100GBASE-CR4/KR4/KP4
Receiver Performance Target

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Introduction

- Addressing 802.3bj Draft 1.1 Comments 392, 159, 258, 261.
- The 802.3bj objective says: “Support a BER of better than or equal to 1E-12 at the MAC/PLS service interface.”
  - What does this mean?
- Due to use of FEC and DFE, errors are going to occur at the MAC/PLS SI in bursts rather than as individual errors.
- Bursts of hundreds of bit errors cause no more frame errors than two sparse bit errors.
- In practice, errors at the MAC layer are measured as frame errors, not bit errors.
- To meet the 1E-12 BER objective, a means to specify the target frame error rate at the MAC/PLS SI and the uncorrectable codeword rate at the RS-FEC service interface is proposed.

Historical Precedence – 1000BASE-T

- 802.3-2012 40.6.1.3.1 specifies receiver performance as follows…
  - "this specification shall be satisfied by a frame error ratio of less than [1E-7] for 125 octet frames"
  - See entire sub-clause below.

40.6.1.3.1 Receiver differential input signals

Differential signals received at the MDI that were transmitted from a remote transmitter within the specifications of 40.6.1.2 and have passed through a link specified in 40.7 are translated into one of the PMA_UNITDATA.indication messages with a bit error ratio less than 10^{-10} and sent to the PCS after link reset completion. Since the 4-D symbols are not accessible, this specification shall be satisfied by a frame error ratio less than 10^{-7} for 125 octet frames.

Historical Precedence – 10GBASE-T

- 802.3-2012 55.5.4.1 specifies receiver performance as follows:
- “This specification shall be satisfied by a frame error ratio less than [9.6E-9] for 800 octet frames with minimum IPG or greater than 799 octet IPG.
- See entire sub-clause below.

55.5.4.1 Receiver differential input signals

Differential signals received at the MDI that were transmitted from a remote transmitter within the specifications of 55.5.3 and have passed through a link specified in 55.7 are received with a BER less than 10^{-12} and sent to the PCS after link reset completion. This specification shall be satisfied by a frame error ratio less than 9.6×10^{-9} for 800 octet frames with minimum IPG or greater than 799 octet IPG.

Relationship between BER and FER

- Assume bit errors are randomly distributed and uncorrelated.
- The frame error ratio (FER) is given by…
  - `FER = 1-(1-BER)^(NBF*8) ~= BER*NBF*8`
    - `Where:`
    - `BER is the bit error ratio`
    - `NBF is the number of octets in a MAC frame`
- The effective BER for a particular frame length is given by…
  - `EBER_F = FER/(NBF*8)`
- As an example, given a target BER of 1E-12 and MAC frames of length 800 octets
  - `FER = 1E-12 * 800*8 = 6.4E-9`

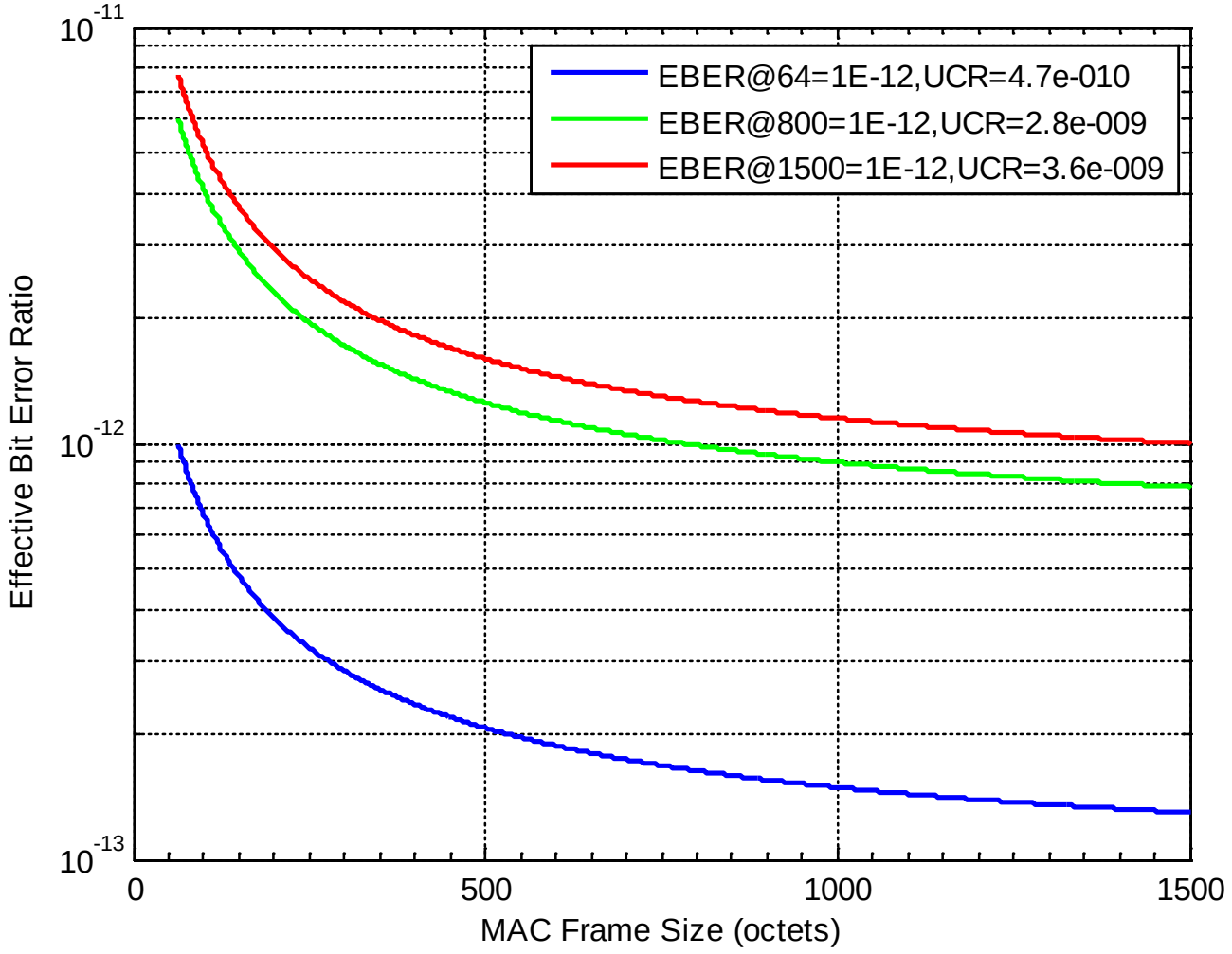
Relationship between FER and UCR

- A relationship between FER and UCR is determined as follows:
  - The FER may be calculated by weighting the FER due to each of the possible overlap values.
  - Define
  - UCR = [FEC] Uncorrectable codeword ratio
  - NBF = # of octets per MAC frame
  - NBC = # of octets per FEC codeword
  - NCF = # of whole codewords per frame = INT(NBF/NBC)
  - For the case where the MAC frame is larger than the FEC codeword
  - FER = UCR*((NCF+2)*(NBF-NCF*NBC)+(NCF+1)*(NBC-NBF+NCF*NBC))/NBC
  - Which reduces to: FER = UCR*(1+NBF/NBC)
  - For the case where MAC frame is not larger than FEC codeword
  - FER = UCR*((NBC-NBF+1)+2*(NBF-1))/NBC
  - Which reduces to: FER = UCR*(1+NBF/NBC)
  - The relationship between FER and UCR (regardless of codeword or frame length) is given by…
    - FER = UCR*(1+NBF/NBC)

Relationship between FER and EBER_F

- From the previous slides we have…
  - `FER = UCR*(1+NBF/NBC)`
  - `EBER_F(NBF) = FER/(NBF*8)`
  - `EBER_F = effective BER per-frame size`
- Which gives…
  - `EBER_F = UCR*(1+NBF/NBC)/(NBF*8)`
  - `= UCR*(1/NBF+1/NBC)/8`
- The graph on next slide shows that for small packets the EBER is much higher than for large packets.
  - We somehow need to balance the two.

EBER_F in relation to frame size



Average EBER and UCR

- The average BER may be determined by assuming a particular distribution of MAC frame lengths.
- Assume there is equal probability of each frame size (i.e., uniform distribution) between 64 and 1518 octets, inclusive.
  - EBER_U = Average EBER for uniform distribution…
  - = sum(EBER(NBF)*NBF*8)/sum(NBF*8)
  - = sum(UCR*(1/NBF+1/NBC)*NBF)/sum(NBF*8)
  - = UCR*sum(1+NBF/NBC)/sum(NBF*8)
  - = UCR*(2*NBC+NBF_A+NBF_B)/(NBC*(NBF_A+NBF_B))
  - sum for NBF over the range NBF_A to NBF_B
  - EBER_U ~= UCR*3.533E-4 (for range 64 to 1518)
- Target UCR for a given average BER
  - UCR = EBER_U*2.830E3

Target frame error rate

- The target frame size and frame error rate should be chosen to bound the average effective BER for an even distribution of packets to 1E-12.
- For the previous slide…
  - `UCR = EBER_U*2.830E3 = 2.830E-9`
  - `FER = UCR*(1+NBF/NBC)`
- Target FER for a range of test frame sizes:
  - `NBF=64, target FER = 3.11E-9`
  - `NBF=785, target FER = 6.30E-9`
  - `NBF={uniform distribution 64 to 1518}, target FER = 6.30E-9`
  - `NBF=800, target FER = 6.37E-9`
  - `NBF=1518, target FER = 9.54E-9`
- Since NBF of 785 and uniform distribution give the same target suggest specification:
  - `FER of 6.30E-9 for either 785-octet frames or uniform distribution of frames from 64 to 1518 octets.`

Conclusion

- Specify receiver performance as a measurement of the MAC frame error ratio (FER) as measured at the MAC/PLS interface.
  - This is not intended preclude specifying a BER at the FEC input.
- Set the FER target to 6.30E-9 measured with either all 785-octet frames or uniform distribution of 64 to 1518 octet frames.
- Specify uncorrectable codeword ratio (UCR) target for the output of the RS-FEC at 2.83E-9.
- The proposed targets are always relevant for 100GBASE-KP4.
- This target is equally relevant for 100GBASE-CR4, and 100GBASE-KR4 when FEC correction is enabled at the receiver.
  - A different analysis is required if FEC correction is disabled.

Thanks!