IEEE-ISTO Std 4900-2021: Digital IF Interoperability Standard

Version 1.0

August 18, 2021

Revision History

Release Level	Release Date	Description
0.1	February 2021	Removed references to SN Removed protected VRTS
0.2	March 2021	• Updated Block Diagram to 650MHz BW • Updated BER Specifications
0.3 (DRAFT 1.0)	July 10, 2021	• Version 0.3 is DRAFT 1.0
1.0	August 18, 2021	• Final 1.0

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1. INTRODUCTION

The data plane interface provides the ability to transmit and receive digitized IF data and corresponding metadata over standard IP networks. This interface is meant to be fully compliant with the VITA 49.2 standards.

Working knowledge of related documents below is assumed.

1.1 RELATED DOCUMENTS

Industry Standard Documents:

- *VITA Radio Transport (VRT) Standard, VITA-49.0 – 2015*
- *VITA Radio Transport (VRT) Standard, VITA-49.2 – 2017*

1.2 DOCUMENT CONVENTIONS

Update if necessary, for IEEE - ITSO

2. DATA PLANE IMPLEMENTATION

The data plane is where the digital IF data and its corresponding metadata are formed into packets for transmission. The VITA 49.2 standard provides many options for packing digital IF data. This flexibility requires that an additional layer of documentation be provided in order to explain a manufacturer's implementation of the standard.

This standard has two independent data plane flows as shown in Figure 1: (1) RF input to network output (RF-to-IP) and (2) network input to RF output (IP-to-RF).

The version data flow is used to convey the type of device or application, the current software build (which includes the FPGA code) and the current time of day so that it can be used to meter data when received by a software-based application.

The following sections outline the different VITA 49.2 Data and Context packet formats. Note that VITA trailers and VRL framing are not currently used for any data flows.

The Vita49.2 specification has a strict definition of what can be included in Signal Data or Signal Context packets in order to maximize interoperability. The standard data flow can support any bandwidth from 10 kHz thru 600 MHz. All digitized IF samples are complex, fixed-point signed numbers where the size of I and Q can range from 4 thru 16 bits.

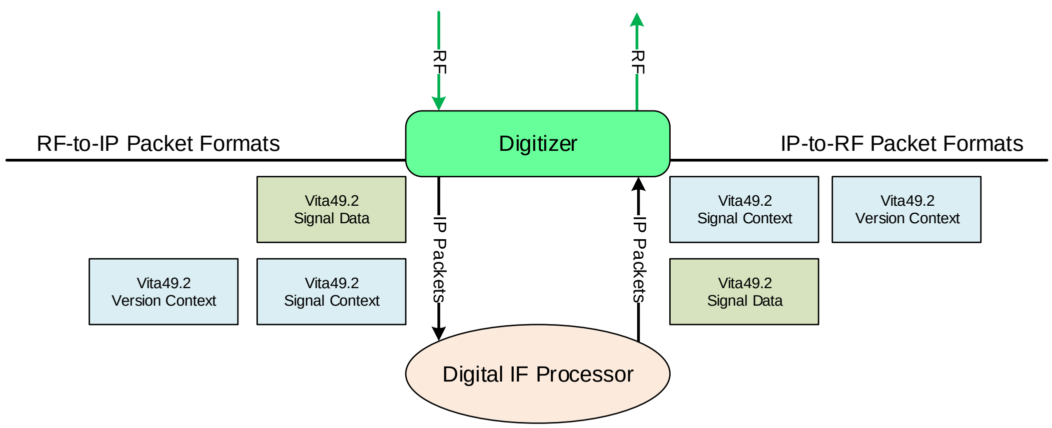

Figure 1. Data Plane Packet Formats

2.1 ETHERNET FRAME

All packets use the same type of Ethernet frame which is shown in Table 1. The frame headers include the standard Ethernet 802.3 format without the optional VLAN tags, a standard IPv4 header and a UDP header.

Table 1. Ethernet Frame

<table>
<tr><td>31</td><td>30</td><td>29</td><td>28</td><td>27</td><td>26</td><td>25</td><td>24</td><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="32">Destination MAC</td></tr>
<tr><td colspan="16">Destination MAC</td><td colspan="16">Source MAC</td></tr>
<tr><td colspan="32">Source MAC</td></tr>
<tr><td colspan="16">Ether Type = 0x0800</td><td colspan="16"></td></tr>
<tr><td colspan="4">0 1 0 0</td><td colspan="4">0 1 0 1</td><td colspan="6">0 0 0 0 0 0</td><td colspan="2">0 0</td><td colspan="16">Total Length = variable</td></tr>
<tr><td colspan="16">Identification = 0x0000</td><td colspan="3">0 0 0</td><td colspan="13">Fragment Offset = 0x0000</td></tr>
<tr><td colspan="8">TTL = 0xFF</td><td colspan="8">Protocol = 0x11</td><td colspan="16">Header Checksum = variable</td></tr>
<tr><td colspan="32">Source IP Address</td></tr>
<tr><td colspan="32">Destination IP Address</td></tr>
<tr><td colspan="16">Source Port</td><td colspan="16">Destination Port</td></tr>
<tr><td colspan="16">Length</td><td colspan="16">Checksum = 0x0000</td></tr>
</table>

Ethernet Frame	IPv4 Header	UDP Header

2.1.1 Ethernet Frame

- **RF-to-IP**
  - Destination MAC

    The MAC address for a unicast Destination IP is discovered by issuing ARP commands each time the network stream is enabled. When using multicast, the Destination MAC is formed from the multicast address so no ARP is required.
  - Source MAC

    The Source MAC for the data NIC on the unit.

- **IP-to-RF**
  - Destination MAC

    When the device is receiving network packets, the Destination MAC address in the received packet must match either the MAC address of the data NIC handling the packet or it must match a multicast MAC address that has been assigned to that data NIC.

  - Source MAC

    The MAC address for the device sending the data or context packets. The Source MAC of the data packet must match its associated context packet because some digitizers uses the context packet information to configure the data packet filters in its FPGA.

2.1.2 IPv4 Header

- **RF-to-IP**
  - Header Checksum

The checksum is filled in by the network interface.

- Source IP Address

  The IP address of the data NIC on the device.

- Destination IP Address

  The Destination IP which could be a unicast or multicast address.

- **IP-to-RF**
  - Header Checksum

    The checksum is filled in by the device sourcing the packet.

  - Source IP Address

    The IP address for the device sending the data or context packets. The Source IP Address of the data packet must match its associated context packet

  - Destination IP Address

    When the device is receiving network packets, the Destination IP Address in the received packet must match either the IP address of the data NIC handling the packet or it must match a multicast MAC address that has been assigned to that data NIC.

2.1.3 UDP Header

- **RF-to-IP**
  - Source Port

    The UDP port of the unit, which defaults to 50000 but can be set to any value from 1024 thru 65535.

  - Destination Port

    The UDP port the packet is being sent to, which defaults to 50000 but can be set to any value from 1024 thru 65535.

- **IP-to-RF**
  - Source Port

    The UDP port of the source of the packets which can be any value from 0 thru 65535.

  - Destination Port

    The UDP port the packet is being sent to on the unit which defaults to 50000 but can be set to any value from 1024 thru 65535.

  - Destination IP Length

    The length of the UDP payload plus the UDP header length (8 bytes).

2.2 Context Packets

The type of context packet is tied to the type of data flow as shown in Table 3.

Table 2. Context Packet Types

Data Flow	Context Packet
Standard	Signal Context (CIF 0)
Version	Signal Context (CIF 1)

2.2.1 Packet Rate

- **RF-to-IP**

  Digitizer will produce 10 context packets per second for any configuration of stream sample rate, sample size and data packet size for the Standard data flows. The packet rate for the Version data flow can be set from 0 (off) thru 100 packets/second.

- **IP-to-RF**

  This standard requires context packets in order to convert inbound Signal Data packets to RF. The Signal (CIF 0) packet rate must be between 2 thru 50 packets/second. The Signal Context (CIF 1) rate is selectable from 0 (off) to 100 packets/second.

2.2.2 Standard Flow Signal Context Packet

This context packet is used for the standard data flow and is the same for RF-to-IP or IP-to-RF. The packet format is shown in Table 4. The VITA 49.2 has renamed the original IF Context packet to Signal Context Indicator Field 0 (CIF 0).

Table 3. Signal Context Packets

<table>
<tr><th>31</th><th>30</th><th>29</th><th>28</th><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>21</th><th>20</th><th>19</th><th>18</th><th>17</th><th>16</th><th>15</th><th>14</th><th>13</th><th>12</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td colspan="2">TSI</td><td>1</td><td>0</td><td colspan="4">SeqNum</td><td colspan="16">Packet Size = 27 words</td></tr>
<tr><td colspan="32">Stream ID = variable</td></tr>
<tr><td colspan="8">0 0 0 0 0 0 0 0</td><td colspan="24">OUI = 0x7C386C (default)</td></tr>
<tr><td colspan="16">Information Class Code = 0x0000 (default)</td><td colspan="16">Packet Class Code = 0x0000 (default)</td></tr>
<tr><td colspan="32">Integer-seconds Timestamp (UTC/GPS/POSIX seconds)</td></tr>
<tr><td colspan="32">Fractional-seconds Timestamp (picoseconds)</td></tr>
<tr><td colspan="32">Context Indicator Field (0xFBB98000 -> context change or 0x7BB98000 -> no change)</td></tr>
<tr><td colspan="32">Reference Point = 0x00000064</td></tr>
<tr><td colspan="32">Bandwidth</td></tr>
<tr><td colspan="32">IF Reference Frequency = 0 Hz</td></tr>
<tr><td colspan="32">RF Reference Frequency</td></tr>
<tr><td colspan="32">IF Band Offset</td></tr>
<tr><td colspan="32">Reference Level</td></tr>
<tr><td colspan="32">Gain/Attenuation</td></tr>
<tr><td colspan="32">Sample Rate</td></tr>
<tr><td colspan="32">Timestamp Adjustment</td></tr>
<tr><td colspan="32">Timestamp Calibration Time (integer secs)</td></tr>
<tr><td colspan="32">State and Event Indicators</td></tr>
<tr><td colspan="32">Data Packet Payload Format</td></tr>
</table>

- **Packet Type (Header, Bits 31 – 28)**

  This must be set to 0x4 which indicates a Context packet with a stream ID.
- **Class Identifier (Header, Bit 27)**

  This must be set to 0x1 which indicates the optional Class Identifier field is included.
- **Reserved (Header, Bits 26 – 25)**

  These reserved bits must be set to 0x0.

- **TimeStamp Mode (Header, Bit 24)**

  The TSM bit is set to 0x1 indicating the timestamp is conveying general timing for context changes.

- **TimeStamp Integer (Header, Bits 23 - 22)**

  The TSI field indicates the time source used to generate the integer seconds which defaults to UTC but can be set to any of the supported time sources.

Table 4. The Meaning of the TSI Codes

TSI Code	Meaning
00	Not allowed
01	Coordinated Universal Time (UTC) which has an epoch of Jan 1, 1970 and includes leapseconds
10	GPS which has an epoch of Jan 6, 1980 but does not include leapseconds
11	POSIX time which has an epoch of Jan 1, 1970 but does not include leapseconds

- **TimeStamp Fractional (Header, Bits 21 - 20)**

  The TSF field indicates the type of fractional seconds but is always picoseconds (0x2).

- **SeqNum (Header, Bits 19 - 16)**

  This 4-bit sequence number is incremented modulo 16 for each IF Context packet.

- **Packet Size (Header, Bits 15 - 0)**

  The number of 32-bit words in the packet including the header and any optional fields. Fixed at 27 words for the Signal Context packet.

- **Stream ID**

  The stream ID defaults to 0 but can be set to any unsigned 32-bit value. This must match the stream ID on the associated Signal Data packets. See section 5.1.2 of the VITA 49.2 specification for more information.

- **Organizational Unique Identifier (Bits 23 – 0)**

  The OUI defaults to the value of 0x7C386C but can be to any 24-bit hexadecimal value. See section 5.1.3 of the VITA 49.2 specification for more information.

- **Information Class Code (Bits 31 - 16)**

  The Information Class defaults to 0x0 but can be set to any 16-bit hexadecimal value on the RF-to-IP side. This field is currently ignored in the IP-to-RF direction. See section 5.1.3 of the VITA 49.2 specification for more information.

- **Packet Class Code (Bits 15 – 0)**

  The Packet Class defaults to 0x0 but can be set to any 16-bit hexadecimal value on the RF-to-IP side. This field is currently ignored in the IP-to-RF direction. See section 5.1.3 of the VITA 49.2 specification for more information.

- **Integer-seconds Timestamp**

The seconds since epoch for the selected time reference (UTC, GPS or POSIX). Note that only UTC time will include leap seconds. Refer to section 5.1.4 and 5.1.5 of the VITA 49.2 specification for complete details.

- **Fractional-seconds Timestamp**

  The number of picoseconds past the integer seconds. In the RF-to-IP direction, this is based on an internal 125 MHz clock for Narrowband and a 250 MHz clock for Wideband modes.

  The internal fractional second clocks are derived from an internal oscillator that can be locked to an external frequency reference.

  The frequency reference signal can be an external 10 MHz, IRIG-DC, 1PPS, or IRIG-B (AM) in that order.

  The picosecond counter is reset to 0 using the 1PPS derived from GPS, IRIG-DC, external 1PPS, or IRIG-B. Refer to Sections 5.1.4 and 5.1.5 of the VITA 49.2 specification for complete details.

- **Context Indicator Field (CIF 0)**

  This field indicates which of the optional CIF 0 metadata fields are included and if a value has changed since the last transmitted context packet. Table 4 shows the context fields that will be included for the RF-to-IP direction and is the minimum set of context fields that must be included for the IP-to-RF direction. Additional context fields can be present in the IP-to-RF direction, but they will be ignored. See Section 9 of the *VITA 49.2 specification* for additional information.

- **Reference Point**

  The reference point indicates location in the system that the digital samples are conveying information about. The value of 0x64 indicates it is at the RF input for the RF-to-IP direction and the RF output in the IP-to-RF direction.

- **Bandwidth**

  The useable bandwidth of the digitized signal. The bandwidths for the standard are specified in 1 Hz increments. Refer to section 9.5.1 of the VITA 49.2 specification for complete details.

- **IF Reference Frequency**

  The IF center frequency of the digitized signal which default to 0 due for zero IF architectures. Refer to section 9.5.5 of the VITA 49.2 specification for complete details.

- **RF Reference Frequency**

  The center frequency of the RF spectrum on the RF input port for the RF-to-IP direction or the center of the spectrum on the RF output port for the IP-to-RF direction. The RF reference frequency in the IP-to-RF direction is status information only. The output center frequency is programmed and is independent of the RF frequency at the stream source to allow frequency translation. Refer to section 9.5.10 of the VITA 49.2 specification for complete details.

- **IF Band Offset**

  The stream offset from the IF center frequency of the digitized signal which default to 0 Hz. The IF center frequency is always 0 Hz for zero IF architectures. The stream offset is a signed number with a 1 Hz resolution and can be set anywhere within the system bandwidth as long as no portion of the stream bandwidth extends beyond the system bandwidth edges. The system bandwidth is defined by the bandwidth parameter above.

  The IF Band Offset value is the Stream Offset for the RF-to-IP direction. It is used as the default Stream Offset in the IP-to-RF direction but can be overridden. Refer to section 9.5.4 of the VITA 49.2 specification for complete details.

- **Reference Level**

  The purpose of the Reference Level field is to relate the physical signal amplitude with the data samples in the Signal Data packet. The unit of measure is power in dBm and represents the full-scale value (max positive value) at the stream output (RF-to-IP) or stream input (IP-to-RF). Refer to section 9.5.9 of the VITA 49.2 specification for complete details.

- **Gain/Attenuation**

  The amount of signal gain or attenuation in dB applied to the samples in the Signal Data packet. The gain field is comprised of first and second stage gains. The first stage gain includes both the analog input gain prior to the ADC and the digital gain in the equalizer following the ADC. The second stage gain is the digital gain in the post-ADC stream. The gain values are used as status in the IP-to-RF direction to allow computing a system path gain from the RF input on the ADC side to the RF output on the DAC side. Refer to section 9.5.3 of the VITA 49.2 specification for complete details.

- **Sample Rate**

  The sampling rate of the samples in the Signal Data packets which can be set. The stream sample rate is approximately 1.25 times the stream bandwidth and will vary depending on the mode (i.e. narrowband, wideband). Refer to section 9.5.12 of the VITA 49.2 specification for complete details.

- **Timestamp Adjustment**

  Adjustments to the timestamp to account for implementation delays. This defaults to 0 picoseconds. Refer to Section 9.7.3.1 of the *VITA 49.2 specification* for complete details.

- **Timestamp Calibration Time**

  Indicates the last time the timestamp was known to be correct. This is populated on the RF-to-IP side for applications that require knowledge of when the timing signal was last locked. Refer to Section 9.7.3.3 of the *VITA 49.2 specification* for complete details.

- **State and Event Indicators**

  Used to convey the state of the calibrated time (bit 19) and frequency reference lock (bit 17) for the samples in the Signal Data packets.

  The calibrated time reference can be IRIG-B, IRIG-DC, 1PPS, NTP, GPS.

The frequency reference can be 10 MHz, IRIG-B, IRIG-DC or 1PPS, GPS.

The lock statuses of the time and frequency references are updated about once per second in the RF-to-IP direction.

The status information is used by the IP-to-RF side to determine if it can operate in Programmed Delay mode and if it can measure end-to-end latency (Measured Delay) or Network Delay. The Measured and Network Delays will be set to 0 if the calibrated time (bit 19) is not locked on the RF-to-IP side.

Refer to section 9.10.8 of the VITA 49.2 specification for complete details.

- **Data Packet Payload Format**

  This field is required to interpret the samples in the Signal Data packets. This standard support only supports complex Cartesian samples (I and Q), link-efficient packing, signed fixed-point and no event or channel tags. It supports sample sizes from 4 through 16 bits without sample component repeats and no unused bits. Refer to section 9.13.3 of the VITA 49.2 specification for complete details.

2.2.3 Version Flow Signal Context Packet

This context packet is used to convey type and version information and conveys precise time of day for software applications that are creating an IP-to-RF data flow (e.g., uplink) and are not using an RF-to-IP data flow (e.g., downlink).

The version packet format is created on the RF-to-IP side and used by the IP-to-RF side to auto-select a compatible packet format, if possible.

The Packet Format is shown in Table 5 and is new in VITA 49.2, which has added four new Context Indicator Fields to provide for additional metadata for the Signal Data Packets. The Version information is contained in the CIF 1 indicator field (see Section 9.1 in the *VITA 49.2 specification*). See Section 2.2.2 for an explanation of TSI, Sequence Number, Packet Size, and Stream ID plus the Integer and Fractional Timestamps.

Table 5. Version Flow Signal Context Packets

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	1	1	0	0	1	TSI		1	0	SeqNum				Packet Size = 11 words															
Stream ID = variable																															
0	0	0	0	0	0	0	0	OUI = 0x7C386C																							
Information Class Code = 0x0001																Packet Class Code = 0x0004															
Integer-seconds Timestamp (UTC/GPS/POSIX seconds)																															
Fractional-seconds Timestamp (picoseconds)																															
Context Indicator Field 0 (0x80000002 -> context change or 0x00000002 -> no change)																															
Context Indicator Field 1 = 0x0000000C																															
V49 Spec Version = 0x00000004																															
Year							Day									Revision						Type				ICD Version					

- **Organizational Unique Identifier (Bits 23 – 0)**

  The OUI default value is 0x7C386C when sending version information. The IP-to-RF side uses the version information to automatically configure itself to a compatible mode, if possible.

- **Information Class Code (Bits 31 - 16)**

  The Information Class must be 0x1 and cannot be changed when sending version information. The IP-to-RF side uses the version information to automatically configure itself to a compatible mode, if possible.

- **Packet Class Codes (Bits 15 – 0)**

  The Packet Class must be 0x4 when sending version information. The IP-to-RF side uses the version information to automatically configure itself to a compatible mode, if possible.

- **Context Indicator Field 0 (CIF 0)**

  This field indicates which of the optional CIF 0 metadata fields are included and if a value has changed since the last transmitted context packet. Table 5 shows that the CIF 1 word is included. No other CIF 0 fields are allowed. See Section 9 of the VITA 49.2 specification for additional information.

- **Context Indicator Field 1 (CIF 1)**

  This field shows that the only two CIF 1 parameters included are the V49 Spec Version and the Version field. No other CIF 1 fields are allowed. See Section 9 of the VITA 49.2 specification for additional information.

- **V49 Spec Version**

  The V49 version must be 0x4 (VITA 49.2) The IP-to-RF side uses the version information to automatically configure itself to a compatible mode, if possible.

- **Year (Bits 31 – 25)**

  The year the software/firmware was compiled starting from the year 2000. See section 9.10.4 of the VITA 49.2 specification for additional details.

- **Day (Bits 24 - 16)**

  The day within the year the software/firmware was compiled starting with a 1 for January 1st. See section 9.10.4 of the VITA 49.2 specification for additional details.

- **Revision (Bits 15 – 10)**

  The Revision number can be used to account for which version created on the same year and day is being used. This will normally be set to 1. See Section 9.10.4 of the *VITA 49.2 specification* for additional details.

- **Type (Bits 9 – 6)**

  The user defined subfield within the version word is used to convey the type of device. The types are defined in Table 7.

Table 6. The Meaning of the Type Codes

Type Code	Meaning
0	Narrowband

Type Code	Meaning
1	Wideband
2 – 16	Reserved

- **ICD Version (Bits 5 – 0)**

  This subfield denotes the version of the data plane standard, as shown in Table 7.

Table 7. The Meaning of the Version Codes

Version Code	Meaning
0	Version 1
1 - 31	Reserved

2.3 DATA PACKETS

The type of data packet is tied to the type of data flow, as shown in Table 8.

Table 8. Data Packet Types

Data Flow	Data Packet
Standard	Signal Data

2.3.1 Packet Rate

- **RF-to-IP**

  The Data packet rate depends on the stream bandwidth, sample size and max packet size, and can vary from 10 through 2.3 million packets/second.

- **IP-to-RF**

  The Data packet rate depends on the stream bandwidth, sample size and max packet size, and can vary from 10 through 2.3 million packets/second.

2.3.2 Standard Flow Signal Data Packet

This data packet is used for the standard data flow and is the same for RF-to-IP or IP-to-RF. The packet format is shown in Table 9. See Section 2.2.2 for an explanation of TSI, Sequence Number, Packet Size, Stream ID, OUI, Information Class, Packet Class plus the Integer, and Fractional Timestamps.

Table 9. Standard Flow Signal Data Packet

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	1	1	0	0	0	TSI		1	0	SeqNum				Packet Size = N+7 words															
Stream ID = variable																															
0	0	0	0	0	0	0	0	OUI = 0x7C386C (default)																							
Information Class Code = 0x0000 (default)																Packet Class Code = 0x0000 (default)															
Integer-seconds Timestamp (UTC/GPS/POSIX seconds)																															
Fractional-seconds Timestamp (picoseconds)																															
Signal Data Payload (complex, 4 thru 16-bit signed, N Words)																															

- **Packet Type (Header, Bits 31 – 28)**

  This must be set to 0x1 which indicates a Data packet with a stream ID.

- **Packet Size**

  The packet size varies based on the number and size of the data samples in the payload. The max packet size (the Ethernet frame payload) is adjustable from 128 bytes to 9000 bytes. The header size of IP (20 bytes), UDP (8 bytes) and VITA (28 bytes) is fixed in this interface.

Sample padding is not supported so the number of complex samples in the data payload will always be such that an integer number of I/Q pairs will be on a 32-bit boundary.

There are always seven header 32-bit words so the final packet size will be the data payload length in words (N) + 7.