False Packet Acceptance for HDLC framing

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Abstract

- The issue raised at the January 2002 EFM meeting:
  - The HDLC Framing introduces high probability for false detection of the reserved HDLC Flag 7E, thus false Ethernet packets will be transmitted to a higher layer.

- In this presentation we calculate the probability of such an event, and we show that this probability equals $8 \cdot 10^{-36}$ for QAM-256.

HDLC Background

- The VDSL PHY uses HDLC framing for the packet transmitted/received to/from the higher layer.
- HDLC Frame includes:
  - Opening Flag — 7E hex
  - Address field — FF hex
  - Control field — 03 hex
  - Information field — Original Ethernet Packet, 1522 octets max.
  - FCS — CRC16 (2 octets)
  - Closing Flag — 7E hex
- To avoid Opening/Closing Flag within the Information field, Byte-stuffing is used:
  - 7E hex ⇒ 7D 5E hex
  - 7D hex ⇒ 7D 5D hex

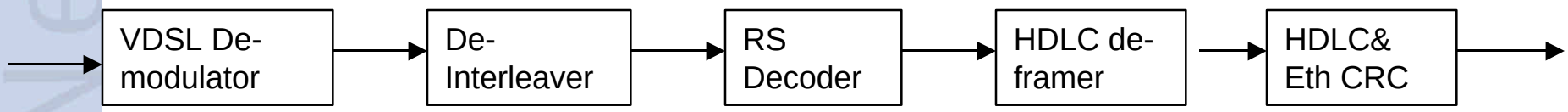
Calculation

The probability we look for depends in the following factors:

- **P1: Probability of at least one Byte error in HDLC frame after the RS-Decoder**
- **P2: Probability that a Byte error generates a HDLC Flag**
- **P3: Probability that the HDLC CRC does not detect the error**
- **P4: Probability that the Ethernet CRC does not detect the error**

The resulting probability for false acceptance of erroneous Ethernet packet is:

$$P_{\text{total}} = P_1 P_2 P_3 P_4$$



Calculation for P1

We start calculating P1 using the following formula (see ref. 1 and 2):

$$P_{\text{out},rs} = \frac{1}{N} \sum_{i=N_c+1}^{N} i \cdot \binom{N}{i} \cdot P_{\text{in},rs}^{\ i} \cdot (1 - P_{\text{in},rs})^{N-i}$$

Where:

$P_{\text{out},rs}$ **is the post-decoding Byte error probability of the Reed-Solomon**

$P_{\text{in},rs}$ **is the pre-decoding Byte error probability of the Reed-Solomon.**

$N = 255 \quad and \quad N_c = 8$ **For (255,239)Reed-Solomon**

Calculation for P1 (cntd')

The pre-decoding error probability is given by:

$$P_{\text{in,rs}} = a \cdot b \cdot P_{SE}$$ **Where:**

$$P_{SE} = 10^{-4}$$ **Is a conservative symbol-error probability of VDSL Physical layer**

b **- Increases the probability due to Symbol splitting into 2 Bytes, in QAM-8, 32, 64, 128. In QAM-(2), 4, 16, 256 a Symbol is never split over symbol boundary. We increase the Byte error probability according to the percentage of cases of Symbol split.**

a **- Is the ratio of Byte rate to Symbol rate, depending on the constellation.**

Calculation for P1 (cntd')

The following table summarizes the above:

Constellation	Number of splits	b	a	$P_{\text{out,rs}}$
QAM-2	0	1.0	8	$4.33 \cdot 10^{-14}$
QAM-4	0	1.0	4	$9.23 \cdot 10^{-17}$
QAM-8	2 out of 8	1.25	2.667	$1.82 \cdot 10^{-17}$
QAM-16	0	1.0	2	$1.88 \cdot 10^{-19}$
QAM-32	4 out of 8	1.5	1.6	$9.64 \cdot 10^{-19}$
QAM-64	2 out of 4	1.5	1.333	$1.88 \cdot 10^{-19}$
QAM-128	6 out of 8	1.75	1.143	$1.88 \cdot 10^{-19}$
QAM-256	0	1.0	1	$3.76 \cdot 10^{-22}$

Calculation for P1 (cntd')

Finally, the probability of at least one Byte-error in a frame of length *F*, at the output of the RS-decoder is:

$$P_1 = 1 - (1 - P_{\text{out,rs}})^F \approx F \cdot P_{\text{out,rs}}$$

Where:

$$F = 1536$$ **Bytes, as a max. limit.**

Calculating P2, P3 and P4

- The probability of the erroneous Byte to be an HDLC flag, 7E hex, is:

$$P_2 = 2^{-8}$$

- The HDLC frame contains 16-bit CRC. Thus the probability that a wrong Flag is not detected is given by:

$$P_3 = 2^{-16}$$

- The Ethernet packet contains 32-bit CRC. Thus the probability that a wrong packet is not detected is given by:

$$P_4 = 2^{-32}$$

Calculating $P_{\text{total}} = P_1 P_2 P_3 P_4$

Using the above process and parameters yields the following:

Constellation	P_{total}
QAM-2	$9.23 \cdot 10^{-28}$
QAM-4	$1.97 \cdot 10^{-30}$
QAM-8	$3.87 \cdot 10^{-31}$
QAM-16	$4.02 \cdot 10^{-33}$
QAM-32	$2.05 \cdot 10^{-32}$
QAM-64	$4.02 \cdot 10^{-33}$
QAM-128	$4.02 \cdot 10^{-33}$
QAM-256	$8.02 \cdot 10^{-36}$

Summary

- We have shown the probability of an erroneous packet not to be detected and being transferred to upper layer.

- This probability is shown to be very low, and for the case of QAM-256 @ Symbol-error rate of 10^{-4} , the probability is $8.02 \cdot 10^{-36}$

  - For 10M EoVDSL, this is about 10^{24} years of endless long Ethernet packet transmission.

  - For 1Gig Ethernet to achieve such performance, BER better than 10^{-19} is needed (see ref 3).

  - For 10Gig Ethernet to achieve such performance, BER better than 10^{-12} is needed (see ref 3).

References

1. ITU-T Draft Recommendation G.975, Series G, “Forward Error Correction for Submarine Systems”, April 2000.
2. John G. Proakis, “Digital Communication”, third edition, chapter 8-1-8, p. 465. (McGraw-Hill, 1995)
3. Rick Walker, Birdy Amrutur, Tom Knotts, Richard Dugan, (Agilent) “64b/66b coding update”, 802.3ae Albuquerque, March 3/6/2000.