Ground Based LISP For Multilink Operation

A SESAR 15.2.4 Solution

ICAO WG-I Meeting 19

2016-01-22  |  FRQ
→ Agenda

→ Introduction
→ Base Procedures
→ Multilink Seamless Operation
→ Seamless Handover Access Network
→ Summary
Introduction: the motivations

A concept that addresses key ATN/IPS requirements
- Covers mobility and multi-homing
- Minimizes the overhead traffic on the A/G datalinks
- Supports Classes of Services

Reduces the complexity in the aircraft:
- Airborne router can assume that any ground system is reachable via every A/G router => default/static routing can be used on board
- Routing/mobility can be managed on ground
- No need for a routing/mobility protocol on board
- Link selection can be supported on board with simple static policy (however dynamic policy can be added)

Reduce complexity of deployment on ground:
- Can be easily deployed over existing ground infrastructure
- Can be based on COTS solutions
- Can ease IPv4 to IPV6 transition issues

Simple to understand - close to ATN/OSI addressing concepts, which will certainly help transition / duality of the ATN applications
High Level System Architecture FCI
Overview Elements and Functions

Airplane IPv6 ICAO Net X

A-R ... Airborne Router
AC-R ... Access Ground Router
A/G-R ... Air/Ground Router
G/G-R ... Ground/Ground Router

Security:
Authentication of AR, Proof of Region Identity
(Key material for Data Integrity/Privacy)

ICAO Net Registering as normal (not roaming) EID
(LISP Priority for Path Preference Incoming, EEM for Mapping Metric -> Priority)
LISP Tunneling xTR

Full IGP Routing
ICAO Net Announcing Metric based on Link Quality and Path Preference Incoming

Static Routing
Path Decision Outgoing Announcing Path Preference Incoming

DefGW X
X / 64

LDACS Reg1 fqU-fqD
LDACS L2-ID X

LDACS SN Terrestrial Region 1

IGP OSPF

LISP EID Space

IP/LDACS GW

COTS IP Router
WAN Infrastructure

AOC ES

LISP MS/MR1

LISP Mapping Server Mapping Resolver

AOC - ATS Region X
LISP EID Space

LISP xTR21 and xTr22 announce Default Routes into region 2 to attract traffic destined to foreign IPv6 Nets (other regions)

LISP xTR21
LISP xTR22

ATS ES

LISP xTR11
LISP xTR12

LISP xTRx1
LISP xTRx2

G/G-R

IGP SP

SEC Region 1
SEC Region 2

IP/SATCOM GW

SAT L2-ID Z

SAT L2-ID
SAT Reg2 fqU-fqD

IP:SATCOM GW

SEC Region 2

DefGW Z
Z / 64

LDACS Reg2 fqU-fqD
LDACS L2-ID Z

LDACS SN Terrestrial Region 2

A/G-R

A/R

AC-R

LISP EID Space

AOC ES

LISP MS/MR2

LISP MS/MR2

LISP EID Space
Elements A-R and AC-R

A-R (Airborne Router)

AC-R (Access Ground Router)

A-R

A / C LAN

AC-R

LDACS SN
Terrestrial Region 1

SATCOM SN
Terrestrial Region 2

AreoMACS SN
Terrestrial Region 3

LDACS
Reg1 fqU-fqD

SATCOM
Reg2 fqU-fqD

AreoMACS
Reg3 fqU-fqD
→ Multilink, Handover Scenario
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→ **Base Procedures**
→ Multilink Seamless Operation
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→ Summary
Registration Phase (Security)

Suggestion for L3 and L2 addresses
128 bit L3 IPv6 address airplane:
- Net-ID: 32 bit Prefix / 24 bit ICAO ID / 8 bit Airplane Network
- Host-ID: 64 bit

LDACS / SATCOM / AeroMACS Layer2-Identifier (L2-ID):
Mapping of Net-ID or 24 bit ICAO-ID into L2 address of LDACS / SATCOM / AeroMACS

Assumption about transport security radio link:
After successful registration a secure communication over air is possible (integrity and optionally privacy)
Location Announcement (Reachability)

Now all internal routers of LDACS SN know how to reach network X / 64 within their domain !!!

### IGP Routing Table xTR11

<table>
<thead>
<tr>
<th>EID</th>
<th>Next Hop</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>2001::1:1</td>
<td>E2 11</td>
</tr>
<tr>
<td>X / 64</td>
<td>2001::1:2</td>
<td>E2 11</td>
</tr>
<tr>
<td></td>
<td>2001::1:3</td>
<td>44</td>
</tr>
</tbody>
</table>

### IGP Routing Table xTR12

<table>
<thead>
<tr>
<th>EID</th>
<th>Next Hop</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>2001::1:1</td>
<td>E2 11</td>
</tr>
<tr>
<td>X / 64</td>
<td>2001::1:2</td>
<td>E2 11</td>
</tr>
<tr>
<td></td>
<td>2001::1:3</td>
<td>55</td>
</tr>
</tbody>
</table>

### OSPF Update, IPv6 X via 2001::1:1, metric E2 11

OSPF metric E2 11 mapped by LISP A/G-R into LISP Priority with usage of Cisco EEM (Embedded Event Manager).

### Site Registration

<table>
<thead>
<tr>
<th>EID</th>
<th>RLOC</th>
<th>PRIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>7.7.1.1</td>
<td>11</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.1.2</td>
<td>11</td>
</tr>
</tbody>
</table>

By specifying preference and quality A-R decides on which path upload traffic is wanted.
Traffic to Location ICAO X (1)

Airplane IPv6 ICAO Net X

LDACS L2-ID X

DefGW X

X / 64

AC-R

LDACS SN Reg1

2001::1:1

SEC Region 1

LISP MS/MR1

AOC ES

SATCOM SN Reg2

2001::1:2

G/G-R

A/G-R

LISP xTR12

LISP xTR21

LISP xTR22

LISP MS/MR2

IPv6 ES1 → IPv6 X

Region X

Mapping Cache xTRx1

Site Registration

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<td>11</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.1.2</td>
<td>11</td>
</tr>
</tbody>
</table>

AOC ES

ATS ES

IPv6 ES1
→ Traffic to Location ICAO X (2)
Traffic from Location ICAO X to Ground ATS ES (1)

Airplane IPv6 ICAO Net X

DefGW X

X / 64

Net-ID part of IPv6 address ES1 is AOC ES!

IPv6 X -> IPv6 ES1

fqD r1, L2-X

IGP Routing Table 2001::1:1

<table>
<thead>
<tr>
<th>EID</th>
<th>Next Hop</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default 1</td>
<td>2001::1:5</td>
<td>66 (xTR11)</td>
</tr>
<tr>
<td>Default 2</td>
<td>2001::1:6</td>
<td>44 (xTR12)</td>
</tr>
</tbody>
</table>

Mapping Cache xTR12

<table>
<thead>
<tr>
<th>EID</th>
<th>RLOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATS ES / 64</td>
<td>7.7.X.1</td>
</tr>
</tbody>
</table>
Traffic from Location ICAO X to Ground ATS ES (2)

Diagram showing the flow of traffic from an Airplane IPv6 ICAO Net X to Ground ATS ES1. The diagram includes the IGP Routing Table and Mapping Cache for the traffic flow.

**IGP Routing Table 2001::1:1**

<table>
<thead>
<tr>
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<th>Next Hop</th>
<th>Metric</th>
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<tbody>
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<td>Default 1</td>
<td>2001::1:5</td>
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<td>Default 2</td>
<td>2001::1:6</td>
<td>44 (xTR12)</td>
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</tbody>
</table>

**Mapping Cache xTR12**

<table>
<thead>
<tr>
<th>EID</th>
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<td>ATS ES / 64</td>
<td>7.7.X.1</td>
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→ **Multilink Seamless Operation**
→ Seamless Handover Access Network
→ Summary
→ Multilink (1): Registration Phase
Multilink (2): Location Announcement

Airplane IPv6 ICAO Net X

DefGW X
X / 64

LDACS L2-ID X

SATCOM L2-ID X

ICAO X, Pref. 2, Quality 1, fgD/2, L2-X

IGP Routing Table xTR21

<table>
<thead>
<tr>
<th>EID</th>
<th>Next Hop</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>2001::2:1</td>
<td>E2 21</td>
</tr>
<tr>
<td>2001::2:1</td>
<td>2001::2:x</td>
<td>77</td>
</tr>
</tbody>
</table>

IGP Routing Table xTR22

<table>
<thead>
<tr>
<th>EID</th>
<th>Next Hop</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>2001::2:1</td>
<td>E2 21</td>
</tr>
<tr>
<td>2001::2:1</td>
<td>2001::2:y</td>
<td>55</td>
</tr>
</tbody>
</table>

OSPF Update IPv4 via 2001::2:1, metric E2 21

E2 > PRD
Via EEM
Map Resp. X: Rloc 7.7.2.1, Pri 21
Map Resp. X: Rloc 7.7.2.2, Pri 21

Site Registration

<table>
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<tr>
<th>EID</th>
<th>RLOC</th>
<th>PRIO</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>7.7.1.1</td>
<td>11</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.1.2</td>
<td>11</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.2.1</td>
<td>21</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.2.2</td>
<td>21</td>
</tr>
</tbody>
</table>

AOC ES

ATS ES

SEC Region 1

SEC Region 2

LDACS SN

SATCOM SN

A/G-R

AC-R

G/G-R

LISP MS/MR1

LISP MS/MR2

EID
RLOC
PRIO
X / 64
7.7.1.1
11
X / 64
7.7.1.2
11
X / 64
7.7.2.1
21
X / 64
7.7.2.2
21
Multilink (3a): Traffic To ICAO X Still Old Path
→ Multilink (3b): Traffic From ICAO X Still Old Path

Airplane IPv6 ICAO Net X

DefGW X

IPv6 X -> IPv6 ES1 fqD r1, L2-X

LDACS L2-ID X

SATCOM L2-ID X

AC-R

IPv6 X -> IPv6 ES1

SEC Region 1

IGP Routing Table 2001::1:1

<table>
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Mapping Cache xTR12

<table>
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<tr>
<th>EID</th>
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<tbody>
<tr>
<td>ATS ES / 64</td>
<td>7.7.X.1</td>
</tr>
</tbody>
</table>

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ESA_ICAO_ATN_IPS_TN1_V03.pptx
**→ Multilink (4a): Seamless Switchover**

**Airplane IPv6 ICAO Net X**

**EID** | **Next Hop** | **Metric**
---|---|---
X / 64 | 2001::2:1 | E2 11
2001::2:1 | 2001::2:x | 77

**IGP Routing Table xTR21**

**EID** | **RLOC** | **PRIO**
---|---|---
X / 64 | 7.7.1.1 | 11
X / 64 | 7.7.1.2 | 11
X / 64 | 7.7.2.1 | 11
X / 64 | 7.7.2.2 | 11

**IGP Routing Table xTR22**

**EID** | **Next Hop** | **Metric**
---|---|---
X / 64 | 2001::2:1 | E2 11
2001::2:1 | 2001::2:y | 55

**Now LISP Priority for Net X of Region 2 has changed (lower value)**
Multilink (4b): Seamless Switchover

ICAO X, Pref. 2, Quality 1, fqD r1, L2-X

LDACS L2-ID X

SATCOM L2-ID X

OSPF Update, IPv6 X
Via 2001::1:1, metric E2 21

OSPF E2 -> LISP PRIO

Now LISP Priority for Net X of Region 1 has changed (higher value)

IGP Routing Table xTR11

<table>
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<th>Metric</th>
</tr>
</thead>
<tbody>
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<tr>
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<td>44</td>
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IGP Routing Table xTR12

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<th>EID</th>
<th>Next Hop</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>2001::1:1</td>
<td>E2 21</td>
</tr>
<tr>
<td>2001::1:1</td>
<td>2001::1:4</td>
<td>55</td>
</tr>
</tbody>
</table>

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Presentation Date: 2016-01-21
Author: FRQ
→ Multilink (4c): Seamless Switchover
→ Multilink (5): Traffic To ICAO X New Path

Traffic from IPv6 ICAO X to AOC ES 1 is a local decision of A-R based on preference.
Multilink (6): Shutdown Link

- IGP Routing Table xTR11
<table>
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<th>Next Hop</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>2001::1:1</td>
<td>62-21</td>
</tr>
<tr>
<td>2001::1:1</td>
<td>2001::1:3</td>
<td>44</td>
</tr>
</tbody>
</table>

- IGP Routing Table xTR12
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<th>Metric</th>
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<tbody>
<tr>
<td>X / 64</td>
<td>2001::1:1</td>
<td>62-21</td>
</tr>
<tr>
<td>2001::1:1</td>
<td>2001::1:4</td>
<td>55</td>
</tr>
</tbody>
</table>

- Site Registration
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<th>RLOC</th>
<th>Prio</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>7.7.1.1</td>
<td>24</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.1.2</td>
<td>21</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.2.1</td>
<td>11</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.2.2</td>
<td>11</td>
</tr>
</tbody>
</table>

- Mapping Cache xTRx1
<table>
<thead>
<tr>
<th>EID</th>
<th>RLOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>X / 64</td>
<td>7.7.2.1</td>
</tr>
<tr>
<td>X / 64</td>
<td>7.7.2.2</td>
</tr>
</tbody>
</table>
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Summary

Key points of this concept:

- **Airborne Router:**
  - Lightweight - No routing/mobility protocol -> simple default routing
  - Mobility/routing management delegated to ground systems
- **A/G router (Interface between access network and IPS Internetwork):**
  - Access SN has to forward the link quality and preference to the LISP border router
  - LISP Border Router maps the link quality to the LISP Priority
  - Location announcement only when the aircraft leaves/enters the access network

The Ground LISP concept is one of the two remaining proposals of the SESAR 15.2.4 project, which is defining the FCI in Europe.
Thank You For Your Attention
Questions?