Using ILNP to Do More for Less

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1 INTRODUCTION

The Internet is now well-established as critical infrastructure with a significant energy demand. Energy is consumed not only by the end devices in a communication, but also when routing and forwarding packets between those endpoints. While some of this consumption could be reduced by energy-aware applications, the system-level transmission costs require a system-level solution.

Mobile devices can frequently change where they are topologically connected to the Internet. Under existing protocols, this change requires all ongoing transport sessions to be terminated and restarted, incurring a significant signalling (and therefore energy) cost. Provider-Independent (PI) addressing, deployed to facilitate multihoming, produces an increasingly fragmented address space, which fills routing tables with unaggregatable address blocks, requiring more storage and more costly lookups, each of which brings an energy cost. These problems are driven by the behaviour of network layer protocols, so must be addressed at the network layer.

The Identifier-Locator Network Protocol (ILNP) is a proposed evolution of IPv6 that separates *network location* and *node identity* into different values[1]. By carefully managing these values, ILNP facilitates network mobility without terminating transport sessions, and multihoming with aggregatable addresses – this avoids both problems identified above, reducing energy consumption.

2 END SYSTEM DYNAMIC MULTIHOMING

Under IPv6, mobility is costly. When a node changes network location, it must terminate and restart all transport sessions. While the mobile node can begin this immediately, and correspondent node must detect the failure of the first session, which typically requires detecting loss, retransmitting packets, and detecting more loss. Then, the two nodes must re-initialise end system state, rediscover congestion windows (incurring more loss), and recover application state.

End System Dynamic Multihoming describes the ability of a node to change network location without violating transport session invariants, and without using middleboxes. Under ILNP, this is achieved by using Node Identifiers (NIDs) as transport endpoint IDs rather than addresses[5]. A NID is dynamically bound to a Locator (L64) which encodes network location. This binding creates a 128-bit value that can be used like an IPv6 address for routing and forwarding – the L64 works as a routing prefix, and the NID can be treated like an interface identifier (IID). Changes in a node's network location are reflected by changing the available L64s that the NID can bind to. The correspondent node can be updated of these changes with a single control message – this is much cheaper than detecting failure, terminating sessions, re-initialising them, and recovering application state[6].

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Multihoming also has the potential to reduce bursts of traffic, resulting in lower congestion. A transport session could multiplex traffic fairly across all available paths between the endpoints, resulting in the same (or higher) throughput without over-using one path[4]. Fair path utilisation has two advantages: the reduced load may reduce congestion, resulting in lower loss rates; and the redundancy of the other paths reduces the impact of loss from a particular path as the session can fail over to others. Taking full advantage of this requires multipath-aware congestion control, which is an area of ongoing research.

3 UNINTENDED BENEFITS

ILNP offers further energy-related benefits beyond low-cost mobility and multihoming.

L64s are excluded from transport state, including checksums. They are therefore mutable on-path, and can be modified by Locator-Rewriting Relays (LRRs)[2]. LRRs can be used to facilitate localised addressing or segment routing without violating end-to-end connectivity. Internet Service Providers (ISPs) could use an LRR to localise the addressing of their clients, allowing them to renumber their internal networks by updating only end systems and the LRRs – this uses the same method as ILNP's regular mobility, but further reduces the overheads of signalling location changes to correspondent nodes.

Localised addressing within an ISP's network could also be used to hide a home server's network location resolving a privacy concern for self-hosted websites. As IPv6 removes the need for Network Address Translation (NAT), and locator rewriting preserves end-to-end connectivity, self-hosting is a much more attractive option, and could reduce energy usage. Regular social media companies, for example, may favour extreme high performance machines and costly multimedia content as a way to attract and retain users (and therefore profits), whereas a user of a self-hosted system may choose to be more frugal in order to reduce the energy and bandwidth costs to which they are directly exposed.

4 SUMMARY

ILNP is an evolution of IPv6 that addresses long-standing challenges around network mobility and multihoming. The flexibility and functionality offered by ILNP also provides opportunities to reduce the energy footprint of Internet operations. A prototype implementation of ILNP for FreeBSD 14.0 is publicly available[3].

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