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**Transmission of IPv6 Packets over Overlay Multilink Network (OMNI)
Interfaces
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Abstract

Mobile nodes (e.g., aircraft of various configurations, terrestrial vehicles, seagoing vessels, mobile enterprise devices, etc.) communicate with networked correspondents over multiple access network data links and configure mobile routers to connect end user networks. A multilink interface specification is therefore needed for coordination with the network-based mobility service. This document specifies the transmission of IPv6 packets over Overlay Multilink Network (OMNI) Interfaces.

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1. Introduction

Mobile Nodes (MNs) (e.g., aircraft of various configurations, terrestrial vehicles, seagoing vessels, mobile enterprise devices, etc.) often have multiple data links for communicating with networked correspondents. These data links may have diverse performance, cost and availability properties that can change dynamically according to mobility patterns, flight phases, proximity to infrastructure, etc. MNs coordinate their data links in a discipline known as "multilink", in which a single virtual interface is configured over the underlying data links.

The MN configures a virtual interface (termed the "Overlay Multilink Network (OMNI) interface") as a thin layer over the underlying Access Network (ANET) interfaces. The OMNI 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 interfaces appear as link layer communication channels in the architecture. The OMNI interface connects to a virtual overlay service known as the "OMNI link". The OMNI link spans a worldwide Internetwork that may include private-use infrastructures and/or the global public Internet itself.

Each MN receives a Mobile Network Prefix (MNP) for numbering downstream-attached End User Networks (EUNs) independently of the access network data links selected for data transport. The MN performs router discovery over the OMNI interface (i.e., similar to IPv6 customer edge routers [[RFC7084](#)]) and acts as a mobile router on behalf of its EUNs. The router discovery process is iterated over each of the OMNI interface's underlying interfaces in order to register per-link parameters (see [Section 12](#)).

The OMNI interface provides a multilink nexus for exchanging inbound and outbound traffic via the correct underlying interface(s). The IPv6 layer sees the OMNI interface as a point of connection to the OMNI link. Each OMNI link has one or more associated Mobility Service Prefixes (MSPs) from which OMNI link MNPs are derived. If there are multiple OMNI links, the IPv6 layer will see multiple OMNI interfaces.

The OMNI interface interacts with a network-based Mobility Service (MS) through IPv6 Neighbor Discovery (ND) control message exchanges [[RFC4861](#)]. The MS provides Mobility Service Endpoints (MSEs) that track MN movements and represent their MNPs in a global routing or mapping system.

This document specifies the transmission of IPv6 packets [[RFC8200](#)] and MN/MS control messaging over OMNI 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. Also, the Protocol Constants defined in [Section 10 of \[RFC4861\]](#) are used in their same format and meaning in this document. The terms "All-Routers multicast", "All-Nodes multicast" and "Subnet-Router anycast" are the same as defined in [RFC4291] (with Link-Local scope assumed).

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

Mobile Node (MN)

an end system with multiple distinct upstream data link connections that are managed together as a single logical unit. The MN's data link connection parameters can change over time due to, e.g., node mobility, link quality, etc. The MN further connects a downstream-attached End User Network (EUN). The term MN used here is distinct from uses in other documents, and does not imply a particular mobility protocol.

End User Network (EUN)

a simple or complex downstream-attached mobile network that travels with the MN as a single logical unit. The IPv6 addresses assigned to EUN devices remain stable even if the MN's upstream data link connections change.

Mobility Service (MS)

a mobile routing service that tracks MN movements and ensures that MNs remain continuously reachable even across mobility events. Specific MS details are out of scope for this document.

Mobility Service Endpoint (MSE)

an entity in the MS (either singular or aggregate) that coordinates the mobility events of one or more MN.

Mobility Service Prefix (MSP)

an aggregated IPv6 prefix (e.g., 2001:db8::/32) advertised to the rest of the Internetwork by the MS, and from which more-specific Mobile Network Prefixes (MNPs) are derived.

Mobile Network Prefix (MNP)

a longer IPv6 prefix taken from an MSP (e.g., 2001:db8:1000:2000::/56) and assigned to a MN. MNs sub-delegate the MNP to devices located in EUNs.

Access Network (ANET)

a data link service network (e.g., an aviation radio access network, satellite service provider network, cellular operator network, wifi network, etc.) that connects MNs. Physical and/or data link level security between the MN and ANET are assumed.

Access Router (AR)

a first-hop router in the ANET for connecting MNs to correspondents in outside Internetworks.

ANET interface

a MN'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 MNs and INET correspondents. Examples include private enterprise networks, ground domain aviation service networks and the global public Internet itself.

INET interface

a node's attachment to a link in an INET.

OMNI link

a virtual overlay configured over one or more INETs and their connected ANETs. An OMNI link can 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.

OMNI interface

a node's attachment to an OMNI link, and configured over one or more underlying ANET/INET interfaces.

OMNI link local address (LLA)

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

OMNI Option

an IPv6 Neighbor Discovery option providing multilink parameters for the OMNI interface as specified in [Section 9](#).

Multilink

an OMNI interface's manner of managing diverse underlying data link interfaces as a single logical unit. The OMNI interface provides a single unified interface to upper layers, while underlying data link selections are performed on a per-packet basis considering factors such as DSCP, flow label, application policy, signal quality, cost, etc. Multilinking decisions are

coordinated in both the outbound (i.e. MN to correspondent) and inbound (i.e., correspondent to MN) directions.

L2

The second layer in the OSI network model. Also known as "layer-2", "link-layer", "sub-IP layer", "data link layer", etc.

L3

The third layer in the OSI network model. Also known as "layer-3", "network-layer", "IPv6 layer", etc.

underlying interface

an ANET/INET interface over which an OMNI interface is configured. The OMNI interface is seen as a L3 interface by the IP layer, and each underlying interface is seen as a L2 interface by the OMNI interface.

Mobility Service Identification (MSID)

Each MSE and AR is assigned a unique 32-bit Identification (MSID) as specified in [Section 7](#).

Spanning Partitioned Administrative Networks (SPAN)

A means for bridging disjoint INET partitions as segments of a unified OMNI link the same as for a bridged campus LAN. The SPAN is a mid-layer IPv6 encapsulation service that supports a unified OMNI link view for all segments.

3. Requirements

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [BCP 14 \[RFC2119\]](#)[RFC8174] when, and only when, they appear in all capitals, as shown here.

An implementation is not required to internally use the architectural constructs described here so long as its external behavior is consistent with that described in this document.

4. Overlay Multilink Network (OMNI) Interface Model

An OMNI interface is a MN virtual interface configured over one or more underlying interfaces, which may be physical (e.g., an aeronautical radio link) or virtual (e.g., an Internet or higher-layer "tunnel"). The MN receives a MNP from the MS, and coordinates with the MS through IPv6 ND message exchanges. The MN uses the MNP to construct a unique OMNI LLA through the algorithmic derivation specified in [Section 7](#) and assigns the LLA to the OMNI interface.

The OMNI interface architectural layering model is the same as in [RFC5558][RFC7847], and augmented as shown in Figure 1. The IP layer therefore sees the OMNI interface as a single L3 interface with multiple underlying interfaces that appear as L2 communication channels in the architecture.

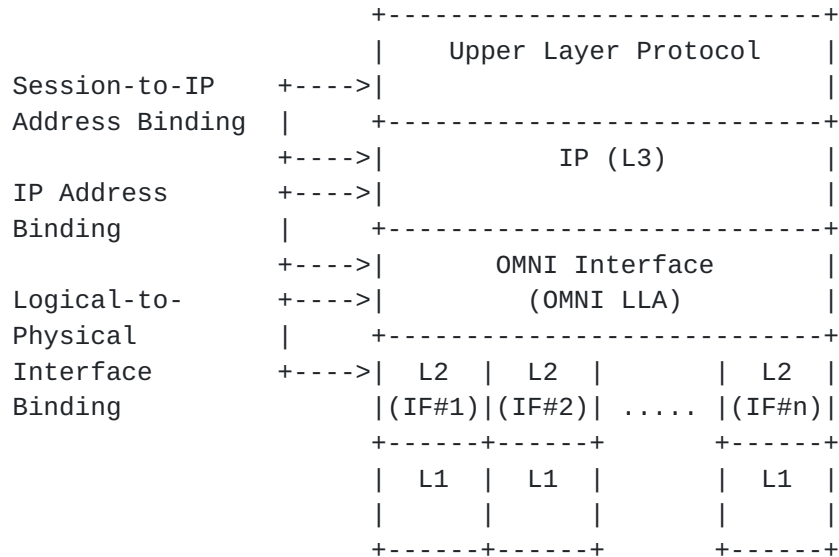


Figure 1: OMNI Interface Architectural Layering Model

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

- o since OMNI LLAs are uniquely derived from an MNP, no Duplicate Address Detection (DAD) or Multicast Listener Discovery (MLD) messaging is necessary.
- o ANET interfaces do not require any L3 addresses (i.e., not even link-local) in environments where communications are coordinated entirely over the OMNI interface. (An alternative would be to also assign the same OMNI LLA to all ANET interfaces.)
- o 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.
- o coordinating ANET interfaces in this way allows them to be represented in a unified MS profile with provisions for mobility and multilink operations.

- o exposing a single virtual interface abstraction to the IPv6 layer allows for multilink operation (including QoS based link selection, packet replication, load balancing, etc.) at L2 while still permitting L3 traffic shaping based on, e.g., DSCP, flow label, etc.
- o L3 sees the OMNI interface as a point of connection to the OMNI link; if there are multiple OMNI links (i.e., multiple MS's), L3 will see multiple OMNI interfaces.

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

Figure 2 depicts the architectural model for a MN connecting to the MS via multiple independent ANETs. When an underlying interface becomes active, the MN's OMNI interface sends native (i.e., unencapsulated) IPv6 ND messages via the underlying interface. IPv6 ND messages traverse the ground domain ANETs until they reach an Access Router (AR#1, AR#2, .., AR#n). The AR then coordinates with a Mobility Service Endpoint (MSE#1, MSE#2, ..., MSE#m) in the INET and returns an IPv6 ND message response to the MN. IPv6 ND messages traverse the ANET at layer 2; hence, the Hop Limit is not decremented.

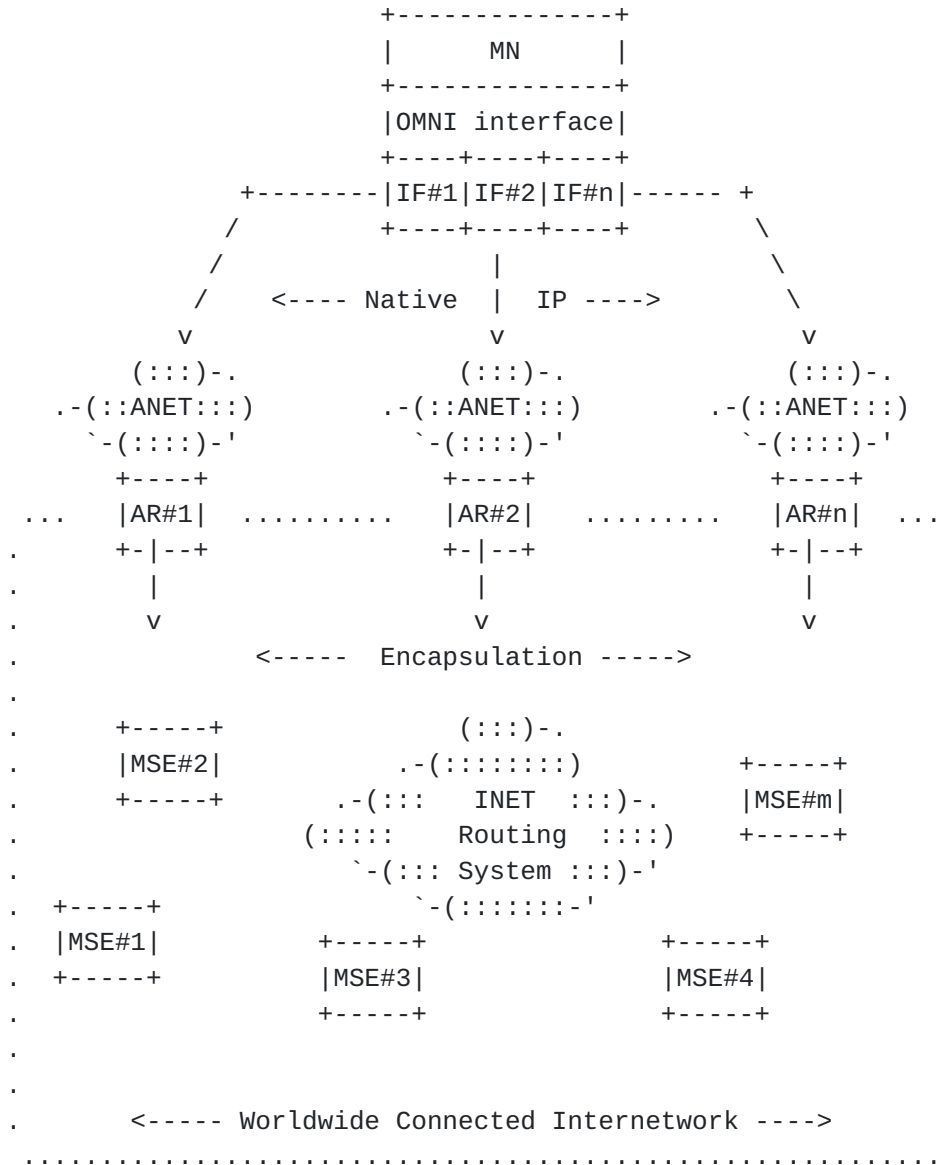


Figure 2: MN/MS Coordination via Multiple ANETs

After the initial IPv6 ND message exchange, the MN can send and receive unencapsulated IPv6 data packets over the OMNI interface. OMNI interface multilink services will forward the packets via ARs in the correct underlying ANETs. The AR encapsulates the packets according to the capabilities provided by the MS and forwards them to the next hop within the worldwide connected Internetwork via optimal routes.

OMNI links span the underlying Internetwork via a mid-layer overlay known as "The SPAN" - see [Section 8](#). Each OMNI link corresponds to a different SPAN overlay (possibly differentiated by a SPAN header codepoint) which may be carried over a completely separate

Internetwork topology. The same as for VLANs, each MN can connect to multiple OMNI links (i.e., multiple SPANs) by configuring a distinct OMNI interface for each link.

5. Maximum Transmission Unit (MTU) and Fragmentation

All IPv6 interfaces are REQUIRED to configure a minimum Maximum Transmission Unit (MTU) of 1280 bytes [[RFC8200](#)]. The network therefore MUST forward packets of at least 1280 bytes without generating an IPv6 Path MTU Discovery (PMTUD) Packet Too Big (PTB) message [[RFC8201](#)].

The OMNI interface configures an MTU of 9180 bytes [[RFC2492](#)]; the size is therefore not a reflection of the underlying interface MTUs, but rather determines the largest packet the OMNI interface can forward or reassemble. The OMNI interface therefore accommodates IP packets up to 9180 bytes while generating IPv6 Path MTU Discovery (PMTUD) Packet Too Big (PTB) messages [[RFC8201](#)] as necessary (see below).

OMNI interfaces employ mid-layer IPv6 encapsulation and fragmentation/reassembly per [[RFC2473](#)] (also known as "SPAN encapsulation" - see [Section 8](#)) to accommodate the 9180 byte MTU. The OMNI interface returns internally-generated PTB messages for packets admitted into the interface that it deems too large (e.g., according to link performance characteristics, reassembly cost, etc.) while either dropping or forwarding the packet as necessary. The OMNI interface performs PMTUD even if the destination appears to be on the same link since an OMNI link node on the path may return a PTB. This ensures that the path MTU is adaptive and reflects the current path used for a given data flow.

OMNI interfaces perform SPAN encapsulation and fragmentation/reassembly as follows:

- o When an OMNI interface sends a packet toward a final destination via an ANET peer, it sends without SPAN encapsulation if the packet is no larger than the underlying interface MTU. Otherwise, it inserts a SPAN header with source address set to the node's own SPAN address and destination set to the SPAN address of the ANET peer. The OMNI interface then uses IPv6 fragmentation to break the packet into a minimum number of non-overlapping fragments, where the largest fragment size is determined by the underlying interface MTU and the smallest fragment is no smaller than 640 bytes. The OMNI interface then sends the fragments to the ANET peer, which reassembles before forwarding toward the final destination.

- o When an OMNI interface sends a packet toward a final destination via an INET interface, it sends encapsulated packets no larger than 1280 bytes without a SPAN header if the destination is reached via an INET address within the same SPAN segment. Otherwise, it inserts a SPAN header with source address set to the node's SPAN address, destination set to the SPAN address of the next hop OMNI node toward the final destination and (if necessary) with a Segment Routing Header [[RFC8754](#)] with the remaining Segment IDs on the path to the final destination. The OMNI interface then uses IPV6 fragmentation to break the encapsulated packet into a minimum number of non-overlapping fragments, where the largest fragment size (including both SPAN and INET encapsulation) is 1280 bytes and the smallest fragment is no smaller than 640 bytes. The OMNI interface then sends the fragments to the SPAN destination, which reassembles before forwarding toward the final destination.

In order to avoid a "tiny fragment" attack, OMNI interfaces unconditionally drop all SPAN fragments smaller than 640 bytes. In order to set the correct context for reassembly, the OMNI interface that inserts a SPAN header MUST also be the one that inserts the IPV6 Fragment Header Identification value. Although all fragments of the same fragmented SPAN packet are typically sent via the same underlying interface, this is not strictly required since all fragments will arrive at the OMNI interface that performs reassembly even if they travel over different paths.

Note that the OMNI interface can forward large packets via encapsulation and fragmentation while at the same time returning advisory PTB messages, e.g., subject to rate limiting. The receiving node that performs reassembly can also send advisory PTB messages if reassembly conditions become unfavorable. The AERO interface can therefore continuously forward large packets without loss while returning advisory messages recommending a smaller size (but no smaller than 1280). Advisory PTB messages are differentiated from PTB messages that report loss by setting the Code field in the ICMPV6 message header to the value 1. This document therefore updates [[RFC4443](#)] and [[RFC8201](#)].

6. Frame Format

The OMNI interface transmits IPV6 packets according to the native frame format of each underlying 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 specified in [[RFC2473](#)], etc.

7. Link-Local Addresses

OMNI interfaces assign IPv6 Link-Local Addresses (i.e., "OMNI LLAs") using the following constructs:

- o IPv6 MN OMNI LLAs encode the most-significant 112 bits of a MNP within the least-significant 112 bits of the IPv6 link-local prefix `fe80::/16`. For example, for the MNP `2001:db8:1000:2000::/56` the corresponding LLA is `fe80:2001:db8:1000:2000::`. See: [\[RFC4291\]](#), [Section 2.5.6](#)) for a discussion of IPv6 link-local addresses.
- o IPv4-compatible MN OMNI LLAs are assigned as `fe80::ffff:[v4addr]`, i.e., the most significant 16 bits of the prefix `fe80::/16`, followed by 64 '0' bits, followed by 16 '1' bits, followed by a 32bit IPv4 address. For example, the IPv4-Compatible MN OMNI LLA for 192.0.2.1 is `fe80::ffff:192.0.2.1` (also written as `fe80::ffff:c000:0201`).
- o MS OMNI LLAs are assigned to ARs and MSEs from the range `fe80::/96`, and MUST be managed for uniqueness. The lower 32 bits of the LLA includes a unique integer "MSID" value between `0x00000001` and `0xfeffffff`, e.g., as in `fe80::1`, `fe80::2`, `fe80::3`, etc., `fe80::feff:ffff`. The MSID `0x00000000` corresponds to the link-local Subnet-Router anycast address (`fe80::`) [\[RFC4291\]](#). The MSID range `0xff000000` through `0xffffffff` is reserved for future use.
- o The OMNI LLA range `fe80::/32` is used as the Teredo service prefix for OMNI interfaces according to the format in [Section 4 of \[RFC4380\]](#) (see [Section 17](#) for further discussion).

Since the prefix `0000::/8` is "Reserved by the IETF" [\[RFC4291\]](#), no MNPs can be allocated from that block ensuring that there is no possibility for overlap between the above OMNI LLA constructs.

Since MN OMNI LLAs are based on the distribution of administratively assured unique MNPs, and since MS OMNI LLAs are guaranteed unique through administrative assignment, OMNI interfaces set the autoconfiguration variable `DupAddrDetectTransmits` to 0 [\[RFC4862\]](#).

8. The SPAN

OMNI links employ an overlay network instance called "The SPAN" (Spanning Partitioned Administrative Networks) that supports forwarding of encapsulated link-scoped messages over an IPv6 overlay routing instance that spans the entire link without decrementing the (link-local) Hop Limit. The OMNI link reserves the Unique Local

Address (ULA) prefix `fd80::/10` [[RFC4193](#)] used for mapping OMNI LLAs to routable SPAN addresses.

SPAN addresses are configured in one-to-one correspondence with MN/MS OMNI LLAs through stateless translation of the prefix. For example, for the SPAN sub-prefix `fd80::/16`:

- o the SPAN address corresponding to `fe80:2001:db8:1:2::` is simply `fd80:2001:db8:1:2::`
- o the SPAN address corresponding to `fe80::ffff:192.0.2.1` is simply `fd80::ffff:192.0.2.1`
- o the SPAN address corresponding to `fe80::1000` is simply `fd80::1000`

The SPAN address presents an IPv6 address format that is routable within the OMNI link routing system and can be used to convey link-scoped messages across multiple hops using IPv6 encapsulation [[RFC2473](#)]. The SPAN extends over the entire OMNI link to include all ARs and MSEs. All MNs are also considered to be "on the SPAN", however SPAN encapsulation is omitted over ANET links when possible to conserve bandwidth (see: [Section 11](#)).

The SPAN allows the OMNI link to be subdivided into "segments" that often correspond to administrative domains or physical partitions. OMNI nodes can use IPv6 Segment Routing [[RFC8754](#)][[RFC8402](#)] when necessary to support efficient packet forwarding to destinations located in other SPAN segments. A full discussion of Segment Routing over the SPAN appears in [[I-D.templin-intarea-6706bis](#)].

9. Address Mapping - Unicast

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

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. The OMNI interface would therefore appear to have multiple L2 connections, and may include information for multiple underlying interfaces in a single IPv6 ND message exchange.

OMNI interfaces use an IPv6 ND option called the "OMNI option" formatted as shown in Figure 3:

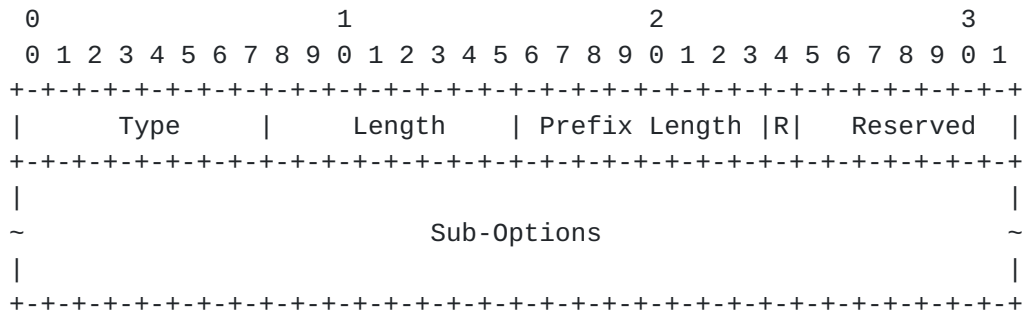


Figure 3: OMNI Option Format

In this format:

- o Type is set to TBD.
- o Length is set to the number of 8 octet blocks in the option.
- o Prefix Length is set according to the IPv6 source address type. For MN OMNI LLAs, the value is set to the length of the embedded MNP. For IPv4-compatible MN OMNI LLAs, the value is set to 96 plus the length of the embedded IPv4 prefix. For MS OMNI LLAs, the value is set to 128.
- o R (the "Register/Release" bit) is set to 1/0 to request the message recipient to register/release a MN's MNP. The OMNI option may additionally include MSIDs for the recipient to contact to also register/release the MNP.
- o Reserved is set to the value '0' on transmission and ignored on reception.
- o Sub-Options is a Variable-length field, of length such that the complete OMNI Option is an integer multiple of 8 octets long. Contains one or more options, as described in [Section 9.1](#).

9.1. Sub-Options

The OMNI option includes zero or more Sub-Options, some of which may appear multiple times in the same message. Each consecutive Sub-Option is concatenated immediately after its predecessor. All Sub-Options except Pad1 (see below) are type-length-value (TLV) encoded in the following format:

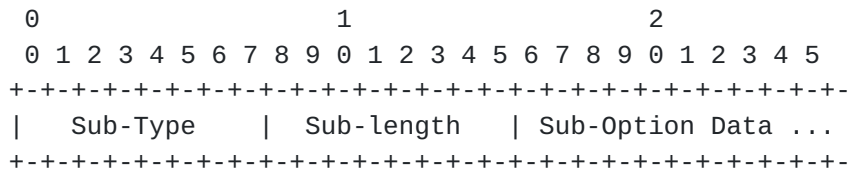


Figure 4: Sub-Option Format

- o Sub-Type is a 1-byte field that encodes the Sub-Option type. Sub-Options defined in this document are:

Option Name	Sub-Type
Pad1	0
PadN	1
ifIndex-tuple (Type 1)	2
ifIndex-tuple (Type 2)	3
MS-Register	4
MS-Release	5

Figure 5

Sub-Types 253 and 254 are reserved for experimentation, as recommended in [[RFC3692](#)].

- o Sub-Length is a 1-byte field that encodes the length of the Sub-Option Data, in bytes
- o Sub-Option Data is a byte string with format determined by Sub-Type

During processing, unrecognized Sub-Options are ignored and the next Sub-Option processed until the end of the OMNI option.

The following Sub-Option types and formats are defined in this document:

9.1.1. Pad1

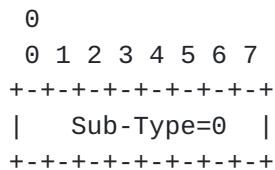


Figure 6: Pad1

- o Sub-Type is set to 0.

- o No Sub-Length or Sub-Option Data follows (i.e., the "Sub-Option" consists of a single zero octet).

9.1.2. PadN

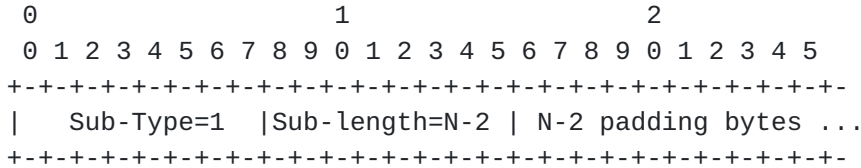


Figure 7: PadN

- o Sub-Type is set to 1.
- o Sub-Length is set to N-2 being the number of padding bytes that follow.
- o Sub-Option Data consists of N-2 zero-valued octets.

9.1.3. ifIndex-tuple (Type 1)

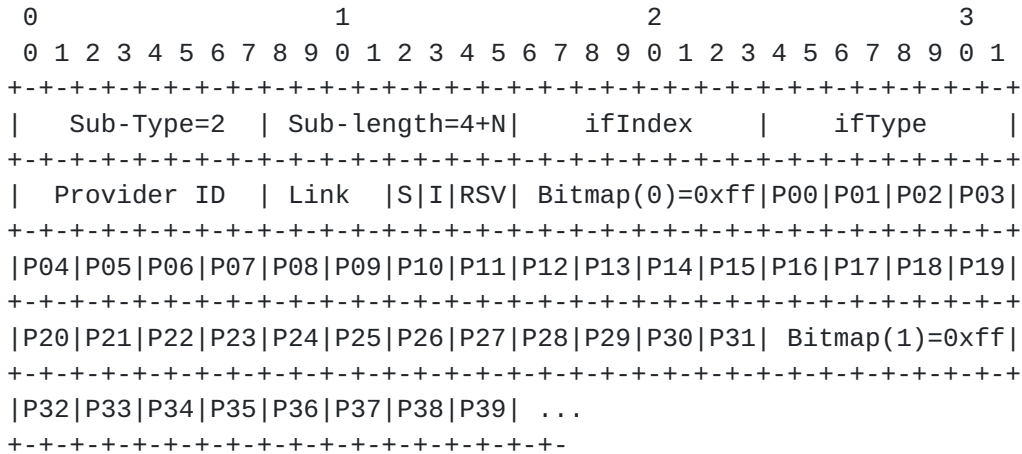


Figure 8: ifIndex-tuple (Type 1)

- o Sub-Type is set to 2.
- o Sub-Length is set to 4+N (the number of Sub-Option Data bytes that follow).
- o Sub-Option Data contains an "ifIndex-tuple" (Type 1) encoded as follows (note that the first four bytes must be present):
 - * ifIndex is set to an 8-bit integer value corresponding to a specific underlying interface. OMNI options MAY include

multiple ifIndex-tuples, and MUST number each with an ifIndex value between '1' and '255' that represents a MN-specific 8-bit mapping for the actual ifIndex value assigned to the underlying interface by network management [RFC2863] (the ifIndex value '0' is reserved for use by the MS). Multiple ifIndex-tuples with the same ifIndex value MAY appear in the same OMNI option.

- * ifType is set to an 8-bit integer value corresponding to the underlying interface identified by ifIndex. The value represents an OMNI interface-specific 8-bit mapping for the actual IANA ifType value registered in the 'IANAifType-MIB' registry [http://www.iana.org].
- * Provider ID is set to an OMNI interface-specific 8-bit ID value for the network service provider associated with this ifIndex.
- * Link encodes a 4-bit link metric. The value '0' means the link is DOWN, and the remaining values mean the link is UP with metric ranging from '1' ("lowest") to '15' ("highest").
- * S is set to '1' if this ifIndex-tuple corresponds to the underlying interface that is the source of the ND message. Set to '0' otherwise.
- * I is set to '0' ("Simplex") if the index for each singleton Bitmap byte in the Sub-Option Data is inferred from its sequential position (i.e., 0, 1, 2, ...), or set to '1' ("Indexed") if each Bitmap is preceded by an Index byte. Figure 8 shows the simplex case for I set to '0'. For I set to '1', each Bitmap is instead preceded by an Index byte that encodes a value "i" = (0 - 255) as the index for its companion Bitmap as follows:

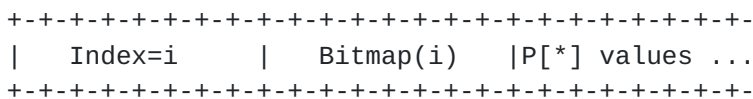


Figure 9

- * RSV is set to the value 0 on transmission and ignored on reception.
- * The remainder of the Sub-Option Data contains N = (0 - 251) bytes of traffic classifier preferences consisting of a first (indexed) Bitmap (i.e., "Bitmap(i)") followed by 0-8 1-byte blocks of 2-bit P[*] values, followed by a second Bitmap (i), followed by 0-8 blocks of P[*] values, etc. Reading from bit 0 to bit 7, the bits of each Bitmap(i) that are set to '1'

indicate the P[*] blocks from the range P[(i*32)] through P[(i*32) + 31] that follow; if any Bitmap(i) bits are '0', then the corresponding P[*] block is instead omitted. For example, if Bitmap(0) contains 0xff then the block with P[00]-P[03], followed by the block with P[04]-P[07], etc., and ending with the block with P[28]-P[31] are included (as shown in Figure 8). The next Bitmap(i) is then consulted with its bits indicating which P[*] blocks follow, etc. out to the end of the Sub-Option. The first 16 P[*] blocks correspond to the 64 Differentiated Service Code Point (DSCP) values P[00] - P[63] [RFC2474]. Any additional P[*] blocks that follow correspond to "pseudo-DSCP" traffic classifier values P[64], P[65], P[66], etc. See [Appendix A](#) for further discussion and examples.

- * Each 2-bit P[*] field 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. Not all P[*] values need to be included in all OMNI option instances of a given ifIndex-tuple. Any P[*] values represented in an earlier OMNI option but omitted in the current OMNI option remain unchanged. Any P[*] values not yet represented in any OMNI option default to "medium".

9.1.4. ifIndex-tuple (Type 2)

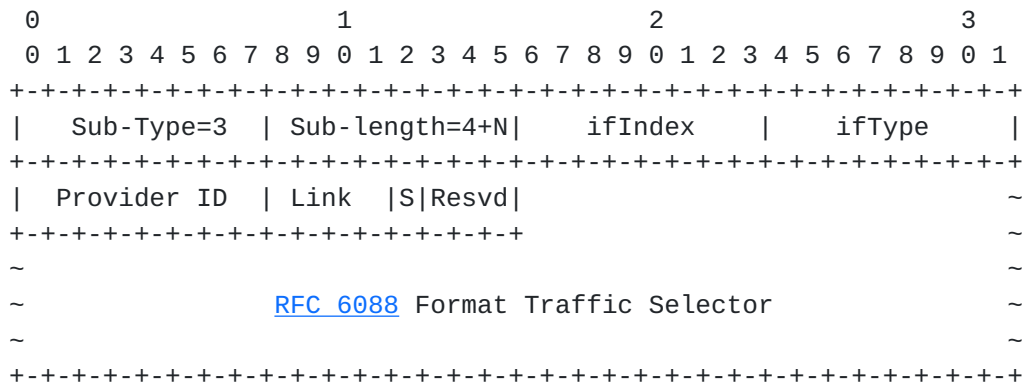


Figure 10: ifIndex-tuple (Type 2)

- o Sub-Type is set to 3.
- o Sub-Length is set to 4+N (the number of Sub-Option Data bytes that follow).
- o Sub-Option Data contains an "ifIndex-tuple" (Type 2) encoded as follows (note that the first four bytes must be present):

- * ifIndex, ifType, Provider ID, Link and S are set exactly as for Type 1 ifIndex-tuples as specified in [Section 9.1.3](#).
- * the remainder of the Sub-Option body encodes a variable-length traffic selector formatted per [\[RFC6088\]](#), beginning with the "TS Format" field.

9.1.5. MS-Register

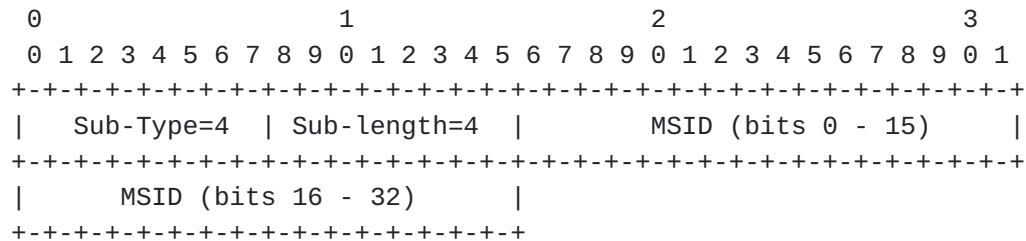


Figure 11: MS-Register Sub-option

- o Sub-Type is set to 4.
- o Sub-Length is set to 4.
- o MSID contains the 32 bit ID of an MSE or AR, in network byte order. OMNI options contain zero or more MS-Register sub-options.

9.1.6. MS-Release

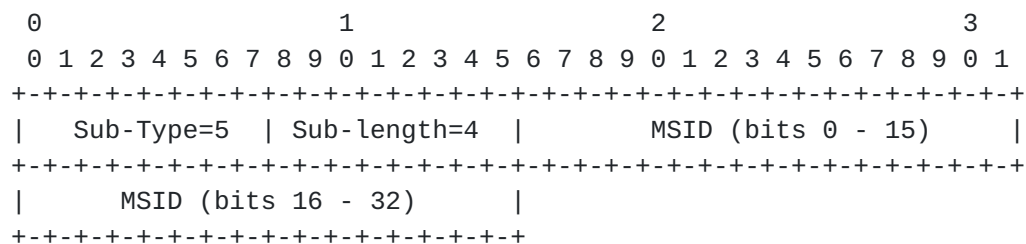


Figure 12: MS-Release Sub-option

- o Sub-Type is set to 5.
- o Sub-Length is set to 4.
- o MSIID contains the 32 bit ID of an MS or AR, in network byte order. OMNI options contain zero or more MS-Release sub-options.

10. Address Mapping - Multicast

The multicast address mapping of the native underlying interface applies. The mobile router on board the MN also serves as an IGMP/MLD Proxy for its EUNs and/or hosted applications per [\[RFC4605\]](#) while using the L2 address of the AR as the L2 address for all multicast packets.

The MN uses Multicast Listener Discovery (MLDv2) [\[RFC3810\]](#) to coordinate with the AR, and ANET L2 elements use MLD snooping [\[RFC4541\]](#).

11. Conceptual Sending Algorithm

The MN's IPv6 layer selects the outbound OMNI interface according to standard IPv6 requirements when forwarding data packets from local or EUN applications to external correspondents. The OMNI interface maintains a neighbor cache the same as for any IPv6 interface, but with additional state for multilink coordination.

After a packet enters the OMNI interface, an outbound underlying interface is selected based on multilink parameters such as DSCP, application port number, cost, performance, message size, etc. OMNI interface multilink selections could also be configured to perform replication across multiple underlying interfaces for increased reliability at the expense of packet duplication.

When an OMNI interface sends a packet over a selected outbound underlying interface, it omits SPAN encapsulation if the packet does not require fragmentation and the neighbor can determine the SPAN addresses through other means (e.g., the packet's destination, neighbor cache information, etc.). Otherwise, the OMNI interface inserts a SPAN header and performs fragmentation if necessary.

OMNI interface multilink service designers MUST observe the BCP guidance in [Section 15 \[RFC3819\]](#) in terms of implications for reordering when packets from the same flow may be spread across multiple underlying interfaces having diverse properties.

11.1. Multiple OMNI Interfaces

MNs may associate with multiple MS instances concurrently. Each MS instance represents a distinct OMNI link distinguished by its associated MSPs. The MN configures a separate OMNI interface for each link so that multiple interfaces (e.g., omni0, omni1, omni2, etc.) are exposed to the IPv6 layer.

Depending on local policy and configuration, an MN may choose between alternative active OMNI interfaces using a packet's DSCP, routing information or static configuration. Each OMNI interface can be configured over the same or different sets of underlying interfaces.

Multiple distinct OMNI links can therefore be used to support fault tolerance, load balancing, reliability, etc. The architectural model parallels Layer 2 Virtual Local Area Networks (VLANs).

12. Router Discovery and Prefix Registration

MNs interface with the MS by sending RS messages with OMNI options under the assumption that a single AR on the ANET will process the message and respond. This places a requirement on each ANET, which may be enforced by physical/logical partitioning, L2 AR beaconing, etc. The manner in which the ANET ensures single AR coordination is link-specific and outside the scope of this document.

For each underlying interface, the MN sends an RS message with an OMNI option with prefix registration information, ifIndex-tuples, MS-Register/Release suboptions containing MSIDs, and with destination address set to All-Routers multicast (ff02::2) [[RFC4291](#)]. Example MSID discovery methods are given in [[RFC5214](#)], including data link login parameters, name service lookups, static configuration, etc. Alternatively, MNs can discover individual MSIDs by sending an initial RS with MS-Register MSID set to 0x00000000.

MNs configure OMNI interfaces that observe the properties discussed in the previous section. The OMNI 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 OMNI 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 OMNI interface also transitions to UP. When all underlying interfaces transition to DOWN, the OMNI interface also transitions to DOWN.

When an OMNI interface transitions to UP, the MN sends RS messages to register its MNP and an initial set of underlying interfaces that are also UP. The MN sends additional RS messages to refresh lifetimes and to register/deregister underlying interfaces as they transition to UP or DOWN. The MN sends initial RS messages over an UP underlying interface with its OMNI LLA as the source and with destination set to All-Routers multicast. The RS messages include an OMNI option per [Section 9](#) with valid prefix registration information, ifIndex-tuples appropriate for underlying interfaces and MS-Register/Release sub-options.

ARs process IPv6 ND messages with OMNI options and act as a proxy for MSEs. ARs receive RS messages and create a neighbor cache entry for the MN, then coordinate with any named MSIDs in a manner outside the scope of this document. The AR returns an RA message with destination address set to the MN OMNI LLA (i.e., unicast), with source address set to its MS OMNI LLA, with the P(roxy) bit set in the RA flags [[RFC4389](#)][[RFC5175](#)], with an OMNI option with valid prefix registration information, ifIndex-tuples, MS-Register/Release sub-options, and with any information for the link that would normally be delivered in a solicited RA message. ARs return RA messages with configuration information in response to a MN's RS messages. The AR sets the RA Cur Hop Limit, M and O flags, Router Lifetime, Reachable Time and Retrans Timer values, and includes any necessary options such as:

- o PIOs with (A; L=0) that include MSPs for the link [[RFC8028](#)].
- o RIOs [[RFC4191](#)] with more-specific routes.
- o an MTU option that specifies the maximum acceptable packet size for this ANET interface.

The AR coordinates with each Register/Release MSID then sends an immediate unicast RA response without delay; therefore, the IPv6 ND MAX_RA_DELAY_TIME and MIN_DELAY_BETWEEN_RAS constants for multicast RAs do not apply. The AR MAY send periodic and/or event-driven unsolicited RA messages according to the standard [[RFC4861](#)].

When the MSE processes the OMNI information, it first validates the prefix registration information. The MSE then injects/withdraws the MNP in the routing/mapping system and caches/discards the new Prefix Length, MNP and ifIndex-tuples. The MSE then informs the AR of registration success/failure, and the AR adds the MSE to the list of Register/Release MSIDs to return in an RA message OMNI option per [Section 9](#).

When the MN receives the RA message, it creates an OMNI interface neighbor cache entry with the AR's address as an L2 address and records the MSIDs that have confirmed MNP registration via this AR. If the MN connects to multiple ANETs, it establishes additional AR L2 addresses (i.e., as a Multilink neighbor). 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 an OMNI option with R set to 1. The OMNI option contains at least one ifIndex-tuple with values specific to this underlying interface, and may contain additional

ifIndex-tuples specific to this and/or other underlying interfaces. The option also includes any Register/Release MSIDs.

- o When an underlying interface transitions to DOWN, the MN sends an RS or unsolicited NA message over any UP underlying interface with an OMNI option containing an ifIndex-tuple for the DOWN underlying interface with Link set to '0'. The MN sends an RS when an acknowledgement is required, or an unsolicited NA when reliability is not thought to be a concern (e.g., if redundant transmissions are sent on multiple underlying interfaces).
- o When the Router Lifetime for a specific AR nears expiration, the MN sends an RS over the underlying interface to receive a fresh RA. If no RA is received, the MN marks the underlying interface as DOWN.
- o When a MN wishes to release from one or more current MSIDs, it sends an RS or unsolicited NA message over any UP underlying interfaces with an OMNI option with a Release MSID. Each MSID then withdraws the MNP from the routing/mapping system and informs the AR that the release was successful.
- o When all of a MNs underlying interfaces have transitioned to DOWN (or if the prefix registration lifetime expires), any associated MSEs withdraw the MNP the same as if they had received a message with a release indication.

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 a an UP underlying interface, the MN declares this underlying interface as DOWN.

The IPv6 layer sees the OMNI interface as an ordinary IPv6 interface. Therefore, when the IPv6 layer sends an RS message the OMNI interface returns an internally-generated RA message as though the message originated from an IPv6 router. The internally-generated RA message contains configuration information that is consistent with the information received from the RAs generated by the MS. Whether the OMNI 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 proactively.

Note: The Router Lifetime value in RA messages indicates the time before which the MN must send another RS message over this underlying interface (e.g., 600 seconds), however that timescale may be

significantly longer than the lifetime the MS has committed to retain the prefix registration (e.g., REACHABLETIME seconds). ARs are therefore responsible for keeping MS state alive on a shorter timescale than the MN is required to do on its own behalf.

13. Secure Redirection

If the ANET link model is multiple access, the AR is responsible for assuring that address duplication cannot corrupt the neighbor caches of other nodes on the link. When the MN sends an RS message on a multiple access ANET link, the AR verifies that the MN is authorized to use the address and returns an RA with a non-zero Router Lifetime only if the MN is authorized.

After verifying MN authorization and returning an RA, the AR MAY return IPv6 ND Redirect messages to direct MNs located on the same ANET link to exchange packets directly without transiting the AR. In that case, the MNs can exchange packets according to their unicast L2 addresses discovered from the Redirect message instead of using the dogleg path through the AR. In some ANET links, however, such direct communications may be undesirable and continued use of the dogleg path through the AR may provide better performance. In that case, the AR can refrain from sending Redirects, and/or MNs can ignore them.

14. AR and MSE Resilience

ANETs SHOULD deploy ARs in Virtual Router Redundancy Protocol (VRRP) [[RFC5798](#)] configurations so that service continuity is maintained even if one or more ARs fail. Using VRRP, the MN is unaware which of the (redundant) ARs is currently providing service, and any service discontinuity will be limited to the failover time supported by VRRP. Widely deployed public domain implementations of VRRP are available.

MSEs SHOULD use high availability clustering services so that multiple redundant systems can provide coordinated response to failures. As with VRRP, widely deployed public domain implementations of high availability clustering services are available. Note that special-purpose and expensive dedicated hardware is not necessary, and public domain implementations can be used even between lightweight virtual machines in cloud deployments.

15. Detecting and Responding to MSE Failures

In environments where fast recovery from MSE failure is required, ARs SHOULD use proactive Neighbor Unreachability Detection (NUD) in a manner that parallels Bidirectional Forwarding Detection (BFD) [[RFC5880](#)] to track MSE reachability. ARs can then quickly detect and

react to failures so that cached information is re-established through alternate paths. Proactive NUD control messaging is carried only over well-connected ground domain networks (i.e., and not low-end ANET links such as aeronautical radios) and can therefore be tuned for rapid response.

ARs perform proactive NUD for MSEs for which there are currently active MNs on the ANET. If an MSE fails, ARs can quickly inform MNs of the outage by sending multicast RA messages on the ANET interface. The AR sends RA messages to MNs via the ANET interface with an OMNI option with a Release ID for the failed MSE, and with destination address set to All-Nodes multicast (ff02::1) [[RFC4291](#)].

The AR SHOULD send MAX_FINAL_RTR_ADVERTISEMENTS RA messages separated by small delays [[RFC4861](#)]. Any MNs on the ANET interface that have been using the (now defunct) MSE will receive the RA messages and associate with a new MSE.

16. Transition Considerations

When a MN connects to an ANET link for the first time, it sends an RS message with an OMNI option. If the first hop AR recognizes the option, it returns an RA with its MS OMNI LLA as the source, the MN OMNI LLA as the destination, the P(roxy) bit set in the RA flags and with an OMNI option included. The MN then engages the AR according to the OMNI link model specified above. If the first hop AR is a legacy IPv6 router, however, it instead returns an RA message with no OMNI option and with a non-OMNI unicast source LLA as specified in [[RFC4861](#)]. In that case, the MN engages the ANET according to the legacy IPv6 link model and without the OMNI extensions specified in this document.

If the ANET link model is multiple access, there must be assurance that address duplication cannot corrupt the neighbor caches of other nodes on the link. When the MN sends an RS message on a multiple access ANET link with an OMNI LLA source address and an OMNI option, ARs that recognize the option ensure that the MN is authorized to use the address and return an RA with a non-zero Router Lifetime only if the MN is authorized. ARs that do not recognize the option instead return an RA that makes no statement about the MN's authorization to use the source address. In that case, the MN should perform Duplicate Address Detection to ensure that it does not interfere with other nodes on the link.

An alternative approach for multiple access ANET links to ensure isolation for MN / AR communications is through L2 address mappings as discussed in [Appendix C](#). This arrangement imparts a (virtual) point-to-point link model over the (physical) multiple access link.

17. OMNI Interfaces on the Open Internet

OMNI interfaces configured over INET interfaces that connect to the open Internet can apply symmetric security services such as VPNs to establish secured tunnels to MSEs (still other underlying interfaces may connect to a MSE directly in a "tethered" arrangement). In environments where an explicit VPN or direct link may be too restrictive, OMNI interfaces configured over INET interfaces can instead use the UDP/IP encapsulation and authentication services specified for Teredo [[RFC4380](#)][RFC6081].

When Teredo encapsulation and authentication services are used, the IPv6 ND control plane messages used to establish neighbor cache state are authenticated while data plane messages are delivered the same as for ordinary best-effort Internet traffic with basic source address-based data origin assurance. Data plane communications via OMNI interfaces that connect over the open Internet without an explicit VPN should therefore employ transport- or higher-layer security to ensure integrity and/or confidentiality.

In addition to authenticated OMNI interface RS/RA exchanges, the Teredo services support secure address resolution and neighbor unreachability detection as discussed in Asymmetric Extended Route Optimization (AERO) [[I-D.templin-intarea-6706bis](#)]. This allows for efficient multilink operations over the open Internet with assured neighbor cache integrity.

OMNI interfaces in the open Internet are often located behind Network Address Translators (NATs). The OMNI interface accommodates NAT traversal using the OMNI LLA prefix fe80::/32 for Teredo IPv6 addresses formatted as discussed in [Section 4 of \[RFC4380\]](#). Further specifications for NAT traversal are discussed in [[I-D.templin-intarea-6706bis](#)][RFC6081][[RFC4380](#)].

18. Time-Varying MNPs

In some use cases, it is desirable, beneficial and efficient for the MN to receive a constant MNP that travels with the MN wherever it moves. For example, this would allow air traffic controllers to easily track aircraft, etc. In other cases, however (e.g., intelligent transportation systems), the MN may be willing to sacrifice a modicum of efficiency in order to have time-varying MNPs that can be changed every so often to defeat adversarial tracking.

Prefix delegation services such as those discussed in [[I-D.templin-6man-dhcpv6-ndopt](#)] and [[I-D.templin-intarea-6706bis](#)] allow OMNI MNs that desire time-varying MNPs to obtain short-lived prefixes. In that case, the identity of the MN would not be bound to

the MNP but rather to the prefix delegation ID and used as the seed for Prefix Delegation. The MN would then be obligated to renumber its internal networks whenever its MNP (and therefore also its OMNI address) changes. This should not present a challenge for MNs with automated network renumbering services, however presents limits for the durations of ongoing sessions that would prefer to use a constant address.

19. IANA Considerations

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

The IANA is instructed to allocate one Ethernet unicast address TBD2 (suggest 00-00-5E-00-52-14 [[RFC5214](#)]) in the registry "IANA Ethernet Address Block - Unicast Use".

The OMNI option also defines an 8-bit Sub-Type field, for which IANA is instructed to create and maintain a new registry entitled "OMNI option Sub-Type values". Initial values for the OMNI option Sub-Type values registry are given below; future assignments are to be made through Expert Review [[RFC8126](#)].

Value	Sub-Type name	Reference
-----	-----	-----
0	Pad1	[RFCXXXX]
1	PadN	[RFCXXXX]
2	ifIndex-tuple (Type 1)	[RFCXXXX]
3	ifIndex-tuple (Type 2)	[RFCXXXX]
4	MS-Register	[RFCXXXX]
5	MS-Release	[RFCXXXX]
6-252	Unassigned	
253-254	Experimental	[RFCXXXX]
255	Reserved	[RFCXXXX]

Figure 13: OMNI Option Sub-Type Values

20. Security Considerations

Security considerations for IPv6 [[RFC8200](#)] and IPv6 Neighbor Discovery [[RFC4861](#)] apply. OMNI interface IPv6 ND messages SHOULD include Nonce and Timestamp options [[RFC3971](#)] when synchronized transaction confirmation is needed.

OMNI interfaces configured over secured underlying ANET interfaces inherit the physical and/or link-layer security aspects of the

connected ANETs. OMNI interfaces configured over INET interfaces connected to the open Internet must use symmetric securing services such as VPNs or asymmetric services such as Teredo authentication [[RFC4380](#)] to authenticate IPv6 ND messages. More general-purpose IPv6 ND securing services such as SEND/CGA [[RFC3971](#)][[RFC3972](#)] can also be considered.

While the OMNI link protects control plane messaging as discussed above, applications should still employ transport- or higher-layer security services to protect the data plane.

Security considerations for specific access network interface types are covered under the corresponding IP-over-(foo) specification (e.g., [[RFC2464](#)], [[RFC2492](#)], etc.).

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Appendix A. Type 1 ifIndex-tuple Traffic Classifier Preference Encoding

Adaptation of the OMNI option Type 1 ifIndex-tuple's traffic classifier Bitmap to specific Internetworks such as the Aeronautical Telecommunications Network with Internet Protocol Services (ATN/IPS) may include link selection preferences based on other traffic classifiers (e.g., transport port numbers, etc.) in addition to the existing DSCP-based preferences. Nodes on specific Internetworks maintain a map of traffic classifiers to additional P[*] preference fields beyond the first 64. For example, TCP port 22 maps to P[67], TCP port 443 maps to P[70], UDP port 8060 maps to P[76], etc.

Implementations use Simplex or Indexed encoding formats for P[*] encoding in order to encode a given set of traffic classifiers in the most efficient way. Some use cases may be more efficiently coded using Simplex form, while others may be more efficient using Indexed. Once a format is selected for preparation of a single ifIndex-tuple the same format must be used for the entire Sub-Option. Different Sub-Options may use different formats.

The following figures show coding examples for various Simplex and Indexed formats:


```

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
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|  Sub-Type=2  | Sub-length=4+N|   ifIndex   |   ifType   |
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
| Provider ID  | Link  |S|0|RSV| Bitmap(0)=0xff|P00|P01|P02|P03|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|P04|P05|P06|P07|P08|P09|P10|P11|P12|P13|P14|P15|P16|P17|P18|P19|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|P20|P21|P22|P23|P24|P25|P26|P27|P28|P29|P30|P31| Bitmap(1)=0xff|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|P32|P33|P34|P35|P36|P37|P38|P39|P40|P41|P42|P43|P44|P45|P46|P47|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|P48|P49|P50|P51|P52|P53|P54|P55|P56|P57|P58|P59|P60|P61|P62|P63|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
| Bitmap(2)=0xff|P64|P65|P67|P68| ...
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

```

Figure 14: Example 1: Dense Simplex Encoding

```

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
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|  Sub-Type=2  | Sub-length=4+N|   ifIndex   |   ifType   |
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
| Provider ID  | Link  |S|0|RSV| Bitmap(0)=0x00| Bitmap(1)=0x0f|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|P48|P49|P50|P51|P52|P53|P54|P55|P56|P57|P58|P59|P60|P61|P62|P63|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
| Bitmap(2)=0x00| Bitmap(3)=0x00| Bitmap(4)=0x00| Bitmap(5)=0x00|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
| Bitmap(6)=0xf0|192|193|194|195|196|197|198|199|200|201|202|203|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|204|205|206|207| Bitmap(7)=0x00| Bitmap(8)=0x0f|272|273|274|275|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|276|277|278|279|280|281|282|283|284|285|286|287| Bitmap(9)=0x00|
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
|Bitmap(10)=0x00| ...
+-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

```

Figure 15: Example 2: Sparse Simplex Encoding

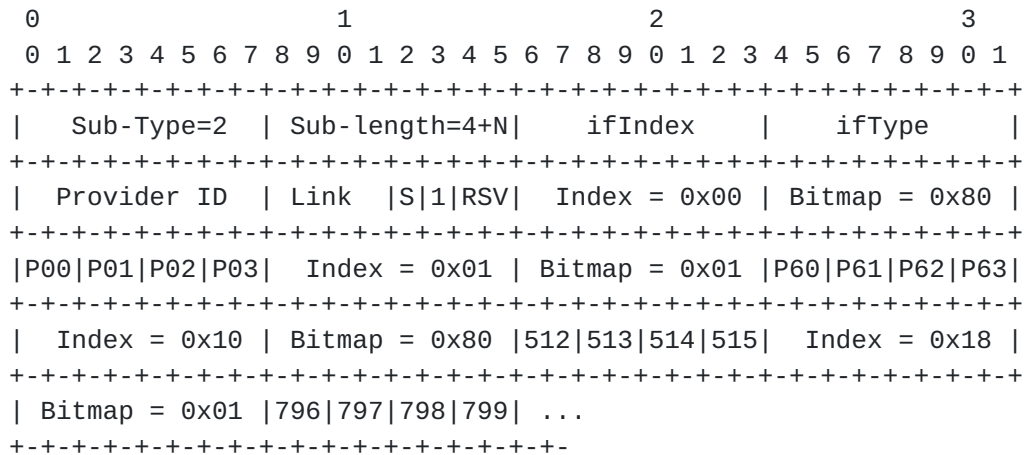


Figure 16: Example 3: Indexed Encoding

Appendix B. 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.

Note that links of this nature may benefit from compression techniques that reduce the bandwidth necessary for conveying the same amount of data. The IETF lpwan working group is considering possible alternatives: [https://datatracker.ietf.org/wg/lpwan/documents].

Appendix C. MN / AR Isolation Through L2 Address Mapping

Per [RFC4861], IPv6 ND messages may be sent to either a multicast or unicast link-scoped IPv6 destination address. However, IPv6 ND messaging should be coordinated between the MN and AR only without invoking other nodes on the ANET. This implies that MN / AR control messaging should be isolated and not overheard by other nodes on the link.

To support MN / AR isolation on some ANET links, ARs can maintain an OMNI-specific unicast L2 address ("MSADDR"). For Ethernet-compatible ANETs, this specification reserves one Ethernet unicast address TBD2 (see: [Section 19](#)). For non-Ethernet statically-addressed ANETs, MSADDR is reserved per the assigned numbers authority for the ANET addressing space. For still other ANETs, MSADDR may be dynamically discovered through other means, e.g., L2 beacons.

MNs map the L3 addresses of all IPv6 ND messages they send (i.e., both multicast and unicast) to MSADDR instead of to an ordinary unicast or multicast L2 address. In this way, all of the MN's IPv6 ND messages will be received by ARs that are configured to accept packets destined to MSADDR. Note that multiple ARs on the link could be configured to accept packets destined to MSADDR, e.g., as a basis for supporting redundancy.

Therefore, ARs must accept and process packets destined to MSADDR, while all other devices must not process packets destined to MSADDR. This model has well-established operational experience in Proxy Mobile IPv6 (PMIP) [RFC5213][RFC6543].

Appendix D. Change Log

<< RFC Editor - remove prior to publication >>

Differences from [draft-templin-6man-omni-interface-17](#) to [draft-templin-6man-omni-interface-18](#):

- o Teredo

Differences from [draft-templin-6man-omni-interface-14](#) to [draft-templin-6man-omni-interface-15](#):

- o Prefix length discussions removed.

Differences from [draft-templin-6man-omni-interface-12](#) to [draft-templin-6man-omni-interface-13](#):

- o Teredo

Differences from [draft-templin-6man-omni-interface-11](#) to [draft-templin-6man-omni-interface-12](#):

- o Major simplifications and clarifications on MTU and fragmentation.
- o Document now updates [RFC4443](#) and [RFC8201](#).

Differences from [draft-templin-6man-omni-interface-10](#) to [draft-templin-6man-omni-interface-11](#):

- o Removed /64 assumption, resulting in new OMNI address format.

Differences from [draft-templin-6man-omni-interface-07](#) to [draft-templin-6man-omni-interface-08](#):

- o OMNI MNs in the open Internet

Differences from [draft-templin-6man-omni-interface-06](#) to [draft-templin-6man-omni-interface-07](#):

- o Brought back L2 MSADDR mapping text for MN / AR isolation based on L2 addressing.
- o Expanded "Transition Considerations".

Differences from [draft-templin-6man-omni-interface-05](#) to [draft-templin-6man-omni-interface-06](#):

- o Brought back OMNI option "R" flag, and discussed its use.

Differences from [draft-templin-6man-omni-interface-04](#) to [draft-templin-6man-omni-interface-05](#):

- o Transition considerations, and overhaul of RS/RA addressing with the inclusion of MSE addresses within the OMNI option instead of as RS/RA addresses (developed under FAA SE2025 contract number DTFAWA-15-D-00030).

Differences from [draft-templin-6man-omni-interface-02](#) to [draft-templin-6man-omni-interface-03](#):

- o Added "advisory PTB messages" under FAA SE2025 contract number DTFAWA-15-D-00030.

Differences from [draft-templin-6man-omni-interface-01](#) to [draft-templin-6man-omni-interface-02](#):

- o Removed "Primary" flag and supporting text.

- o Clarified that "Router Lifetime" applies to each ANET interface independently, and that the union of all ANET interface Router Lifetimes determines MSE lifetime.

Differences from [draft-templin-6man-omni-interface-00](#) to [draft-templin-6man-omni-interface-01](#):

- o "All-MSEs" OMNI LLA defined. Also reserved fe80::ff00:0000/104 for future use (most likely as "pseudo-multicast").
- o Non-normative discussion of alternate OMNI LLA construction form made possible if the 64-bit assumption were relaxed.

Differences from [draft-templin-atn-aero-interface-21](#) to [draft-templin-6man-omni-interface-00](#):

- o Minor clarification on Type-2 ifIndex-tuple encoding.
- o Draft filename change (replaces [draft-templin-atn-aero-interface](#)).

Differences from [draft-templin-atn-aero-interface-20](#) to [draft-templin-atn-aero-interface-21](#):

- o OMNI option format
- o MTU

Differences from [draft-templin-atn-aero-interface-19](#) to [draft-templin-atn-aero-interface-20](#):

- o MTU

Differences from [draft-templin-atn-aero-interface-18](#) to [draft-templin-atn-aero-interface-19](#):

- o MTU

Differences from [draft-templin-atn-aero-interface-17](#) to [draft-templin-atn-aero-interface-18](#):

- o MTU and RA configuration information updated.

Differences from [draft-templin-atn-aero-interface-16](#) to [draft-templin-atn-aero-interface-17](#):

- o New "Primary" flag in OMNI option.

Differences from [draft-templin-atn-aero-interface-15](#) to [draft-templin-atn-aero-interface-16](#):

- o New note on MSE OMNI LLA uniqueness assurance.
- o General cleanup.

Differences from [draft-templin-atn-aero-interface-14](#) to [draft-templin-atn-aero-interface-15](#):

- o General cleanup.

Differences from [draft-templin-atn-aero-interface-13](#) to [draft-templin-atn-aero-interface-14](#):

- o General cleanup.

Differences from [draft-templin-atn-aero-interface-12](#) to [draft-templin-atn-aero-interface-13](#):

- o Minor re-work on "Notify-MSE" (changed to Notification ID).

Differences from [draft-templin-atn-aero-interface-11](#) to [draft-templin-atn-aero-interface-12](#):

- o Removed "Request/Response" OMNI option formats. Now, there is only one OMNI option format that applies to all ND messages.
- o Added new OMNI option field and supporting text for "Notify-MSE".

Differences from [draft-templin-atn-aero-interface-10](#) to [draft-templin-atn-aero-interface-11](#):

- o Changed name from "aero" to "OMNI"
- o Resolved AD review comments from Eric Vyncke (posted to atn list)

Differences from [draft-templin-atn-aero-interface-09](#) to [draft-templin-atn-aero-interface-10](#):

- o Renamed ARO option to AERO option
- o Re-worked [Section 13](#) text to discuss proactive NUD.

Differences from [draft-templin-atn-aero-interface-08](#) to [draft-templin-atn-aero-interface-09](#):

- o Version and reference update

Differences from [draft-templin-atn-aero-interface-07](#) to [draft-templin-atn-aero-interface-08](#):

- o Removed "Classic" and "MS-enabled" link model discussion
- o Added new figure for MN/AR/MSE model.
- o New Section on "Detecting and responding to MSE failure".

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](#):

- o Removed discussion of encapsulation (out of scope)
- o Simplified MTU section
- o Changed to use a new IPv6 ND option (the "aero option") instead of S/TLLAO
- o 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](#):

- 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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