Comparison Metrics for Ethernet Frame FEC

Metrics

1. Efficiency
2. Legacy operation
3. Impact on existing clauses
4. Impact on new (for EFM) Clauses
5. Impact on test equipment and testing methodology
6. Flow Control - Maintaining the line rate at 1.25Gb/s
7. Cost and complexity of implementation
8. Performance differences

1. Efficiency of F-FEC vs. S-FEC

- Frame FEC overhead: 7.3%
- Assuming
  - Carrier Extension for frame concatenation
  - Packet Size 1518
  - Ethernet Framing 20
  - FEC Data 123

- Stream FEC overhead: 8.2%
- Assuming:
  - Frame size 191
  - FEC Data 17

2. Legacy Operation of F-FEC

- At any given time an Ethernet frame is observed in the line
- FEC parity is inserted during idle periods

- Existing unmodified Ethernet equipment can receive an F-FEC stream
  - Advantage: test equipment, appliances, incremental upgrade of network, no auto-negotiation required

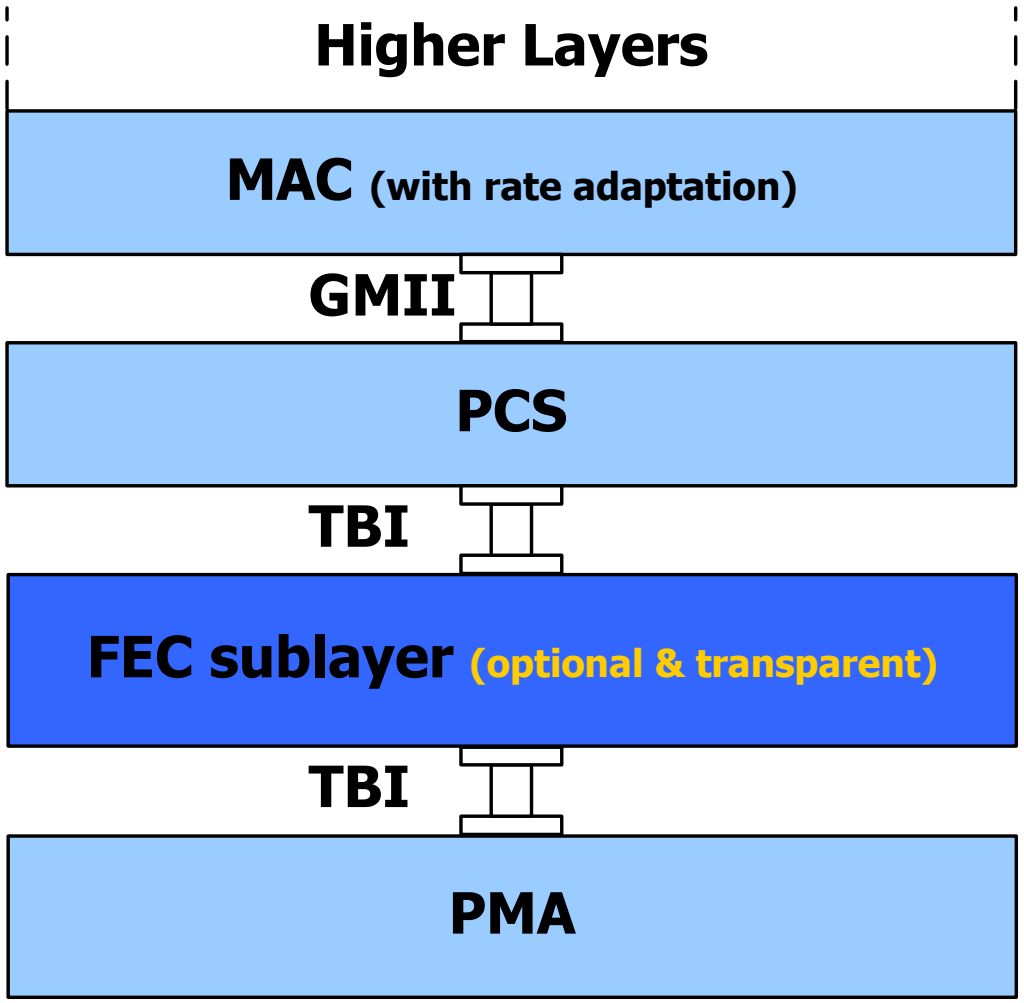
2. Legacy Operation of F-FEC

- How:
  - Parity bytes added at the end of the frame maintaining the atomic frame structure
  - FEC is coded before the 8B/10B code
- Legacy devices observe a normal Ethernet frame
  - FEC can pass-through existing PMD
  - FEC can pass-through existing PMA
  - FEC can pass-through existing PCS
  - FEC can pass-through existing MAC

3. Impact on Existing Clauses

- MAC (Clause 3):
  - Addition of IPG stretching (similar to 802.3ae)
- PCS (Clause 36):
  - No changes
- PMA (Clause 36):
  - No changes (EN_CDET not optional)
- Auto-Negotiation (Clause 37):
  - No Change
- PMD (Clause 38/39):
  - No Change
- Analysis of performance of existing PMA/PMD parts @ 10-4 still required for both FEC

FEC Layering in Ethernet Stack



4. Impact on New Clauses

- FEC sub-layer (new clause)
- OAM (Clause 55)
  - No change for F-FEC
- MPCP (Clause 56)
  - No change for F-FEC
  - Unlike S-FEC:
    - Does not requires major rewrite to generate 'reset signal' for FEC at upstream reception
    - Does not impose jitter on MPCP timestamps
    - MPCP timer is not synchronized to FEC framing cycle
- P2MP PMDs (Clause 58)
  - Can work with fast PMDs and slow PMDs
  - F-FEC is self synchronizing and does not require special preamble
  - Analysis of performance @ 10-4 still required for both FEC

5. Impact on Test Equipment and Testing Methodology

- F-FEC is compliant with existing 1000Base-X enabled test equipment, as parity bytes added at the end of the frame maintaining the atomic frame structure:
- Field equipment (in IT departments, and at Telcos)
  - Stress MAC/Protocol layer
  - Will work unmodified on FEC enabled link
- Legacy lab equipment (Smartbits etc.)
  - Device & Network analysis still works

- Frame FEC leverages deployed equipment and methods improving time to market

6. F-FEC Rate Adaptation

- In F-FEC rate adaptation function is open loop
  - State of FEC encoder is not exposed to MAC
  - Idles are sent following frames based on total frame length 'IPG stretching', adapting TX MAC rate
  - Known ratio between the frame size to additional parity bytes per packet
- Idles replace parity bytes in receiver following reception
  - Distance between frames is unchanged
  - MPCP timestamp which is based on counter counting bytes on line is not broken

7. Cost and Complexity of Implementation

- FEC implemented in silicon:
  - Framing logic
  - 1500 byte buffer
  - FEC core (dominant factor)
- FEC gain is in system cost
  - Improve optical performance
    - More splits
    - More distance
  - Reduce port cost for OLT by serving more ONUs
    - With better optics, even greater improvement

8. Performance Differences - Gain

- Frame FEC has larger coding gain than S-FEC
  - 8B/10B code violations are translated to erasures
  - Erasures give locations of errors in stream improving code's ability to correct
  - For S-FEC a single error in 10B symbol is translated to two errors, offsetting potential gain from erasures

8. Performance Differences - Efficiency

- Frame FEC has better line efficiency
  - 7.3% overhead
  - F-FEC Uses (255,239) code (93.7%)
  - F-FEC concatenates small frames to form a packet train with carrier-extension
- Stream FEC has lower efficiency
  - 8.2% overhead
  - S-FEC effective code is (208,191) (91.8%)

8. Performance Differences – Failure Recovery

- Frame FEC resynchronizes for each frame
- Following error condition, next frame would be recovered

- Stream FEC synchronizes with special preamble
- Following error condition, many FEC periods required for reacquisition of synchronization

Summary

Item	S-FEC	F-FEC
Efficiency	8.2% overhead	7.3% overhead
Optical gain	10-4 to 10-12	Higher with erasures
Legacy equipment	Not supported	Supported
Inter-layer	Synchronous to MAC with added signals	No added control signals
MPCP	Requires special preamble for uplink, reset line at OLT, synchronizing ONU MPCP to FEC layer, problem with MPCP timestamp	Not affected
Complexity	Same	Same
Auto-negotiation	Required	Not required
Failure recovery	Slow	Fast – self synchronous