Draft Specification for the AOS Frame Header Error Control Field

Proposed update to 732.0-B-4 AOS Space Data Link Protocol

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Objective

Correct the incomplete specification of the Frame Header Error Control field of the Transfer Frame Primary Header. Corrections should be consistent with existing implementations if possible.

The current specification is incomplete because it does not specify

- where the "virtual fill" is to be inserted
- what values should be used for that virtual fill

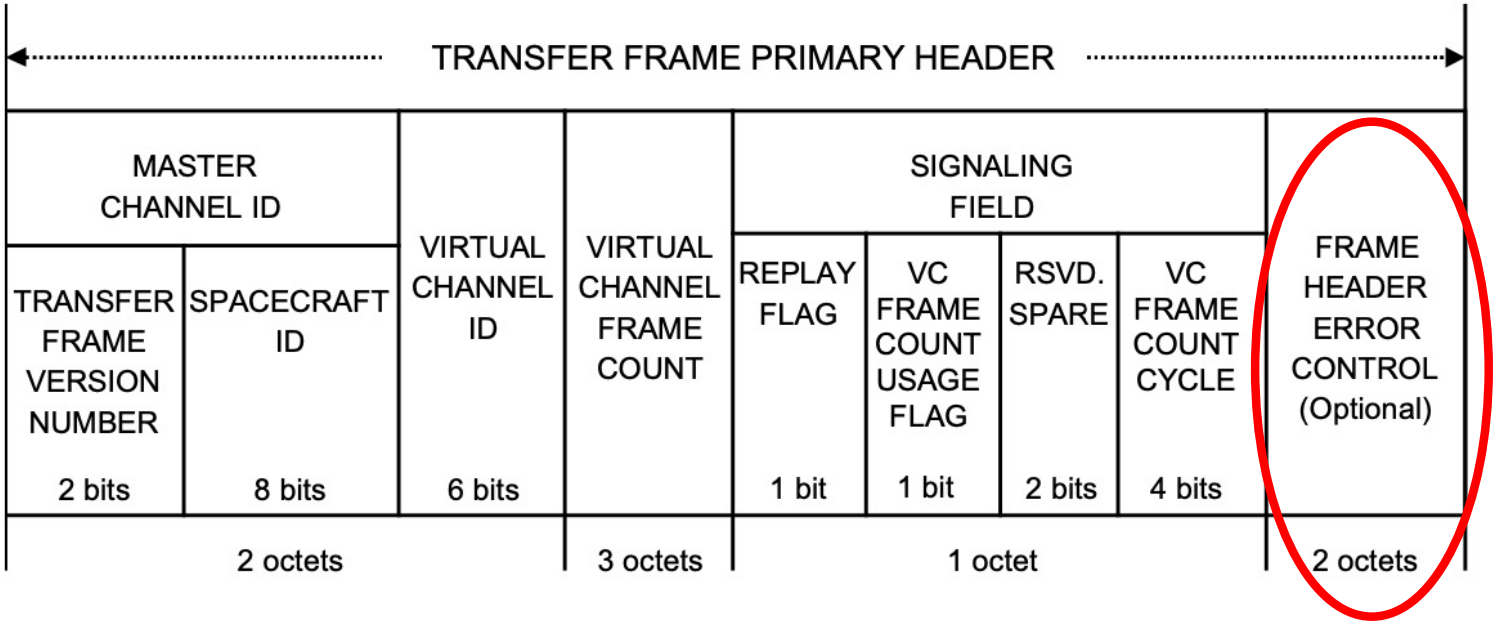

Figure 4-2: Transfer Frame Primary Header

Copied from 732.0-B-4

Current status

This field is not commonly used today. It has been used to allow AOS Transfer Frame routing prior to Reed-Solomon decoding.

Space agency comments received

- ESA [Modenini, 10 April, 2022, corrected 25 April 2022]
  "We did our check internally, and confirm that we always implemented that with the ~~right~~ left-hand virtual fill (on the MSB)."

- NASA GSFC [Sank, 28 March 2022]
  "TESS does what we expect, (0 fill and at the beginning if I remember right). In the past NASA used switched circuits."

- NASA JPL [O'Dea, 25 April 2022]
  "DSN hasn't implemented use of the FHEC field as far as I know."
  From the DTT operator's manual: "The HDR parameter is intended to enable and disable the FHEC field but is not currently implemented."

- CNES [Sank, from Vialard, Fall 2021 CCSDS meeting?]
  "Does not use the FHEC; they do full RS decode at the ground station."

Proposed changes (1 of 4)

Corrections needed

- Specification of virtual fill
- Location of virtual fill
- The Reed-Solomon code is used as a systematic code

The proposed wording closely follows that in the “TM Coding” Blue Book (131.0-B-3).

Add

f) Five symbols of virtual fill shall be used to logically complete the Reed-Solomon codeword. This virtual fill shall:

i. consist of all zeros;
ii. not be transmitted;
iii. be inserted only at the beginning of the codeword.

g) The selected code is a systematic code.

Proposed changes (2 of 4)

Clarifications

- Specification of code construction

From

…shall be a shortened Reed-Solomon (10,6) code

To

…shall be a Reed-Solomon (15, 11) code over GF(2^4), shortened by 5 symbols, and converted to GF(2), to form a binary (40, 24) code.

Proposed changes (3 of 4)

Clarifications

- Bit to symbol mapping

From

f) The bit to R-S symbol mapping shall be:

bits in the header	symbol
0,1,2,3	0
4,5,6,7	1
8,9,10,11	2
12,13,14,15	3
40,41,42,43	4
44,45,46,47	5
48,49,50,51	6
52,53,54,55	7
56,57,58,59	8
60,61,62,63	9

To

h) The bit to R-S symbol mapping shall be:

bits in the header	symbol	function
—	1	virtual fill
—	2	virtual fill
—	3	virtual fill
—	4	virtual fill
—	5	virtual fill
0,1,2,3	6	systematic symbol
4,5,6,7	7	systematic symbol
8,9,10,11	8	systematic symbol
12,13,14,15	9	systematic symbol
40,41,42,43	10	systematic symbol
44,45,46,47	11	systematic symbol
48,49,50,51	12	parity symbol
52,53,54,55	13	parity symbol
56,57,58,59	14	parity symbol
60,61,62,63	15	parity symbol

Proposed changes (4 of 4)

Editorial corrections

- Exponential notation

From	To
<1×10E-07	$< 10^{-7}$
1×10E-05	10^{-5}
2×10E-05	2×10^{-5}
1×10E-05	10^{-5}

Path forward

- Do we have consensus?
- If so, can the SLP working group submit this as an editorial correction to the AOS Space Data Link Protocol Blue Book (732.0-B-4)?

4.1.2.6 Frame Header Error Control

4.1.2.6.1 If implemented, Bits 48-63 of the Transfer Frame Primary Header shall contain the Frame Header Error Control.

NOTE – The 10-bit Master Channel Identifier, the 6-bit Virtual Channel Identifier, and the 8-bit Signaling Field may all be protected by an optional error detecting and correcting code, whose check symbols are contained within this 16-bit field.

4.1.2.6.2 The presence or absence of the optional Frame Header Error Control shall be established by management.

4.1.2.6.3 If present, the Frame Header Error Control shall exist in every Transfer Frame transmitted within the same Physical Channel.

4.1.2.6.4 Once set by management, the presence or absence of the Frame Header Error Control shall be static throughout a Mission Phase.

4.1.2.6.5 The mechanism for generating the Frame Header Error Control shall be a Reed-Solomon (15, 11) code over GF(2^4), shortened by 5 symbols, and converted to GF(2), to form a binary (40, 24) code. The parameters of the selected code are as follows:

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a) 'J=4' bits per Reed-Solomon (R-S) symbol.

b) 'E=2' symbol error correction capability within an R-S code word.

c) The field generator polynomial shall be:

$$F(X) = x^4 + x + 1$$

over GF(2)

d) The code generator polynomial shall be:

$$g(x) = (x + \alpha^6)(x + \alpha^7)(x + \alpha^8)(x + \alpha^9)$$

over GF(2^4)

where $F(\alpha) = 0$,

$\alpha^6 = 1100$, $\alpha^7 = 1011$

$\alpha^8 = 0101$, $\alpha^9 = 1010$

also:

$g(x) = x^4 + \alpha^3 x^3 + \alpha x^2 + \alpha^3 x + 1$

over GF(2^4)

and:

$\alpha^0 = 0001$, $\alpha^3 = 1000$

$\alpha = 0010$

e) Within an R-S symbol, the transmission shall start from the bit on the left side; e.g.,

$\alpha^3 = 1000$

shall be transmitted as a 1 followed by three 0s.

f) Five symbols of virtual fill shall be used to logically complete the Reed-Solomon codeword. This virtual fill shall:

i. consist of all zeros;
ii. not be transmitted;
iii. be inserted only at the beginning of the codeword.

g) The selected code is a systematic code.

h) The bit to R-S symbol mapping shall be:

bits in the header	symbol	function
—	1	virtual fill
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0,1,2,3	6	systematic symbol
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48,49,50,51	12	parity symbol
52,53,54,55	13	parity symbol
56,57,58,59	14	parity symbol
60,61,62,63	15	parity symbol

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NOTES

1 The purpose of this field is to provide a capability for protecting some key elements in the Transfer Frame Primary Header.

2 Whether this field should be used on a particular Physical Channel is determined based on the mission requirements for data quality and the selected options for the Channel Coding Sublayer.

3 The header error correction code can correct up to and including two symbol errors. This is sufficient to meet the performance of $<10^{-7}$ Data Fields missing at a 10^{-5} channel bit error rate, for random bit errors. In the case of convolutional coded channels, in particular when the convolutional coding is interleaved, the Data Field loss rate will drop to 2×10^{-5} at an operating point equivalent to a channel bit error rate of 10^{-5}. This is the result of the burst errors typical of the convolutional decoders.

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