EPoC RF Bandwidth Task Force Choices

September 2012

Goal

- The goal of this presentation is to identify choices the Task Force needs to make regarding the EPoC RF Bandwidth, as well as to provide proposals.

Should this presentation stop at Identifying the Choices or should It also include the proposals?

Outline

Part I – Frame the Problem

- Mandatory and Optional RF Bandwidths
- Required RF Bandwidth with Exclusion sub-band Approach
- Choices to be made
  - List of Task Force Choices
  - Slides describing each of the Choices

Part II – Proposals

- Proposals for each choice in the list

Part I
Frame The Problem

Mandatory and Optional RF Bandwidths

- The standard should specify the RF bandwidth for any supported PHY modes. Possible modes could include the following,
  - FDD Downstream
  - FDD Upstream
  - TDD
- The standard should specify the RF bandwidth (for each PHY mode) that is mandatory and any that are optional for the CLT and CNU to support

Required RF Bandwidth with Exclusion sub-bands Approach – Illustration

- Required RF Bandwidth

- Configured to support a smaller (continuous) RF Bandwidth

- Configured to support a smaller (discontinuous) RF Bandwidth

Exclusion Sub-bands

Required RF Bandwidth with Exclusion sub-bands Approach

- We recommend that the standard specify a Required RF Bandwidth for each PHY mode in the standard
- The standard should support smaller RF bandwidths by excluding portions of the Required RF Bandwidth
- This allows for RF bandwidths that are continuous and also RF bandwidths which consist of a set of discontinuous sub-bands
- The standard will need to specify the rules for exclusion sub-bands

List of Task Force Choices

1. Specify the Required RF Bandwidth for each supported PHY mode.
2. Specify the rules for exclusion sub-bands.
3. Specify the out-of-band (OOB) emission requirements.
4. Do we specify the absolute subcarrier frequencies?

1. Required Bandwidth Decision

- Fill in the table below

	PHY Mode 1	PHY Mode 2	PHY Mode 3
Mandatory Required RF Bandwidth			
Optional RF Bandwidth			

- The Task Force may choose to include an optional RF a Bandwidth for increased future capacity, or it may only include the Mandatory Required RF bandwidth
- Additional rows can be added to this table to include other parameters like minimum and maximum operating frequency, etc.

2. Rules for Exclusion Sub-bands

- Required RF Bandwidth

- Excluded a contiguous sub-band (e.g. 6 or 8 MHz)
  - Probably allowed

- Exclude multiple sub-bands of different RF bandwidths
  - Do we allow this?

- A few sub-bands, widely separated (adding up to required RF Bandwidth)
  - Do we allow this?

2. Rules for Exclusion Sub-bands

- The standard will need to specify a set of rules specifying what exclusion sub-bands are allowed
- Example rules
  - All exclusion sub-bands are a multiple of 6 MHz
  - The remaining RF spectrum after a set of exclusion sub-bands consists of no more than three non-contiguous sub-band
  - Etc.
- There at least three motivations for exclusion sub-bands
  - Less RF bandwidth is available than the full RF bandwidth
  - There is a legacy service (e.g. DOCSIS) within the RF band
  - There is narrowband noise within the band

3. Specify the out-of-band (OOB) emission requirements?

- Outside the RF spectrum and within some exclusion sub-bands, there will be legacy services
- The PHY needs to limit its out-of-band (OOB) emissions in those frequencies to avoid causing harmful interference to those legacy services
- The Task Force needs to specify OOB emission requirements that the PHY must meet, to avoid causing harmful interference

4. Do we use Absolute Subcarrier Frequency?

- Some systems specify the actual OFDM subcarrier frequencies all the way from DC up to a very high upper frequency limit
  - As an example DVB-C2 specifies the exact OFDM subcarrier frequencies over the range from DC to approximately 3 GHz
- The Upstream and Downstream are specified by a subset of subcarrier frequencies

Part II
Proposals

Required RF Bandwidth Proposals

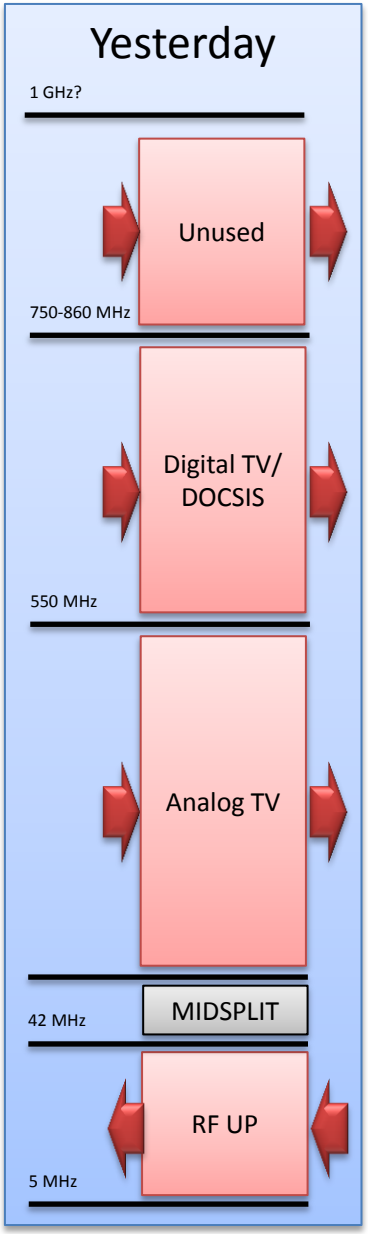
List of Proposals

1. 500 (800) MHz Required RF Bandwidth for FDD Downstream mandatory for CLT and CNU. No optional RF Bandwidth (Ed Boyd)
2. Other

EPoC FDD Downstream Spectrum & Channel Bonding

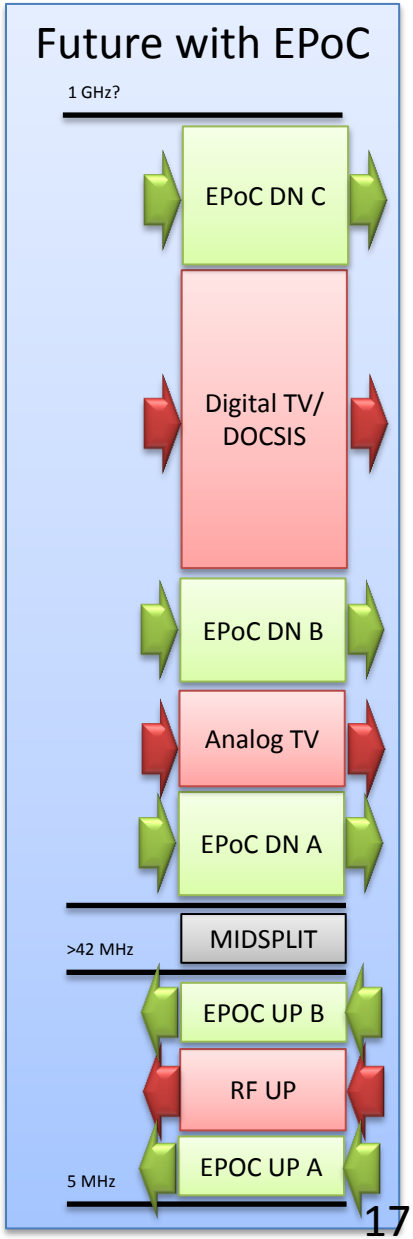
Ed Boyd, Broadcom

EPoC FDD Requirements

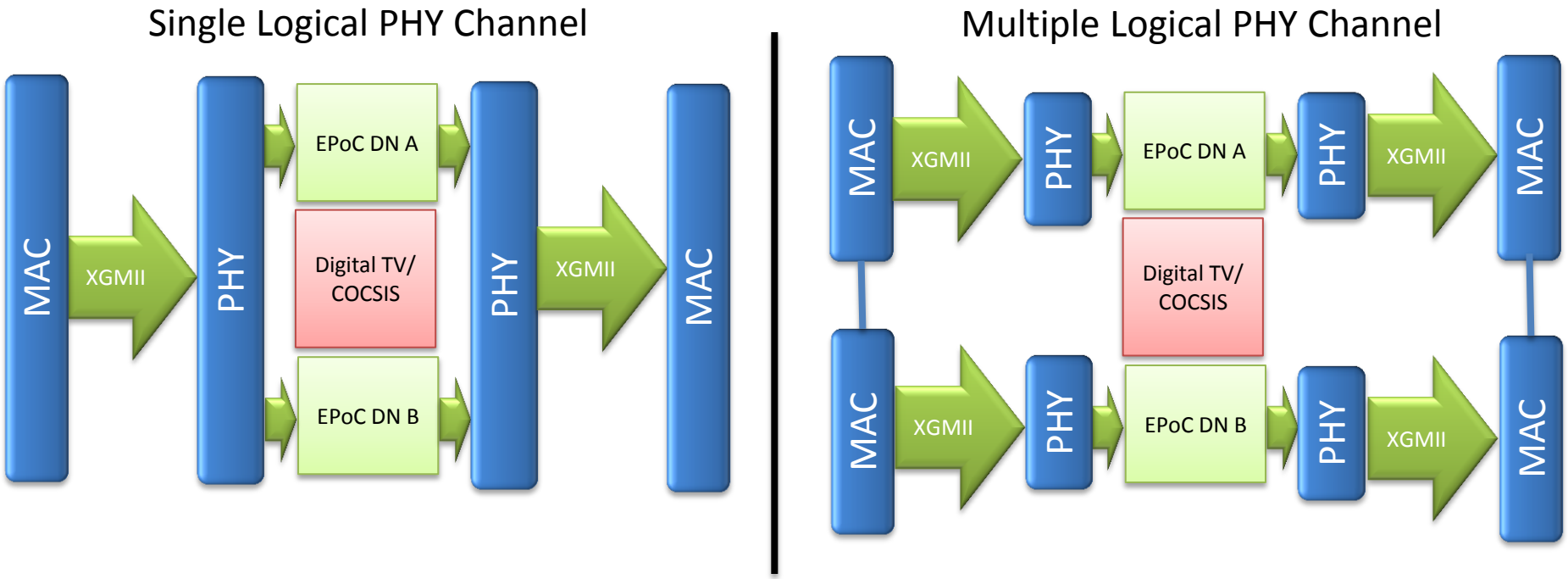


- EPoC should be flexible enough to exist anywhere in today's spectrum and maybe slightly above (up to 1GHz?)
- EPoC spectrum should support multiple blocks in different areas of the spectrum that act as a single channel.
- EPoC spectrum blocks should support granularity of 6MHz (down) & 3.2 MHz (up) or less to full occupy block allocated for EPoC.

How do we bond multiple channels?



Bonding Channel Options



- Two options exist for combining multiple blocks of spectrum into a single pipe.
- PHY can bond across a split in spectrum and show a single logical PHY pipe to the MAC.
- MAC or higher layer functions can bond multiple PHY channels on a packet by packet basis.

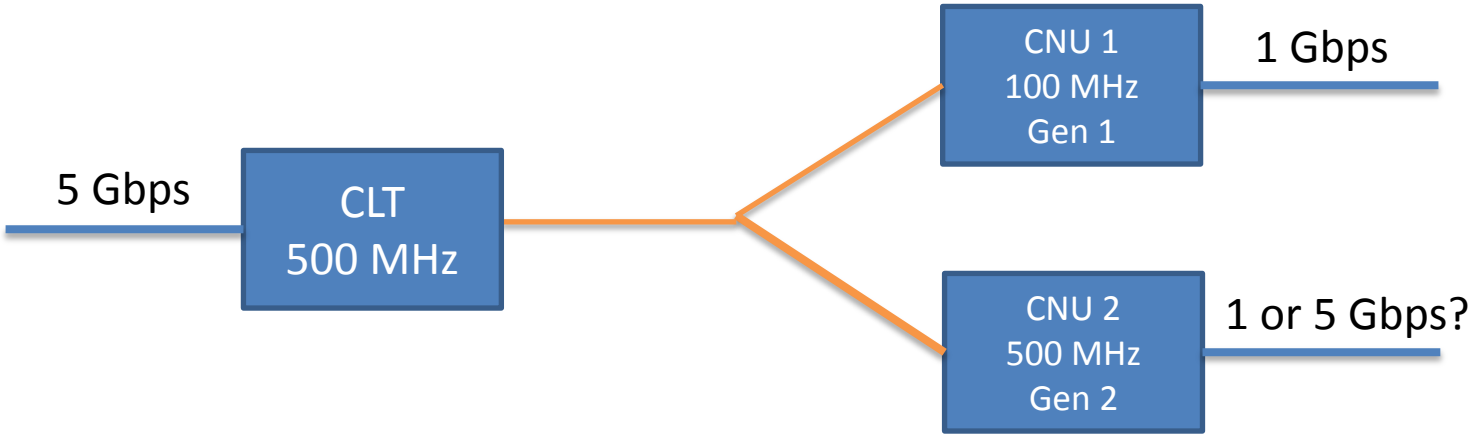
Bonding Ethernet Links

- PHY bonding is the simplest and lowest cost solution.
  - Logic shared across a wide channel is more cost effective than dedicated logic in multiple channels.
- PHY bonding has better statistic multiplexing than link aggregation
  - Link aggregation assigns packets to links based on Ethernet DA/SA.
  - Distribution will not be even based on DA/SA.
- PHY bonding has lower delays
  - Wider single pipe has shorter delay than multiple small pipes
  - Buffering packets into multiple MAC channels and re-ordering packets will increase delay.

PHY bonding is a better solution if possible.

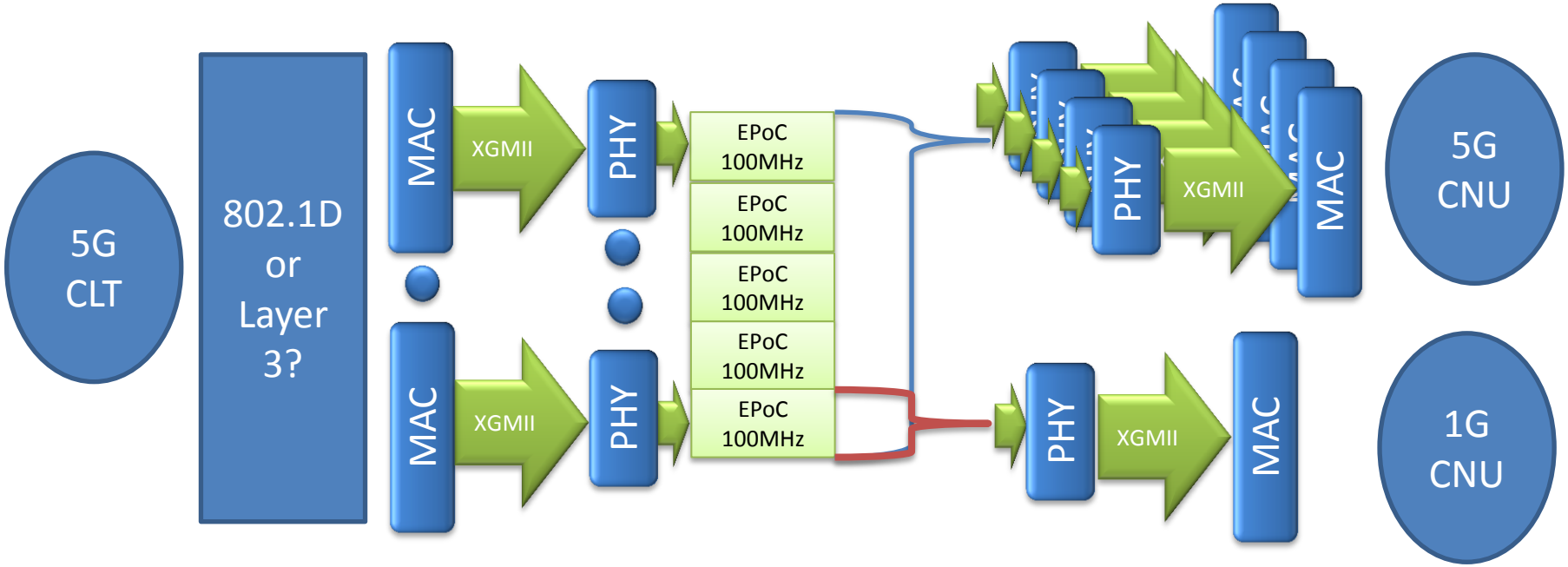
(What about devices with different capabilities?)

Multiple Rate EPOC Devices



- If CNUs support different spectrum capacities, how do we handle them in EPoC?
- In Ethernet, a 10/100/1000 Ethernet device goes down to speed of the lowest speed device. (e.g. All CNUs must be 5 Gbps on CLT or the network is limited to 1 Gbps) – Not Good.
- In EPON, 1Gbps and 10Gbps co-exist by carrying both signals on the fiber. (e.g. the CLT would need 600MHz on the coax with a dedicated 500MHz and 100MHz downstream) – Not Good.

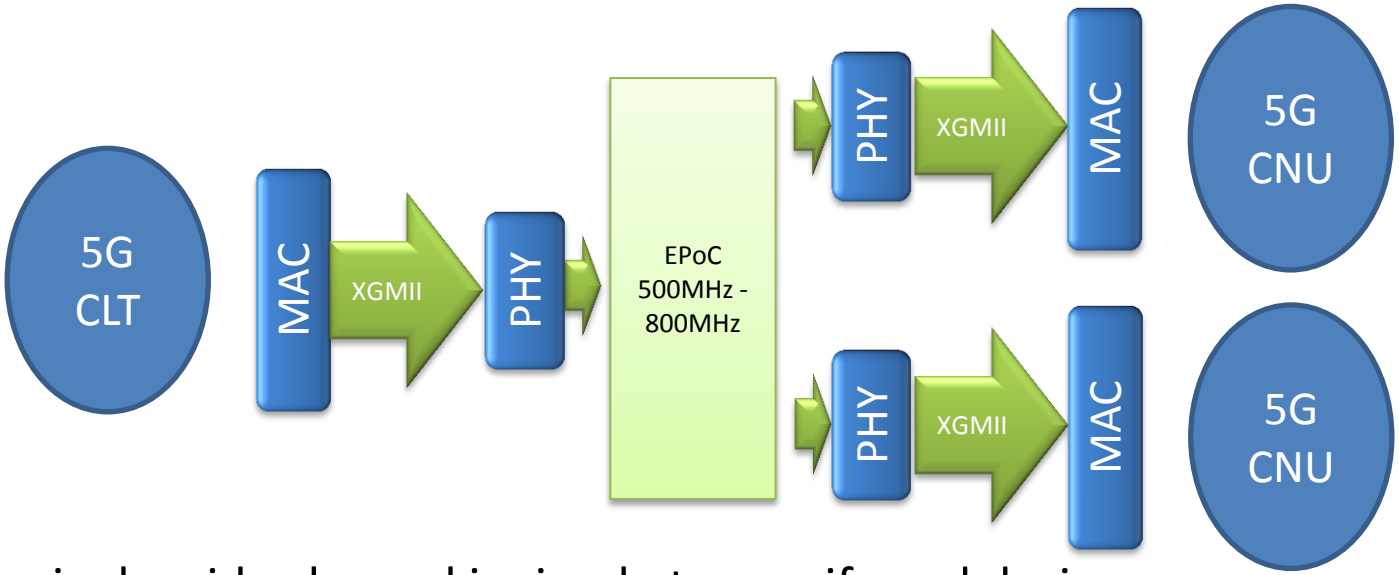
Legacy Channel Bonding Example



- Unicast, Multicast, and Broadcast must be switched based on destination.
- PHY can't provide packet L2 packet switching. Must go above MAC.
- 802.1D, link aggregation, or L3 function to switch traffic into sub-channels? To my knowledge, nothing exists in 802.1/3 to solve this problem.
- DOCSIS like solution with packet order marking, switching into logical channels buffers, re-ordering buffers needed. New standard in 802.1D?

Do we really want to go in this direction?

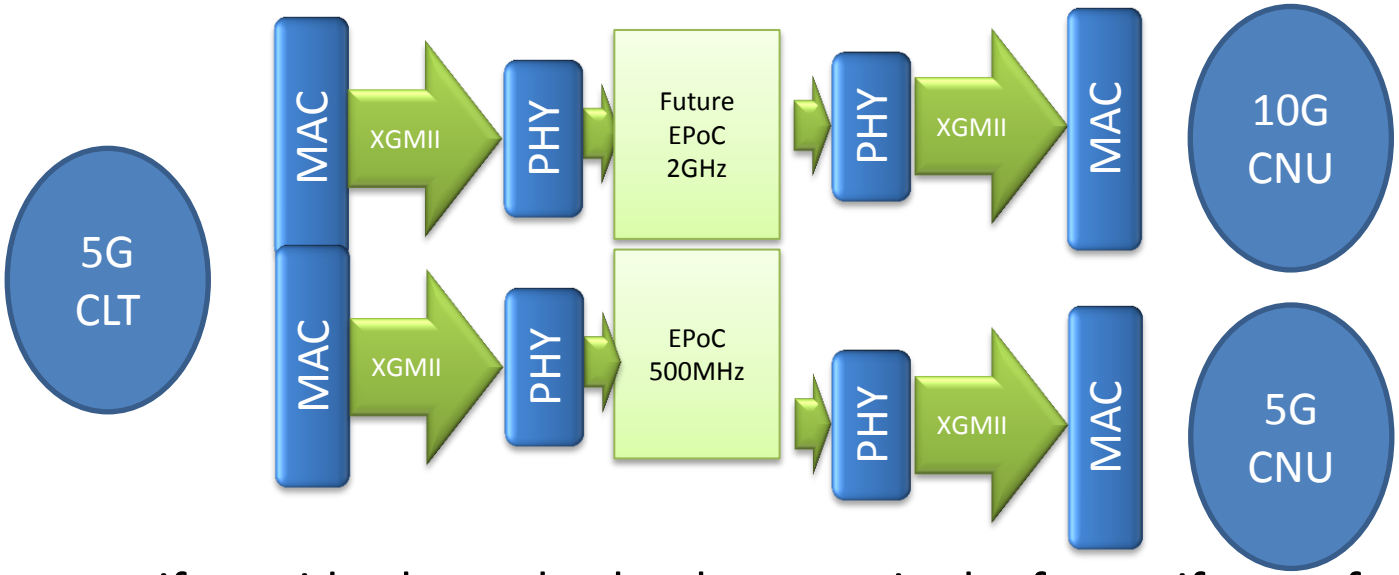
Full Channel Support



- The single wide channel is simple to specify and design.
- EPoC shouldn't be specified to compete with devices below 1 Gbps.
- It is economically and technically feasible to build devices to cover 100's of MHz of spectrum today.
- Channel bonding adds additional delay, cost, and complexity and requires a new standard.
- A high performance, flexible, and configurable full band solution gives EPoC a distinct identity.

Isn't this what the operators want to see?

Full Channel Future?



- If we specify a wide channel, what happens in the future if more frequency (1GHz-3GHz) becomes available?
- New PHY standard could use 1-3GHz to add 10Gbps downstream.
- 1G/10G EPON method of double downstream channel with CNU only tuning into a single channel would work well in this scenario.
- With large channel, penalty from duplicating broadcast is balanced with narrow tuner advantage.
- DOCSIS channel bonding probably could be avoided

Spectrum Conclusions

- PHY Bonding is better Packet/MAC layer bonding
- Channel Bonding with Legacy channels has significant challenges and might require a new 802.1D specification.
- New 802.1D channel bonding would make significant non-PHY differences between a CLT and an OLT.
- Covering the entire cable spectrum is the simpler solution. Bandwidth grows with spectrum availability.
- Additional discussion needed on minimum spectrum, range of spectrum to cover, and notching spectrum.

Other Options for Full RF Bandwidth

- TBD