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An Annotated Bibliography for IPv4-IPv6 Transition and Coexistence
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Abstract

The Internet is in the early stages of what may be a protracted period of coexistence of IPv4 and IPv6. Network operators are challenged with the task of activating IPv6 without negative impact on operating IPv4 networks and their customers. This draft is an informational "annotated bibliography" compiled to help in the analysis and development of basic guidelines and recommendations for network operators. The goal of this document is to survey the current state of RFCs, Internet-Drafts and external reference materials that define the use cases, problem statements, protocols, transition mechanisms and coexistence tools that will be of interest to a network operator planning to turn on IPv6.

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1. Introduction

Since the IPv6 protocol was defined in 1995 as RFC 1883 (replaced in 1998 by RFC 2460) the Internet has been in a long transition from IPv4 to IPv6. In reality, we are still in the early stages of what is likely to be a protracted period of coexistence, where IPv6 penetration in hosts (both servers and clients) will gradually ramp up as networks make IPv6 available through their infrastructures.

Network operators face a daunting task to design and implement plans to activate IPv6 without negative impact on large (in some cases very large) operating IPv4 networks with many live customers. Some basic guidelines and recommendations for network operators are being developed (<http://tools.ietf.org/html/draft-lee-v4v6tran-problem>) and this draft is an informational companion to that effort. The goal of this document is to survey the current state of RFCs, active (and expired but still relevant) Internet-Drafts and external reference materials that define the use cases, problem statements, protocols, transition mechanisms and coexistence tools that will be of interest to a network operator planning to turn on IPv6.

This is a dynamic and evolving marketplace of ideas. At best, this draft is a blurry snapshot of the landscape near to the time of its publication. The editor intends this compendium to be merely the starting point for an active database or wiki available for community contribution including feedback on the real-world experience of network operators as they turn on IPv6.

The following sections comprise an annotated bibliography of the currently available documentation to knowledge of the editor. It is provided as informational guidance only, and any network operator contemplating an IPv6 implementation will of course exercise due diligence in researching all the issues, standards and recommendations and analyze applicability to the particular network operation.

Note that as the body of this text includes full reference information for the bibliography entries these are not included in the normal Reference section.

[Editor's note to be removed before publication:

While this draft is circulating, the editor is interested in any and all pointers to additional useful references. Contributions of capsule summaries and applicability for any of the listed entries would also be appreciated and will be graciously acknowledged. If I have missed anyone who already chipped in, this will be cheerfully rectified upon your reminder via a private e-mail.]

2. IPv6 and related Protocol Specifications

"IPv6 Node Requirements" J. Loughney, Ed. April 2006
<http://tools.ietf.org/html/rfc4294>

"IPv6 Node Requirements RFC 4294-bis" E. Jankiewicz, J. Loughney, T. Narten
<http://tools.ietf.org/html/draft-ietf-6man-node-req-bis>

RFC 4294 and its update draft are included by reference. These provide a comprehensive overview of the IPv6 baseline specifications and the reader is directed to them to avoid a redundant listing here.

3. Problem Statements and Use Cases

"Problem Statements of IPv6 Transition of ISP" Y. Lee, Ed.
<http://tools.ietf.org/html/draft-lee-v4v6tran-problem>

This draft is being developed by an ad-hoc group interested in providing guidance to network operators on the IPv6 transition. It will include high level use cases (as contributed by IETF participants with network operator experience) and a problem statement documenting what additional work IETF could do to provide sufficient tools and guidance for the network operators

"Mobile Networks Considerations for IPv6 Deployment" R. Koodli
<http://tools.ietf.org/html/draft-ietf-v6ops-v6-in-mobile-networks>

Mobile Internet access from smartphones and other mobile devices is accelerating the exhaustion of IPv4 addresses. IPv6 is widely seen as crucial for the continued operation and growth of the Internet, and in particular, it is critical in mobile networks. This document discusses the issues that arise when deploying IPv6 in mobile networks. Hence, this document can be a useful reference for service providers and network designers.

"Routing Loop Attack using IPv6 Automatic Tunnels: Problem Statement and Proposed Mitigations", G. Nakibly and F. Templin
<http://tools.ietf.org/html/draft-ietf-v6ops-tunnel-loops>

"Use Case for IPv6 Transition for a Large-Scale Broadband Service" H/Tian and XY. Li
<http://tools.ietf.org/html/draft-tian-v4v6tran-broadband-sp-usecase>

[v4v6 drafts to be]
Huang: Broadband Use Case
Zhou: Mobile Use Case

4. Deployment Scenarios and Architectures

"Emerging Service Provider Scenarios for IPv6 Deployment", B. Carpenter, S. Jiang
<http://tools.ietf.org/html/draft-ietf-v6ops-isp-scenarios>

"Framework for IP Version Transition Scenarios", B. Carpenter, S. Jiang and V. Kuarasingh
<http://tools.ietf.org/html/draft-carpenter-v4v6tran-framework>

5. How-to, Whitepapers and FAQs

RFC 5211 "An Internet Transition Plan." J. Curran, July 2008
<http://tools.ietf.org/html/rfc5211>

"Guidelines for Using Transition Mechanisms During IPv6 Deployment" J. Arkko and F. Baker
<http://tools.ietf.org/html/draft-arkko-ipv6-transition-guidelines>

"IPv6 Transition Guide For A Large ISP Providing Broadband Access", G. Yang (Ed.), L. Hu and J. Lin
<http://tools.ietf.org/html/draft-yang-v4v6tran-ipv6-transition-guide>

"IPv6 Rollout: Where do we start?" O. Crepin-Leblond
<http://www.slideshare.net/ocl999/suggestion-for-an-ipv6-roll-out>

"Everything Sysadmin" T. Limoncelli
<http://everythingsysadmin.com/2009/01/google-enables-ipv6-for-most-s.html>
<http://everythingsysadmin.com/2010/08/methods-of-converting-to-ipv6.html>

"Happy Eyeballs: Trending Towards Success (IPv6 and SCTP)", D. Wing, A. Yourtchenko, P. Natarajan.
<http://tools.ietf.org/html/draft-wing-http-new-tech>

This draft makes several recommendations to ensure user satisfaction and a smooth transition from HTTP's pervasive IPv4 to IPv6 and from TCP to SCTP. While the target audience is app developers and content providers, network operators should be aware of techniques needed to maintain peaceful coexistence without negative impact on end-user perception of service level.

"Migrating SIP to IPv6 Media Without Connectivity Checks" D. Wing, A. Yourtchenko

<http://tools.ietf.org/html/draft-wing-dispatch-v6-migration>

During the migration from IPv4 to IPv6, it is anticipated that an IPv6 path might be broken for a variety of reasons, causing endpoints to not receive RTP data. Connectivity checks would detect and avoid the user noticing such a problem, but there is industry reluctance to implement connectivity checks.

This document describes a mechanism allowing dual-stack SIP endpoints to attempt communications over IPv6 and fall back to IPv4 if the IPv6 path is not working. The mechanism does not require connectivity checks.

"IPv6 Deployment in Internet Exchange Points (IXPs)", Roque Gagliano

<http://tools.ietf.org/html/draft-ietf-v6ops-v6inixp>

This draft suggests that in an Internet Exchange Point one might use an address that helps in debugging routing exchanges. One could also look at what other folks do, embedding identifying marks in addresses. For example, Facebook includes "face:b00c" in the IID portion of their address.

6. Transition/Coexistence Tools

As network operators and end-users independently proceed with transition to IPv6 while others continue to use IPv4, a potentially long period of coexistence will ensue. Variations on terminology have been used since the specification of IPv6; transition implies a process whereby the star of IPv6 rises and the star of IPv4 sets; coexistence implies that both will operate together. Due to thoroughly discussed limits to the growth of an Internet using only IPv4, IPv6 is a necessary technology for the future of the Internet. However, nothing compels the elimination of IPv4; no protocol police will forbid its use in the foreseeable future. IPv4 may disappear due to irrelevance when IPv6 is so pervasive to make it redundant, but network operators should be prepared to operate IPv4 and IPv6 in a mixed deployment for some time. However, the techniques and mechanisms supported by a network operator can be expected to evolve

and change over time as a rational goal would be to gradually shift coexistence costs (real operational expense as well as convenience) from "early adopters" of IPv6 to the shrinking pool of IPv4 maintainers.

Various techniques are required for coexistence, roughly divided into three categories:

1. Address Mapping: Many situations will require the use of address mapping to maintain scalability in the face of dwindling IPv4 global address space and to support translation and tunneling approaches.
2. Tunneling: A method for the encapsulation and transport of one protocol over or through the infrastructure that favors the other, e.g. IPv6 traffic via an IPv4 infrastructure
3. Translation: A mechanism for rewriting packets from one protocol to the other so they can be delivered as native (non-encapsulated) packets typically due to incompatible end nodes, e.g. an IPv6 client to an IPv4 server.

These categories are not mutually exclusive, as some scenarios and solutions incorporate aspects of multiple approaches.

RFC 4213 "Basic Transition Mechanisms for IPv6 Hosts and Routers" E. Nordmark and R. Gilligan October 2005
<http://tools.ietf.org/html/rfc4213>

6.1. Address Mapping

"An Incremental Carrier-Grade NAT (CGN) for IPv6 Transition", Sheng Jiang, Dayong Guo, Brian Carpenter
<http://tools.ietf.org/html/draft-ietf-v6ops-incremental-cgn>

"Stateful NAT64: Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers" Bagnulo, Matthews, van Beijnum
<http://tools.ietf.org/html/draft-ietf-behave-v6v4-xlate-stateful>

"Legacy NAT Traversal for IPv6: Simple Address Mapping for Premises Legacy Equipment (SAMPLE)"
<http://tools.ietf.org/html/draft-carpenter-software-sample>

"Some Considerations on the Load-Balancer for NAT64" D. Zhang et al.
<http://tools.ietf.org/html/draft-wang-behave-nat64-load-balancer>

"NAT64 for Dual Stack Mobile IPv6" B. Sarikaya and F. Xia
<http://tools.ietf.org/html/draft-sarikaya-behave-mext-nat64-dsmip>

"NAT64 for Proxy Mobile IPv6" B. Sarikaya and F. Xia
<http://tools.ietf.org/html/draft-sarikaya-behave-netext-nat64-pmip>

"A Note on NAT64 Interaction with Mobile IPv6" W. Haddad and C. Perkins
<http://tools.ietf.org/html/draft-haddad-mext-nat64-mobility-harmful>

"Referrals Across an IPv6/IPv4 Translator" D. Wing, October 19, 2009
<http://tools.ietf.org/html/draft-wing-behave-nat64-referrals-01>

While this draft is expired, this issue remains a topic of conversation, including a Bar-BoF at IETF 78. Referrals across disparate address domains may be needed for provision of services such as SIP during transition.

"Flexible IPv6 Migration Scenarios in the Context of IPv4 Address Shortage" M. Boucadair (Ed.) et al, October 20, 2009 (expired)
<http://tools.ietf.org/html/draft-boucadair-behave-ipv6-portrange-04>

This memo presents a solution to solve IPv4 address shortage and ease IPv4-IPv6 interconnection. The document presents a set of incremental steps for the deployment of IPv6 as a means to solve IPv4 address exhaustion. Stateless IPv4/IPv6 address mapping functions are introduced and IPv4-IPv6 interconnection scenarios presented.

This memo advocates for a more proactive approach for the deployment of IPv6 into operational networks. This memo specifies the IPv6 variant of the A+P. Both encapsulation and translation scheme are covered. Moreover, two modes are elaborated: the binding mode (compatible mode with DS-lite) and the stateless mode.

6.1.1. Dual-Stack Lite (DS-lite)

<http://www.networkworld.com/community/node/46600>

"Dual-Stack Lite Broadband Deployments Following IPv4 Exhaustion" A. Durand et al.
<http://tools.ietf.org/html/draft-ietf-softwire-dual-stack-lite>

This document revisits the dual-stack model and introduces the dual-stack lite technology aimed at better aligning the costs and benefits of deploying IPv6 in service provider networks. Dual-stack lite enables a broadband service provider to share IPv4 addresses among

customers by combining two well-known technologies: IP in IP (IPv4-in-IPv6) and Network Address Translation (NAT).

"Dual-stack Lite Mobility Solutions" B. Sarikaya and F. Xia October 11, 2009 (expired)

<http://tools.ietf.org/html/draft-sarikaya-softwire-dslitemobility-01>

Two solutions are presented to show how to use Dual-Stack Lite transition technique in mobile networks: one for Proxy Mobile IPv6 and the other for Dual-Stack Mobile IPv6. Proxy Mobile IPv6 allows IPv4 nodes to receive mobility services using an IPv4 home address. In case of client based mobility using DSMIPv6, mobile node is a dual-stack node and it can receive an IPv4 home address from the home agent which is co-located with DS-lite carrier-grade NAT.

"Scalable Operation of Address Translators with Per-Interface Bindings" J. Arkko and L. Eggert February 9, 2009 (expired)

<http://tools.ietf.org/html/draft-arkko-dual-stack-extra-lite-00>

This document explains how to employ address translation in networks that serve a large number of individual customers without requiring a correspondingly large amount of private IPv4 address space.

"Gateway Initiated Dual-Stack Lite Deployment" F. Brockners et al.

<http://tools.ietf.org/html/draft-ietf-softwire-gateway-init-ds-lite>

Gateway-Initiated Dual-Stack lite (GI-DS-lite) is a modified approach to the original Dual-Stack lite (DS-lite) applicable to certain tunnel-based access architectures. GI-DS-lite extends existing access tunnels beyond the access gateway to an IPv4-IPv4 NAT using softwires with an embedded context identifier, that uniquely identifies the end-system the tunneled packets belong to. The access gateway determines which portion of the traffic requires NAT using local policies and sends/receives this portion to/from this softwire tunnel.

"Deployment DS-lite in Point-to-Point Access Network" Y. Lee (Ed.) et al. <http://tools.ietf.org/html/draft-zhou-softwire-ds-lite-p2p>

Gateway-Initiated Dual-Stack lite (GI-DS-lite) is a proposal to logically extend existing access tunnels beyond the access gateway to DS-Lite Address Family Transition Router element (AFTR) using softwires with an embedded context identifier. This memo describes a deployment model using GI-DS-lite in Point-to-Point access network.

"Deploying Dual-Stack Lite in IPv6 Network" M. Boucadair (Ed.) et al.

<http://tools.ietf.org/html/draft-boucadair-dslite-interco-v4v6>

Dual-Stack lite requires that the AFTR must have IPv4 connectivity. This forbids a service provider who wants to deploy AFTR in an IPv6-only network. This memo proposes an extension to implement a stateless IPv4-in-IPv6 encapsulation in the AFTR so that AFTR can be deployed in an IPv6-only network.

6.2. Tunneling Mechanisms

RFC 2473 "Generic Packet Tunneling in IPv6 Specification." A. Conta and S. Deering, December 1998

<http://tools.ietf.org/html/rfc2473>

RFC 2529 "Transmission of IPv6 over IPv4 Domains without Explicit Tunnels" B. Carpenter and C. Jung March 1999.

RFC 3056 "Connection of IPv6 Domains via IPv4 Clouds" B. Carpenter and K. Moore February 2001

<http://tools.ietf.org/html/rfc3056>

RFC 3053 "IPv6 Tunnel Broker" A. Durand, I. Guardini and D. Lento January 2001

<http://tools.ietf.org/html/rfc3053>

6.2.1. Teredo

"Teredo Extensions", D. Thaler

<http://tools.ietf.org/html/draft-thaler-v6ops-teredo-extensions>

6.2.2. IPv6 Rapid Deployment (6rd)and Extensions

RFC 5569 "IPv6 Rapid Deployment on IPv4 Infrastructures (6rd)" R. Despres January 2010 <http://tools.ietf.org/html/rfc5569>

RFC 5969 "IPv6 Rapid Deployment on IPv4 Infrastructures (6rd)- Protocol Specification" W. Townsley and O. Troan August 2010

<http://tools.ietf.org/html/rfc5969>

"IPv6 Across NAT44 CPEs (6a44)" R. Despres, B. Carpenter and S. Jiang

<http://tools.ietf.org/html/draft-despres-software-6a44>

IPv6 Across NAT44 CPEs (6a44) 6a44 is based on an address mapping and on a mechanism whereby suitably upgraded hosts behind a NAT may obtain IPv6 connectivity via a stateless 6a44 server function operated by their Internet Service Provider. With it, traffic between two 6a44 hosts in a single site remains within the site. Except for IANA numbers that remain to be assigned, the specification

is intended to be complete enough for running codes to be independently written and interwork.

Note that this draft converges and supersedes work started in two separate drafts, which are no longer relevant:

<http://tools.ietf.org/html/draft-despres-softwire-6rdplus-00>

<http://tools.ietf.org/html/draft-lee-softwire-6rd-udp-02>

6.2.3. Tunnel Support Protocol (TSP)

RFC 5572 "IPv6 Tunnel Broker with the Tunnel Setup Protocol (TSP)" M. Blanchet and F. Parent, February 2010

<http://tools.ietf.org/html/rfc5572>

TSP is an Experimental RFC defining a method for a tunnel client to negotiate tunnel characteristics with a tunnel broker. It enables tunnels in various deployment architectures including NAT traversal and mobility, and for user authentication it utilizes:

RFC 4422 "Simple Authentication and Security Layer (SASL)" A. Melikov and K. Zeilenga(Eds.) June 2006

<http://tools.ietf.org/html/rfc4422>

6.2.4. Residual IPv4 Deployment over IPv6-only Infrastructure

Further down the transition road, operators may desire to retire IPv4 routing support and move their backbone networks to IPv6-only. There may be residual IPv4 legacy customers (clients and servers) still requiring the delivery of IPv4 packets. While the previously proposed Dual-Stack Transition Mechanism (DSTM) approach attempted to satisfy this use case, it was complex and stateful. A stateless approach to IPv4 residual deployment (4rd) is defined in section 3.2 of the Stateless Address Mapping (SAM) draft. At the time of this publication, several network operators in Japan are planning implementation to support residual IPv4 customers.

"Stateless Address Mapping (SAM) - a Simplified Mesh-Softwire Model" Despres, R. July 12, 2010

<http://tools.ietf.org/html/draft-despres-softwire-sam-01>

6.2.5. Address Plus Port (AplusP)

"The A+P Approach to the IPv4 Address Shortage" R. Bush (Ed.) October 27, 2009 (expired, but authors indicate a new draft is coming)

<http://tools.ietf.org/html/draft-ymbk-aplusp>

This draft discusses the possibility of address sharing by treating some of the port number bits as part of an extended IPv4 address (Address plus Port, or A+P). Instead of assigning a single IPv4 address to a customer device, we propose to extend the address by "stealing" bits from the port number in the TCP/UDP header, leaving the applications a reduced range of ports. This means assigning the same IPv4 address to multiple clients (e.g., CPE, mobile phones), each with its assigned port-range. In the face of IPv4 address exhaustion, the need for addresses is stronger than the need to be able to address thousands of applications on a single host. If address translation is needed, the end-user should be in control of the translation process - not some smart boxes in the core.

"Aplusp Lite - A light weight aplusp approach" Z. Xiaoyu
<http://tools.ietf.org/html/draft-xiaoyu-aplusp-lite>

This document proposes a solution aimed at providing IPv4 continuity in IPv6 environment. The proposed solution is expected to alleviate the public IPv4 depletion problem while maximize the benefits from IPv6 deployment, and meet the desired service availability and reliability with affordable cost.

6.2.5.1. IRON-RANGER and ISATAP Solutions

A body of RFCs and drafts in progress provide an alternative approach to IPv4/IPv6 coexistence. This approach utilizes tunneling techniques to create "overlay" networks. While currently considered "Experimental" it may be of interest to network operators as an alternative network architecture.

RFC 5214 "Intra-Site Automatic Tunnel Addressing Protocol (ISATAP)"
F. Templin et al. March 2008 <http://tools.ietf.org/html/rfc5214>

RFC 5320 "The Subnetwork Encapsulation and Adaptation Layer (SEAL)"
F. Templin (Ed.) February 2010 <http://tools.ietf.org/html/rfc5320>

RFC 5558 "Virtual Enterprise Traversal (VET)" F. Templin (Ed.)
February 2010 <http://tools.ietf.org/html/rfc5558>

RFC 5579 "Transmission of IPv4 Packets over Intra-Site Automatic Tunnel Addressing Protocol (ISATAP) Interfaces" F. Templin (Ed.)
February 2010 <http://tools.ietf.org/html/rfc5579>

RFC 5720 "Routing and Addressing in Networks with Global Enterprise Recursion (RANGER)" F. Templin (Ed.) February 2010
<http://tools.ietf.org/html/rfc5720>

<http://tools.ietf.org/html/draft-templin-intarea-seal>

<http://tools.ietf.org/html/draft-templin-intarea-vet>

<http://tools.ietf.org/html/draft-templin-iron>

6.3. Translation

From the earliest specification of IPv6 IETF contributors have recognized that translation would be a necessary tool for transition and coexistence, as IPv6 was designed as an incompatible replacement rather than an extension of IPv4. The original approach to stateless translation defined in RFC 2765 and its implementation as NA(P)T-PT as described in RFC 2766 had a number of issues that resulting in the approach being deprecated by RFC 4966. Recently the Behave WG has taken on the work of defining a set of scenarios covering the use cases for translation, prioritizing the work and defining new solutions that overcome the deficiencies of the historic approach.

6.3.1. Historic Approach

RFC 2765 "Stateless IP/ICMP Translation (SIIT)." E. Nordmark, February 2000 <http://tools.ietf.org/html/rfc2765>

RFC 2766 "Network Address Translation - Protocol Translation (NAT-PT)." G. Tsirtsis and P. Srisresh, February 2000 <http://tools.ietf.org/html/rfc2766>

RFC 2767 "Dual-Stack Hosts Using 'Bump in the Stack' Technique (BIS)" K. Tsuchiay, H. Higuchi and Y. Atarashi February 2000

RFC 3338 "Dual-Stack Hosts Using 'Bump in the API' (BIA)" S. Lee, et al. October 2002 <http://tools.ietf.org/html/rfc3338>

These two RFCs are proposed for obsolescence by a draft that combines both:

"Dual-Stack Hosts Using 'Bump in the Host' (BIH)" B. Huang, H. Deng and T. Savolainen <http://tools.ietf.org/html/draft-huang-behave-bih>

6.3.2. Current Translation Approaches

A renewed effort to define new translation mechanisms started with discussions in the Internet Area (intarea) meeting and the Technical Plenary at IETF 71 in Dublin, and continued at a special meeting in

Montreal in October 2008. This led to a commitment by contributors in the Behave WG to take on the work. A set of scenarios were defined along with a framework for the translation solutions.

"A Framework for IPv4/IPv6 Translation" F. Baker et al.
<http://tools.ietf.org/html/draft-ietf-behave-v6v4-framework>

This draft (Framework) is the place to start to understand the historic context for translation, the definition and rationale for the set of translation scenarios and canonical definitions for some of the terminology that arises when talking about translation and coexistence in general.

The 4 deployment modes for these scenarios are:

1. Connecting between the IPv4 Internet and the IPv6 Internet
2. Connecting an IPv6 network to the IPv4 Internet
3. Connecting an IPv4 network to the IPv6 Internet
4. Connecting between an IPv4 network and an IPv6 network

As solutions may differ with respect to the initiating end of the conversation, 8 scenarios are defined in the Framework draft, as recapped in the following sections along with specifications that fit each scenario.

Some general specifications that are cited in the various solution specifications (or may be in subsequent revisions) are:

"IPv6 Addressing of IPv4/IPv6 Translators" C. Bao et al. August 16, 2010 <http://tools.ietf.org/html/draft-ietf-behave-address-format-10>

"DNS64: DNS extensions for Network Address Translation from IPv6 Clients to IPv4 Servers" M. Bagnulo et al. July 5, 2010
<http://tools.ietf.org/html/draft-ietf-behave-dns64-10>

"Analysis of 64 Translation" R. Penno, T. Saxena and D. Wing
<http://tools.ietf.org/html/draft-penno-behave-64-analysis>

Due to specific problems, NAT-PT was deprecated by the IETF as a mechanism to perform IPv6-IPv4 translation. Since then, new effort has been undertaken within IETF to standardize alternative mechanisms to perform IPv6-IPv4 translation. This document evaluates how the new translation mechanisms avoid the problems that caused the IETF to deprecate NAT-PT.

6.3.2.1. An IPv6 network to the IPv4 Internet

The Framework defines Scenario 1 for an early adopter (end user or network operator) which establishes an IPv6 network and needs to maintain access to the global IPv4 Internet, preferably without assigning IPv4 addresses to the nodes of the IPv6 network. Either the Stateful or Stateless solutions proposed may satisfy this deployment scenario.

"Stateful NAT64: Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers" M. Bagnulo, P. Matthews and I. van Beijnum
<http://tools.ietf.org/html/draft-ietf-behave-v6v4-xlate-stateful>

"IP/ICMP Translation Algorithm" X. Li, C. Bao and F. Baker
<http://tools.ietf.org/html/draft-ietf-behave-v6v4-xlate>

6.3.2.2. The IPv4 Internet to an IPv6 network

The Framework defines Scenario 2 for a node on the IPv4 Internet initiating a transmission to a node on an IPv6 network. The original approach to this deployment was SIIT (in RFC 2765) which has been deprecated (by RFC 4966). The Stateless Translation solution for Scenario 1 also would work for this case as it does support IPv4-initiated communication with a subset of IPv6 addresses.

6.3.2.3. The IPv6 Internet to an IPv4 network

The Framework defines Scenario 3 where a legacy IPv4 network has a requirement to provide services to users in the IPv6 Internet. Stateful Translation with static AAAA records in DNS to represent the IPv4-only hosts will work.

"Stateful NAT64: Network Address and Protocol Translation from IPv6 Clients to IPv4 Servers" M. Bagnulo, P. Matthews and I. van Beijnum
<http://tools.ietf.org/html/draft-ietf-behave-v6v4-xlate-stateful>

"DNS64: DNS extensions for Network Address Translation from IPv6 Clients to IPv4 Servers" M. Bagnulo et al.
<http://tools.ietf.org/html/draft-ietf-behave-dns64>

Alternatively, host-based translation (BIH) or tightly-coupled translators may be considered.

6.3.2.4. An IPv4 network to the IPv6 Internet

Scenario 4 is not easy to solve but fortunately will not arise until significant IPv6 uptake. In-network translation is not viable, and other techniques should be considered including host-based translation (BIH) or tightly-coupled translators that adapt legacy hosts or networks to the IPv6 Internet.

6.3.2.5. An IPv6 network to an IPv4 network

Scenario 5 describes a configuration where both the IPv6 network and IPv4 network are within the administrative control of the same organization. It appears amenable to the same solutions proposed for Scenario 1.

6.3.2.6. An IPv4 network to an IPv6 network

Scenario 6 is the mirror image of Scenario 5, with communication initiated from the IPv4 side. It appears amenable to the same solution proposed for Scenario 2.

6.3.2.7. The IPv6 Internet to the IPv4 Internet

The Framework indicates that Scenario 7, the interconnection of the IPv4 Internet with the IPv6 Internet may appear to be an ideal case for an in-network translator (such as the deprecated NAT-PT), but there is no viable way to map the immense IPv6 address space onto IPv4. This situation would not entail until significant IPv6 adoption, and has not been a priority for solution.

6.3.2.8. The IPv4 Internet to the IPv6 Internet

Scenario 8 presents a challenge similar to Scenario 7.

7. Prefix and Address Assignment and Distribution

RFC 4291 "IP Version 6 Addressing Architecture." R. Hinden, S. Deering. February 2006.

<http://tools.ietf.org/html/rfc4291>

RFC 5952 "A Recommendation for IPv6 Text Representation" S. Kawamura and M. Kawashima, August 2010

<http://tools.ietf.org/html/rfc5952>

"IPv6 Addressing of IPv4/IPv6 Translators" C. Bao et al. (Status: Standards Track, in RFC Editor will update RFC 4291)

<http://datatracker.ietf.org/doc/draft-ietf-behave-address-format/>

RFC 3177 "IAB/IESG Recommendations on IPv6 Address Allocations to Sites." IAB, IESG. September 2001.
<http://tools.ietf.org/html/rfc3177>

"IPv6 Address Assignment to End Sites", T. Narten, G. Huston, R. Roberts, 12-Jul-10
<http://tools.ietf.org/html/draft-narten-ipv6-3177bis-48boundary>

RFC 5942 "IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes." H. Singh, W. Beebee, E. Nordmark. July 2010.
<http://tools.ietf.org/html/rfc5942>

RFC 4862 "IPv6 Stateless Address Autoconfiguration." S. Thomson, T. Narten, T. Jinmei. September 2007.
<http://tools.ietf.org/html/rfc4862>

RFC 4941 "Privacy Extensions for Stateless Address Autoconfiguration in IPv6." T. Narten, R. Draves, S. Krishnan. September 2007.
<http://tools.ietf.org/html/rfc4941>

The IPv6 addressing architecture presumes that the remaining 64 bits are an endpoint interface identifier. This could be the MAC Address (EUI-64 Address) in an appropriate encoding, or it could be what is called a "privacy address", which is a random number. You will find the most common approach to that, for hosts, in this RFC.

RFC 3315 "Dynamic Host Configuration Protocol for IPv6 (DHCPv6)." R. Droms (Ed.), J. Bound, B. Volz, T. Lemon, C. Perkins, M. Carney. July 2003. <http://tools.ietf.org/html/rfc3315>

8. Experiments, Trials and Prototypes

6bone (concluded)
<http://go6.net/ipv6-6bone/>

Hurricane Electric (ongoing)
<http://www.he.net/>

T-Mobile USA (ongoing)
<http://groups.google.com/group/tmoipv6beta>

Comcast (ongoing)
<http://www.comcast6.net/>

Internode ADSL (Ongoing)
<http://ipv6.internode.on.net/access/adsl/>

Verizon FiOS (small scale test - concluded)

<http://newscenter.verizon.com/press-releases/verizon/2010/verizon-begins-testing-ipv6.html>

9. Implementation Reports

IPv6 Rapid Deployment

<http://tools.ietf.org/html/rfc5569>

Google has hosted a meeting of IPv6 Implementers in 2009 and 2010, several presentations covered experimental or live transition experience.

<https://sites.google.com/site/ipv6implementors/2009/agenda>

<https://sites.google.com/site/ipv6implementors/2010/agenda>

10. Books on IPv6

Blanchet, Marc. "Migrating to IPv6: a Practical Guide to Implementing IPv6 in Mobile and Fixed Networks." Chichester, England: J. Wiley & Sons, 2006. Print.

Sill, Karl A. "IPv6 Mandates: Choosing a Transition Strategy, Preparing Transition Plans, and Executing the Migration of a Network to IPv6." Indianapolis, IN: Wiley, 2008. Print.

11. Miscellaneous

See the Dancing Turtle, but only if you have native IPv6!

<http://www.kame.net/>

A little more detail than a Dancing Turtle, on your IPv6 readiness can be obtained by using this site put up by Jason Fesler:

<http://test-ipv6.com/>

There is an extension for Firefox (and perhaps other browsers) that displays the IP address of web pages you visit, clearly indicating when you are connected via IPv4 or IPv6. In Firefox, click on Tools..Add-ons..Extensions and search for ShowIP.

Eric Vyncke is collecting some statistics on IPv6 penetration.

<http://www.vyncke.org/ipv6status/>

A reasonable estimation of how fast the sky is falling.

<http://www.potaroo.net/tools/ipv4/>

A graphical representation of IPv4 depletion.

<http://www.ipv4depletion.com/old.html>

"IPv6 Adoption Remains Slow, Survey Says" W. Jackson, GCN Sept. 5, 2101

<http://gcn.com/articles/2010/09/14/adoption-of-ipv6-is-slow.aspx>

<http://www.nro.net/documents/GlobalIPv6SurveySummaryv2.pdf>

Some troubling, yet interesting news about what operators and end-user organizations are thinking about IPv6 adoption at this time.

A study of some of the brokenness around Path MTU Discovery

http://www.ripe.net/ripe/meetings/ripe-60/presentations/Stasiewicz-Measurements_of_IPv6_Path_MTU_Discovery_Behaviour.pdf

Clunet hosts a mailing list with IPv6 operator participation.

Various transition-related topics are brought up there from time to time. <http://lists.clunet.de/mailman/listinfo/ipv6-ops>

12. Security Considerations

This draft does not introduce any security considerations.

13. IANA Considerations

This draft does not require any action from IANA.

[Note to RFC Editor: this section may be removed.]

14. Conclusions

This draft is merely the starting point for a network operator planning an IPv6 rollout. The intention of the editor was to document the great work that is already available that can help in the process and to perhaps save a few hours of redundant effort for someone to find this information. Of course, this will be out of date before it is published as active research continues in coexistence and transition tools. The editor hopes it is at least a useful "You Are Here" map to help navigate the thrill rides available in the IPv6 theme park.

This compendium could serve as an initial set of data to populate an active database or wiki. This would allow continuing community contribution including feedback on the real-world experience of network operators as they turn on IPv6.

15. References

15.1. Normative References

None.

15.2. Informative References

Complete reference information is included in the body of the draft.

16. Acknowledgments

This bibliography is a recapitulation of the contributions of the authors of the cited RFCs, drafts, websites and other publications and many folks on the v6ops and v4v6transition mailing lists, the editor has freely borrowed abstract and summary text from the cited works and e-mail postings. In addition, the editor wishes to acknowledge significant contributions and suggestions from Fred Baker, Brian Carpenter, Remi Despres, Tina Tsou, Yiu Lee, Marc Blanchet, Med Boucadair, Fred Templin and many contributors on the v4v6trans mailing list. The mailing list archive can be found at: <https://www.ietf.org/mailman/listinfo/v4tov6transition>

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