

## Transmission of IPv6 Packets over Fibre Channel

### Status of this Memo

This document specifies an Internet standards track protocol for the Internet community, and requests discussion and suggestions for improvements. Please refer to the current edition of the "Internet Official Protocol Standards" (STD 1) for the standardization state and status of this protocol. Distribution of this memo is unlimited.

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### Abstract

This document specifies the way of encapsulating IPv6 packets over Fibre Channel, and the method of forming IPv6 link-local addresses and statelessly autoconfigured addresses on Fibre Channel networks.

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## 1. Introduction

Fibre Channel (FC) is a high speed serial interface technology that supports several Upper Layer Protocols including Small Computer System Interface (SCSI) and IPv4 as specified in [IPFC].

The purpose of this document is to specify a way of encapsulating IP version 6 [IPv6] over Fibre Channel and to describe a method of forming IPv6 link-local addresses [AARCH] and statelessly autoconfigured addresses on Fibre Channel networks. This document also describes the content of the Source/Target Link-layer Address option used in Neighbor Discovery [DISC] when the messages are transmitted on a Fibre Channel network.

Warning to readers familiar with Fibre Channel: both Fibre Channel and IETF standards use the same byte transmission order. However, the bit numbering is different. See Appendix C for guidance.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [KEYWORDS].

## 2. Summary of Fibre Channel

### 2.1. Overview

Fibre Channel (FC) is a gigabit speed network technology primarily used for Storage Networking. Fibre Channel is standardized in the T11 Technical Committee of the InterNational Committee for Information Technology Standards (INCITS), an American National Standard Institute (ANSI) accredited standards committee.

Fibre Channel devices are called Nodes. Each Node has one or more Ports that connect to Ports of other devices. Fibre Channel may be implemented using any combination of the following three topologies:

- a point-to-point link between two Ports;
- a set of Ports interconnected by a switching network called a Fabric, as defined in [FC-FS];
- a set of Ports interconnected with a loop topology, as defined in [FC-AL-2].

A Node Port is more precisely called an N\_Port. A Node Port that is capable of operating in a loop topology using the loop specific protocols is designated as an NL\_Port. The term Nx\_Port is used to generically indicate these two kinds of Node Port.

A Fabric Port is more precisely called an F\_Port. A Fabric Port that is capable of operating in a loop topology using the loop specific protocols is designated as an FL\_Port. The term Fx\_Port is used to generically indicate these two kinds of Fabric Port.

From an IPv6 point of view, a Fibre Channel network, built with any combination of the FC topologies described above, is an IPv6 Link [IPv6]. IPv6-capable Nx\_Ports are what [IPv6] calls Interfaces.

### 2.2. Identifiers and Login

Fibre Channel entities are identified by permanent 64 bit long Name\_Identifier. [FC-FS] defines several formats of Name\_Identifier. The value of the first four bits defines the format of a Name\_Identifier. These names are referred to in a more precise manner as follows:

- an Nx\_Port's Name\_Identifier is called N\_Port\_Name;
- an Fx\_Port's Name\_Identifier is called F\_Port\_Name;
- a Node's Name\_Identifier is called Node\_Name;
- a Fabric's Name\_Identifier is called Fabric\_Name.

An Nx\_Port connected to a Fibre Channel network is associated with two identifiers, its permanent N\_Port\_Name and a volatile 24 bit address called N\_Port\_ID. The N\_Port\_Name is used to identify the Nx\_Port, while the N\_Port\_ID is used for communications among Nx\_Ports.

Each Nx\_Port acquires an N\_Port\_ID from the Fabric by performing a process called Fabric Login or FLOGI. The FLOGI process is used also to negotiate several communications parameters between the Nx\_Port and the Fabric, such as the receive data field size, which determines the maximum size of the Fibre Channel frames that may be transferred between the Nx\_Port and the Fabric.

Before effective communication may take place between two Nx\_Ports, they must complete a process called Port Login or PLOGI. The PLOGI process provides each Nx\_Port with the other Nx\_Port's N\_Port\_Name, and negotiates several communication parameters, such as the receive data field size, which determines the maximum size of the Fibre Channel frames that may be transferred between the two Nx\_Ports.

Both Fabric Login and Port Login may be explicit, i.e., performed using specific FC control messages (called Extended Link Services or ELS), or implicit, in which the parameters are specified by configuration or other methods.

### 2.3. FC Levels and Frame Format

[FC-FS] describes the Fibre Channel protocol using 5 different levels. The FC-2 and FC-4 levels are relevant for this specification. The FC-2 level defines the FC frame format, the transport services, and control functions necessary for information transfer. The FC-4 level supports Upper Level Protocols, such as IPv4, IPv6 or SCSI. The Fibre Channel frame format is depicted in figure 1.

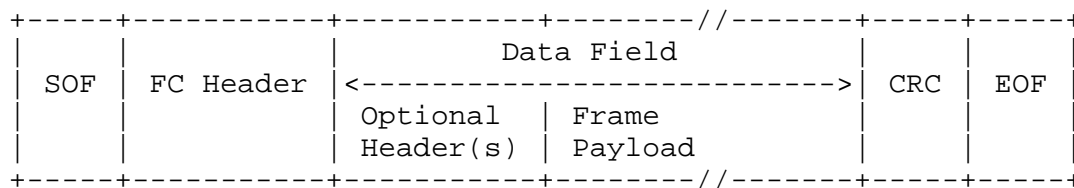


Fig. 1: Fibre Channel Frame Format

The Start of Frame (SOF) and End of Frame (EOF) are special FC transmission words that act as frame delimiters. The CRC is 4 octets long and uses the same 32-bit polynomial used in FDDI.

The FC Header is 24 octets long and contains several fields associated with the identification and control of the Data Field.

The Data Field is of variable size, ranging from 0 to 2112 octets, and includes the user data in the Frame Payload field, and Optional Headers. The currently defined Optional Headers are:

- ESP\_Header;
- Network\_Header;
- Association\_Header;
- Device\_Header.

The value of the SOF field determines the FC Class of service associated with the frame. Five Classes of service are specified in [FC-FS]. They are distinguished primarily by the method of flow control between the communicating Nx\_Ports and by the level of data integrity provided. A given Fabric or Nx\_Port may support one or more of the following Classes of service:

- Class 1: Dedicated physical connection with delivery confirmation;
- Class 2: Frame multiplexed service with delivery confirmation;
- Class 3: Datagram service;
- Class 4: Fractional bandwidth;
- Class 6: Reliable multicast via dedicated connections.

#### 2.4. Sequences and Exchanges

An application level payload such as IPv6 is called Information Unit at the FC-4 level of Fibre Channel. Each FC-4 Information Unit is mapped to an FC Sequence by the FC-2 level. An FC Sequence consists of one or more FC frames related by the value of the Sequence\_ID (SEQ\_ID) field of the FC Header.

The maximum data that may be carried by an FC frame is 2112 octets. The maximum usable frame size depends on the Fabric and Nx\_Port implementations and is negotiated during the Login process. Whenever an Information Unit to be transmitted exceeds this value, the FC-2 level segments it into multiple FC frames, sent as a single Sequence. The receiving Nx\_Port reassembles the Sequence of frames and delivers a reassembled Information Unit to the FC-4 level. The Sequence Count (SEQ\_CNT) field of the FC Header may be used to ensure frame ordering.

Multiple Sequences may be related together as belonging to the same FC Exchange. The Exchange is a mechanism used by two Nx\_Ports to identify and manage an operation between them. The Exchange is opened when the operation is started between the two Nx\_Ports, and closed when the operation ends. FC frames belonging to the same

Exchange are related by the value of the Exchange\_ID fields in the FC Header. An Originator Exchange\_ID (OX\_ID) and a Responder Exchange\_ID (RX\_ID) uniquely identify the Exchange.

### 3. IPv6 Capable Nx\_Ports

This specification requires an IPv6 capable Nx\_Port to have the following properties:

- The format of its N\_Port\_Name MUST be one of 0x1, 0x2, 0x5, 0xC, 0xD, 0xE, 0xF (see section 6.1). IPv6 support for other Name\_Identifier formats is outside the scope of this specification;
- It MUST support Class 3;
- It MUST support continuously increasing SEQ\_CNT [FC-FS];
- It MUST be able to transmit and receive an FC-4 Information Unit at least 1304 octets long;
- It SHOULD support a receive data field size for Device\_Data FC frames of at least 1024 octets.

### 4. IPv6 Encapsulation

#### 4.1. FC Sequence Format

An IPv6 packet is mapped to an Information Unit at the FC-4 level of Fibre Channel, which in turn is mapped to an FC Sequence by the FC-2 level. An FC Information Unit containing an IPv6 packet MUST carry the FC Network\_Header [FC-FS] and the LLC/SNAP header [IEEE-LLC], resulting in the FC Information Unit format depicted in figure 2.

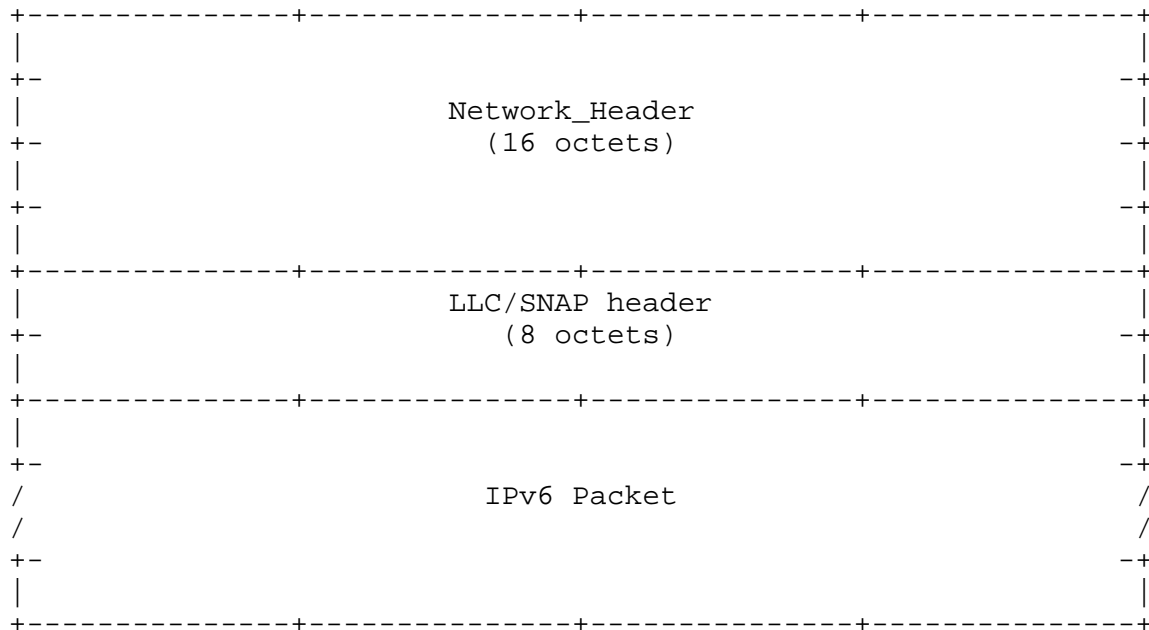


Fig. 2: FC Information Unit Mapping an IPv6 Packet

The FC ESP\_Header [FC-FS] MAY be used to secure the FC frames composing the FC Sequence. [AH] or [ESP] may be used to provide security at the IPv6 layer. Other types of FC Optional Header MUST NOT be used in an IPv6 FC Sequence.

Typically, a Sequence consists of more than one frame. Only the first frame of the Sequence MUST include the FC Network\_Header and the LLC/SNAP header. The other frames MUST NOT include them, as depicted in figure 3.

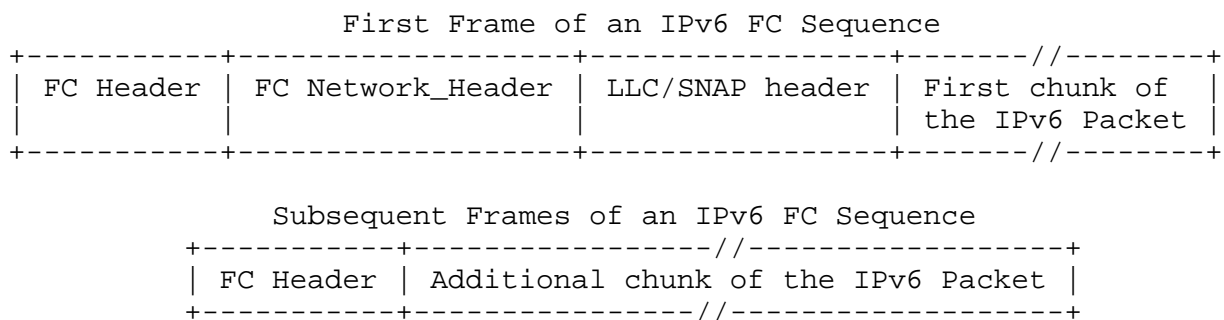


Fig. 3: Optional Headers in an IPv6 FC Sequence

## 4.2. FC Classes of Service

This specification uses FC Class 3. IPv6 packets carrying Neighbor Discovery [DISC] messages MUST be encapsulated in Class 3 FC frames. Other IPv6 packets SHOULD use Class 3 as well. The use of other Classes of service is outside the scope of this specification.

## 4.3. FC Header Code Points

The fields of the Fibre Channel Header are depicted in figure 4. The D\_ID and S\_ID fields contain respectively the destination N\_Port\_ID and the source N\_Port\_ID. To encapsulate IPv6 over Fibre Channel the following code points MUST be used:

- R\_CTL: 0x04 (Device\_Data frame with Unsolicited Data Information Category [FC-FS])
- TYPE: 0x05 (IP over Fibre Channel)
- CS\_CTL/Prio: 0x0
- DF\_CTL: 0x20 (Network\_Header) for the first FC frame of an IPv6 Sequence, 0x00 for the following FC frames. If the FC ESP\_Header is used, then 0x60 for the first FC frame of an IPv6 Sequence, 0x40 for the following FC frames.
- F\_CTL, SEQ\_ID, SEQ\_CNT, OX\_ID, RX\_ID, Parameter: see section 10, section 11, and [FC-FS] for additional requirements.

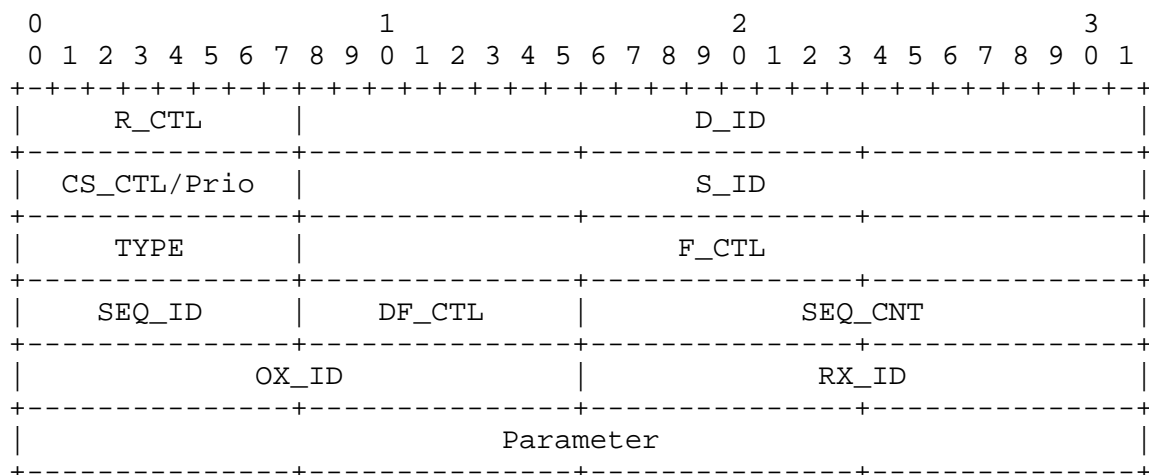


Fig. 4: FC Header Format



#### 4.4. FC Network\_Header

The fields of the FC Network\_Header are depicted in figure 5. For use with IPv6 the N\_Port\_Names formats MUST be one of 0x1, 0x2, 0x5, 0xC, 0xD, 0xE, 0xF. IPv6 support for other Name\_Identifier formats is outside the scope of this specification.

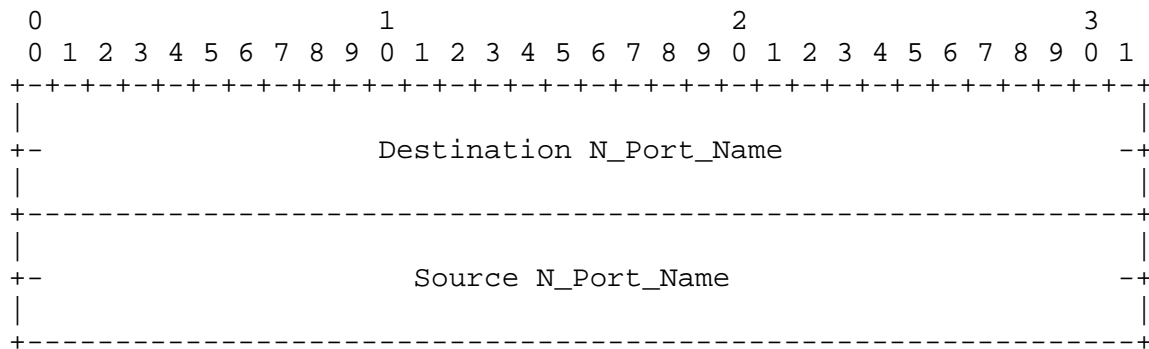


Fig. 5: FC Network\_Header Format

#### 4.5. LLC/SNAP Header

The fields of the LLC/SNAP Header [IEEE-LLC] are depicted in figure 6. To encapsulate IPv6 over Fibre Channel the following code points MUST be used:

- ```
- DSAP: 0xAA
- SSAP: 0xAA
- CTRL: 0x03
- OUI: 0x00-00-00
- PID: 0x86-DD
```

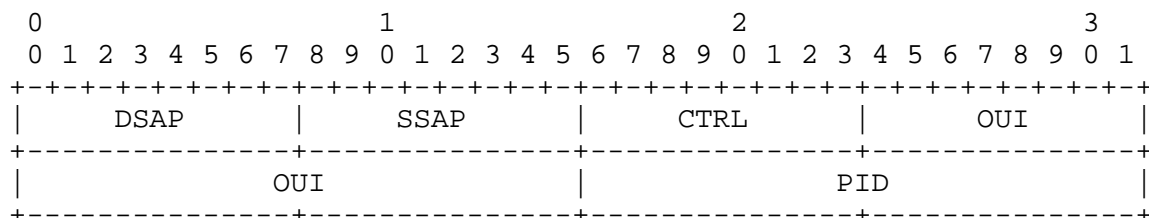


Fig. 6: LLC/SNAP Header Format

## 4.6. Bit and Byte Ordering

IPv6 packets are mapped to the FC-4 level using the big-endian byte ordering that corresponds to the standard network byte order or canonical form.

## 5. Maximum Transfer Unit

The default MTU size for IPv6 [IPv6] packets over Fibre Channel is 65280 octets. This size may be reduced by a Router Advertisement [DISC] containing an MTU option that specifies a smaller MTU, or by manual configuration of each Nx\_Port. However, as required by [IPv6], the MTU MUST NOT be lower than 1280 octets. If a Router Advertisement received on an Nx\_Port has an MTU option specifying an MTU larger than 65280, or larger than a manually configured value, that MTU option MAY be logged to system management but MUST be otherwise ignored.

As the default MTU size far exceeds the message sizes typically used in the Internet, an IPv6 over FC implementation SHOULD implement Path MTU Discovery [PMTUD], or at least maintain different MTU values for on-link and off-link destinations.

For correct operation in a routed environment, it is critically important to configure an appropriate MTU option in Router Advertisements.

For correct operation when mixed media (e.g., Ethernet and Fibre Channel) are bridged together, the smallest MTU of all the media must be advertised by routers in an MTU option. If there are no routers present, this MTU must be manually configured in each node which is connected to a medium with a default MTU larger than the smallest MTU.

## 6. Stateless Address Autoconfiguration

### 6.1. IPv6 Interface Identifier and Address Prefix

The IPv6 Interface ID [AARCH] for an Nx\_Port is based on the EUI-64 address [EUI64] derived from the Nx\_Port's N\_Port\_Name. The IPv6 Interface Identifier is obtained by complementing the Universal/Local bit of the OUI field of the derived EUI-64 address.

[FC-FS] specifies a method to map format 0x1 (IEEE 48 bit address), or 0x2 (IEEE Extended), or 0x5 (IEEE Registered) FC Name\_Identifiers in EUI-64 addresses. This allows the usage of these Name\_Identifiers to support IPv6. [FC-FS] also defines EUI-64 mapped FC Name\_Identifiers (formats 0xC, 0xD, 0xE, and 0xF), that are derived from an EUI-64 address. It is possible to reverse this address mapping to obtain the original EUI-64 address in order to support IPv6.

Stateless address autoconfiguration MUST be performed as specified in [ACONF]. An IPv6 Address Prefix used for stateless address autoconfiguration of an Nx\_Port MUST have a length of 64 bits.

## 6.2. Generating an Interface ID from a Format 1 N\_Port\_Name

The Name\_Identifier format 0x1 is depicted in figure 7.

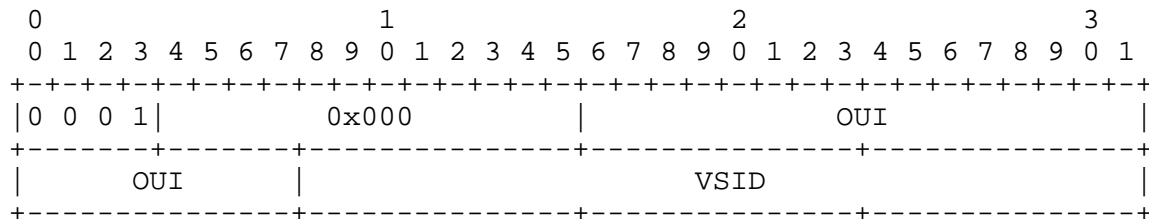


Fig. 7: Format 0x1 Name\_Identifier

The EUI-64 address derived from this Name\_Identifier has the format depicted in figure 8 [FC-FS].

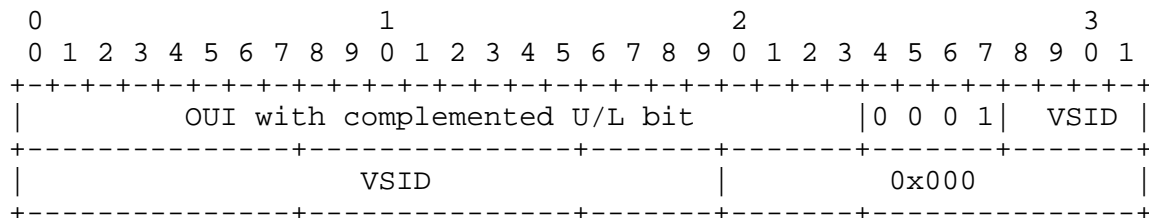


Fig. 8: EUI-64 Address from a Format 0x1 Name\_Identifier

The IPv6 Interface Identifier is obtained from this EUI-64 address by complementing the U/L bit in the OUI field. So the OUI in the IPv6 Interface ID is exactly as in the FC Name\_Identifier. The resulting IPv6 Interface Identifier has local scope [AARCH] and the format depicted in figure 9.

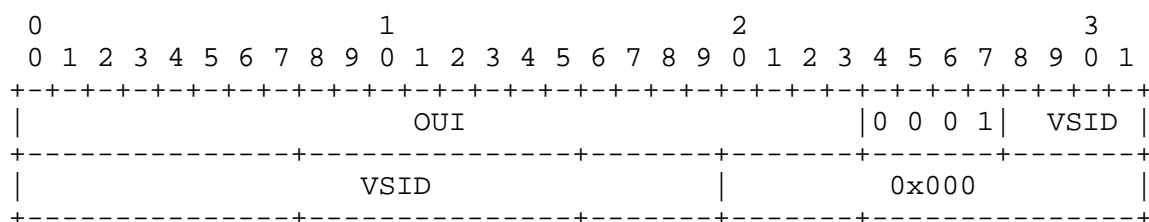


Fig. 9: IPv6 Interface ID from a Format 0x1 Name\_Identifier

As an example, the FC Name\_Identifier 0x10-00-34-63-46-AB-CD-EF generates the IPv6 Interface Identifier 3463:461A:BCDE:F000.

### 6.3. Generating an Interface ID from a Format 2 N\_Port\_Name

The Name\_Identifier format 0x2 is depicted in figure 10.

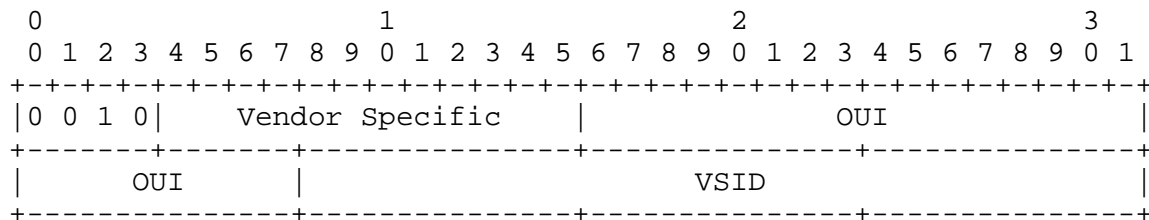


Fig. 10: Format 0x2 Name\_Identifier

The EUI-64 address derived from this Name\_Identifier has the format depicted in figure 11 [FC-FS].

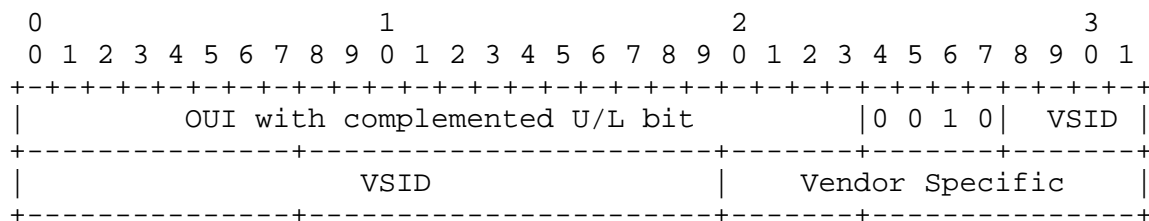


Fig. 11: EUI-64 Address from a Format 0x2 Name\_Identifier

The IPv6 Interface Identifier is obtained from this EUI-64 address by complementing the U/L bit in the OUI field. So the OUI in the IPv6 Interface ID is exactly as in the FC Name\_Identifier. The resulting IPv6 Interface Identifier has local scope [AARCH] and the format depicted in figure 12.

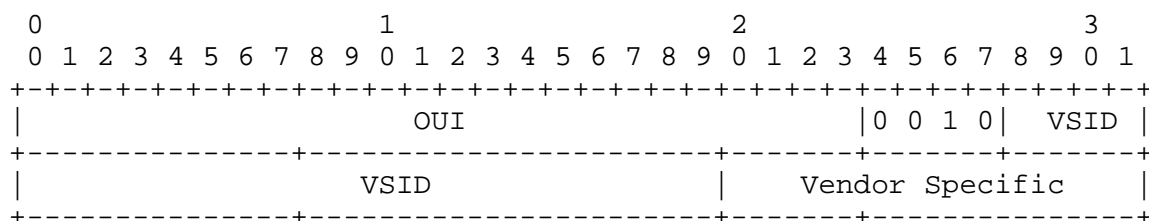


Fig. 12: IPv6 Interface ID from a Format 0x2 Name\_Identifier

As an example, the FC Name\_Identifier 0x27-89-34-63-46-AB-CD-EF generates the IPv6 Interface Identifier 3463:462A:BCDE:F789.

#### 6.4. Generating an Interface ID from a Format 5 N\_Port\_Name

The Name\_Identifier format 0x5 is depicted in figure 13.

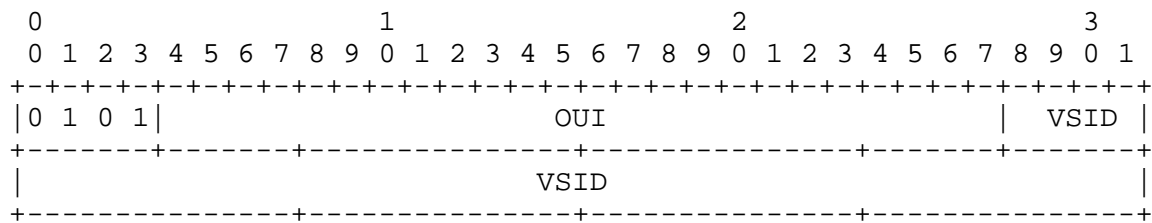


Fig. 13: Format 0x5 Name\_Identifier

The EUI-64 address derived from this Name\_Identifier has the format depicted in figure 14 [FC-FS].

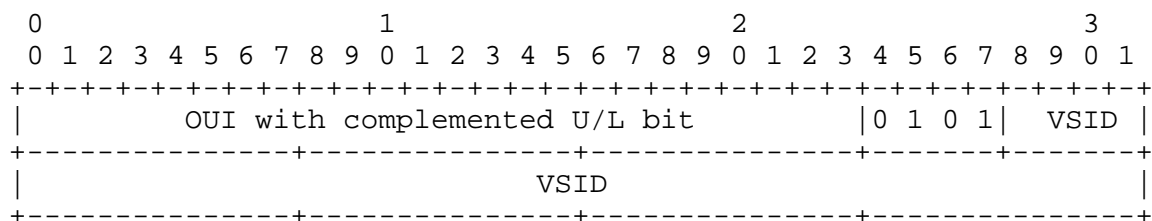


Fig. 14: EUI-64 Address from a Format 0x5 Name\_Identifier

The IPv6 Interface Identifier is obtained from this EUI-64 address complementing the U/L bit in the OUI field. So the OUI in the IPv6 Interface ID is exactly as in the FC Name\_Identifier. The resulting IPv6 Interface Identifier has local scope [AARCH] and the format depicted in figure 15.

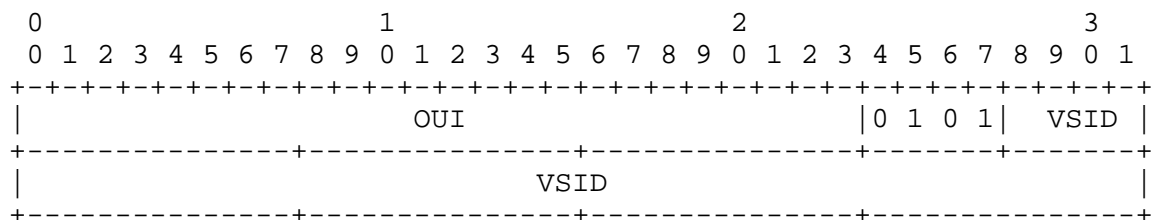


Fig. 15: IPv6 Interface ID from a Format 0x5 Name\_Identifier

As an example, the FC Name\_Identifier 0x53-46-34-6A-BC-DE-F7-89 generates the IPv6 Interface Identifier 3463:465A:BCDE:F789.

### 6.5. Generating an Interface ID from an EUI-64 mapped N\_Port\_Name

The EUI-64 mapped Name\_Identifiers formats (formats 0xC through 0xF) are derived from an EUI-64 address by compressing the OUI field of such addresses. The compression is performed by removing from the OUI the Universal/Local and Individual/Group bits, and by putting bits 0 to 5 of the OUI in the first octet of the Name\_Identifier, and bits 8 to 23 of the OUI in the second and third octet of the Name\_Identifier, as shown in figure 16.

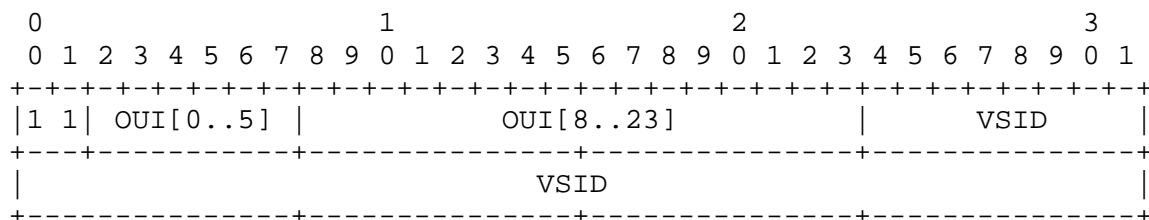


Fig. 16: EUI-64 Mapped Name\_Identifiers Format

The EUI-64 address used to generate the Name\_Identifier shown in figure 16 has the format depicted in figure 17.

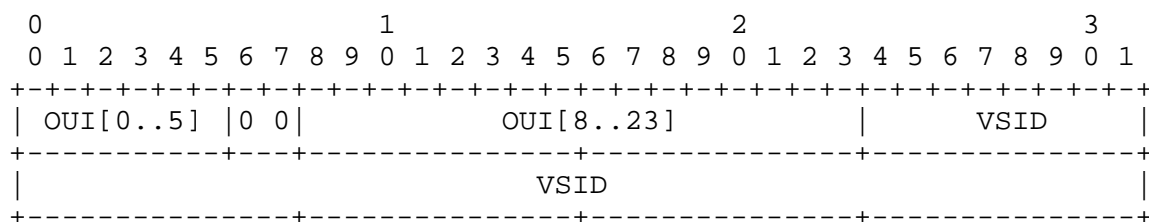


Fig. 17: EUI-64 Address from an EUI-64 Mapped Name\_Identifier

The IPv6 Interface Identifier is obtained from this EUI-64 address by complementing the U/L bit in the OUI field. The resulting IPv6 Interface Identifier has global scope [AARCH] and the format depicted in figure 18.

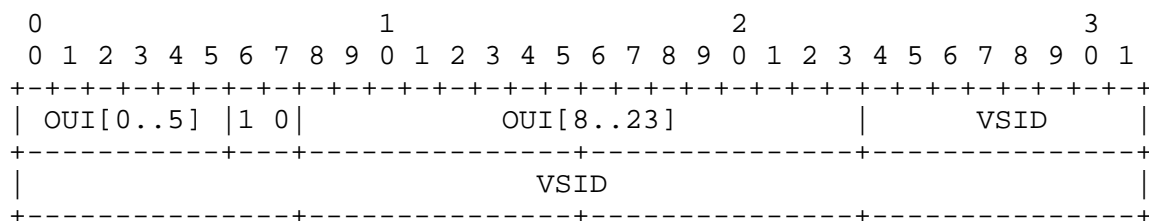


Fig. 18: IPv6 Interface ID from an EUI-64 Mapped Name\_Identifier

As an example, the FC Name\_Identifier 0xCD-63-46-AB-01-25-78-9A generates the IPv6 Interface Identifier 3663:46AB:0125:789A.

## 7. Link-Local Addresses

The IPv6 link-local address [AARCH] for an Nx\_Port is formed by appending the Interface Identifier, as defined in section 6, to the prefix FE80::/64. The resulting address is depicted in figure 19.

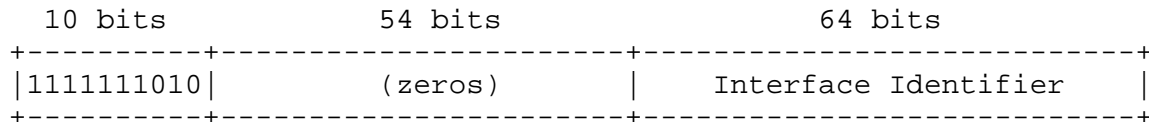


Fig. 19: IPv6 link-local Address Format

## 8. Address Mapping for Unicast

An Nx\_Port has two kinds of Fibre Channel addresses:

- a non-volatile 64-bit address, called N\_Port\_Name;
- a volatile 24-bit address, called N\_Port\_ID.

The N\_Port\_Name is used to uniquely identify the Nx\_Port, while the N\_Port\_ID is used to route frames to the Nx\_Port. Both FC addresses are required to resolve an IPv6 unicast address. The fact that the N\_Port\_ID is volatile implies that an Nx\_Port MUST validate the mapping between its N\_Port\_Name and N\_Port\_ID when certain Fibre Channel events occur (see Appendix B).

The procedure for mapping IPv6 unicast addresses into Fibre Channel link-layer addresses uses the Neighbor Discovery Protocol [DISC]. The Source/Target Link-layer Address option has the format depicted in figure 20 when the link layer is Fibre Channel.

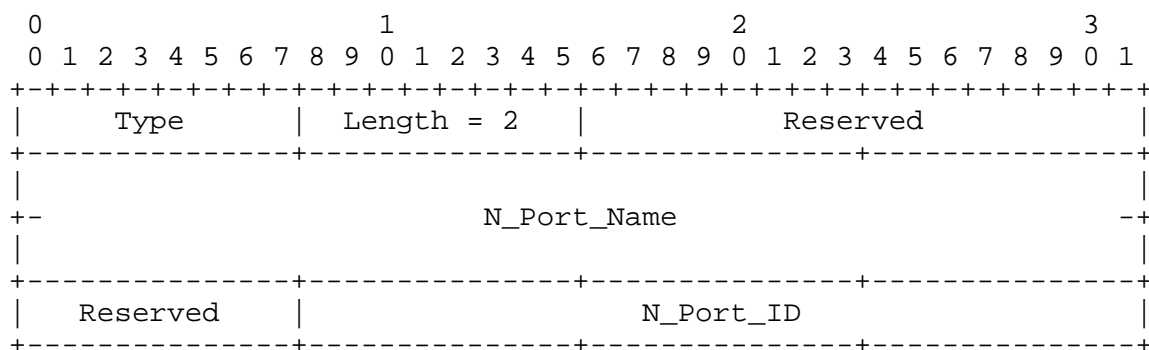


Fig. 20: Source/Target Link-layer Address option for Fibre Channel

Type:                   1 for Source Link-layer address.  
                         2 for Target Link-layer address.

Length:                 2 (in units of 8 octets).

N\_Port\_Name:            This field contains the Nx\_Port's N\_Port\_Name.  
N\_Port\_ID:              This field contains the Nx\_Port's N\_Port\_ID.

Reserved fields MUST be zero when transmitting, and MUST be ignored when receiving.

## 9. Address Mapping for Multicast

By default, all best-effort IPv6 multicast packets MUST be mapped to FC Sequences addressed to the broadcast N\_Port\_ID 0xFF-FF-FF. In particular, datagrams addressed to all-nodes multicast address, all-routers multicast address, and solicited-node multicast addresses [AARCH] MUST be sent as Class 3 FC Sequences addressed to the broadcast N\_Port\_ID 0xFF-FF-FF. In this case, the Destination N\_Port\_Name field of the FC Network\_Header MUST be set to the value 0x10-00-FF-FF-FF-FF-FF-FF. Appendix A specifies how to transmit a Class 3 broadcast FC Sequence over various Fibre Channel topologies.

An Nx\_Port supporting IPv6 MUST be able to map a received broadcast Class 3 Device\_Data FC frame to an implicit Port Login context in order to handle IPv6 multicast packets. The receive data field size of this implicit Port Login MUST be the same across all the Nx\_Ports connected to the same Fabric, otherwise FC broadcast transmission does not work. In order to reduce the need for FC Sequence segmentation, the receive data field size of this implicit Port Login SHOULD be 1024 octets. This receive data field size requirement applies to broadcast Device\_Data FC frames, not to ELSSs.

Receiving an FC Sequence carrying an IPv6 multicast packet MAY trigger some additional processing by the Nx\_Port if that IPv6 packet requires a unicast reply. In this case, if a valid Port Login to the Nx\_Port that sent the IPv6 multicast packet does not exist, the Nx\_Port MUST perform such a Port Login, and then use it for the unicast IPv6 reply. In the case of Neighbor Discovery messages [DISC], the N\_Port\_ID to which the Port Login is directed is taken from the N\_Port\_ID field of the Source/Target Link-layer Address option.

As an example, an Nx\_Port processes a received broadcast FC Sequence carrying an IPv6 multicast unsolicited router advertisement [DISC] simply by passing the carried IPv6 packet to the IPv6 layer. Instead, if a received broadcast FC Sequence carries an IPv6 multicast solicitation message [DISC] requiring a unicast reply, and



no valid Port Login exists with the Nx\_Port sender of the multicast packet, then a Port Login MUST be performed in order to send the unicast reply message. If a received broadcast FC Sequence carries an IPv6 multicast solicitation message [DISC] requiring a multicast reply, the reply is sent to the broadcast N\_Port\_ID 0xFF-FF-FF.

Best-effort IPv6 multicast for other multicast group addresses MAY use Fibre Channel Multicast Groups [FC-FS], if supported by the particular FC topology and implementation.

## 10. Sequence Management

FC Sequences are REQUIRED to be non-streamed. In order to avoid missing FC frame aliasing by Sequence\_ID reuse, an Nx\_Port supporting IPv6 is REQUIRED to use continuously increasing SEQ\_CNT [FC-FS]. Each Exchange MUST start with SEQ\_CNT = 0 in the first frame, and every frame transmitted after that MUST increment the previous SEQ\_CNT by one. Any frames received from the other N\_Port in the Exchange shall have no effect on the transmitted SEQ\_CNT.

## 11. Exchange Management

To transfer IPv6 packets, each Nx\_Port MUST have a dedicated Exchange for sending data to each Nx\_Port in the network and a dedicated Exchange for receiving data from each Nx\_Port.

An Exchange Responder is not required to assign RX\_IDs. If an RX\_ID of 0xFFFF is assigned, the Exchange Responder is identifying Exchanges based on S\_ID / D\_ID / OX\_ID only.

When an Exchange is created between two Nx\_Ports for unicast IPv6 packets, it remains active while the Nx\_Ports are logged in with each other. Each FC broadcast and ELS [FC-FS] SHOULD use a separate short lived Exchange.

For IPv6, Exchanges MUST NOT transfer Sequence Initiative, because they are used in a unidirectional mode. The Sequence Initiative bit in the F\_CTL field of the FC Header [FC-FS] MUST be set to 0.

The mechanism for aging or expiring exchanges based on activity, timeout, or other methods is outside the scope of this document.

The Exchange Originator MAY terminate Exchanges by setting the F\_CTL LS bit [FC-FS]. Exchanges MAY be torn down by the Exchange Originator or Exchange Responder by using the ABTS (Abort Sequence) protocol [FC-FS]. IPv6 Exchanges SHOULD NOT be terminated by Logout, since this may terminate active Exchanges on other FC-4s [FC-FS].

## 12. Security Considerations

IPv6 does not introduce any additional security concerns beyond those that already exist within the Fibre Channel protocols. Zoning techniques based on FC Name Server masking (soft zoning) do not work with IPv6, because IPv6 over Fibre Channel does not use the FC Name Server. The FC ESP\_Header [FC-FS] may be used to secure the FC frames composing FC Sequences carrying IPv6 packets. All the techniques defined to secure IPv6 traffic at the IPv6 layer may be used in a Fibre Channel environment.

## 13. Acknowledgments

The author would like to acknowledge the authors of [IPFC], [ETHER], and [IPv6-1394], since some part of this document has been derived from them, as well as the ANSI INCITS T11.3 Task Group members who reviewed this document.

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## A. Transmission of a Broadcast FC Sequence over FC Topologies

### A.1. Point-to-Point Topology

No particular mechanisms are required for this case. The Nx\_Port connected at the other side of the cable receives the broadcast FC Sequence having D\_ID 0xFFFFFFFF.

### A.2. Private Loop Topology

An NL\_Port attached to a private loop MUST transmit a Class 3 broadcast FC Sequence by using the OPN(fr) primitive signal [FC-AL-2].

- a) The source NL\_Port first sends an Open Broadcast Replicate (OPN(fr)) primitive signal, forcing all the NL\_Ports in the loop (except itself) to replicate the frames that they receive while examining the FC Header's D\_ID field.
- b) The source NL\_Port then removes the OPN(fr) signal when it returns to it.
- c) The source NL\_Port then sends the Class 3 broadcast FC Sequence having D\_ID 0xFFFFFFFF.

### A.3. Public Loop Topology

An NL\_Port attached to a public loop MUST NOT use the OPN(fr) primitive signal. Rather, it MUST send the Class 3 broadcast FC Sequence having D\_ID 0xFFFFFFFF to the FL\_Port at AL\_PA = 0x00 [FC-AL-2].

The Fabric propagates the broadcast to all other FC\_Ports [FC-FS], including the FL\_Port which the broadcast arrives on. This includes all F\_Ports, and other FL\_Ports.

Each FL\_Port propagates the broadcast by using the primitive signal OPN(fr), in order to prepare the loop to receive the broadcast sequence.

### A.4. Fabric Topology

An N\_Port connected to an F\_Port MUST transmit the Class 3 broadcast FC Sequence having D\_ID 0xFFFFFFFF to the F\_Port. The Fabric propagates the broadcast to all other FC\_Ports [FC-FS].

## B. Validation of the <N\_Port\_Name, N\_Port\_ID> mapping

### B.1. Overview

At all times, the <N\_Port\_Name, N\_Port\_ID> mapping must be valid before use.

After an FC link interruption occurs, the N\_Port\_ID of an Nx\_Port may change, as well as the N\_Port\_IDs of all other Nx\_Ports that have previously performed Port Login with this Nx\_Port. Because of this, address validation is required after a LIP in a loop topology [FC-AL-2] or after NOS/OLS in a point-to-point topology [FC-FS].

N\_Port\_IDs do not change as a result of Link Reset (LR) [FC-FS], thus address validation is not required in this case.

### B.2. FC Layer Address Validation in a Point-to-Point Topology

No validation is required after LR. In a point-to-point topology, NOS/OLS causes implicit Logout of each N\_Port and after a NOS/OLS each N\_Port must again perform a Port Login [FC-FS].

### B.3. FC Layer Address Validation in a Private Loop Topology

After a LIP [FC-AL-2], an NL\_Port must not transmit any data to another NL\_Port until the address of the other port has been validated. The validation consists of completing either ADISC or PDISC [FC-FS].

For a requester, this specification prohibits PDISC and requires ADISC. As a responder, an implementation may need to respond to both ADISC and PDISC for compatibility with other FC specifications.

If the three FC addresses (N\_Port\_ID, N\_Port\_Name, Node\_Name) of a logged remote NL\_Port exactly match the values prior to the LIP, then any active Exchange with that NL\_Port may continue.

If any of the three FC addresses has changed, then the remote NL\_Port must be logged out.

If an NL\_Port's N\_Port\_ID changes after a LIP, then all active logged in NL\_Ports must be logged out.

#### B.4. FC Layer Address Validation in a Public Loop Topology

A FAN ELS may be sent by the Fabric to all known previously logged in NL\_Ports following an initialization event. Therefore, after a LIP [FC-AL-2], NL\_Ports may wait for this notification to arrive, or they may perform an FLOGI.

If the F\_Port\_Name and Fabric\_Name contained in the FAN ELS or FLOGI response exactly match the values before the LIP and if the AL\_PA [FC-AL-2] obtained by the NL\_Port is the same as the one before the LIP, then the port may resume all Exchanges. If not, then FLOGI must be performed with the Fabric and all logged in Nx\_Ports must be logged out.

A public loop NL\_Port must perform the private loop validation as specified in section B.3 to any NL\_Port on the local loop that has an N\_Port\_ID of the form 0x00-00-XX.

#### B.5. FC Layer Address Validation in a Fabric Topology

No validation is required after LR (link reset).

After NOS/OLS, an N\_Port must perform FLOGI. If, after FLOGI, the N\_Port's N\_Port\_ID, the F\_Port\_Name, and the Fabric\_Name are the same as before the NOS/OLS, then the N\_Port may resume all Exchanges. If not, all logged in Nx\_Ports must be logged out [FC-FS].

#### C. Fibre Channel Bit and Byte Numbering Guidance

Both Fibre Channel and IETF standards use the same byte transmission order. However, the bit numbering is different.

Fibre Channel bit numbering can be observed if the data structure heading shown in figure 21 is cut and pasted at the top of the figures present in this document.

```

      3               2               1               0
    1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0 9 8 7 6 5 4 3 2 1 0
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+

```

Fig. 21: Fibre Channel Bit Numbering

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