The Internet without IP addresses - A new approach to the Internet Architecture

These slides can be found at http://goo.gl/mwxH6

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Thanks

• Prof Timothy Gonsalves
• Reena Singh
• IU-ATC project meeting:
  • DST(IN) and EPSRC (UK)
ILNP
Identifier-Locator Network Protocol

1. Why?
2. What?
3. How?
4. Where?
The changing world of IP

• How to support a *harmonised solution to many network functions in a scalable manner?*
  • Multi-homing (host and site).
  • Mobility (host and network).
  • Multi-path capable transport protocols.
  • Localised addressing (NAT).
  • Traffic engineering capability.
  • Packet-level, end-to-end security.
  • Virtual machine migration/mobility.

• Current solutions for such functions remain disparate, do not function well together and/or may not scale well.
Use of IP addresses today
# Naming Architecture: IP

<table>
<thead>
<tr>
<th>Protocol Layer</th>
<th>IP</th>
</tr>
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<tbody>
<tr>
<td>Application</td>
<td>FQDN or IP address</td>
</tr>
<tr>
<td>Transport</td>
<td>IP address (+ port number)</td>
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<tr>
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<td>IP address</td>
</tr>
<tr>
<td>(Interface)</td>
<td>IP address</td>
</tr>
</tbody>
</table>

**Entanglement 😞**

FQDN = fully qualified domain name
Separate Semantics

• Semantic overload of IP address:
  • **locator** semantics + **identifier** semantics
  • ease implementation of multi-homing, mobility, etc ...

• This is a known problem:
  • RFC4984, IAB, 2007
  • RFC2101, IAB, 1997
  • **IEN1, 1977**; IEN19, 1978, IEN23, 1978

• Many solutions now proposed:
  • HIP, LISP, SHIM6, SixOne – re-use of IP address
  • **ILNP** – only solution to deprecate use of IP addresses
# Naming Architecture: IP vs ILNP

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<td>IP address (+ port number)</td>
<td>(Node) Identifier (+ port number)</td>
</tr>
<tr>
<td>Network</td>
<td>IP address</td>
<td>Locator</td>
</tr>
<tr>
<td>(Interface)</td>
<td>IP address</td>
<td>(dynamic mapping)</td>
</tr>
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**Entanglement 😞**  
**Separation ☺**  

FQDN = fully qualified domain name
ILNP
Identifier-Locator Network Protocol

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What is ILNP?

• Identifier Locator Network Protocol:

• ILNP enhances Internet Protocol functionality through the use of crisp **naming**.

• March 2010: IRTF RRG Chairs recommend ILNP for development within the IETF (RFC6115 Feb 2011)

• People:
  • Ran Atkinson (Cheltenham Research, US)
  • Saleem Bhatti (University of St Andrews, UK)
Identifier-Locator namespaces in ILNP

- **Locator, L:**
  - Topologically significant.
  - Names a (sub)network (as today’s *network prefix*).
  - Used only for routing and forwarding in the core.
- **(Node) Identifier, NID:**
  - Is not topologically significant.
  - Names a logical/virtual/physical node, does **not** name an interface.
- **Upper layer protocols bind only to NID.**
ILNP: transport layer state

A = IP address
P = port number

At X:

At Y:

L = Locator
I = Identifier
P = port number

At X:

At Y:
Namespaces & namebindings

IP – static

- Application
- Transport session
- IP subnetwork
- Physical interface

ILNP – dynamic

- FQDN
- Application
- Transport session
- NID
- IP subnetwork
- Physical interface

animated knot from http://meritbadge.org/wiki/index.php/Knot#Granny_knot
ILNP: Locator Properties

• Locator names an IP (sub)network.
• Locator is equivalent to an IP routing prefix:
  • Multiple Locators can be used simultaneously.
  • Nodes can change their Locator values during the lifetime of an ILNP session.
• Enables “NAT”, mobility, multi-homing, end-to-end IPsec, site-controlled traffic engineering, etc.
• Locators NEVER used for transport layer state, e.g. by TCP, UDP, SCTP, etc.
  • end-to-end state now independent of topology
ILNP: Identifier (NID) Properties

• NID names a **node**, not an **interface**
• **Remains constant** during the lifetime of a transport session
• Nodes may use multiple NIDs concurrently:
  • only one NID for a given transport session
  • NIDs can be stable over time
• IPv6 ID formats supported by ILNP:
  • e.g. EUI-64, Private (RFC4941), CGA (RFC3972)
• Only NID is used by TCP, UDP, SCTP, IPsec, etc.
ILNP
Identifier-Locator Network Protocol

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ILNP: Engineering

• Could have gone “clean slate” … not practical.
• Main architectural ideas can be applied as extensions to both IPv4 and IPv6:
  • current RFCs cover both
• Focus here is on IPv6, as the engineering is cleaner, but IPv4 is also possible.
• ILNP extensions to IPv6 – ILNPv6:
  • Routers see an ordinary IPv6 packet.
  • ILNPv6 hosts see an ILNPv6 packet.
ILNPv6

• Can be seen as a set of extensions to IPv6:
  • Same packet format as IPv6, with extensions
  • No changes required in core IPv6 routers
  • Incrementally deployable on IPv6 networks
  • Backwards compatible with IPv6 devices

• Split 128-bit IPv6 address:
  • 64-bit Locator (L64) (sub)network name.
  • 64-bit Identifier (NID) node name.
  • encode NID and L64 into existing IPv6 packet
IPv6 addresses and ILNPv6 I-L vectors

IPv6 address (as in RFC3587 + RFC4291):

\[
\begin{array}{c|c|c|c}
| & 3 & 45 \text{ bits} & 8/16 \text{ bits} & 64 \text{ bits} \\
\hline
\text{Unicast Routing Prefix} & Interface Identifier
\end{array}
\]

ILNPv6 I-L vector (as in RFC6741):

\[
\begin{array}{c|c|c}
| & 64 \text{ bits} & 64 \text{ bits} \\
\hline
\text{Locator} & \text{Node Identifier (NID)}
\end{array}
\]

- Same syntax and semantics as IPv6 routing (address) prefix
- These bits only examined and acted upon by end systems
IPv6 packet header – host view

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 | 1 |
| 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 |
| +-----------------------------------------------+-----------------------------------------------+|
| | Version | Traffic Class | Flow Label |
| +-----------------------------------------------+-----------------------------------------------+|
| +-----------------------------------------------+ Payload Length | Next Hdr | Hop Limit |
| +-----------------------------------------------+-----------------------------------------------+|
| +-----------------------------------------------+ Source IPv6 Address |
| +-----------------------------------------------+ Destination IPv6 Address |

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ILNPv6 packet header – host view

<table>
<thead>
<tr>
<th>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</th>
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<tbody>
<tr>
<td>Version</td>
</tr>
<tr>
<td>Payload Length</td>
</tr>
<tr>
<td>Source Locator</td>
</tr>
<tr>
<td>Source Identifier</td>
</tr>
<tr>
<td>Destination Locator</td>
</tr>
<tr>
<td>Destination Identifier</td>
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</tbody>
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DNS enhancements

• New DNS records required (RFC6742):
  • NID – node identifier
  • L64 – ILNPv6 locator
  • L32 – ILNPv4 locator
  • LP – locator pointer

• Product support:
  • NLnetLabs.nl – available today
  • BIND – coming soon
Example 1: Localised Addressing (aka NAT) (from RFC6748)
NAT in IPv4 and IPv6

- **NAT**:  
  - single address shared amongst many hosts (use of port numbers for multiplexing)
- **End-to-end integrity lost**, as identity namespace has a discontinuity at the site border router (SBR), impacting other end-to-end functions (e.g. IPsec)
- SBR may have to perform other functions also, e.g. application proxy
NAT equivalent in ILNPv6

- Localised ‘addressing’ is a feature not a hack:
  - Locator is not part of the end system transport session state.
  - $L_L$ as in RFC4193 (ULA)
  - end-to-end view
- SBRs perform Locator rewriting without affecting end-to-end state.
Example 2:
Mobile Networks
(from RFC6748)
Current IP mobility model

• Use of proxies:
  • home agent (HA), foreign agent (FA)
• Use of indirection via tunnelling:
  • mobile hosts looks to be non-mobile to correspondent nodes
  • IP-in-IP tunnel can cause problems
• Home address (HoA) – identity:
  • DNS lookup resolves to HoA
• Care-of-Address (CoA) – locator
• Similar principle for mobile networks
• IPv6 improvements for Mobile IPv6
Mobile IP – basic operation

1) MH arrives at FN, and locates FA (using agent advertisements from FA or by solicitation).
2) MH completes registration procedure with FA.
3) MH updates HA with its new CoA (i.e. the FA).
4) Host A now tries to contact MH. Packets for MH are intercepted by HA.
5) HA tunnels the packets from Host A to the CoA for MH (i.e. the FA).
6) The FA de-encapsulates the inner IP packet and transmits the packet locally to MH.
7) The packets from MH to Host A are sent directly from the FN.

Improved in IPv6:
• mobile host can act as FA
• use of Binding Update – send CoA to HostA

IP-in-IP encapsulation

\[
\begin{array}{c|c}
\text{data} & \text{src=HostA}
\end{array}
\begin{array}{c|c}
\text{dst=MH} & \text{src=HostA}
\end{array}
\begin{array}{c|c}
\text{dst=MH} & \text{src=HostA}
\end{array}
\begin{array}{c|c}
\text{dst=CoA} & \text{src=HostA}
\end{array}
\]
Mobile networks in ILNPv6 [1]

- Locator re-writing can ‘hide’ site movement from internal nodes.
- SBR changes Locator value as the mobile network moves:
  - Sends **Locator Update** (LU) messages to correspondents.
  - Updates DNS with new Locator value
ILNP Locator Update (LU) [1]

Locator change triggered

Hard hand-over
(new L values can be learned from IPv6 router advertisements)
Mobile networks in ILNPv6 [2]

- Network layer soft-hand-off possible.
- Requires 2+ radio channels / interfaces.
- SBRs handle Locator rewriting + forwarding as required.
ILNP Locator Update (LU) [2]

Soft hand-over
(new L values can be learned from IPv6 router advertisements)
Other functionality ...

- Multi-homing
- Multi-path transport
- VM migration/mobility
- Traffic engineering options
- Improved packet and network security
- See papers:
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Identifier-Locator Network Protocol

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ILNP: Status (March 2013)

- 8+ years of peer-reviewed architectural research:
  - Papers and talks available at ILNP web site [http://ilnp.cs.st-andrews.ac.uk/](http://ilnp.cs.st-andrews.ac.uk/) (also advert for PhD student)
- 9 Experimental status RFCs (IRTF RRG):
  - RFCs 6740-6748 (Nov 2012)
- PhD students:
  - 2 PhD students currently funded
  - 2 more PhD students expected in ~6 months
- Open source prototypes from University of St Andrews:
  - FreeBSD “ping demo” available soon.
  - Linux “ping demo” in ~12 months.
Thank you! Questions?

• ILNP further information:
  • see http://ilnp.cs.st-andrews.ac.uk/ for links to RFCs, papers and talks
  • ... or come and talk to me!

• Reading – start off with:
  • “Evolving the Internet Architecture Through Naming”, IEEE JSAC, Oct 2010, (7 pages)
    http://dx.doi.org/10.1109/JSAC.2010.101009