Naming for Networking

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Using naming

A lot of the challenges we have with the use of IP today (both IPv4 and IPv6) could be solved by a cleaner approach to naming!

1. Introduction
2. ILNPv6 - changing naming and addressing
3. Approach to mobility
4. Approach to multi-homing, NAT and security
5. Project status

Mobile IP [1]

- Support mobile users without affecting others
- Transparency:
  - to upper layers
  - to remote end-systems
- IPv4 and IPv6:
  - IP address indicates **point of attachment to network**
- Movement of host means:
  - new IPv4 address?
  - update routing information?

Mobile IP [2]

- Mobile host (MH):
  - **home address**, home network (HN), home agent (HA)
  - **care-of-address (CoA)**, foreign network (FN), foreign agent (FA)
- Communication:
  - HA sends packets to CoA: IP-in-IP enscapsulation
  - HA must reply to ARP for MH
- CoA:
  - foreign agent
  - may be new IP address (co-located CoA)

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Mobile IP [3]

1) MH arrives at FN, and locates FA (using agent advertisements from FA or by solicitation).

2) MH completes registration procedure with FA.

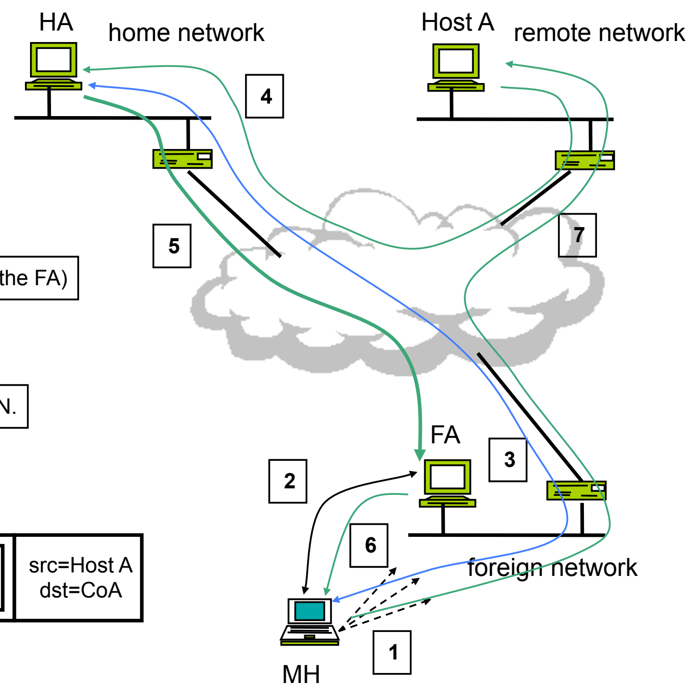
3) MH updates HA with its new CoA (i.e. the FA).

4) Host A now tries to contact MH. Packets for MH are intercepted by HA.

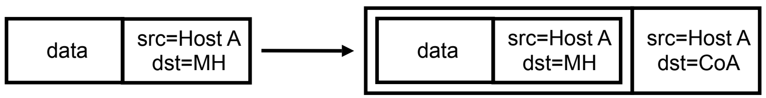
5) HA tunnels the packets from Host A to the CoA for MH (i.e. the FA)

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.



IP-in-IP encapsulation



Mobile IP [4]

- ✔ Transparent to non-mobile hosts
- ✔ Does not break/change existing IP addressing and routing
- ✔ Can be introduced into the network as required (incrementally)
- ✔ Normal (unicast) routers do not need to be modified
- ✔ Does not affect DNS usage

- ✘ Complex architecture:
  - use of addresses
  - use of agents
- ✘ Asymmetric routing:
  - could be inefficient
  - QoS
  - higher layer protocol operation (e.g. TCP)
- ✘ Security:
  - firewalls configuration
  - authentication
  - end-to-end security
- ✘ Hand-off: FAs and FA/HA

Mobile IPv6

- Stateless address auto-configuration:
  - find an address (CoA) for use at the FN
- Neighbour discovery:
  - find default router
- No FA required to support mobility:
  - MH takes care of home address and foreign address
- Need dynamic DNS update support
- Route optimisation:
  - send CoA to remote end-system
- IPv6 Binding Update:
  - similar function to ILNPv6 Locator Update
- Security (?):
  - authentication and privacy

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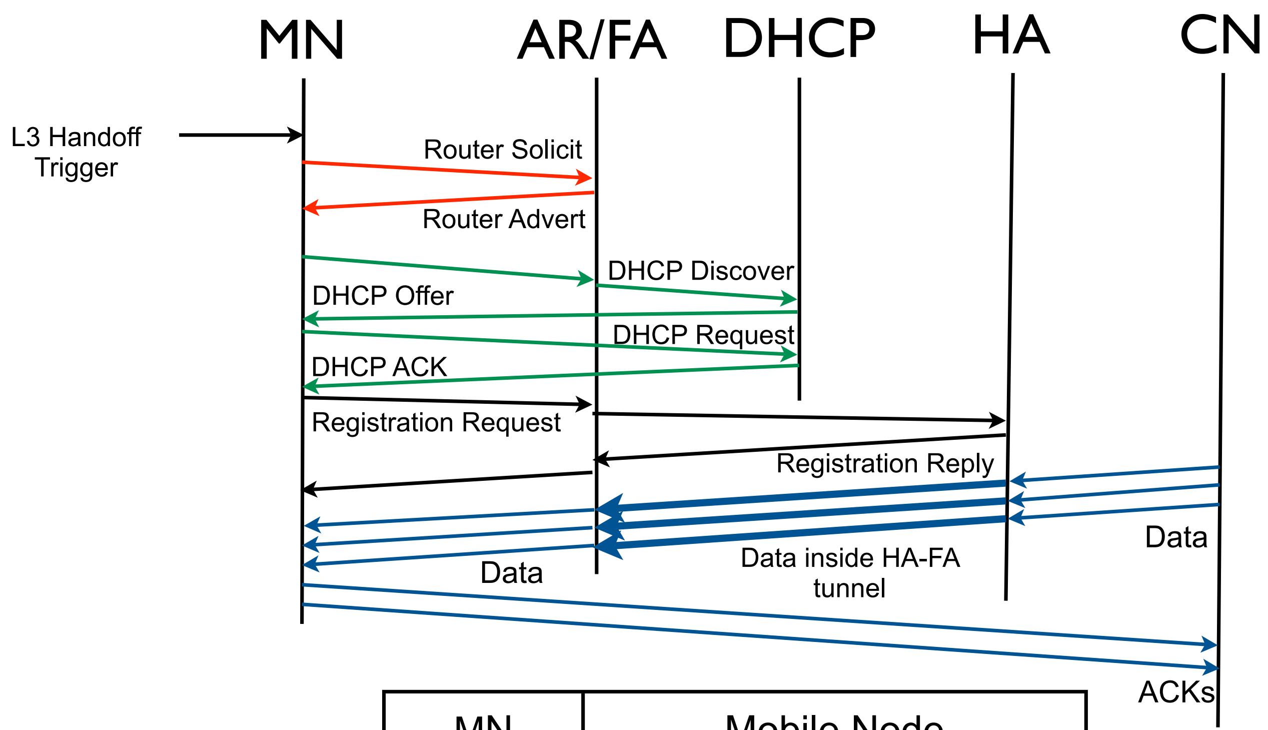
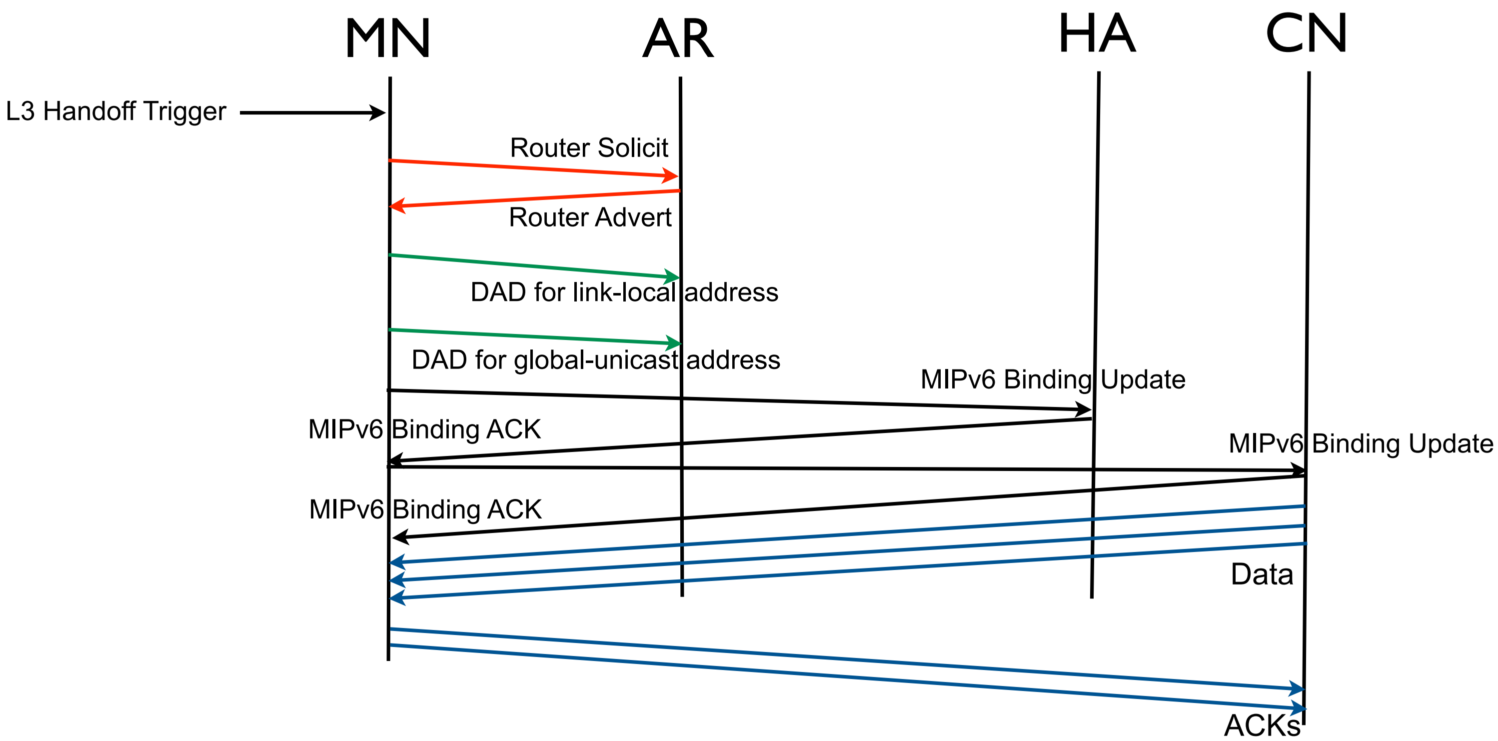
MIPv4 Network Handoff



MN	Mobile Node
AR/FA	Router/Foreign Agent
DHCP	DHCP Server
HA	Home Agent
CN	Correspondent Node

MIPv6 Network Handoff



MN	Mobile Node
AR	Router serving MN
HA	Home Agent
CN	Correspondent Node

Existing Mobility Approaches

- Mobile IPv4 (MIPv4):
  - not widely implemented or deployed at present
  - complex protocol: mobile node (MN), Home Agent (HA), Foreign Agent (FA)
  - numerous optional optimisations have been proposed
- Mobile IPv4 (MIPv6):
  - also not widely implemented or deployed at present
  - protocol similar to MIPv4
  - even more complex with numerous extensions proposed

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Architectural Claim

If we provide a richer set of namespaces then the Internet Architecture can better support mobility, multi-homing, and other important capabilities:

- *provide broader set of namespaces than at present*
- *reduce/eliminate names with overloaded semantics*
- *provide crisp semantics for each type of name*

“Standing on the Shoulders of Giants”

- Computer Science is sometimes accused of blindly reinventing the wheel.
- We actively tried to avoid that, so credit to:
  - IEN1 for the use of separate names at layers 3 and 4
  - Dave Clark for (c.1995) email to a public IRTF list proposing to split the IP address into two pieces
  - Mike O’Dell for two early proposals (8+8, GSE)
    - IETF claimed these ideas were unworkable
  - IRTF Name Space RG (NSRG)
- We extended and enhanced those early ideas to address a broad set of issues with our comprehensive proposal.

ILNPv6

- We propose an alternative networking protocol derived from IPv6, which we call ***ILNPv6***:
  - could be considered a set of enhancements to IPv6
  - provides full backwards compatibility with IPv6
  - provides full support for incremental deployment
  - IPv6 routers do not need to change
- *ILNPv6* splits the IPv6 address in half:
  - ***Locator (L)***: 64-bit name for the subnetwork
  - ***Identifier (I)***: 64-bit name for the host

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IPv6 Packet Header

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version| Traffic Class |           Flow Label                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Payload Length        |  Next Hdr     |   Hop Limit   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                                                               +
|                                                               |
+-+-                        Source Address                    -+-+
|                                                               |
+                                                               +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                                                               +
|                                                               |
+-+-                     Destination Address                  -+-+
|                                                               |
+                                                               +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

ILNPv6 Packet Header

```
 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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version| Traffic Class |           Flow Label                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Payload Length        |  Next Hdr     |   Hop Limit   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                        Source Locator                         +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                      Source Identifier                        +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                      Destination Locator                      +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                    Destination Identifier                     +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Locators versus Identifiers

- **Locator (L):**
  - uses the existing “Routing Prefix” bits of an IPv6 address
  - names a single subnetwork (/48 allows subnetting)
  - **topologically significant, so the value of L changes as subnetwork connectivity changes**
  - only used for routing and forwarding
- **Identifier (I):**
  - uses the existing “Interface ID” bits of an IPv6 address
  - **names (physical/logical/virtual) host, not an interface**
  - remains constant even if connectivity/topology changes
  - uses IEEE EUI-64 syntax, which is the same as IPv6
    - MAC-based Identity is very probably globally unique
  - only used by transport-layer (and above) protocols

Use of Identifiers and Locators

- All ILNP nodes:
  - have 1 or more Identifiers at a time
  - only Identifiers used at Transport-Layer or above
  - have 1 or more Locators at a time
  - only Locators are used to route/forward packets
- An ILNP “node” might be:
  - a single physical machine,
  - a virtual machine,
  - or a distributed system.

Naming Comparison

Protocol Layer	IP	ILNP
Application	FQDN or IP address	FQDN
Transport	IP address (+ port number)	Identifier (+ port number)
Network	IP address	Locator
Link	MAC address	MAC address

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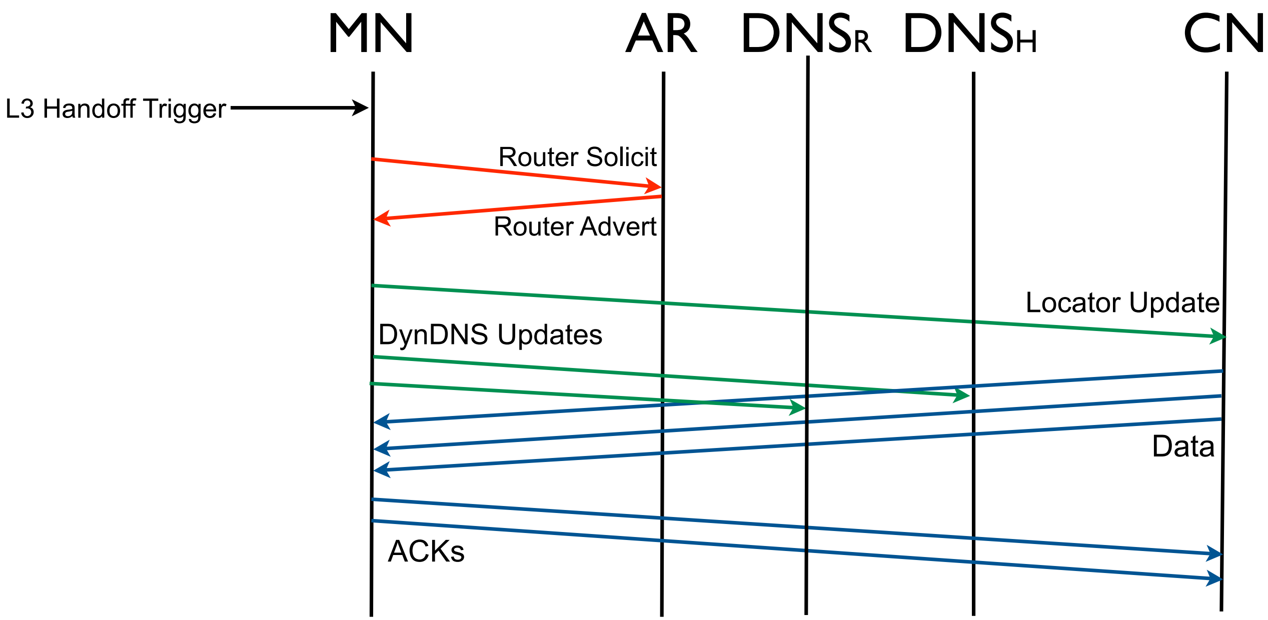
Naming and Mobility

- With MIP (v4 and v6), IP addresses retain their dual role, used for both **location** and **identity**:
  - overloaded semantics creates complexity, since all IP addresses are (potentially) topologically significant
- With ILNP, identity and location are separate:
  - **new Locator used as host moves**
    - reduces complexity: only Locator changes value
  - **constant Identifier as host moves**
    - agents not needed and triangle routing never occurs
  - **upper-layer state (e.g. TCP, UDP) only uses Identifier**

Mobility Implementation

- Implementation in correspondent node:
  - uses DNS to find MN's set of Identifiers and Locators
  - only uses Identifier(s) in transport-layer session state
  - uses Locator(s) only to forward/route packets
- Implementation in mobile node (MN):
  - accepts new sessions using currently valid I values
  - With ILNPv6, when the MN moves:
    - MN uses *ICMP Locator Update (LU)* to inform other nodes of revised set of Locators for the MN
    - LU can be authenticated via IP Security (or new Nonce Option)
    - MN uses *Secure Dynamic DNS Update* to revise its Locator(s) in its Authoritative DNS server

ILNPv6 Network Handoff



MN	Mobile Node
AR	Router serving MN
DNSR	DNS Server (reverse)
DNSH	DNS Server (forward)
CN	Correspondent Node

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Multi-Homing with ILNP

- ILNP supports both forms of multi-homing
- *ICMP Locator Update* mechanism handles uplink changes (e.g. fibre cut/repair)
- ILNP reduces size of RIB in DFZ:
  - more-specific routing prefixes are no longer used for this
- In turn, this greatly helps with BGP scalability
- New DNS *Locator Pointer (LP)* record enhances DNS scalability for site multi-homing
- **Also supports mobile networks**

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Mobile networks

- Mobile networks are a special case of site multi-homing:
  - the site border router must (discover and) use a new routing prefix, i.e. new Locator value, when the network connectivity changes.
- The other hosts in the mobile network all need to adopt the new Locator value:
  - this will require Locator updates to be sent to all current correspondents
- A DNS *Locator Pointer* (LP) Record can be used to name a Locator (L) record for the site:
  - optimisation possible for management via site border router (work in progress)

ILNPv6: NAT Integration

- NAT is here to stay:
  - most residential gateways use NAT or NAPT
  - #1 user-requested feature for IPv6 routers is NAT
- ILNPv6 eliminates issues with NAT:
  - upper-layer protocol state is bound to I only, never to L
  - only value of L changes as the NAT is traversed
  - so NAT function now invisible to upper-layer protocols
- ILNPv6 IPsec is not affected by NAT:
  - Security Association is bound to Identifiers, not Locators
  - ILNP AH covers Identifiers, but does not cover Locators
  - ILNP IPsec and NAT work fine together
    - special-case "IPsec NAT traversal" code is no longer needed

Security Considerations

- IP Security with ILNP:
  - can use IPsec AH and ESP for cryptographic protection
  - ILNP AH includes I values, but excludes L values
  - IPsec Security Association (SA) bound to value of I, not L
- Existing IETF DNS Security can be used as-is

ILNP: Integrated Solution

- Mobility support is better integrated than MIPv4 or MIPv6:
  - mobility is native capability
  - mobility mechanisms are much simpler
  - authentication is practical to deploy
- Multi-homing and mobile network support improved over MIPv4 and MIPv6:
  - supports dynamic multi-homing for hosts and networks
  - multi-homing also integrated with mobility
  - routing scalability (BGP, DFZ RIB) is greatly improved
- NAT support is integrated
- IPsec support is integrated

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References

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  http://www.cs.st-andrews.ac.uk/~saleem/papers/2008/mobiarch2008/mobiarch2008-abh2008.pdf

ILNPv6: No Free Lunch

- No globally-routable network interface name:
  - potential impact on SNMP MIBs, e.g. to get interface counters form a particular interface.
- A few legacy apps might remain problematic:
  - e.g. FTP is probably the worst case:
    - FTP mis-uses the IP address as application-layer name.
- DNS reliance is not new, but is more explicit:
  - at present, users perceive “DNS fault” as “network down”.
  - ILNP creates no new DNS security issues.
  - existing IETF standards for *DNS Security* and *Secure Dynamic DNS Update* work fine without alteration:
    - already supported in BIND and other DNS servers.

DNS Enhancements

Name	DNS Type	Definition
Identifier	I	Names a Node
Locator	L	Names a subnet
Reverse Locator	PTRL	FQDN for the DNS Server responsible for subnet L
Reverse Identifier	PTRI	FQDN for the I that is present at subnet L
Locator Pointer	LP	Forward pointer from FQDN to an L record

FQDN = fully qualified domain name

IAB Naming and Addressing Workshop 18-19 October 2006 [1]

RFC4984 (Sep 2007), p4

The clear, highest-priority takeaway from the workshop is the need to devise a scalable routing and addressing system, one that is scalable in the face of multihoming, and that facilitates a wide spectrum of traffic engineering (TE) requirements.

IAB Naming and Addressing Workshop 18-19 October 2006 [2]

RFC4984 (Sep 2007), p6

.... workshop participants concluded that the so-called "locator/identifier overload" of the IP address semantics is one of the causes of the routing scalability problem as we see today. Thus, a "split" seems necessary to scale the routing system, although how to actually architect and implement such a split was not explored in detail.

Other naming/addressing proposals (not a comprehensive list)

- Host Identity Protocol (HIP) - host-based:
  - IRTF and IETF - RFC4423.
  - (research grade) implementations available.
  - extra layer of naming using public-key.
- SHIM6 - host-based:
  - IETF - Internet drafts.
  - shim layer with address semantic overloading.
- LISP - network-based:
  - IETF - Internet drafts.
  - end-system “transparent”.
  - use of tunnels and additional state in the network.

Next steps

- Demo implementation of ILNPv6 in BSD UNIX
  - which is in progress now.
- Implementation will be used in experiments to test feasibility of ILNPv6:
  - verify backwards compatibility with IPv6 routers.
  - wide area testing on UK SuperJANET connectivity between St Andrews (Scotland) and London (England).
  - later extend to international testing over IPv6 backbone.
- Fine-tune ILNP design and implementation based on experimental results.
- Retro-fit to IPv4(?)

Application areas

- Pervasive and Ubiquitous Computing:
  - transparency for mobility and end-to-end security
- Complex, heterogeneous network scenarios:
  - civil defence and emergency response
  - military networks
- Autonomous and semi-autonomous networks:
  - mobile sensor networks
  - unmanned autonomous vehicles (UAVs)
- Long term evolution (LTE) - edge network:
  - layer 3 soft-handoff, vertical hand-off, net neutrality

Summary

- ILNP treats the IP Address as consisting of separate Identifier & Locator values.
- This enables native Mobility (without agents).
- Also, Multi-Homing, NAT, and Security are well integrated with Mobility.
- Improvements in the Naming Architecture enable simpler protocol approaches and ILNP is consistent with the wider goals of the future direction for Internet architecture.

Thank you!

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  - Steve Hailes s.hailes@cs.ucl.ac.uk