EFM-Cu Framing & Error Detection

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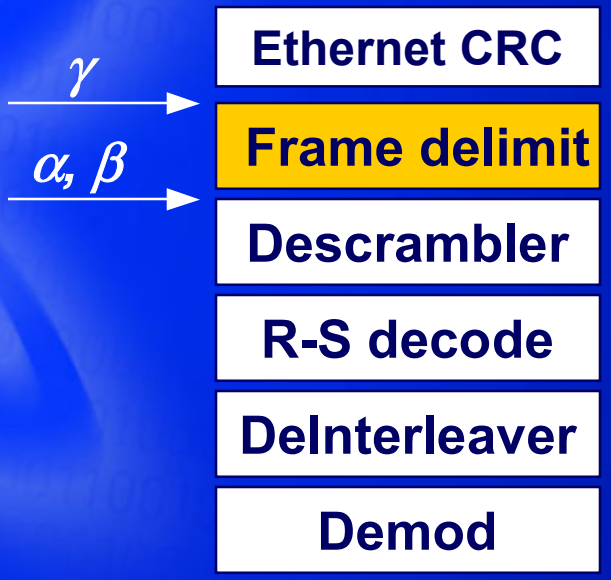
Status

- ITU-T Q4/15 has defined a Packet Mode TPS-TC (i.e., PTM-TC) for xDSL
  - Transport of Ethernet frames a key intended use
- Questions raised in Raleigh regarding its suitability
  - DSL BER performance levels lower than traditional Ethernet Levels
  - Uses HDLC, a method out of favor in 802.3
  - PTM-TC not widely reviewed in 802.3 before adoption by ITU-T

The Issues

- MTTFPA – Mean Time To False Packet Acceptance
  - Probability that an errored packet will not be detected by the PHY/MAC
    - **Depends on underlying BER, and detection/correction capabilities of coding and framing**
  - What's an acceptable level?
    - **∞ not possible**
    - **10 billion years has been consider acceptable**
    - **That's ~10^{25} bits, or ~10^{21} frames**
- Framing overhead
  - Lower overhead ⇒ longer reach for given bitrate
  - Deterministic overhead

Stack



HDLC, 64b/66b, or ?

Interleaver

- Convolutional interleaver enhances burst-noise protection
  - 250 µsec. And 500 µsec. protection common
  - But generates latency:

Line rate, Mb/s		1.62	3.24	6.48	12.96	25.92
Value of *N*/*I*		8				
250 µsec of erasure correction	*M*, octets	2	4	8	16	32
	Delay, msec	5.9				
500 µsec of erasure correction	*M*, octets	4	8	16	32	64
	Delay, msec	11.8				

From [3]

  - May be turned off

R-S Decode

- Code operates on 8-bit symbols (*m*=8, bytes)
- Can correct up to *t* byte errors, $t = \lfloor (n-k)/2 \rfloor$
- Output byte error ratio, P_E, as a function of channel byte error rate *p*:

$$P_E \approx \frac{1}{2^8 - 1} \sum_{j=t+1}^{2^8-1} j \binom{2^8 - 1}{j} p^j (1-p)^{2^8-1-j}$$

- Output BER, $P_B \approx \frac{1}{2} P_E$
- SCM (*n*,*k*): (*255*,*239*) $\Rightarrow$ $t = 8$
- MCM (*n*,*k*): (*240*,*224*), (*144*,*128*) mandatory $\Rightarrow$ $t = 8$

Descrambler

- Self-synchronizing
  - $x^{23} + x^{18} + 1$
- Reduces long run length occurrences
  - Keep demodulator happy
- 2× - 3× BER multiplication

"Back of Envelope" Calculations

- VDSL spec'd for BER = 10^{-7} at α/β - interface
  - T1.424 Part 1, § 12.3
  - $\Rightarrow 10^{-7} \times 2 \times 255 \approx 5 \times 10^{-5}$ R-S codeword error ratio
- 2^{-32} prob. errored frame not detected for Ethernet CRC
- $5 \times 10^{-5} \times 2^{-32} \approx 10^{-14}$, **» 10^{-21}**
- Need to get ~7 orders of magnitude from frame encapsulation, or elsewhere

On VDSL Noise Margin …

- DSL performance levels spec'd with 6 dB noise margin
  - i.e., specified BER levels would be met even if noise level were increased by 6 dB
  - So typical α/β-interface BER is actually $\approx 10^{-22}$
- Helps ensure data types requiring a certain bit rate will continue to work
- Non-adaptive Ethernet performance goals fit this model
- $\Rightarrow$ **Retain the margin**

Frame Encapsulation

- G.993.1 PTM-TC
  - Byte-stuffed HDLC with FCS-16
- 64b/66b
- Other?

HDLC PTM-TC

- 16-bit CRC
  - 2^{-16} detection failure (~2×10^{-5})
  - Detects all single, double, and odd bit errors; all error bursts ≤16 bits
- Pros
  - Fast, easy frame lock; look for <flag><non-flag> sequence
  - Low complexity
  - Low average overhead for long frames (~0.8%)
- Cons
  - High overhead for short frames (~8%)
  - Overhead variable: data- & frame-length-sensitive
    - **Could be 50+% worst-case**

64b/66b

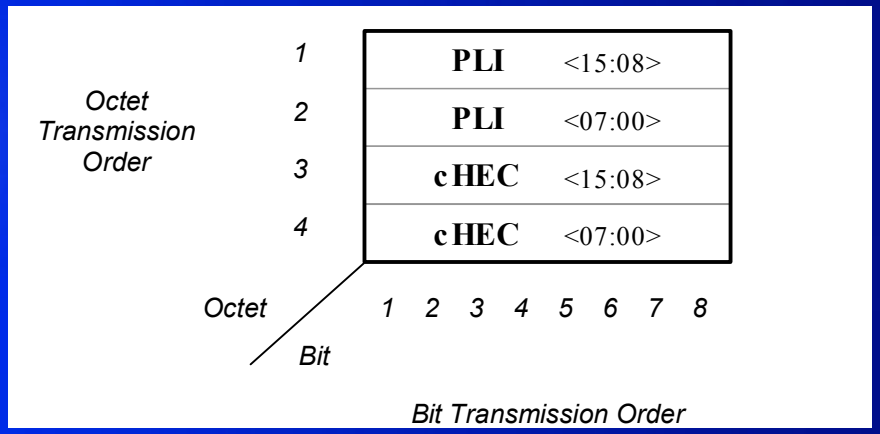
- Pros
  - Low overhead upper bound
  - Limited run-length (but not needed here)
  - Control codes protected against 3-bit errors
    - **But bit errors at R-S output not independent; analysis difficult**
- Cons
  - High Complexity (~2K flip-flops [2])
  - Slow, complex frame lock
  - No additional error protection for data bytes:

0	1	D0	D1	D2	D3	D4	D5	D6	D7

    - **Any bit errors in D0-D7 still a valid codeword**
    - **Reputation for robustness due to typical low underlying PMD BER**
  - Not byte-aligned; poor fit with α/β-interface

Other Alternatives

- Rather than HDLC flag-transparency, use G.gfp-style header [5]:



  - Header contains Frame Length info
  - No need for transparency mechanism
- Pros: Fixed overhead per frame overhead
- Cons: Complicates frame-lock

Recommendation (1)

- Add “ERROR” signal to α/β-interface to allow reporting of uncorrectable R-S codewords
  - Lowers error rate bound by [4]:

$$\frac{1}{t!} = \frac{1}{8!} = 2.5 \times 10^{-5}$$

  - Combined with HDLC FCS, should be adequate robustness
  - TPS-TC above α/β-interface then knows to discard bad data

Recommendation (2)

- Use PDU-length-type header (e.g. G.gfp) if HDLC flag-transparency is unacceptable

References

1. Sklar,Bernard; *Digital Communications*; Prentice-Hall, 2000
2. Walker, et al; *64b/66b coding update*, IEEE 802.3ae presentation, March 2000
3. ATIS Committee T1.424, Trial-Use Standard, *Very-high-bit-rate Digital Subscriber Lines (VDSL) Metallic Interface*; to be published
4. McEliece, R.J., & Swanson; *On the Decoder Error Probability for Reed-Solomon Codes*; NASA TDA Progress Report 42-84, Oct.-Dec. 1985
5. ITU-T Draft Recommendation G.gfp, October 2001, *Generic Framing Procedure*