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

Mobile nodes (e.g., aircraft of various configurations) communicate with networked correspondents over multiple access network data links and configure mobile routers to connect their on-board networks. Mobile nodes connect to access networks using either the classic or mobility service-enabled link model. 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 independently of the access network data links selected for data transport. The MN performs router discovery the same as for customer edge routers [RFC7084], and acts as a mobile router on behalf of its on-board networks. The MN connects to access networks using either the classic [RFC4861] or Mobility Service (MS)-enabled link model.
In the classic model, all IPv6 Neighbor Discovery (IPv6 ND) messaging is directly over native access network interfaces managed according to the weak end system model. The MN discovers neighbors on the link through link-scoped multicast and/or unicast transmissions that map to their corresponding link layer addresses per standard address resolution / mapping procedures. The MN then coordinates with mobility agents located in the larger Internetwork beyond the first-hop access links by employing an on-board mobility function. This arrangement requires the MN to engage in active mobility messaging on its own behalf and with no assistance from the access network.

In the MS-enabled model, a virtual interface (termed the "aero interface") is configured as a thin layer over the underlying access network 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, while underlying access network interfaces appear as link layer communication channels in the architecture. The aero interface connects to a virtual overlay cloud service known as the "aero link".

Each aero link has one or more associated Mobility Service Prefixes (MSPs) that identify the link. An MSP is an aggregated IPv6 prefix from which aero link MNPs are derived. If the MN connects to multiple aero links, then it configures a separate aero interface for each link.

The aero interface interacts with the ground-domain MS through IPv6 ND control message exchanges [RFC4861]. The MS tracks MN movements and represents their MNPs in a global routing or mapping system.

The aero interface provides a traffic engineering nexus for guiding inbound and outbound traffic to the correct underlying interface(s). The IPv6 layer sees the aero interface as a point of connection to the aero link; if there are multiple aero links (i.e., multiple MS’s), the IPv6 layer will see multiple aero interfaces.

This document specifies the transmission of IPv6 packets [RFC8200] and MN/MS control messaging over aeronautical ("aero") interfaces in the MS-enabled link model, and also includes all necessary details for MN operation in the classic link model.

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:
Access Network (ANET)
a data link service network (e.g., an aviation radio access
network, satellite service provider network, cellular operator
network, etc.) protected by physical and/or link layer security.
Each ANET connects to outside Internetworks via border security
devices such as proxys, firewalls, packet filtering gateways, etc.

ANET interface
a node’s attachment to a link in an ANET.

Internetwork (INET)
a connected network region with a coherent IP addressing plan that
provides transit forwarding services for ANET mobile nodes and
INET correspondents. Examples include private enterprise
networks, aviation networks and the global public Internet itself.

INET interface
a node’s attachment to a link in an INET.

aero link
a virtual overlay cloud service configured over one or more INETs
and their connected ANETs. An aero link may comprise multiple
INET segments joined by bridges the same as for any link; the
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 ANET/INET interfaces.

aero address
an IPv6 link-local address constructed as specified in Section 7,
and assigned to an aero interface.

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 virtual interface configured over one or
more ANET interfaces, which may be physical (e.g., an aeronautical
radio link) or virtual (e.g., an Internet or higher-layer "tunnel").
The MN coordinates with the MS through IPv6 ND message exchanges.
The aero interface architectural layering model is the same as in [RFC7847], and augmented as shown in Figure 1. The IPv6 layer therefore sees the aero interface as a single network layer interface with multiple underlying ANET interfaces that appear as link layer communication channels in the architecture.

```
+----------------------------+
|          TCP/UDP           |
| TCP/UDP                   +---->|                            |
| Address Binding           |     +----------------------------+
| IPv6                     +---->|                            |
| IP Address Binding        |     +----------------------------+
| aero Interface            +---->|       (aero address)       |
| Logical-to-Interface     |     +----------------------------+
| IF#1, IF#2, ..., IF#n    | (IF#1), (IF#2), ..., (IF#n) |
| Binding                  +---->|                            |
| Physical Interface       |     +----------------------------+
| L1 | L1 | L2 | L2 | L2 | L2 |
| Binding                  +---->|                            |
```

Figure 1: Aero Interface Architectural Layering Model

The aero virtual interface model gives rise to a number of opportunities:

- since aero interface link-local addresses are uniquely derived from an MNP (see: Section 7, no Duplicate Address Detection (DAD) messaging is necessary over the aero interface.

- ANET interfaces can remain unnumbered in environments where communications are coordinated entirely over the aero interface.

- as ANET interface properties change (e.g., link quality, cost, availability, etc.), any active ANET interface can be used to update the profiles of multiple additional ANET interfaces in a single message. This allows for timely adaptation and service continuity under dynamically changing conditions.

- coordinating ANET interfaces in this way allows them to be represented in a unified MS profile with provisions for mobility and multilink operations.

- exposing 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 while still permitting queuing at the IPv6 layer based on, e.g., traffic class, flow label, etc.

the IPv6 layer sees the aero interface as a point of connection to the aero link; if there are multiple aero links (i.e., multiple MS’s), the IPv6 layer will see multiple aero interfaces.

Other opportunities are discussed in [RFC7847].

5. Maximum Transmission Unit

All IPv6 interfaces MUST configure an MTU of at least 1280 bytes [RFC8200], while the aero interface configures an MTU based on the largest MTU among all underlying ANET interfaces (up to 9180 bytes).

The aero interface returns internally-generated IPv6 Path MTU Discovery (PMTUD) Packet Too Big (PTB) messages [RFC8201] for packets admitted into the aero interface that are too large for the outbound underlying ANET interface. Similarly, the aero interface performs PMTUD even if the destination appears to be on the same link since a proxy on the path could return a PTB message. PMTUD therefore ensures that the aero interface MTU is adaptive and reflects the current path used for a given data flow.

Applications that cannot tolerate loss due to MTU restrictions should refrain from sending packets larger than 1280 bytes, since dynamic path changes can reduce the path MTU at any time. Applications that may benefit from sending larger packets even though the path MTU may change dynamically can use larger sizes.

6. Frame Format

The aero interface transmits IPv6 packets according to the native frame format of each underlying ANET interface. For example, for Ethernet-compatible interfaces the frame format is specified in [RFC2464], for aeronautical radio interfaces the frame format is specified in standards such as ICAO Doc 9776 (VDL Mode 2 Technical Manual), for tunnels over IPv6 the frame format is exactly as specified in [RFC2473], etc.

7. Link-Local Addresses

A MN "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 each ANET interface (and also to the aero interface in the MS-enabled model). 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). The MN uses the base aero address for IPv6 ND messaging, but accepts packets destined to all aero addresses equally (i.e., the same as for any multi-addressed IPv6 interface).

In the MS-enabled link model, MS endpoint (MSE) aero addresses are allocated from the range fe80::/96, and MUST be managed for uniqueness by the collective aero link administrative authorities. The lower 32 bits of the address includes a unique integer value, e.g., fe80::1, fe80::2, fe80::3, etc. The address fe80:: is the IPv6 link-local Subnet Router Anycast address [RFC4291] and the address fe80::ffff:ffff is reserved; hence, these values are not available for general assignment.

In the classic link model, ANET link devices number their interfaces from the range fe80::/96 the same as above except that these addresses need not be managed for uniqueness outside of the local ANET link. It is therefore possible that different ANET links could reuse numbers from the fe80::/96 space since the addresses are link-scope only.

In a mixed model, both the classic and MS-enabled numbering schemes can be used without conflict within the same ANET, as the two services would be conducted as ships in the night. A mix of MNs operating according to classic and MS-enabled models could then operate within the same ANETs without interference.

Since MN aero addresses are guaranteed unique by the nature of the unique MNP delegation, aero interfaces set the autoconfiguration variable DupAddrDetectTransmits to 0 [RFC4862].
8. Address Mapping - Unicast

Aero interfaces maintain a neighbor cache for tracking per-neighbor state the same as for any IPv6 interface and use the link-local address format specified in Section 7. IPv6 Neighbor Discovery (ND) [RFC4861] messages on aero interfaces use the native Source/Target Link-Layer Address Option (S/TLLAO) formats of the underlying ANET interfaces (e.g., for Ethernet the S/TLLAO is specified in [RFC2464]).

MNPs 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. The aero interface would therefore appear to have multiple link layer connections, and may therefore include information for multiple ANET interfaces in a single message exchange.

Aero interfaces use a new IPv6 ND options called the "Aero Registration (AR)" option. MNPs invoke the MS by including the AR option in Router Solicitation (RS), Neighbor Solicitation and Neighbor Advertisement (NA) messages, and the MS includes the AR option in unicast Router Advertisement (RA) messages.

AR options in a MN’s RS/NS/NA messages are formatted as shown in Figure 2:
### Figure 2: Aero Registration (AR) Option Format in RS/NS/NA Messages

In this format:

- **Type** is set to TBD.

- **Length** is set to the number of 8 octet blocks in the option (with trailing zero padding added if necessary to produce an integral number of 8 octet blocks).
Prefix Length is set to the length of the MNP embedded in the MN’s aero address.

R (the "Register" bit) is set to ‘1’ to assert the MNP registration or set to ‘0’ to request de-registration.

Reserved is set to the value ‘0’ on transmission.

A list of N (ifIndex[i], P[i])-tuples are included as follows:

* ifIndex[i] [RFC2863] is set to a 16-bit integer value corresponding to a specific underlying ANET interface. The first ifIndex MUST correspond to the ANET interface over which the message is sent. Once the MN has assigned an ifIndex to an ANET interface, the assignment MUST remain unchanged until the MN disables the interface. MNs MUST number each ifIndex with a value between ‘1’ and ‘0xffff’.

* P[i] is a per-ifIndex set of Preferences that correspond to the 64 Differentiated Service Code Point (DSCP) values [RFC2474] pertaining to the ANET interface. Each (P00 - P63) field is set to the value ‘0’ ("disabled"), ‘1’ ("low"), ‘2’ ("medium") or ‘3’ ("high") to indicate a QoS preference level for ANET interface selection purposes.

AR options in unicast RA messages from the MS are formatted as shown in Figure 3:

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-----------------------------------------------+
|      Type     |   Length = 1  | Prefix Length |R|  Reserved   |
+-----------------------------------------------+
|                         Prefix Lifetime               |
+-----------------------------------------------+
|                         Prefix Lifetime               |
                      +-----------------------------------------------+
Figure 3: Aero Registration (AR) Option Format in RA messages

In this format:

* Type is set to TBD.

* Length is set to the constant value ’1’ (i.e., 1 unit of 8 octets).

* Prefix Length is set to the length associated with the aero address of the destination MN.
- R is set to ‘1’ to confirm registration or set to ‘0’ to release/decline registration.
- Reserved is set to the value ‘0’ on transmission.
- Prefix Lifetime is set to the time in seconds that the MSE will maintain the Prefix registration.

9. Address Mapping - Multicast

The multicast address mapping of the native underlying ANET interface applies. 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. Address Mapping for IPv6 Neighbor Discovery Messages

Per [RFC4861], IPv6 ND messages may be sent to either a multicast or unicast link-scoped IPv6 destination address. For aero interfaces in the MS-enabled model, however, IPv6 ND messaging must be coordinated between the MN and MS only without invoking other nodes on the ANET.

For this reason, ANET links maintain one or more unicast link-layer address ("MSADDR") for the purpose of supporting MN/MS IPv6 ND messaging. For Ethernet-compatible ANETs, this specification reserves one Ethernet unicast address 00-00-5E-00-52-14. For non-Ethernet statically-addressed ANETs, MSADDR is reserved per the assigned numbers authority for the ANET addressing space. On still other links, one or more MSADDR is discovered through dynamic link-layer beacons received from ANET access routers.

MNs operating according to the MS-enabled model map all IPv6 ND messages they send (i.e., both multicast and unicast) to an MSADDR instead of to an ordinary unicast or multicast link-layer address. In this way, all of the MN’s IPv6 ND messages will be received by MS devices that are configured to accept packets destined to MSADDR (i.e., a point-to-point neighbor model). Note that multiple MS devices on the link could be configured to accept packets destined to MSADDR, e.g., as a basis for virtual router redundancy.

Therefore, ANET access routers MUST accept and process packets destined to MSADDR, while all other devices MUST NOT process packets destined to MSADDR. This model has a well-established operational experience in Proxy Mobile IPv6 (PMIP) [RFC5213][RFC6543].
11. Conceptual Sending Algorithm

The MN’s IPv6 layer selects the outbound aero interface according to standard IPv6 requirements. The aero interface maintains default routes and neighbor cache entries for MSEs, and may also include additional neighbor cache entries created through other means (e.g., Address Resolution, static configuration, etc.).

When the MN sends an NS message for Address Resolution, the aero interface forwards the message to an MSE (see: Section 12) which acts as a link-layer forwarding agent according to the NBMA link model. The resulting NA message will provide link-layer address information for the neighbor. When Neighbor Unreachability Detection is used, the NS/NA exchange confirms reachability the same as for any IPv6 interface.

After a packet enters the aero interface, an outbound ANET interface is selected based on traffic engineering information such as DSCP, application port number, cost, performance, etc. Aero interface traffic engineering could also be configured to perform replication across multiple ANET interfaces for increased reliability at the expense of packet duplication.

When a target neighbor has multiple link-layer addresses (each with a different traffic engineering profile), the aero interface selects ANET interfaces and neighbor link-layer addresses according to both its own outbound preferences and the inbound preferences of the target neighbor.

11.1. Multiple Aero Interfaces

MNs may associate with multiple MS instances concurrently. Each MS instance represents a distinct aero link distinguished by its associated MSPs. The MN configures a separate aero interface for each link so that multiple interfaces (e.g., aero0, aerol, aer02, etc.) are exposed to the IPv6 layer.

Depending on local policy and configuration, an MN may choose between alternative active aero interfaces using a packet’s DSCP, routing information or static configuration. In particular, the MN can add the MSPs received in Prefix Information Options (PIOs) [RFC4861] [RFC8028] as guidance for aero interface selection based on per-packet source addresses.

Each aero interface can be configured over the same or different sets of ANET interfaces. Each ANET distinguishes between the different aero links based on the MSPs represented in per-packet IPv6 addresses.
Multiple distinct aero links can therefore be used to support fault
tolerance, load balancing, reliability, etc. The architectural model
parallels Layer 2 Virtual Local Area Networks (VLANs), where the MSPs
serve as (virtual) VLAN tags.

12. Router Discovery and Prefix Registration

ANET access routers accept IPv6 ND messages destined to the link-
local Subnet Router Anycast Address (fe80::), all-routers multicast
and any unicast link-local IPv6 addresses they are configured to
listen to. ANET access routers that support the classic link model
configure link-local addresses that are guaranteed not to conflict
with MN link-local addresses as discussed in Section 7. ANET access
routers that support the MS-enabled model configure the link-layer
address MSADDR (see: Section 10) and act as proxies for all MSEs from
the range fe80::1 through fe80::ffff:fffe.

MNs that support the classic model perform ordinary RS/RA exchanges
over each ANET the same as for ordinary IPv6 links. ANET access
routers send RAs with an IPv6 link-local source address from the
range fe80::1 through fe80::ffff:fffe that is guaranteed not to
conflict with the MN’s aero address nor the address of any other
routers on the link. The RA messages include normal configuration
options including prefix information, MTU, etc. The MNs are then
responsible for coordinating their ANET interfaces on their own
behalf and for coordinating with any INET-based mobility agents. No
further support from the ANET is needed.

MNs that support the MS-enabled model interface with the MS by
sending RS messages with AR options. For each ANET interface, the MN
sends initial RS messages with AR options with link-layer address set
to MSADDR and with network-layer address set to either a specific MSE
address or to all-routers multicast. The ANET access router receives
the RS messages and contacts the corresponding MSE (when the
destination is all-routers multicast, the access router itself
selects an MSE). When the MSE responds, the ANET access router
returns RA messages with AR options and with any information for the
link that would normally be delivered in a solicited RA message.

Note that some ANET access routers that listen on MSADDR may not be
configured to recognize and/or process AR options. Those access
routers must still obey the requirements of [RFC4861] that state:

"Future versions of this protocol may define new option types.
Receivers MUST silently ignore any options they do not recognize
and continue processing the message."
In that case, the access router processes the RS message and returns an RA message according to the classic link model including any configuration options but without including an AR option. Upon receiving the RA message, the MN must manage this ANET interface according to the classic link model and must not configure it as an underlying interface of the aero interface.

MNs 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.

When an aero interface transitions to UP, the MN sends initial RS messages to register its MNP and an initial set of underlying ANET interfaces that are also UP. The MN sends additional RS messages to refresh lifetimes and to register/deregister underlying ANET interfaces as they transition to UP or DOWN.

MS-enabled ANET access routers coordinate with the MSE and send RA messages with configuration information in response to a MN’s RS messages. The RA includes a Router Lifetime value and PIOs with (A; L=0) that include MSPs for the link. The configuration information may also include Route Information Options (RIO) options [RFC4191] with more-specific routes, and an MTU option that specifies the maximum acceptable packet size for the link. The ANET access router sends immediate unicast RA responses without delay; therefore, the 'MAX_RA_DELAY_TIME' and 'MIN_DELAY_BETWEEN_RAS' constants for multicast RAs do not apply. The ANET access router MAY send periodic and/or event-driven unsolicited RA messages, but is not required to do so for unicast advertisements [RFC4861].

The MN sends RS messages from within the aero interface while using an UP underlying ANET interface as the outbound interface. Each RS message is formatted 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 initial RS messages over an UP underlying interface with its aero address as the source and the address of an MSE as the destination. The RS messages include AR options with a valid Prefix Length as well as ifIndex and P(i) values appropriate for underlying ANET interfaces. The MS-enabled ANET access router processes RS messages and forwards the information in the AR option to the MSE.
When the MSE processes the AR information, if the prefix registration was accepted the MSE injects the MNP into the routing/mapping system then caches the new Prefix Length, MNP, ifIndex and P(i) values. The MSE then returns an RA message to the MN with an AR option with a non-zero Prefix Lifetime if the prefix assertion was acceptable; otherwise, with a zero Prefix Lifetime.

When the MN receives the RA message, it creates a default route with next hop address set to the MSE found in the RA source address and with link-layer address set to MSADDR. The ANET access router will then forward packets acting as a proxy between the MN and the actual MSE.

The MN then manages its underlying ANET interfaces according to their states as follows:

- When an underlying ANET interface transitions to UP, the MN sends an RS over the ANET interface with an AR option. The AR option contains a first ifIndex-tuple with values appropriate for this ANET interface, and may contain additional ifIndex-tuples appropriate for other ANET interfaces.

- When an underlying ANET interface transitions to DOWN, the MN sends an RS or unsolicited NA (uNA) message over any UP ANET interface with an AR option containing an ifIndex-tuple for the DOWN ANET interface with all P(i) values set to ‘0’. The MN sends an RS when an acknowledgement is required, or an uNA when reliability is not thought to be a concern (e.g., if redundant transmissions are sent on multiple ANET interfaces).

- When a MN wishes to release from the current MSE, it sends an RS message over any UP ANET interface with an AR option with R set to 0. The corresponding MSE then withdraws the MNP from the routing/mapping system and returns an RA message with an AR option with Prefix Lifetime set to 0.

- When all of a MNs underlying interfaces have transitioned to DOWN, the MSE withdraws the MNP the same as if it had received a message with an AR option with R set to 0.

The MN is responsible for retrying each RS exchange up to MAX_RTR_SOLICITATIONS times separated by RTR_SOLICITATION_INTERVAL seconds until an RA is received. If no RA is received over multiple UP ANET interfaces, the MN declares this MSE unreachable and tries a different MSE.

The IPv6 layer sees the aero interface as an ordinary IPv6 interface. Therefore, when the IPv6 layer sends an RS message the aero interface
returns an internally-generated RA message as though the message originated from an IPv6 router. The internally-generated RA message contains configuration information (such as Router Lifetime, MTU, etc.) that is consistent with the information received from the RAs generated by the MS.

Whether the aero interface IPv6 ND messaging 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 IPv6 ND messaging process until an RS is received from the IPv6 layer, while others may elect to initiate the process independently of any IPv6 layer messaging.

13. IANA Considerations

The IANA is instructed to allocate an official Type number from the IPv6 Neighbor Discovery Option Formats registry for the Aero Registration (AR) option. Implementations set Type to 253 as an interim value [RFC4727].

The IANA is instructed to allocate one Ethernet unicast address, 00-00-5E-00-52-14 [RFC5214] in the registry "IANA Ethernet Address Block - Unicast Use".

14. Security Considerations

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

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

15. Acknowledgements


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16. References

16.1. Normative References


16.2. Informative References


Appendix A. Aero Registration Option Extensions for Special-Purpose Links

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 aero registration option format for ATN/IPS is shown in Figure 4, where the ‘Q(i)’ fields provide link preferences for the corresponding transport port number.
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 MS aero addresses cannot overlap. Additionally, this specification currently 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). This coding would include MNP bits 64-117 in bits 10-63 of the Aero address while continuing to encode MNP bits 0-63 in the least-significant 64 bits.

Appendix C. VDL Mode 2 Considerations

ICAO Doc 9776 is the "Technical Manual for VHF Data Link Mode 2" (VDLM2) that specifies an essential radio frequency data link service for aircraft and ground stations in worldwide civil aviation air
traffic management. The VDLM2 link type is "multicast capable"
[RFC4861], but with considerable differences from common multicast
links such as Ethernet and IEEE 802.11.

First, the VDLM2 link data rate is only 31.5Kbps - multiple orders of
magnitude less than most modern wireless networking gear. Second,
due to the low available link bandwidth only VDLM2 ground stations
(i.e., and not aircraft) are permitted to send broadcasts, and even
so only as compact layer 2 "beacons". Third, aircraft employ the
services of ground stations by performing unicast RS/RA exchanges
upon receipt of beacons instead of listening for multicast RA
messages and/or sending multicast RS messages.

This beacon-oriented unicast RS/RA approach is necessary to conserve
the already-scarce available link bandwidth. Moreover, since the
numbers of beaconing ground stations operating within a given spatial
range must be kept as sparse as possible, it would not be feasible to
have different classes of ground stations within the same region
observing different protocols. It is therefore highly desirable that
all ground stations observe a common language of RS/RA as specified
in this document.

An aircraft that encounters a beaconing ground station can elect to
solicit either the classic or MS-enabled link models discussed in
Section 12. If the aircraft employs the classic link model, it sends
an RS message with no AR option. The ground station will return an
RA message with no AR option along with any configuration options for
the link (e.g., prefix information, MTU, etc.). If the aircraft
wishes to engage the MS-enabled model, it instead sends an RS message
with an AR option.

Upon receipt of an RS message with an AR option, the ground station
proceeds according to the MS-enabled model if it is configured to do
so. If the ground station does not recognize the AR option (or, if
it is not configured for MS-enabled operation) it instead ignores the
option and processes the rest of the RS message per [RFC4861].

This flexibility notwithstanding, VDLM2 ground stations must be
consistent in terms of the service they offer. In particular, while
it is permissible for a ground station to simultaneously offer
different link models to different aircraft, it should not switch
between the classic and MS-enabled operating models for ongoing RS/RA
exchanges with the same aircraft.
Appendix D. RS/RA Messaging as the Single Standard API

At the ICAO Working Group I Mobility Subgroup meeting in London, July 8-12, 2019 an assertion was made that the MS-enabled link model must employ a different message type besides RS/RA. This was based on the pretext that including a new IPv6 ND option in an RS message would cause routers that do not recognize the option to do "strange things". However, [RFC4861] assures that standards-compliant routers will correctly process an RS with unrecognized options due to the following Section 4.1 requirement:

"Future versions of this protocol may define new option types. Receivers MUST silently ignore any options they do not recognize and continue processing the message."

Indeed, this same normative requirement appeared in both RFC2461 and RFC1970 (the predecessors of RFC2460) dating back to August 1996. Therefore, any router that refused to continue processing an RS message after encountering a properly-formed but unrecognized option would not be standards-compliant and should not be used in any production network capacity.

Assuming for a moment however that a new message type were used to invoke the MS-enabled link model, this would require two message exchanges between the MN and ANET access router - a first exchange with RS/RA with no new IPv6 ND options, and a second exchange with the new message type. However, on links such as VDLM2 (see: Appendix C) the addition of a second message exchange would impart unacceptable delay in closing the link and unacceptable extraneous message overhead that impacts link capacity for all. This clearly indicates a need to include all link establishment and mobility service signaling in a single message exchange and not multiple.

These factors motivate a need for including a new IPv6 ND option in RS/RA messages instead of creating a new message type. Routers that recognize the options can at their discretion either honor or ignore them, while assuring that the MN will be provided with either its first choice or second choice link model. However, service providers that do not offer MN customers their first choice may risk losing business to others that do.

Appendix E. Change Log

<< RFC Editor - remove prior to publication >>

Differences from draft-templin-atn-aero-interface-06 to draft-templin-atn-aero-interface-07:
o Removed "nonce" field from AR option format. Applications that require a nonce can include a standard nonce option if they want to.

o Various editorial cleanups.

Differences from draft-templin-atn-aero-interface-05 to draft-templin-atn-aero-interface-06:

o New Appendix C on "VDL Mode 2 Considerations"

o New Appendix D on "RS/RA Messaging as a Single Standard API"

o Various significant updates in Section 5, 10 and 12.

Differences from draft-templin-atn-aero-interface-04 to draft-templin-atn-aero-interface-05:

o Introduced RFC6543 precedent for focusing IPv6 ND messaging to a reserved unicast link-layer address

o Introduced new IPv6 ND option for Aero Registration

o Specification of MN-to-MSE message exchanges via the ANET access router as a proxy

o IANA Considerations updated to include registration requests and set interim RFC4727 option type value.

Differences from draft-templin-atn-aero-interface-03 to draft-templin-atn-aero-interface-04:

o Removed MNP from aero option format - we already have RIOs and PIOs, and so do not need another option type to include a Prefix.

o Clarified that the RA message response must include an aero option to indicate to the MN that the ANET provides a MS.

o MTU interactions with link adaptation clarified.

Differences from draft-templin-atn-aero-interface-02 to draft-templin-atn-aero-interface-03:

o Sections re-arranged to match RFC4861 structure.

o Multiple aero interfaces

o Conceptual sending algorithm
Differences from draft-templin-atn-aero-interface-01 to draft-templin-atn-aero-interface-02:

- Removed discussion of encapsulation (out of scope)
- Simplified MTU section
- Changed to use a new IPv6 ND option (the "aero option") instead of S/TLLAO
- Explained the nature of the interaction between the mobility management service and the air interface

Differences from draft-templin-atn-aero-interface-00 to draft-templin-atn-aero-interface-01:

- Updates based on list review comments on IETF ‘atn’ list from 4/29/2019 through 5/7/2019 (issue tracker established)
- added list of opportunities afforded by the single virtual link model
- added discussion of encapsulation considerations to Section 6
- noted that DupAddrDetectTransmits is set to 0
- 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.
- Significant re-work of "Router Discovery" section.
- New Appendix B on Prefix Length considerations

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

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

Authors’ Addresses