EPoC FDD Downstream RF Bandwidth Proposal

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EPON over Coax

Outline

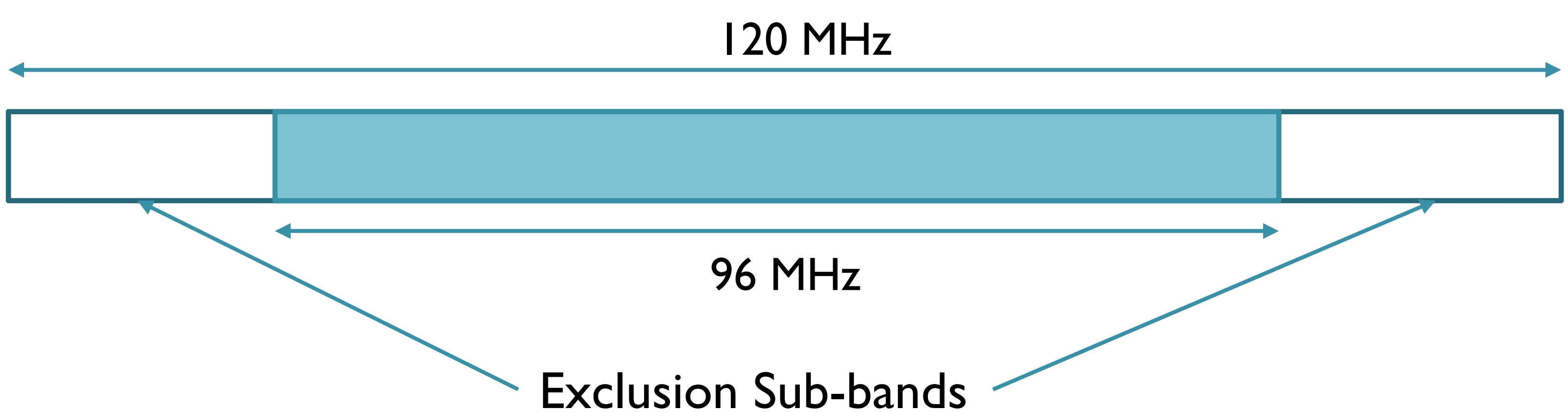
- Proposal for Downstream RF Bandwidth
- Bandwidth and Sampling Rate Choice
- Complexity for Proposed RF Bandwidth
- Complexity Scaling with RF Bandwidth
- Evolution in RF Bandwidth

Proposal for Downstream RF Bandwidth

- RF Bandwidth depends on product supported data rate
  - CLTs and CNUs will support some of these data rates

Supported Data Rate	FDD Downstream RF Bandwidth
1 Gb/s	120 MHz
2 Gb/s	240 MHz
4 Gb/s	480 MHz
5 Gb/s	600 MHz

- Smaller RF Bandwidths can be supported by use of Exclusion sub-bands



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Bandwidth and Sampling Rate Choice

- EPON is based around a time quanta (TQ) of 16 ns
- To enable a low-cost design and maintain synchronization between MPCP and PHY it is desirable to have a PHY sampling rate that is commensurate with the MPCP clock rate
- One method to do this is for the period of the PHY sample clock to divide evenly into the TQ value of 16 ns.
- The sampling rate of 125 MHz gives a 8 ns sample period which divides evenly into the 16 ns TQ
  - Sampling rates of 250 and 500 MHz are sample periods of 4 ns and 2 ns respectively, which both divide evenly into 16 ns TQ

Bandwidth and Sampling Rate Choice

- If the Task Force selects an OFDM PHY then the bandwidth of the N-point FFT is approximately equal to the sampling rate (f_s)
- The bandwidth of the OFDM waveform can be reduced from the sampling rate to a lower bandwidth by setting some of the outer subcarrier values to zero (often called null values)
- If we select a sampling rate of f_s = 125 MHz and null out approximately 4% of the subcarriers we will obtain an OFDM signal bandwidth of 120 MHz (or a little smaller to provide a guard band)

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Complexity of the Proposed Bandwidth

- The complexity of 120 MHz system is right for the market today
- The analog-to-digital converters (ADCs) and the digital-to-analog converters (DACs) can be significantly less complex and power hungry compared to a higher-bandwidth system
- 120 MHz OFDM PHY
  - FFT and IFFT, QAM modulator/demodulator, Channel Estimator, and other Modulation/Demodulation functions can all be build it a low-cost CMOS device
- FEC
  - The high-speed forward error correction for 1 Gb/s can be built in a low-cost CMOS device

Complexity Scaling with RF Bandwidth

- What is the impact of scaling the RF Bandwidth on device complexity?
- Let $BW_2 = K \times BW_1$, where K is an Integer
  - Example: BW_1 = 120 MHz, K = 4 and BW_2 = 480 MHz

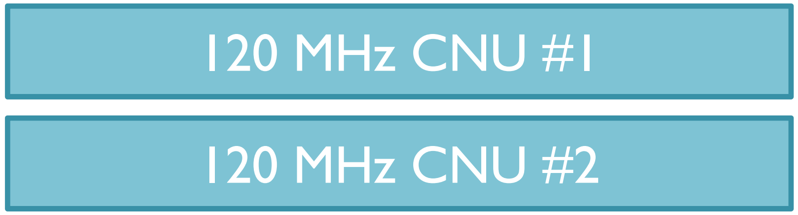
TX/RX Sub-block	Scaling with K	Scaling with K=4
ADC	≈K	≈4
DAC	≈K	≈4
FFT/IFFT	$K \mathrm{Log}_2(K \times N)/\mathrm{Log}_2(N)$	≈4.6
Modulator	K	4
Demodulator	K	4
Channel Estimator	K	4
FEC Encoder	K	4
FEC Decoder	K	4
RF PA TX Power (Linear Scale)	K	4

Complexity Scaling with RF Bandwidth

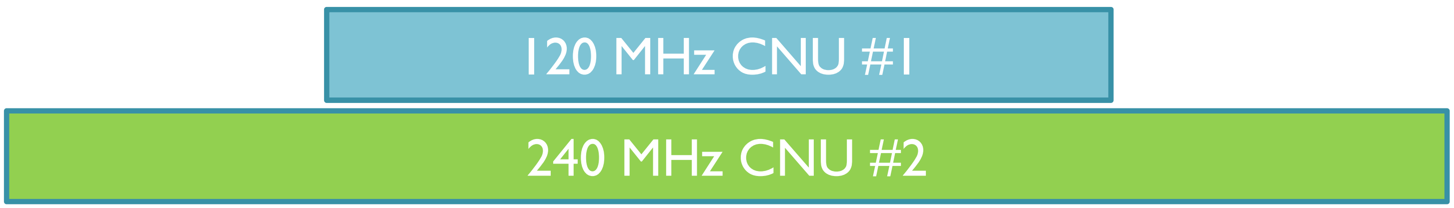
- Table on previous slide assumes PHY blocks are scaled it complexity (size) while maintaining clock frequency
- It is possible to run the clock frequency at a higher rate and in those cases the size may not scale at the same rate as in previous slide
- However, if a higher clock rate is used there is an increase in power consumption
- In some case, the clock rate cannot be increased since the clock is at near highest rate, at the smaller bandwidth
- Complexity increase can impact both size and power consumption

Evolution in RF Bandwidth

- First Generation 120 MHz CNUs



- It is possible to evolve a system from First Generation products of 120 MHz to Second Generation products of 240 MHz (or 480 MHz)
- One approach is to center the two bandwidths at the same center frequency



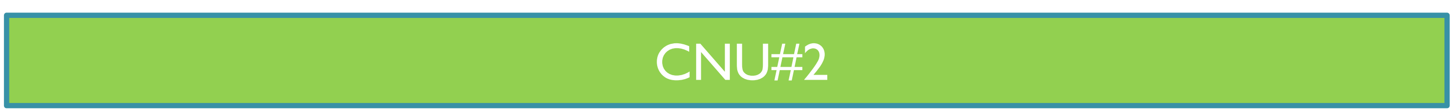
- PHY Layer allocates resource blocks of sub-carriers to the appropriate CNU
- PHY is RF Bandwidth aware

Evolution in RF Bandwidth – Resource Allocation Examples

- Equal Resource Allocation

- More resources to CNU#2

- All resources to CNU#2



XGMII

- Let us define the “Information Rate” over the XGMII interface as the data rate of Ethernet Frames, measured in Gb/s. This excludes the Idle Frames sent over the XGMII
- The maximum Information Rate depends on the underlying PHY rate. Let’s Illustrate with a few examples
- Case #1 – All CNUs 120 MHz and 1 Gb/s data rate
  - Information Rate over XGMII interface ≤ 1 Gb/s
- Case #2 – All CNUs 96 MHz and 800 Mb/s
  - Information Rate over XGMII interface ≤ 800 Mb/s
- Case #3 – Mixture of 120 MHz (1 Gb/s) CNUs and 240 MHz (2 Gb/s) CNUs
  - Information Rate over XGMII interface depends on the distribution of Ethernet Frames to Gen1 and Gen2 CNUs

Downstream Scheduler Impact

- If RF bandwidth is lowered from 120 MHz to 96 MHz for all CNUs then scheduler needs to be aware of maximum PHY Rate (800 Mb/s versus 1 Gb/s)
  - Limit maximum XGMII Information Rate to 800 Mb/s
- If there is a mixture of Generations with different RF Bandwidths, then the downstream scheduler needs to be aware of the mixture
  - XGMII Information Rate depends on the mixture of CNUs being served
- Either way, scheduler has to be aware of the RF Bandwidths of the CNUs

Motion

- EPoC FDD downstream shall support a baseline RF Bandwidth of 120 MHz
- Moved:
- Seconded:

Conclusions

- Offered a proposal for EPoC FDD Downstream RF Bandwidth
- Demonstrated how an OFDM system with that bandwidth has commensurate timing with the EPOC clock
- Showed how PHY complexity scales with RF Bandwidth
- Illustrated how a mixture of RF Bandwidths can be supported in a network