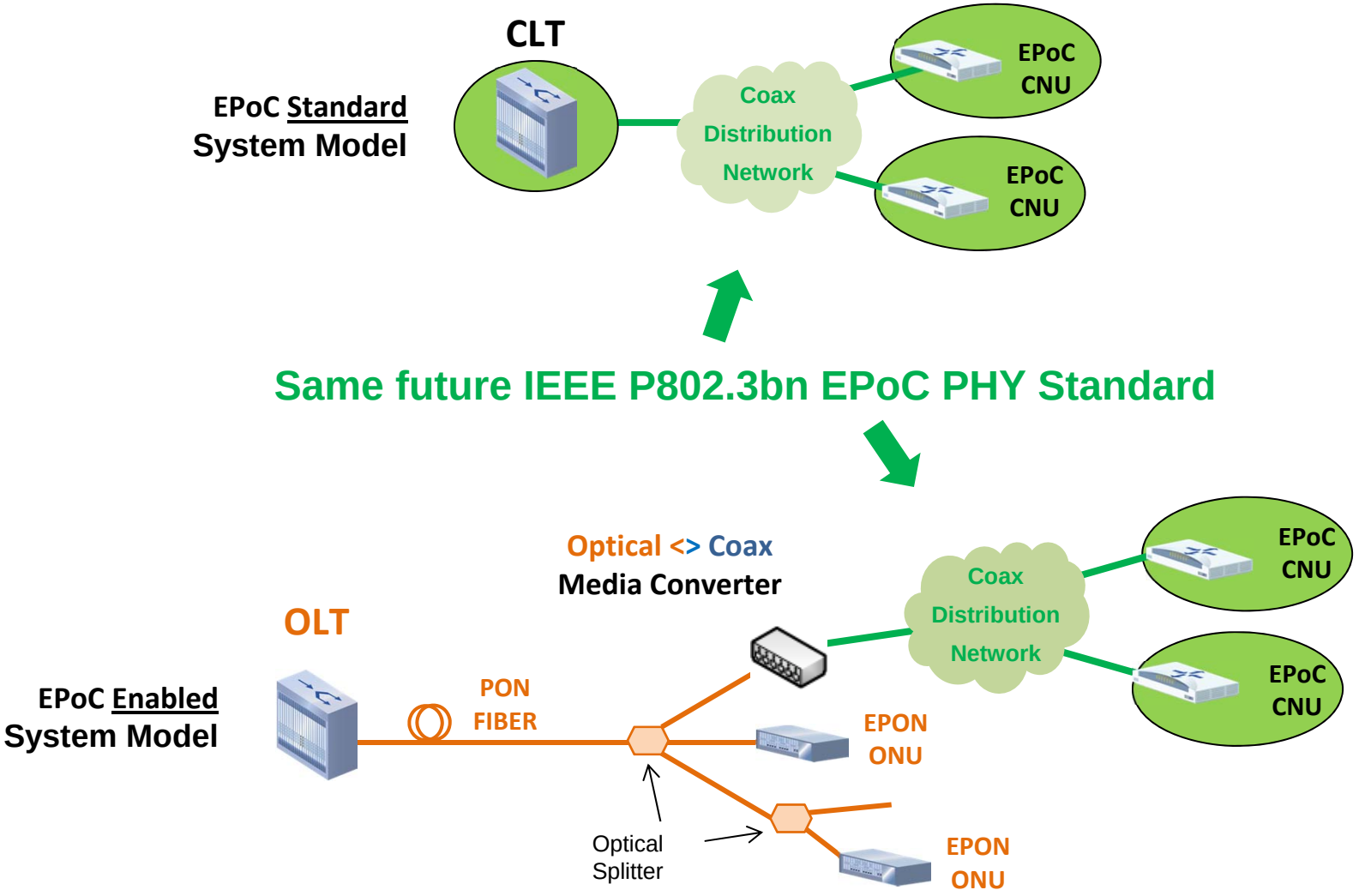
Enabled Products



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CableLabs EPoC Systems Specification Project

Defining:

- EPoC system and architecture based on the IEEE P802.3bn PHY
- DPoE Extensions
- Fiber Conversion Unit (FCU);
  - aka media converter
  - Bridge and repeater modes
- and more

Overview of Challenges

- Cable industry push to gigabit services over existing coax cable networks, includes:
  - Orthogonal Frequency Division Multiplexing (OFDM)
  - “Next generation” Forward Error Correction
    - Low Density Parity Coding (LDPC)
  - Denser modulation rates
    - 4096 QAM (12 bits/second/Hz) and beyond
  - Multiple RF channel multiplexing (e.g. “bonding”)
  - Flexible configuration for matching to available RF spectrum, channel conditions, and well known interference
    - PHY layer data rate follows cable operator configuration

Downstream

Decisions to date:

- LDPC FEC, single rate 14400/16200
- 40-bit CRC per information word to meet 802.3 MTTFPA
- OFDM 192 MHz, 4K FFT, 3800 50 KHz subcarriers per channel
  - Subcarrier use types: excluded, data, PHY Link, continuous pilots
- 24 MHz minimum RF spectrum
- PHY Link channel
  - Well known configuration and placement in RF spectrum;
    - easily discoverable
  - Used for PHY discovery, initialization, ranging, and maintenance
  - Performs Ethernet “link negotiation”
- Repeating 128 symbol cycle Superframe

Downstream (and Upstream) Challenges:

- IEEE 802.3 layer model and conventions
- Rate matching to 10 Gbps EPON XGMII
- Multiple OFDM channels multiplexed for operation up to 10 Gbps

PHY

Upstream

Decisions:

- LDPC FEC, 3 code word rates/sizes (similar to D3.1)
- 40-bit CRC per information word
- OFDMA 192 MHz, 4K FFT, 3800 50 KHz subcarriers
- Single channel. RF spectrum: 10 MHz minimum to 192 MHz

Challenges:

- OFDMA "Super Frame" concept to organize various signal types:
  - Frame size: 5 or 6 probe symbols + 256 symbols, repeating
  - Wide band probes: OFDM timing, synchronization, channel estimation
  - PHY Link channel
    - PHY Discovery, Fine Ranging
  - Resource Blocks for MAC data, pilots,
- Resource Blocks (RBs): 8 or 16 symbols in time, 1 subcarrier in frequency contain: data, pilots, start / end burst marker

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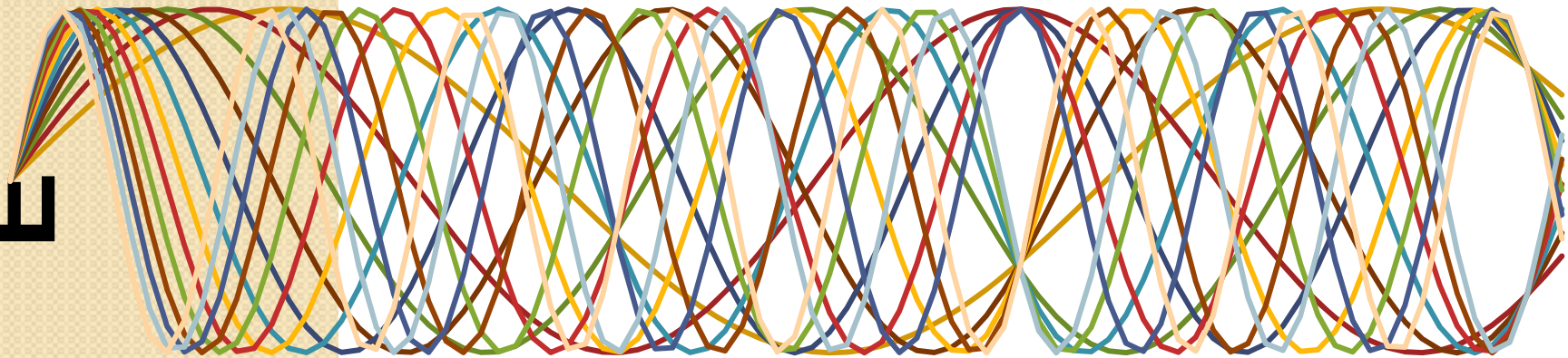
CABLE NETWORK REQUIREMENTS



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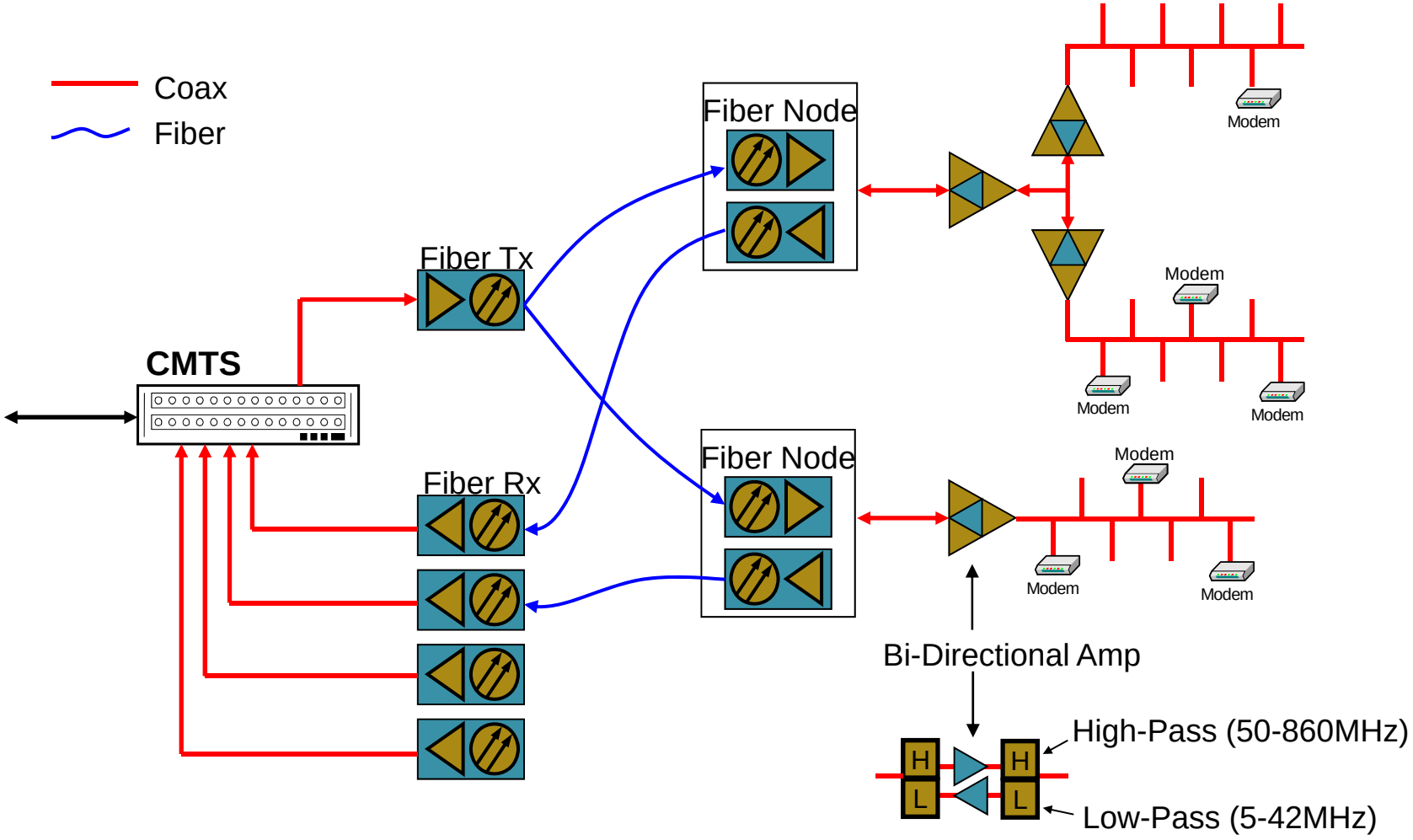
Terms

- DOCSIS – Data-Over-Cable Service Interface Specification
  - CM – Cable Modem
    - Device at the customer's premises
  - CMTS – Cable Modem Termination System
    - Device at the operator's headend
- EPoC – IEEE P802.3bn
  - CNU – Coax Network Unit
  - CLT – Coax Line Terminal
- EPON – IEEE Std 802.3™-2012
  - ONU – Optical Network Unit
  - OLT – Optical Line Terminal
- HFC – Hybrid-Fiber Coax
  - The physical media that separates the CM & CMTS.
  - A Fiber Node performs the electrical <> optical conversion between the analog modulated fiber and the coax network.

DOCSIS

Hybrid Fiber-Coaxial Network (Access Network)



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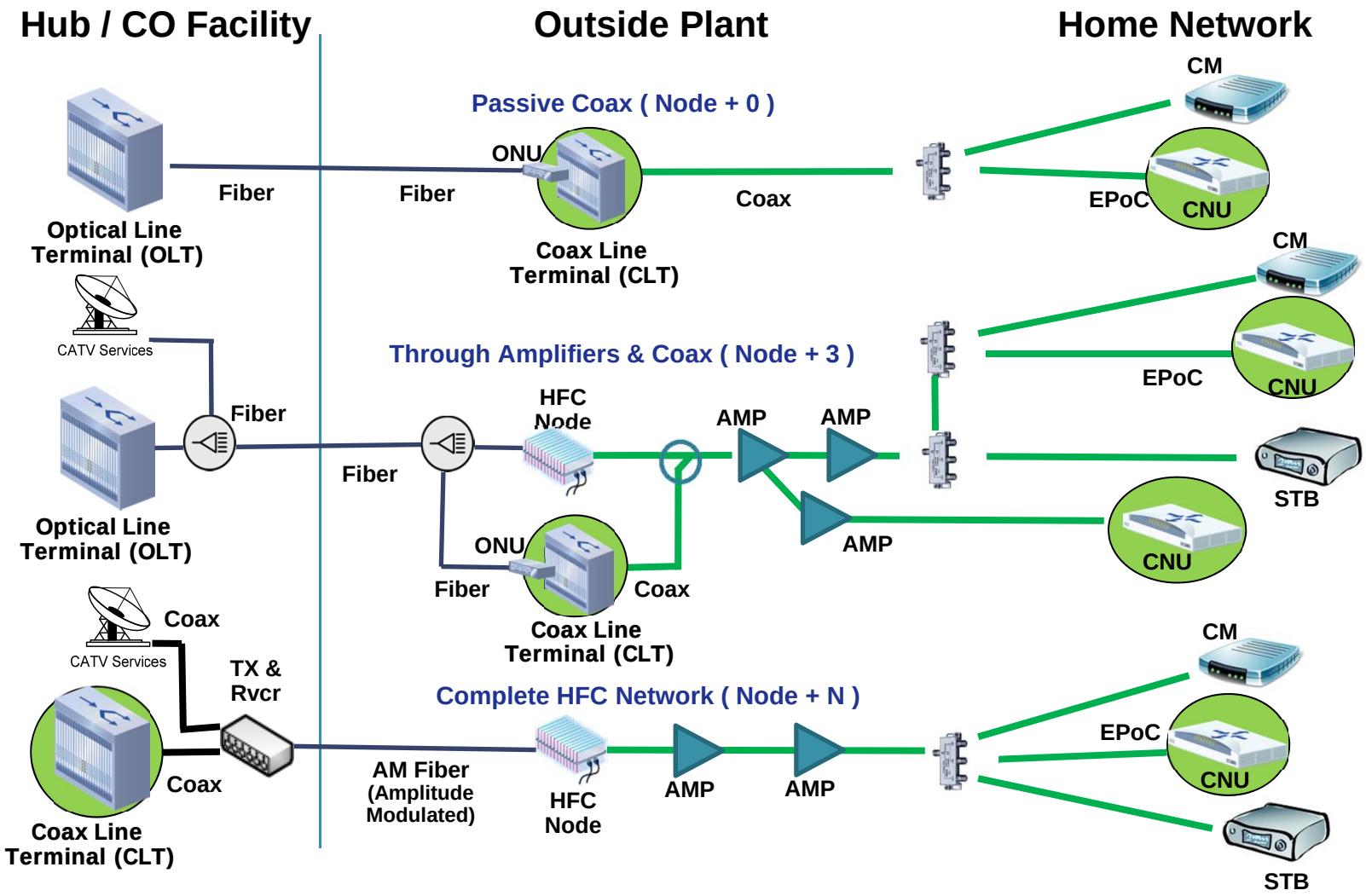
EPoC Topologies



Why OFDM?

- OFDM for better noise immunity
  - Narrower carriers (50 KHz)
- Up to 192 MHz of occupied spectrum per channel
  - 3800 usable subcarriers
- Independent configuration per subcarrier
  - Excluded (off, no energy)
  - Data (bit loading from BPSK to 4096+ QAM)
  - Unused (not modulated)
  - Pilots
- Excluded subcarriers -> permit “notches” to deploy around other services and well known stable noise sources (e.g. LTE) while maximizing spectrum use

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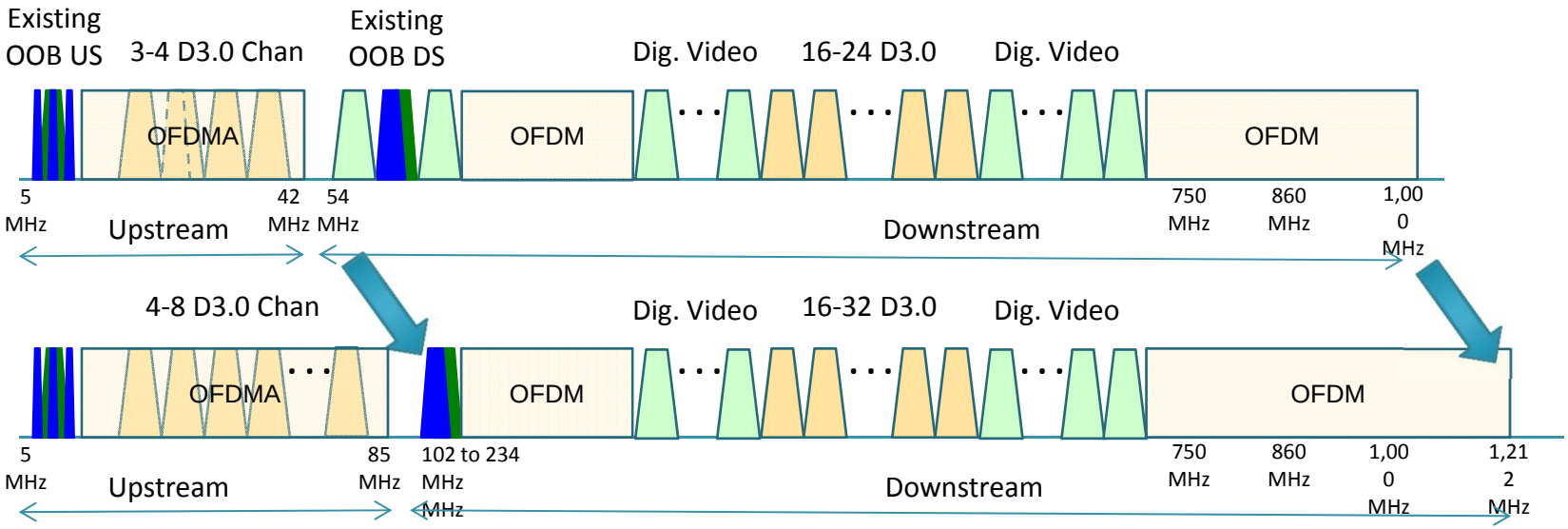
Spectrum Allocation Overview

- Downstream - Deploy EPoC in available spectrum
  - Other services: Digital video channels, DOCSIS 3.0 and 3.1 (N * 6 MHz + OFDM)
- Upstream – Deploy EPoC in available spectrum
  - Other services: DOCSIS 3.0 and 3.1
  - Note: DOCSIS 3.1 can TDMA share with DOCSIS 3.0 channels, EPoC cannot
- Cable operators will provision RF spectrum for EPoC allocation versus other services. Flexibility for adjusting allocations is a must.
- Upstream / downstream frequency split will likely change:
  - e.g., 5 to 42 MHz moving to 5 to 85 MHz (5 to 234 MHz is EPoC maximum)
- Top end downstream passband will change from 1000 MHz to 1200+ MHz



Common Component Architecture Elements with DOCSIS 3.1

- Same/similar OFDM / OFDMA numerology
  - 4K FFT size (note: D3.1 also has 8K FFT)
  - 204.8 MHz sample rate
  - Similar Cyclic Prefix and Window sizes
- Same Upstream LDPC FEC coding and rates
  - Note: P802.3bn selected a different downstream LDPC FEC
- Same electrical input and output requirements
  - Power and spurious emissions
  - Similar frequency ranges
- Proactive Network Management (PNM) support

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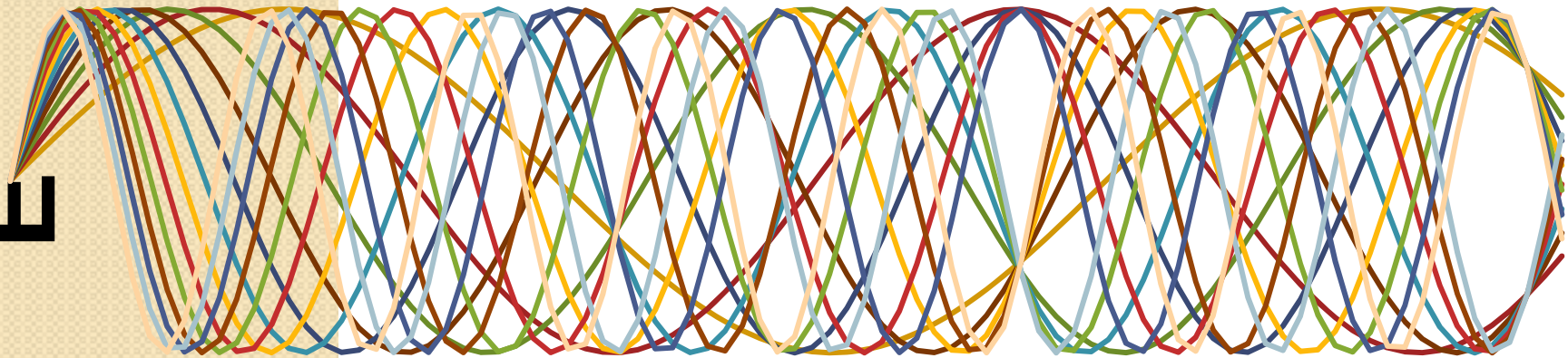
PHY LINK CHANNEL



DOCSIS

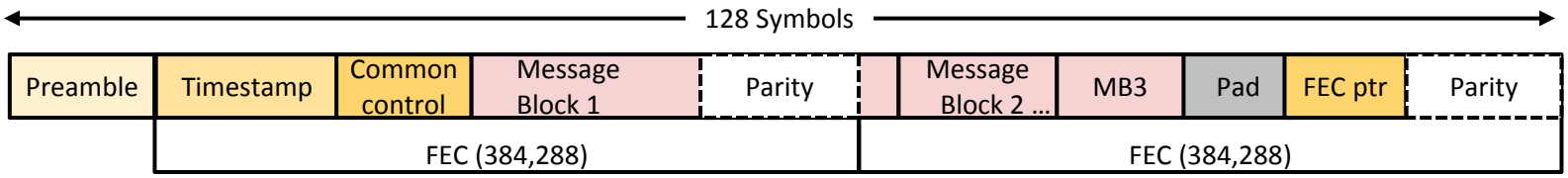
PHY Link

What is it & Why do we need it

- Separate link used to establish OFDM & OFDMA channel parameters:
  - DS Number of OFDM channels
  - US & DS channel frequency bounds; upper extreme, lower extreme, internally excluded bands
  - US & DS channel profile; modulation level for each of the 4096 subcarriers
  - DS & US Cyclic Prefix, Windowing & Time interleaving parameters
  - US PHY Link frequency and OFDMA frame parameters: Probe Period size (5/6 symbols), Pilot pattern

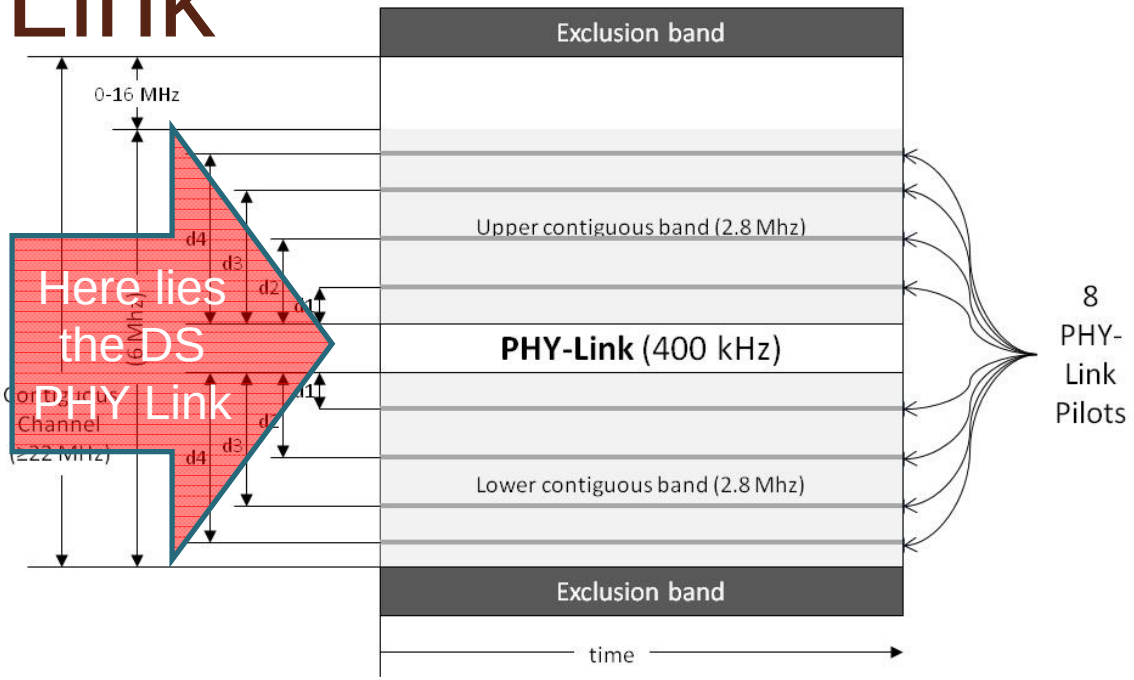
DS PHY Link

- Establishes the downstream OFDM Frame



DS PHY Link

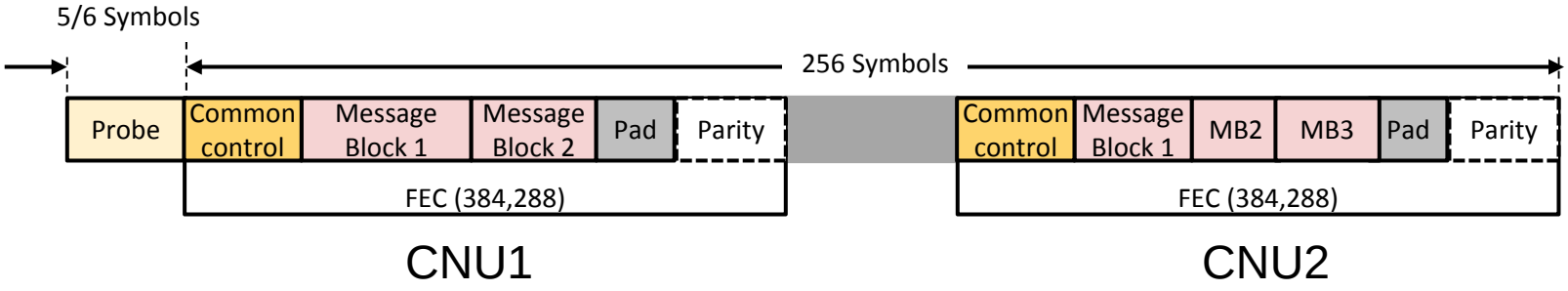
- Easy to find!



- Known parameters:
  - 8 adjacent subcarriers (400 kHz wide),
  - 4 continuous pilots above and below PHY Link at known distances
  - fixed preamble (8 symbols)
  - fixed OFDM frame (preamble + 128 symbols)

US PHY Link

- Parameters provisioned via DS PHY Link
- Access scheduled by DS PHY Link
- Conform to US OFDMA frame



CNU bring up using PHY Link

- CNU acquires the DS PHY Link
- CNU gathers DS & US OFDM/A channel parameters
  - CLT broadcasts OFDM/A channel parameters
- CLT opens a PHY Discovery opportunity
  - Special use of the 5/6 symbol Probe Period
- CNU responds to PHY Discovery with MAC Address
- CLT assigns a CNU_ID, performs Fine Ranging, sets pre-equalizer settings, etc.
- CLT declares CNU to be “Link-UP” and informs upper layers a new CNU has been found.

Other PHY Link tasks

- DS PHY Link
  - schedules channel Probe opportunities
  - Performs ongoing channel fine ranging
  - IEEE tasks (TBD)
- US PHY Link
  - Could maintain CNU synchronization during sleep periods (TBD)

PHY Link Summary

- Well known downstream configuration in well known locations
- Removes complexities of OFDM configuration, timing, and routine management from higher layers; e.g. MPCP, OAM, DBA

Summary

- P802.3bn represents the application of OFDM / OFDMA to extend EPON over Coax
- Final architecture and operational details will be determined by consensus of the Task Force and the ballot approval process.
- The resulting PHY standard will enable several deployment models, increasing the number of choices for cable operators.

Ethernet is constantly evolving.

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Q&A

Questions:

- Was this tutorial worthwhile?
- Should we plan to do a Part 2 for next plenary?
  - Downstream / upstream framing
  - Upstream 1D to 2D mapping

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THANK YOU!!