

EPoC Modulation Profile

IEEE 802.3bn – Multiple Profile ad-hoc

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Background (see [1])

- In OFDM systems, transmission is implemented using a large number of adjacent, orthogonal, modulated subcarriers
- QAM symbols combined with Forward Error Correction (FEC) techniques are used to realize a robust protection against errors
- In case of a coax cable distribution network, several dimensions could be explored for improving the spectral efficiency of the users connected to the system:
 - Frequency dimension: bit loading and MCS (see next slide)
 - Time dimension: adaptive or static
 - User dimension: single or multiple

Background – Frequency Dimension (see [1])

Bit Loading

- In multicarrier systems, each (or a small group) of the narrowband subcarriers can be individually modulated. In particular, the QAM order for each subcarrier can be selected based on its individual narrowband channel quality.
- This ability to optimize subcarrier QAM orders across the total bandwidth of the communications channel is known as **Bit Loading**. The term bit loading commonly assumes that FEC rate is not changed across subcarriers.

Modulation and Coding Scheme (MCS)

- Another way to match the channel quality across subcarriers allocated for a given transmission is referred to as the **Modulation and Coding Scheme (MCS)**.
- The scheme is realized by applying the same modulation and coding to all the subcarrier carrying the code word, matching the average channel quality.
- In general, different MCSs may differ both in terms of the QAM order of modulation and FEC code rate (k/n) and typically, for each QAM order, there may be multiple code rates available to select, for finer granularity.

EPoC Context – what agreed so far

- Single profile is more suitable for continuous mode like FDD DS, while multiple profiles can be implemented for burst mode, like TDD DS/US and FDD US (see e.g. [2] and technical decision #19)
- Channel conditions tend to a more static model, sensitive primarily to slowly varying diurnal and seasonal change. As a result, adaptability can be realized by assigning each situation the correct profile within a predefined subset of static profiles
 - Single profile selected on a per plant basis for continuous mode (FDD DS)
 - Multiple profiles selected on a per-plant and per-user base, for burst mode
- Since the range of time/frequency variations is relatively modest, the choice of subcarrier modulation may be simplified by grouping subcarriers together and applying a QAM order to the group, or by applying MCS approach (see [1]).

EPoC Modulation Profile – TDD DS burst mode

- In case of TDD DS, CNUs are grouped per their DS profile and packets are transmitted by the CLT on a per group base (see [2])
 - FEC code words can be long for better robustness/performance
 - Markers are inserted at PHY level to instruct the CNU receiver about what portion of the data is matching what profile (see [3, 4])
 - The scheduler needs only to consider destination for grouping
- The proposed solutions rely on using MCS to define profiles and applying frequency interleaving at OFDM symbol level to average channel conditions over the band (see [5])
 - Using bit loading would increase scheduler complexity (frequency awareness and OFDM symbol timing becomes necessary at MPCP level to correctly handle profile switch)

EPoC Modulation Profile – FDD/TDD US burst mode

- In case of FDD/TDD US, each CNU is assigned a limited amount of resources per each grant
- using the same scheme as for TDD DS may not be beneficial to match the channel conditions as averaging will only happen on a small portion of spectrum, different from each assignment
- Instead, exploring the frequency variability is better (see [2, 6]) with the application of bit loading on a per subcarrier-group base or of MCS targeting average channel condition of the assigned spectrum for the particular CNU
 - FEC code words needs to be short for packing efficiency
 - Markers are inserted at PHY level to instruct the CLT receiver about what profile have been used for the transmission (see [2, 3, 4])
 - Using MCS will match the TDD DS case for burst mode

EPoC Modulation Profile – FDD DS continuous mode

- In case of FDD DS, single profile is used (broadcast mode) and signaling to instruct the receiver can be done via configuration
- Two options are possible:
 - A. Applying common MCS over the entire spectrum, with frequency interleaving at OFDM symbol level to average channel conditions
 - B. Applying common bit loading curve over the entire spectrum, with granularity at sub-carrier group (to limit overhead)

Note: In both cases, bad sub-carriers (or bad sub-carrier groups) can be nulled or excluded from the transmission, in case needed
- Option A will match the TDD DS case and could be preferred to leverage the same PHY in the CLT – a single profile can be implemented also in TDD DS by configuration, when needed

References

- [1] “Adaptive Bit Loading and MCS definition”, by Rob Howald, Andrea Garavaglia and Hesham ElBakoury, December 2012
- [2] boyd_3bn_04_0313: “EPOC Upstream Multiple Modulation Profiles”, Ed Boyd (Broadcom) and Juan Montojo (Qualcomm)
- [3] boyd_3bn_03_0313: “EPOC Upstream Burst Markers”, Ed Boyd (Broadcom)
- [4] varanese_3bn_01a_0313: “Burst Markers for EPoC Burst Mode”, Nicola Varanese, Hendrik Schoeneich, Juan Montojo (Qualcomm)
- [5] garavagl_03a_0113: “Multiple Profiles for EPoC”, Andrea Garavaglia and Nicola Varanese (Qualcomm)
- [6] “Modulation Profiles in EPoC US”, Marc Werner (Qualcomm), MMP ad-hoc, February 2013