IP Next Generation (IPng)

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Why Me?

- in data networking at Harvard since 1970
- co-founder of a U.S. regional Internet provider
- IESG Operational Requirements co-AD
- appointed IETF IPng Area co-Director
  - with Allison Mankin
- co-directed IETF IPng effort

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History

- Why?
  - apparently running out of IP addresses
  - routing table bloat
- August 1990
  - projected exhaustion of Class B space by March 1994
- November 1991
  - Routing and Addressing (ROAD) group formed
  - ROAD report (March '92)
    - » do CIDR
    - » issue call for IPng proposals

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History, contd.

- July 1992
  - IAB issues "IP version 7"
  - IETF issues call for IPng proposals
- July 1993
  - ipdecide BOF & IESG plenary
    - » IESG to take on responsibility formaking IPng recommendation (do not let the market decide)
- August 1993
  - temporary IETF area formed to consolidate IPng activity

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History, contd.

- December 1993
  - RFC 1550 call for IPng White Papers
- July 1993
  - IPng recommendation
- October 1994
  - IESG approved recommendation
- February 1995
  - base documents ready for Proposed Standard

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IPng Proposals

- multiple working groups
- different approaches to solve addressing and routing problems
- different views on problems
- optimize different aspects of problems
- not right or wrong
- learned from all efforts

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Available Timeframe

- Address Lifetime Expectations (ALE) working group
  - Frank Solensky, FTP Software <solensky@ftp.com>
  - Tony Li, Cisco Systems <tli@cisco.com>
- made prediction at Seattle & Toronto IETF meetings
  - 2005 - 2011
- mixed view of confidence level
  - questions on base data & assumes no paradigm shifts
  - routing tables are still going to be a problem

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Scope of IPng

- development, testing & deployment will take time
- still we seem to have adequate time in IPv4 address space but not excessive (excluding paradigm shifts)
- can do more than 'just' fix addresses
- use requirements process to determine actual scope of IPng effort

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IPng Technical Requirements

- IPng requirements process
  - Frank Kastenholz, FTP Software <kasten@ftp.com>
  - Jon Crowcroft, UCL <J.Crowcroft@cs.ucl.ac.uk>
- RFC1550 request for white papers
- requirements document
  - based on Frank Kastenholz/Craig Partridge draft
  - criteria, discussion & time frame
- RFC 1726

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IPng Criteria

- at least 10^9 networks, 10^{12} end-systems
  - safer goal 10^{12} nets, 10^{15} end-systems
- conservative routing schemes
- topologically flexible
- high performance
- straightforward transition plan from IPv4
- robust service
- media independent

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IPng Criteria, contd.

- datagram service
- autoconfiguration
- secure operation
- globally unique names
- access to standards
- support multicasting
- extensible
- support service classes

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IPng Criteria, contd.

- support mobility
- include control protocol (ping etc.)
- support for private networks (tunneling)

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Result of Proposal Reviews

- significant flaws seen in all proposals
- revised proposal offered by SIPP WG after reviews
- answers most of the perceived problems
  - routing and addressing
  - transition
  - autoconfiguration
  - source routing support
- synthesis of multiple efforts

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Address Length

- hotly discussed issue
- four basic views
  - 8 bytes is enough, more is inefficient
  - 16 bytes is about right, 8 is not enough
  - use 20 byte NSAPs, provide global harmonization
  - variable length gives best safety and efficiency
- many detailed arguments
- consensus is that 16 bytes is enough

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IPng description

- expanded from IPv4 addressing capability (16 byte addresses)
- simple header
- support for extension headers and options
- support for authentication and privacy
- support for autoconfiguration
- support for source routes
- simple and flexible transition from IPv4
- flow ID

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IPng Addresses

- propose mapping algorithms from and to other environments
- where addresses are globally unique and assigned with regard to network topology
- IETF should work with other organizations for development of such mappings
- common addresses facilitate transition to IPng
- goal to provide a 1:1 mapping between address types (e.g. IPX, NSAP, E164)

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IPng Documents

IPng Specification:

R. Hinden, Ed. *IPng Protocol Specification*
draft-hinden-ipng-ipv6-spec-00.txt

Addressing Architecture:

R. Hinden, Ed. *IPng Addressing Architecture*
draft-hinden-ipng-addr-00.txt

Y. Rekhter et al *An Architecture for IPv6 Unicast Address Allocation*
draft-rekhter-ipng-arch-IPv6-addr-01.txt

Internet Control Message Protocol:

A. Conta et al *ICMP and IGMP for the Internet Protocol Version 6 (IPv6)*
draft-ietf-sipp-icmp-igmp-00.txt

Transition Mechanisms:

R. Gilligan *Simple Internet Transition Overview*
draft-gilligan-ipv6-sit-overview-01.txt

R. Gilligan et al *Transition Mechanisms for IPv6 Hosts and Routers*
draft-gilligan-ipv6-trans-mech-00.txt

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IPng Documents, contd.

Security

R. Atkinson *IPv6 Security Architecture*
draft-atkinson-ipng-sec-00.txt.

R. Atkinson *IPv6 Authentication Header*
draft-atkinson-ipng-auth-00.txt

R. Atkinson *IPv6 Encapsulating Security Payload (ESP)*
draft-atkinson-ipng-esp-00.txt

Domain Name System

S. Thomson et al *DNS Extensions to support IP version 6*
draft-thomson-ipng-dns-00.txt, October 1994.

Auto Configuration

S. Thomson et al *IPv6 Address Autoconfiguration Protocol*

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IPng Documents, contd.

Program Interfaces

R. Gilligan et al *IPv6 Program Interfaces for BSD Systems*
draft-gilligan-ipv6-bsd-api-00.txt

OSI NSAP Mapping

B. Carpenter et al *Recommendations for OSI NSAP usage in IP6*
draft-carpenter-ip6-nsap-map-00.txt

Routing

T. Li et al *ERP IPv6 Routing Header*
draft-sdr-ipv6-format-00.txt

G. Malkin *RIP for IPv6*
draft-ietf-ripv2-ripng-00.txt

Y. Rekhter et al *IDRP for IPv6*
draft-ietf-idr-idrp-v6-00.txt

F. Baker et al *OSPF IPv6 Extensions*
draft-ietf-ospf-ipv6-ext-00.txt

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Security

- there is a recognition that the Internet needs strong security
- the goal is to provide strong protection as a matter of course throughout the Internet
- separate use of encryption from use of authentication
- support of authentication header is required in IPng
- support of privacy header is required in IPng

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Security, contd.

- a key management infrastructure is required but outside of IPng effort
- inclusion of cryptography for authentication and/or privacy may add to the cost and impact the performance of an implementation, but it is worth the cost
- IETF work underway to embed signed keys in DNS
- need framework for firewalls under IPng

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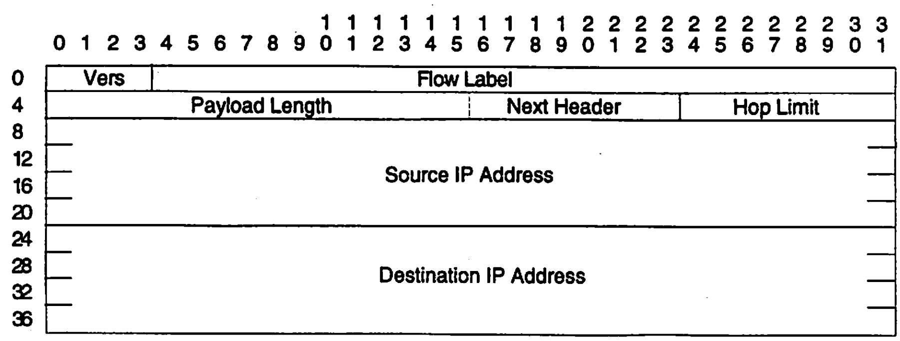
IPv6 Header



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IPv6 Header Fields

Version - Internet Protocol version # = 6 (4-bit field)

Flow Label - used to label packets requesting special handling by routers within a network (28-bit field)

Payload Length - length of the packet following the IPv6 header, in octets (16-bit unsigned integer)

if = 0 the actual packet length in Hop-by-Hop option

Next Header - the type of header immediately following the IPv6 header (8-bit selector field)

Hop Limit - decremented by 1 by each node that forwards the packet. packet discarded if Hop Limit is decremented to zero (8-bit unsigned integer)

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IPv6 Header Fields, contd.

Source Address - an address of the initial sender of the packet (128 bit field)

Destination Address - an address of the intended recipient of the packet (128 bit field)

may not be the ultimate recipient, if Routing Header is present

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IPv6 Header Changes from IPv4

- longer address - 32 bits -> 128 bits
- fragmentation fields moved to separate header
- header checksum field eliminated
- header length field eliminated (fixed length header)
- length field excludes IPv6 header
- "Time to Live" -> "Hop Limit"
- "Protocol" -> "Next Header"

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Changes, contd.

- 64 bit field alignment
- added Flow Label
- excluded TOS bits

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IPv6 Extension Headers

- less used functions moved to Extension Headers
- only present when needed
- extensible
  - Hob-by-Hop
  - Routing
  - Fragment
  - Authentication
  - Privacy
  - End-to-End

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Hop-by-Hop Options Header

- used to carry optional information
- examined by every node along packet's delivery path
- e.g., extended packet length option

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IPv6 Header Option Handling

- highest-order two bits of each option specify the action to be taken if unknown option
  - 00 - skip this option
  - 01 - discard the packet
  - 10 - discard the packet & send ICMP message
  - 11 - undefined
  - – eases introduction of new options
- third-highest-order bit in Hop-by-Hop options
  - – include option in the Authentication integrity assurance computation (option data that changes en route must be excluded)

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Routing Header

- lists one or more intermediate nodes to be "visited" on the way to a packet's destination
- nodes or clusters
- designed to support SDRP

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Fragment Header

- used to send payloads larger than path MTU to destination
- fragmentation performed only by source nodes

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Authentication Header

- provides authentication and integrity assurance
- uses Security Assoc. ID (SAID)
  - identifies to the receiver(s) the pre-established security association to which this packet belongs. (32 bit field)

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Privacy Header

- provides confidentiality and integrity by encrypting data
- data can be
  - transport-layer (e.g. UDP or TCP) frame
  - entire IPv6 datagram
  - part of IPv6 datagram
- must be the last non-encrypted field in a packet (if present)
- uses Security Association Identifier (SAID)

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End-to-End Option Header

- used to carry optional information
- examined only by destination node
- same format as Hop-by-Hop Option header

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Packet Size Issues

- minimum link MTU = 576 bytes
  - IPv4 = 68 bytes
- links with MTU < 576 must do link-layer fragmentation & reassembly
- IPv6 nodes may avoid Path MTU Discovery by limiting packets to 576 bytes
- minimum reassembly buffer = 1500

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Flow Label

1	3	24
T	TC	flow ID

- T - time sensitivity
  0 = yes
  1 = no
- TC - Traffic Class
  – type of flow
- Flow ID - random, unique-to-source value
  – combined with source address to identify traffic flow

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IPv6 Address Representation

- HEX in blocks of 16 bits
  – ABFE:76B3:0000:0000:0000:34DE:3421:0012
- leading zero suppression
  – ABFE:76B3:0:0:0:34DE:3421:12
- compressed format removes strings of 0s
  – ABFE:76B3::34DE:3421:12

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IPv6 Address Types

Allocation	Prefix (binary)	Fraction
reserved	0000 0000	1/256
reserved	0000 0001	1/256
NSAP Allocation	0000 001	1/128
IPX Allocation	0000 010	1/128
reserved	0000 011	1/128
reserved	0000 1	1/32
reserved	0001	1/16
reserved	001	1/8
provider-based unicast	010	1/8
reserved	011	1/8
reserved for geographic	100	1/8
reserved	101	1/8
reserved	110	1/8
reserved	1110	1/16
reserved	1111 0	1/32
reserved	1111 10	1/64
reserved	1111 110	1/128
local use address	1111 1110	1/256
multicast address	1111 1111	1/256

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IPv6 Unicast Address Examples

- Address Autoconfiguration example

n	m	48
subscriber prefix	subnet ID	node ID

- global provider address example

3	n	m	p	125-n-m-p
010	provider prefix	subscriber ID	subnet ID	node ID

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IPv6 Unicast Address Examples, contd.

- local use address example

8	n	m	120-n-m
1111 1110	0000....0000	subnet ID	node ID

- loopback address

  FE00:0:0:0:0:0:0:1 (FE00::1)

- unspecified address

  0:0:0:0:0:0:0:0 (0::0)

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IPv6 Unicast Address Examples, contd.

- IPv4-only address example

80	16	32
0000....0000	0000	IPv4 address

- IPv4 compatible IPv6 address example

80	16	32
0000....0000	FFFF	IPv4 address

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Other IPv6 Address Examples, contd.

- cluster address example

n	128-n
cluster prefix	00000.....00000

- IPv6 multicast address example

8	4	4	112
1111 1111	flags	scop	GID

  - low order flag bit
    - 0 - permanent
    - 1 - non-permanent

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OSI NSAPs & IPv6

- basic recommendation
- use NSAP with imbedded IPv6 address
- use normal IPv6 address architecture
- if mapping needed
  - can map some NSAPs into 16 byte IPv6 address
  - not encouraged
  - requires routing exchange between environments

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IPv6 Transition Goals

- allow incremental upgrade from IPv4 hosts to IPv6
- few sequence dependencies
- support what vendors will do
- allow IPv4-only hosts to talk to IPv6-only hosts
- finish before IPv4 addresses run out

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IPv6 Transition Techniques

- IPv4 compatible addresses
- IPv4 address embedded in IPv6 address
- IPv6 in IPv4 encapsulation
- tunnel IPv6 across IPv4 topology
- IPv4 <-> IPv6 header translation
  - optional

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IPv6-in-IPv4 Encapsulation

- allows IPv6 hosts to exchange traffic over IPv4 networks
- 'sending rules' tell hosts & routers when to encapsulate
- use of embedded IPv4 addresses allow tunnel auto-configuration
- mostly used host-to-host & router-to-host
- encapsulated by IPv4 source node
- IPv4 ICMP errors return to the right place

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IPv6/IPv4 Header Translation

- allows IPv6-only hosts to exchange traffic with IPv4-only hosts
- requires translating router within network
- algorithmic mapping of addresses
- translation discouraged by many

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Address Autoconfiguration

- three types of autoconfiguration
  - server-less
  - state-less server
  - state-full server
- IPng Address Autoconfiguration effort deals with 1st two
- DHCP deals with state-full server
- security policy an issue
- aim to minimize host knowledge of routing

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In Closing

"In anything at all, perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away."

Antoine de Saint-Exupery

"Everything should be made as simple as possible, but not simpler."

A. Einstein

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