EPoC Modulation Orders

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Introduction(1)

- What is the modulation order?
  - It is the OFDM/OFDMA bit loading per subcarrier. It is adaptively set by ranging and probing the channel.
- What is a “single modulation order”?
  - It is a single common bit loading per subcarrier mapping. In the downstream, the mapping is used by the CLT to broadcast OFDM to all CNU. In the upstream, all the CNU use a common mapping to send burst OFDMA to the CLT.

Introduction(2)

- What is a “multiple modulation orders”?
  - It is a bit loading per subcarrier mapping that is specific to each CNU.
  - In downstream, the CLT uses a CNU specific mapping to send messages to that CNU. CLT to CNU messages are unicast and not understood by other CNU. The modulation is burst OFDMA.
  - In upstream, the CNU uses his mapping to send burst OFDMA to the CLT.

DOWNSTREAM MODULATION ORDERS

Downstream Multiple Modulation Orders

- Pros
  - May improve modulation efficiency.
  - More time diversity.
- Cons
  - Higher complexity at CLT and CNU.
  - Higher overhead.
  - Increased latency.
  - Complicate interleaving for burst error protection.
  - Complicate distribution of time and synchronization.
  - Require downstream MAP.
  - Less frequency diversity.
  - May require additional pilots.
  - Not as efficient at packing bits.

Downstream Multiple Modulation Orders

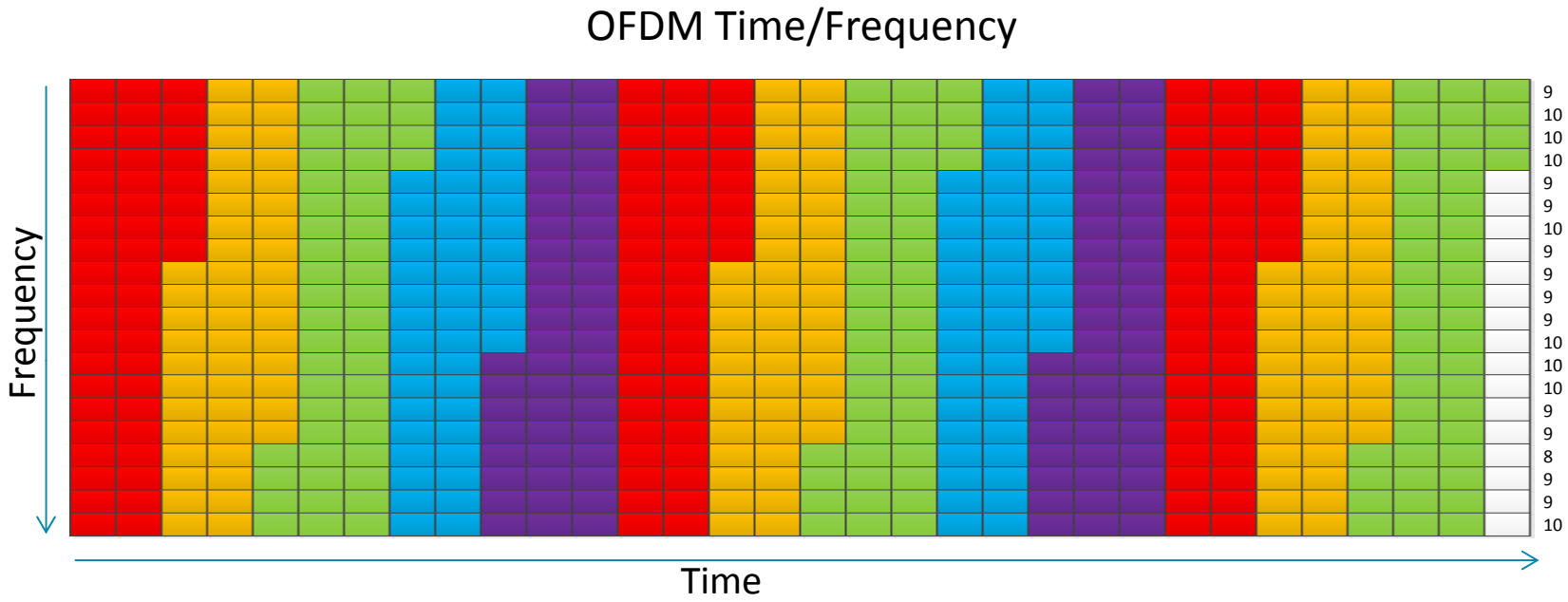
- Why it is not needed
  - Efficiency gain will be minimal and will be erased by additional overhead and complexity (at CLT & CNU).
  - May require additional pilots for synchronization and channel estimation to support dynamic bit loading change on subcarriers.
  - Cable plant is engineered to provide about same level[1] and SNR at each taps between amplifiers. Levels are usually within a 3 dB window.
  - Services in the cable plant (DOCSIS and MPEG video) operate successfully in broadcast mode.
  - Interleaving function is complex to implement.
    - If payload is distributed across few subcarriers (time diversity), interleaving is not required.
    - If payload is short in time but across many subcarriers (frequency diversity), interleaving is required.

[1]:IEEE 802.3 EPoC Study Group, March 2012 Meeting: Cable System Overview, Matt Schmitt

Downstream Modulation Orders

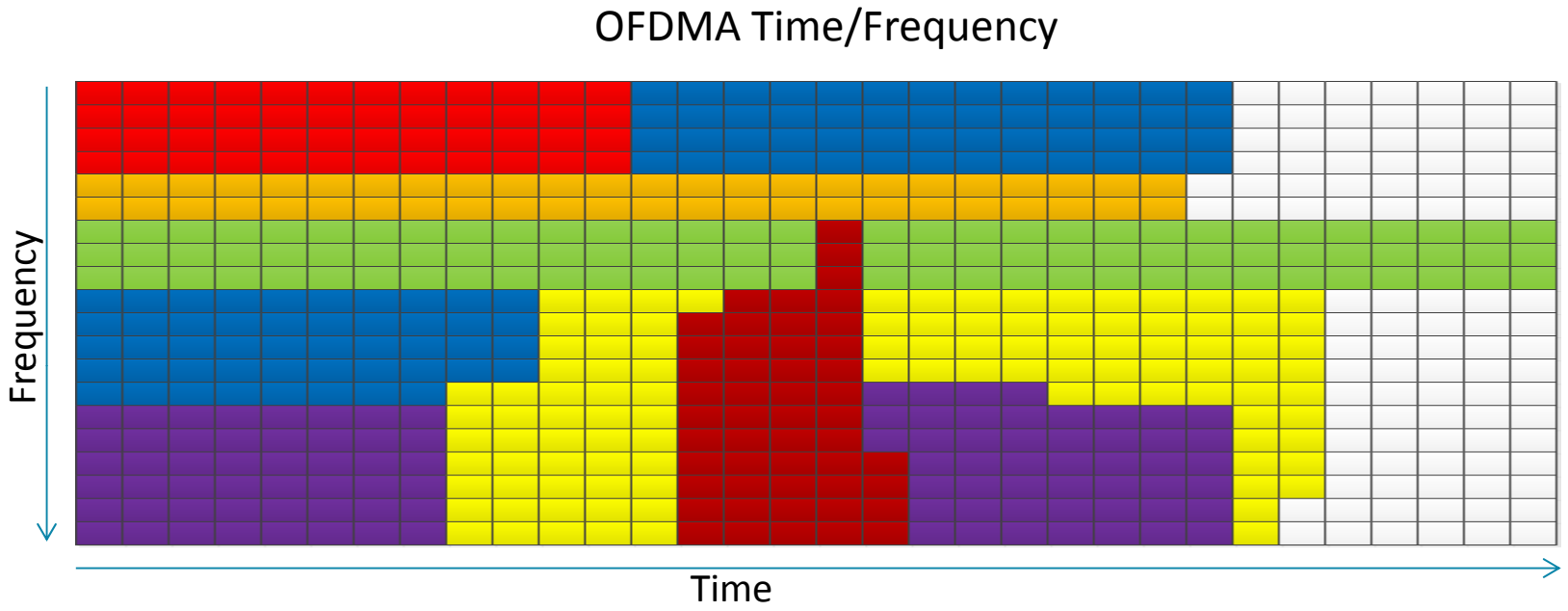
- Why a single modulation profile is preferable
  - Allow large LDPC blocks, coding is on the whole data stream.
  - Higher coding gain.
  - Lower latency for FEC and Interleaver.
  - Simple interleaving for burst noise error protection.
  - Lower overhead
    - No need to shorten FEC block size.
    - No need to broadcast multiple downstream modulation order.
    - Lower pilot to payload ratio.
  - Deterministic and static transport delay. Ease distribution of time and synchronization.
  - May end up with higher efficiency as overhead is reduced.

Downstream Modulation Orders



- Traffic is broadcast to all CNU
- FEC blocks are aligned across all frequencies

Downstream Modulation Orders



- Traffic is unicast
- FEC blocks are aligned to payload per CNU
- Bit loading changes dynamically from CNU to CNU
- May require additional pilots for synchronization as bit loading changes between unicast message.

Downstream Modulation Orders

- A single broadcast modulation order requires
  - Regular channel probing to estimate the worst case channel conditions in order to set CP and bit loading per subcarrier.
  - Mechanism that prevents defective or problematic CNU to limit throughput of network. This problem also needs to be addressed for case where multiple modulation orders are used in the network.
  - CNU that cannot achieve a given performance level (set by network operator) should not be admitted in the network.

UPSTREAM MODULATION ORDERS

Upstream Multiple Modulation Orders

- Pros
  - Improve modulation efficiency.
  - Minimal impact to CNU.
- Cons
  - Higher complexity for CLT, has to store and track multiple CNU profiles.
  - Higher complexity for upstream MAC scheduler, has to manage N-dimensions (Time-Frequency-CNU profiles).

Upstream Multiple Modulation Orders

- Why it may not be needed
  - Noises are funneling to the CLT. Channel noise and ingress are independent of CNU transmissions.
  - After CNUs are calibrated for slope and level pre-equalization, SNR on each subcarrier will be the similar for all CNUs. If level pre-equalization is implemented per subcarrier, SNR on each subcarrier will be identical for all CNU.
  - DOCSIS upstream operates successfully. It uses the same burst profile for all transmitter on same channel.
  - We can address the requirements of different service by using a limited set of modulation order.

Upstream Modulation Orders

- A single modulation order will require:
  - Regular channel probing to estimate the worst case channel conditions in order to adjust CP and bit loading per subcarrier.
  - Mechanism that prevents defective or problematic CNU to limit throughput of network.
  - CNU that cannot achieve a given throughput or level of performance should not be admitted in the network.
  - Level pre-equalization at the TX to correct for level and slope introduced by the cable plant. If level pre-equalization is per subcarrier then there is no reason to use a per CNU upstream modulation profile.

Upstream Modulation Orders

- Possible future task force contributions:
  - For CNU that cannot be successfully pre-equalized (i.e. not meeting TX power requirement). Should they be allowed to join the network at a lower rate, using a subset of subcarrier frequencies? Should we have multiple upstream modulation profiles?
  - Does the throughput increase justify the complexity increase?

Conclusion

- To minimize latency, complexity and overhead, we should use one modulation order and continuous broadcast in the downstream.
- A single modulation order for the downstream is suitable as cable plant are designed for broadcast downstream traffic.
- A single upstream modulation order per channel is suitable. Today, on a given DOCSIS upstream channel, all CMs use the same channel parameter and burst parameter configurations

Thank you

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