IP without IP addresses

http://ilnp.cs.st-andrews.ac.uk/

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- http://ilnp.cs.st-andrews.ac.uk/

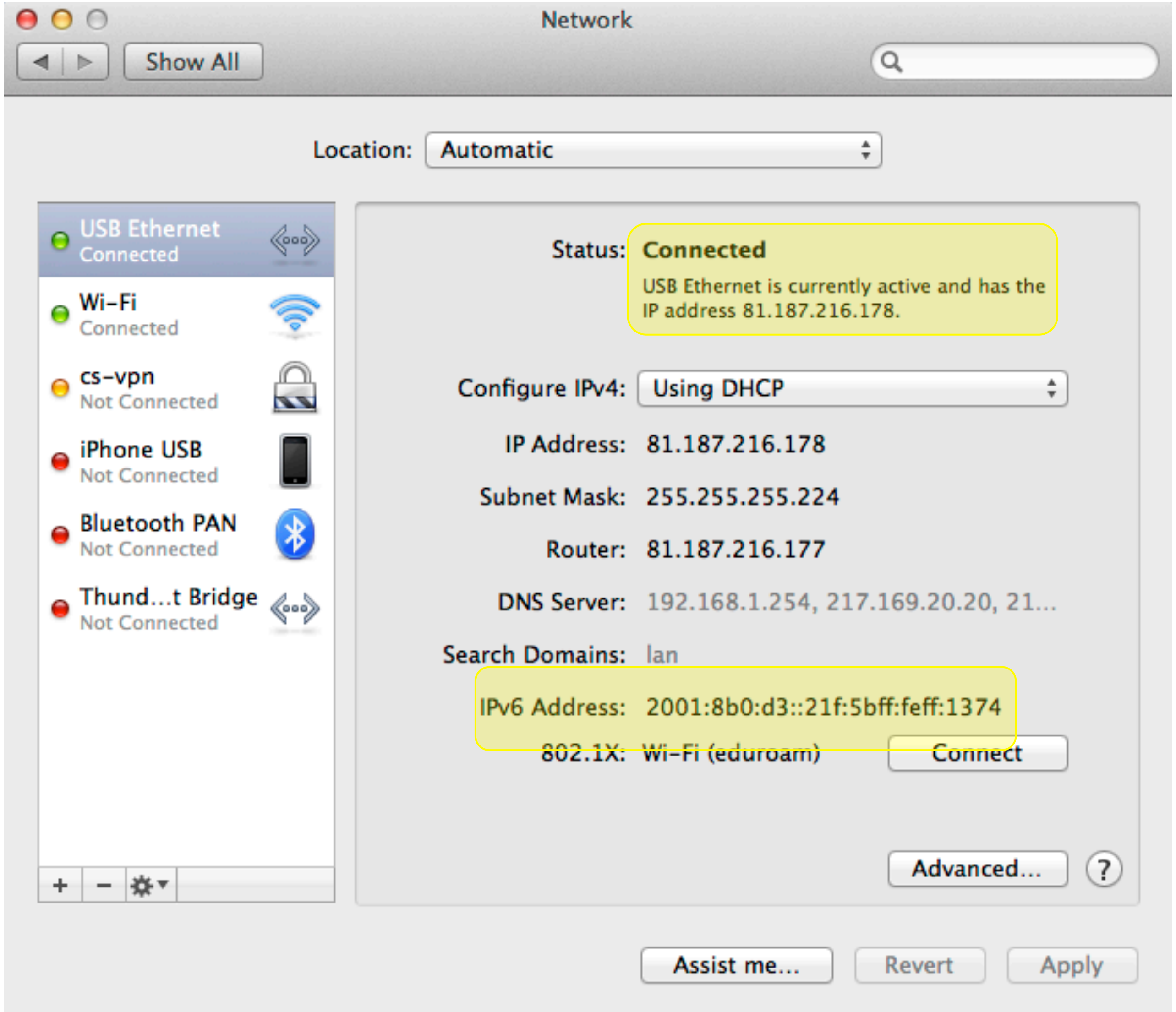
ILNP
Identifier-Locator Network Protocol

1. **Why?**
2. What?
3. How?

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

Protocol Layer	IP
Application	FQDN or IP address
Transport	IP address (+ port number)
Network	IP address
(Interface)	IP address

Entanglement ☹

FQDN = fully qualified domain name

RFC2101 (Feb 1997)

IPv4 Address Behaviour Today
RFC2101 (IAB, Informational) pp 3-4

3. Ideal properties.

... it is easy to see the ideal properties of identifiers and locators. Identifiers should be assigned at birth, never change, and never be re-used. Locators should describe the host's position in the network's topology, and should change whenever the topology changes.

Unfortunately neither of the these ideals are met by IPv4 addresses.

RFC4984 (Sep 2007)

Report from the IAB Workshop on Routing and Addressing
RFC4984 (IAB, Informational) , 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.
```

New namespaces, separate semantics

- This is a well-known problem:
  - RFC4984, IAB (2007)
  - RFC2101, IAB (1997)
  - IEN1 (1977)
- Semantic overload of IP address:
  - **locator** semantics + **identifier** semantics
  - ease implementation of multi-homing, mobility, etc …
- Many "ID/Locator separation" solutions proposed:
  - HIP, LISP, SHIM6, SixOne – re-use of IP address
  - **ILNP – deprecate use of IP addresses**

Naming Architecture: IP vs ILNP

Protocol Layer	IP	ILNP
Application	FQDN or IP address	FQDN (RFC1958)
Transport	IP address (+ port number)	(Node) Identifier (+ port number)
Network	IP address	Locator
(Interface)	IP address	(dynamic mapping)
	Entanglement ☹	**Separation ☺**

FQDN = fully qualified domain name

ILNP
Identifier-Locator Network Protocol

1. Why?
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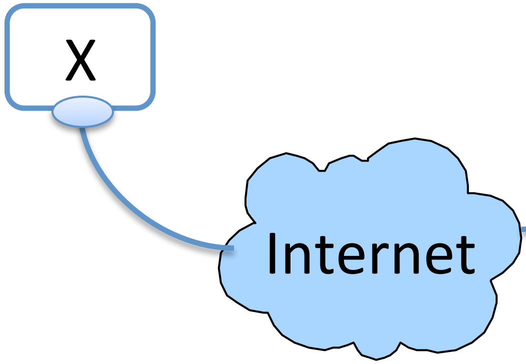
ILNP

- Identifier Locator Network Protocol:
  - http://ilnp.cs.st-andrews.ac.uk/
- 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)

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 example



A = IP address
P = port number

At X:
<TCP: A_X, P_X, A_Y, P_Y> <IP: A_X, A_Y>

At Y:
<TCP: A_Y, P_Y, A_X, P_X> <IP: A_Y, A_X>

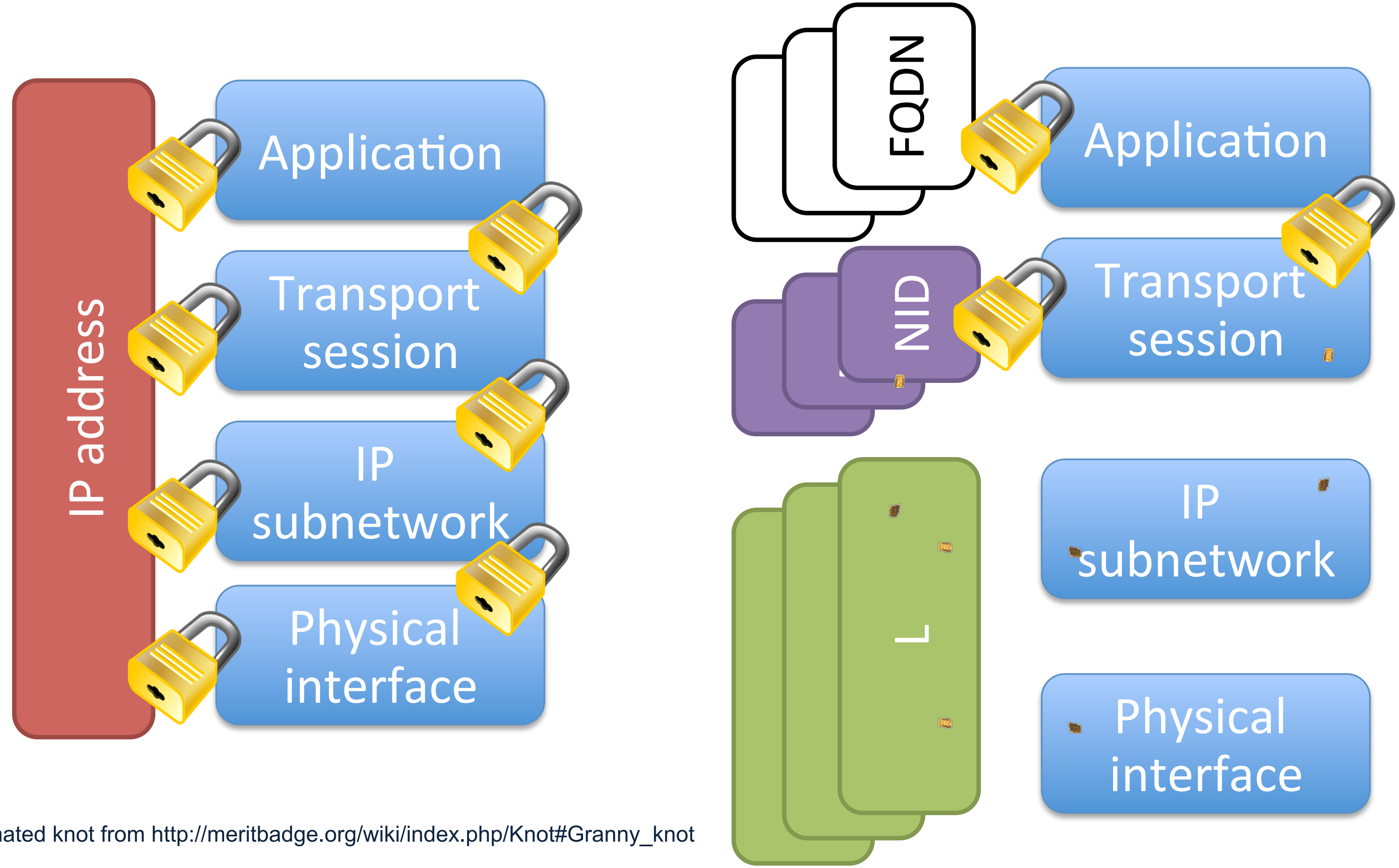
L = Locator
I = (Node) Identifier
P = port number

At X:
<TCP: I_X, P_X, I_Y, P_Y> <IP: L_X, L_Y>

At Y:
<TCP: I_Y, P_Y, I_X, P_X> <IP: L_Y, L_X>

Namespaces & namebindings

IP – static ILNP – dynamic



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 NID 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

1. Why?
2. What?

3. How?

ILNP: Engineering

- Possible to try a “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 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

encode L64 and NID values into IPv6 packets

```
IPv6 address (as in RFC3587 + RFC4291):

 | 3 |     45 bits         | 8/16 bits |       64 bits               |
 +---+---------------------+-----------+-----------------------------+
 |        Unicast Routing Prefix       |     Interface Identifier    |
 +---+---------------------+-----------+-----------------------------+
```

IPv6 routing (address) prefix

same syntax, different semantics

```
ILNPv6 I-L vector (as in RFC6741):

 |               64 bits               |       64 bits               |
 +---+---------------------+-----------+-----------------------------+
 |               Locator               |   Node Identifier (NID)     |
 +---+---------------------+-----------+-----------------------------+
```

same syntax and semantics as
IPv6 routing (address) prefix
so IPv6 core routers work as today

these bits only examined and
acted upon by end systems

IPv6 packet header – router view

```
 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 IPv6 Address                   +
|                                                               |
+-                                                             -+
|                                                               |
+                                                               +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                      Destination IPv6 Address                 +
|                                                               |
+-                                                             -+
|                                                               |
+                                                               +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

ILNPv6 packet header – host view

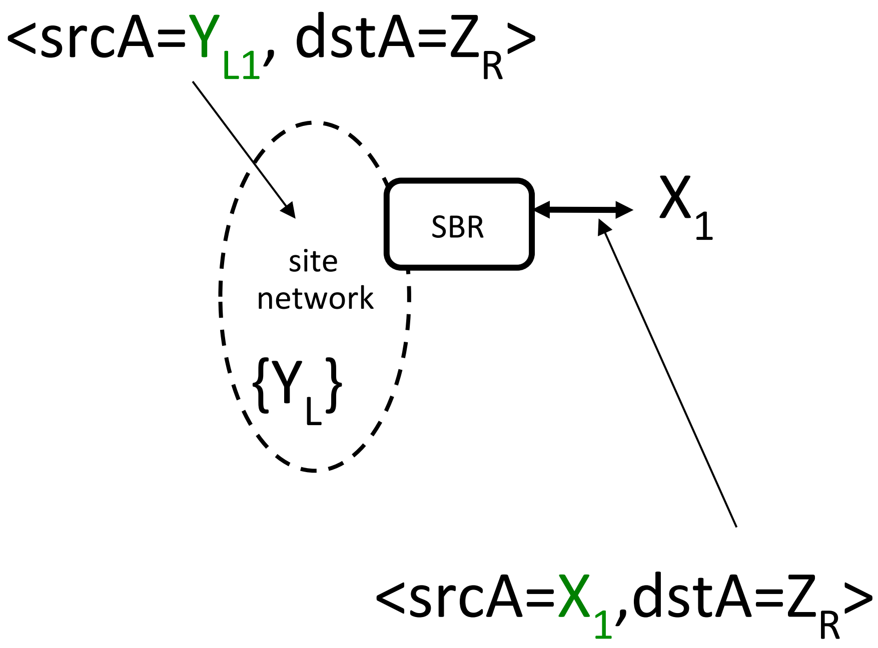
```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version| Traffic Class |           Flow Label                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+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

DNS enhancements

- New DNS records required (RFC6742):
  - NID – node identifier
  - L64 – ILNPv6 locator
  - L32 – ILNPv4 locator
  - LP – locator pointer
- Product support available:
  - NLnetLabs.nl – NSD (Feb 2013)
  - ISC – BIND (June 2013)

Example 1:
Localised Addressing
(aka NAT)
(from RFC6748)

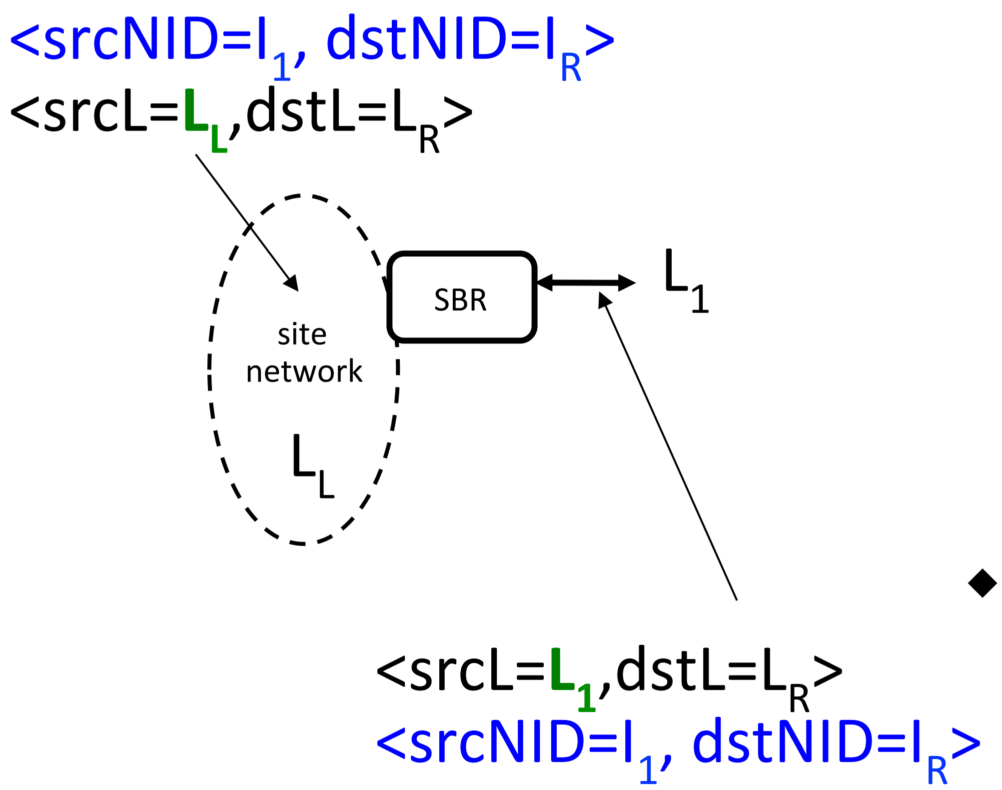
NAT in IPv4 and IPv6



SBR site border router

- **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.

SBR site border router

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.

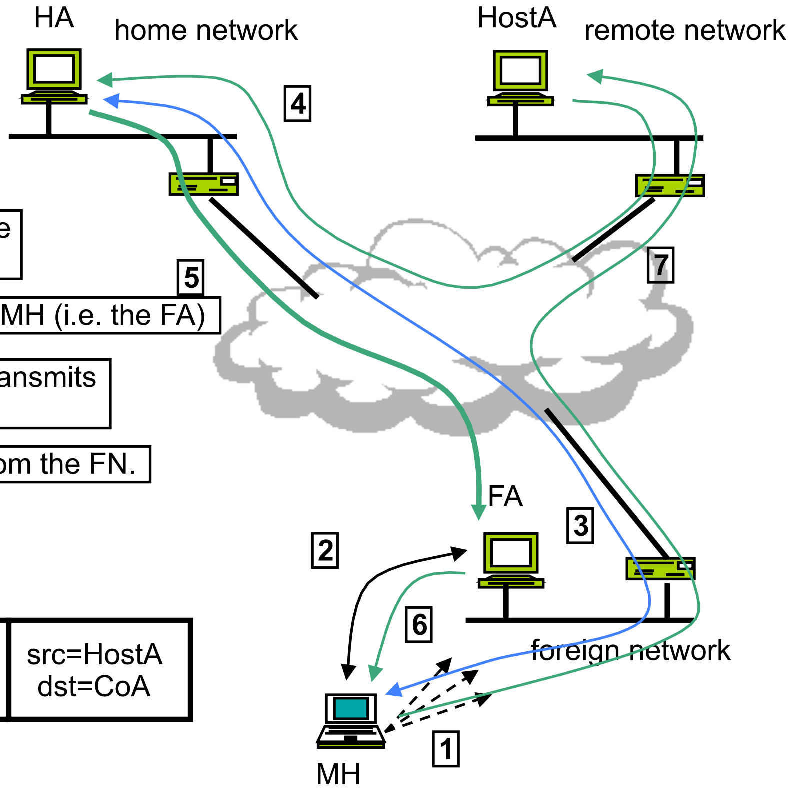
3) MH updates HA with its new CoA (i.e. the FA).

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

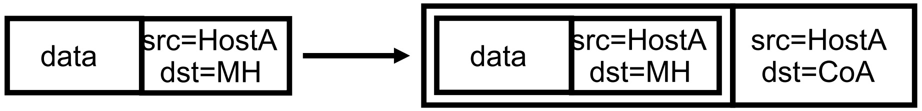
5) HA tunnels the packets from Host A to the CoA for MH (i.e. the FA)

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.



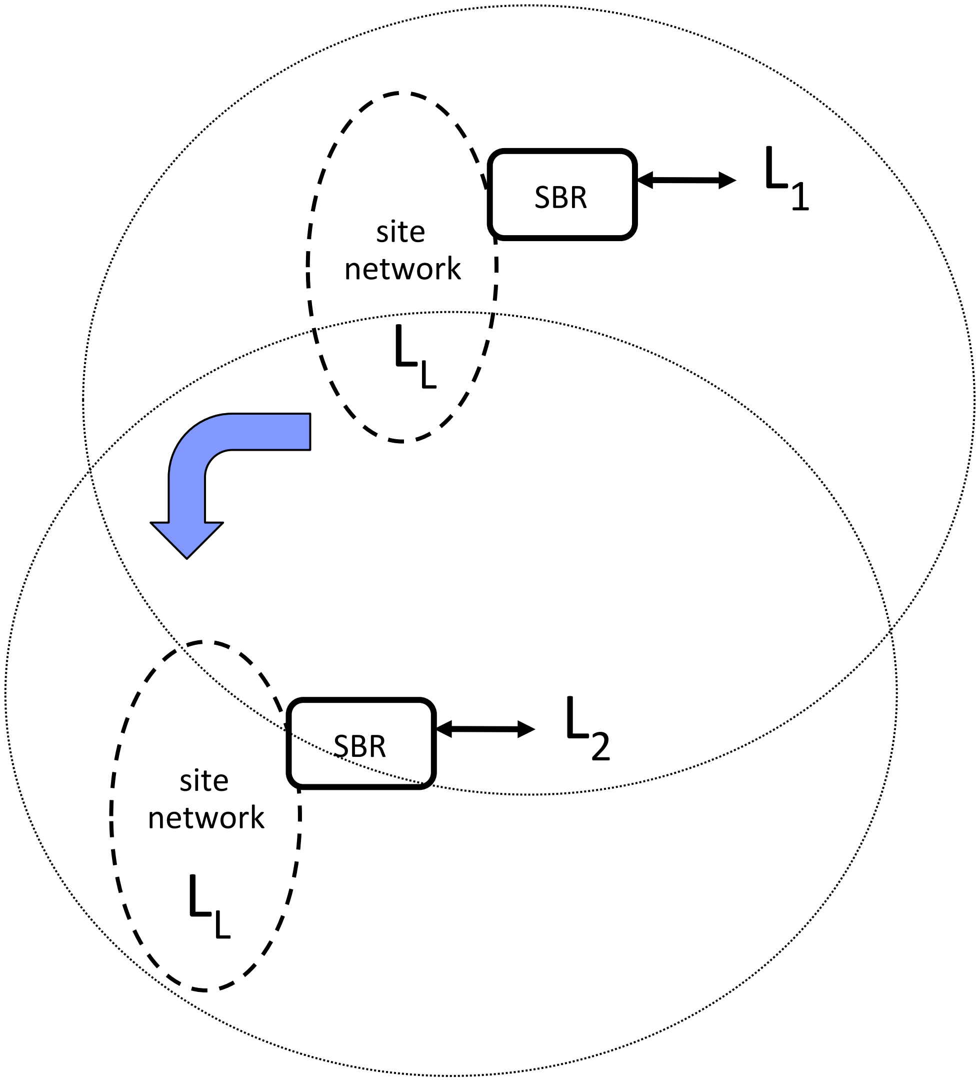
IP-in-IP encapsulation



Improved in Mobile IPv6:

- mobile host can act as its own FA
- use of Binding Update – send CoA to HostA

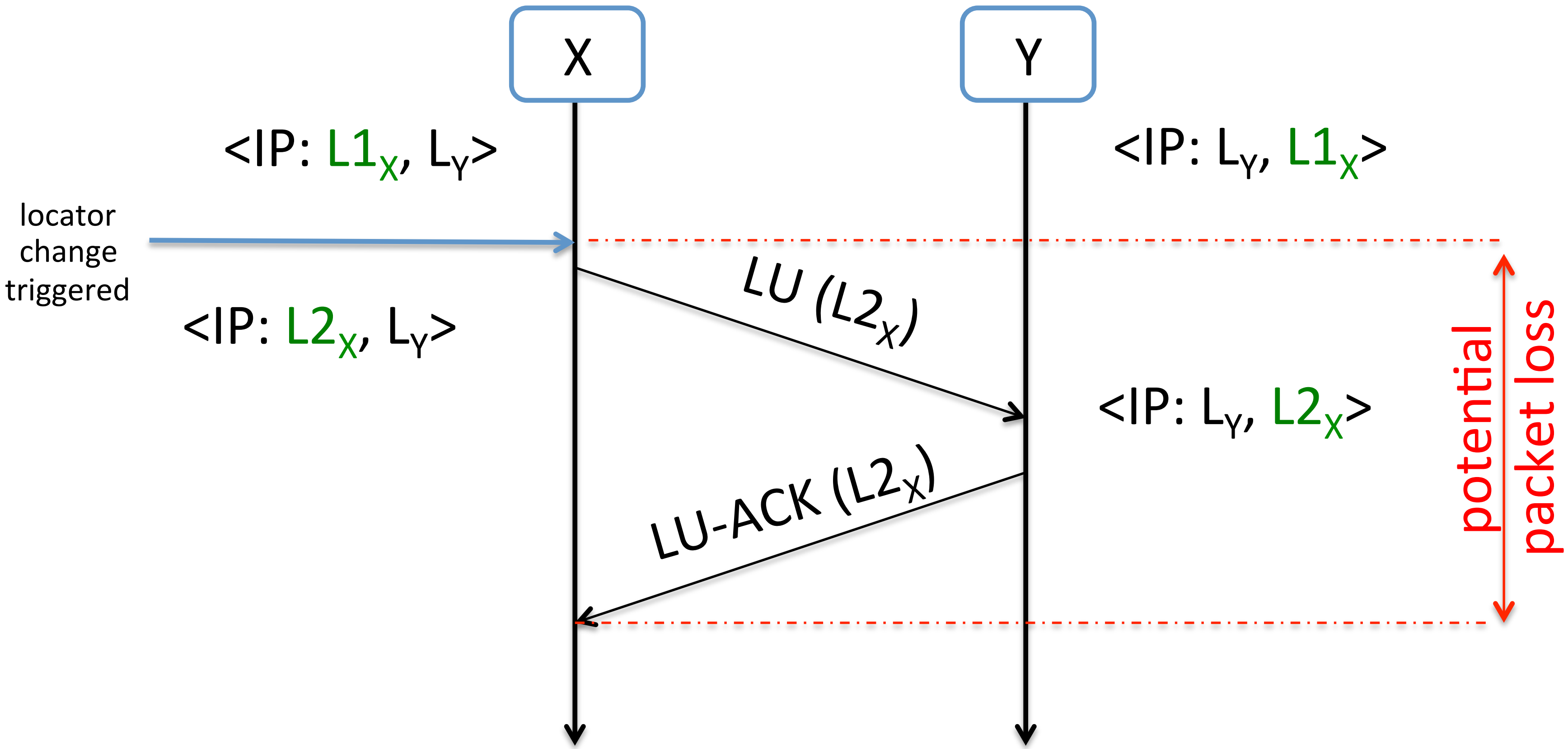
Mobile **networks** in ILNPv6 [1]



- 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

SBR site border router

ILNP Locator Update (LU) [1]

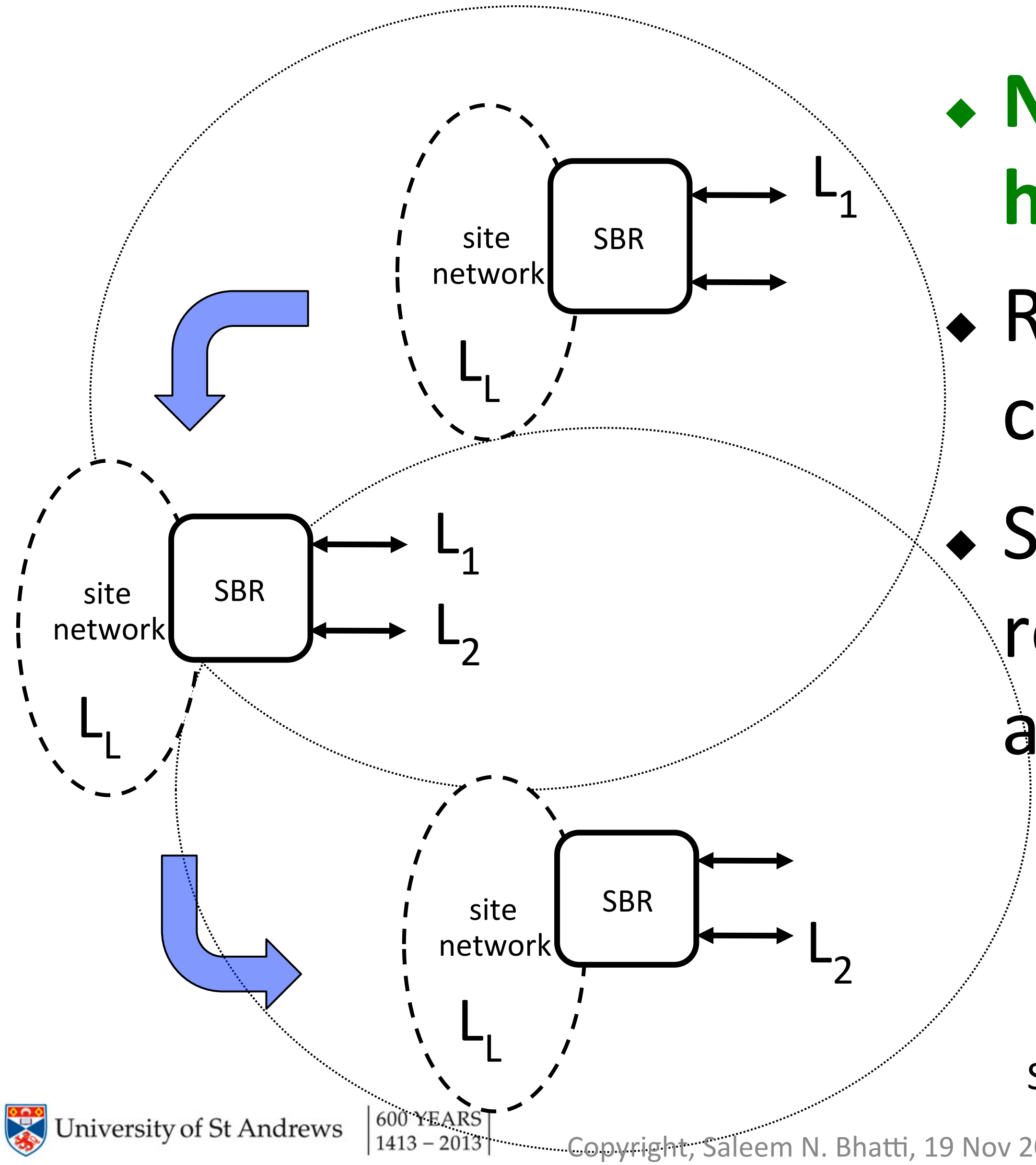


Hard hand-over

(similar to Binding Update for Mobile IPv6)

(new L values can be learned from IPv6 router advertisements)

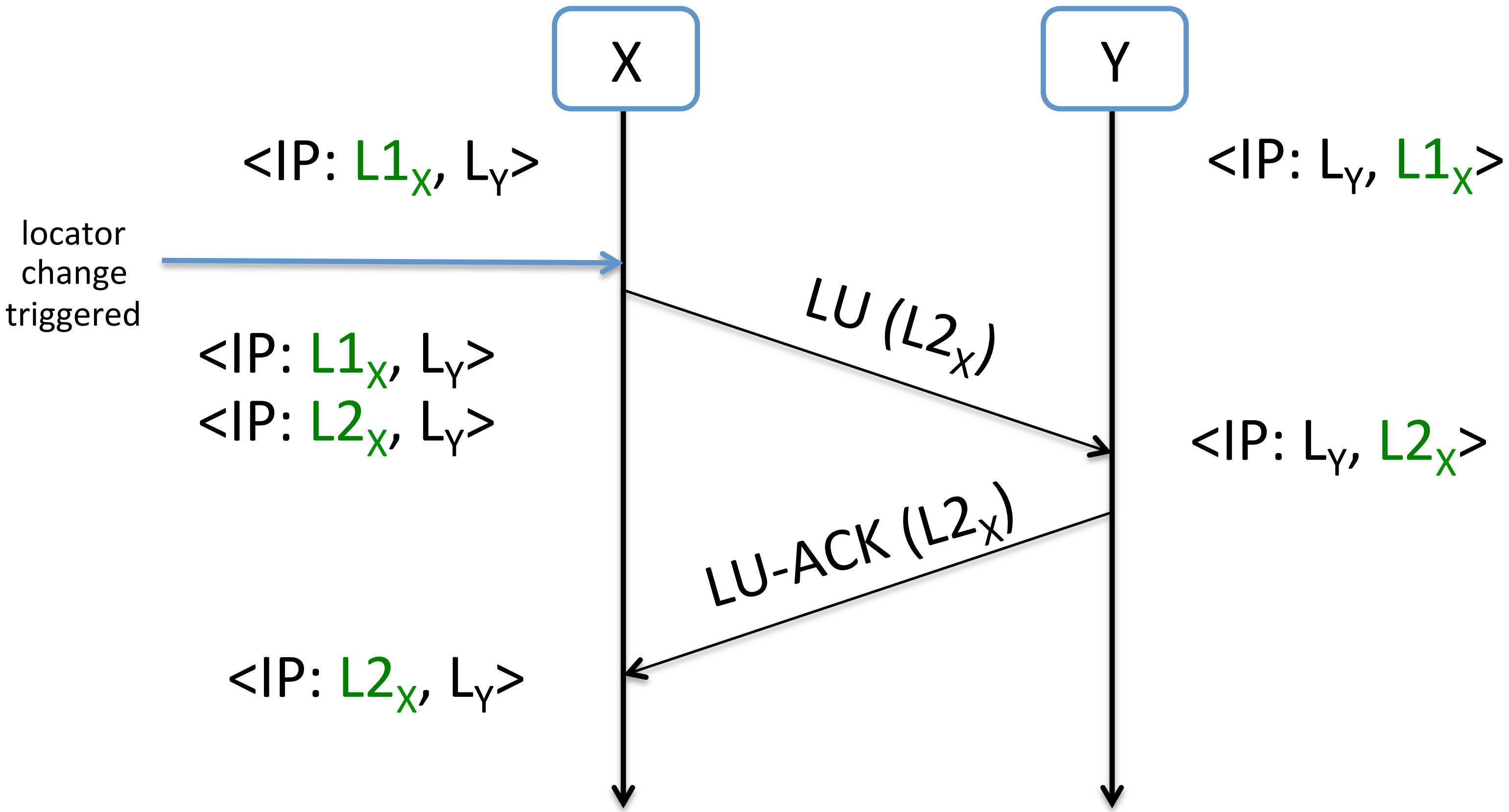
Mobile **networks** in ILNPv6 [2]



- **Network layer soft-hand-off possible.**
- Requires 2+ radio channels / interfaces.
- SBRs handle Locator rewriting + forwarding as required.

SBR site border router

ILNP Locator Update (LU) [2]



Soft hand-over

(new L values can be learned from IPv6 router advertisements)

Other harmonised functionality ...

- Multi-homing
- Multi-path transport
- VM migration/mobility
- Traffic engineering options
- Improved packet and network security
- See papers:
  - http://ilnp.cs.st-andrews.ac.uk/

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!
  - **I have PhD positions open ☺**
- Reading – start off with:
  - "Evolving the Internet Architecture Through Naming", *IEEE JSAC*, Oct 2010 http://dx.doi.org/10.1109/JSAC.2010.101009
  - RFC6740, Nov 2012 http://tools.ietf.org/html/rfc6740
    RFC6741, Nov 2012 http://tools.ietf.org/html/rfc6741