End-of-Burst Detection in 10G

Jeff Mandin
PMC-Sierra

802.3av Tokyo – April 2008

PCS Desync

1. Desync at the ONU's downstream receiver happens when either:

   - 3 consecutive uncorrectable FEC codewords are received (3 CWs = about 595 ns)

   - 16 Sync Header errors occur within the span of two FEC codewords. In Gaussian noise:
     - Probability of desync in first codeword (198.2 ns) is 0.781928137
     - Probability of desync by 54th 66b block (345.6 ns) is 0.999954909

2. Let's assume that we do the same at the upstream receiver

Considerations for Upstream End-of-burst Detection

1. Time between bursts

   - The specification enables vendors to differentiate by providing aggressive timing between bursts. The requirement for laserOn time and SyncTime is unbounded in 10G.

   - Consequently, it's desirable for the PCS layer to enable 250ns or less between bursts

2. Sync Pattern

   - When 2 ONUs transmit in succession on the upstream, the second ONU begins to transmit the 0x55 pattern as the first ONU is turning its laser off

   - If the OLT receiver is checking sync headers, the 0x55 pattern (received at the PCS during periods when the analog receiver is stable) will appear to be real data

   - So it's tricky to try to detect upstream end-of-burst by checking the sync headers

Mechanisms for upstream end-of-burst detection

1. Time-based
   - The OLT is actually aware of when the burst is supposed to end (ie. the end of the GATE slot)
   - XGMII and separation of Tx and Rx paths have prevented us from making use of this till now

2. Signalled by ONU
   - The ONU can mark the final codeword of its burst by a particular combination of sync headers in the parity 66b blocks
   - Necessitates protecting the parity header bits with FEC
   - At reception, the final codeword might end up being uncorrectable or otherwise lost. This necessitates some additional special logic

2. Desynchronization Detection
   - One possibiilty is requiring 595 ns between bursts
   - Another possibility is for the OLT to begin looking for the delimiter of next burst before it has established that the current burst has completed (ie. “soft desync”)

Solution #1: Time-limited upstream burst

- We shouldn't have to work hard to recreate what we already know
- There can be some kind of signal from the MAC control entity to the PCS eg.
  a) New signal for 10GBASE-PR XGMII
  b) an MDIO register
    - MDIO is a facility for configuration/monitoring rather than realtime control
    - However a vendor's implementation could continuously update the MDIO parameter via a fast mechanism - so that the OLT would automatically desync according to a non-static criteria such as end of GATE time
- This scheme does not help for Discovery
  – Consequently when "close" (ie. within 600 ns) consecutive bursts happen in a discovery window it still might end up treated as a "collision"

Solution #2: ONU signals end-of-burst to the OLT

1. The transmitting ONU can have awareness of the last FEC codewords of its burst
   - Data detector can be extended so that it discovers the last block before it has been transmitted (rather than after transmission as it does currently)
2. On the final 3 codewords in the burst: ONU places special values for the sync header fields of the parity blocks to signal the Last-codewords-in-burst to the OLT
   - eg. : =➔ 11 10 00 11 00 01 11 00 00 11 11 11
   - Remember that the Sync Headers are not actually used for sync on the upstream
   - The parity sync headers need to be protected by FEC (that's fine because there is the 29 bits of unused pad in the codeword)
3. If one or two of the last 3 codewords is uncorrectable, the OLT can still identify the end of burst
   - if all 3 are uncorrectable, then OLT declares desync anyway

Solution #3: Soft Desync

1. In this solution, the OLT PCS relies on consecutive uncorrectable FEC codewords to guarantee desynchronization after 595 ns

2. To enable gaps between bursts that are shorter than 595 ns, the OLT PCS searches for the start-of-burst delimiter while data (or what seems to be data) from the previous burst is still being received.

3. Necessary to avoid false detection of correlator (which can appear with tolerated bit errors in shifts of legitimate uncorrected data).

4. Sequence is:

    1. Trigger event (eg. An uncorrectable FEC CW) causes OLT synchronization process to begin scanning of incoming data (on all alignments) for Start-of-Burst Delimiter

    2. If a start-of-burst-delimter is detected, then the synchronization process emptys the FEC buffer and begins to fill it again based on the new alignment

    3. Otherwise, successful decode of a FEC CW causes the OLT to stop scanning for start-of-burst delimiter.

Summary

1. 10G burst-mode requires quick detection of end-of-burst. The problem is more difficult than in 1G because there is less distance between valid and invalid data

2. Since there are tradeoffs, several approaches are presented:

   a) OLT ends the burst at the end of the GATE timeslot
   - PCS requirement for gap between bursts is 0 (for data bursts); 600 ns (for Discovery)
   - simple and effective, but might be regarded as taking liberties with the purpose of MDIO.

   b) OLT relies on the ONU to mark the end of the burst
   - PCS requirement for gap between bursts is 0 (for both data and discovery)
   - One and two block bursts present difficulties

   c) Soft Desync
   - PCS requirement for gap between bursts is around 64-200 ns (depending on trigger)

Backup

Soft Desync: what is the trigger to start scanning?

a) FEC Codeword decode failure:

- Minimum time between bursts would be duration of a codeword ie. 198.4ns

b) Sync Header errors

- The 0x55 sync pattern transmitted by the next ONU will appear to the OLT to be valid 01 or 10 sync header data

- To remedy this, we could redefine the upstream Sync Headers to carry 00 and 11 instead where they now carry 10 and 01 respectively

- Then: (eg.) 4 out of (eg.) 10 bad (ie. 01 or 10) sync headers would trigger the OLT PCS to start scanning for a new start-of-burst delimiter

- PCS requirement for minimum time between bursts could be reduced to 64ns or so

ONU signalling end of a very short burst

1. If the ONU sends a 1- or 2-codeword burst, and then the entire burst is uncorrectable, the OLT will not be able to detect the end of burst

2. A Solution:

   a) For 1 or 2 codeword bursts, a ONU transmits a postamble pattern after the last codeword

   b) Postamble needs to have sufficient Hamming Distance from real data blocks

   c) ONU needs to request the transmission time for the postamble in REPORT

   d) OLT looks for the postamble after the first or second codeword in the case where all codewords so far in the burst were uncorrectable.

Estimated Time to Desync in Noise Using Sync Header Errors

1. In Gaussian noise, the probability of a bad header (ie. 11 or 00) in a non-parity position is .5

2. Detection of 16 bad headers within 2 FEC CWs causes a desync

3. For simplification of calculation, we look only at the headers of the non-parity blocks. The parity blocks are assumed to always have bad headers (so the true probabilities are a bit lower than these estimates). Probability of desync within *n* blocks (for 26 < n < 58) is thus:

$$P(n) < 1 - \left\{ \left[\sum_{i=0}^{11} \{ n!/[i! * (n-i)!] \} \right] / 2^{n} \right\}$$

4. So:
   P(27) < 0.781928137
   P(50) < 0.999954909