Bonding at PHY-Layer

of N× DFT Blocks

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Disclaimer

- This presentation tries to be non-controversial
  - we seem to have consensus already on the need for Bonding at PHY-Layer
- Describes ***how*** Bonding at PHY-layer could be done
  - more specifically, constraints on HOW the specification text would be written
  - combining two or more [192MHz] DFT Blocks, appearing from above as single link
  - intends to apply to both upstream and downstream
- NOT ***when*** or ***how many*** to Bond
  - does NOT address “Generational” issues
  - does NOT address which DFT blocks used to/from particular CNUs vs. time

Synchronization of N× DFT Blocks

- Transmitter synchronizes two or more DFT Blocks
      - » each transmitted at different RF center frequency

  - Macro-level synchronization, **to help avoid out-of-order delivery**
    - – symbol boundaries synchronized across blocks
      - » shared symbol structure: same duration of cyclic prefix, gaps (if any), preamble (if any)
      - » preserves coherency of RF subcarriers across blocks (see below)
    - – bonded transmissions on two+ DFT Blocks begin & end at same time
      - » i.e., at same symbol boundaries, avoiding skew in ordering at both endpoints (Tx & Rx)

  - Micro-level synchronization, for coherency / orthogonality
    - – Tx clocks synchronized across blocks (i.e., derived from same reference)
    - – to ensure coherency of RF subcarrier spacing across blocks
      - » preserves orthogonality **so MSOs can allocate adjacent RF Blocks**

Spreading Payload Bits across N× DFT Blocks

- Assume some upper layer payload to be transmitted over N× DFT Blocks
  - How to avoid introducing time-skew when spreading payload bits?
  - How many payload bits go into each DFT Block?
    - RF center frequency is different for each DFT Block
      - » at opposite ends of the spectrum, even
      - so can expect different carrying capacity for each Block
        - » different attenuation, impairments, notching,…
        - » different MCS = different modulation density or different FEC coding-rate
  - Split payload bits [unequally] N-ways, according to capacity of each Block
      - carrying capacity = # info bits per symbol (not including parity bits)
      - carrying capacity = (FEC code-rate) **×** Σ {bitloading per subcarrier}
    - DFT Block_i carries a Fraction_i of the payload bits
      - where Fraction_i = (capacity of Block_i) ÷ (capacities of Block_1+Block_2+… +Block_N)
      - Note: Similar to how a wideband PHY spanning all N× Blocks might distribute bits

  - **Result:** Payload begins and ends simultaneously on all N× Blocks
      - i.e., **no out-of-order transmission or reception**
        - » eliminates complexity due to skew of [DOCSIS-like] Layer-2 bonding

FEC for N× DFT Blocks

- FEC applied independently within each participating DFT Block
  - since each DFT Block may have different code-rate
    - may be at opposite ends of the spectrum, with different attenuation or impairments
  - codewords would NOT span boundary between DFT Blocks
    - codeword optimizations can be applied within each DFT Block
      - » such as those described in pietsch_01a_0912.pdf
  - maintains macro-level synchronization
    - all participating DFT Blocks start and stop transmitting simultaneously
      - » i.e., on the same symbol boundaries
    - no out-of-order transmission or reception

– Interleaver (if any) could perhaps be applied similarly—needs further study
  - interleaving not always needed (e.g., TDD at High-RF?)
  - when needed, is beneficial to preserve macro-level synchronization among Blocks

Summary / Conclusions

- Described how bonding of N× DFT Blocks could be done (not when or how many)
  - Macro-level synchronization among participating DFT Blocks
    - » helps avoid out-of-order delivery
  - Micro-level synchronization for coherence & orthogonality
    - » enables MSOs to allocate adjacent RF Blocks
  - Payload bits divided [unequally] N-ways (proportional to carrying capacity of each Block)
    - » so bonded transmissions start & stop simultaneously on all participating DFT Blocks
  - FEC applied independently within each DFT Block
    - » maintains in-order delivery from all participating Blocks
- These same constraints enable vendor-differentiated PHY implementations
  - vendors can implement via single monolithic PHY implementation
    - e.g., UHF ADC approach (spanning N× [disjoint] DFT Blocks)
  - vendors can implement via bonding of multiple single-Block PHYs
    - » e.g., to address single or two-Block CNUs
    - » e.g., to address operation at High-RF (above Nyquist frequency of wideband ADCs)
- Different equivalent approaches to writing specification text:
  - Text describing single-Block OFDM
    - plus text describing how to bond two or more DFT Blocks
  - Text describing single full-band multi-Block OFDM
    - with the constraints described above (synchronization, FEC,…)