EPoC Modulation Profile

Andrea Garavaglia and Nicola Varanese – Qualcomm

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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