Frame Error Rate

IEEE 802.3bj Task Force

September 24-26, 2012, Geneva, Switzerland

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Introduction

- This presentation addresses 802.3bj Draft 1.1 comments 159, 258, 261 and 392
- 802.3bj is required to support a bit error rate of 1e-12 or better at MAC/PLS service interface
- 32-bit Ethernet CRC in MAC frames provides a mechanism to measure frame error rate (FER) in MAC layer
- MAC frames can vary in size between 64 octets and 2000 octets
- RS encoding is mandatory for 100GBASE-CR4, 100GBASE-KR4 and 100GBASE-KP4
- In brown_3bj_02_0912 the problem of determining FER is studied assuming independent bit errors in MAC layer
- Questions that need to be studied
  - How does FER measured in MAC layer depend on required bit error rate (BER) at the MAC/PLS service interface?
  - How does FER depend on the RS code?
  - How does FER depend on modes of RS decoder operation?
- Here a methodology to compute MAC frame error rate is proposed for required BER at MAC/PLS service interface

Assumptions

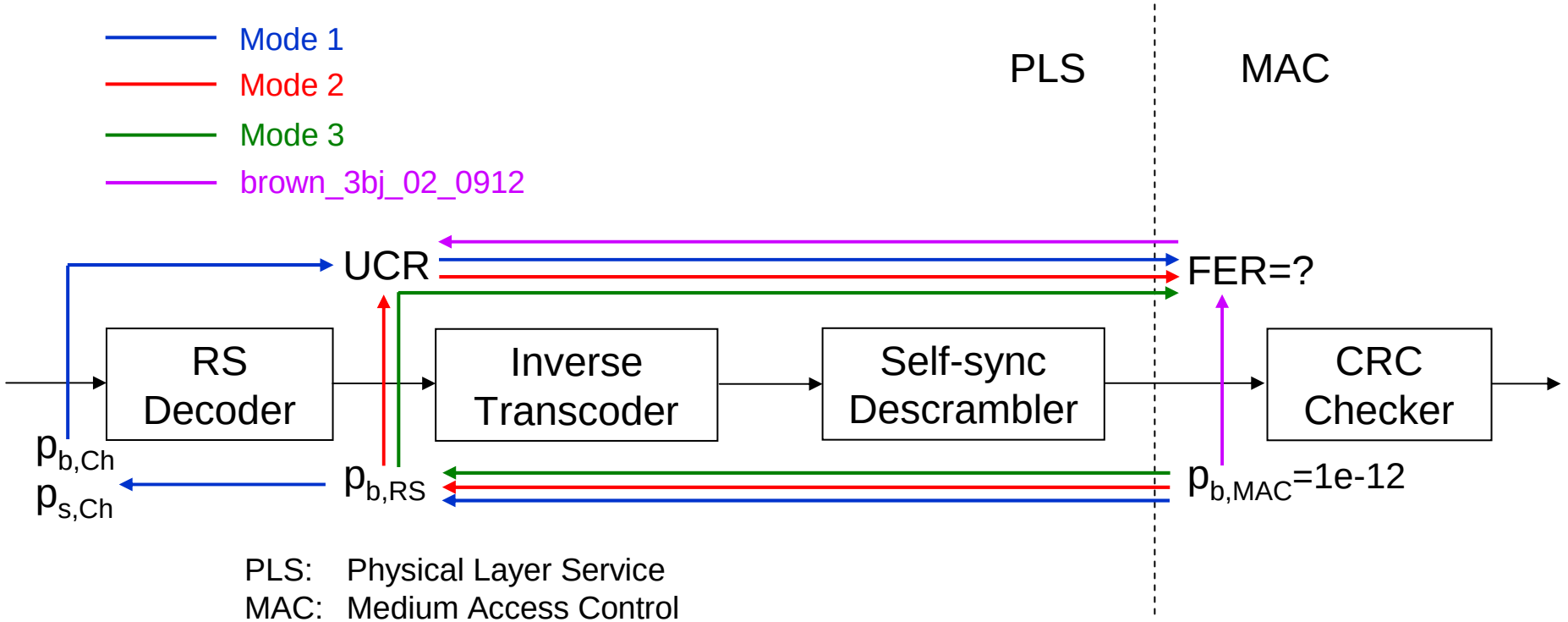
- Three modes of Reed-Solomon (RS) decoder operation are considered in order to evaluate the MAC frame error rate for a required bit error rate at MAC/PLS service interface
  - Mode 1: RS decoder performs error correction

    RS-FEC sublayer latency ~90ns
  - Mode 2: RS decoder performs only error detection prior to releasing data

    RS-FEC sublayer latency ~50ns
  - Mode 3: RS decoder performs only error detection in trailing mode

    RS-FEC sublayer latency ~5ns
- 3x error multiplication due to self-sync descrambler in physical coding sublayer (PCS)
- Inverse transcoding does not have an impact on error rate
- Independent bit errors at RS decoder input

Methodology to Compute FER



PLS: Physical Layer Service
MAC: Medium Access Control
$p_{b,MAC}$: Bit error rate at PLS/MAC interface
$p_{b,RS}$: Bit error rate at RS decoder output
$p_{b,Ch}$: Bit error rate at RS decoder input
$p_{s,Ch}$: Symbol error rate at RS decoder input
UCR: Uncorrectable Codeword Ratio
FER: Frame Error Rate
CRC: Cyclic Redundancy Check

Mode 1

NBF: Number of octets per MAC frame

NBC: Number of octets per RS codeword

RS(n,k) code with error correction capability t and symbol size m

100GBASE-KR4 and 100GBASE-CR4 employ RS(528,514), t=7 and m=10 code

100GBASE-KP4 employs RS(544,514), t=15 and m=10 code

$$p_{b,RS} = \frac{p_{b,MAC}}{3}$$

$$p_{b,RS} = \frac{2^{m-1}}{2^m - 1} \sum_{i=t+1}^{n} \frac{i}{n} \binom{n}{i} p_{s,Ch}^{i} \left(1 - p_{s,Ch}\right)^{n-i}$$

Compute $p_{s,Ch}$ such that $p_{b,RS} = \frac{1e-12}{3}$

$$UCR = \sum_{i=t+1}^{n} \binom{n}{i} p_{s,Ch}^{i} \left(1 - p_{s,Ch}\right)^{n-i}$$

$$FER = UCR\left(1 + \frac{NBF}{NBC}\right)$$

Relationship between FER and UCR derived in brown_3bj_02_0912

Mode 2 and Mode 3

In Mode 2 errors in RS codeword can be detected prior to releasing data.

MAC/PLS interface *is* aware of errors that have occurred.

$$p_{b,RS} = \frac{p_{b,MAC}}{3}$$

$$UCR = 1 - \left(1 - p_{b,RS}\right)^{nm}$$

$$FER = UCR\left(1 + \frac{NBF}{NBC}\right)$$

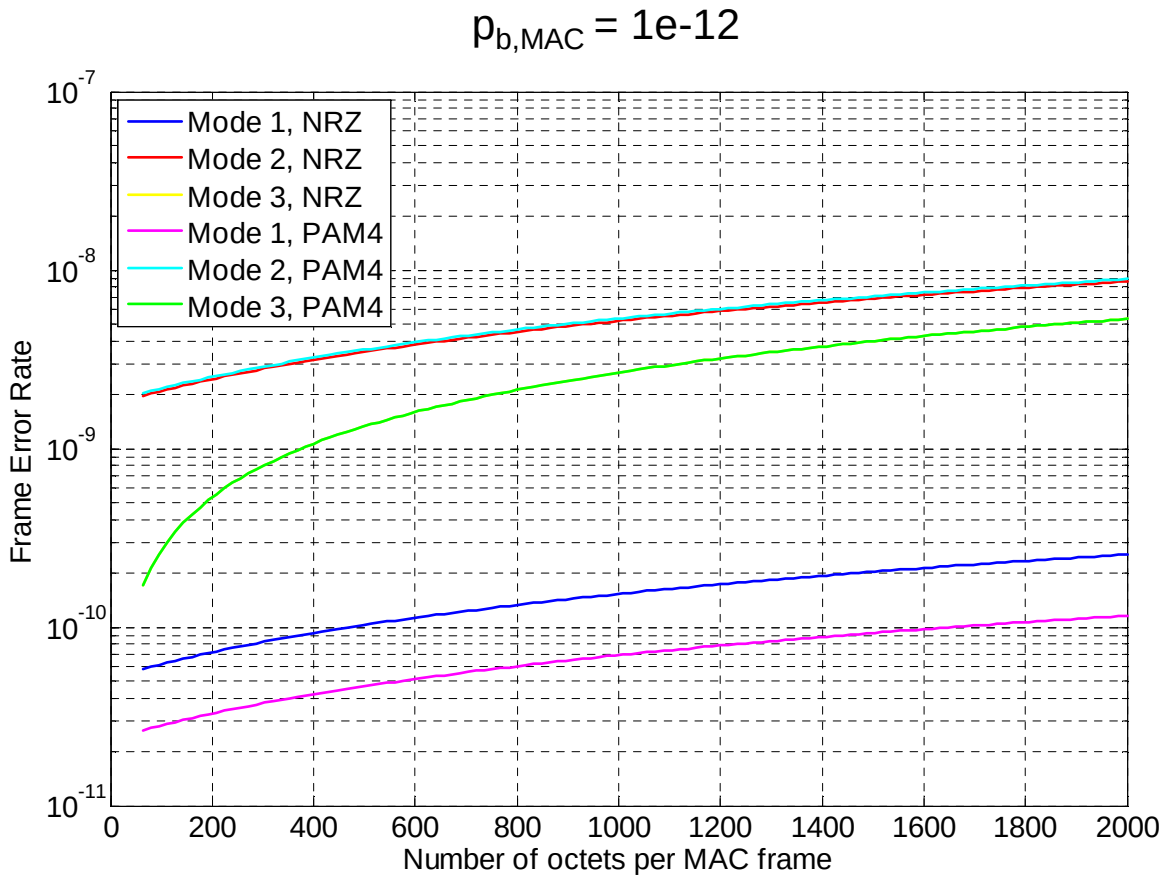
In Mode 3 errors in RS codeword can only be detected in trailing mode.

MAC/PLS interface *is not* aware of errors that have occurred.

$$p_{b,RS} = \frac{p_{b,MAC}}{3}$$

$$FER = 1 - \left(1 - p_{b,RS}\right)^{8NBF}$$

Frame Error Rate



Yellow and green curves are on top of each other

Frame Error Rate for 800-Octet Frames

NBF = 800

$p_{b,MAC}$ = 1e-12

FER	NRZ	PAM4
Mode 1	1.3e-10	6e-11
Mode 2	4.5e-9	4.6e-9
Mode 3	2.1e-9	2.1e-9

- Two extreme cases
  - If bit errors at MAC/PLS interface are uncorrelated as assumed in brown_3bj_01_0912, then

$$FER = 1 - (1 - 1e-12)^{8\times800} \approx 8 \times 800 \times 1e-12 = 6.4e-9$$

  - If bit errors at MAC/PLS interface are highly correlated, i.e., bits in a frame are either all correct or all wrong, then

$$FER = 1e-12$$

Summary

- Presented a methodology to compute frame error rate for required bit error rate at MAC/PLS service interface
- Frame error rate is a function of
  - MAC frame size in octets
  - Modes of RS decoder operation
  - Signaling scheme used
- For 800-octet MAC frames and a required bit error rate of 1e-12 at MAC/PLS service interface, the frame error rate varies between 6e-11 and 4.6e-9

Thank You