

MTTFPA Discussions for No-FEC Operation

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Introduction

- Mean Time to False Packet Acceptance (MTTFPA) is targeted to be longer than Age of the Universe.
- As IEEE 802.3 CRC32 and self sync scrambler do not share common factors, CRC32 burst error detection capability is maintained although the descrambler multiplies the errors by 3 times. CRC32 can detect the following errors for Ethernet packets up to 9K Bytes [2].
 - Up to three random errors
 - Two bursts of up to 8 bits
 - One burst of up to 32 bits
- However CRC32 burst error detection capability can be comprised,
 - If 64B/66B block sync head or type field is corrupted, or
 - If there is error spill-in/spill-out. In case of error spilling, 4-bit hamming distance of CRC32 has been certified by exhaustive simulations.

walker_1_0100.pdf

Introduction

- An Ethernet packet:

	Preamble	Start Delimiter	DA	SA	T/L	LLC (OPT)	Payload	Pad (opt)	FCS	IPG
Octets	7	1	6	6	2	46-1500		4	>=12	

- The frame from DA to FCS is checked by CRC32.
- A basic Ethernet frame is between 64 to 1518 octets.
- After 64B/66B coding, a 64-octet frame consists of 10 blocks.



64B/66B Code Overview

- Pure data block has a “01” sync head and eight 8-bit data.



- Pure command block has “10” sync head, one 8-bit type field and 8 7-bit commands.



- Mixed command/data block has “10”, one 8-bit type field and 8 7-bit field. Start of packet (SOP) and end of packet (EOP) are implicitly transmitted. The following two blocks have EOP at different locations:



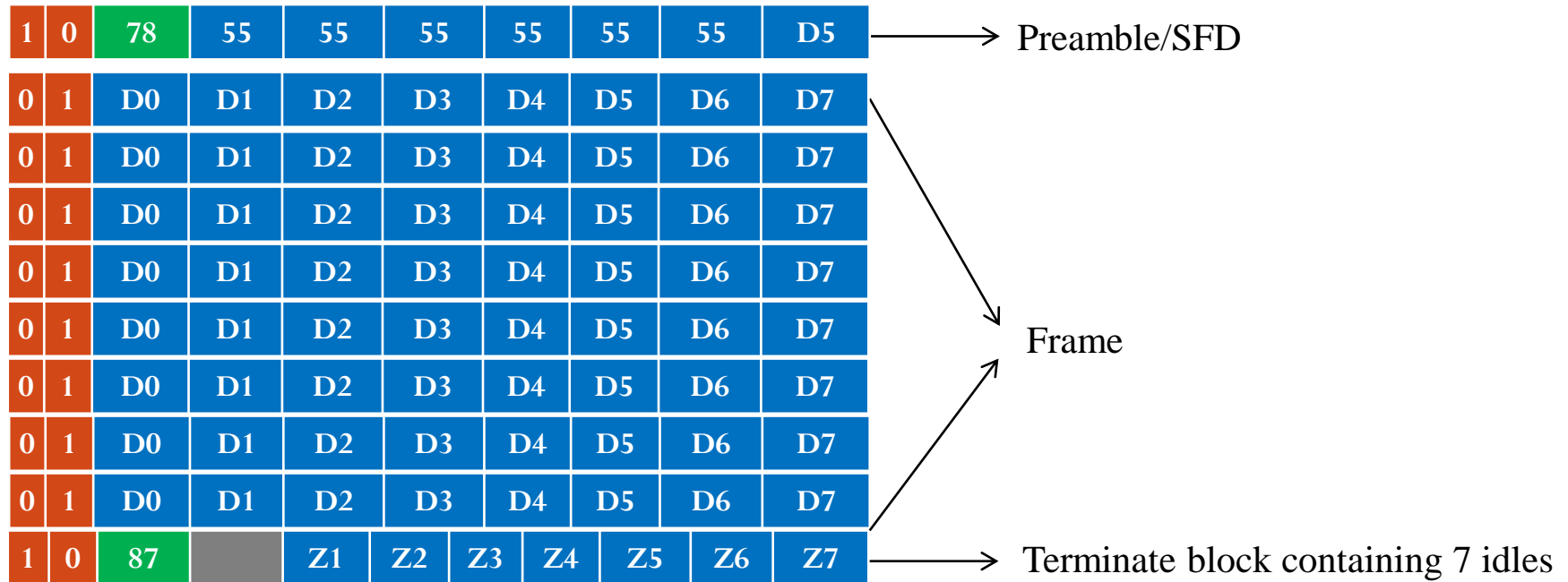
- “00” or “11” are invalid sync heads.

64B/66B Blocks in 10GBASE-R

Input Data	S y n c	Block Payload									
Bit Position:	0 1 2	65									
Data Block Format:											
D ₀ D ₁ D ₂ D ₃ /D ₄ D ₅ D ₆ D ₇	01	D ₀	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆	D ₇		
Control Block Formats:		Block Type Field									
C ₀ C ₁ C ₂ C ₃ /C ₄ C ₅ C ₆ C ₇	10	0x1e	C ₀	C ₁	C ₂	C ₃	C ₄	C ₅	C ₆	C ₇	
C ₀ C ₁ C ₂ C ₃ /O ₄ D ₅ D ₆ D ₇	10	0x2d	C ₀	C ₁	C ₂	C ₃	O ₄	D ₅	D ₆	D ₇	
C ₀ C ₁ C ₂ C ₃ /S ₄ D ₅ D ₆ D ₇	10	0x33	C ₀	C ₁	C ₂	C ₃			D ₅	D ₆	D ₇
O ₀ D ₁ D ₂ D ₃ /S ₄ D ₅ D ₆ D ₇	10	0x66	D ₁	D ₂	D ₃	O ₀			D ₅	D ₆	D ₇
O ₀ D ₁ D ₂ D ₃ /O ₄ D ₅ D ₆ D ₇	10	0x55	D ₁	D ₂	D ₃	O ₀	O ₄	D ₅	D ₆	D ₇	
S ₀ D ₁ D ₂ D ₃ /D ₄ D ₅ D ₆ D ₇	10	0x78	D ₁	D ₂	D ₃		D ₄	D ₅	D ₆	D ₇	
O ₀ D ₁ D ₂ D ₃ /C ₄ C ₅ C ₆ C ₇	10	0x4b	D ₁	D ₂	D ₃	O ₀	C ₄	C ₅	C ₆	C ₇	
T ₀ C ₁ C ₂ C ₃ /C ₄ C ₅ C ₆ C ₇	10	0x87				C ₁	C ₂	C ₃	C ₄	C ₅	C ₆
D ₀ T ₁ C ₂ C ₃ /C ₄ C ₅ C ₆ C ₇	10	0x99	D ₀			C ₂	C ₃	C ₄	C ₅	C ₆	C ₇
D ₀ D ₁ T ₂ C ₃ /C ₄ C ₅ C ₆ C ₇	10	0xaa	D ₀	D ₁		C ₃	C ₄	C ₅	C ₆	C ₇	
D ₀ D ₁ D ₂ T ₃ /C ₄ C ₅ C ₆ C ₇	10	0xb4	D ₀	D ₁	D ₂		C ₄	C ₅	C ₆	C ₇	
D ₀ D ₁ D ₂ D ₃ /T ₄ C ₅ C ₆ C ₇	10	0xcc	D ₀	D ₁	D ₂	D ₃		C ₅	C ₆	C ₇	
D ₀ D ₁ D ₂ D ₃ /D ₄ T ₅ C ₆ C ₇	10	0xd2	D ₀	D ₁	D ₂	D ₃	D ₄		C ₆	C ₇	
D ₀ D ₁ D ₂ D ₃ /D ₄ D ₅ T ₆ C ₇	10	0xe1	D ₀	D ₁	D ₂	D ₃	D ₄	D ₅		C ₇	
D ₀ D ₁ D ₂ D ₃ /D ₄ D ₅ D ₆ T ₇	10	0xff	D ₀	D ₁	D ₂	D ₃	D ₄	D ₅	D ₆		

- Block type field has 4-bit hamming distance.
- Errors on type field could corrupt frame structure.
- 64B/66B validity is checked in PCS

A 64-octet Frame with Minimum IPG

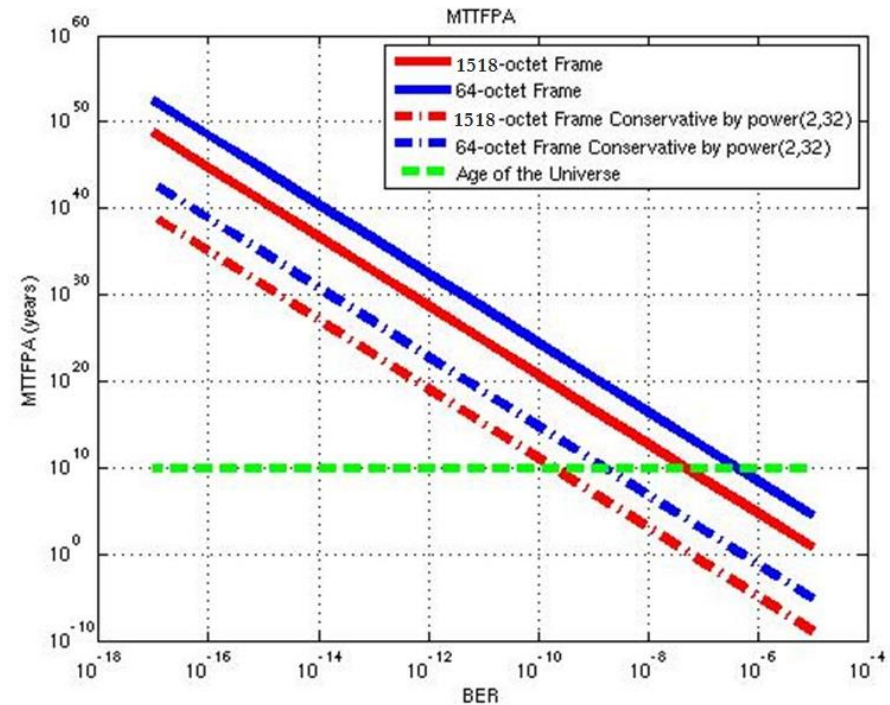


PCS checks 604 bits for a 64-octet frame:

- 10 bits in the start block
- 66*8 bits in the data blocks
- 66 bits in the terminate block. (Invalid control codes are marked as errors)

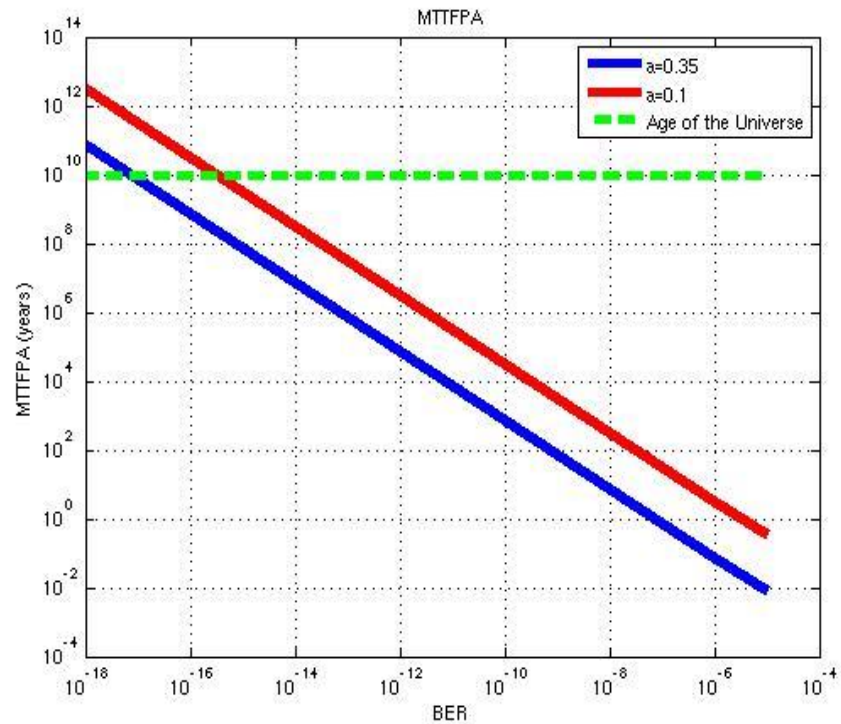
MTTFPA for Random Errors

- A conservative estimation can be made in 802.3ae by assuming any four or more errors will generate a false packet acceptance event (walker_1_0300).
- Walker's result is conservative by 2^{32} as CRC32 random error detect capability is not considered.
- Due to the error multiplication effect of the descrambler, the “packet size” for the error rate calculation is:
64-octet frame: $58 + 66 * 9 = 652$
1518-octet frame: 12648
- MTTFPA is not a problem when there is no DFE error propagation.



MTTFPA with DFE EP

- Adding DFE error propagation in Walker's analysis as in 802.3bp [3, 5]. Not conservative by 2^{32} .
- Gilbert error propagation model is used to DFE error propagation analysis. Suppose parameter "a" (P_{EP}) can be constraint to 0.35 for no-FEC operations. [6]
- At $DER=1e-12$, MTTFPA is **5.25e6** years for $a=0.1$ and **1.23e5** years for $a=0.35$.



MTTFPA Estimation for 64-octet Frames

MTTFPA Calculation Analysis

- MTTFPA calculation on slide 8 is conservative because bursts longer than 4bits can be detected in most cases if there is no 64B/66B sync head/type field corruption.
 - CRC32 burst detection capability is maintained after the self sync descrambler if all the errors are contained in the same frame.
 - When there is error spilling, 4-bit burst detection capability is conservative. In this case, only certain error patterns are undetectable [4].
 - A burst caused by a 1-tap DFE contains only all 1's. Exhaustive simulations for bursts up to 32 bits have been performed and show that this kind of burst is always detectable even with error spilling.

Errors on Transcodes/Type Fields

- Type field has hamming distance 4. Errors on sync head/type field could corrupt the structure of a frame. Therefore, CRC32 detection capability may be comprised. There are mainly 4 cases:
 1. If the sync head of a data block is corrupted to “10” and the type field happens to be valid. A data block could become a terminate block and a packet is “shortened”.
 2. If the sync head of a terminate block is corrupted to “01”. A terminate block becomes a data block.
 3. Type field corruption of a start block could change the location of the SOP between S0 and S4.
 4. Type field corruption of a terminate block could change the location of the EOP.

64B/66B Validity Check:

- Some transcode and type field errors can be detected by validity check in PCS.
- Case 1, if a data block is corrupted to a terminate block. Its following block is a data/terminate block instead of a control/start block. This block is invalid.
- Case 2, a corrupted terminate block do not cause a problem as the following block is a control block. A control block inside of a packet is invalid.
- Case 3, changing the location from s0 to s4 would create 4 control characters that must valid, so it very unlikely. Changing from s4 to s0 requires changing type field from 0x33 to 0x78. This is not possible for a simple burst (caused by a 1-tap DFE), but possible for a burst from a unconstrained DFE.
- Case 4, a shorten framed is not a problem for the same reason in case 3. However **elongated packet is a problem.**

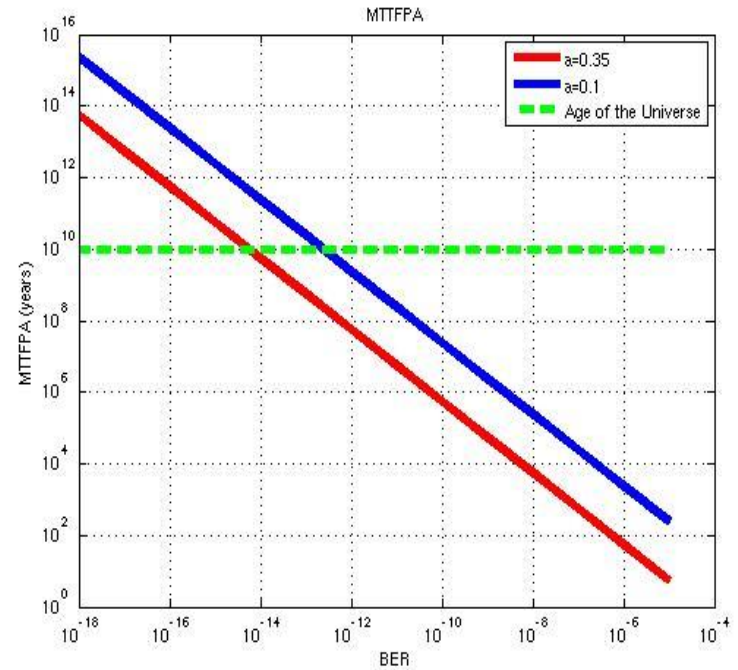
Case 4:

- There are 8 possible cases that a packet can be elongated by a simple burst 4'b1111 and still valid.
- Due to the 3x error multiplication effect of descrambler, the probability for this to happen is: $P_T = DER * 3 * P_{EP}^3 * (1 - P_{EP}) * 8/8$

Type Field	87	99	aa	b4	cc	d2	e1	ff
	10000111	10011001	10101010	10110100	11001100	11010010	11100001	11111111
87	10000111	10000111	10000111	10000111	10000111	10000111	10000111	10000111
99	100 1100 1	10011001	10011001	10011001	10011001	10011001	10011001	10011001
aa	10101010	10101010	10101010	10101010	10101010	10101010	10101010	10101010
b4	10110100	10110100	101 10100	10110100	10110100	10110100	10110100	10110100
cc	11001100	11001100	11001100	1 100 1100	11001100	11001100	11001100	11001100
d2	11010010	11010010	1 10100 10	11010010	110 100 10	11010010	11010010	11010010
e1	11100001	1 1100 001	11100001	11100001	11100001	11100001	11100001	11100001
ff	1 1111 111	11111111	11111111	11111111	11111111	11111111	111 1111 1	11111111

MTTFPA Estimation for 1-tap DFE:

- A single burst up to 32 bits is always detectable.
- All frame structure corruptions can be detected by PCS except case 4.
- MTTFPA at $DER=1e-12$ for $a=0.35$ is $4.05e7$ years; for $a=0.1$ is $1.25e9$ years.
- At $DER=1e-12$, $a=0.35$ and 0.1 are corresponding to normalized DFE coefficients 0.54 and 0.44 . DFE coefficient limit 0.5 in Table 110-10 indicates $a \sim 0.35$ due to the existence of multiple taps. [6]
- To meet MTTFPA at $DER=1e-12$, a needs to be ~ 0.05 corresponding to DFE tap value 0.41 .



DFE Coefficient Constraints

- DFE coefficient constraints are needed to guarantee MTTFPA but this may impact DER.
- We tried test case 2 (30mm package) in COM model. All settings are default for CR4 except DER_0 is set to $1e-12$. Channel is a 3m 24AWG QSFP-4SFP cable, and the victim is P1_TX1 [7].
- Considering there are multiple DFE taps, DFE coefficients are constrained to 0.35 for the first feedback tap and 0.1 for the rest.

	COM	Max DFE Coef.
Without DFE constraints	3.014	0.4548
With DFE constraints	2.895	0.35

This is one of the easiest 3m channel in [7]. DER fails with DFE coefficient constraints.

MTTFPA Improvement

- If we add **length check** in PCS, case 3 and 4 no longer can be caused by a single burst.
 - MTTFPA is dominated by double bursts and is not a problem.
- On PCS TX side, extra 14 length information bits need to be inserted after EOP to replace 2 idles. PCS validity check needs to be changed for length check instead of idles for these two control codes after EOP. For example, the terminate block of the 64-octet frame needs to be changed to:



- Alternative, 16 bit length information can be added before EOP. Type field needs to be changed. PCS validity check rule stays the same.



MTTFPA Improvement

- Alternatively we can add another layer of CRC:
 - With CRC8, $MTTFPA = 4.05e7 * 2^8 = 1.04e10$ Years for $a=0.35$ and $MTTFPA = 1.25e9 * 2^8 = 3.20e11$ years for $a=0.1$.
 - With CRC16, $MTTFPA = 4.05e7 * 2^{16} = 2.65e12$ Years for $a=0.35$ and $MTTFPA = 1.25e9 * 2^{16} = 8.19e13$ years for $a=0.1$.
- A unscrambled CRC 8 has been adopted in 10GBase-T clause 55.
- As in the length check, extra 8 or 14 CRC parity bits need to be inserted after EOP to replace 1 or 2 idles. 64B/66B validity rule needs to be modified for the control codes after EOP.



- CRC8 or CRC16 parities can also be added before EOP to keep 64B/66B validity check rules. But type field content needs to be changed.



Conclusions:

- DFE error propagation has a huge impact on MTTFPA. DFE shape is suggested to be constrained to guarantee MTTFPA at certain DER.
- MTTFPA at $DER=1e-12$ is not a problem if there is no DFE error propagation.
- With DFE error propagation, MTTFPA fails unless DER target is set to be better than $1e-15$ or DFE taps are tightly constrained for $DER=1e-12$.
- With extra length or CRC check, MTTFPA target can be safely achieved.

References:

- [1] P. Koopman, “32-bit cyclic redundancy codes for internet applications,” Conf. Dependable Systems and Networks (DSN), July 2002.
- [2] http://www.ieee802.org/3/bj/public/jul12/cideciyan_01_0712.pdf
- [3] http://www.ieee802.org/3/ap/public/nov05/szczepanek_01_1105.pdf
- [4] http://grouper.ieee.org/groups/802/3/10G_study/public/july99/figueira_1_0799.pdf
- [5] [10GBASE-KR FEC Tutorial.pdf](#)
- [6] [ran_020415_25GE_adhoc.pdf](#)
- [7] [shanbhag_020415_25GE_adhoc_v2.pdf](#)