DIFI Specification v1.3

MILCOM 2024 DIFI Workshop
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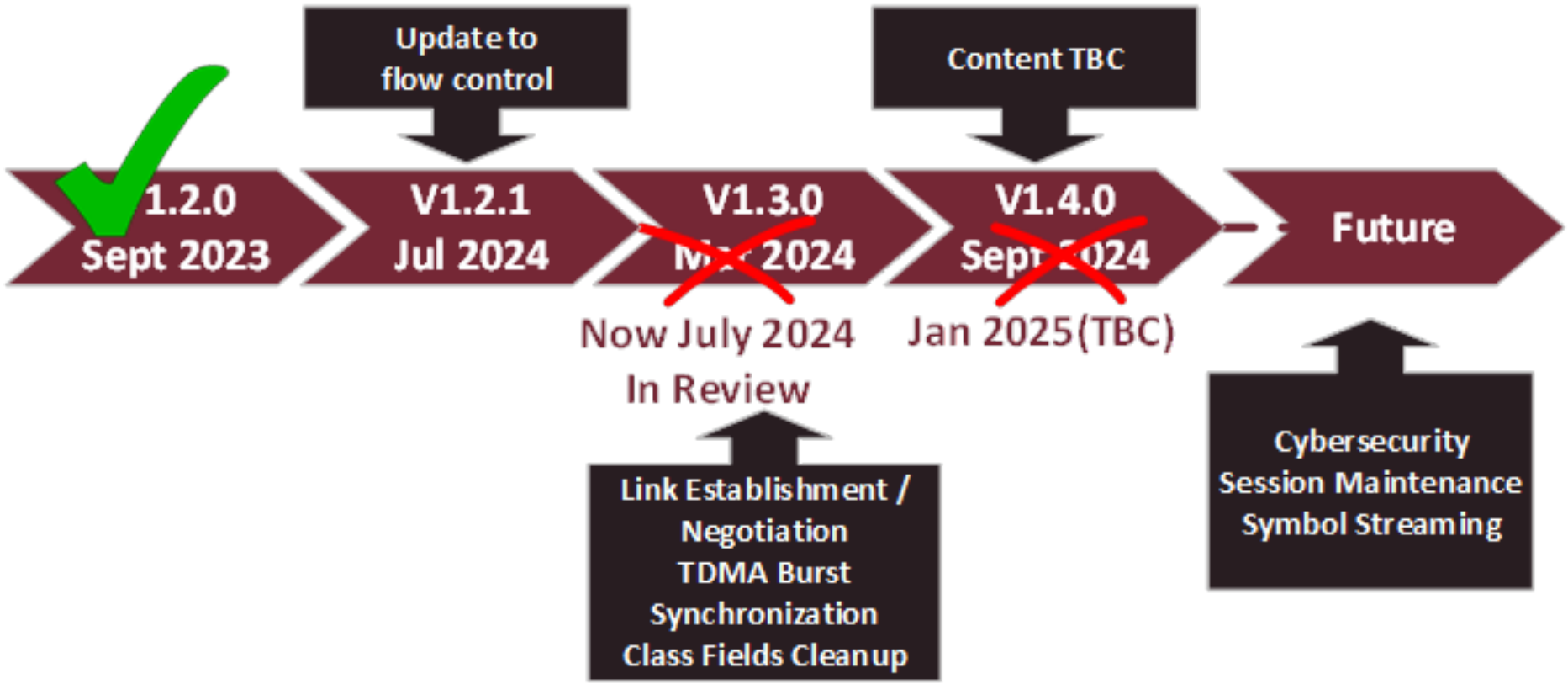
Release Roadmap

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

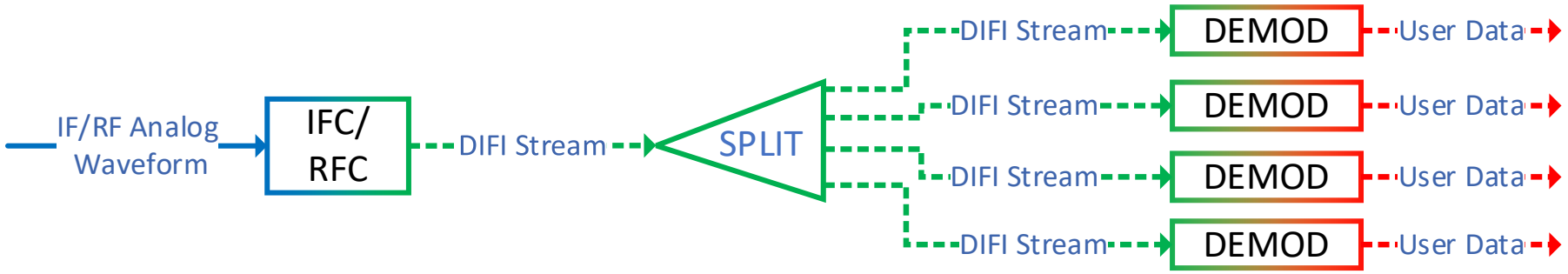


DIFI v1.3 Overview

- Link Establishment / Negotiation
- New Information and Packet Classes
- TDMA Burst Synchronization
- General Class Fields Cleanup

Link Establishment / Negotiation

- The DIFI link establishment process allows the setup of streams between devices across the DIFI protocol, negotiating parameters in-band and enabling packet flow without user intervention.
- Assumptions:
  - Once connected, each set of two devices will negotiate the operational parameters of the link
  - The system designer is responsible for ensuring appropriate IP connectivity
- Example:

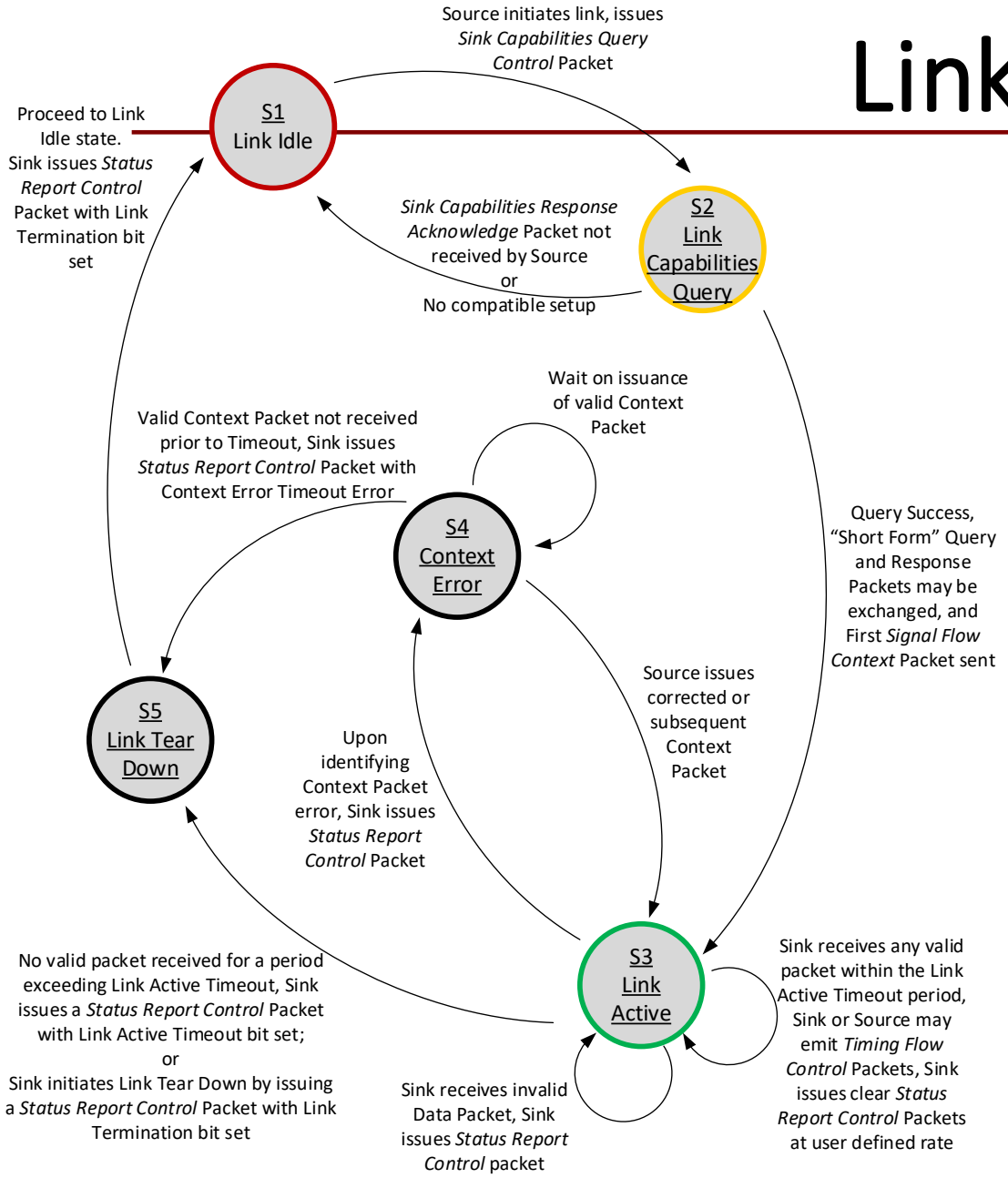


- IFC/RFC provides full bandwidth (500 MHz) to Splitter (1:1 negotiation)
- SPLIT can provide a subset of the full bandwidth to downstream devices
- Each DEMOD requests a particular section of spectrum from SPLIT

Link Establishment Process Overview

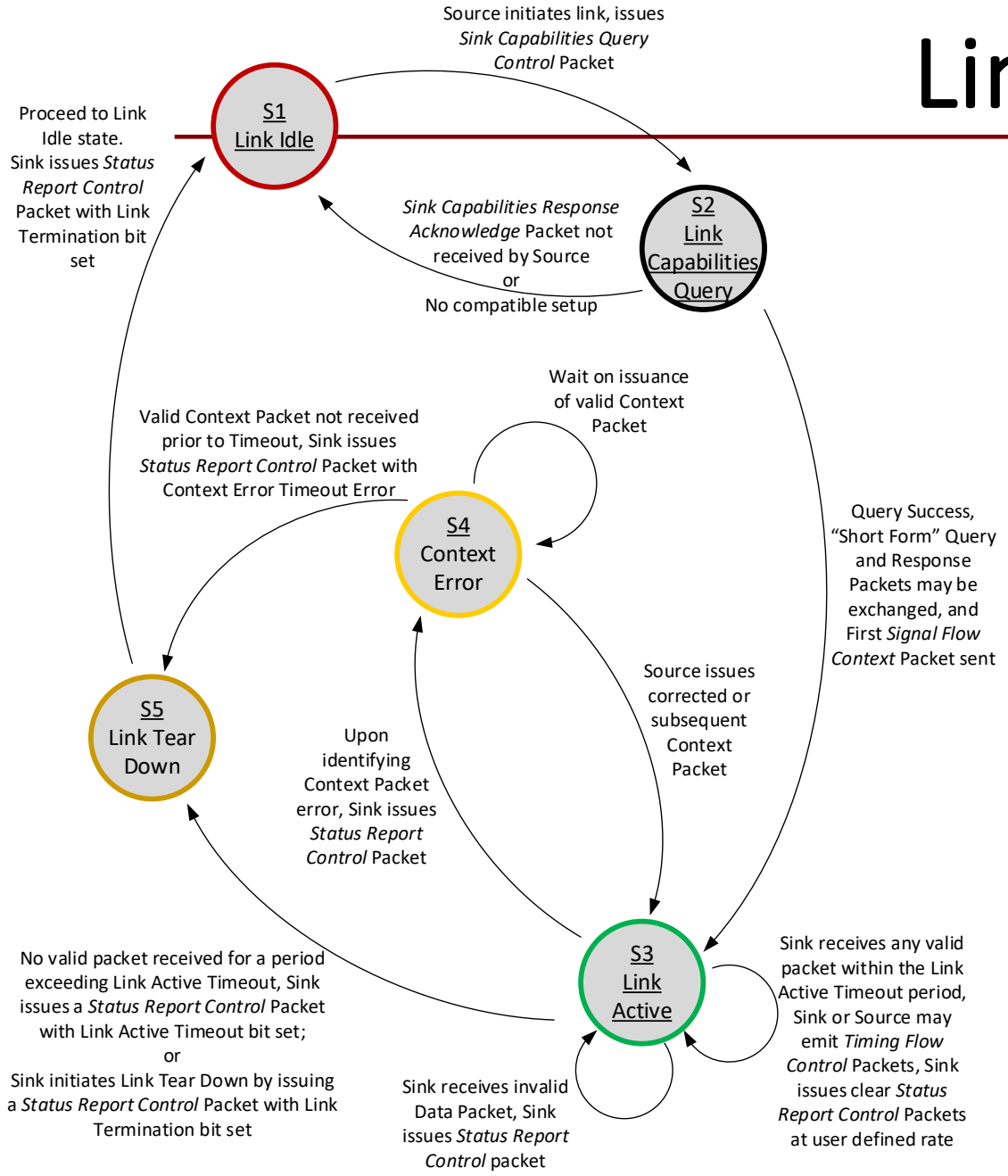
- Five states for the link that capture activation -> teardown
- Negotiate parameters before link initializes
- While active, sink can report on link status
- Multiple options for link teardown
  - Source-initiated
  - Sink-initiated

Link Establishment Process



- Link Initiation and Activation
  - S1 – Link Idle
  - S2 – Link Capabilities Query
  - S3 – Link Active

Link Establishment Process Cont.



- Link Error Handling and Teardown
  - S4 – Context Error
  - S5 – Link Tear Down
  - S1 – Link Idle

Information Classes

- Existing in v1.2.0
  - Info Class 0x0 (Basic Data Plane)
  - Info Class 0x1 (Version Flow)
  - Info Class 0x2 (Flow Control, Sample Count)
  - Info Class 0x3 (Flow Control, Real Time)
- Additional Proposed in v1.3.0
  - Info Class 0x100 (Basic Data Plane)
  - Info Class 0x101 (Link Establishment)
  - Info Class 0x102 (Flow Control, Sample Count, with Link Establishment)
  - Info Class 0x3 (Flow Control, Real Time, with Link Establishment)

Packet Classes

- Existing in v1.2.x
  - Data Packet Classes
    - 0x0 (Data, Real Time)
    - 0x2 (Data, Sample Count)
  - Context Packet Classes
    - 0x1 (Context, Real Time)
    - 0x3 (Context, Sample Count)
    - 0x4 (Version Flow)
  - Command Packet Classes
    - 0x5 (Flow Control, Sample Count
    - 0x6 (Flow Control, Real Time)
- Additional Proposed in v1.3.0
  - Extension Command Packet Classes
    - 0x7 (Sink Capabilities Query Control)
    - 0x8 (Sink Capabilities Response Acknowledge)
    - 0x9 (Status Response Control)

Sink Capabilities Query Control Packet (Class 0x7)

- The Sink Capabilities Query Control Packet has a “long form” and a “short form” version
  - Long Form
    - Provides the way for the DIFI Source to query DIFI Sink capabilities
    - Uses Control Indicator Fields 0 and 1
  - Short Form
    - Characterize Network Latency/Jitter
    - Requests a Timestamped Response
    - Can be used as a ‘heartbeat’ query to verify the link is still active

Sink Capabilities Query Ctrl Pkt (Class 0x7) Cont.

Table 4-26 Sink Capabilities Query Extension Control Packet (Long Form)

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	Word #
0	1	1	1	1	0	0	0	TSI		TSF		Packet Count				Packet Size (13 words)																1
Stream Identifier																																2
Zero Padding Count				0	0	0	24-Bit DIFI CID (0x6A621E16)																										3
Information Class																Packet Class																4
Integer Timestamp																																5
Fractional Timestamp																																6
																																7
1	0	1	0	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Message ID																																9
Controllee ID																																10
Controller ID																																11
0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13

Sink Capabilities Query Ctrl Pkt (Class 0x7) Cont.

Table 4-27 Sink Capabilities Query Extension Control Packet (Short Form)

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	Word #
0	1	1	1	1	0	0	0	0	0	0	1	Packet Count				Packet Size (12 words)																1
Stream Identifier																																2
Zero Padding Count				0	0	0	24-Bit DIFI CID (0x6A621E16)																											3
Information Class																Packet Class																4
Integer Timestamp																																5
Fractional Timestamp																																6
																																7
1	0	1	0	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Message ID																																9
Controllee ID																																10
Controller ID																																11
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Sink Time Calibration (integer seconds)																																13
Sink Time Calibration (fractional seconds)																																14
																																15

Sink Capabilities Response Acknowledge Packet (Class 0x8)

- The Sink Capabilities Response Acknowledge Packet Class provides the responses to the “long form” and a “short form” versions of the Sink Capabilities Query Control Packet. The Acknowledge packet’s:
  - Long Form
    - Discrete values
      - Used by devices that support discrete parameter values
      - Example: Sample Rate support for 25 Msps, 12.5 Msps, and 6.25 Msps
    - Ranges
      - Used by devices that support a range of values
      - Example: Sample Rate support for 25 Msps through 1 Msps, resolution 1 Msps
  - Short Form
    - Characterize Network Latency/Jitter
    - Requests a Timestamped Response
    - Can be used as a ‘heartbeat’ query to verify the link is still active

Sink Capabilities Response Ack Pkt (Class 0x8) Cont.

Table 4-28 Sink Capabilities Extension Acknowledge Packet (Long Form, Discrete Values)

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	Word #
0	1	1	1	1	1	0	0	TSI		TSF		Packet Count				Packet Size (Variable)																1
Stream Identifier																																2
Zero Padding Count				0	0	0	24-Bit DIFI CID (0x6A621E16)																											3
Information Class																Packet Class																4
Integer Timestamp																																5
Fractional Timestamp																																6
																																7
1	0	1	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Message ID																																9
Controllee ID																																10
Controller ID																																11
0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13
Number of Information Classes Specified (16 bits)																First Supported Information Class																14
2nd Supported Information Class																3rd Supported Information Class																15
N-1st Supported Information Class																Nth Supported Information Class																16
Reserved																Number of Reference Points supported																17
First Reference Point Supported																																18
Seond Reference Point Supported																																19
...																																20
Nth Reference Point Supported																																21
Reserved																1	# Max BWs/Samp Rates																22
First Sample Rate Supported																																23
																																24
...																																25
																																26
Nth Sample Rate Supported																																27
																																28
First Maximum Bandwidth Supported																																29
																																30
...																																31
																																32
Nth Maximum Bandwidth Supported																																33
																																34

Sink Capabilities Response Ack Pkt (Class 0x8) Cont.

Table 4-29 Sink Capabilities Extension Acknowledge Packet (Long Form, Ranges)

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	Word #
0	1	1	1	1	1	0	0	TSI		TSF		Packet Count				Packet Size (Variable)																1
Stream Identifier																																2
Zero Padding Count					0	0	0	24-Bit DIFI CID (0x6A621E16)																										3
Information Class																Packet Class																4
Integer Timestamp																																5
Fractional Timestamp																																6
																																7
1	0	1	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Message ID																																9
Controllee ID																																10
Controller ID																																11
0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	12
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	13
Number of Information Classes Specified (16 bits)																First Supported Information Class																14
2nd Supported Information Class																3rd Supported Information Class																15
N-1st Supported Information Class																Nth Supported Information Class																16
Reserved																Number of Reference Points supported																17
First Reference Point Supported																																18
Seond Reference Point Supported																																19
...																																20
Nth Reference Point Supported																																21
Reserved																0	0x0000 (SR Resolution) or 0x0001 (SR Rate Ratio)																22
Minimum Sample Rate																																23
																																24
Maximum Sample Rate																																25
																																26
Sample Rate Resolution or Rate Ratio																																27
																																28
Minimum Ratio of Sample Rate to Bandwidth																																29

Sink Capabilities Response Ack Pkt (Class 0x8) Cont.

Buffer Size (Bytes)	72 73
Nearly Late Time Threshold	74 75
Link Active Timeout Period	76 77 78
Context Error Timeout Period	79 80 81

- Buffer Size: Sink's buffer size in bytes
- Nearly Late Time Threshold, Link Active Timeout Period, and Context Error Timeout Period are declared at time of link establishment and then used in link error handling and teardown

Sink Capabilities Response Ack Pkt (Class 0x8) Cont.

Table 4-30 Sink Capabilities Response Extension Acknowledge Packet (Short Form)

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	Word #
0	1	1	1	1	1	0	0	0	0	0	1	Packet Count				Packet Size 18 Words																1
Stream Identifier																																2
Zero Padding Count					0	0	0	24-Bit DIFI CID (0x6A621E16)																										3
Information Class																Packet Class																4
Integer Timestamp																																5
Fractional Timestamp																																6
																																7
1	0	1	0	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	8
Message ID																																9
Controllee ID																																10
Controller ID																																11
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Integer Second Timestamp of Control Packet																																13
Fractional Second Timestamp of Control Packet																																14
																																15
Integer Second Time at Sink at Time of Reception of Control Packet																																16
Fractional Second Time at Sink at Time of Reception of Control Packet																																17
																																18

Status Response Control Packet (Class 0x9)

- The Status Response Control Packet is intended for the DIFI Sink to be able to report back to the DIFI Source on the state of the link
- Control Packets should also be issued periodically by the Sink at a user-determined rate between one and one hundred packets per second.
- When there are no errors at the time of the periodically issued packets, the Status Report Control Packet shall be sent with all error bits set to zero, indicating an “all clear” condition.
- In the case of a Sink Error (e.g., loss-of-lock), the Sink shall promptly issue a Status Report Control Packet indicating the error, and shall continue to flag the error in subsequent periodically issued packets until the error is resolved.

Status Response Control Packet (Class 0x9)

4.4.5 Status Report Control 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	Word #
0	1	1	1	1	0	0	0	TSI		TSF		Packet Count				Packet Size = 15																1
Stream Identifier																																2
0	0	0	0	0	0	0	0	24-Bit DIFI CID (0x6A621E)																								3
Information Class																0x0009																4
Integer Second Timestamp																																5
Fractional Second Timestamp																																6
																																7
1	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Message ID																																9
Controllee ID/UUID (default to 0x00000000 if unused)																																10
Controller ID/UUID (default to 0x00000000 if unused)																																11
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Error Code Payload (two words)																																14
																																15

Error Code Payload

	Packet Errors																													
Word 1	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
	Selected Packet Type not defined	Selected TSM not allowed	Selected TSI not allowed	Selected TSF not allowed	Incorrectly Specified Packet Size	Specified Pad Bit Count not permitted	Specified Information Class not defined	Specified Packet Class not in Information Class	Packet Class not defined	Late Context Packet arrival (TSI/TSF Timestamp error)	Late Data Packet arrival (TSI/TSF Timestamp error)	Reference Point not recognized	Bandwidth too large for sample rate	Fractional Hz specified	IF Reference Frequency resolution error	IF Reference Frequency out of range	RF Reference Frequency resolution error	RF Reference Frequency out of range	IF Offset too large	Reference Level mismatch	Sample rate resolution error	Sample rate out of range	Data Payload Config incorrectly specified	Unsupported Bit Depth	Frequency Allocation Conflict	Simultaneous Stream Capacity Exceeded	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
	Sink Errors																Warnings															
Word 2	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
	Frequency LOL causing data stoppage	Timebase LOL causing data stoppage	Buffer Underflow	Buffer Overflow	Link Active Timeout	Context Error Timeout	Link Termination	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Probable Packet Drop - Context	Probable Packet Drop - Data	Nearly Late Context Packet arrival	Nearly Late Data Packet arrival	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved

Controller / Controllee Assignment

- Devices in an implementation are initially assigned numbers but are not specifically assigned as controller or controllee. This assignment is a part of system configuration, and as such is “out of band”, with respect to DIFI Link Establishment.

- Each device in the implementation is identified by its number (so in this case, 32-bit numbers may NOT be used twice), but not explicitly identified as controller or controllee. In this approach, the issuer of the Control Packet places its number in the Controller ID field and places the number of the intended recipient of the Control Packet in the Controllee ID field. In this approach, the issuer and target of the Control Packet are clearly indicated by the numbers in the Controller ID and Controllee ID fields respectively.

- Since all the devices in the implementation are identified at the outset, all the device roles are “known” by all the other devices and configured out of band by the system designer.

TDMA Burst Synchronization

- Covered by Jim Rosenberg in separate presentation

Class Fields Cleanup

- Credit to:
  - Lisa Chan, L3Harris
  - Jim Rosenberg, Wavestream

- In DIFI v1.2, descriptions of each packet parameter could be duplicated or recreated in several places, introducing opportunities for lack of coherency after updates or simply different descriptions, confusing the reader (and editors!). There was also no table or representation of all of the capability in one place.

- In DIFI v1.3, the goal is to combine information and packet class details in a way that reduces duplication and makes comparing packets more straightforward, as well as clearly describe the information & packet class correlations.

Class Fields Cleanup Cont.

Table 4-1 Supported Packet Types and Packet Classes

v1.2 Packet Types	v1.2 Packet Classes
0x1 **Data** packet with a stream ID	Standard Flow Signal **Data**, 0x0000
	Sample Count Signal Flow **Data**, 0x0002
0x4 **Context** packet with a stream ID	Standard Flow Signal **Context**, 0x0001
	Sample Count Signal **Context**, 0x0003
	Version Flow Signal **Context**, 0x0004
0x6 **Command** Packet with a stream ID	Sample Count Timing Flow **Control**, 0x0005
	Real Time TSF Timing Flow **Control**, 0x0006

Table 4-2 Correlation between Information Classes and Packet Classes

	Packet Classes →	0x0000	0x0001	0x0002	0x0003	0x0004	0x0005	0x0006		
	↓ Information Classes	Standard Flow Signal Data	Standard Flow Signal Context	Sample Count Signal Data	Sample Count Signal Context	Version Flow Signal Context	Sample Count Timing Flow Control	Real Time TSF Timing Flow Control	Purpose of Information Class ↓	Version in which first incorporated
0x0000	Basic Data Plane	X	X						To convey digitized I/Q data samples and associated context	v1.0
0x0001	Version Flow					X			To convey version and time of day for synchronization (legacy)	v1.0
0x0002	Data Plane plus Flow Control			X	X		X		To convey I/Q data, associated context, and control for synchronization	v1.2
0x0003	Data Plane plus Flow Control,	X	X					X	To convey I/Q data, associated context, and control for synchronization	v1.2

Packet Types
- Data Packet
- Context Packet
- Command Packet