Introduction to TDD

Compared with FDD

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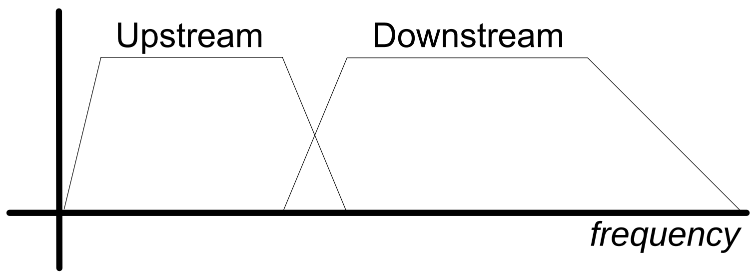
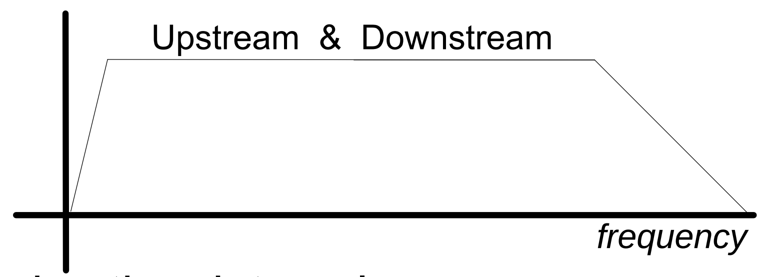
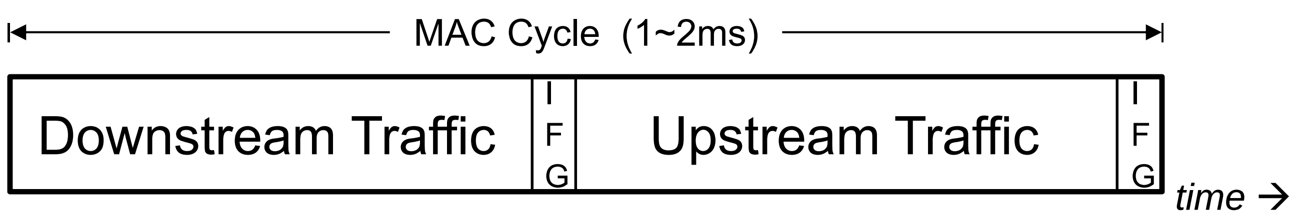
Introduction: FDD vs. TDD

- **FDD = Frequency-Division Duplexing**
  - Paired spectral allocations required: Split into two non-overlapping bands
    - HFC Split is typically rigidly fixed by stationary diplex filter transition band
  - Upstream & Downstream traffic transmitted in dedicated freq. bands
    - typically simultaneously & independently (i.e., full-duplex)





- **TDD = Time-Division Duplexing**
  - Single spectral allocation only →
  - Channel-time divided into non-overlapping time intervals
  - Upstream & Downstream traffic transmitted in alternating intervals
    - i.e., not simultaneously (half-duplex), but fast alternation emulates full-duplex:



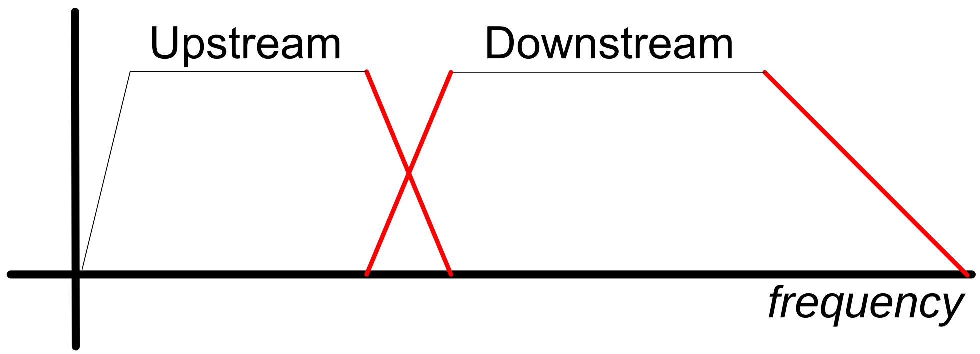
Benefits: FDD vs. TDD

- **FDD** easily traverses long HFC cascades (designed for the Node+Large era)
    - Easily conveyed over analog optics
    - Upstream from low-power CNUs can use the band with lowest attenuation
    - But every amplifier has two diplexors (difficult & expensive to change them)

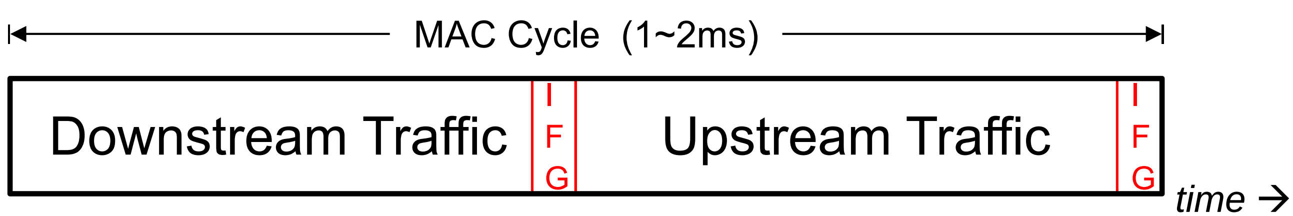
- **TDD** offers more flexibility (better targets fiber deep & Node+small plants)
    - Single (unpaired) spectrum allocation
        - same benefits exploited by major new Access standards: TDD-LTE & WiMAX
    - Channel-width is doubled (given same total spectral allocation as FDD)
        - capability of bursting wider channel allocation in either direction
        - ingress interference easier to mitigate (more opportunities to bitload around it)
            - » Upstream & Downstream de-rated ~equally
    - Peak datarates are doubled (without split-allocation as in FDD)
        - by enabling the entire channel-width to be flexibly scheduled for US or DS
        - e.g., symmetric mix for Business Services; Residential more likely asymmetric
    - Software-level agility of up/downstream mix (from millisecond-to-millisecond)
            - » statistical multiplexing (*stat-mux*) at Layer 2

PHY-Layer Overhead: FDD vs. TDD

- **FDD** wastes a spectral guard band (consumed by diplex filter transition)
  - band-width is ~25% of the Split frequency
  - current HFC plants waste 42~54MHz (25%×48MHz = 12MHz wasted)
  - if the split were moved to 300MHz, wasted band-width would be ~75MHz



- **TDD** wastes two IFGs per MAC Cycle (IFG = Inter-Frame Gap)
  - time delay for nodes to switch between: Talk → Listen → Talk modes
  - i.e., transceiver turnaround time: Downstream→Upstream→Downstream
  - Overhead = (IFG+IFG)÷(MAC Cycle duration) ≈ (7μs + 7μs)÷1ms ≈ 2%



Scheduling Efficiency: FDD vs. TDD

- Overhead
  - FDD is continuous downstream, bursted upstream
    - each burst requires a preamble
  - TDD is bursted downstream, bursted upstream
    - difference is two IFGs, plus one downstream preamble
    - ~2% difference in channel-time overhead
      - cf., FDD's ~25% spectral guard band overhead
- Latency
  - FDD supports efficient continuous downstream
    - but only ~half the peak capacity of TDD
    - hence, more likely to become congested (no statmux with upstream capacity)
  - TDD has non-continuous downstream
    - ½ MAC cycle waiting time (on average) for channel to become available

Summary: FDD vs. TDD

- **FDD** supports long HFC cascades
    - – FDD was appropriate for the Node+Large era
    - – works well, until you occupy to capacity
  - But requires paired spectral allocations
    - – with typically rigid inflexible diplex filters locking MSOs into '*crystal ball*' Split
  - Peak datarates are ~half that of TDD
    - – e.g., given symmetric spectral allocations
  - FDD overhead consumes ~25% of spectrum at the Split frequency

- **TDD** offers flexible allocation of double the peak datarate
  - i.e., capable of bursting the entire spectral allocation in either direction
  - with single spectrum allocation (does not require paired spectrum)
  - TDD overhead consumes ~2% of channel-time
    - – e.g., switching-time between upstream & downstream traffic
  - Flexible Up/Downstream capacities (statmux agility, from msec-to-msec)
    - – Symmetric Business Services; Asymmetric for Residential