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**Transmission of IPv6 Packets over Aeronautical ("aero") Interfaces**  
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Abstract

Mobile nodes (e.g., aircraft of various configurations) act as mobile routers for their on-board networks, and may have multiple data links for communicating with networked correspondents. Mobile nodes configure a virtual interface (termed the "aero interface") as a thin layer over their underlying data link interfaces. This document specifies the transmission of IPv6 packets over aeronautical ("aero") interfaces.

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## [1.](#) Introduction

Mobile Nodes (MNs) such as aircraft of various configurations may have multiple data links for communicating with networked correspondents. These data links often have differing performance, cost and availability characteristics that can change dynamically according to mobility patterns, flight phases, proximity to infrastructure, etc.

Each MN receives an IPv6 Mobile Network Prefix (MNP) that can be used by on-board networks regardless of the actual link or links selected for data transport. The MN acts as a mobile router on behalf of its on-board networks, but appears as a multi-addressed host from the perspective of off-board correspondents. This implies the need for a virtual interface (termed the "aero interface") configured as a thin layer over the underlying data link interfaces.

The aero interface is therefore the only interface abstraction exposed to the IPv6 layer, and behaves according to the Non-Broadcast, Multiple Access (NBMA) interface principle. This document



specifies the transmission of IPv6 packets [[RFC8200](#)] over aeronautical ("aero") interfaces.

## 2. Terminology

The terminology in the normative references applies; especially, the terms "link" and "interface" are the same as defined in the IPv6 [[RFC8200](#)] and IPv6 Neighbor Discovery (ND) [[RFC4861](#)] specifications.

The following terms are defined within the scope of this document:

underlying Internetwork

a connected network region that has a coherent IP addressing plan and is either physically isolated or separated from other networks by packet filtering border routers. Examples include private enterprise networks, aviation networks and the global public Internet itself.

aero link

a Non-Broadcast, Multiple Access (NBMA) virtual overlay configured over an underlying Internetwork. Nodes on the aero link appear as single-hop neighbors from the perspective of the virtual overlay even though they may be separated by many underlying Internetwork hops. An aero link may comprise multiple segments joined by bridges the same as for any link; the underlying Internetwork addressing plans in each segment may be mutually exclusive and managed by different administrative entities.

aero interface

a node's attachment to an aero link, and configured over one or more underlying interfaces

aero node

a node with an aero interface attached to an aero link.

aero address

an IPv6 link-local address constructed as specified in [Section 7](#), and assigned to an aero interface.

underlying link

a link that connects an aero node to the underlying Internetwork.

underlying interface

an aero node's interface point of attachment to an underlying link.



### 3. Requirements

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 [RFC2119]. Lower case uses of these words are not to be interpreted as carrying [RFC2119](#) significance.

### 4. Aeronautical ("aero") Interface Model

An aero interface is a MN's virtual interface configured over one or more underlying links, which may be physical (e.g., an Ethernet) or virtual (e.g., an Internet or higher-layer "tunnel"). The MN discovers routers on the aero link through Router Solicitation (RS) / Router Advertisement (RA) message exchanges.

The aero interface architectural layering model is the same as in [RFC7847], and reproduced here (in an augmented form) as shown in Figure 1. The aero interface is therefore a single network-layer interface with multiple link-layer addresses.

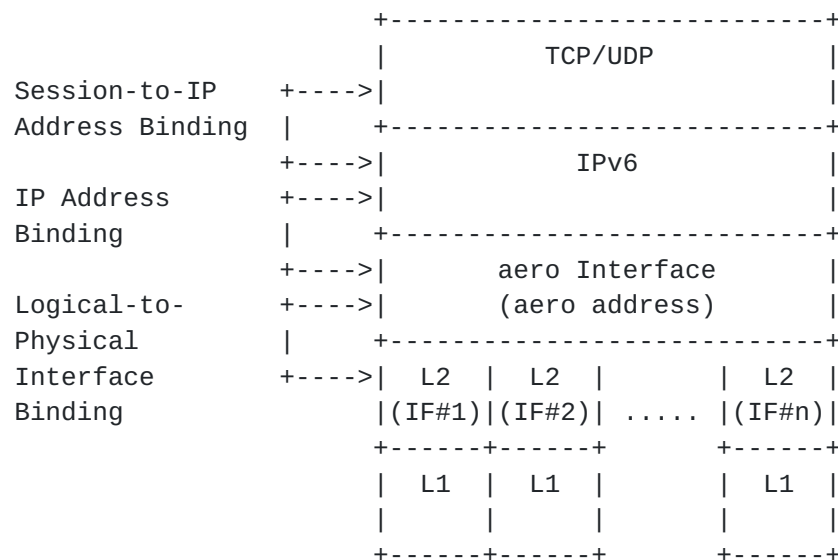


Figure 1: aero Interface Architectural Layering Model

The aero virtual interface gives rise to a number of opportunities that are not available if each underlying interface was exposed to the IPv6 layer independently:

- o since IPv6 interfaces must assign a unique IPv6 link-local address, only the aero interface (i.e., and not the underlying interfaces) needs to assign a unique IPv6 link-local address. Since aero interface link-local addresses are uniquely derived



from an MNP (see: [Section 7](#), this means that no Duplicate Address Detection (DAD) messaging is necessary over either the aero interface or any underlying interfaces.

- o as underlying interfaces become activated or deactivated (e.g., due to changes in aircraft flight phases), an active underlying interface can be used to report on the status of an interface that has been deactivated.
- o coordinating underlying interfaces in this way allows them to be presented to a mobility anchor point, thereby enabling more agile multilink and mobility support.
- o exposing only a single virtual interface abstraction to the IPv6 layer allows for traffic engineering (including QoS based link selection, packet replication, load balancing, etc.) at the link layer and with no supporting structures needed at the IPv6 layer.

Other opportunities are discussed in [[RFC7847](#)].

## 5. Maximum Transmission Unit

The aero interface Maximum Transmission Unit (MTU) is derived from the underlying interface MTUs and set to a value that ensures that the MTU for each underlying interface is respected. The aero interface MTU may be common to all data flows or differ between data flows. Regardless of the strategy by which the MTU is determined, the aero link administrative authority should configure routers to advertise a conservative MTU for all nodes noting that fragmentation should be avoided if possible.

In common practice, there may be additional encapsulation headers inserted by various forms of Layer 2 tunnels on the path to an on-link neighbor. Such tunnels SHOULD be instrumented to accommodate the native MTU of the underlying interface, but in some cases it may be prudent to reduce the size of the underlying interface MTU to allow room for L2 encapsulation. Especially for underlying links with low-end performance characteristics, it is imperative that packets that successfully traverse the underlying link are not dropped in the network due to a size restriction.

In a preferred approach, the aero interface MTU should be set to a value no smaller than the largest MTU among all underlying interfaces. The aero interface itself then MUST return locally-generated ICMPv6 "Packet Too Big" messages for packets that are too large to traverse the selected underlying interface in one piece. This ensures that the MTU is adaptive and reflects the underlying interface used for a given data flow.





Alternatively, the aero interface MTU may be determined as the minimum MTU among all underlying interfaces. However, this may result in under-utilization of robust underlying interfaces after a low-end underlying interface has degraded the common minimum MTU. For example, if the underlying interfaces have MTUs 1500, 1472 and 1400, then the minimum aero interface MTU is 1400.

If any underlying interface has an MTU smaller than 1280, the aero interface **MUST** either perform IPv6 fragmentation when using this interface or disable the underlying interface.

The MTU for an underlying interface is normally determined from information provided either statically or dynamically when the interface becomes active. If an underlying interface MTU dynamically reports an MTU smaller than any minimum MTU already determined then the aero interface **MUST** either perform IPv6 fragmentation when using this interface, or disable the underlying interface.

The aero interface **MAY** also receive an RA with an MTU option. If the advertised MTU is no larger than 1500, the aero interface MTU is set to the new value and the aero interface **MUST** either perform IPv6 fragmentation over any underlying interface having a smaller MTU or disable the underlying interface.

If the advertised MTU is larger than 1500, the aero interface sets the new value and disables any underlying interface having a smaller MTU instead of fragmenting, since IPv6 destinations are not required to reassemble more than 1500 bytes.

## **6. Frame Format and Encapsulation**

The aero interface transmits IPv6 packets according to the frame format of the underlying interface while using the link-local address format specified in [Section 7](#). For example, for an Ethernet interface the frame format is exactly as specified in [\[RFC2464\]](#), for an IPv6 tunnel over IPv4 the frame format is exactly as specified in [\[RFC4213\]](#), etc.

MNs and routers exchange IPv6 ND messages over their aero interfaces using link-local IPv6 source and destination addresses. Therefore, when the MN and router are not on the same physical link encapsulation is necessary to convey the messages over multiple underlying network hops. When an underlying interface connects to an underlying network that applies encapsulation, the aero interface need not apply encapsulation itself. When the underlying network does not apply encapsulation, the aero interface must apply some form of IPv6 over IP encapsulation according the IP protocol version of the underlying interface.



When encapsulation is applied either by the underlying network or the aero interface itself, the size of IPv6 packets that can be conveyed in a single piece is reduced due to the size of the encapsulation headers. The encapsulation headers can be accommodated by either reducing the aero interface MTU (see: [Section 5](#)) or through the use of fragmentation during encapsulation.

## 7. Link-Local Addresses

A MN's "aero address" is an IPv6 link-local address with an interface identifier based on its assigned MNP. MN aero addresses begin with the prefix `fe80::/64` followed by a 64-bit prefix taken from the MNP (see: [Appendix B](#)). For example, for the MNP:

```
2001:db8:1000:2000::/56
```

the corresponding aero addresses are:

```
fe80::2001:db8:1000:2000
```

```
fe80::2001:db8:1000:2001
```

```
fe80::2001:db8:1000:2002
```

```
... etc. ...
```

```
fe80::2001:db8:1000:20ff
```

When the MN configures aero addresses from its MNP, it assigns them to the aero interface. The lowest-numbered aero address serves as the "base" address (for example, for the MNP `2001:db8:1000:2000::/56` the base aero address is `fe80::2001:db8:1000:2000`). MNs and routers use the base address for the purpose of maintaining neighbor cache entries, but the MN accepts packets destined to all aero addresses as equivalent.

A router's aero address is allocated from the range `fe80::/96`, and MUST be managed for uniqueness by the aero link administrative authority. The lower 32 bits of the aero address includes a unique integer value, e.g., `fe80::1`, `fe80::2`, `fe80::3`, etc. The address `fe80::` is reserved as the IPv6 link-local Subnet Router Anycast address [[RFC4291](#)], and the address `fe80::ffff:ffff` is reserved as the unspecified aero address; hence, these values are not available for general assignment.

For multi-segment aero links, the routers of each segment MUST assign aero addresses that are unique among all routers on the (collective) link. Although the address assignment policy is completely at the



discretion of the aero link administrative authority, a useful technique may be to assign a different aggregated portion of the fe80::/96 prefix to each segment, e.g., fe80::/120, fe80::0100/120, fe80::0200/120, etc.

Since the MN's aero addresses are guaranteed unique by the nature of the unique MNP encapsulation, and since the router's aero address is guaranteed unique through administrative configuration, aero interfaces set the autoconfiguration variable DupAddrDetectTransmits to 0 [RFC4862].

## 8. Address Mapping - Unicast

The aero interface maintains a neighbor cache for tracking per-neighbor state the same as for any interface. The aero interface uses standard IPv6 Neighbor Discovery (ND) messages including Router Solicitation (RS), Router Advertisement (RA), Neighbor Solicitation (NS), Neighbor Advertisement (NA) and Redirect [RFC4861]. IPv6 ND messages on aero interfaces include zero or more Source/Target Link-Layer Address Options (S/TLLAOs) formatted as shown in Figure 2:

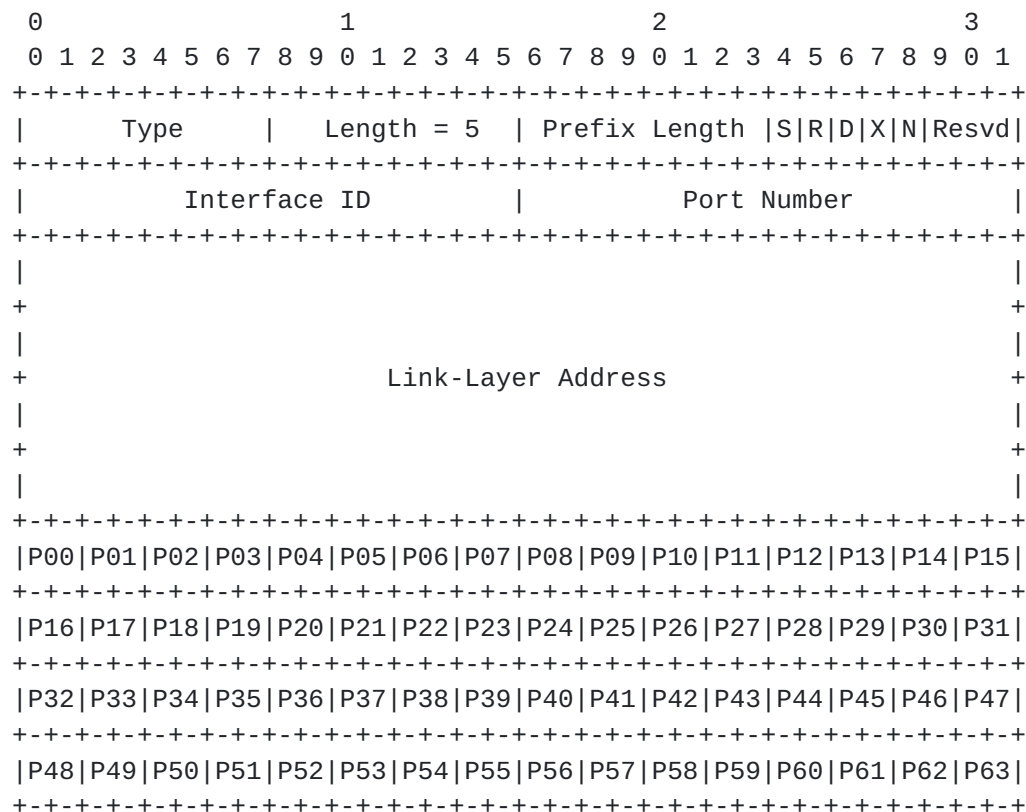


Figure 2: Source/Target Link-Layer Address Option (S/TLLAO) Format

In this format:



- o Type is set to '1' for SLLAO or '2' for TLLAO.
- o Length is set to the constant value '5' (i.e., 5 units of 8 octets).
- o Prefix Length is set to the MNP prefix length for the aero address found in the source (RS), destination (RA) or target (NA) address. For RS messages, the router creates or updates a neighbor cache entry and announces the MNP in the routing system, then returns an RA with Router Lifetime set to the MNP assertion lifetime.
- o S (the 'Source' bit) is set to '1' in the S/TLLAO of an ND message that corresponds to the underlying interface over which the ND message is sent, and set to 0 in all other S/TLLAOs.
- o R (the "Release" bit) is set to '1' in the SLLAO of an RS message sent for the purpose of withdrawing an MNP; otherwise, set to '0'. If the message contains multiple SLLAOs, only the R value in the SLLAO with S set to 1 is consulted and the values in other SLLAOs are ignored. The router withdraws the MNP, then returns an RA with Router Lifetime set to '0'.
- o D (the "Disable" bit) is set to '1' in the S/TLLAOs of an RS/NA message for each Interface ID that is to be disabled in the recipient's neighbor cache entry; otherwise, set to '0'. If the message contains an S/TLLAO with D=1 and Interface ID 0xffff, the node disables the entire neighbor cache entry. If the message contains multiple S/TLLAOs the D value in each S/TLLAO is consulted.
- o X (the "proXy" bit) is set to '1' in the SLLAO of an RS/RA message when there is a proxy in the path; otherwise, set to '0'. If the message contains multiple SLLAOs, only the X value in the SLLAO with S set to '1' is consulted and the values in other SLLAOs are ignored..
- o N (the "(Network Address) Translator (NAT)" bit) is set to '1' in the SLLAO of an RA message if there is a translator in the path; otherwise, set to '0'.
- o Resvd is set to the value '0' on transmission and ignored on receipt.
- o Interface ID is set to a 16-bit integer value corresponding to a specific underlying interface. Once the MN has assigned an Interface ID to an underlying interface, the assignment MUST remain unchanged until the MN disables the aero interface. The value '0xffff' is reserved as the router Interface ID, i.e.,





routers MUST use Interface ID '0xfff', and MNs MUST number their Interface IDs with values between 0 and 0xfffe.

- o Port Number and Link-Layer Address are set to the addresses assigned to the underlying interface, or to '0' when the addresses are left unspecified. For transmission over physical interfaces such as Ethernet, the Link-Layer Address is set to the same format as in the appropriate interface specification (e.g., IPv6 over Ethernet [[RFC2464](#)]) beginning with the lowest-numbered byte of the field and ending in trailing null padding to a total of 16 bytes. For transmission over tunnel interfaces, the Link-Layer address is set to an IPv6 address for IPv6 encapsulation or an IPv4-mapped IPv6 address for IPv4 encapsulation. When TCP or UDP are used as part of the encapsulation, Port Number is set to the encapsulation protocol port number; otherwise, set to '0'.
- o P(i) is a set of Preferences that correspond to the 64 Differentiated Service Code Point (DSCP) values [[RFC2474](#)]. Each P(i) is set to the value '0' ("disabled"), '1' ("low"), '2' ("medium") or '3' ("high") to indicate a QoS preference level for underlying interface selection purposes.

MNs such as aircraft typically have many wireless data link types (e.g. satellite-based, cellular, terrestrial, air-to-air directional, etc.) with diverse performance, cost and availability properties. From the perspective of ND, the aero interface would therefore appear to have multiple link-layer addresses. In that case, ND messages MAY include multiple S/TLLAOs -- each with an Interface ID that corresponds to a specific underlying interface.

When the MN includes S/TLLAOs solely for the purpose of announcing new QoS preferences, it sets both Port Number and Link-Layer Address to 0 to indicate that the addresses are not to be updated in the router's neighbor cache.

When an ND message includes multiple S/TLLAOs, the S/TLLAO corresponding to the underlying interface used to transmit the message MUST set S to '1'.

## **9. Address Mapping - Multicast**

When the underlying network does not support multicast, aircraft map link-scoped multicast addresses to the link-layer address of a router, which acts as a multicast forwarding agent. The mobile router on board the aircraft also serves as an IGMP/MLD Proxy for its EUNs and/or hosted applications per [[RFC4605](#)] while using the link-layer address of the router as the link-layer address for all multicast packets.



## **10. Router Discovery**

MNs and routers configure aero interfaces that observe the properties discussed in the previous section. The aero interface and its underlying interfaces are said to be in either the "UP" or "DOWN" state according to administrative actions in conjunction with the interface connectivity status. An aero interface transitions to UP or DOWN through administrative action and/or through state transitions of the underlying interfaces. When a first underlying interface transitions to UP, the aero interface also transitions to UP. When all underlying interfaces transition to DOWN, the aero interface also transitions to DOWN.

MNs and routers coordinate through RS/RA exchanges via the aero interface, and use IPv6 ND messages to maintain neighbor cache entries. When an aero interface transitions to UP, the MN sends initial RS messages to assert its MNP and register an initial set of underlying interfaces that are also UP. The MN sends additional RS messages to the router's unicast address to refresh MNP and/or router lifetimes, and to register/deregister underlying interfaces as they transition to UP or DOWN. Routers configure their aero interfaces as advertising interfaces, and therefore send RA messages with configuration information in response to a MN's RS message. Routers send immediate unicast RA responses without delay; therefore, the 'MAX\_RA\_DELAY\_TIME' and 'MIN\_DELAY\_BETWEEN\_RAS' constants for multicast RAs do not apply. Routers MAY send periodic and/or event-driven unsolicited RA messages, but are not required to do so for unicast advertisements [[RFC4861](#)].

The MN sends RS messages from within the aero interface while using an UP underlying interface as the outbound interface. Each message is formatted as an ordinary RS message as though it originated from the IPv6 layer, but the process is coordinated wholly from within the aero interface and is therefore opaque to the IPv6 layer. The MN sends an initial RS message over an UP underlying interface with its base aero address as the source address, all-routers multicast as the destination address and with an SLLAO with a valid Prefix Length for the MNP. The SLLAO also sets S to 1 and contains valid Interface ID and P(i) values appropriate for the underlying interface.

When the router receives the RS message it accepts the message if the prefix assertion was acceptable (otherwise, it drops the message silently). If the prefix assertion was accepted, the router injects the MNP into the routing system then registers the new Interface ID, Port Number, Link-Layer Address and P(i) values in a neighbor cache entry. The router then returns an RA with its aero address as the source address, the aero address of the MN as the destination address and with Router Lifetime set to a non-zero value.



After the MN receives the initial RA confirming the MNP assertion, it notes the router's aero address and uses this address as the destination for all subsequent RS messages it sends to this router. The MN then manages its underlying interfaces according to their states as follows:

- o When an underlying interface transitions to UP, the MN sends an RS over the underlying interface with its base aero address as the source address, the router's aero address as the destination address, and with one or more SLLAOs. The SLLAO corresponding to the underlying interface sets S to 1 and contains valid Interface ID and P(i) values appropriate for this underlying interface, while any additional SLLAOs set S to 0 and contain valid Interface ID and P(i) values appropriate for other underlying interfaces.
- o When an underlying interface transitions to DOWN, the MN sends an RS over any UP underlying interface with an SLLAO for the DOWN underlying interface with D set to 1. The RS may include additional SLLAOs for additional underlying interfaces as above.
- o When a MN wishes to release its router from service, it sends an RS message over any UP underlying interface with an SLLAO with R set to 1. When the router receives the RS message, it withdraws the MNP from the routing system and marks its neighbor cache entry for the MN as "departed". The router then returns an RA message with Router Lifetime set to 0.
- o When all of a MN's underlying interfaces have transitioned to DOWN, the router withdraws the MNP and marks the neighbor cache entry as "departed" the same as if it had received an RS with an SLLAO with R set to 1. This gives rise to the possibility that an underlying network could issue RS messages on the MN's behalf in case the MN is unable to communicate.

The MN is responsible for retrying each RS/RA exchange up to MAX\_RTR\_SOLICITATIONS times separated by RTR\_SOLICITATION\_INTERVAL seconds until an RA is received. If no RA is received, the MN declares the underlying interface DOWN, but MAY try again later, e.g., if underlying link conditions become more favorable.

The IPv6 layer sees the aero interface as an ordinary IPv6 interface. Therefore, when the IPv6 layer sends an RS message over the aero interface, the aero interface must return an internally-generated RA message as though the message originated from the router. The internally-generated RA message must contain configuration information (such as Router Lifetime, MTU, etc.) that is consistent with the information received from the RAs generated by the actual router. Whether the aero interface RS/RA process is initiated from



the receipt of an RS message from the IPv6 layer is an implementation matter. Some implementations may elect to defer the RS/RA process until an RS is received from the IPv6 layer, while others may elect to initiate the RS/RA process independently of any IPv6 layer messaging.

## **11. IANA Considerations**

No IANA actions are required.

## **12. Security Considerations**

Security considerations are the same as defined for the underlying interface types, and readers are referred to the appropriate underlying interface specifications.

IPv6 and IPv6 ND security considerations also apply, and are specified in the normative references.

## **13. Acknowledgements**

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#### **Appendix A. S/TLLAO Extensions for Special-Purpose Links**

The S/TLLAO format specified in [Section 8](#) includes a Length value of 5 (i.e., 5 units of 8 octets). However, special-purpose aero links may extend the basic format to include additional fields and a Length value larger than 5.

For example, adaptation of the aero interface to the Aeronautical Telecommunications Network with Internet Protocol Services (ATN/IPS) includes link selection preferences based on transport port numbers in addition to the existing DSCP-based preferences. ATN/IPS nodes maintain a map of transport port numbers to 64 possible preference fields, e.g., TCP port 22 maps to preference field 8, TCP port 443 maps to preference field 20, UDP port 8060 maps to preference field 34, etc. The extended S/TLLAO format for ATN/IPS is shown in Figure 3, where the Length value is 7 and the 'Q(i)' fields provide link preferences for the corresponding transport port number.



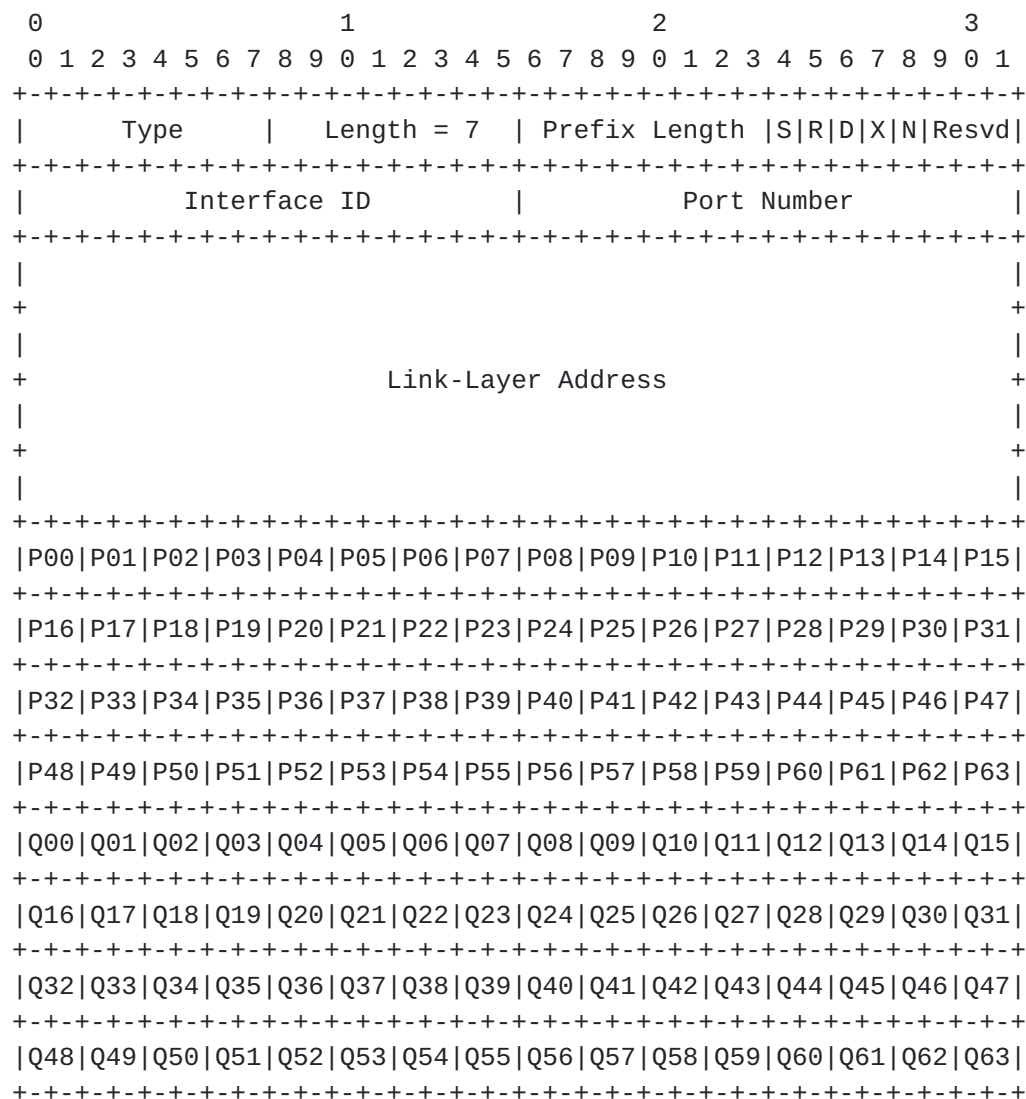


Figure 3: ATN/IPS Extended S/TLLAO Format

## Appendix B. Prefix Length Considerations

The IPv6 addressing architecture [RFC4291] reserves the prefix `::/8`; this assures that MNPs will not begin with `::32` so that MN and router aero addresses cannot overlap. Additionally, this specification observes the 64-bit boundary in IPv6 addresses [RFC7421].

MN aero addresses insert the most-significant 64 MNP bits into the least-significant 64 bits of the prefix `fe80::/64`, however [RFC4291] defines the link-local prefix as `fe80::/10` meaning "fe80" followed by 54 unused bits followed by the least-significant 64 bits of the address. Future versions of this specification may adapt the 54 unused bits for extended coding of MNP prefixes of /65 or longer (up to /118).



## [Appendix C](#). Change Log

<< RFC Editor - remove prior to publication >>

Differences from [draft-templin-atn-aero-interface-00](#) to [draft-templin-atn-aero-interface-01](#):

- o Updates based on list review comments on IETF 'atn' list from 4/29/2019 through 5/7/2019 (issue tracker established)
- o added list of opportunities afforded by the single virtual link model
- o added discussion of encapsulation considerations to [Section 6](#)
- o noted that DupAddrDetectTransmits is set to 0
- o removed discussion of IPv6 ND options for prefix assertions. The aero address already includes the MNP, and there are many good reasons for it to continue to do so. Therefore, also including the MNP in an IPv6 ND option would be redundant.
- o Significant re-work of "Router Discovery" section.
- o New [Appendix B](#) on Prefix Length considerations

First draft version ([draft-templin-atn-aero-interface-00](#)):

- o Draft based on consensus decision of ICAO Working Group I Mobility Subgroup March 22, 2019.

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