Overlay Multilink Network (OMNI) Interface – IETF Update and Status

IETF 6MAN Working Group

July 28, 2020

Fred L. Templin (fred.l.templin@boeing.com)

The Boeing Company

Action Plan from ICAO WG-I Mobility Subgroup #10 Conference (Vienna, Austria, 2/10/2020):

- Working Group I Mobility Subgroup to issue IETF Liaison Statement
- Required by IETF to publish RFC standards on behalf of another standards organization (ICAO)
- Well-established and commonly-used mechanism
- The Liaison Statement would be published on the IETF website and available for public viewing (https://datatracker.ietf.org/liaison/)
- IETF Intarea Area Director (Eric Vyncke) has been following our progress and has offered to shepherd the work. Options:
  - Form a new IETF working group (this is typically a long process)
  - **Publish as working group document of the IETF 6man working group**
  - Publish as AD-sponsored

IETF Status as of 7/28/2020

- **2/18/2020 – IETF requests draft re-name: ‘draft-templin-6man-omni-interface’**
- 3/13/2020 – Liaison Statement discussion during WG-I/30 Teleconference
- 3/27/2020 – Liaison Statement coordination with TFSG
- **3/29/2020 - Liaison Statement submitted to IETF**
- **3/31/2020 - Presented draft at IETF 6man interim wg session. Questions:**
  - Alex Petrescu (MNP lengths greater than /64?)
  - Erik Kline (on the need for a virtual interface?)
  - Saulo Da Silva (how does this relate to mobility solutions?)
  - Continued list discussion encouraged
- 04/01/2020 – 05/03/2020 – draft updates based on IETF input; Tony Whyman docs
- **5/05/2020 – IETF direction:**
  - **Preferred approach to publish as 6man RFC; backup for Eric Vyncke to AD-sponsor**
  - **Liaison statement schedule current (COVID-19 crisis restricts IETF to all-virtual meetings)**
- **7/28/2020 Next step: 6MAN wg adoption call**

OMNI Advantages (1)

- Flexible virtual link model supported by RFC2473 encapsulation and RFC4193 addressing
  - **Link model for host-based solutions is a sometimes-mobile HOST that travels from its home link with a singular address (20th century archetype)**
  - **Link model for OMNI is an always-mobile ROUTER with no home link and a portable IoT with multi-addressing (21st century archetype)**
- Supports operation w/o access network address configuration
  - **Each node receives a stable and unchanging Mobile Network Prefix (MNP)**
  - **Stable and unique LLA and ULA addresses statelessly derived from MNP**
  - **No Care-of Addresses -> no MLDv2 or Duplicate Address Detection (DAD)**
  - **No Home Address or home link model needed**
  - **No Prefix Delegation messaging needed**
  - **Significant savings in avoiding costly and unnecessary radio transmissions**
- Includes multilink coordination parameters in IPv6 ND messages
  - **No adjunct messaging service such as MIPv6 Binding Updates needed**

Advantages (2)

- Safety-Based and Performance-Based Multilink (SBM/PBM) Support
  - **Each OMNI interface connects to a distinct SBM virtual link**
  - **Segment Routing selects SBM interface and navigates SBM topology**
  - **Each OMNI interface independently coordinates PBM**
- Based on standard IPv6 ND messaging with no adjunct protocol messages
  - **RS/RA (Router Discovery; Multilink coordination)**
  - **NS/NA (Address Resolution; Neighbor Unreachability Detection)**
- Path MTU assurance and Path MTU diversity
  - **Supports native interface MTU (e.g., 1500) W/O ENCAPSULATION REDUCTION**
  - **Supports MTU diversity up to 9180 without MTU-related packet loss**
  - **FRAGMENTATION REQUIRED when encapsulating over 1280MTU links**

Advantages (3)

- Simplified security over Access Networks with OMNI-aware Access Router
  - **RS/RA in access network between mobile node and AR (physical; link-layer security)**
  - **AR securely connects with Mobility Service Endpoints in service Internetwork via secured spanning tree in overlay network (network-layer security for spanning tree)**
  - **VPN security (e.g., DTLS); SEND still supported over "open-Internet" Access Networks**
- In the network, OMNI virtual overlay supports distributed mobility management (DMM) where mobility coordination load is spread between potentially many mobility service endpoints instead of concentrated at only one or a few agents.
  - **Massively-Distributed Mobility Management (MDMM)**
- A single MN to ground RS/RA message exchange can also be used to coordinate multiple network service endpoints in point-to-multipoint fashion.
  - **Significant savings in over-the-air control messaging**

Advantages (4)

- Because of the OMNI link RFC2473 encapsulation and RFC4193 Unique Local Addressing (ULA), **any** Mobility Service Endpoint can service **any** access links
  - ➢ **For example, if a Mobility Service Endpoint lives in a SITA network, the OMNI link allows it to simultaneously service links from an aircraft that come in through *any* provider (ARINC, Inmarsat, SITA, others)**
  - ➢ **OMNI interface connects MN to the OMNI link and allows multilink coordination through a common Mobility Service Endpoint even though there are multiple service providers**
- Because of Proxys, Mobility Service Endpoint failures can be quickly detected and reported to the MN without excessive over-the-air keepalive messaging
- **NAT Traversal – uses the same encapsulation format and “bubble” messaging as for RFC4380. Penultimate hop toward final destination uses segment routing and encapsulation for route optimization**

OMNI Link Local Addresses

- OMNI LLA format change to support generalized MNPs
- Old format embedded MNP in lower 64 bits of fe80::/64
- New format embeds MNP in lower 112 bits of fe80::/16
- Example for MNP 2001:db8:1:2::/64
  - Old: fe80::2001:db8:1:2
  - **New: fe80:2001:db8:1:2::**
- Advantages:
  - Allows future use for MNPs longer than /64
  - Still supports human-readable form – important!
  - MNPs easily translated into OMNI LLAs and vice-versa
  - OMNI LLAs easily translated into **OMNI Unique Local Addresses** and vice-versa

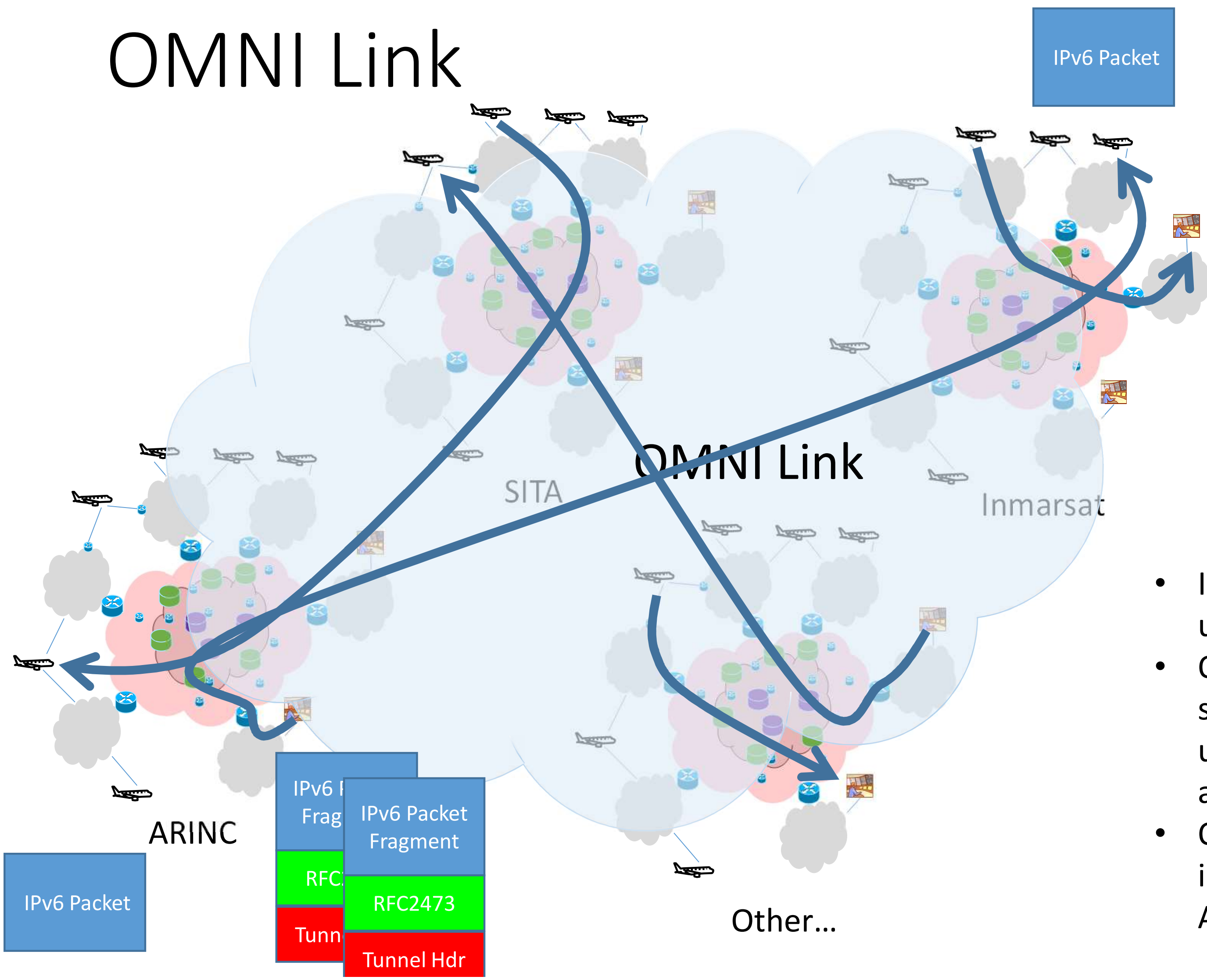
The OMNI Link

- Multiple network service providers behave as a single logical domain
- Virtual link model using **RFC2473 encapsulation** – **“Spanning tree”**
- **OMNI Unique Local Addresses (ULAs)** taken from **RFC4193**, and in one-to-one correspondence with OMNI LLAs:
  - OMNI LLA: fe80:2001:db8:1:2::
  - **OMNI ULA: fc80:2001:db8:1:2::**
  - **ULAs and LLAs can be converted one to another by simply flipping bit 6**
- **Encapsulated packets with OMNI ULAs can traverse IPv6 routers acting as OMNI link Bridges to connect segments of the OMNI link**
- **IPv6 ND messages can travel multiple spanning tree hops without decrementing the Hop Limit – presents a unified NBMA link view**

The OMNI Link - Accommodating Reality

- In an ideal world, there would be one large worldwide Internetwork for all of civil aviation (like the global public Internet model)
- In the real world, however, there are many different aeronautical communications service providers and each will run and operate their own Internetworks **(ARINC, SITA, Inmarsat, others)**
- Each Internetwork is seen as a **partition** (or **segment**) of the worldwide "link" over which the ATN/IPS is configured
- **OMNI link bridges disjoint Internetworking underlays into a single, unified link – each Internetworking underlay is a separate Segment**

OMNI Link



- Initially, Internetworking underlays partitioned
- OMNI link is a "second story" that sees the underlying partitions as a bridged campus LAN
- OMNI link supports both inter- and intra-partition ATN/IPS comms

Implementation Status

- OMNI virtual interface can be accommodated in one of two ways:
  - TUN/TAP interface from a user application
  - Kernel tunnel virtual interface per linux sit, fou, etc.
- Currently instrumenting the AERO functions as an add-on feature to OpenVPN (user application-based) – plan to release Q42020
- Also have custom “isatapd” that provides bare-minimum process context for AERO functions
- Ultimate goal to port to linux kernel module
- Expect to use linux Wireguard for network layer security in any case

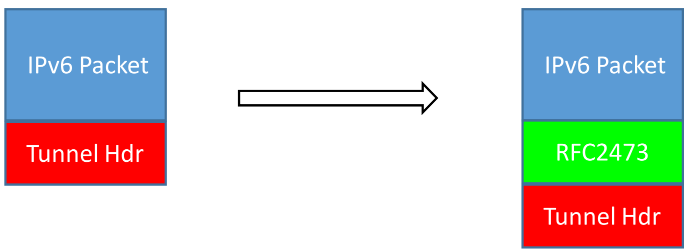
Document Status and Plans

- “Transmission of IPv6 Packets over Overlay Multilink Network (OMNI) Interfaces”
- draft-templin-6man-omni-interface
- “IPv6-over-(foo)” document
- Defines new IPv6 ND message option type (the OMNI option)
- **Next step: 6man working group adoption call**

Backups

RFC2473 Encapsulation

- Mid-layer header between the IPv6 header and the (per-Internetwork) encapsulation header:



- RFC2473 header uses OMNI ULAs as source and destination
- OMNI ULAs are routable within the overlay BGP routing system, so standard BGP routing is supported
- OMNI ULAs are stable (not mobile); hence, there is no mobility impact within the routing system

OMNI Link and Fragmentation/MTU

- Encapsulation causes packets smaller than 1280 bytes to exceed 1280 bytes -> **FRAGMENTATION NEEDED FOR ENCAPSULATION OVER IPv6**
- Since fragmentation is needed, use a robust reassembly size -> **9180 Bytes**
- Aviation data links typically 1Mbps or less -> **accommodate full native MTU of the air interface w/o leaving a "hole" to accommodate ground encapsulation (e.g., if the air interface supports 1500, provide the full 1500 and not just 1400)**
- Within the ground domain, most links are 10Gbps or greater, but only guarantee for the ground domain path MTU is 1280 -> **ground fragmentation must be applied to limit encapsulated packets to 1280 bytes or less**
- Fragmentation NOT a performance bottleneck -> **iperf3 proves that IP fragmentation works at high data rates**
- Reassembly is deferred until the OMNI link egress

SBM and PBM

- Each OMNI interface is a MN's connection to a separate OMNI link
- If there are multiple OMNI links, there are multiple OMNI interfaces (**omni0**, **omni1**, **omni2**, etc.)
- OMNI interfaces connect to mutually independent topologies; multiple interfaces enables **Safety-Based Multilink (SBM)**
- Each OMNI interface may be configured over multiple underlying interfaces for **Performance-Based Multilink (PBM)**
- **SBM and PBM are enabled by the OMNI virtual interface model**

Segment Routing

- Applications can use **Segment Routing** to select the OMNI link to be used for SBM
- Set the packet destination address to the Anycast OMNI ULA for the desired OMNI link (e.g., fc80::, fc81::, fc82::, etc.)
- Insert a Routing Header with the final destination IPv6 address plus any intermediate OMNI ULAs that need to be visited on the path
  - **Standard IPv6 routing** directs the packets to the head-end interface connection to the OMNI link
  - **Segment routing** steps through the intermediate OMNI link segments toward the final destination

Non-Proxy Access Network Alternatives

- OMNI interfaces might be used by nodes that connect without a first-hop AR acting as a Proxy
- Can use **Direct link (point-to-point)** or **VPN links** beneath OMNI interface to connect to a Server
- **Internetworking alternative** – use UDP/IP encapsulation per RFC4380 with network-layer authentication for IPv6 ND control messages (RS/RA/NS/NA) and application-layer security for the data plane
  - Works even if there are Network Address Translators (NATs) in the path
  - Provides secure operation over the open Internet

Time-Varying MNPs

- Some use cases outside of civil aviation may want to supply MNs with Time-Varying (i.e., not fixed) MNPs
- May be necessary for applications where it is desirable for MN to not be easily traced by its IPv6 address
- Solution:
  - Use OMNI with DHCPv6-PD to obtain short-lived and/or temporary MNPs
  - Use flexible network renumbering to renumber MN’s end user networks when the MNP changes

Additional OMNI Option Contents

- Include Network Access Identifier (NAI) sub-option for OMNI option
- Include Geo Coordinate sub-option for OMNI option
- Can accommodate any necessary information via TLVs

Fragmentation and MTU

- Fragmentation and Reassembly are now a must-implement
  - **Absolutely required for tunnels over IPv6 due to 1280 minMTU**
  - **Allows aviation data links to use native MTU size (e.g., 1500)**
  - **Reassembly up to 9180 for full MTU diversity**
- “Advisory” Packet-Too-Big can be sent if reassembly becomes painful
- Updates RFC4443; RFC8201

Application in Other Domains

- IETF Intelligent Transportation System (its) working group (aka “IP Wireless Access for Vehicular Environments” (ipwave)) is publishing a problem statement and use case document for **worldwide ground transportation and urban air mobility**
- Not only vehicles, but also pedestrians with cellphones
- Use cases currently cite only MIPv6 and PMIPv6 with **multilink subnet**
- **OMNI proposed on the mailing list as alternate link model**
- Document author acknowledged the opportunities, and committed to cite OMNI link model for vehicular environments. Will also cite AERO and LISP as mobility candidates.
- **An enormous market – orders of magnitude larger than aviation**

Next Steps

- Continue to work with IETF Area Director and 6man chairs
- Encourage list discussion on 6man mailing list
- IETF 108 scheduled for July 25-31, 2020 in Madrid – difficult to say if international travel will be restored by that time
- In lieu of IETF face-to-face meetings, continued virtual teleconfs anticipated (e.g., similar to ICAO WG-I)
- Regular status updates to be submitted to ICAO WG-I Mobility Subgroup - propose OMNI/AERO as final solution at June meeting

OMNI/AERO Points for Consideration (1)

- Uses Neighbor Discovery protocol beyond the original architectural scope of the RFC
  - ➢This is IPv6 ND per RFC4861. The OMNI link is an IPv6 link that observes the NBMA principle. RFC4861 provides clear guidance for documents (e.g. OMNI) that specify IPv6 ND over NBMA link types.

OMNI/AERO Points for Consideration (2)

- Not designed to propagate across the network through a custom proxy to a custom server
  - **A link is defined as any lower-layer service that can transit an IPv6 packet without decrementing the Hop Limit**
  - **Links** consist of L2 **segments** joined by **bridges**. The AERO Proxy acts as a bridge between the air-ground and ground-ground networks.
  - Physical segments (e.g., Ethernet, Radio) on the A/G side and virtual segment (e.g., tunnel) on G/G side. But, it is all just a **link** with **bridged** L2 **segments**.
  - IPv6 ND (RFC4861) was designed to operate over bridged links; IPv6 fragmentation ensures that bridging media with dissimilar MTUs is accommodated

OMNI/AERO Points for Consideration (3)

- COTS routers don’t support required extraction of custom NDS extension
  - ➢Routers that do not recognize OMNI option in RS message ignore it and return an RA message with no OMNI option. The MN can then revert to Plan B.
  - ➢Code is small; added the same as any IPv6 ND option (e.g., RDNSS)
  - ➢IETF publication will guide vendors to rapid deployment

OMNI/AERO Points for Consideration (4)

- Plan A could reveal RFC incompatibilities in standard COTS routers during the deployment phase risking long delays in deployment
  - **RFC4861-compliant routers MUST ignore unrecognized options in ND messages and process the rest of the message normally**
  - **Only RFC4861-compliant standard routers should be used**
  - If routers do not recognize Plan A, MN automatically reverts to Plan B

OMNI/AERO Points for Consideration (5)

- Plan A Creates incompatibility for Proxy Mobile IPv6 used in 3GPP and would require significant development for ground based Proxy Mobile IPv6
  - ➢Proxy MIPv6 has not received much attention in WG-I and is not listed as a mobility solution alternative. The fixed nature of the LMA and MAG arrangements do not allow for flexible DMM deployment
  - ➢Any Proxy MIPv6 deployments can revert to Plan B if they do not recognize Plan A RS message
  - ➢With OMNI/AERO, there is no need for PMIPv6

OMNI/AERO Points for Consideration (6)

- Both plans are aviation specific solutions
  - IETF has agreed to include OMNI/AERO as a solution alternative in the IP for Wireless Access in Vehicular Environments (ipwave) problem statement and use cases.
  - Represents an enormous market (worldwide ground transportation, urban air mobility, pedestrians, etc.)
  - Market may be many orders of magnitude larger than civil aviation

OMNI/AERO Points for Consideration (7)

- Plan A requires ICAO endorsement to IETF which enables AERO solution and disadvantages Mobile Proxy IPv6 (Picking winners over losers)
  - Plan A and Plan B were initiated together to accommodate the tussle.
  - Plan A going forward has no disadvantages to solutions that prefer Plan B.

OMNI/AERO Points for Consideration (8)

- Plan A nor Plan B have a security risk analysis but security in plan B can be addressed without IETF RFC updates
  - The OMNI document has a Security Considerations section the same as for any IETF document. However, the OMNI option does not introduce any new security risks but instead inherits the security architecture established for aviation data link subnetworks.
  - Different security models for different access network types:
    - Secured Access Networks with first-hop router use Proxy model
    - Direct link to Server uses physical security of direct link
    - VPN link to Server uses link-layer security of VPN link
    - Open Internet connections use SEcure Neighbor Discovery (SEND)