UHF Packet Format; Transparent Mode

The UHF Transceiver Type II [1] supports transmission and reception of packets in “transparent (PIPE)” mode. When transparent mode is activated, user data in 128 byte chunks (matching the maximum payload length) is periodically sent to the radio via the UART interface. Once set into transparent mode, the radio will persist in that mode until explicitly commanded to leave or no data has been received within a specified timeout period (1 to 255 seconds, default of 10 seconds).

Transparent mode is used to support the use of forward error correction (FEC) [2][3] to enhance the robustness of data transmission. Several FEC schemes are outlined below.

The requirement to support Cubesat Protocol (CSP) packets. We can consider a CSP packet[1] to be an application layer packet. The application layer packet will be sent via one or more transparent mode packets.

Transparent mode packets are at most 128 bytes long. CSP packets may be longer, so it will take one or more transparent mode packets to transport a CSP packet. In addition, some FEC scheme codeword lengths are greater than 128 bytes, meaning that a codeword may require one or more transparent mode packets.

All this means that we need to keep track of the number of codewords in a CSP packet, and the number of transparent mode packets needed to send the total number of codewords that make up the CSP packet. We also need to keep track of the actual CSP packet length, and because it can be fragmented, the current fragment number.

To simplify the packet fragmentation logic, we will choose to always send a full transparent mode packet. This means that for the final bytes of the CSP packet (the last fragment), which are unlikely to equal exactly one transparent mode packet, we will need to zero-pad the packet.

When more than one packet is needed to send a codeword, packet ordering is critical.

To keep track of the parameters that define the The FEC scheme, number of packets per codeword, the length of the user packet, and the current fragment of the user packet to maintain packet ordering means that a secondary (MAC) header is needed within the Data Field 2 (payload) as shown in Figure 11 of [1]. Note that the user packet size is 119 bytes since the MAC header requires 9 bytes.

An important implication of the MAC header scheme is that with 8 bits for packet number tracking and assuming a worst case FEC rate of 1/6, a transparent mode packet will be able to support CSP packets that are ≤ 255*119/6 = 5057 bytes. The closest power of two is 4096. At 19200 bps it takes at least 57.1 ms to send one packet, which means that it would take 12.3

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[1] The terms CSP packet and user packet are interchangeable in this discussion. User packet is more general.

seconds to send a 4096 byte CSP packet with FEC at rate = 1/6. This is a pretty long time, but means that having 8 bits for the packet number is probably okay. The maximum transmission unit size for a CSP packet should be more like 1500 (typical Ethernet MTU), which would take 25 packets or 4.5 seconds. Still pretty long, but a good compromise. In practice, the lowest FEC rate should be ½, so all the numbers above are divided by 3.

The MAC header cannot be encoded using the chosen FEC scheme since there would have to be a separate control channel to inform the ground and satellite systems of the FEC scheme in use. Such a channel can not be supported for amateur and other non-Northern SPIRIT users. However, the MAC header information is crucial and should be made as robust as possible. So, a fixed FEC scheme is employed that all parties know, namely Golay encoding [2][3]. We choose the (24, 3, 8) scheme and constrain the MAC header to be 36 bits so that the codewords need only 9 bytes of the Data Field 2 payload.

A proposed structure is shown in Figure 1, with field definitions in Table 1. The top structure is taken from Figure 11 of [1].

Note that the MAC Header is always in the payload even if there is no user data. There may be an option to send a zero-length CSP packet to the MAC as a keep-alive packet if that is ever needed.

Table 1 The PHY Header field details

Field	Length	Description
Modulation/FEC Scheme	9 bits	Two enumerated values representing a specific combination of modulation [1] and FEC scheme. See Table 2 for details.
Codeword Fragment Index	7 bits	An unsigned integer. 0 if no codeword, otherwise the index to the codeword fragment. Depending on the FEC scheme, 1 or more codeword fragments compose a codeword.
User Packet Length	12 bits	The unsigned integer representing the user packet length of [0,4095]
User Packet Fragment Index	8 bits	The index of the current user packet fragment
Golay parity	36 bits	The parity bits from Golay (24,3,8) encoding

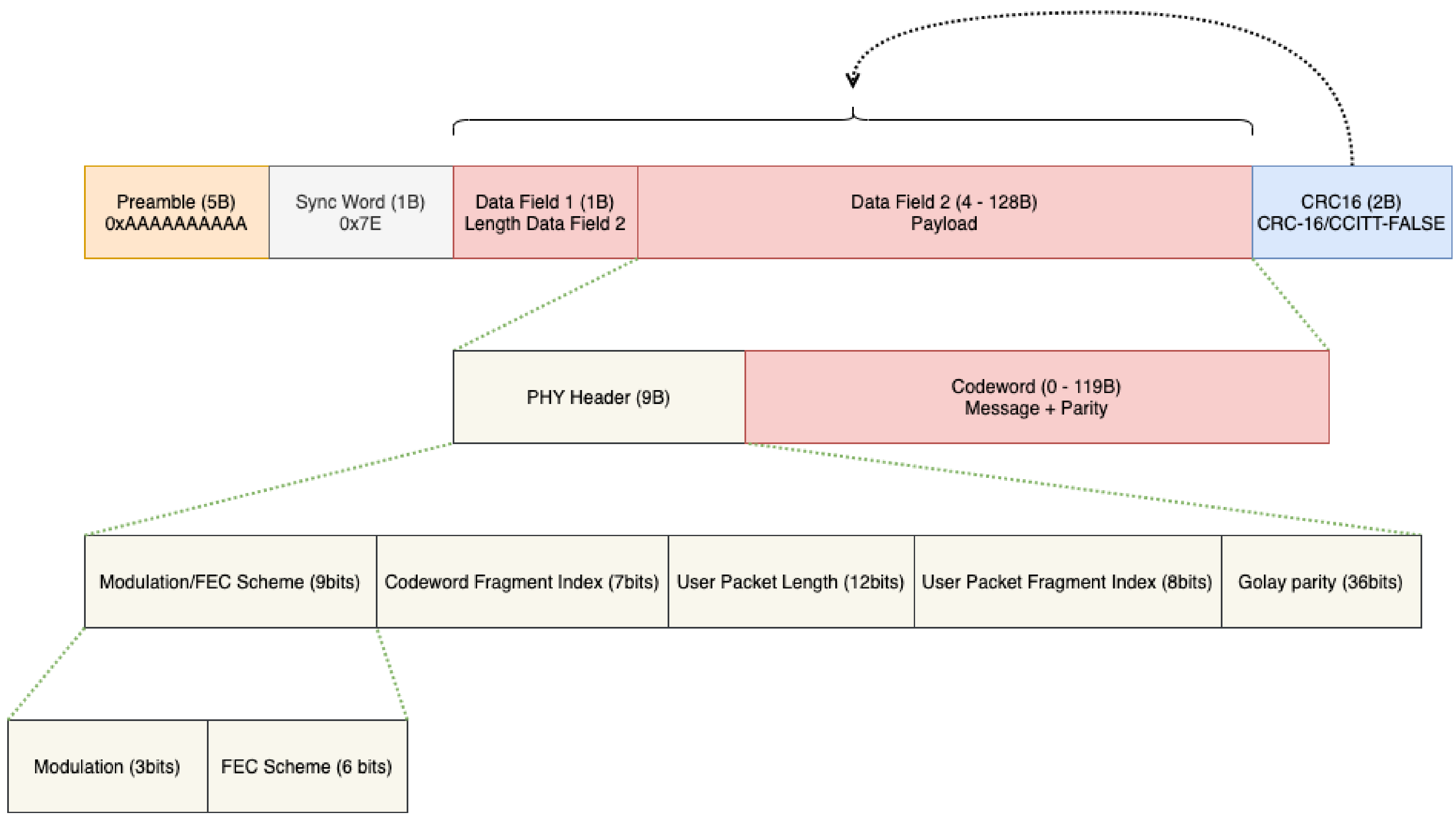

Figure 1 The proposed Data Field 2 (Payload) format in transparent mode. † All the parity bits are not at the end; 12 parity bits follow every 12 header bits from the 4 main fields

Table 2 The Modulation/FEC Schemes supported.

Field	Length	Description
Modulation[2]	3 bits	RF Mode # as shown in Table 11 of [1]
FEC Scheme[3] [4][5][6][7][8]	6 bits	Unsigned integer value enumerating schemes [0,4] Convolutional coding with r = ½, ⅔, ¾, ⅚, ⅞ [5,10] Reed-Solomon (255,239) with interleaving 1, 2, 3, 4, 5, 8 [11,16] Reed-Solomon (255,223) with interleaving 1, 2, 3, 4, 5, 8 [17,20] CCSDS Turbo k=1784, r = ½, ⅓, ¼, ⅙ [21,24] CCSDS Turbo k=3568, r = ½, ⅓, ¼, ⅙ [25,28] CCSDS Turbo k=7136, r = ½, ⅓, ¼, ⅙ [29,32] CCSDS Turbo k=8920, r = ½, ⅓, ¼, ⅙ [33,35] CCSDS Orange book LDPC, n = 1280, 1356, 2048 [36,39] IEEE 802.11n LDPC n = 648, r = ½, ⅔, ¾, ⅚ [40,43] IEEE 802.11n LDPC n = 1296, r = ½, ⅔, ¾, ⅚ [44,47] IEEE 802.11n LDPC n = 1944, r = ½, ⅔, ¾, ⅚ [48,62] reserved [63] no fec

[1] Endurosat, User Manual UHF Transceiver Type II, Rev 1.8, January 1, 2020.

[2] Huffman, W., & Pless, V. (2003). *Fundamentals of Error-Correcting Codes.* Cambridge: Cambridge University Press. doi:10.1017/CBO9780511807077

[3] Wikipedia contributors. "Binary Golay code." *Wikipedia, The Free Encyclopedia*, 14 Apr. 2021. Web. 3 Jun. 2021.

[4] Castiñeira Moreira, Jorge, and Patrick G Farrell. *Essentials of Error-control Coding*. West Sussex, England: John Wiley & Sons, 2006.

[5] Moon, Todd K. *Error Correction Coding : Mathematical Methods and Algorithms.* Hoboken, N.J.: Wiley-Interscience, 2005.

[6] CCSDS, Low Density Parity Check Codes for use in Near-Earth and Deep Space Applications, Experimental Specification CCSDS 131.1-O-2, Sept 2007.

[7] CCSDS, TM Synchronization and Channel Coding CCSDS 131.0-B-2., Sept 2007.

[8] IEEE P802.11n/D10: “Draft IEEE Standard for Local Metropolitan networks–Specific requirements. Part 11: Wireless LAN Medium Access Control (MAC), and Physical Layer (PHY) specifications: Enhancements for Higher Throughput“, 2006.

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[2] It is not clear whether the other modulation schemes (OOK, GMSK, 2FSK, 4FSK, adn 4GFSK) available can be employed.

[3] Not all schemes will be necessarily developed. It is unlikely that Turbo FEC will be employed because of the very large codewords required, which may cause challenges when transmitting digital audio.