Optical Data Interface
ODI-2 Transport Layer
Preliminary Specification

Revision Date 171002

ODI 3-part Specification

ODI-2.1: High-Speed Formats

- 8 to 16 bit data formats
- Packing Methods
- Optimized for SDR & 5G

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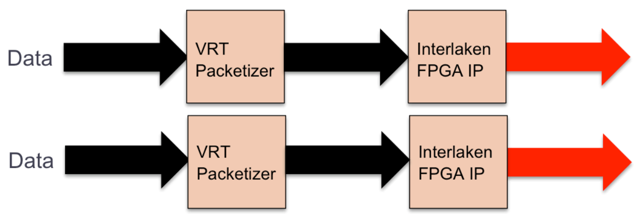
Data Formats

ODI-2: Transport Layer



- VITA-49 “VRT” Packets
- FPGA Optimized
- Port Aggregation
- Context Packets

Transport Layer

ODI-1: Physical Layer

- 12 lane multimode optics
- 12.5 & 14.1 Gb/s
- Interlaken Protocol
- Flow Control

Physical Layer

ODI-2 Scope

- ODI-2 defines the transport layer of the Optical Data Interface (ODI) specification. The ODI-2 Transport Layer sits one level higher than the ODI-1 Physical Layer, and defines the packet structure for sending data from a producer to a consumer. ODI-2 also uses the packet structure to aggregate optical ports together for higher aggregate bandwidth. Any data may be streamed using ODI-2, while the next layer higher, ODI-2.1, defines specific data formats for high speed sample streaming.

- Packet definitions are based on VITA 49.0-2015, also known as the VITA Radio Transport Standard, and is commonly abbreviated as VRT.

- The transport layer includes:
  - VRT packet rules
  - VRT packet definition for arbitrary block data
  - ODI Port aggregation

ODI-2 Compliance

- RULE: All implementations of of this specification SHALL comply with all the rules in this specification.
- RULE: All implementations of of this specification SHALL comply with all the requirements in the Interlaken Protocol Definition, Revision 1.2 or later.
- RULE: All implementations of of this specification SHALL comply with all the requirements in the VITA 49.0-2015 VITA Radio Transport (VRT) standard
- RECOMMENDATION: All implementations of of this specification SHOULD comply with all the recommendations in this specification.
- RULE: All implementations of of this specification SHALL clearly specify any and all deviations from the recommendations in this specification.
- RULE: All implementations of of this specification SHALL comply with the documentation requirements of this specification

Glossary - 1

- Device
  - An assembly that generates or receives data and has one or more optical ports
- Port
  - A single optical connector on a device, and the associated electronics
- Cable
  - A multiple fiber cable that connects between two ports
- Link
  - A unidirectional connection between two ports, consisting of 12 lanes of multimode optical transmission. A bi-directional connection has two links, one in each direction.
- Producer
  - ODI device that generates data to be sent over one or more optical ports
- Consumer
  - ODI device that receives data sent over one or more optical ports
- Transmitter
  - Interlaken term for a producer
- Receiver
  - Interlaken and VITA term for a consumer
- Emitter
  - VITA term for a producer

Glossary - 2

- Interlaken
  - Interlaken is the name of a chip-to-chip interface specification that is used by ODI to transfer packets between two ODI ports. It is the primary communication protocol. Separately, the packet structure sent over Interlaken is defined to be VRT, defined in the ODI-2 specifications.
- VRT
  - VRT is an abbreviation for VITA Radio Transport, standardized in VITA 49.0, and enhanced by other VITA 49x specifications. VRT specifies the structure and behavior of VRT packets, which carry data and context information about signals, and the data stream itself.
- Channel
  - "Channel" is used differently in Interlaken specifications than is commonly understood in operational or instrumentation systems as a signal channel.
  - Channel is used by Interlaken to enable a completely different data stream with its own flow control. ODI generally uses only a single Interlaken channel.
  - Channel is used by VRT similarly to instrumentation systems.
  - Synchronous instrumentation channels are encoded into the VRT stream in a rotating sequence, and are referred to as a "sample vector" in VRT parlance. VRT Sample Vector Size field is the number of instrumentation channels minus 1. This assumes synchronous channels, all at the same data rate and resolution.

Glossary - 3

- Word
  - An Interlaken Word is 8 bytes (64 bits)
  - A VRT Word is 4 bytes (32 bits)
- Burst
  - In Interlaken, data is divided into data bursts, each delineated by one or more burst control words.
- BurstMax
  - An Interlaken parameter that determines the maximum number of data bytes sent for each burst. Typically, streaming data will be set with these burst lengths. ODI allows 256 and 2048 byte BurstMax.
- BurstShort
  - An Interlaken parameter that reflects the shortest burst allowed.
- BurstMin
  - An Interlaken parameter for the Optional Scheduling Enhancement that guarantees all packets are at least BurstMin in length, and no idle control words will be needed for long packets.
- Packet
  - A packet refers to the block of data sent between Interlaken SOP and EOP (Start of Packet and End of Packet) indicators. At the Interlaken layer, the format of the packet is unknown. ODI-2 has defined the packet to be VRT packets. The term packet within ODI refers to both.

Glossary - 4

- Prologue
  - The Prologue refers to fields within a VRT data or context packet that precede the data payload or Context Fields respectively. A standard 28-byte Prologue is defined for data packets, and a standard 32-byte Prologue is defined for Context packets.
- Trailer
  - The Trailer refers to the 4-byte field that follows the data payload within a VRT Data packet. There is no trailer associated with Context packets.
- Train
  - For streaming applications, the Train refers to a series of packets, typically of the same size, sent sequentially from a producer, but not including the final packet, called the Caboose
- Caboose
  - For streaming applications, the Caboose refers to the final packet sent from the producer. It may or may not be the same size as the Train packets.
- Processing-efficient packing
  - Processing-efficient packing refers to a data packing method within the VRT Packet data payload where the packed data is aligned to 32-bit boundaries.
- Link-efficient packing
  - Link-efficient packing refers to a data packing method within the VRT Packet data payload where the data is packed as tightly as possible, leading to the highest sample density and speed.

Glossary - 5

- Sample Vector
  - A Sample Vector is defined within VITA 49.0 as a collection of synchronous Data Samples. This is the common method of transporting multi-channel sample data within the VRT data payload fields. Vector size describes the number of channels. However, the VRT Vector Size Field, used in ODI-2.1, is calculated as the vector size minus one. Therefore a two-channel stream has a vector size of two, but a Vector Size Field of 1.

ODI-2 What is it?

- ODI-2 specifies the transport layer for one or more ODI ports specified in ODI-1 Physical Layer. The transport layer includes definition of the packet structure, which is largely based on the VITA 49.0 VITA Radio Transport (VRT) standard. ODI-2 chooses a subset of the standard for transporting arbitrary block data from a producer to a consumer. The VRT packet standard also allows context information to be sent. ODI-2 also uses the packet structure to aggregate ports, allowing several ODI ports to combine their bandwidth into a single stream.

- ODI-2 uses the VRT Extension Data Packet to send arbitrary block data from one device to another.

- ODI-2 defines a mandatory fixed “Prologue” before the data payload, and a mandatory Trailer after the data payload. By mandating Prologue and Trailer fields, FPGA-based devices can deal quickly and deterministically with VRT packets.

- Similarly, ODI-2 uses the VRT Extension Context Packet to send arbitrary context data from one device to another

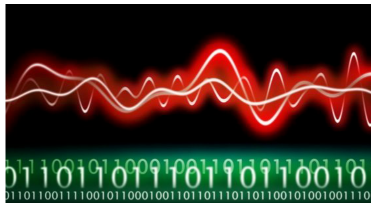
- ODI-2 specifies the rules for aggregating ports. ODI ports are aggregated by synchronizing the packet transmission from each of the ports being aggregated. Each port sends a VRT data packet at the same time. Interlaken SOP (Start of Packet) signals are combined with VRT Prologue data to synchronize the packets.

- ODI-2 does not specify the content and data formats of the data. However, ODI-2.1 specifies the data formats for 8-bit to 16-bit multi-channel sample data.

ODI-2 Packet Specifications

Packets are fundamental to ODI

VITA 49 "VRT" Data Packets



- VITA Radio Transport
- Standard data formats
- Multiple channels
- Storage framing
- SDR compatible

- Packets are bracketed by Interlaken SOP and EOP signals
- Packets contain single channel or multi-channel sample data
- Packet boundaries allow for error recovery
- Packets allow port aggregation and synchronization
- Consecutive packets are sent to stream data
- All data is stored as packets
- Packets are independent of the underlying transmission method
- Packets are compliant with VITA 49.0 standard

Interlaken Command
VRT Prologue &Trailer
Data

Packet structure

← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Trailer
EOP	

- Packets are documented by using the structure shown to the left.
- Interlaken defines words to be 64 bits, or 8 Bytes. VRT words are 32 bits, or 4 Bytes. Packets are documented using 8-Byte words as shown to the left to match Interlaken, the physical transmission methods.
- These words are often divided into two 4-Byte areas due to VRT field boundaries.
- Fields are color coded to indicate Interlaken commands, VRT Prologue and Trailer fields, and Data fields.

Packet structure - Data

- Interlaken Command
- VRT Prologue &Trailer
- Data

← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Trailer
EOP	

- RULE: ODI-2 devices sending data SHALL comply with the Data Packet and Streams section of VITA 49.0, Section 6.
- OBSERVATION: VITA 49.0 specifies two data packet types, IF Data and Extension Data, but they have similar Prologue and Trailer requirements.
- The Prologue is the mandated 28 Bytes that precedes the data.
- RULE: ODI-2 devices SHALL include all seven Prologue fields plus the Trailer field, as defined in VITA-49.0
- RULE: ODI-2 devices SHALL comply with the diagrams and descriptions of each field.

Legend
Interlaken Command
VRT Prologue &Trailer
Data

Packet structure - Data

← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Trailer
EOP	

← Interlaken Start of Packet Command

VRT Data Prologue. 28 Bytes.
Stream ID, Length of packet, Data formats, Optional time stamps

Data Payload
Up to 256 Kbytes of data
Always a multiple of 32 bytes
Typically long (>16K) to get efficiency

← **VRT Trailer** (errors, overload, events)

← Interlaken End of Packet

Data Packet Structure, Header

- The figure below shows the content of the mandatory header for data packets, and is reflective of VITA 49.0 IF and Extension Data packets.
- Pkt Type (28-31): If X=0, the header indicates a IF Data packet.
  If X=1, the header indicates an Extension Data packet.
- Bit 28 of the Pkt Type SHALL be set to 1. This indicates Stream ID field is present
- C bit (27) SHALL be set to 1. This indicates a Class ID fields are present
- T bit (26) SHALL be set to 1. This indicates a Trailer is present after the data payload.
- RR bits (24-25) SHALL be set to 0. These are VITA reserved bits.
- TSI bits (22-23) SHALL be set to either 01, 10, or 11, depending on the VITA timestamp method chosen. These indicate that TimeStamp-Integer field is present. If the device does not support timestamps, then 11 SHALL be used.
- TSF bits (20-21) SHALL be set to either 01, 10, or 11, depending on the VITA timestamp method chosen. These indicate that TimeStamp-Fractional fields are present. If the device does not support timestamps, then 11 SHALL be used.
- Packet Count (16-19) is a modulo-16 counter that counts the number of data packets sent. Bit 16 is the LSB. Packet Count will increment for each packet sent.
- Packet Size (0-15) indicates how many VRT 32-bit (4-Byte) words are present in the entire data packet, including the mandatory 7 (seven) Prologue fields and the Trailer field. Therefore, the Packet Size indicates the data payload size plus 8 (eight). Maximum VRT size is 65535 4-Byte words. Since ODI-1 requires all packet lengths to be divisible by 32 Bytes, the maximum ODI size is 65,528 VRT words, or 262,112 Bytes.

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
Pkt Type 0 0 X 1				C	T	R R		TSI		TSF		Packet Count				Packet Size															

Data Packet Structure, Stream ID

- Stream ID is an abbreviation for Stream Identifier
- The Stream ID is a 32-bit field, whose value is the same for all data and context packets associated with that stream
- RULE: All ODI-2 devices SHALL include a Stream ID field
- RULE: The default Stream ID for a single port device SHALL be 4096, as shown in the diagram below.
- OBSERVATION: Default Stream ID of 4096 matches the default Stream ID of VITA 49A.
- RULE: In a multi-port device where the ports are to be aggregated, each additional port's Stream ID SHALL be incremented by 64.
- OBSERVATION: In a 4-port aggregation, the Stream IDs are

  Port 1: 4096

  Port 2: 4160

  Port 3: 4224

  Port 4: 4288
- OBSERVATION: By incrementing by 64 for each additional port, each port can be identified by the Stream ID. Incrementing by 64 still allows downstream devices processing the data to increment the Stream ID by 1, as envisioned by VITA 49A, without causing duplication of Stream ID.
- RULE: Stream ID SHALL be programmable by the user.

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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Figure shows Stream ID field configured for Stream ID= 4096

Data Packet Structure, Class ID

- Class ID is a required field of 64 bits, shown as two 32-bit words below.
- The purpose of Class ID is to identify the Information Class used for the application, and the Packet Class from which each packet was made.
- RULE: ODI-2 devices SHALL include a Class ID structure as documented below, and the VITA 49.0 diagram
- OBSERVATION: There is also an example VITA 49A Class ID shown. ODI-2.1 will use something similar.
- OUI will be set to the AXIe OUI of 2-4-5-C-C-B or to the OUI of the device vendor.
- Reserved (24-26) is set to 0 per VITA 49.0
- Pad Bit Count (27-31) is set per VITA 49.0
- PERMISSION: IF a device vendor uses their own OUI, they MAY define the Information Class Code and Packet Class Code as they wish, pursuant to VITA 49.0.
- RULE: IF a vendor uses the AXIe OUI, and they are implementing Extension Data packets, THEN they SHALL set the Information Class Code and the Packet Class Code each to F-F-F-F.
- RULE: IF a vendor uses the AXIe OUI, and they are implementing IF Data Packets defined in an auxiliary ODI specification, such as ODI-2.1, THEN they SHALL set the Information Class Code and the Packet Class Code to the value specified in the auxiliary ODI standard.

<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="5">Pad Bit Count</td><td colspan="3">Reserved</td><td colspan="24">OUI</td></tr>
<tr><td colspan="16">Information Class Code</td><td colspan="16">Packet Class Code</td></tr>
</table>

Figure 6.1.3-1: The Contents of the Class ID Field

VITA 49.0 and ODI-2

<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="8">Set Per VRT</td><td colspan="24">FF-FF-FA</td></tr>
<tr><td colspan="8">Fixed Value</td><td colspan="2">Res.</td><td colspan="2" rowspan="2">R/C</td><td colspan="4" rowspan="2">Data Type</td><td colspan="16" rowspan="2">Vector Size</td></tr>
<tr><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
</table>

Figure 6.3-1 Organization of the Standard Data Packet Class Identifier

VITA 49A Example

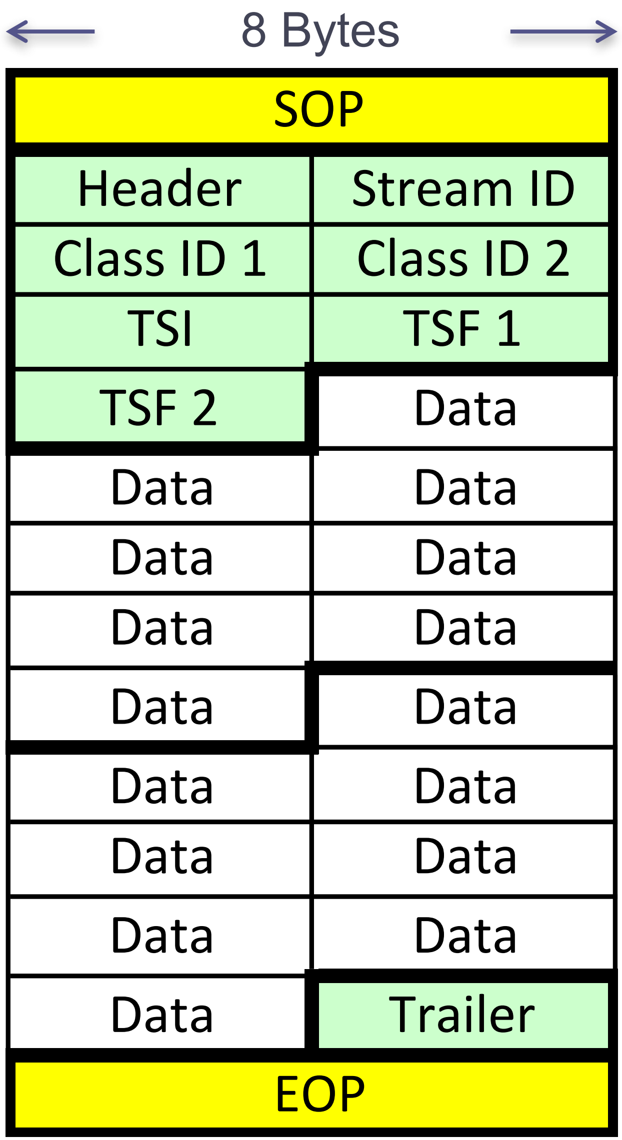
Data Packet Structure, Timestamps

8 Bytes

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Data
Data	Trailer
EOP	

- Timestamp fields are mandatory
- Timestamp fields include TSI, TSF 1, and TSF 2, each 4 bytes wide.
- RULE: IF the TSI field is set to 11, THEN the ODI-2 device SHALL set TSI and TSF fields to the null value of F-F-F-F.
- OBSERVATION: TSI value of 11 indicates that the timestamp data is null, but the fields are still present.
- RULE: If the device can execute Timestamps, then it SHALL execute GPS timestamps (TSI=10).
- RULE: If the TSI is set to 10 or 11, THEN the ODI-2 device SHALL set TSI and TSF fields to the values indicated by VITA 49.0
- A consumer of data SHALL ignore timestamp fields if it cannot operate on the timestamps.

Data Packet Structure, Data Payload



- Data Payload occurs between the 28-Byte Prologue and the 4-Byte Trailer
- RULE: Data Payload length SHALL be an integer multiple of 32 Bytes.
- OBSERVATION: ODI-1 requires all packets to be an integer multiple of 32-bytes. Since the Prologue and Trailer sum to 32 Bytes, the above rule forces the entire packet to be a multiple of 32 Bytes.
- PERMISSION: IF an ODI-2 device uses Extension Data Packets, THEN there is no restriction on the content of the data.
- RULE: IF the ODI-2 device uses AXIe OUI and does not use Extension Data Packets, then the data SHALL comply with the auxiliary standard specified.
- OBSERVATION: If the data payload is not naturally divisible by 32 Bytes, null data may be appended at the end of the data payload to do so. With Packet Length specified in the Packet Header and Pad Bit Count specified in the Class ID field, the valid data may be determined.
- OBSERVATION: Most multi-channel sample packing can be chosen to make streaming "Train" packets divisible by 32 bytes.

Data Packet Structure, Trailer

- Trailer is a mandatory field of 32 bits.
- RULE: An ODI-2 device SHALL implement the Data Packet Trailer as defined in VITA 49.0
- RULE: The Calibrated Time Indicator, Valid Data Indicator, Reference Lock Indicator, AGC/MGC Indicator, Detected Signal Indicator, Spectral Inversion Indicator, Over-range Indicator, and Sample Loss Indicator SHALL be enabled and set in the trailer if their values are known.
- PERMISSION: An ODI-2 device MAY use User-Defined Indicators
- PERMISSION: An ODI-2 device MAY use the E field and Associated Context Packet Count field, but is not required to do so.
- RULE: If a consumer receives Trailer information that it can't act on, it SHALL continue operation as normal.

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
Enables												State and Event Indicators												E	Associated Context Packet Count						

Figure 6.1.7-1: The IF Data Packet Trailer

Enable Bit Position	Indicator Bit Position	Indicator Name
31	19	Calibrated Time Indicator
30	18	Valid Data Indicator
29	17	Reference Lock Indicator
28	16	AGC/MGC Indicator
27	15	Detected Signal Indicator
26	14	Spectral Inversion Indicator
25	13	Over-range Indicator
24	12	Sample Loss Indicator
[23..20]	[11..8]	User-Defined Indicators

Table 6.1.7-1: Indicator Bits and Enable bits
Each Indicator functions as indicated, but only when the corresponding Enable bit is set otherwise, the Indicator bit is undefined.

ODI-2 Context Packet Specifications

Context Packets

- Adopting the VRT packet definitions allows the use of Context Packets in addition to Data Packets. Context Packets convey metadata related to the signal.
- Handling Context Packets is optional capability of ODI-2 devices. There is no requirement to do so. A producer is NOT required to generate Context Packets, but MAY do so.
- A consumer is NOT required to act on Context Packets received, but MAY do so. A consumer that receives Context Packets that it does not know how to process is required only to continue normal operation. That is, the reception of Context Packets should not interfere with otherwise normal operation.
- Context Packets are compliant with VITA 49.0 standard
- Like Data Packets, VRT defines two Context Packet types – IF Context Packets and Extension Packets. They are to be used with IF Data Packets streams and Extension Data Packet streams respectively.
- Context Packets have a standard 32 Byte header and no trailer.
- Context Packets, like data packets, must be a multiple of 32 Bytes in length

Legend
Interlaken Command
VRT Prologue &Trailer
Data

Packet structure - Context

← 8 Bytes → = 1 Interlaken Word

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	Context Ind.
Context	Context
Context	Context
Context	Context
Context	Context
Context	Context/Pad
Context/Pad	Context/Pad
Context/Pad	Context/Pad
Context/Pad	Context/Pad
EOP	

← Interlaken Start of Packet Command

VRT Context Prologue. 32 Bytes.

Similar to VRT Data Prologue plus Context Indicator field

Context Fields

Always a multiple of 32 bytes

Final 32 bytes will include final context fields, plus any “Pad” bytes of null data to insure context packets are always a multiple of 32 bytes.

← Interlaken End of Packet

Context Packet Prologue

- RULE: An ODI-2 producer that generates Context Packets SHALL include the Prologue fields specified for Context Packets

Context Packet Structure, Header

- The figure below shows the content of the mandatory header for Context packets, and is reflective of VITA 49.0 IF and Extension Context packets.
- Packet Type (28-31): Packet Type SHALL be the value 010X as shown

  If X=0, the header indicates a IF Context packet.

  If X=1, the header indicates an Extension Context packet.
- C bit (27) SHALL be set to 1. This indicates a Class ID fields are present
- RR bits (24-25) SHALL be set to 0. These are VITA reserved bits.
- The TSM bit (24) is the TimeStamp Mode bit, indicating whether the TimeStamp in the Context packet is being used to covey timing of Context events with fine or coarse resolution. If TSI is set to 11 (no TimeStamp, but TimeStamp field is present) the TSM bit SHALL be set to 1. Otherwise the TSM bit will be set according to VITA-49.0, Section 7.
- TSI bits (22-23) SHALL be set to either 01, 10, or 11, depending on the VITA timestamp method chosen. These indicate that TimeStamp-Integer field is present. If the device does not support timestamps, then 11 SHALL be used.
- TSF bits (20-21) SHALL be set to either 01, 10, or 11, depending on the VITA timestamp method chosen. These indicate that TimeStamp-Fractional fields are present. If the device does not support timestamps, then 11 SHALL be used.
- When a Context Packet Stream is paired to a Data Packet Stream, the TSI and TSF fields SHALL be the same.
- Packet Count (16-19) is a modulo-16 counter that counts the number of Context packets sent. Bit 16 is the LSB. Packet Count will increment for each packet sent.
- Packet Size (0-15) indicates how many VRT 32-bit (4-Byte) words are present in the entire Context packet, including the mandatory 8 (eight) Prologue fields.
- OBSERVATION: The C, TSI, TSF, Packet Count, and Packet Size fields in Context packets function the same way as for Data 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
Packet Type 0 1 0 X				C	R	R	TSM	TSI		TSF		Packet Count				Packet Size															

Context Packet Structure, Stream ID

- Stream ID is an abbreviation for Stream Identifier
- The Stream ID is a 32-bit field, whose value is the same for all data and context packets associated with that stream
- RULE: All ODI-2 devices SHALL include a Stream ID field
- RULE: The Stream ID for a Context packet SHALL match the Stream ID for the related Data Packet Stream.
- OBSERVATION: ODI-2 specifies that Data Packet Stream IDs must be programmable by the user. Since related Context packets must share the same Stream ID, they must also be programmable to the same value.
- OBSERVATION: The default Stream ID is 4096, the same as for Data 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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0

Figure shows Stream ID field configured for Stream ID= 4096

Context Packets, Context Indicator Field

← 8 Bytes →

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	Context Ind.
Context	Context
Context	Context
Context	Context
Context	Context
Context	Context/Pad
Context/Pad	Context/Pad
Context/Pad	Context/Pad
Context/Pad	Context/Pad
EOP	

- Context Indicator Field serves as the first word of the Context Section in a VRT Context packet. ODI documents this field as the final field in the Prologue for Context Packets.
- It is used to indicate the presence or absence of specific Context Data that follows.
- It is a mandatory field for VITA 49.0 IF Context packets
- It is a mandatory field for all ODI-2 Context packets.
- RULE: Context Indicator Field SHALL be present in an ODI-2 Context packet.
- RULE: IF the ODI-2 device uses AXIe OUI and does not use Extension Context packets, then the Context Indicator SHALL comply with the auxiliary standard specified.
- PERMISSION: If the ODI-2 device uses Extension Context packets, then it MAY define the value of the Context Indicator field in any way it wishes.
- OBSERVATION: An Extension Context packet may use the Context Indicator field in a manner similar to that in an IF Context packet, but with different definitions. It may also use it for actual Context.
- OBSERVATION: It is possible to define a Extension Context packet of only 32 bytes, using the Context Indicator field as Context Data.

Context Packets, Context Data

← 8 Bytes →

SOP	
Header	Stream ID
Class ID 1	Class ID 2
TSI	TSF 1
TSF 2	Context Ind.
Context	Context
Context	Context
Context	Context
Context	Context
Context	Context/Pad
Context/Pad	Context/Pad
Context/Pad	Context/Pad
Context/Pad	Context/Pad
EOP	

- Context Data follows the Context Packet Prologue
- For IF Context Packets, the Context Data SHALL be the Context Fields indicated by the Context Indicator Field.
- For Extension Context Packets, the Context Data is defined by the vendor.
- RULE: If using Extension Context packets, the vendor SHALL document the behavior of the Context Indicator Field and the Context Data.
- OBSERVATION: IF Context packets will exist only if a vendor uses their own OUI and defined classes, publicly available OUI and defined classes, or the AXIe OUI and defined classes.
- OBSERVATION: If a device uses the AXIe OUI, the definition of the classes and related fields will be specified in an auxiliary specification, such as ODI-2.1.
- RULE: All Context packets SHALL be an integer multiple of 32 Bytes.
- PERMISSION: If the Context Data is not naturally a multiple of 32 Bytes in length, pad Bytes may be appended to create a 32 Byte packet before signaling an Interlaken EOP.

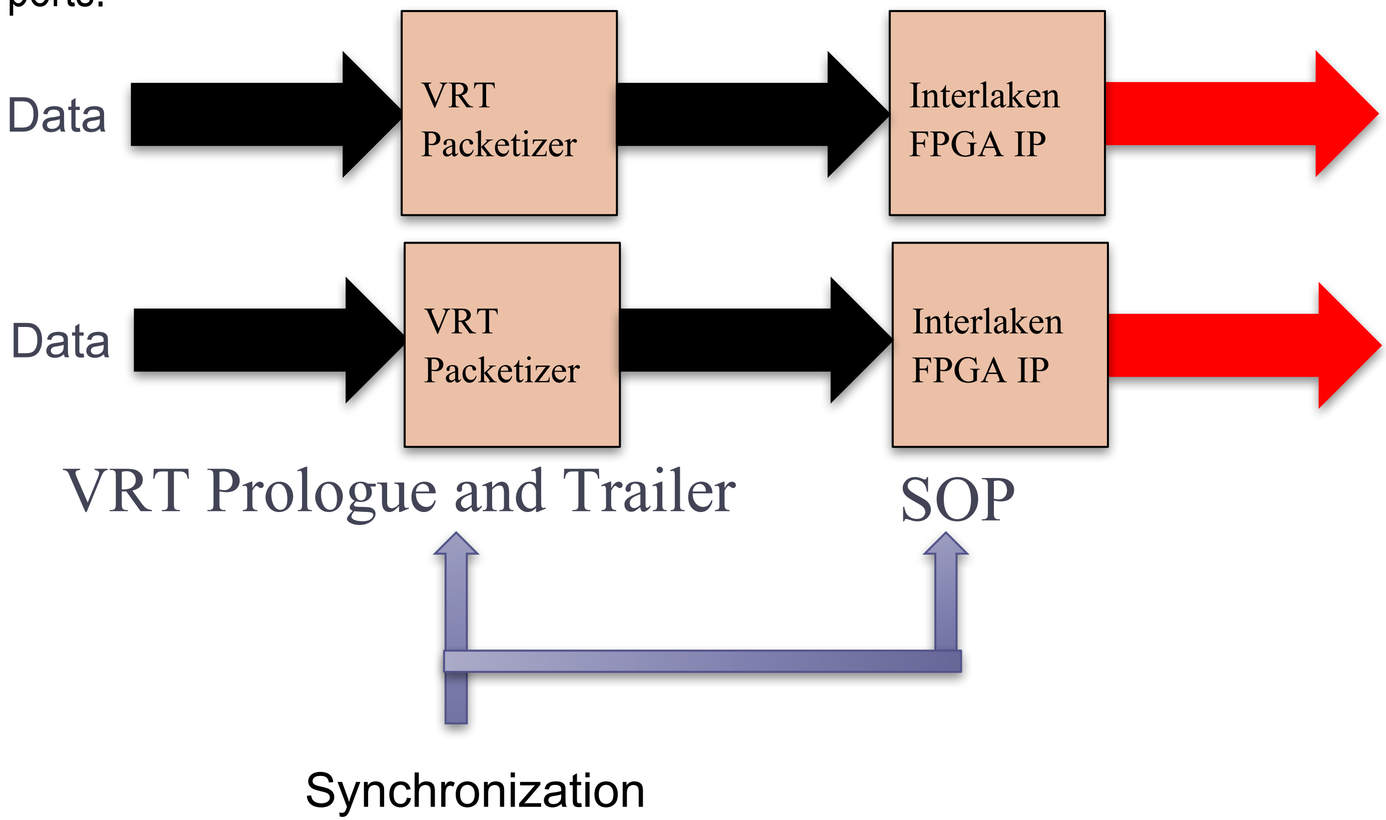
ODI-2 Port Aggregation

ODI-2 Port Aggregation

- ODI-2 Port Aggregation a method to use multiple ports to send a synchronous data at higher speeds than can be achieved with a single port.
- Port aggregation is an optional capability.
- Port Aggregation does NOT include using multiple ports to send simultaneous asynchronous data streams. That ability is already allowed in ODI-1, and does not need any further specification.
- The two use cases for port aggregation are:
  - Transporting multi-channel data whose aggregate bandwidth is beyond the single port bandwidth
  - Transporting single channel data whose aggregate bandwidth is beyond the single port bandwidth
- ODI-2 uses the VRT packet structure, coupled with Interlaken SOP (Start of Packet commands) to synchronize data across multiple ports.
- There is no theoretical limit to the number of ports that can be aggregated, but four ports is a feasible number.
- ODI-2 uses a per-port method of flow control over aggregated ports.

Port Aggregation – Synchronizing Packets

Synchronization occurs by sending equal-sample-length VRT packets simultaneously. The beginning of all packets start at the same time, indicated by an Interlaken SOP signal. Using this method, EOP may not occur on all ports simultaneously, but often does. The VRT packetizer consists of inserting 28 Byte Prologue and 4 Byte Trailer around the block data, as defined earlier in ODI-2. This method guarantees that sample data from the same period of time is transported across all ports.



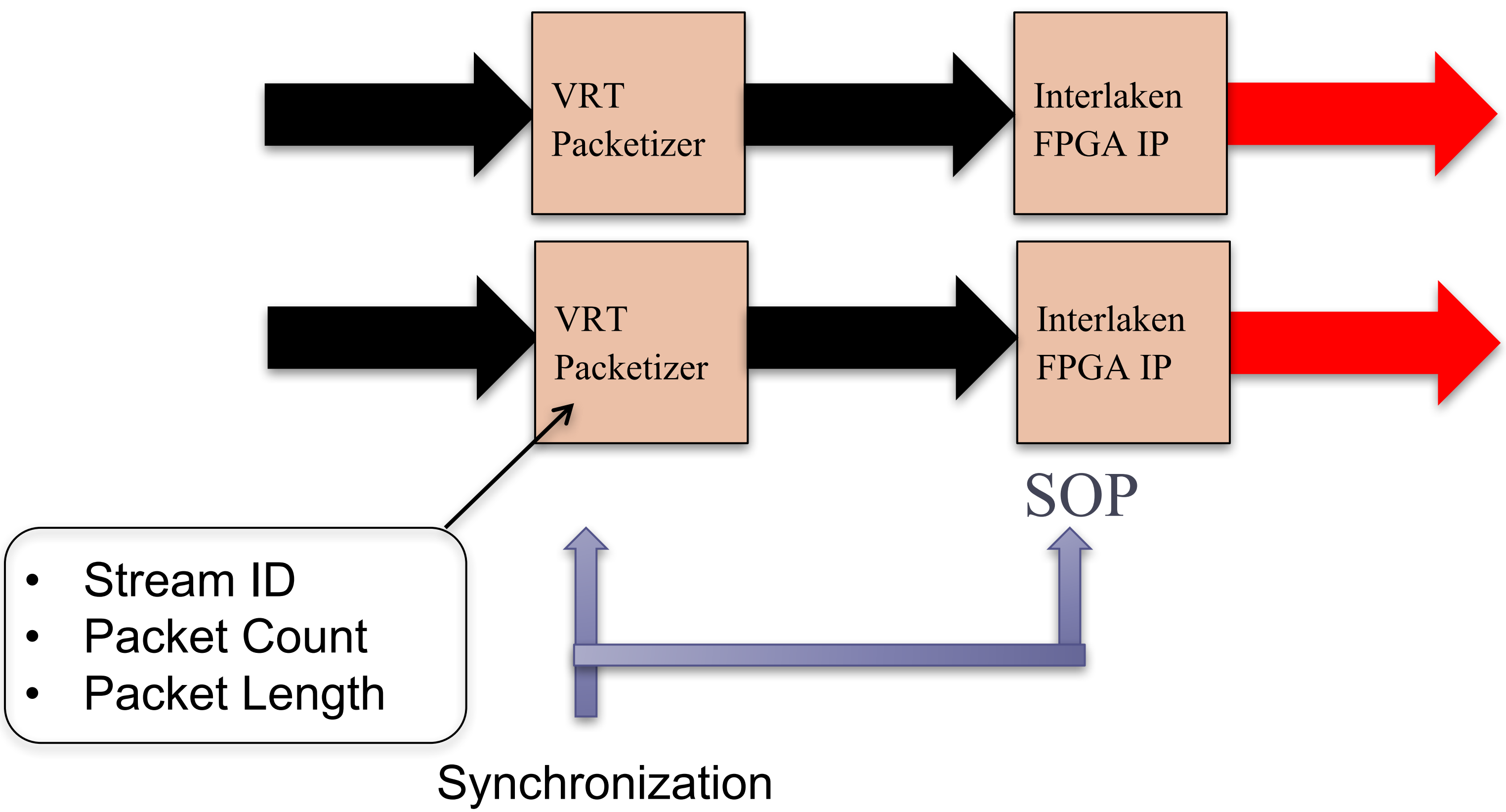
ODI-2 Port Aggregation – Synchronization 1

- RULE: ODI-2 producers that implement port aggregation SHALL send Interlaken SOP signals on all aggregated ports within 5 ns of each other.
- OBSERVATION: 5ns corresponds to within two or three Interlaken words. This is shorter than any defined packet, and removes ambiguity of which packets are aligned across the ports. Feasible implementations will use hardware signals sent to all ODI ports simultaneously

Port Aggregation – Synchronizing Packets (2)

Stream ID: A separate Stream ID SHALL be assigned to each stream. This allows stored data to distinguish between ports.

Packet Count in the header SHALL begin with zero for the first packet, and is incremented after each packet is sent. This allows the consumer to align packets correctly.



Stream ID and Packet Count

- RULE: In a multi-port device where the ports are to be aggregated, each additional port's Stream ID SHALL be incremented by 64.
- OBSERVATION: In a 4-port aggregation, the default Stream IDs are

    Port 1: 4096

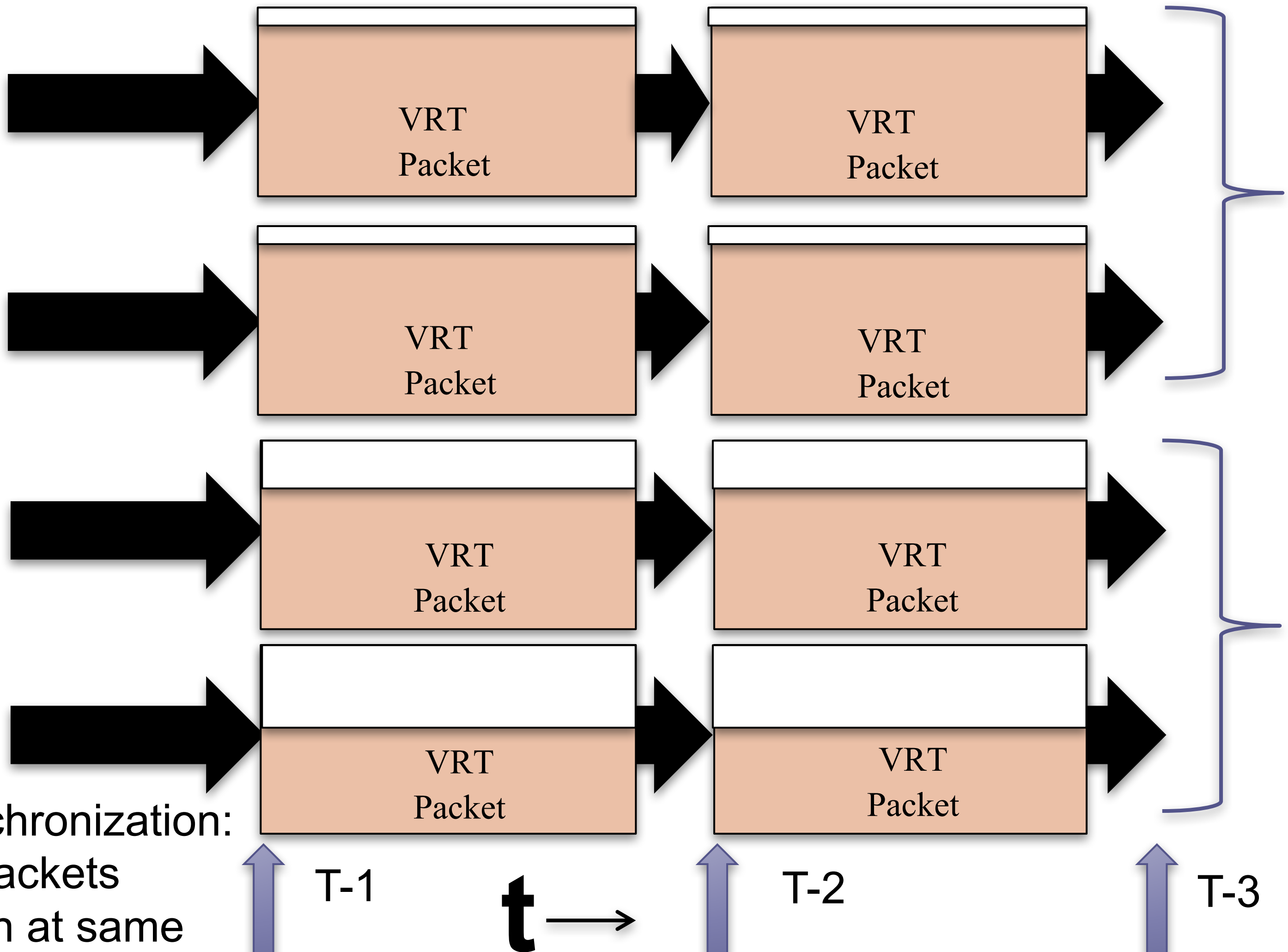
    Port 2: 4160

    Port 3: 4224

    Port 4: 4288
- OBSERVATION: By incrementing by 64 for each additional port, each port can be identified by the Stream ID. Incrementing by 64 still allows downstream devices processing the data to increment the Stream ID by 1, as envisioned by VITA 49A, without causing duplication of Stream ID.
- RULE: Packet Count in the header SHALL begin with zero for the first packet, and is incremented after each packet is sent.
- OBSERVATION: This rule allows the consumer to align packets correctly.
- RULE: ALL ports being aggregated SHALL send the same Packet Count for each synchronized packet across all ports
- OBSERVATION: the above rule allows recovery from a line outage, perhaps caused by an Electrostatic Discharge event. Since Packet Count is a modulo-16 counter, it unambiguously aligns the beginning of a packet with the correct packet.

Port Aggregation – Single and Multi-channel Data

Complete packets are not buffered, just enough for an Interlaken burst of 2K bytes. Max packet size is <256K bytes, implying 127 Interlaken bursts. Brown area indicates duty cycle.



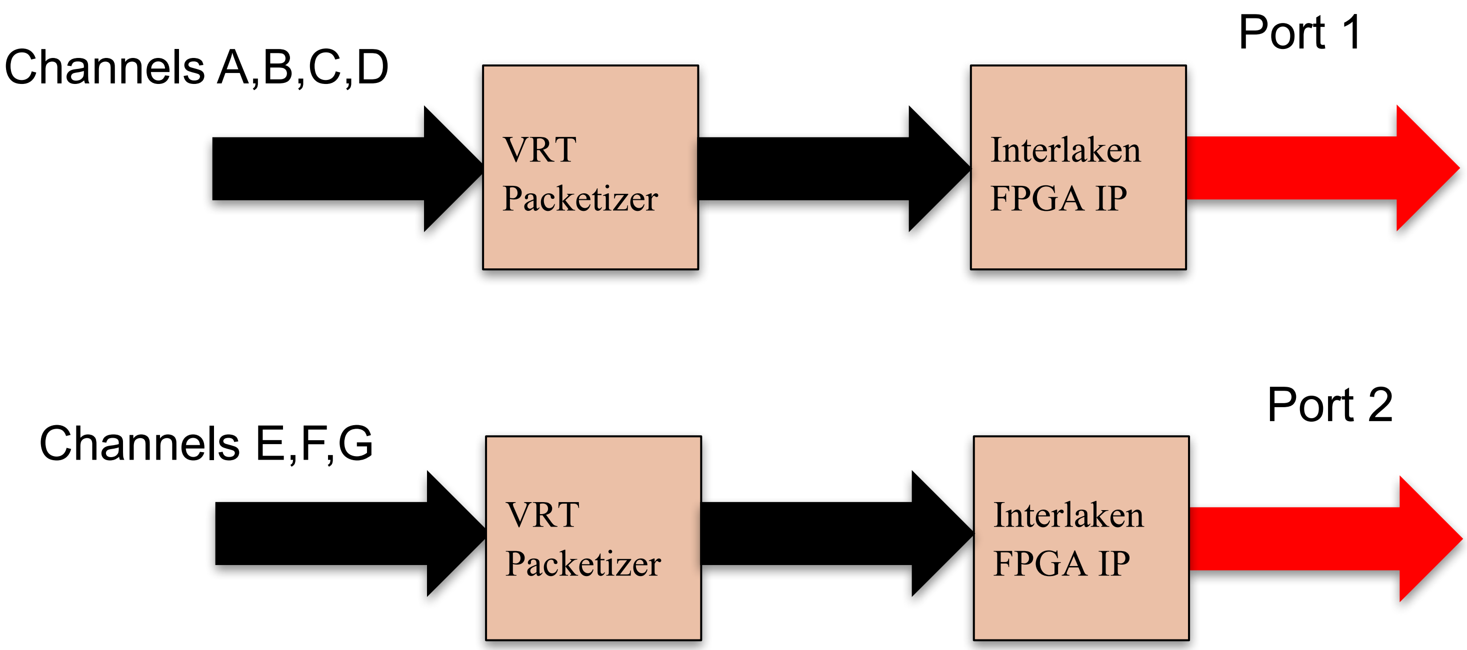
Example of very high speed single channel data split into two ports

Example of multi-channel data on two ports, where one port has more channels than the other

Synchronization: All packets begin at same time

Port Aggregation – Multiple channels

Synchronization occurs by sending equal-sample-length VRT packets simultaneously. The beginning of all packets will start at the same time, indicated by an Interlaken SOP signal. EOP may not occur simultaneously, but must occur before the next SOP.



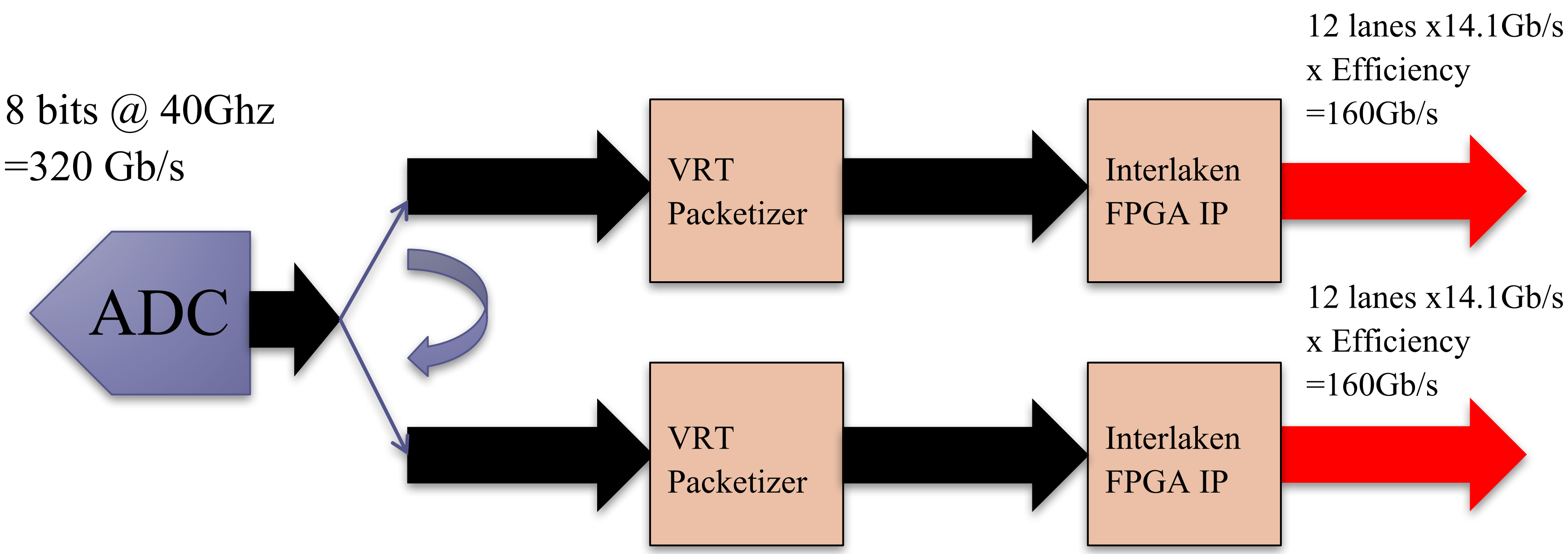
In the example above, all channels send the same number of samples per packet. Therefore, the packet size of Port 1 will be 1.33 that of Port 2.

ODI-2 Port Aggregation – Multiple Channels

- RULE: ODI-2 devices that implement port aggregation SHALL send the same number of samples per channel per packet across all ports
- OBSERVATION: The above rule ensures that the number of samples for each channel will be the same across all packets being sent simultaneously. By definition, it also ensures that each packet covers the same time period.
- PERMISSION: For multi-channel data, a device MAY include more channels on one port than another.
- OBSERVATION: The above permission reflects the fact that the number of channels may not be cleanly divisible by the number of ports.
- RECOMMENDATION: A device SHOULD NOT include more than one channel on any given port than it includes on another given port.
- OBSERVATION: The above recommendation minimizes differences in packet sizes between aggregated ports.

Port Aggregation – Single channel, Transmission

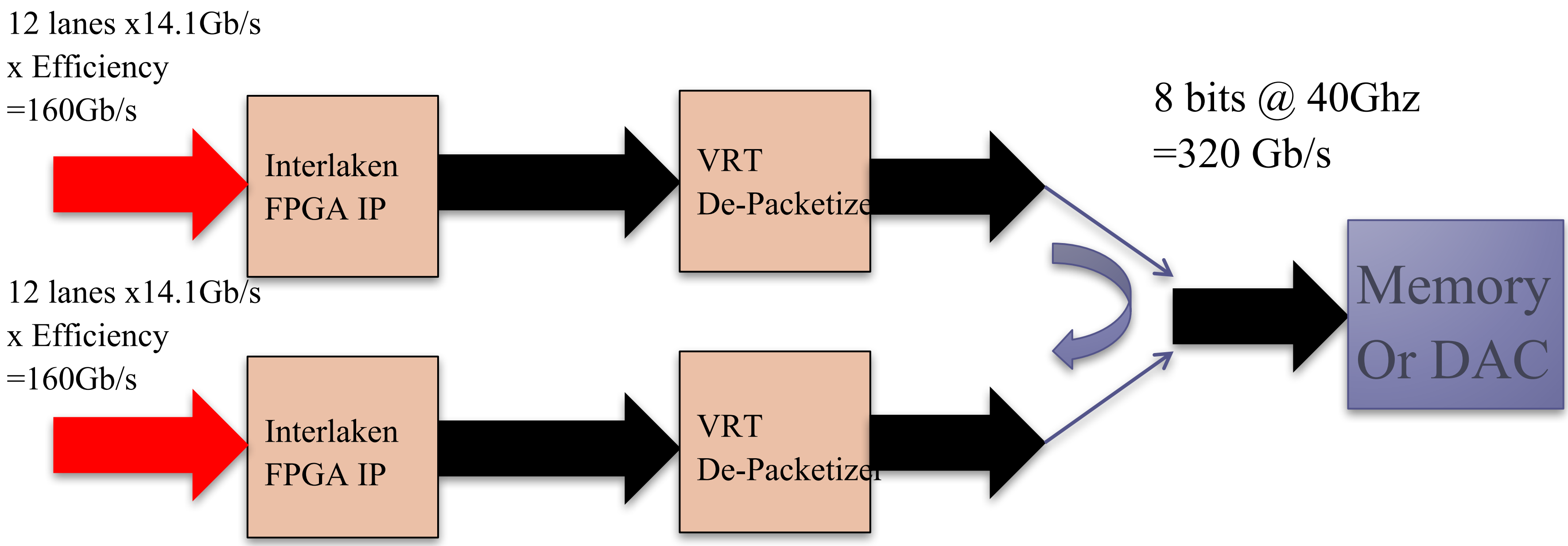
Samples of a single channel are sent in a round robin fashion to each port, packaged in a VRT packet. Here is an example:



- Consecutive samples are transmitted in a round robin technique to each port.
- Interlaken SOP bit is set on each port at beginning of VRT packet. This allows port alignment.
- The example shows 2 port aggregation. Any number of ports my be aggregated.

Port Aggregation – Single channel, Reception

VRT Packets are extracted from each port, and the data interleaved again to form the original stream. Example:



- Interleaved data in a round robin technique to create original stream
- Interlaken SOP bit set on each port at beginning of VRT packet. This allows port alignment.
- The example shows 2 port aggregation. Any number of ports my be aggregated

ODI-2 Port Aggregation – Single Channel

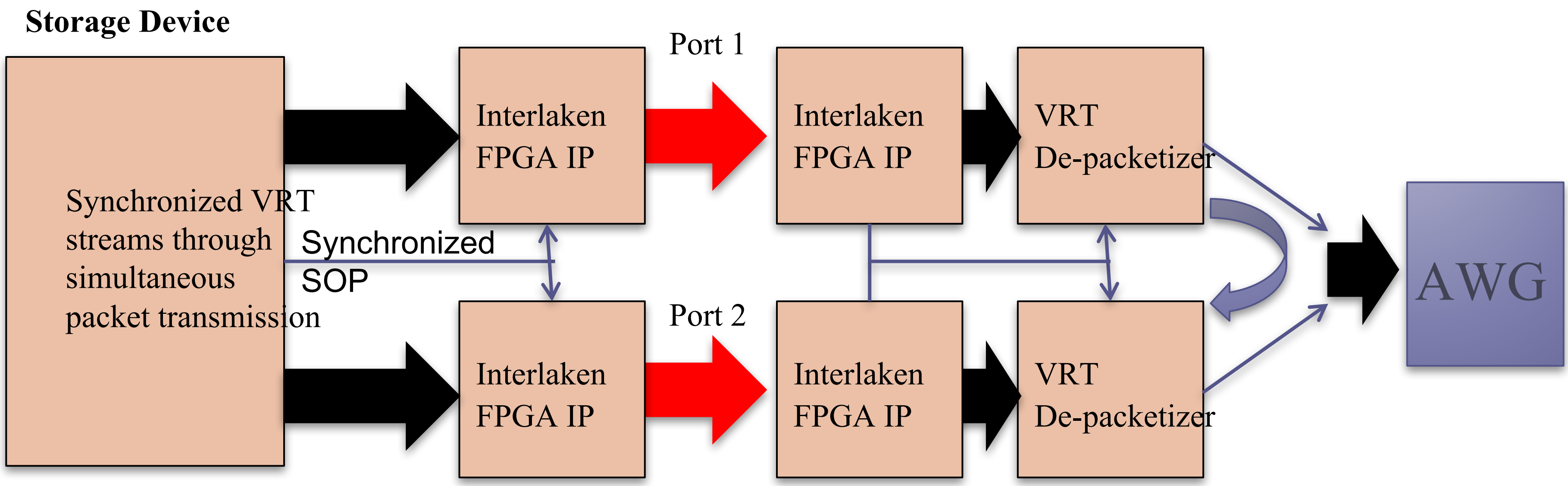
- RULE: ODI-2 devices that implement port aggregation for a single channel SHALL send the same number of samples per packet across all ports
- OBSERVATION: The above rule ensures straight forward interleaving of packets.

Port Aggregation – Flow control

- Flow control is needed in any application where the consumer is pacing the timing of the samples. This is most common when an AWG (arbitrary waveform generator) or other type of signal generator uses flow control to keep the average rate of data from the producer, which could be a storage device, to match its own sampling rate.
- Flow control has been defined earlier in ODI-1 on a per port basis. There are two methods, In-Band and Out of Band. Both rely on XON/XOFF signals being sent from the consumer to the producer, either by a reverse Interlaken link, or an explicit electrical signal.
- Port Aggregation uses a per-port method of flow control. That is, each port is controlled with separate XON/XOFF signals as with the single port flow control model.

Port Aggregation – Flow control

With port aggregation, the producer forces parallel synchronous packet transmission, with SOP on all streams occurring within a defined window. **Shown without flow control**



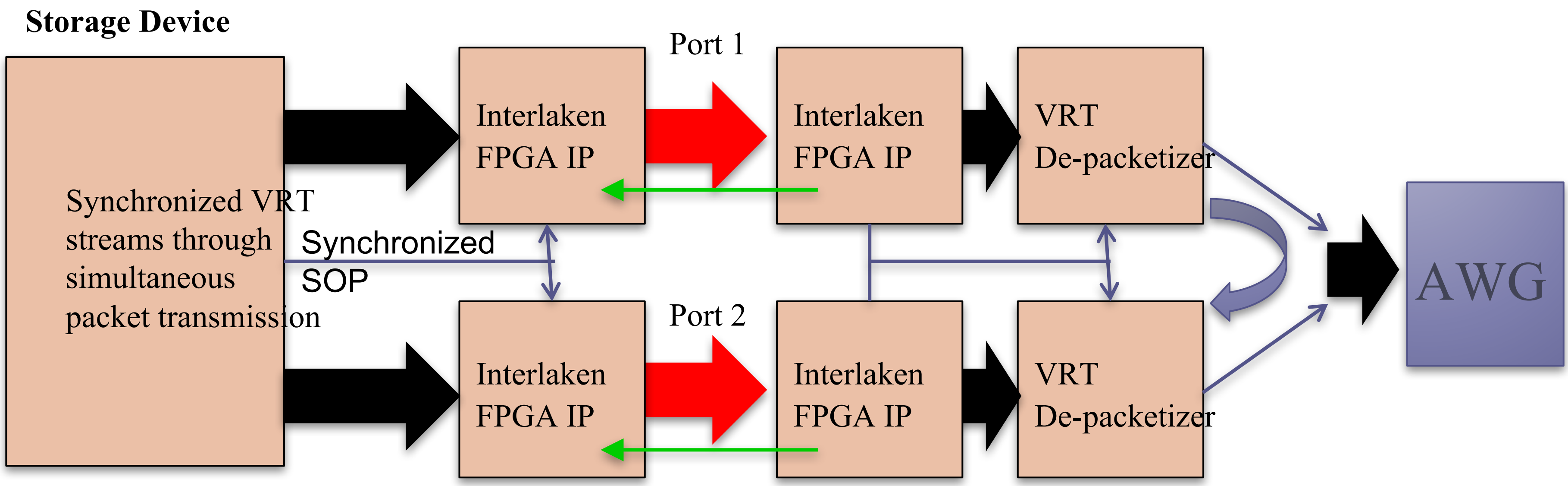
The consumer aligns the incoming packets so the VRT Data Payload (raw sample data) is perfectly aligned across all ports. These samples are either interwoven (as shown, which is the case of fast single channel data) or sent synchronously to multiple channels.

Aggregating Ports – Flow control per port

With per port flow control, each port is controlled independently from the consumer.

Here is the previous example shown with per port flow control.

Flow control is shown in green.



Since the packets are aligned at SOP, they will each be transported before the next SOP. This allows uneven packet lengths, such as when there are more channels on one port than another, to be handled appropriately by the consumer.

Port Aggregation – Flow control

- RULE: During port aggregation all ports using flow control SHALL use either In-Band flow control or Out-of-Band flow control, but not a mixture of the two.
- OBSERVATION: Out-of-Band flow control requires an electrical signal for each port. Therefore a 4-port device would require four electrical signals. PXI and AXIe support 8 and 12 trigger lines respectively, and these lines can be designated to be the OOB flow control lines. It is possible to define an ODI system that requires more flow control lines than the number of backplane trigger lines in a modular instrument system.
- RECOMMENDATION: Devices that support OOB flow control SHOULD include an explicit OOB signal for each port.
- OBSERVATION: The above recommendation allows direct connections between devices without the use of modular backplane signals. This is useful for connecting non-modular devices together, or for expanding the OOB flow control capacity of a modular system.

Documentation requirements

- RULE: All ODI-2 devices SHALL document the VRT packet structures and classes that they support.
- OBSERVATION: The above rule aligns with the VITA 49.0 rule of documenting all packet structures. Following the VITA rules will meet the above ODI-2 rule.
- RULE: All ODI-2 devices SHALL document their port aggregation capabilities, including:
  - -Number of ports capable of being aggregated
  - -Single port bandwidth requirements or capability when in port aggregation mode
  - -In Band and Out of Band flow control modes supported
  - -Per port and en banc flow control modes supported.