Universal Serial Bus 4 (USB4™) Inter-Domain Service Protocol

Apple Inc.
Hewlett-Packard Inc.
Intel Corporation
Microsoft Corporation
Renesas Corporation
STMicroelectronics
Texas Instruments

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AMD			
Joe Scanlon			
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Clinton Bauder	Carlos Calderon	Thomas LaPerre	Rob McKeever
Collin Pieper	Reese Schreiber		
Intel Corporation			
Mickey Gutman	Uri Hermoni	Abdul Ismail	Brad Saunders
Leonid Shaposhnik	Uri Soloveychik	Stephanie Wallick	Gal Yedidia
Vladimir Yudovich			
Microsoft Corporation			
Rahul Ramadas			

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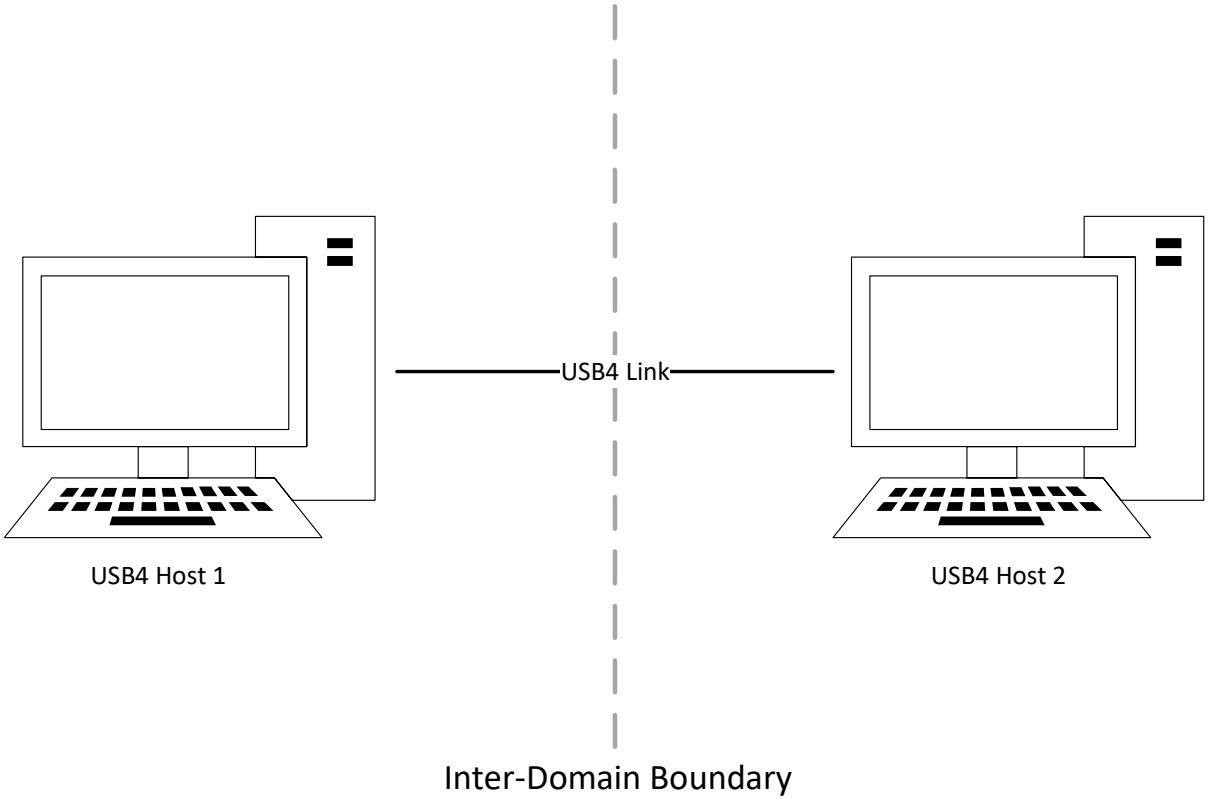
1 Introduction

USB4 is designed around a Domain that includes a Host, several Devices, and a Connection Manager running on the Host to manage the Domain. Although Domains are generally independent, USB4 allows for communication between Host Routers in adjacent Domains and between the Connection Managers in these Domains. The USB4 specification defines the Inter-Domain communication mechanism, but it does not specify how to set up a service to run over the Inter-Domain channel.

Figure 1-1. Connecting two USB4 Domains



USB4 provides the means to establish Inter-Domain Services between software stacks running in peer Domains. Tunneling of Ethernet traffic over USB4, defined in Chapter 5 of this specification, is an example of an Inter-Domain Service. Inter-Domain Services on peer Domains use the Host Interface in their local Host Routers to tunnel traffic through the USB4 fabric.

Inter-Domain Services are established using the Inter-Domain Protocol. The Inter-Domain Protocol is executed by peer Connection Managers, using Inter-Domain Control Packets for communication between the peer Connection Managers.

This specification defines the Inter-Domain Protocol and describes how to identify/setup an Inter-Domain Service using the Inter-Domain Protocol. It also defines the Inter-Domain Service to tunnel Ethernet traffic between USB4 Domains. Additional methods, outside the scope of this specification, may be needed to support Inter-Domain communication when more than two Domains are involved.

1.1 Inter-Domain Service Overview

During Domain enumeration, the Connection Manager discovers Inter-Domain Links using the flow described in the USB4 Connection Manager (CM) Guide.

Once the Local Connection Manager has discovered an Inter-Domain Link it uses the protocol defined in this specification to query the Remote Connection Manager of the other Domain about its capabilities. Responses are in the form of a series of Inter-Domain Packets, some of which contain a Properties Block as defined in Chapter 4. The Properties Block describes the Inter-Domain services a host offers. The Local Connection Manager then configures one or more

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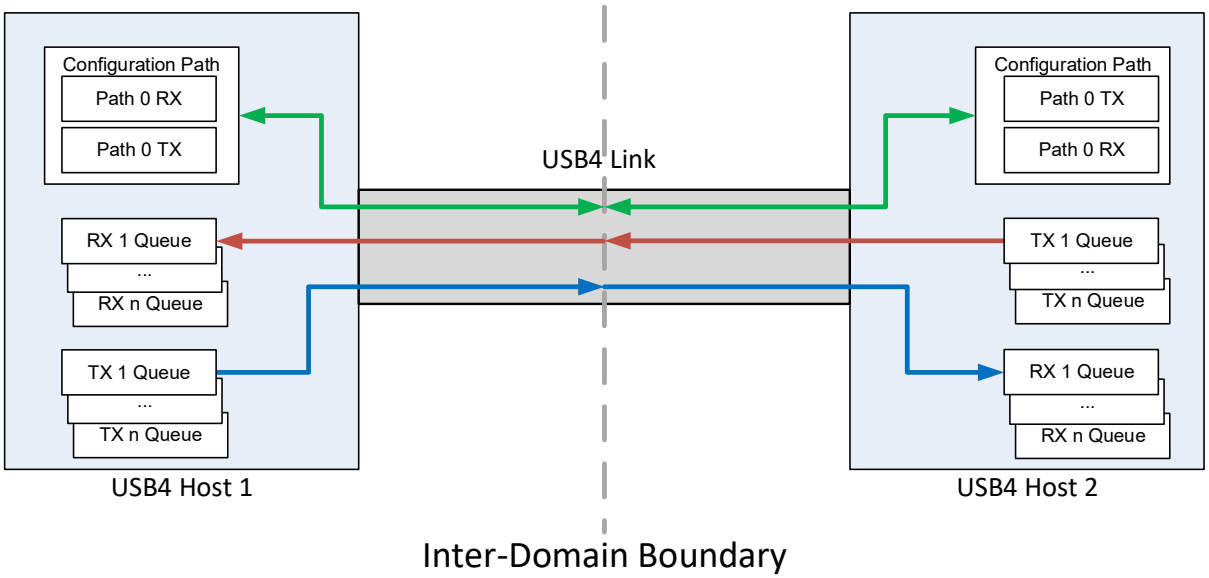
services published in the Properties Block. When service configuration is complete, one or more Tunneled Protocol Paths are established, and it is the responsibility of the overlaying protocol (e.g. Ethernet Protocol) to take over communication.

Figure 1-2. Inter-Domain Service Overview



1.2 Endian Conventions

All Control Packets sent across Path 0 meet ordering requirements as stated in the USB4 Specification. Endianness within the payload of a Tunneled Packet is defined by the protocol which is tunneled (see chapter 5).

UUID (universally unique identifier) values are written in canonical textual representation of 32 hexadecimal digits. For example, the UUID value of the Inter-Domain Discovery Protocol is B638D70E-42FF-40BB-97C2-90E2C0B2FF07. When written as part of a packet, the UUID values take four DWORDs, and the bytes within each DWORD are swapped. For example, the above UUID value is written as:

DWORD	Value
0	0x0ED738B6
1	0xBB40FF42
2	0xE290C297
3	0x07FFB2C0

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1.3 Scope of the Specification

This specification is primarily targeted at platform operating system/BIOS/device driver developers that want to take advantage of the Inter-Domain communication capabilities of USB4.

1.4 Specification Organization

Chapter 1 provides an overview, Chapters 2, 3 and 4 contain technical information defining the Inter-Domain Discovery Protocol and Chapter 5 defines Inter-Domain Services (and specifically Ethernet over USB4).

1.5 Related Specifications

[USBCC] USB Type-C™ Cable and Connector Specification, Release 2.0 (USB Type-C Specification), August 2019

[USBPD] Universal Serial Bus Power Delivery Specification, Revision 3.0 Version 2.0 + ECNs, February 07, 2020 (USB PD Specification)

[USB4CM] Universal Serial Bus 4 (USB4™) Connection Manager Guide, Revision 1.0, April 2021

[USB4] Universal Serial Bus 4 (USB4™) Specification, Version 1.0, August 2019

1.6 Conventions

1.6.1 Precedence

If there is a conflict between text, figures, and tables, the precedence shall be tables, figures, and then text.

1.6.2 Keywords

The following keywords differentiate between the levels of requirements and options.

1.6.2.1 Informative

Informative is a keyword that describes information in this specification that intends to discuss and clarify requirements and features as opposed to mandating them.

1.6.2.2 May

May is a keyword that indicates a choice with no implied preference.

1.6.2.3 N/A

N/A is a keyword that indicates that a field or value is not applicable and has no defined value and shall not be checked or used by the recipient.

1.6.2.4 Normative

Normative is a keyword that describes features that are mandated by this specification.

1.6.2.5 Optional

Optional is a keyword that describes features not mandated by this specification. However, if an optional feature is implemented, the feature shall be implemented as defined by this specification (optional normative).

1.6.2.6 Reserved

Reserved is a keyword indicating reserved bits, bytes, words, fields, and code values that are set-aside for future standardization. The use and interpretation of these may be specified by future extensions to this specification and, unless otherwise stated, shall not be utilized or adapted by vendor implementation. A reserved bit, byte, word or field shall be set to zero by the sender and shall be ignored by the receiver. Reserved field values shall not be sent by the sender and, if received, shall be ignored by the receiver.

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1.6.2.7 Shall

Shall is a keyword indicating a mandatory (normative) requirement. Designers are mandated to implement all such requirements to ensure interoperability with other compliant devices.

1.6.2.8 Should

Should is a keyword indicating flexibility of choice with a preferred alternative. Equivalent to the phrase "it is recommended that".

1.6.3 Capitalization

Some terms are capitalized to distinguish their definition in the context of this specification from their common English meaning. Words not capitalized have their common English meaning.

1.6.4 Italic Text

Italic text is used to identify variable names, register field and packet field names, or reference specification titles.

1.6.5 Numbering

Numbers that are immediately followed by a lowercase "b" (e.g., 01b) are binary values. Numbers that are immediately followed by an uppercase "B" are byte values. Numbers that are immediately followed by a lowercase "h" (e.g., 3Ah) are hexadecimal values. Numbers not immediately followed by either a "b", "B", or "h" are decimal values.

1.6.6 Bit, Byte, DW, and Symbol Conventions

A bit, byte, DW, or Symbol residing in location n within an array is denoted as bit(n), byte(n), DW(n), or Symbol(n).

A sequence of bits, bytes, DWs, or Symbols residing in locations n to m (inclusive) within an array is denoted as bit[m:n], byte[m:n], DW[m:n], or Symbol[m:n].

1.6.7 Implementation Notes

Implementation notes are not a normative part of this specification. They are included for clarification and illustration only. Implementation notes within this specification are enclosed in a box and set apart from the other text.

1.6.8 Pseudo Code

Throughout this specification, pseudo code is used to illustrate operating principles. Comments are demarcated by double forward slashes ("//"). The pseudo code conventions include:

```
if/else conditions;
   if (condition)
      // true operations
   else
      // false operations

for loops:
   for (conditions)
      // operations
```

1.7 Terms and Abbreviations

This section lists and defines the terms and abbreviations used throughout this specification. See the USB4 Specification for additional terms and abbreviations. Note that terms and abbreviations not defined here, use their generally accepted or dictionary meaning.

Term/Abbreviation	Description
Inter-Domain Packet	A Control Packet sent between peer Connection Managers.

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Term/Abbreviation	Description
Inter-Domain Discovery Protocol	The protocol used by peer Connection Managers to identify each other, probe their properties, and manage the Inter-Domain Link.
Inter-Domain Service	Sets up Paths between Connection Managers to allow tunneled Packets between Domains, carrying traffic for a certain service. Ethernet over USB4 (USB4NET) is an example of an Inter-Domain Service
Tunneled Protocol Path	A Path used for Tunneled protocol traffic over an Inter-Domain connection for an Inter-Domain Service. This Path uses a non-zero HopID.

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2 Discovery Packet Formats

This section defines the structure of the Control Packets used by peer Connections Managers for Inter-Domain communication.

A source of an Inter-Domain packet shall not use a value in this specification that is marked as "Rsvd".

A source of an Inter-Domain packet shall set a field that is marked "Rsvd" to zero.

The target of an Inter-Domain packet shall drop an Inter-Domain packet that has any of its defined fields set to a Rsvd value. If the packet is an Inter-Domain Response packet, then the target shall invalidate the Inter-Domain Request packet that corresponds to the Inter-Domain Response packet. The target may reissue the Inter-Domain Request packet.

The target of an Inter-Domain packet shall drop an Inter-Domain packet that has any of its defined fields set to an illegal value. If the packet is an Inter-Domain Response packet, then the target shall invalidate the Inter-Domain Request packet that corresponds to the Inter-Domain Response packet. The target may reissue the Inter-Domain Request packet.

The target of an Inter-Domain packet shall ignore any fields that are marked "Rsvd" independent of the actual value received.

2.1 Inter-Domain Packet Format

Figure 2-1 defines the core structure of an Inter-Domain Control Packet. Subsequent sections describe the structure of a Control Packet based on the *PacketType* field.

Figure 2-1. Inter-Domain Packet Format

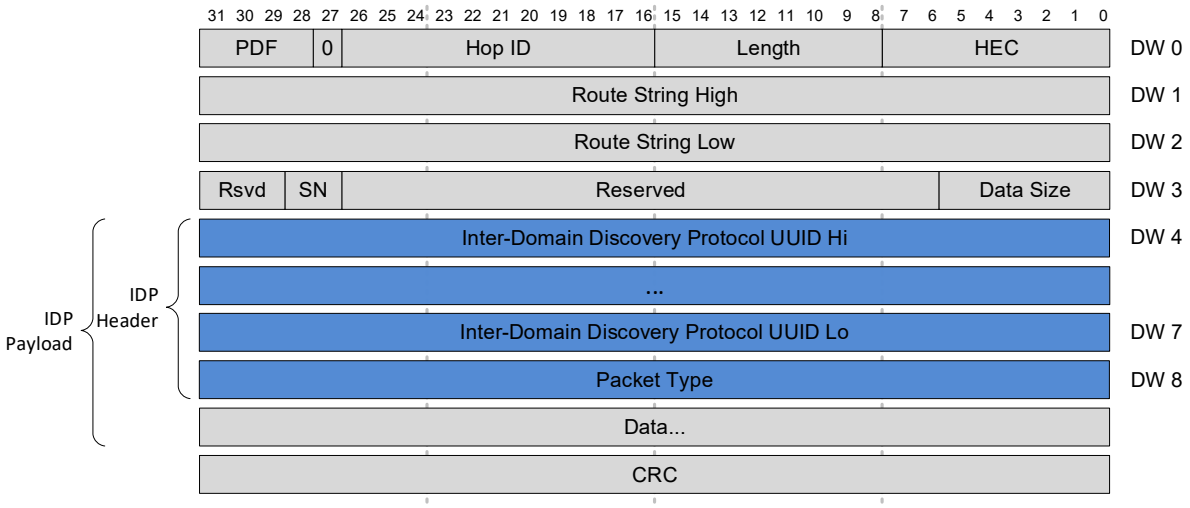

Table 2-1. Inter-Domain Packet Format Fields

DW	Bits	Description
0	31:0	**Header** – Transport Layer Packet header Bits: Description 7:0: HEC - Header Error Control 15:8: Length - Payload size in bytes excluding the padding size 26:16: HopID – Shall be set to 000h 27: SuppID – Shall be set to 0 31:28: PDF - Shall be set to 6 for an Inter-Domain Request or 7 for an Inter-Domain Response.
1	31:0	**Route String High**

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DW	Bits	Description
2	31:0	**Route String Low.** See *USB4.Table 6-1*
3	5:0	**Data Size** –This field is used to indicate the number of doublewords in the Inter-Domain Packet Payload (IDPP) excluding the CRC.
3	28:27	**SN** – Sequence Number. A Connection Manager may set any value in an Inter-Domain Request Packet. The target of an Inter-Domain Request Packet shall write the value in the Request Packet into the Response Packet.
7:4	31:0	**Inter-Domain Discovery Protocol UUID** – A 128 bit UUID representing the Inter-Domain Discovery Protocol (B638D70E-42FF-40BB-97C2-90E2C0B2FF07) DWORD: Value 4: 0x0ED738B6 5: 0xBB40FF42 6: 0xE290C297 7: 0x07FFB2C0
8	31:0	**Packet Type –** The type of this packet as defined by Table 2-2
9:9+N -1	31:0	**Data** – The data payload (N DWords of data) based on the *Packet Type*
9+N	31:0	**CRC** – See Table 6-1 in the USB4 Specification for details on how this shall be calculated

Table 2-2. Inter-Domain Packet Types

Value	Name	Description
0-1	Reserved	
2	UUID Response	A response to a UUID Request
3	Properties Read Request	A request for another Domain's Properties Block
4	Properties Read Response	A response to a Properties Read Request
5	Properties Changed Notification	Informs a peer Domain that the local Connection Manager has changed its Properties Block and may have modified the Inter-Domain services it offers
6	Properties Changed Response	A response to a Properties Changed Notification
7	Error Response	An error response to any packet type
8-11	Reserved	
12	UUID Request	A request for another Domain's UUID and route string
13-14	Reserved	
15	Link State Status Request	A request for another Domain's Target Link Width and Supported Link Width
16	Link State Status Response	A response to a Link State Status Request
17	Link State Change Request	A request for another Domain to modify its Target Link Width
18	Link State Change Response	A response to a Link State Change Request
19	Time Sync	Indicates progress in the Inter-Domain Time Sync protocol
20+	Reserved	

2.2 Inter-Domain UUID Request Packet Format

Figure 2-2 defines the structure of an Inter-Domain UUID Request Packet.

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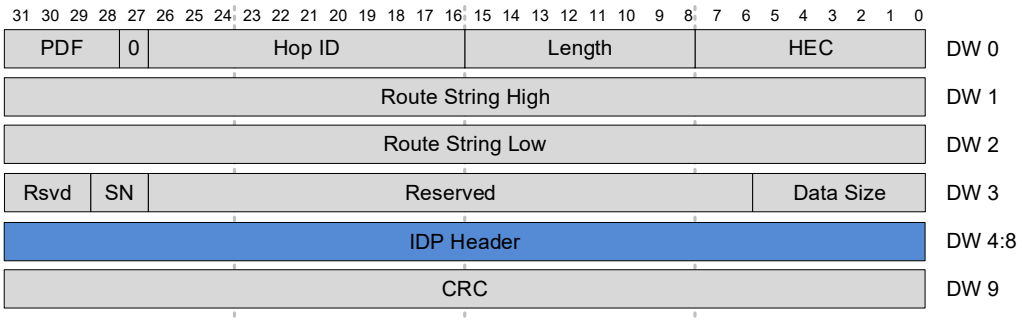
Figure 2-2. Inter-Domain UUID Request Packet Format



2.3 Inter-Domain UUID Response Packet Format

Figure 2-3 defines the structure of an Inter-Domain UUID Response Packet.

Figure 2-3. Inter-Domain UUID Response Packet Format

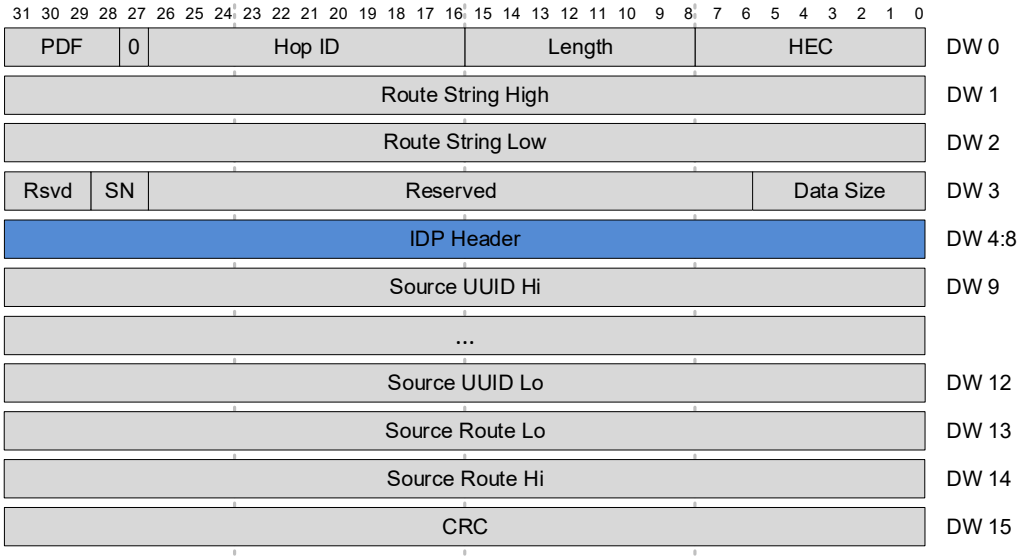


Table 2-3. Inter-Domain UUID Response Packet Fields

DW	Bits	Description
9:12	31:0	**Source UUID** – A 128 bit UUID representing the sender's Inter-Domain UUID, generated using the ISO/IEC 9834-8:2014 specification. Source UUID uniquely identifies a Domain.
13:14	31:0	**Source Route** – The sender's Route String. The *Source Route* field shall set to the value of the Route String field in the Inter-Domain UUID Request Packet In case of a loop inside a Domain, the Connection Manager may use this information to identify the location of the loop within the Domain.

2.4 Inter-Domain Properties Read Request Packet Format

Figure 2-4 defines the structure of an Inter-Domain Properties Read Request Packet.

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Figure 2-4. Inter-Domain Properties Read Request Packet Format

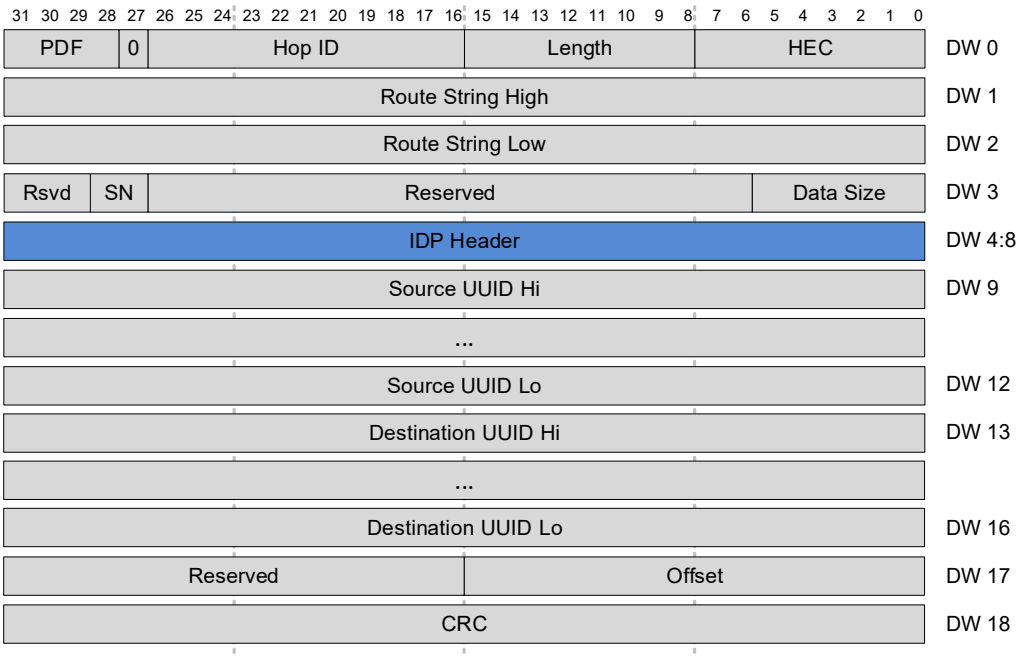

Table 2-4. Inter-Domain Properties Read Request Packet Fields

DW	Bits	Description
9:12	31:0	**Source UUID** – A 128 bit UUID representing the sender's Inter-Domain UUID
13:16	31:0	**Destination UUID** – A 128 bit UUID representing the receiver's Inter-Domain UUID.
17	15:0	**Offset** – The offset in DWORDS into the Properties Block that the Remote Connection Manager shall start populating in the appropriate field of the Inter-Domain Read Response Packet.
17	31:16	**Reserved**

2.5 Inter-Domain Properties Read Response Packet Format

Figure 2-5 defines the structure of an Inter-Domain Properties Read Response Packet.

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Figure 2-5. Inter-Domain Properties Read Response Packet Format

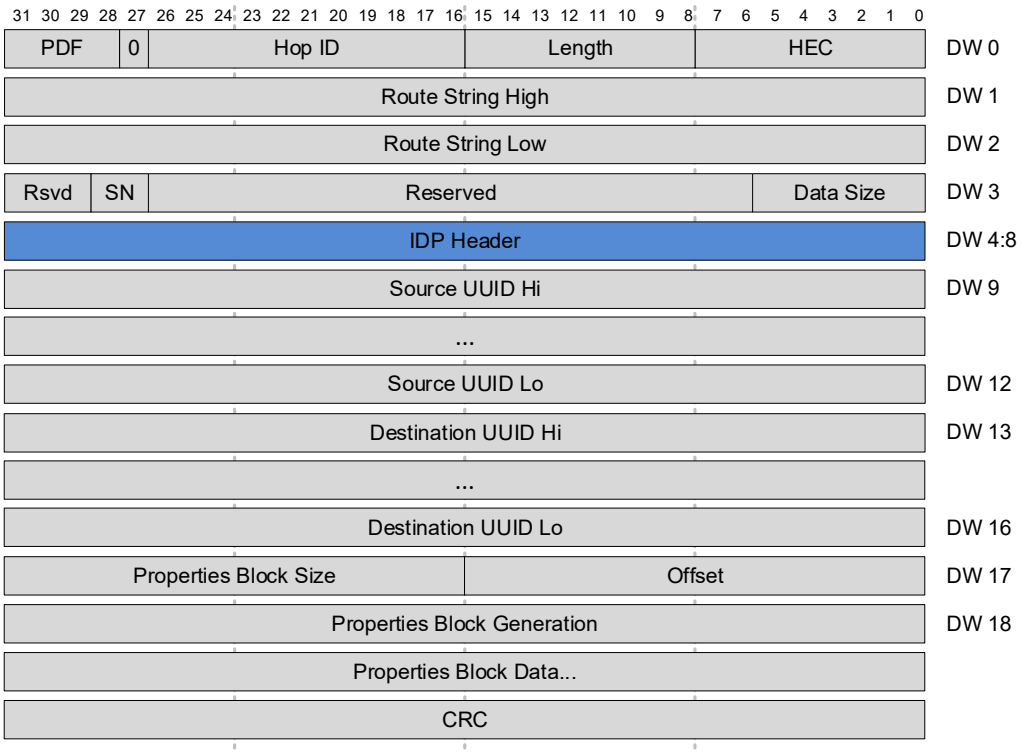

Table 2-5. Inter-Domain Properties Read Response Packet Fields

DW	Bits	Description
9:12	31:0	**Source UUID** – A 128 bit UUID representing the sender's Inter-Domain UUID
13:16	31:0	**Destination UUID** – A 128 bit UUID representing the receiver's Inter-Domain UUID. This field shall be set to the value received in the *Source UUID* field of the Inter-Domain Properties Read Request Packet.
17	15:0	**Offset** – The offset in DWORDS into the Properties Block that is delivered in this packet in the *Properties Block Data* field. This shall be equal to the *Offset* field in the Inter-Domain Properties Read Request Packet
17	31:16	**Properties Block Size** – The size, in DWORDS, of the entire Properties Block
18	31:0	**Properties Block Generation** – A monotonically incrementing number that tracks the generation of the Properties Block. Each time the local Properties Block is modified, the generation shall increment, and upon transmission, be reflected here. It is recommended that a new pseudo-random value is loaded each time the Connection Manager resets its Inter-Domain Discovery Protocol state. See Section 3.2 for usage of this field.
19:19 +(n-1)	31:0	**Properties Block Data** – The Properties Block data containing n DWs. Section 3.2 defines the rules for partitioning the Properties Block among multiple Inter-Domain Properties Read Response Packets.

2.6 Inter-Domain Properties Changed Notification Packet Format

Figure 2-6 defines the structure of an Inter-Domain Properties Changed Notification Packet.

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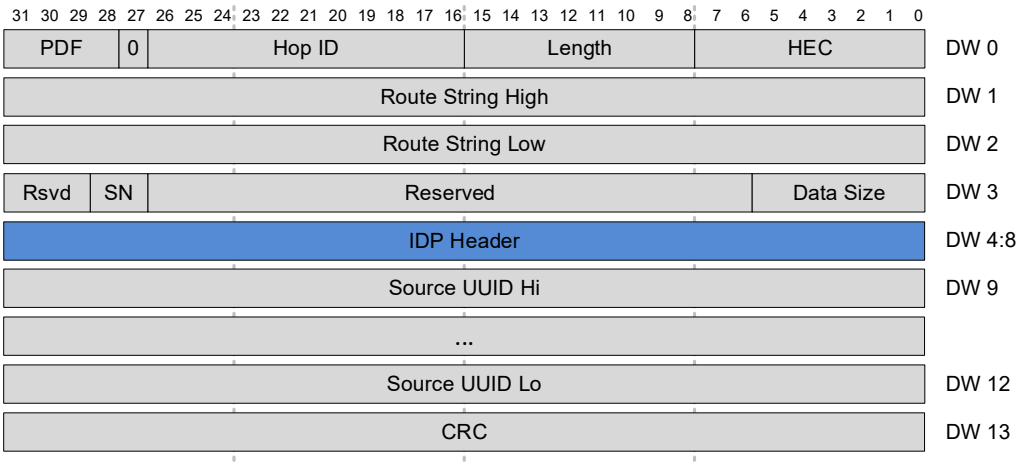
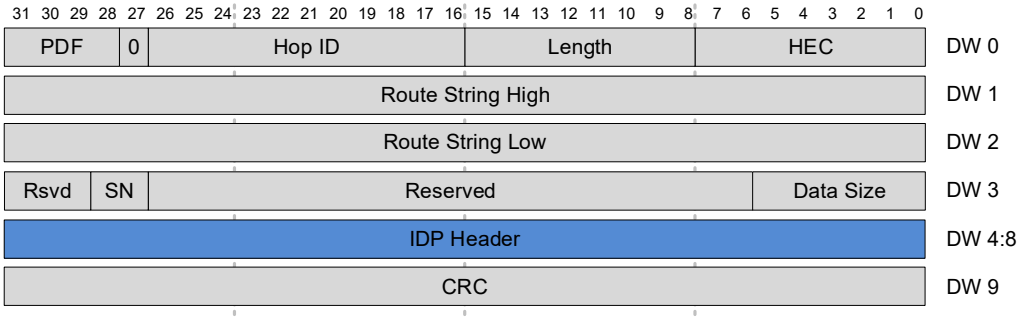
Figure 2-6. Inter-Domain Properties Changed Notification Packet Format



2.6.1 Inter-Domain Properties Changed Response Packet Format

Figure 2-7 defines the structure of an Inter-Domain Properties Changed Response Packet.

Figure 2-7. Inter-Domain Properties Changed Response Packet Format



2.7 Inter-Domain Error Response Packet Format

Figure 2-8 defines the structure of an Inter-Domain Error Response Packet.

Figure 2-8. Inter-Domain Error Response Packet Format

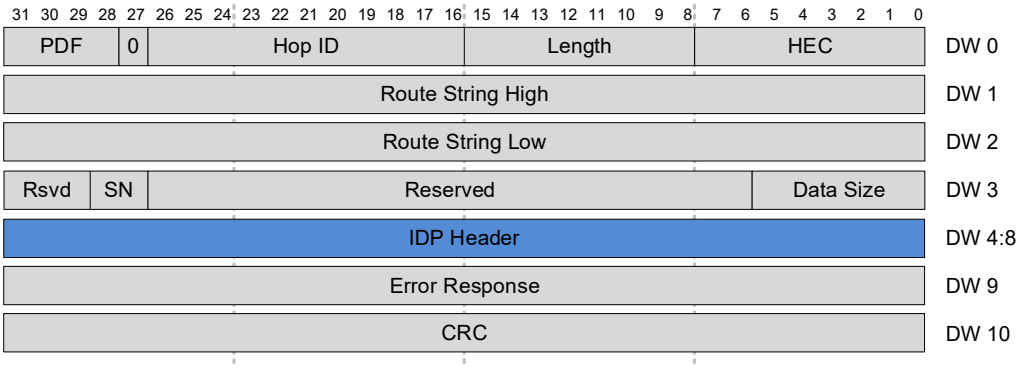


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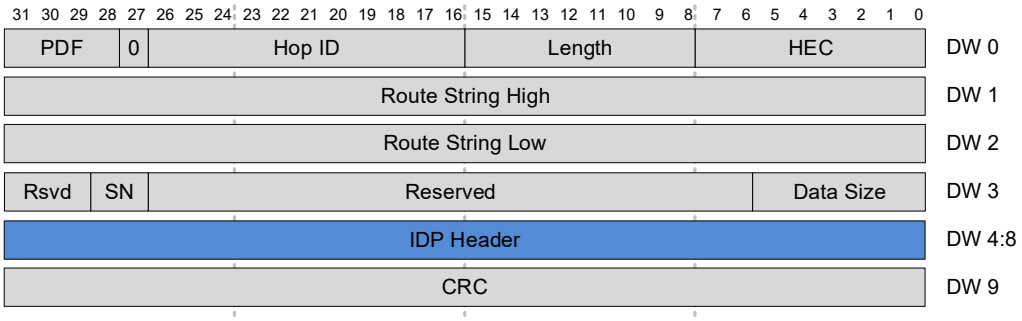
Table 2-6. Inter-Domain Error Response Packet Fields

DW	Bits	Description
9	31:0	**Error Response** Value: Meaning 1: Unknown Packet Type 3: Not Supported 4: Not Ready All other values: Reserved

2.8 Inter-Domain Link State Status Request Packet Format

Figure 2-9 defines the structure of an Inter-Domain Link State Status Request Packet.

Figure 2-9. Inter-Domain Link State Status Request Packet Format



2.9 Inter-Domain Link State Status Response Packet Format

Figure 2-10 defines the structure of an Inter-Domain Link State Status Response Packet.

Figure 2-10. Inter-Domain Link State Status Response Packet Format

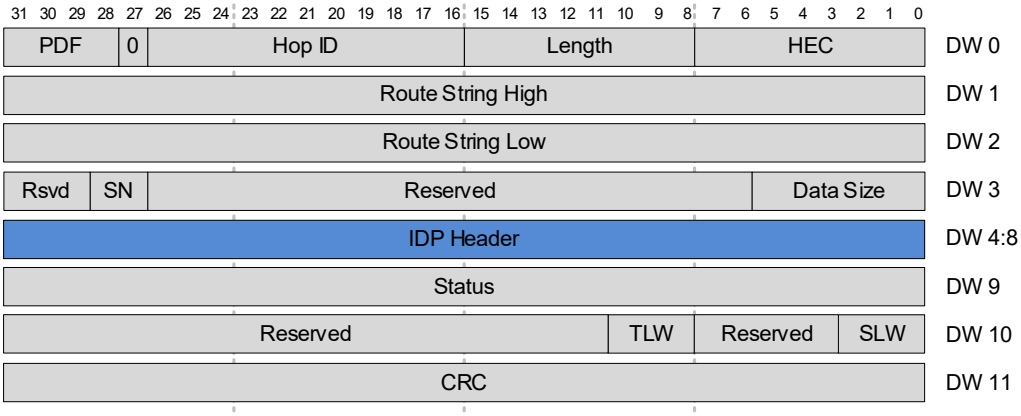


Table 2-7. Inter-Domain Link State Status Response Packet Fields

DW	Bits	Description
9	31:0	**Status** - shall be set to 0 to indicate successful response to the request
10	1:0	**Supported Link Width (SLW)** – Bits 21:20 of register LANE_ADP_CS_0[1]

[1] The Lane Adapter Configuration Capability of the Adapter that is facing the Inter-Domain Link

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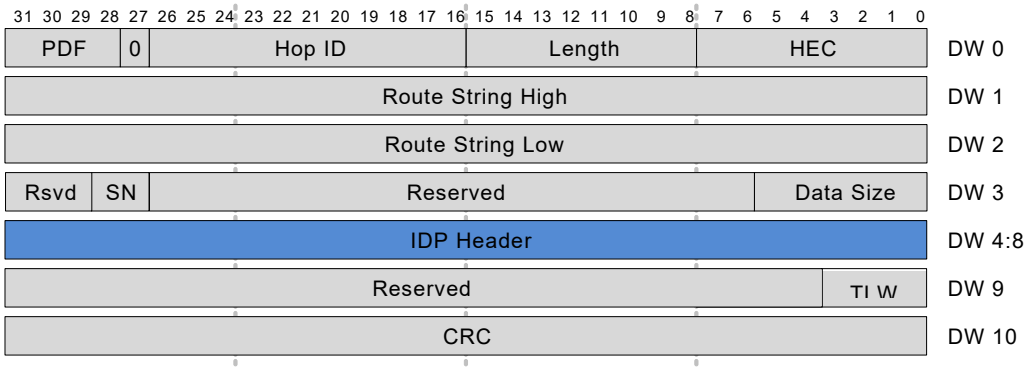
DW	Bits	Description
10	7:2	**Reserved**
10	9:8	**Target Link Width (TLW)** – Bits 5:4 of register LANE_ADP_CS_1
10	31:10	**Reserved**

2.10 Inter-Domain Link State Change Request Packet Format

Figure 2-11 defines the structure of an Inter-Domain Link State Change Request Packet.

Figure 2-11. Inter-Domain Link State Change Request Packet Format



See Table 2-7 for definition of the *TLW* field.

2.11 Inter-Domain Link State Change Response Packet Format

Figure 2-11 defines the structure of an Inter-Domain Link State Change Response Packet.

Figure 2-12. Inter-Domain Link State Change Response Packet Format

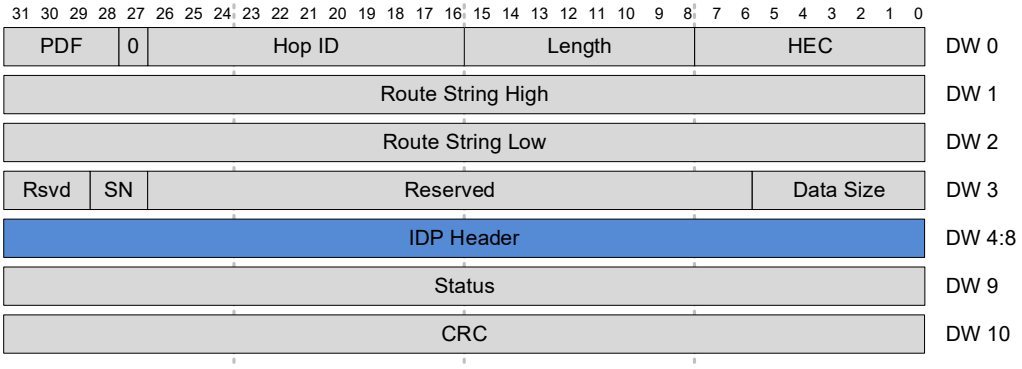


Table 2-8. Inter-Domain Link State Status Response Packet Fields

DW	Bits	Description
9	31:0	**Status** - shall be set to 0 to indicate successful queuing of the request

2.12 Inter-Domain Time Sync Packet Format

Figure 2-13 defines the structure of an Inter-Domain Time Sync Packet.

Figure 2-13. Inter-Domain Time Sync Packet Format

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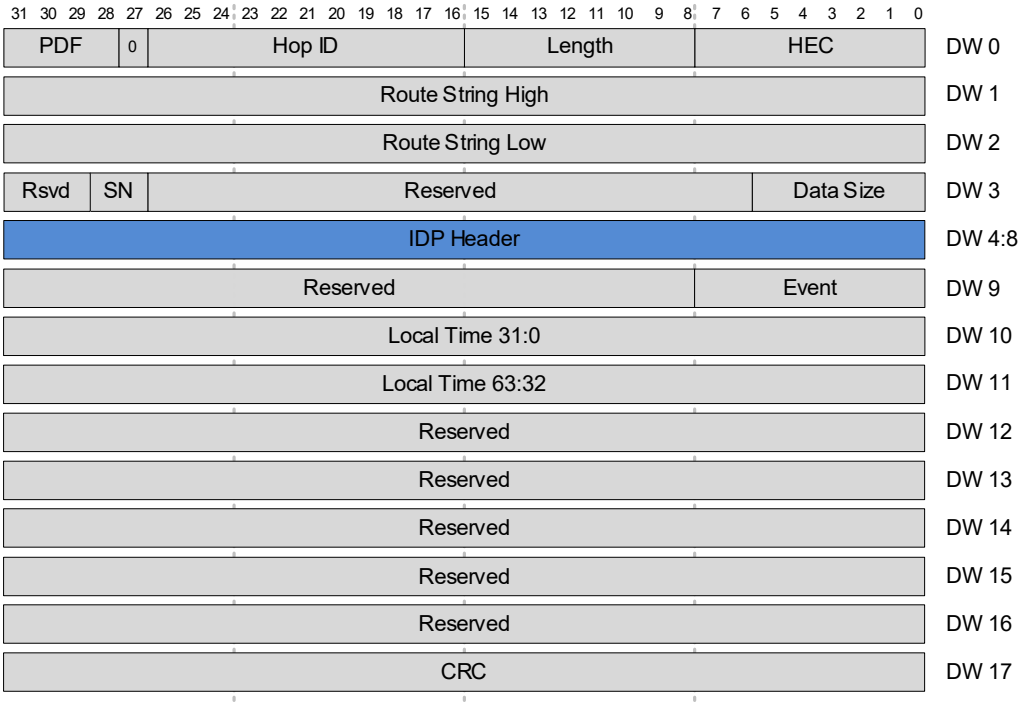

Table 2-9. Inter-Domain Time Sync Packet Fields

DW	Bits	Description
9	7:0	**Event** – Defines the type of Inter-Domain Time Sync Packet. 00h – Local Time 01h – Follower Ready 02h – Source Ready 03h – Follower Enabled 04h – Disruption Else: Reserved
10	31:0	**Local Time 31:0** – This field contains the least significant 32 bits of the Local Time in nanoseconds. This field is reserved when the Event field is different than 00h.
11	31:0	**Local Time 63:32** – This field contains the most significant 32 bits of the Local Time in nanoseconds. This field is reserved when the Event field is different than 00h.

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3 Service Discovery

3.1 Inter-Domain Discovery

The Local Connection Manager uses the mechanisms described in Section 3.2.1 and Section 3.3 of the USB4 Connection Manager Guide to identify an Inter-Domain Link.

Upon discovery of an Inter-Domain link, the Local Connection Manager issues an Inter-Domain UUID Request Packet to the Remote Connection Manager. If the Connection Manager does not receive an Inter-Domain UUID Response Packet within 1 second, it shall resend the request ten times, each time waiting for 1 second for a response. If no response is received, the Local Connection manager shall abort the Inter-Domain Discovery Protocol.

If Inter-Domain Discovery Protocol is aborted, and an Inter-Domain UUID Request Packet is later received, the recipient shall respond with an Inter-Domain UUID Response Packet. The recipient shall also issue an Inter-Domain UUID Request Packet to the peer in order to restart Inter-Domain Discovery.

During identification of an Inter-Domain Link each Connection Manager receives the 128-bit UUID value of the peer-Domain Connection Manager which can be used for unambiguous Domain identification.

3.2 Discovery of Peer Host Properties

Each Connection Manager sends an Inter-Domain Properties Read Request Packet and the receiver shall respond with an Inter-Domain Properties Read Response Packet. The Inter-Domain Properties Read Response Packet contains its Inter-Domain Properties Block (see Section 4.3 for the structure of the Properties Block).

If the Connection Manager does not receive an Inter-Domain Properties Read Response Packet within 1 second, it shall resend the request ten times, each time waiting for 1 second for a response. If no response is received, the Local Connection manager shall abort the Inter-Domain Discovery Protocol.

If the response does not contain the entire Properties Block (evident by comparing the *Data Size* field in the Inter-Domain Packet Header to the *Properties Block Size* field), the requester may ask for the next section of the Properties Block by issuing another Inter-Domain Properties Read Request Packet with the *offset* field advanced.

When the Properties Block is transferred using more than one Inter-Domain Properties Read Response Packet, all Inter-Domain Properties Read Response Packets but the last shall be maximum-length USB4 Packets.

When the Properties Block is transferred using more than one Inter-Domain Properties Read Response Packet, the receiving peer shall monitor the value of the *Properties Block Generation* field in successive Inter-Domain Properties Read Response Packets. If the value changes between successive Packets, the Connection manager shall read the Properties Block again from start.

3.3 Discover Change in Inter-Domain Capabilities

If a host's capabilities change (such as adding or removing new services) it shall inform any Inter-Domain peers by sending an Inter-Domain Properties Changed Notification Packet. Peers shall respond using an Inter-Domain Properties Changed Response Packet. The peer shall send an Inter-Domain Properties Read Request Packet. The Connection Manager in the host that sent Inter-Domain Properties Changed Notification Packet responds with an Inter-Domain Properties Read Response as defined in Section 3.2. The Connection Manager shall increment the value in the *Properties Block Generation* field to indicate that the Properties Block has changed.

If the Connection Manager does not receive an Inter-Domain Properties Changed Response Packet within 1 second, it shall resend the request ten times, each time waiting for 1 second for a response.

A host that sends or receives an Inter-Domain Properties Changed Notification Packet shall terminate any existing services with the Domain not included in the updated Properties Block.

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A host that sends or receives an Inter-Domain Properties Changed Notification Packet shall establish new services with the Domain included in the updated Properties Block.

If a change in the Properties Block includes a change in the Inter-Domain Time Sync Entry, then the Connection Managers shall execute the flow defined in Section 3.5.3.

3.4 Link Management

3.4.1 Gen 2 or Gen 3 speed

An Inter-Domain Link shall operate in either Single Lane or Symmetric mode. If both Inter-Domain peers support Lane Bonding, this configuration shall be negotiated.

The Connection Manager of each host shall do the following:

- Exit Lane Bonding if the *Supported Link Width* field of the local Port facing the Inter-Domain Link is set to x1.
- Exit Lane Bonding if the Inter-Domain Link operated previously as a single-Lane Link, and the Connection Manager wishes to maintain the previous Link state.
- The Local Connection Manager shall issue a Link State Status Request Packet to its peer Domain. If the Connection Manager does not receive an Inter-Domain Link State Status Response Packet within 1 second, it shall resend the request ten times, each time waiting for 1 second for a response. If no response is received, the Local Connection manager shall exit Lane Bonding. Note that the peer Connection Manager may delay a response due to its current workload.
- Exit Lane Bonding if the *Supported Link Width* field received in the Link State Status Response Packet is set to x1.
- Compare the Local Domain's Inter-Domain UUID to the Remote Domain's Inter-Domain UUID. UUIDs are compared in canonical form, one byte at a time, starting from left to right. For example, a UUID of 44444444-AAAA-BBBB-444444444444 is larger than a UUID of 44334444-AAAA-BBBB-444444554444.
- The Local Domain that has a higher UUID shall:
    - Upon receiving a Link State Change Request Packet with the *Target Link Width* field set to 0x3, and if Lane Bonding is supported by the Port facing the Inter-Domain Link, set the *Target Link Width* field in both Lane Adapters of the Port to 0x3.
    - Upon receiving a Link State Status Request Packet, a Ver. 2 Connection Manager shall respond with "Not Ready" status if it has not updated its *Target Link Width* field yet. A Ver.1 Connection Manager which has not updated its *Target Link Width* field yet may respond with "Not Ready" status or respond with *Target Link Width* field set to 0x1.
    - Upon receiving a Hot Plug Event Packet with the UPG bit set to 1b, read Lane 0 Adapter's *Negotiated Link Width* field (bits 25:20 of register LANE_ADP_CS_1) to verify that Lane Bonding is successful. Alternatively, poll the Lane 0 Adapter's *Negotiated Link Width* field for three seconds to wait for bonding to complete.
    - If bonding does not complete, assume single-Lane operation.
    - Exit Lane Bonding.
- The Local Domain that has a lower UUID shall:
    - Issue a Link State Change Request Packet with *Target Link Width* field set to 0x3. If the Connection Manager does not receive an Inter-Domain Link State Change Response Packet within 1 second, it shall resend the request ten times, each time waiting for 1 second for a response. If no response is received, the Local Connection manager shall abort Lane Bonding.

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- Issue a Link State Status Request. If a response is not received within 1 second or is received with a "Not Ready" status, or the *Target Link Width* field is set to 0x1, resend the request up to ten times, each time waiting for 1 second for a response. If the response for the final Link State Status Request is an error response, or the *Target Link Width* field set to 0x1, or if no response is received, the Local Connection manager shall abort Lane Bonding.

- Set the Local *Target Link Width* field (bits 9:4 of register LANE_ADP_CS_1) to the maximum allowed value for both the Lane 0 and Lane 1 Adapters.

- Set the *Lane Bonding* bit (bit 15 in register LANE_ADP_CS_1) on either Lane Adapter to initiate Lane Bonding. Wait for the Lane 0 to reach CL0 state.

- Upon receiving a Hot Plug Event Packet with the UPG bit set to 1b, read Lane 0 Adapter's *Negotiated Link Width* field (bits 25:20 of register LANE_ADP_CS_1) to verify that Lane Bonding is successful. Alternatively, poll the Local Lane 0 Adapter's *Negotiated Link Width* field for *USB4.tBonding* to confirm the change.

If Lane Bonding fails, a Connection Manager shall disable Lane 1 as described in the Section 4.2.2 of the USB4 Specification.

An example flow is given in Appendix A.

3.4.2 Gen 4 Speed

An Inter-Domain Link may come up as either Symmetric or Asymmetric.

The Connection Manager may transition the Inter-Domain Link from Asymmetric to Symmetric by setting the *Target Asymmetric Link* field to 00b in the Lane Adapter Configuration Capability of the Port adjacent to the Inter-Domain Link and causing Link Initialization.

The Connection Manager shall not initiate a transition to Asymmetric operation on an Inter-Domain Link.

3.5 Time Synchronization

Support for Time Synchronization over an Inter-Domain Link is optional. If Time Sync is supported over Inter-Domain Links, the Connection Manager shall implement the requirements in this section, an Inter-Domain Time Sync Entry in the Properties Block (see Section 4.3.4.3.1), and the exchange of Inter-Domain Time Sync Packets (see Section 2.12).

A Connection Manager that does not support Time Sync over Inter-Domain Links shall ignore the Inter-Domain Time Sync Entry in the Properties Block of its partner.

The rest of this section applies to a Connection Manager that support Time Sync over Inter-Domain Links.

The Connection Manager shall execute the following flow:

- If the Properties Block of the partner does not contain an Inter-Domain Time Sync Entry, then Time Sync shall be disabled on the Inter-Domain Link. The flow is aborted.

- If the Immediate Value field in the Inter-Domain Time Sync Entry of the partner's Properties Block has bit[0] set to 0b, then Time Sync shall be disabled on the Inter-Domain Link. The flow is aborted.

- Determine the Inter-Domain Time Source and the Inter-Domain Time Follower

    - If bits[2:1] in the Immediate Value field in the Inter-Domain Time Sync Entries of both Connection Managers are identical, then

        - If the value is 01b or 10b,

            - If the Connection Manager's UUID value is lower than that of the partner, then this Domain shall be the Inter-Domain Time Source.

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- Else, this Domain shall be the Inter-Domain Time Follower
    - See in Section 3.4 how to compare UUID values.
    - If the value is 11b, then Time Sync shall be disabled on the Inter-Domain Link. The flow is aborted.
  - Else,
    - If bits[2:1] in the Immediate Value field of the local Properties Block have a lower value than the partner's, then this Domain shall be the Inter-Domain Time Follower
    - Else, this Domain shall be the Inter-Domain Time Source.
- Determine the Time Sync mode to be used on the Inter-Domain Link
  - If bits[6:4] in the Immediate Value field in the Inter-Domain Time Sync Entry of any of the Connection Managers indicates a Ver. 1 Router, then a Bi-Directional HiFi mode shall be used.
  - Else, Enhanced Uni-Directional mode shall be used
    - If bit[3] in the Immediate Value field in the Inter-Domain Time Sync Entry of any of the Connection Managers requests Hifi mode, then Enhanced Uni-Directional Hifi mode shall be set.
    - Else, Enhanced Uni-Directional MedRes mode shall be set.
- The Inter-Domain Time Source shall send an Inter-Domain Time Sync Packet to its partner with Event field = "Local Time" and the Local Time field containing the local time at the Inter-Domain Time Source.
- Upon receiving the Inter-Domain Time Sync Packet, the Inter-Domain Time Follower shall,
  - Indicate to the Routers in the Domain that a Time Disruption Event is occurring.
  - Initiate a Post Time Mechanism in each Router and poll each Router till completed. See Section "Post Time Mechanism" in the USB4 Base Specification.
  - Once all Routers transition to source time using Time Posting, the Inter-Domain Time Follower shall send an Inter-Domain Time Sync Packet to its partner with Event field = "Follower Ready".
- Upon receiving the Inter-Domain Time Sync Packet, the Inter-Domain Time Source shall,
  - Set the Time Sync mode at the Port of the Inter-Domain Link.
  - Set the *Inter-Domain Time Responder* bit to 1b in the TMU Adapter Configuration Capability of the Downstream Port of the Inter-Domain Link.
  - Send an Inter-Domain Time Sync Packet to its partner with Event field = "Source Ready".
- Upon receiving the Inter-Domain Time Sync Packet, the Inter-Domain Time Follower shall,
  - Set the Time Sync mode at the Port of the Inter-Domain Link.
  - Set the *Inter-Domain Time Initiator* bit to 1b in the TMU Adapter Configuration Capability of the Downstream Port of the Inter-Domain Link
  - Set the *Inter-Domain Enable* bit to 1b in the TMU Router Configuration Capability of the Router Configuration Space of its Host Router

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  - Indicate to the Routers in the Domain that the Time Disruption Event has ended
  - Send an Inter-Domain Time Sync Packet to its partner with Event field = "Follower Enabled".
- The flow is now complete.

3.5.1 Disruption Events

A Time Sync disruption at the Domain that is the Inter-Domain Time Source is propagated to the Domain that is the Inter-Domain Time Follower.

The Connection Managers shall execute the following flow:

- The Inter-Domain Time Source sends an Inter-Domain Time Sync Packet to its partner with Event field = "Disruption".
- Upon receiving the Inter-Domain Time Sync Packet, the Inter-Domain Time Follower shall,
  - Indicate to the Routers in the Domain that a Time Disruption Event is occurring
  - Send an Inter-Domain Time Sync Packet to its partner with Event field = "Follower Ready".
- Upon receiving the Inter-Domain Time Sync Packet, the Inter-Domain Time Source shall,
  - Handle the disruption event
  - Send an Inter-Domain Time Sync Packet to its partner with Event field = "Source Ready".
- Upon receiving the Inter-Domain Time Sync Packet, the Inter-Domain Time Follower shall,
  - Indicate to the Routers in the Domain that the Time Disruption Event has ended
  - Send an Inter-Domain Time Sync Packet to its partner with Event field = "Follower Enabled".
- The flow is complete.

3.5.2 Disconnect of the Inter-Domain Link

If Inter Domain Time Sync is active when an Inter-Domain Link is disconnected, then the Connection Managers shall go through the following flow:

Inter-Domain Time Source:

- Set the *Inter-Domain Time Responder* bit to 0b in the TMU Adapter Configuration Capability of the Downstream Port of the Inter-Domain Link.

Inter-Domain Time Follower:

- Set the *Time Disruption* bit to 1b in the TMU Router Configuration Capability of all Routers in the Domain
- Set the *Inter-Domain Enable* bit to 0b in the TMU Router Configuration Capability of the Router Configuration Space of the Host Router
- Set the *Inter-Domain Time Initiator* bit to 0b in the TMU Adapter Configuration Capability of the Downstream Port of the Inter-Domain Link
- Wait for at least 100 milliseconds

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- Set the *Time Disruption* bit to 0b in the TMU Router Configuration Capability of all Routers in the Domain

3.5.3 Change in Time Sync setting

If a change in the Properties Block includes a change in the Inter-Domain Time Sync Entry, then the Connection Managers shall execute the following flow after the Connection Managers complete the exchange of Properties Block information:

- Each Connection Manager shall recalculate whether Inter-Domain Time Sync shall be enabled.
- If Inter-Domain Time Sync shall be enabled, then the Connection Manager shall recalculate the identity of the Inter-Domain Time Source and the Inter-Domain Time Follower
- If Inter-Domain Time Sync shall be enabled, then the Connection Manager shall recalculate the Time Sync accuracy required on the Inter-Domain Link
- If there is no change in any of the above, the flow is complete
- If Inter-Domain Time Sync was previously enabled and the new decision is to disable it, then the Connection Manager shall go through the flow defined in Section 3.5.2.
- Else, if Inter-Domain Time Sync was previously disabled and the new decision is to enable it, then the Connection Manager shall go through the enabling flow defined earlier in this section.
- Else, if the role of Inter-Domain Time Source and the Inter-Domain Time Follower changes, then the Connection Manager shall go through the flow defined in Section 3.5.2, followed by the enabling flow defined earlier in this section.
- Else, if the accuracy required on the Inter-Domain Link changes, then the Connection Manager shall go through the Disruption flow defined in Section 3.5.2.

3.6 Inter-Domain Error Recovery

If a Discovery Protocol packet is received with an unknown or reserved *Packet Type* field, the packet shall be discarded, and the receiver shall respond with an Error Response Packet containing an *Error Response* field set to “Unknown Packet Type”.

If a Connection Manager receives an Inter-Domain UUID Request Packet on Lane 1 of the Inter-Domain Link, it shall respond to the Packet, ignore it, or respond with an Error Response Packet containing an *Error Response* field set to “Not Supported”.

If a Connection Manager receives a Link State Status Request Packet, it shall respond as soon as possible with the request values. However, if the necessary resources are unavailable, a Ver.2 Connection Manager shall respond with the “Not Ready” status, while a Ver. 1 Connection Manager may repond according to section 3.4.1.

If a Connection Manager receives a Link State Change Request Packet, it shall service it as soon as possible by setting the requested values to each local Port of the Inter-Domain Link. However, if the necessary resources are unavailable, the Connection Manager may respond with the “Not Ready” status.

If an Error Response Packet is received, the receiver shall do the following depending on the *Error Response* field:

- *Not Ready*: Reissue the request up to ten times (one per second), and then fail the request if a proper response is not received.
- Unknown Packet Type: Fail the request

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3.7 Termination of Discovery Protocol

When an Inter-Domain Link is disconnected, and the Connection Manager receives a Hot Plug Event Packet with the UPG bit set to 1b from Lane 0 of the Port connected to the Inter-Domain Link, the Connection Manager shall terminate any Inter-Domain Services running with the disconnected Domain. It shall also initialize its Discovery Protocol state with the disconnected Domain.

If Inter Domain Time Sync is active when an Inter-Domain Link is disconnected, then the Connection Managers shall go through the flow defined in Section 3.5.2.

Before a Connection Manager transitions the Routers in its Domain to Sleep state, the Connection Manager shall terminate any Inter-Domain Services. It shall also initialize its Discovery Protocol state. When the Connection Manager in a neighbor Domain detects that the neighbor Domain enters Sleep state, the Connection Manager may initialize its Discovery Protocol state. When the Domain exits Sleep state, the Connection Manager in the neighbor Domain receives a Hot Plug Event Packet with the UPG bit set to 0b. The Connection Manager shall initialize its Discovery Protocol state, if it did not do it already. If Inter Domain Time Sync is active, then each Connection Manager shall also go through the flow defined in Section 3.5.2

When a Connection Manager receives a Properties Changed Notification Packet on an Inter-Domain Link with a *Source UUID* field that is different from the *Source UUID* value established with the neighbor Domain on this Inter-Domain Link, the Connection Manager shall terminate any Inter-Domain Services running with the disconnected Domain. It shall also initialize its Discovery Protocol state with the disconnected Domain. The Connection Manager shall then start the Discovery Protocol with the neighbor Domain.

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4 Inter-Domain Properties

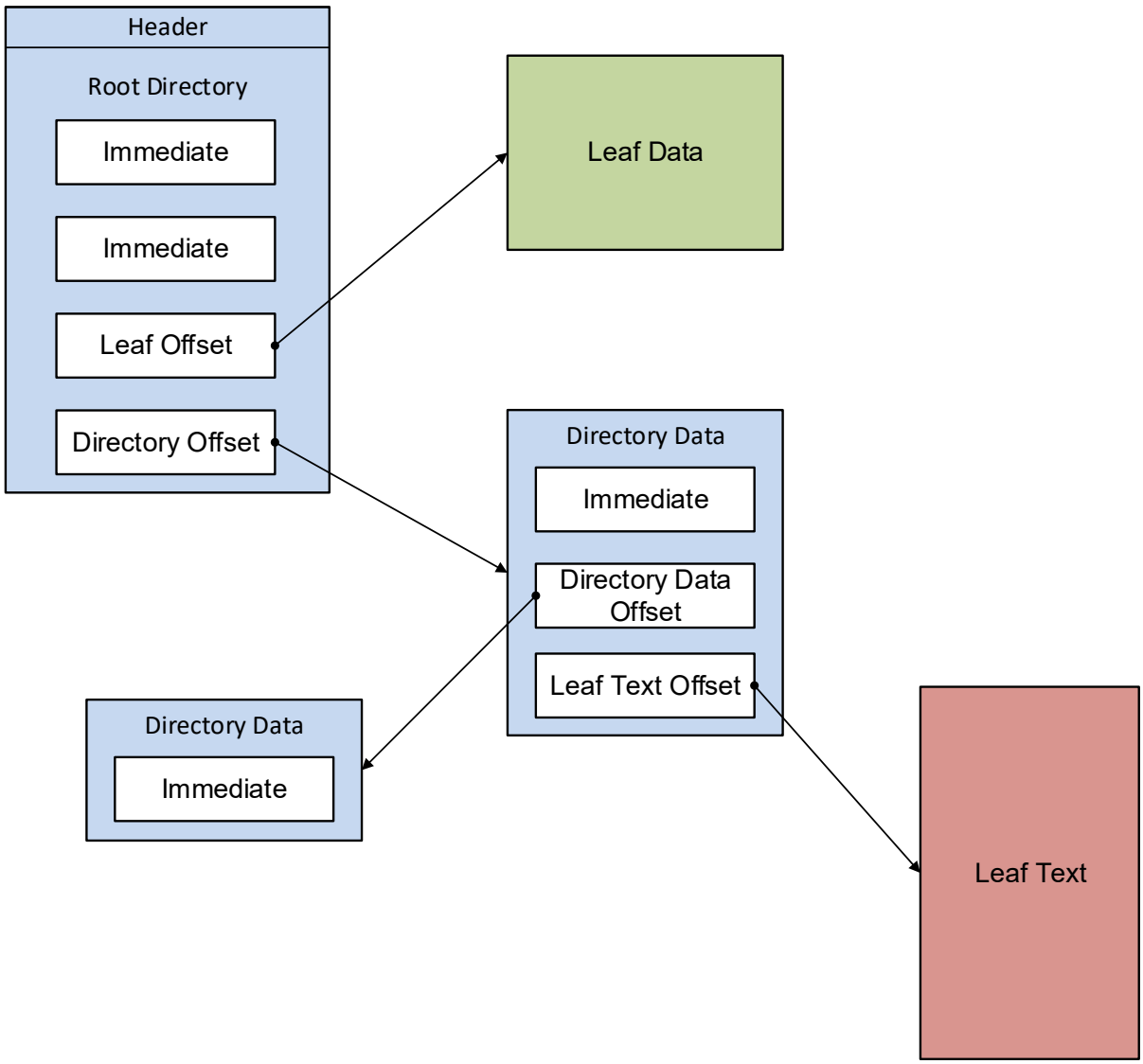
This section defines the data structures and format of the Properties Block that describes a host's Inter-Domain properties. The Properties Block is transmitted in response to receiving an Inter-Domain Properties Read Request Packet.

The Properties Block shall be transmitted to a peer USB4 Host in response to a request for properties and shall include the size of the entire Properties Block, even if it has been spilt among various packet payloads.

Refer to Section 3.2 for more information on how to split the Properties Block.

This format is comprised of a Root Directory that provides basic identification information as well as optional Entries. These Entries may contain data or point to another Entry within the Properties Block.

Figure 4-1. Illustration of Typical Properties Block



4.1 Bit, byte, and DWORD ordering

Data structures defined in Section 4.3 appear in the order these are present within an Inter-Domain Properties Read Response Packet. DWORDs are listed in increasing order. Bits within each DWORD are presented in the order within the Packet; bit[0] within a DWORD of the

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Properties Block resides in bit[0] in the respective DWORD in the Inter-Domain Properties Read Response Packet.

4.2 Reserved Values and Fields

The Connection Manager shall not write a field with a value that is marked as "Reserved". The Connection Manager shall set a field that is marked "Reserved" to zero.

The Connection Manager shall ignore any field in the partner's Properties Block that is marked "Reserved" in this specification.

The Connection Manager shall ignore any Entry in the partner's Properties Block with a Key value not defined in this specification.

4.3 Properties Block Contents

4.3.1 Properties Block Header

Each Properties Block shall begin with two required DWORDs, "Version" and a "Required Fixed Value" first and "Root Directory Length" second.

Figure 4-2. Properties Block Header Format

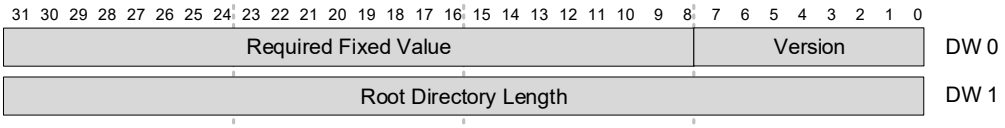


Table 4-1. Properties Block Header Fields

DW	Bits	Description
0	7:0	**Version** – This field shall be set to 0x01 for implementations conformant to this specification.
0	31:8	**Required Fixed Value**[2] – This field shall be set to 0x555844 for backwards compatibility reasons.
1	31:0	**Root Directory Length** – The length in DWORDs of the Root Directory contents. This length does not include DW0 and DW1.

The required fields are described in subsequent sections.

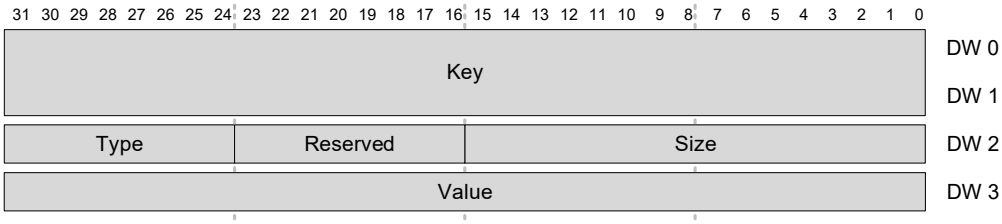
These fields, along with the required Entries described (See Section **Error! Reference source n ot found.**), are required within the Properties Block even if no optional properties Entries are added.

The hierarchical organization of the Properties Block is based upon a key-value paired Entry. Each key-value pair represents an elemental Entry such as a directory, a pointer (offset), or a value. This section specifies the format of these building blocks; their required usage is described later in this specification.

4.3.2 Generic Key-Value Entry format

Each Entry shall have the format shown in Figure 4-3.

Figure 4-3. Generic Key-Value Entry Format



[2] Historical Tidbit: This converts to 'UXD' which stood for "USB Cross Domain"

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Table 4-2. Generic Key-Value Entry Fields

DW	Bits	Description
1:0	31:0	**Key** – A 64-bit value representing the Entry. The key shall relate to an 8-character ASCII code description of the Entry. For instance, 0x76656E646F726964 relates to 'vendorid'. This value shall not be NULL terminated. 0x0 - 0xFFFFFFFFFFFF0000: Reserved for use by this specification. See Table 4-8 for a list of defined keys. 0xFFFFFFFFFFFF0001 - 0xFFFFFFFFFFFFFFFF: Vendor defined keys, see the Section 4.3.5.
2	15:0	**Size** – The size of the value in regard to *Type* field - defined in more detail in the following sections.
2	23:16	**Reserved**
2	31:24	**Type** – A defined 8-bit value that specifies the version of the Entry. Defined types include: Value: Type of Entry 0x00: Reserved 0x64 ('d'): Leaf Data Offset 0x74 ('t'): Leaf Text Offset 0x76 ('v'): Immediate Value 0x44 ('D'): Directory Data Offset 0x80 – 0xFF: Reserved for vendor-defined Types. See Section 4.3.5.1.

4.3.2.1 Immediate Value Entry format

All Immediate Value Entries shall have the format shown in Figure 4-4.

Figure 4-4. Immediate Value Entry Format

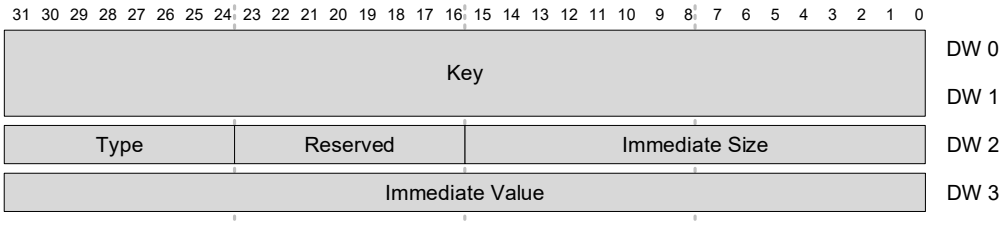

Table 4-3. Immediate Value Entry Fields

DW	Bits	Description
2	15:0	**Immediate Size** – Shall be set to 1.
2	31:24	**Type** – Immediate Value Entries shall use the type 0x76 ('v').
3	31:0	**Immediate Value** – A 32-bit value.

An Immediate Value Entry describes a scalar value of 32 bits or less. Interpretation of the value is defined per set of *Key* + *Type* fields.

4.3.2.2 Leaf Data Offset Entry format

All Leaf Data Offset Entries shall have the format shown in Figure 4-5.

Figure 4-5. Leaf Data Offset Entry Format

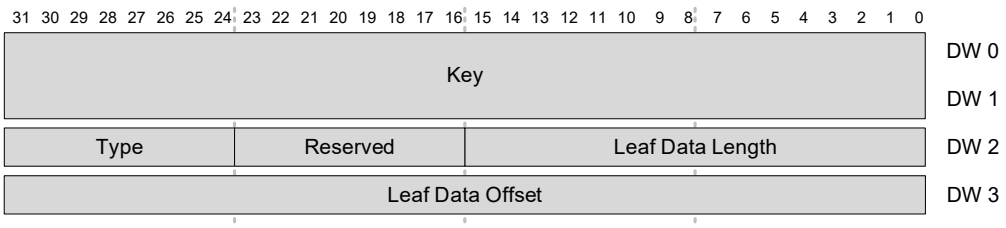

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Table 4-4. Leaf Data Offset Entry Fields

DW	Bits	Description
2	15:0	**Leaf Data Length** – The number of DWORDs of leaf data which is pointed to by the leaf data offset.
2	31:24	**Type** – Leaf Data Offset Entries shall use the type 0x64 ('d').
3	31:0	**Leaf Data Offset** – The number of DWORDs from the start of the Properties Block (absolute offset) to a Leaf Data Entry that contains data of length specified by the *Leaf Data Length* field. The structure of the corresponding Leaf Data Entry is defined by the *Key* + *Type* fields.

4.3.2.3 Leaf Text Offset Entry format

All Leaf Text Offset Entries shall have the format shown in Figure 4-6.

Figure 4-6. Leaf Text Offset Entry Format

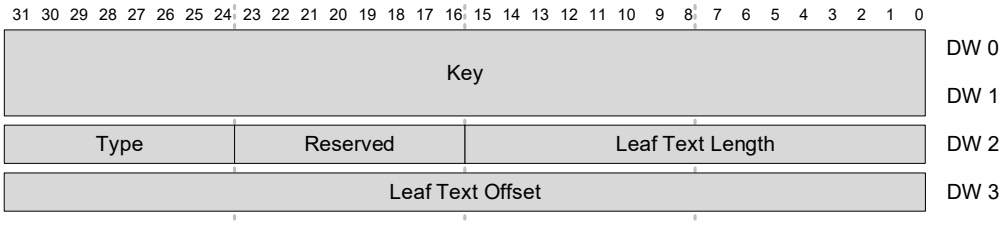

Table 4-5. Leaf Text Offset Entry Fields

DW	Bits	Description
2	15:0	**Leaf Text Length** – The number of DWORDs of leaf data which is pointed to by the leaf text offset.
2	31:24	**Type** – Leaf Text Offset Entries shall use the type 0x74 ('t').
3	31:0	**Leaf Text Offset** – The number of DWORDs from the start of the Properties Block (absolute offset) to the data that contains UTF-8 encoded text data of length specified by the *Leaf Text Length* field. Text data is required to be NULL terminated and zero padded to the next DWORD boundary. Interpretation of corresponding Leaf Text Entry is defined by the *Key* + *Type* fields.

4.3.2.4 Directory Data Offset Entry format

All Directory Data Offset Entries shall have the format shown in Figure 4-7.

Figure 4-7. Directory Data Offset Entry Format

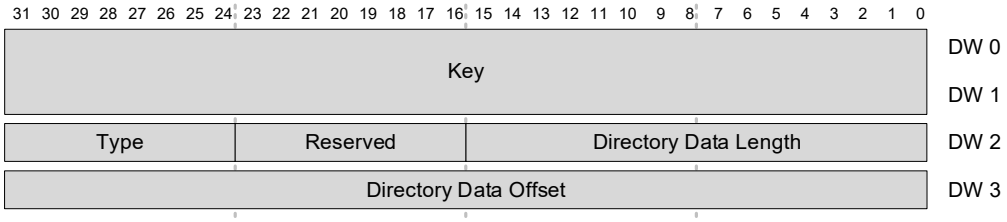

Table 4-6. Directory Data Offset Entry Fields

DW	Bits	Description
2	15:0	**Directory Data Length** – The number of DWORDs of directory content which is pointed to by the *Directory Data Offset* field. This length shall include the length of the directory UUID and Directory Data (see Figure 4-8), but not any data which is pointed to by an offset Entry within the directory referenced.
2	31:24	**Type** – Directory Data Offset Entries shall use the type 0x44 ('D').
3	31:0	**Directory Data Offset** – An offset from the start of the Properties Block that contains a directory, the size of its contents specified by the *Directory Data Length* field.

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4.3.3 Directory Data Entry format

All Directory Data Entries shall have the format shown in Figure 4-8.

Figure 4-8. Directory Data Entry Format

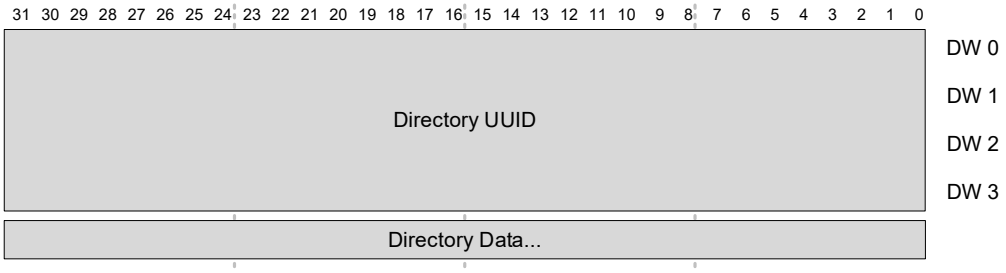

Table 4-7. Directory Data Entry Fields

DW	Bits	Description
3:0	31:0	**Directory UUID** – A 128 bit universally unique ID to identify the directory (Refer to ISO/IEC 9834-8:2014). This entry identifies a specific instance of a service. It can be used to tear down the service by removing the entry from the Properties Block and sending an Inter-Domain Properties Changed Notification Packet to the neighbor Connection Manager.
4	31:0	**Directory Data** – A directory that contains Entries and its size defined by its corresponding "Directory Data Length" minus the directory's UUID length.

Directory Data shall be contiguous (one Entry after another) and may begin at an offset after the preceding Entry.

A Directory Data Entry may include Immediate Value Entries, Leaf Data Offset Entries, Leaf Text Offset Entries, and Directory Data Offset Entries.

The Root Directory is defined as a standard Directory Data Entry except that it contains a Root Directory header (*Version* and *Root Directory Length* fields), instead of a *Directory UUID* header.

4.3.4 Defined Entries

Offsets within Entries are not required to point to offsets in succession as they are ordered in the Properties Block.

4.3.4.1 Defined Keys

Table 4-8. Directory Key values

Key	ASCII Conversion	Description
0x76656E646F726964	vendorid	Vendor ID - An Entry that identifies the vendor of the Local Connection Manager software.
0x6465766963656964	deviceid	Device ID – A vendor specific Entry that further identifies the Local Connection Manager software.
0x6465766963657276	devicerv	Device Revision - A vendor-specific Entry that identifies the revision of the Local Connection Manager software.
0x6D6178686F706964	maxhopid	Max HopID - An Entry that describes the maximum input HopID supported for an Inter-Domain connection.
0x74696D6573796E63	timesync	Time Sync – An Entry that defined Time Sync behavior. see Section 4.3.4.3.1
0x7072746369640000	prtcid	An Entry that identifies the protocol described by the directory. Decoding of this entry are specific to each Directory UUID value.
0x7072746376657273	prtcvers	An Entry that identifies the version of the protocol described by the directory. Decoding of this entry are specific to each Directory UUID value.

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Key	ASCII Conversion	Description
0x7072746373746E73	prtcstns	An Entry that describes the settings of the software or hardware controlling the protocol described by the directory. May be useful as a bitmask. Decoding of this entry are specific to each Directory UUID value.
0x7072746372657673	prtcrevs	A vendor-specific Entry that identifies the revision of the software controlling the protocol described by the directory. Decoding of this entry are specific to each Directory UUID value.
0x6e6574776f726b00	network	A Directory Data Offset that points to a Directory Data Entry that contains information for Ethernet over USB4 protocol (USB4NET).
0x746172676574646D	targetdm	Reserved for future use.
0x6578746469737000	extdisp	Reserved for future use.
0x6175746873757000	authsup	Reserved for future use.

4.3.4.2 Required Entries

Each Properties Block is required to include the following Entries within the Root Directory:

- Vendor ID: An Immediate Value Entry with the key 'vendorid', which contains LS bits of the *Immediate Value* field a 16-bit organizationally unique number that identifies the implementor of the Local Connection Manager. The USBIF is the registration authority and assigns these IDs.
- Device ID: An Immediate Value Entry with the key 'deviceid'. which identifies the Local Connection Manager software. This *Immediate Value* field is vendor defined.
- Max HopID: An Immediate Value Entry with the key 'maxhopid', which describes the maximum input HopID supported for an Inter-Domain connection. The LS bits of the *Immediate Value* field contain a 7-bit HopID value.

4.3.4.3 Optional Entries

4.3.4.3.1 Inter-Domain Time Sync (Immediate Value Entry)

The Properties Block shall include an Inter-Domain Time Sync entry if the Domain supports Inter-Domain Time Sync. Inclusion of this Entry is optional otherwise.

This is an Immediate Value Entry with the Key 'timesync'.

Table 4-9 defines the contents of the Immediate Value field.

Table 4-9. Decoding of 'timesync' Immediate Value field

Bit	Description
0	Indicates if the Domain supports Inter-Domain Time Sync 0b – Not supported 1b - Supported
1-2	Indicates whether this host may serve as a Time Sync Folllower 00b – Reserved 01b –Host may act as a Follower without affecting protocols currently tunelled in the Domain 10b – Host may act as a Follower with acceptable impact on protocols currently tunelled in the Domain. 11b – Domain does not support a Follower's role or impact on protocols currently tunelled in the Domain is not acceptable. If the *Inter-Domain Not Supported* bit in the Host Router is set to "Not Supported", then this field shall be set to 11b.
3	Request to enable Hifi mode when Link operates at Gen 4 speed. 0b – Connection Manager does not request Hifi mode 1b – Connection Manager requests Hifi mode

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Bit	Description
4-6	USB4 Version of the Router adjacent to the Inter-Domain Link. This field shall equal the *Major Version* sub-field of the *USB4 Version* field in the Router Configuration Space.
7-31	Reserved

4.3.5 Vendor defined keys

0xFFFFFFFFFFFF0000 - 0xFFFFFFFFFFFFFFFF may be used as vendor defined keys within the Root Directory. These keys will be decoded based upon the *vendorid* and *deviceid* values present within the Root Directory.

0xFFFFFFFFFFFF0000 - 0xFFFFFFFFFFFFFFFF may be used as Directory-Data-Entry-specific keys when used within Directory Data Entries. These keys are decoded based upon the Directory Data Entry which contains these Entries.

Vendors are free to define the contents of these Vendor Defined Entries but must conform to the generic Entry format. Furthermore, if a defined type is used with a vendor-defined key, adherence to the Entry format for that defined type is required.

4.3.5.1 Vendor defined types

Vendors may define their own Entry types within the range 0x80 - 0xFF. These custom Entries must conform with the generic Entry format, see Table 4-2.

4.3.6 Protecting against buffer overruns

The Properties Block is required to be transmitted with the full size of the Property Block data buffer. This size should be taken into consideration when using the offset vectors so that decoding software does not overstep the bounds of the buffer that contains the Properties Block data.

Keys and types may have human readable conversions; however, they are not required to be NULL terminated. Software shall be careful not to overrun a buffer containing a character representation of a key or type using the length of each Entry and not look for NULL terminations.

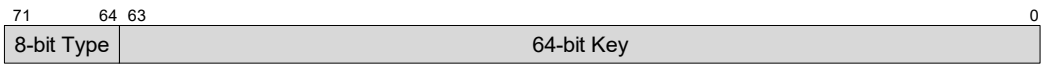
Leaf Text Entries are required to be NULL terminated, however, a string length is also provided so that software does not overrun this character buffer.

Leaf Data Entries and Directory Data Entries are provided with a size of the data which is referenced. This size is required to properly decode these structures.

4.3.7 Obtaining a one to one relationship between *Key* and Entry

The scope of a *Key* is within the Directory Entry that contains it. The same *Key* value may be used in different Directory Entries to identify different usages. Within one Directory Entry, a *Key* may be used multiple times, at most once with each *Type* field value. Therefore, when trying to establish a unique Entry ID within a Directory Entry, use a 72-bit ID by concatenating the *Type* and *Key* as shown in Figure 4-9.

Figure 4-9. Unique Directory Scope Entry ID



4.3.8 Discovery protocol layers

The Properties Block allows peer USB4 Domains to communicate to each other the basic service layers available above the USB4 native host interface layer. USB4 Inter-Domain Properties is designed to be a light-weight solution for the very simplest discovery of basic Inter-Domain protocols, but it does not prohibit more feature-rich solutions to be built on top of it.

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4.3.9 Sample Properties Block

Table 4-10. Sample Properties Block

Offset	Value	Decoding
00	555844 01	Version = 1
01	00000018	Root Directory length (the Root Directory has 24 DWs content)
02	76656e64	"vend" (this is an Immediate entry containing the Vendor ID value)
03	6f726964	"orid"
04	76 00 0001	Type = "v" Size=1
05	00000a27	Immediate value, Vendor ID
06	76656e64	"vend" (this is a Leaf Text Offset entry pointing to a text string describing the vendor)
07	6f726964	"orid"
08	74 00 0003	Type="t" Size=3
09	0000001a	Leaf Text Offset, (“Apple Inc.”)
0A	64657669	"devi" (this is an Immediate entry containing the Device ID value)
0B	63656964	"ceid"
0C	76 00 0001	Type="v" Size=1
0D	0000000a	Immediate value, Device ID
0E	64657669	"devi" (this is a Leaf Text Offset entry pointing to a text string describing the device)
0F	63656964	"ceid"
10	74 00 0003	Type="t" Size=3
11	0000001d	Leaf Text Offset, (“Macintosh”)
12	6D617868	"maxh" (this is an Immediate entry containing the maximum input HopID value)
13	6F706964	“opid”
14	76 00 0001	Type="v" Size=1
15	00000003	Max HopID value = 3
16	6e657477	"netw" (a Directory Data Offset to Directory Data of type “network”)
17	6f726b00	"ork"
18	44 00 0014	"D" R 20
19	00000021	Directory data offset, (Network Directory)
		(End of Root Directory)
1A	4170706c	"Appl" (A Leaf Text entry)
1B	6520496e	"e In"
1C	632e0000	"c."

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Offset	Value	Decoding
1D	4d616369	"Maci" (A Leaf Text entry)
1E	6e746f73	"ntos"
1F	68000000	"h"
20	00000000	Padding[3]
		Start of a Directory Data entry of type "network"
21	ca8961c6	Directory UUID, Network Directory
22	9541ce1c	Directory UUID, Network Directory
23	5949b8bd	Directory UUID, Network Directory
24	4f5a5f2e	Directory UUID, Network Directory
25	70727463	"prtc" (Immediate entry that identifies the protocol described by the directory)
26	69640000	"id"
27	76 00 0001	"v" R 1
28	00000001	Immediate value, Network Protocol ID
29	70727463	"prtc"
2A	76657273	"vers"
2B	76 00 0001	"v" R 1
2C	00000001	Immediate value, Network Protocol Version
2D	70727463	"prtc"
2E	72657673	"revs"
2F	76 00 0001	"v" R 1
30	00000001	Immediate value, device driver Revision
31	70727463	"prtc"
32	73746e73	"stns"
33	76 00 0001	"v" R 1
34	00000000	Immediate value, Network Protocol Settings

[3] This is not required, but illustrates that it is possible to do so

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5 Service Configuration

Once Service Discovery is completed, each Connection Manager is aware of its peer Domain's available Inter-Domain Services. To use a service, a protocol UUID and a protocol specific Login Packet is defined, which is used to initiate the configuration and establishment of USB4 Paths. Service drivers use their protocol UUID, encoded into each Inter-Domain packet, as a mechanism for determining which Inter-Domain packets are addressed to each service that has been configured. If a Connection Manager receives an Inter-Domain packet with a protocol UUID that it does not support, it shall ignore the packet.

A single instance of each supported Inter-Domain Service may be set between peer Connection Managers.

5.1 Ethernet over USB4 (USB4NET)

This section defines how to tunnel Ethernet traffic over USB4 (USB4NET).

5.1.1 Setup of a USB4NET Service

A USB4NET Inter-Domain Service may be established after both Connection managers include a proper 'network' Directory Data Entry in their Property Blocks. Each Connection Manager sends an Inter-Domain USB4NET Login Packet to the peer Domain. Upon receipt of an Inter-Domain USB4NET Login Packet, the peer Connection Manager shall send an Inter-Domain USB4NET Login Response Packet or an Error Response Packet. If the Connection Manager does not receive an Inter-Domain Login Response Packet, it shall resend the request for at least 1 minute or till a response is received. It is recommended that Inter-Domain USB4NET Login Packets are first sent frequently (e.g. every 100ms) and later at a reduced rate (e.g. every 1 second). If no response is received, the Local Connection manager shall abort the USB4NET login.

If a USB4NET login is aborted, and an Inter-Domain USB4NET Login Packet is later received, the recipient shall respond with an Inter-Domain USB4NET Login Response Packet. The recipient shall also issue an Inter-Domain USB4NET Login Packet to the peer in order to establish a USB4NET Service.

Once a successful Inter-Domain USB4NET Login Response Packet is transmitted, the Connection Manager may set and enable a Path from the Inter-Domain Link that is associated with the Packet to a Receive Descriptor Ring in the Host Router's Host Interface.

Upon reception of an Inter-Domain USB4NET Login Response Packet, a Connection Manager may set an outbound Path from a Transmit Descriptor Ring in the Host Interface Adapter of its Host Router to the Lane Adapter that has been identified as the Inter-Domain boundary.

The Connection Manager may delay setting the inbound and outbound Paths and enabling the respective Descriptor Rings till a successful Inter-Domain USB4NET Login Response Packet is transmitted and an Inter-Domain USB4NET Login Response Packet is received. At that time, the Connection Manager shall enable the Descriptor Rings and set both Paths, if it has not done so already.

5.1.2 Termination of a USB4NET Service

A Connection Manager may terminate a USB4NET Service by sending an Inter-Domain USB4NET Logout Packet to the peer Domain. This allows the peer Connection Manager the opportunity to cleanly terminate its service(s). The peer Connection Manager shall then respond with an Inter-Domain USB4NET Logout Response Packet. If the Connection Manager does not receive an Inter-Domain Logout Response Packet within 1 second, it shall resend the request ten times, each time waiting for 1 second for a response. If no response is received, it is assumed to have been received and shutdown proceeds.

Once a successful Inter-Domain USB4NET Logout Response Packet is transmitted, the responding Connection Manager shall tear down the Path and shall disable the Receive Descriptor Ring associated with the defunct login.

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Upon reception of an Inter-Domain USB4NET Logout Response Packet, a Connection Manager shall tear down the Path and shall disable the Transmit Descriptor Ring associated with the defunct login.

Should the USB4 Link, Paths, or USB4NET Service be terminated with traffic still pending transmission, all traffic not posted yet to a Transmit Descriptor Ring is failed back to the network stack, if appropriate, or dropped.

Before a Connection Manager transitions the Routers in its Domain to Sleep state, the Connection Manager shall terminate any USB4NET Services as described in this section.

5.1.3 Directory Data Entry

The Properties Block includes a USB4NET Directory Data Entry for USB4NET. A Directory Data Offset Entry in the Root Directory Entry points to the USB4NET Directory Data Entry.

A USB4NET Directory Data Entry contains the following:

- A Directory UUID with contents that are unique to this Directory Data Entry.
- An Immediate Value Entry of *Type* = prtcid with value = 0x1 (protocol is USB4NET)
- An Immediate Value Entry of *Type* = prtcvers

Table 5-1. Version of USB4NET Protocol (prtcvers)

Value	Decoding
0x1	Version of this specification
All other values	Reserved

- An Immediate Value Entry of *Type* = prtcstns. The Immediate Value field is a bit vector with contents described in Table 5-2

Table 5-2. Decoding of prtcstns Immediate Value field

Bit	Description
0	End-to-End (E2E) Flow Control is supported for USB4NET traffic. 0b – Not supported 1b - Supported It is recommended to support End-to-End Flow Control.
1	This host supports the USB4NET Frame format, including the *Frame ID* field 0b – Not supported 1b – Supported Shall be set to 1b.
2	This host supports segmentation of Ethernet frames with payload of up to 64KB into USB4 Frames. 0b –Host supports reception of up to 64KB Ethernet frames. It is recommended that host only sends Ethernet frames of up to 1500 bytes, but it may deliver Ethernet frames of up to 64KB. 1b – Host supports 64KB Ethernet frames on transmit and receive. See Section 5.1.5 for more details.
3-31	Reserved

5.1.4 USB4NET Packet Formats

This section defines the structure of the Control Packets used by peer Connections Managers for USB4NET service.

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A source of a USB4NET Packet shall not use a value in this specification that is marked as “Rsvd”.

A source of a USB4NET Packet shall set a field that is marked “Rsvd” to zero.

The target of a USB4NET packet shall drop a packet that has any of its defined fields set to a Rsvd value. If the packet is a USB4NET Response packet, then the target shall invalidate the USB4NET Request packet that corresponds to the USB4NET Response packet. The target may reissue the USB4NET Request packet.

The target of a USB4NET packet shall drop a packet that has any of its defined fields set to an illegal value. If the packet is a USB4NET Response packet, then the target shall invalidate the USB4NET Request packet that corresponds to the USB4NET Response packet. The target may reissue the USB4NET Request packet.

The target of a USB4NET packet shall ignore any fields that are marked “Rsvd” independent of the actual value received.

5.1.4.1 Inter-Domain USB4NET Packet

Figure 5-1 defines the structure of a generic Inter-Domain USB4NET Packet.

Figure 5-1. Inter-Domain USB4NET Packet Format

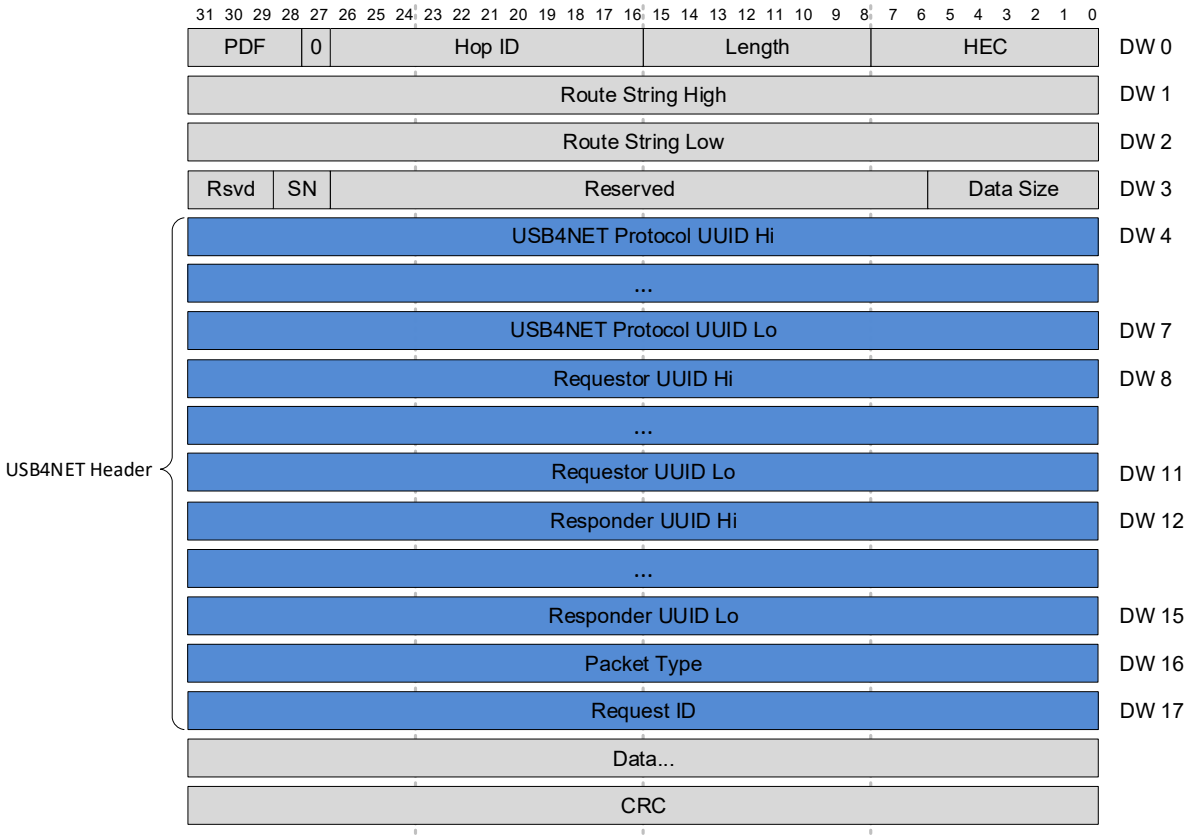

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Table 5-3. Inter-Domain USB4NET Packet Fields

<table>
<tr><th>DW</th><th>Bits</th><th>Description</th></tr>
<tr><td>0</td><td>31:0</td><td>Header – Transport Layer Packet header
<table>
<tr><th>Bits</th><th>Description</th></tr>
<tr><td>7:0</td><td>HEC - Header Error Control</td></tr>
<tr><td>15:8</td><td>Length - Payload size in bytes excluding the padding size</td></tr>
<tr><td>26:16</td><td>HopID – Shall be set to 000h</td></tr>
<tr><td>27</td><td>SuppID – Shall be set to 0</td></tr>
<tr><td>31:28</td><td>PDF - Shall be set to 6 or 7</td></tr>
</table></td></tr>
<tr><td>1</td><td>31:0</td><td>Route String High</td></tr>
<tr><td>2</td><td>31:0</td><td>Route String Low. See USB4.Table 6-1</td></tr>
<tr><td>3</td><td>5:0</td><td>Data Size –This field is used to indicate the number of doublewords in the Inter-Domain Packet Payload (IDPP) excluding the CRC.</td></tr>
<tr><td>3</td><td>28:27</td><td>SN – Sequence Number. Not used, a Connection Manager may assign any value.</td></tr>
<tr><td>4:7</td><td>31:0</td><td>USB4NET Protocol UUID – A 128 Bit UUID representing the USB4NET protocol, 798F589E-3616-8A47-97C6-5664A920C8DD
<table>
<tr><th>DWORD</th><th>Value</th></tr>
<tr><td>4</td><td>0x9E588F79</td></tr>
<tr><td>5</td><td>0x478A1636</td></tr>
<tr><td>6</td><td>0x6456C697</td></tr>
<tr><td>7</td><td>0xDDC820A9</td></tr>
</table></td></tr>
<tr><td>8:11</td><td>31:0</td><td>Requestor UUID – A 128 Bit UUID representing the Requestor’s Inter-Domain UUID</td></tr>
<tr><td>12:15</td><td>31:0</td><td>Responder UUID – A 128 Bit UUID representing the Responder’s Inter-Domain UUID</td></tr>
<tr><td>16</td><td>31:0</td><td>Packet Type– A USB4NET packet type, as defined by Table 5-4</td></tr>
<tr><td>17</td><td>31:0</td><td>Request ID– An incrementing, sequential 32-bit value used to match packet responses.
Shall be incremented per each Request Packet sent.
Shall be copied from each Request Packet to the same field in the Response Packet.</td></tr>
</table>

Table 5-4. Inter-Domain USB4NET Packet Types

Value	Name	Description
0	Login	Sent from the Requestor to the Responder. This packet requests a login of a USB4NET Service with the Responder.
1	Login Response	A response from the Responder to the Requestor of a Login.
2	Logout	Sent from the Requestor to cancel a USB4NET Service with the Responder.
3	Logout Response	A response from the Responder to the Requestor of a Logout.
All other values	Reserved	Reserved

5.1.4.2 Inter-Domain USB4NET Login Request Packet

Figure 5-2 defines the structure of an Inter-Domain USB4NET Login Request Packet.

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Figure 5-2. Inter-Domain USB4NET Login Request Packet Format

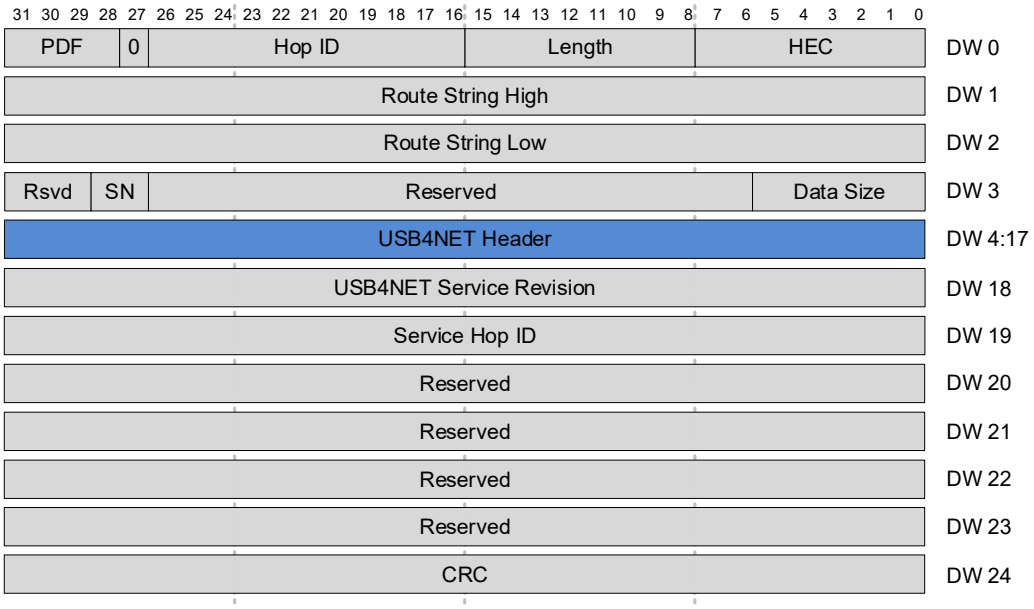

Table 5-5. Inter-Domain USB4NET Login Request Packet Fields

DW	Bits	Description
18	31:0	**USB4NET Service Revision** – A value representing the revision of the USB4NET Service protocol. Set to 1.
19	31:0	**Service Hop ID** – This is the HopID used by this service when transmitting packets from this domain to its peer domain. The Service Hop ID shall not exceed the value reported by the peer Domain in its Properties Block.

5.1.4.3 Inter-Domain USB4NET Login Response Packet

Figure 5-3 defines the structure of an Inter-Domain USB4NET Login Response Packet.

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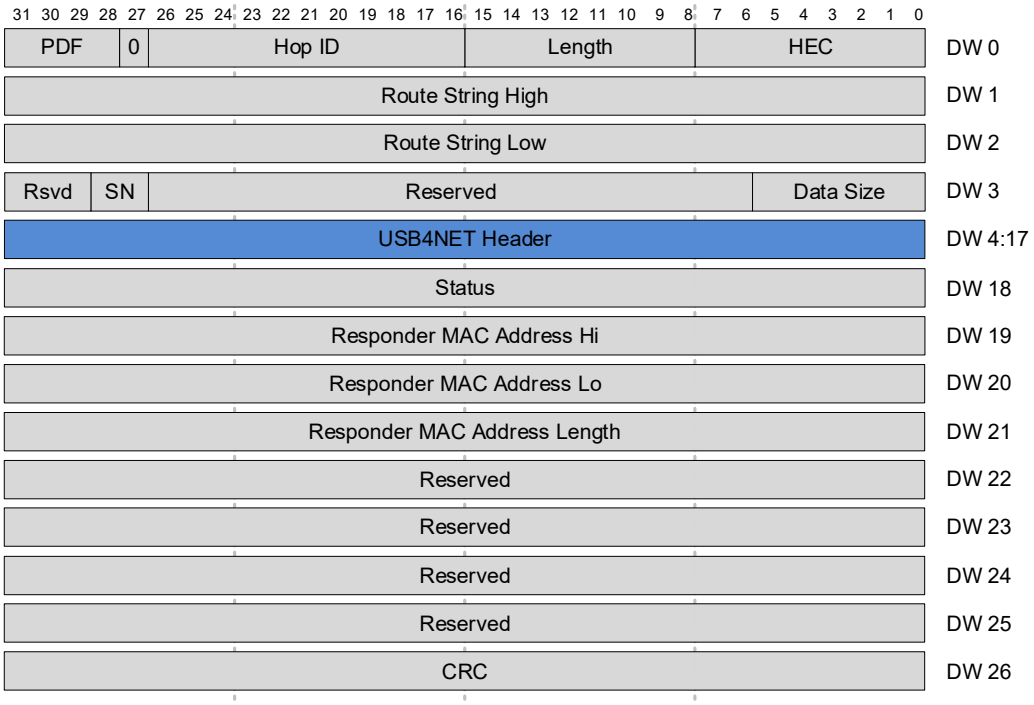
Figure 5-3. Inter-Domain USB4NET Login Response Packet Format



If the Responder already has a login with another Requestor or otherwise cannot process this request it shall return a failure indication in the Status field of the Inter-Domain USB4NET Login Response Packet.

Table 5-6. Inter-Domain USB4NET Login Response Packet Fields

DW	Bits	Description
18	31:0	**Status** Value: Meaning 0: Success 1 – 0x7FFFFFFFH: Reserved. Receiving any value in this range shall be considered a failure response to the corresponding USB4NET Login Request. 0x80000000H+: Vendor defined Failure
19:20	31:0	**Responder MAC Address** – The responder's MAC address. Responder MAC Address Hi is most significant 4 bytes of the responder's MAC address.
21	31:0	**Responder MAC Address Length** – The length, in bytes, of the responder's MAC address. Typically, 6.

5.1.4.4 Inter-Domain USB4NET Logout Request Packet

Figure 5-4 defines the structure of an Inter-Domain USB4NET Logout Request Packet.

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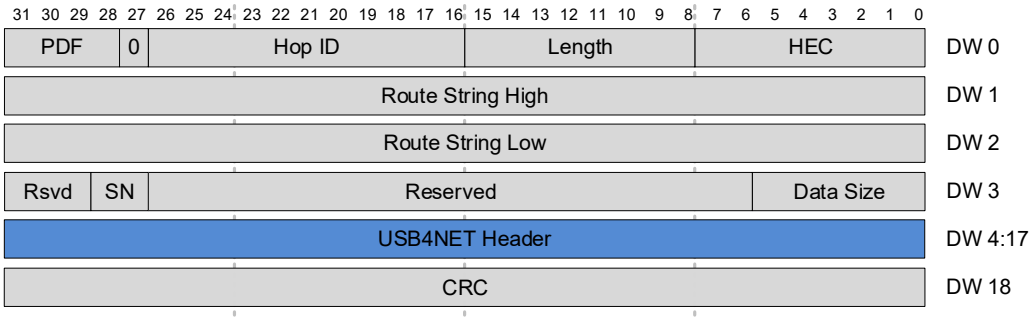
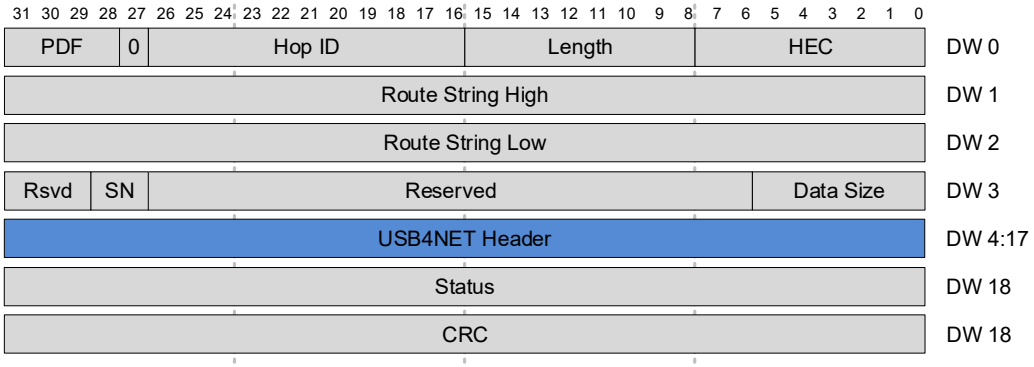
Figure 5-4. Inter-Domain USB4NET Logout Packet Format



5.1.4.5 Inter-Domain USB4NET Logout Response Packet

Figure 5-5 defines the structure of an Inter-Domain USB4NET Logout Response Packet.

Figure 5-5. Inter-Domain USB4NET Logout Response Packet Format



Refer to Table 5-6 for the definition of the *Status* field.

5.1.5 Tunneling Ethernet Packets over USB4

Once a Path has been established for USB4NET Service, Ethernet frames are tunneled across this Path. These frames are prepended with an USB4NET Frame header as described below.

Note: USB4NET does not directly handle any network packet retransmission. The network stack automatically attempts retransmission for any traffic (TCP packets) that is guaranteed delivery. For instance, TCP retransmits any TCP packet that fails or times out and USB4NET will dutifully (re)transmit it. UDP may not retransmit and its protocol is designed to accommodate this.

A Tunneled USB4NET Packet assigns a 1h value to the SoF field and a 2h value to the EoF field in the USB4 Packet Header. See the USB4 Specification for details on the SoF and EoF fields.

The USB4NET Frame Header shall be posted into a Data Buffer in host memory using Little Endian notation. Each field in the USB4NET Frame Header is posted such that the least-significant byte resides in the lowest-addressed byte in host memory.

The USB4NET Ethernet data shall be posted into a Data Buffer in host memory using Big Endian notation. An Ethernet frame depicted in Figure 5-6 in Ethernet network order is posted byte-wise from left to right, starting with the lowest-addressed byte in host memory.

5.1.5.1 Tunneling of Ethernet frames with up to 1500B of payload

A Connection Manager shall support transmitting and receiving Ethernet frames as described in this section.

Ethernet frames sent down from the network stack are packaged and pushed onto a Transmit Descriptor Ring, where they will be sent to the Inter-Domain peer. When a USB4 packet is

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received by the peer host, it is parsed, and the Ethernet frame is passed to the corresponding network stack.

Figure 5-6 depicts encapsulation of a single Ethernet frame into a USB4 Frame. The USB4 Frame starts with a 12-byte header defined in Table 5-7, followed by an Ethernet frame with up to 1518 bytes. Each Ethernet frame is encapsulated into a separate USB4 Frame.

Figure 5-6. Inter-Domain USB4NET Frame Format

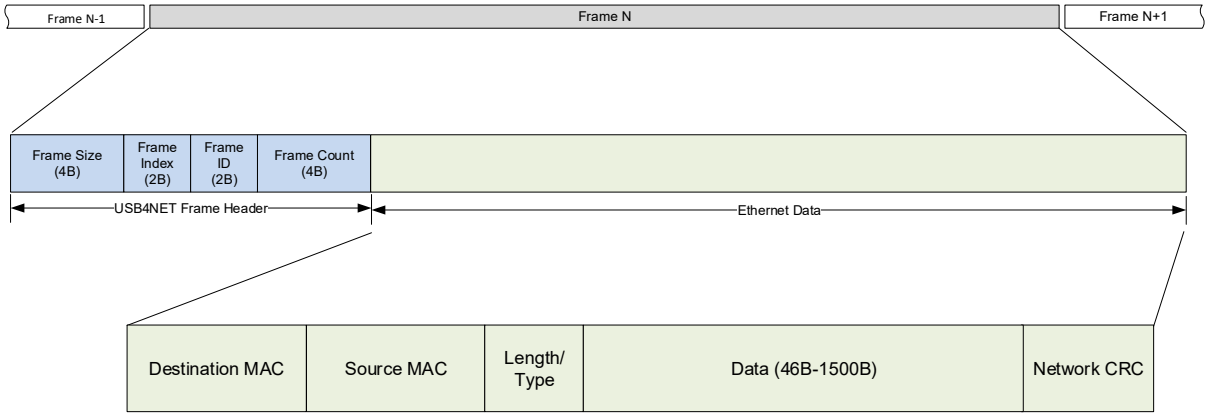

Table 5-7. Inter-Domain USB4NET Frame Format Fields

Field	Description
Frame Size (32 bits)	The length, in bytes, of the Ethernet Data portion of the frame.
Frame Index (16 bits)	The n-th frame of this network packet (zero based). Shall be set to 0.
Frame ID (16 bits)	A sequential ID to distinguish this frame from the previous and next. This field continuously increments by one each time a frame is sent (with wraparound to zero when it reaches 0xFFFF).
Frame Count (32 bits)	The total number of frames that are expected for this network packet. Shall be set to 1.

5.1.5.2 Tunneling of 64KB Ethernet Frames

A Connection Manager shall receive large Ethernet frames as described in this section. A Connection Manager may transmit large Ethernet frames as described in this section. However, if bit[2] in the *prtcstns* Immediate Value field (see Table 5-2) of the partner Connection Manager is set to 0b, it is recommended that the Connection Manager does not transmit large Ethernet frames.

USB4NET supports encapsulation of larger Ethernet frames with payloads of up to 64KB. As described in Figure 5-7, USB4NET software splits the large Ethernet frame into 4KB USB4 Frames (with a possible exception of the last USB4 Frame that may be shorter). Each 4KB Frame starts with a USB4NET Frame Header. The USB4 Frames are delivered to the Host Interface for transmission to the USB4 peer Domain.

The receiving Host Interface at the peer Domain delivers the received USB4 Frames to its USB4NET software. The receiving USB4 software reconstructs the original large Ethernet frame from the received USB4 Frames.

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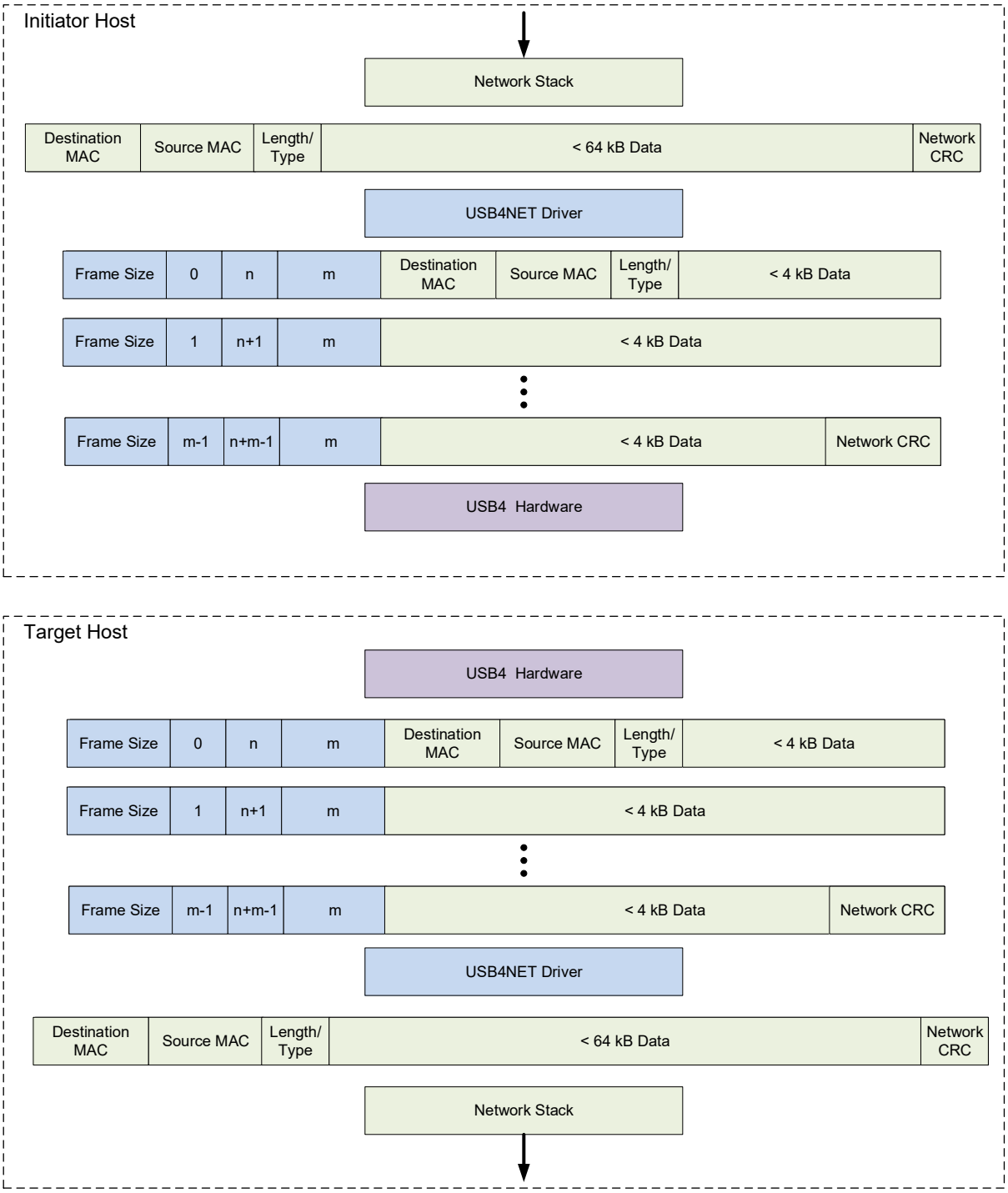
Figure 5-7. Encapsulation of 64KB Ethernet Frames



5.1.5.3 MAC Address

Higher level software running on each Host usually requires unique MAC Addresses to properly operate a Network stack. This section defines how the Local Connection Manager may generate one using the 64-bit *UUID* field in the Host Router's Router Configuration Space. The UUID is the basis for a MAC address-style identifier for USB4NET, being condensed to the appropriate size via the algorithm below.

```
uint32_t deviceID           = (UUID >> 4) & 0x0FFFFFFF;
uint16_t projectID_swapd    = bit_swap_16((UUID >> 32) & 0x0000FFFF);
```

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```
uint16_t authorityID_swapd  = bit_swap_16((UUID >> 48) & 0x0000FFFF);
bool multicast              = false;
bool locallyAdministered    = true;

MACAddress.bytes[5] =  ((deviceID << 4) & 0xF0) |
                       ((routerID << 2) & 0x0C) |
                       (USB4PortNumber & 0x03);
MACAddress.bytes[4] =  ((deviceID >> 4) & 0xFF);
MACAddress.bytes[3] =  ((deviceID >> 12) & 0xFF);
MACAddress.bytes[2] =  ((deviceID >> 20) & 0xFF) ^
                       ((authorityID_swapd >> 0) & 0x03);
MACAddress.bytes[1] =  ((authorityID_swapd >> 2) & 0xFF);
MACAddress.bytes[0] =  (((multicast ? 1 : 0) << 0)) |
                       ((locallyAdministered ? 1 : 0) << 1) |
                       ((authorityID_swapd >> 8) & 0xFC) ^
                       ((projectID_swapd) & 0xFC);
```

5.1.5.4 Flow Control

Each Connection Manager shall enable per-Link flow control over the inter-Domain Link. A Dedicated Flow Control scheme shall be used.

If End-to-End (E2E) flow control is supported by both peers (as reported in their Properties Blocks), then each Connection Manager shall enable End-to-End flow control in both Transmit and Receive Descriptor Rings.

5.1.6 Example USB4NET Inter-Domain Properties in the Properties Block

Table 5-8. Inter-Domain USB4NET in a Properties Block

Offset	Value	Decoding
		Start of a Directory Data Offset entry
16	6e657477	"netw"
17	6f726b00	"ork"
18	44 00 0014	"D" R 20
19	00000021	Directory data offset, (Network Directory)
		Start of a Directory Data entry
21	ca8961c6	Directory UUID, Network Directory
22	9541ce1c	Directory UUID, Network Directory
23	5949b8bd	Directory UUID, Network Directory
24	4f5a5f2e	Directory UUID, Network Directory
25	70727463	"prtc"
26	69640000	"id"
27	76 00 0001	"v" R 1
28	00000001	Immediate value, Network Protocol ID = 0x1 (USB4NET)
29	70727463	"prtc"
2A	76657273	"vers"
2B	76 00 0001	"v" R 1
2C	00000001	Immediate value, Network Protocol Version = 0x1
2D	70727463	"prtc"
2E	72657673	"revs"
2F	76 00 0001	"v" R 1

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Offset	Value	Decoding
30	00000001	Immediate value, USB4NET device driver Revision
31	70727463	"prtc"
32	73746e73	"stns"
33	76 00 0001	"v" R 1
34	00000003	Immediate value, Network Protocol Settings

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6 Interoperability with Thunderbolt™ 3 (TBT3) Systems

This chapter defines requirements for system software (operating system/BIOS/device driver) to be compatible with a neighbor TBT3 Connection Manager.

6.1 Discovery Packet Formats

6.1.1 Inter-Domain Packet Format

Table 6-1 defines Packet Types in addition to the ones defined in Table 2-2.

Table 6-1. Inter-Domain Packet Types

Value	Name	Description
1	TBT3 UUID Request	A request for another Domain's UUID and route string

6.1.2 Inter-Domain UUID Request Packet Format

An Inter-Domain UUID Request Packet contains a *Packet Type* field equal to either 1 or 12.

6.1.3 Inter-Domain UUID Response Packet Format

The Inter-Domain UUID Response Packet for an Inter-Domain UUID Request Packet with a *Packet Type* field equal to 1 shall not contain a *Source Route* field. DW 13 shall include the *CRC* field.

6.2 Service Discovery

6.2.1 Inter-Domain Discovery

If an Inter-Domain UUID Request Packet is received with a *Packet Type* field equal to 1, the recipient shall respond with an Inter-Domain UUID Response Packet with the structure defined in Section 6.1.3. Responding to Inter-Domain UUID Request Packets with a *Packet Type* field equal to 1 shall be independent of any responses sent for Inter-Domain UUID Request Packets with a *Packet Type* field equal to 12.

6.3 Service Configuration

6.3.1 Ethernet over USB4 (USB4NET)

6.3.1.1 Packet Types

6.3.1.1.1 Inter-Domain USB4NET Login Request Packet

Table 6-2. Inter-Domain USB4NET Login Request Packet Fields

DW	Bits	Description
19	31:0	**Service Hop ID** – This is the HopID used by this service when transmitting packets from this domain to its peer domain. The Service Hop ID shall not exceed the value reported by the peer Domain in its Properties Block. To support a TBT3-compatible neighbor Connection Manager, if the Properties Block read from the neighbor Connection Manager does not contain a maxhopid Entry, then the Router shall use HopID=15 for this service when transmitting packets from this domain to its peer domain.

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A Example Inter-Domain Bonding Flow

Figure A-1and Figure A-2 give an example flow of the Bonding Flow.

Figure A-1. Bonding Flow – Part I

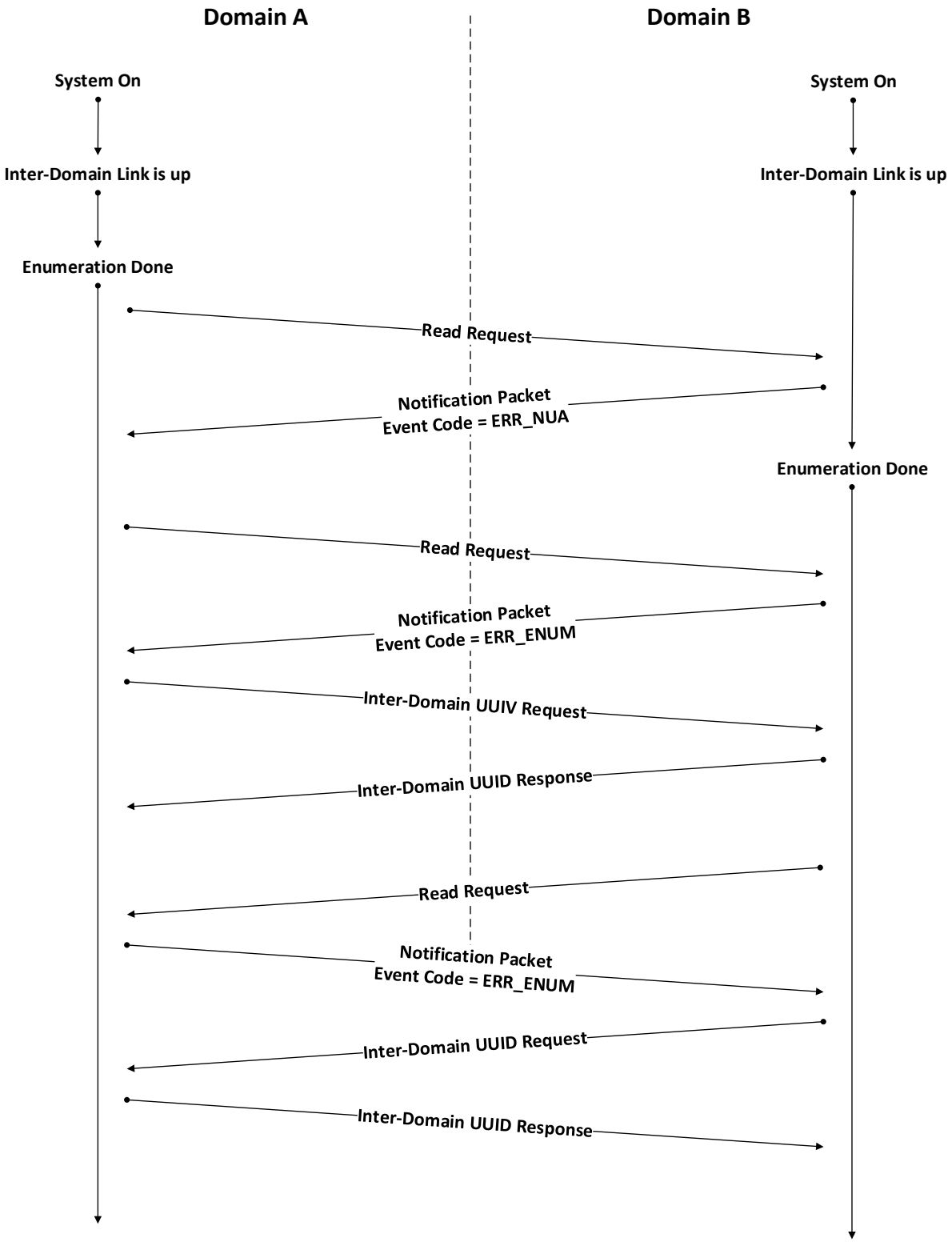

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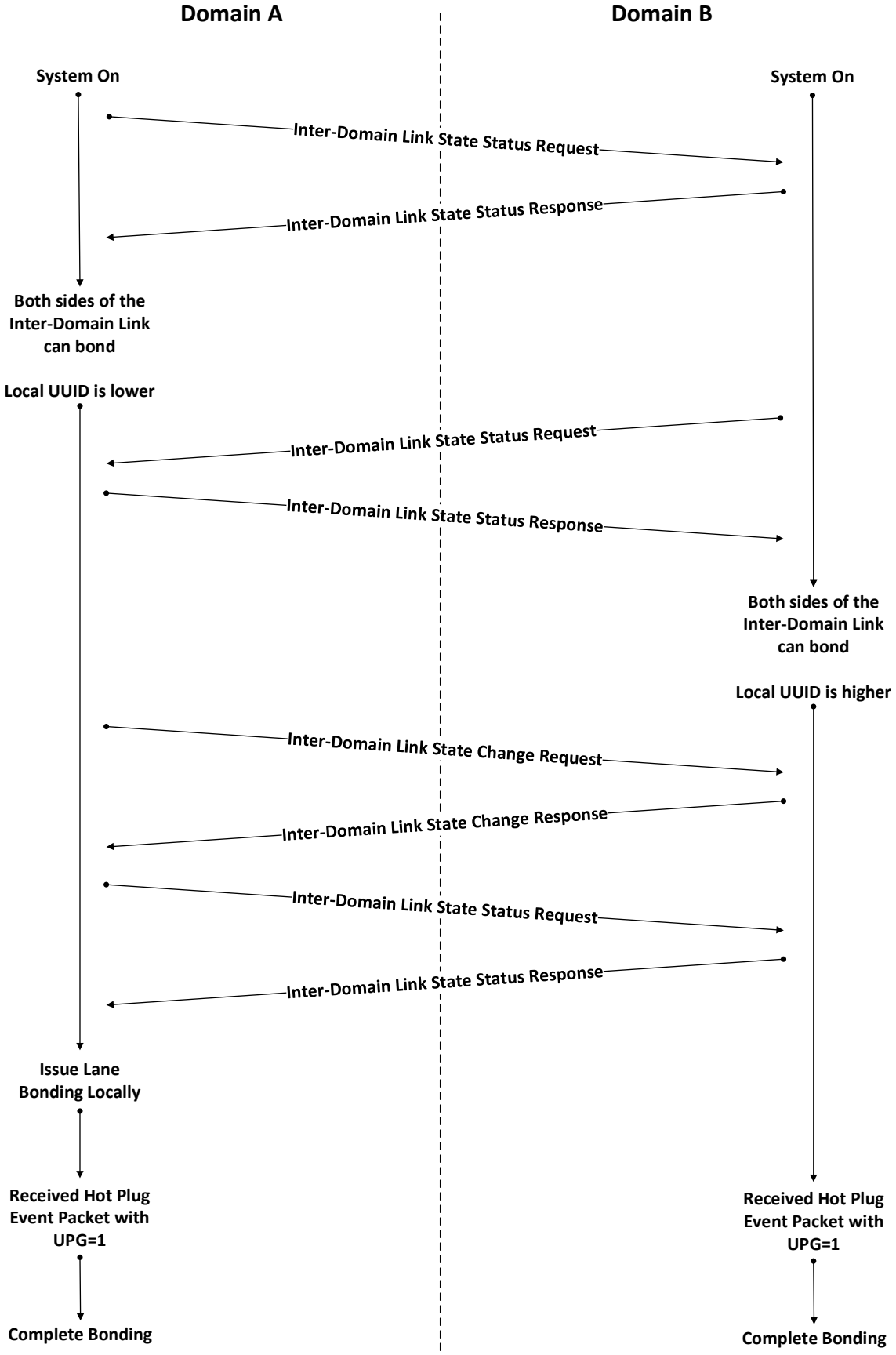
Figure A-2. Bonding Flow – Part II



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