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IPV6 OVERVIEW

A brief introduction

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AGENDA

- Why IPv6? (Key drivers)
- IPv6 Header
- Extension Headers
- IPv6 Addressing
- ICMPv6
- Neighbor Discovery
- Autoconfiguration
- IPv6 Support for QOS
- IPv6 Configuration
- References & Useful Links
- What’s next?

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WHY IPV6 (KEY DRIVERS)

IPv4 Limitations

Delay in IPv6

IPv6 Expectations

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IPV4 LIMITATIONS

- IPv4 Address Exhaustion
  - 32 bit address space ~ 4 billion addresses
  - Inefficient use of address space
  - Concentration of IPv4 addresses in US
  - IPv4 addresses particularly scarce in Asia
- Routing Overhead
  - Variable header size, resulting in more processing needs
  - No ordering of options
  - Fragmentation ID field overhead irrespective of fragmentation
- IPv4 Max Header Length Limit of 60 octets
- Security and Authentication techniques

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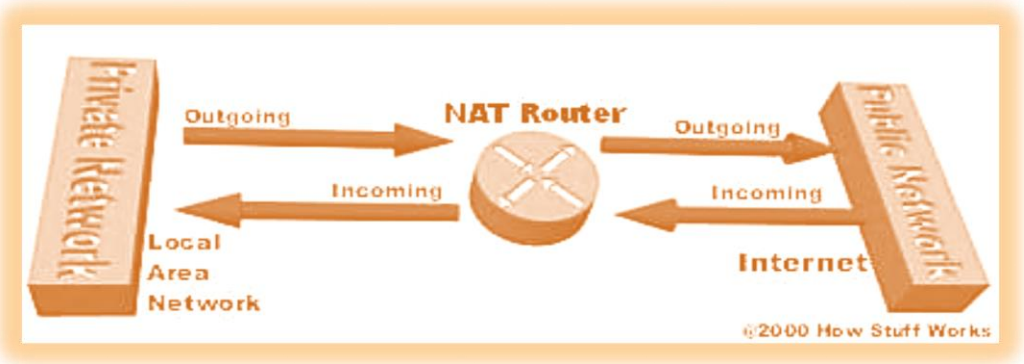
DELAY IN IPV6

CIDR (Supernetting)

- Classless Inter Domain Routing
- Normal IP/Network prefix

NAT

- Network Address Translation



IPv5 ?

- An experimental stream protocol which never made it

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IPV6 EXPECTATION

- Provide large number of Addresses
  - Explosion of addressable devices
  - 3.7x10^21 addresses per square inch of the earth's surface
- Globally unique and hierarchical addressing
  - Reduction in size of routing tables
- Future market needs
  - Security (Built-in authentication and encryption)
  - Routing Efficiency
  - QOS
  - Mobility
  - Extensibility
- Interoperability with IPv4
  - To make migration to IPv6 easier

IPV6 HEADER

IPv4 and IPv6 Header Comparison

IPv6 Header Fields

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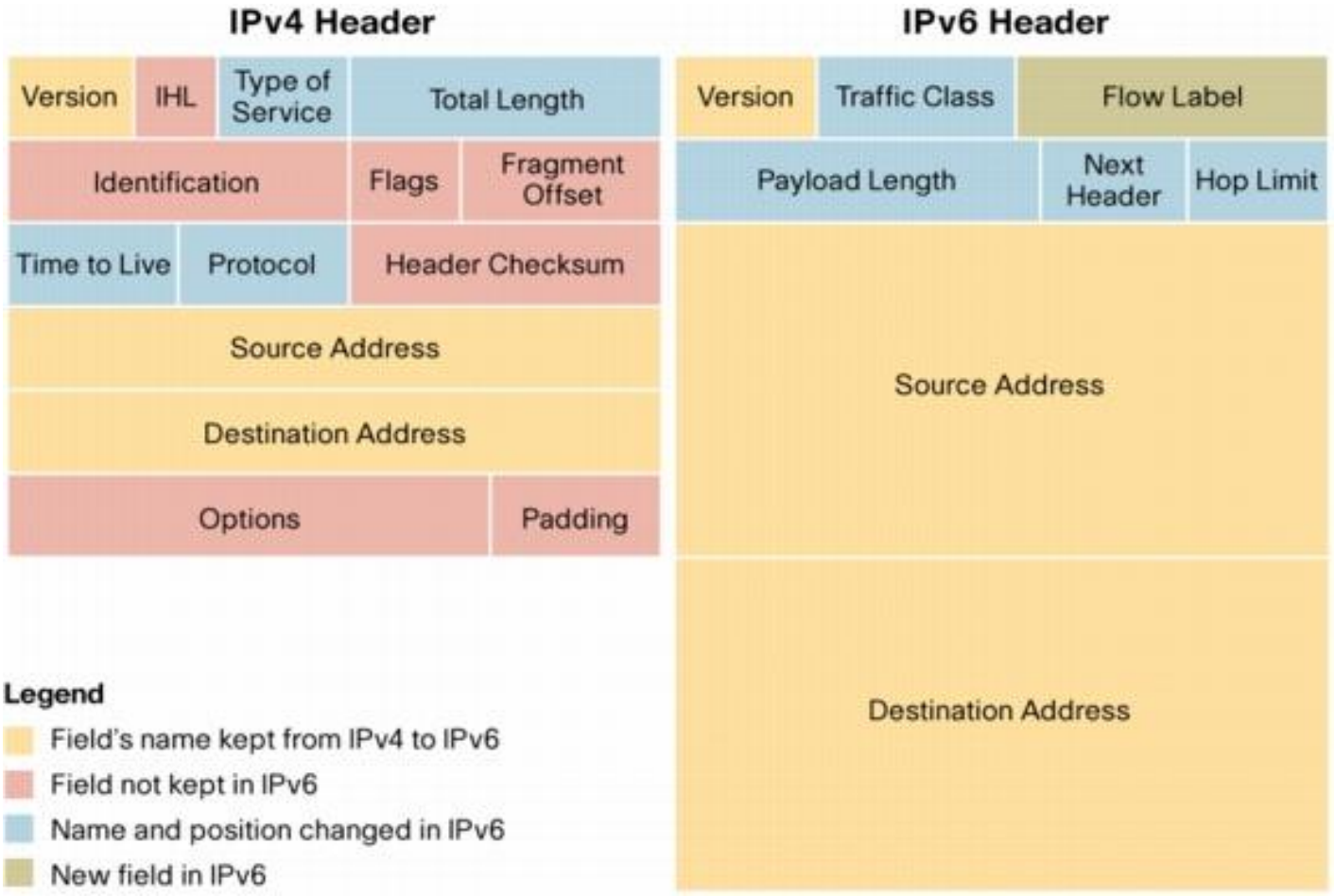
HEADERS SIDE BY SIDE



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IPV6 HEADER FIELDS (40 OCTETS)

- Version (4 bits): 0110
- Traffic Class (8 bits):
  - 6 bit Differentiated Service Code Point
    - packet classification for QOS guarantees
  - 2 bit Explicit Congestion Notification
    - 00 – Non ECN capable Transport
    - 01 & 10 – ECN capable Transport
    - 11 – Congestion Encountered
- Flow Label (20 bits):
  - Uniquely identifies a flow (flow label and source address)
  - Routers need not process header of each packet in a flow
  - Hosts themselves can apply them

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IPV6 HEADER FIELDS (40 OCTETS)

- Payload Length (16 bits):
  - Size of payload including any extension headers
  - Set to 0 when Hop By Hop extension header carries a Jumbo Payload option
- Next Header (8 bits):
  - Identifies transport protocol or next extension header
  - Values consistent with IPv4 Protocol field
- Hop Limit (8 bit):
  - Decremented by 1 at each node the packet visits
  - When value is 0, packet is discarded
- Source Address & Destination Address (128 bits each)
  - Specifies Source and Destination IPv6 address respectively

EXTENSION HEADERS

IPv4 Options and EH

Extension Header Mechanism

Types and Order of Extension Headers

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IPV4 OPTIONS AND EH

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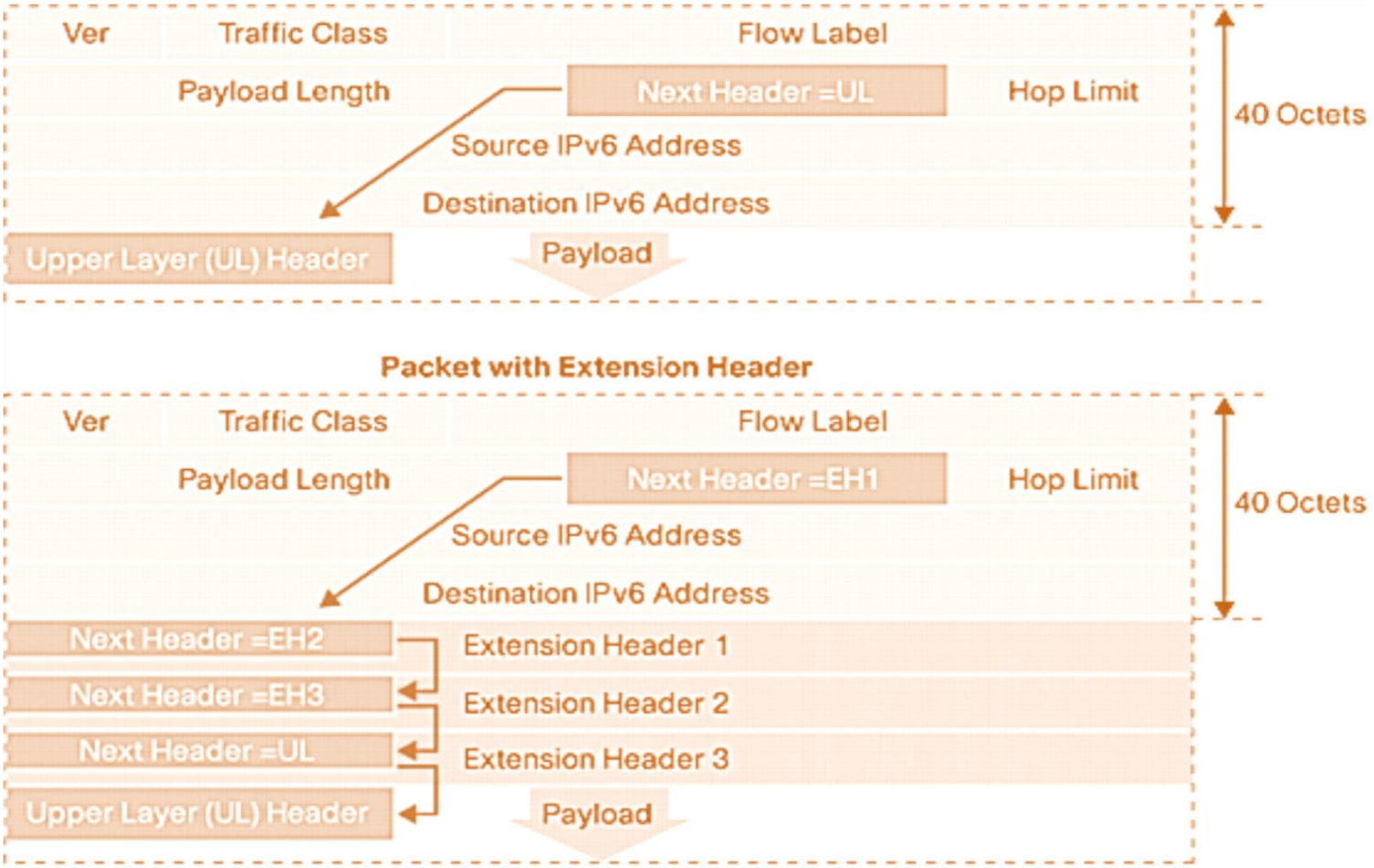
EXTENSION HEADER MECHANISM



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TYPES AND ORDER OF EXTENSION HEADERS

Order	Header Type	NH	EH Processed
1	Basic IPv6 Header		
2	Hop by Hop Options	0	Every Router
3	Destination Options (with Routing Options)	60	Routers Listed in Routing Extension
4	Routing Header	43	List of Routers To Cross
5	Fragment Header	44	Destination
6	Authentication Header	51	After Reassembling Packet
7	Encapsulation Security Payload Header	50	Cipher content of remaining info
8	Destination Options	60	Destination
9	Mobility Header	135	Destination
	No next header	59	
Upper Layer	TCP/UDP/ICMPv6	6/17/58	

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IPV6 ADDRESSING

Address Representation

Address Components

Address Types

Unicast Address

Anycast Address

Multicast Address

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ADDRESS REPRESENTATION

- All addresses are 128 bit
- Specified as 8 sets of 4 hexadecimal digits each separated by colons.
  - XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX:XXXX
  - Egs: `3ffe:3700:0200:00ff:0000:0000:0000:0001`
- Reduction techniques
  - Leading zeroes in group may be omitted
  - Contiguous all-zero groups may be replaced by "::"
  - Only one such group can be replaced.
  - Egs:
    - `3ffe:3700:0200:00ff:0000:0000:0000:0001` can be written as `3ffe:3700:200:ff::1`
    - `3FFE:0000:0000:0000:1010:2A2A:0000:0001` can be written as `3ffe::1010:2A2A:0:1`

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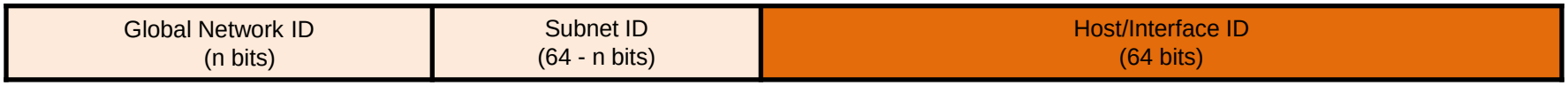
ADDRESS COMPONENTS



- High order 64 bits
  - Network and Subnet ID
- Lower order 64 bits
  - Interface ID
  - Can be derived from MAC address burned into the hardware
    - Split MAC address into two 24 bit values
      - Egs: Mac addr C2:00:54:FE:00:00
    - Insert FF:FE in the middle of the 2 values
      - Egs: C2:00:54: FF:FE:FE:00:00
    - Seventh bit of MAC is flipped to get the EUI-64 address
      - Egs: C0:00:54: FF:FE:FE:00:00
    - Group them in orders of four hex digits to get the host ID
      - Egs: C000:54FF:FEFE::

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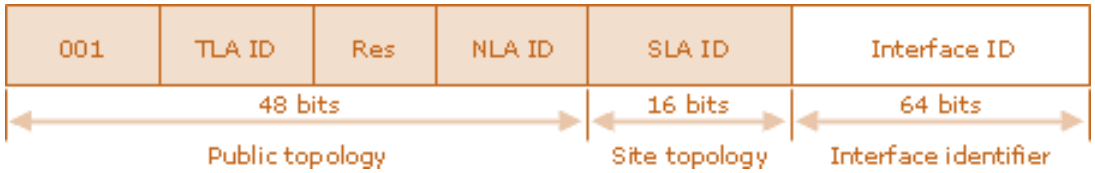
ADDRESS TYPES

- Unspecified Address
  - Addressed with all zeroes “::”
  - Used to indicate absence of address
- Loopback Address
  - Similar to 127.0.0.1 in IPv4, addressed as “::1”
  - Used to identify the loopback interface
- Unicast Address
  - Host to Host communication
- Anycast Address
  - Communication to any one host of a group of hosts.
- Multicast Address
  - Group of hosts communication

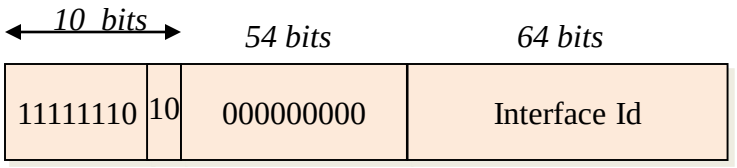
UNICAST ADDRESS

- Aggregatable Global Unicast Address
  - Globally routable address
  - Format Prefix of 001
  - Designed for aggregation of addresses in routing tables
  - Top Level Aggregation ID and Next Level Aggregation ID are assigned by ISP
    - Can be aggregated geographically.

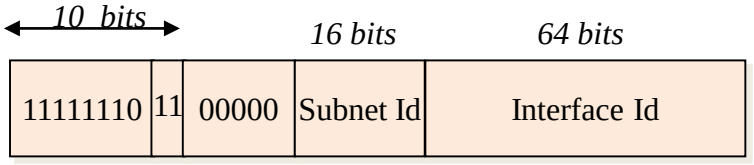


UNICAST ADDRESS

- Local Use Address
  - Link-Local Address
    - Within a link
    - Prefix FE:80::/64
    - Shouldn't be used outside a link
    - Plug and Play address
    - Local n/w isolated from external links



  - Site-Local Address
    - Within a site
      - Behind NAT
      - Within VPN
    - Prefix FE:C0::/48
    - Shouldn't be forwarded outside site
    - Communication within site unaffected by changes to external links
    - Deprecated



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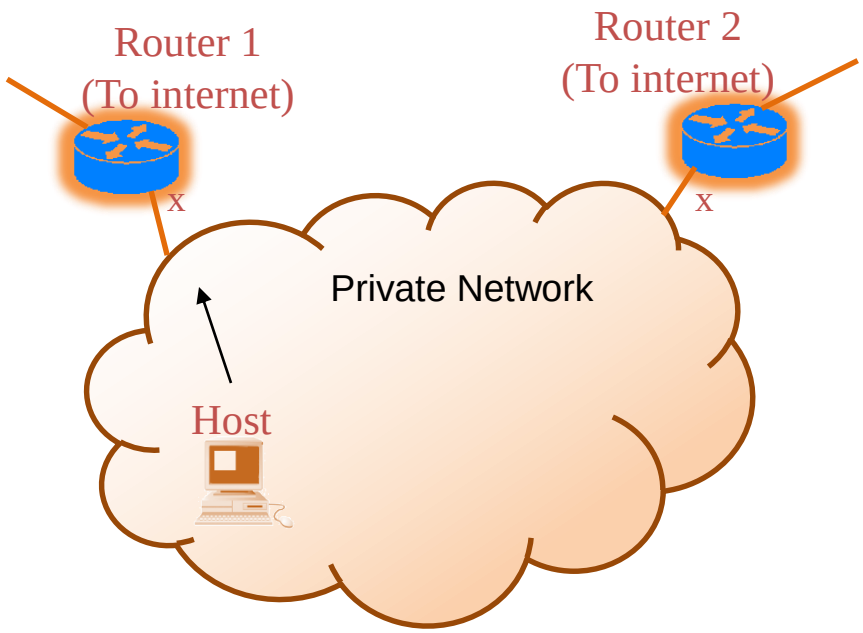
UNICAST ADDRESS

- IPv6/IPv4 address embedding
  - IPv4 compatible IPv6 address
    - ::<IPv4 address>
      - Egs: For IPv4 address 10.232.72.32, IPv4 compatible IPv6 address is ::10.232.72.32
    - Special addresses for dual stack devices.
  - IPv4-mapped IPv6 address
    - ::FFFF:<IPv4 address>
      - Egs: For IPv4 address 10.232.72.32, IPv4-mapped IPv6 address is ::FFFF:10.232.72.32
    - Used for devices which are only IPv4 capable
  - 6to4 IPv6 address
    - Prefix 2002::/16 with node's IPv4 address
      - Egs: 2002:aabb:ccdd::/48 where node's IPv4 address is aa.bb.cc.dd
    - Used by dual stack host or router

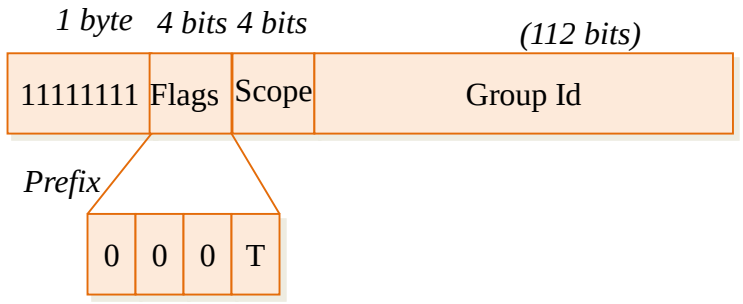
ANYCAST ADDRESS

- An identifier for a set of interfaces, typically of different nodes.
- Packet sent to Anycast Address reaches only the interface nearest to the sender.
- Belongs to Global Unicast Address Range
- Suitable for load balancing and content delivery systems.
- Another use scenario would be a mobile device locking to one among a group of access points.
- Problems with stateful interactions



MULTICAST ADDRESS

- Identifier for a set of interfaces
- Similar to IPv4 multicast
- Packets sent to a multicast address are delivered to all the interfaces identified by the address.
- Takes the functionality of broadcast



- Prefix FF::/8
- Flag Bit T
  - 0 permanent, 1 transient
- Scope
  - 1 Node local
  - 2 Link local
  - 5 Site local
  - 8 Organization Local
  - E Global
- Group ID 1-All routers, 2-All nodes

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MULTICAST ADDRESS

IPv6 Well-known multicast address	IPv4 Well-known multicast address	Multicast Group
FF01:0:0:0:0:0:0:1	224.0.0.1	All-nodes address
FF01:0:0:0:0:0:0:2	224.0.0.2	All-routers address
FF02:0:0:0:0:0:0:1	224.0.0.1	All-nodes address
FF02:0:0:0:0:0:0:2	224.0.0.2	All-routers address
FF02:0:0:0:0:0:0:5	224.0.0.5	OSPFIGP
FF02:0:0:0:0:0:0:6	224.0.0.6	OSPFIGP-DR‘s
FF02:0:0:0:0:0:0:9	224.0.0.9	RIP routers
FF02:0:0:0:0:0:0:D	224.0.0.13	All PIM routers
FF05:0:0:0:0:0:0:2	224.0.0.2	All-routers address
FF0X:0:0:0:0:0:0:101	224.0.1.1	Network time protocol NTP

Node local scope	Link local scope	Site local scope	Any valid scope

ICMPV6

Network Layer differences

Types of Messages

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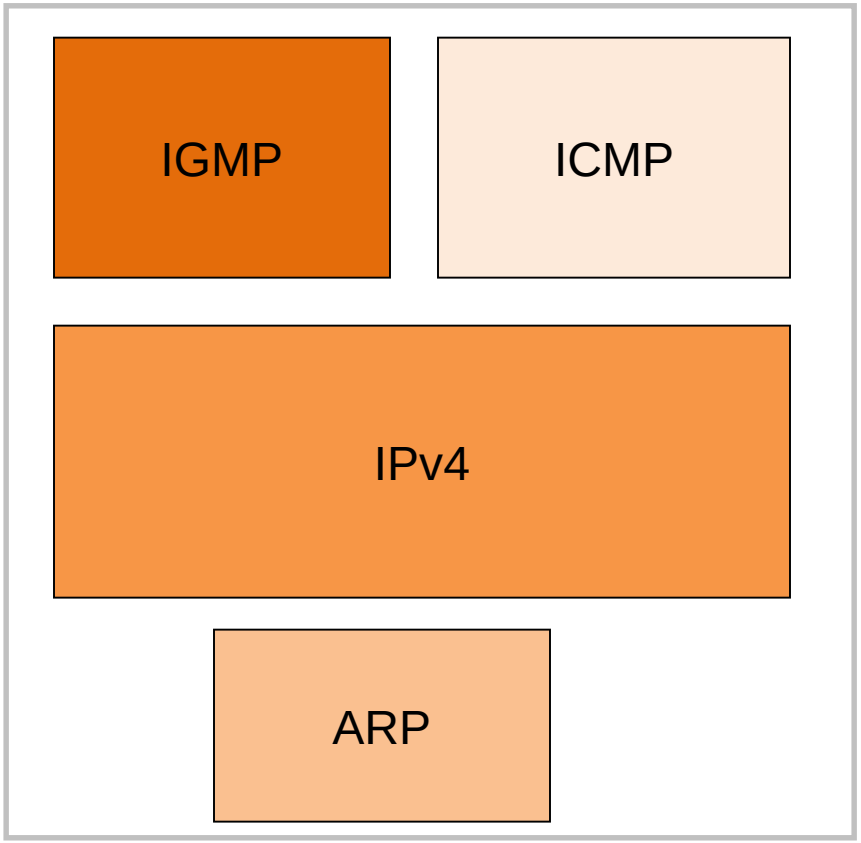
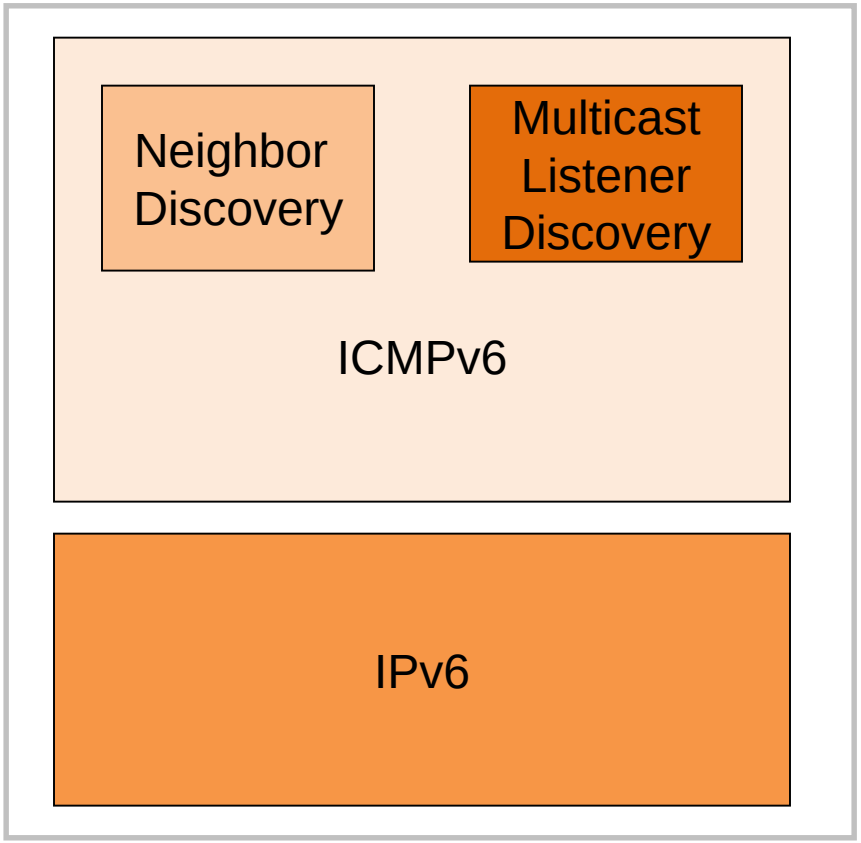
NETWORK LAYER DIFFERENCES

Version 4



Version 6



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TYPES OF MESSAGES

- Error Reporting
  - Destination Unreachable
  - Packet too big
  - Time Exceeded
  - Parameter Problem
- Query
  - Echo Request / Reply
  - Router Solicitation / Advertisement
  - Neighbor Solicitation / Advertisement
  - Group Membership

NEIGHBOR DISCOVERY

ND Messages

ND Options

What can ND do?

Address Resolution

Host Data structures

States of Neighbor Cache entry

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ND MESSAGES

- Router Solicitation
- Router Advertisement
- Neighbor Solicitation
- Neighbor Advertisement
- Router Redirect

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ND OPTIONS

- Source Link-Layer address Option
- Destination Link-Layer address Option
- Prefix Information Option
- Redirect Header Option
- MTU Option

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WHAT CAN ND DO?

- Router Discovery
- Prefix Discovery
- Parameter Discovery
- Address Autoconfiguration
- Address Resolution
- Next-hop determination
- Neighbor Unreachability Detection
- Duplicate Address Detection
- Redirect

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ADDRESS RESOLUTION

- Node 1 send out Neighbor Solicitation
  - Uses Solicited-Node multicast Address of Node2 as DA
  - Target Address in ND header is Node2 IPv6 address
  - Option contains its own link layer address

- Node 2 is registered for this multicast address
  - Receives this packet
  - Adds node 1 link layer to its cache
  - Sends a Unicast NA with
    - Target address containing its IPv6 address
    - Option containing its Link Layer address

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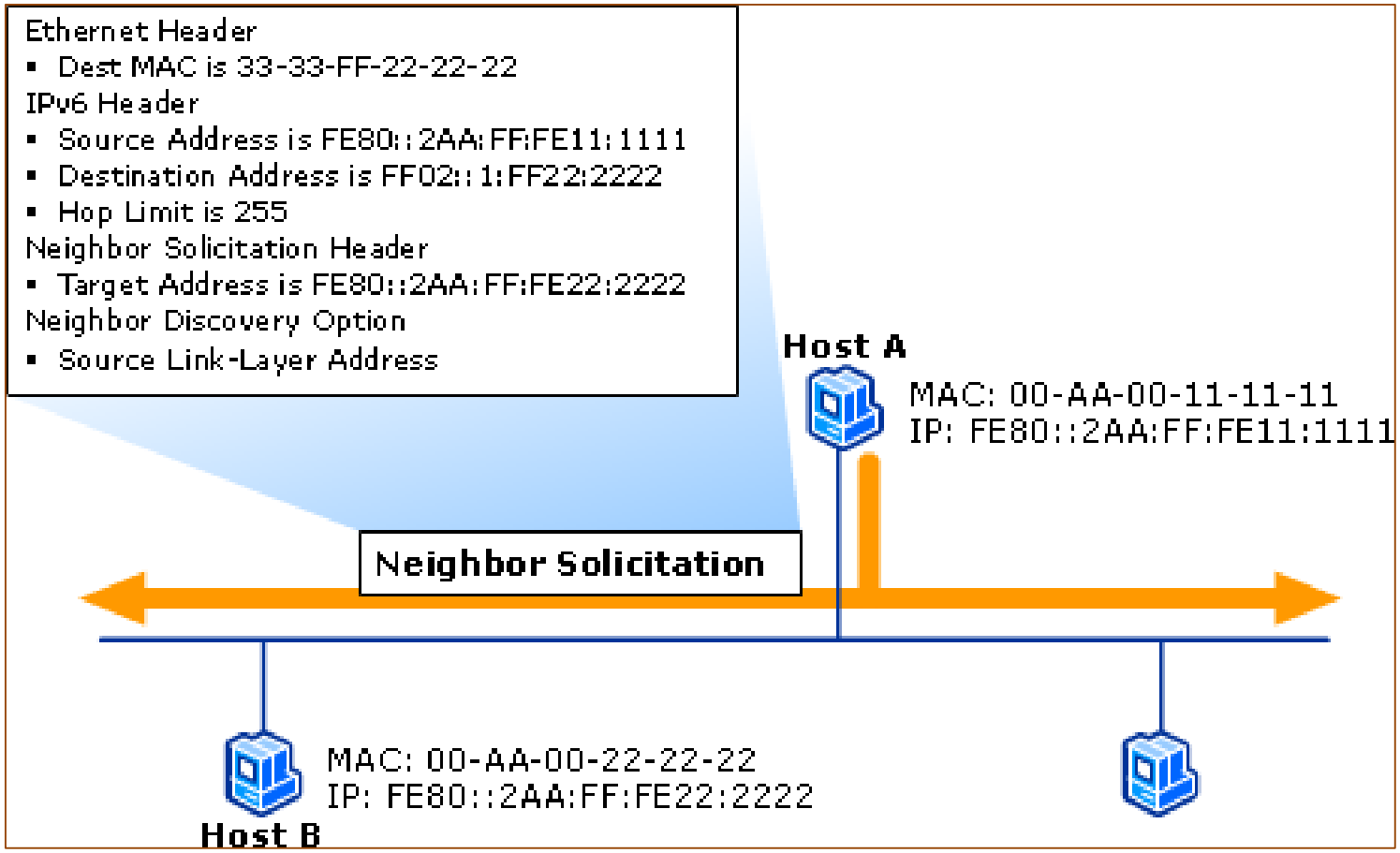
ADDRESS RESOLUTION



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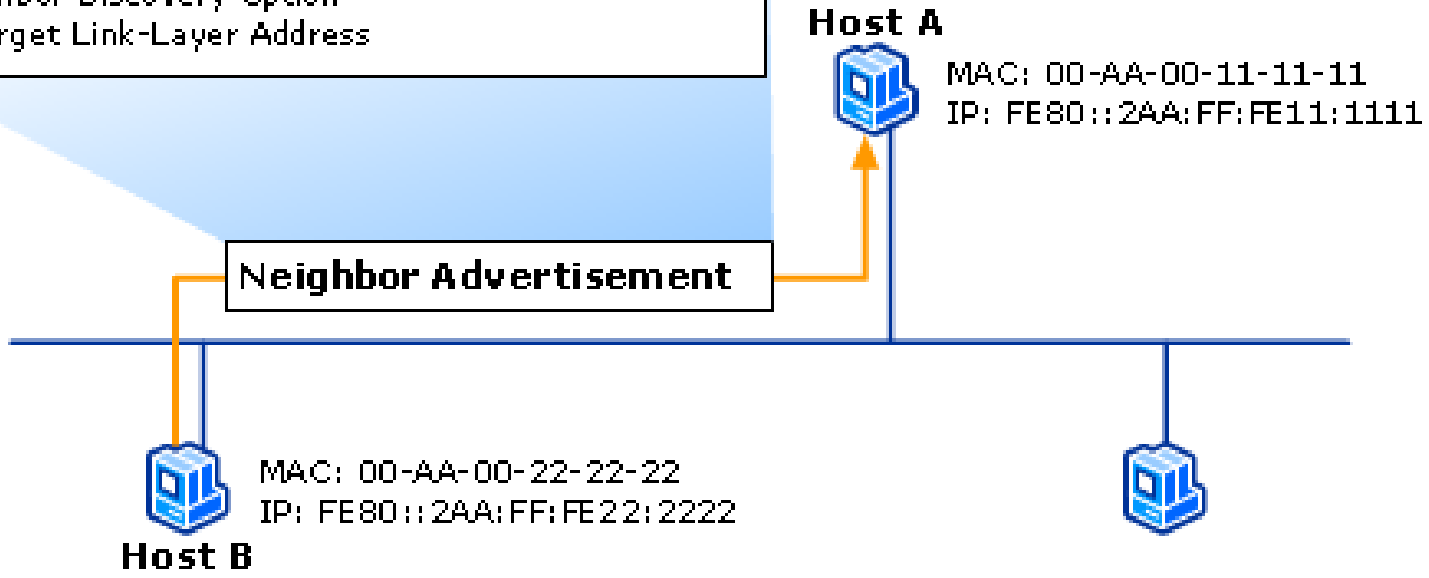
ADDRESS RESOLUTION

Ethernet Header
- Dest MAC is 00-AA-00-11-11-11

IPv6 Header
- Source Address is FE80::2AA:FF:FE22:2222
- Destination Address is FE80::2AA:FF:FE11:1111
- Hop Limit is 255

Neighbor Solicitation Header
- Target Address is FE80::2AA:FF:FE22:2222

Neighbor Discovery Option
- Target Link-Layer Address



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HOST DATA STRUCTURES

- Neighbor Cache
- Destination Cache
- Prefix List
- Default Router List

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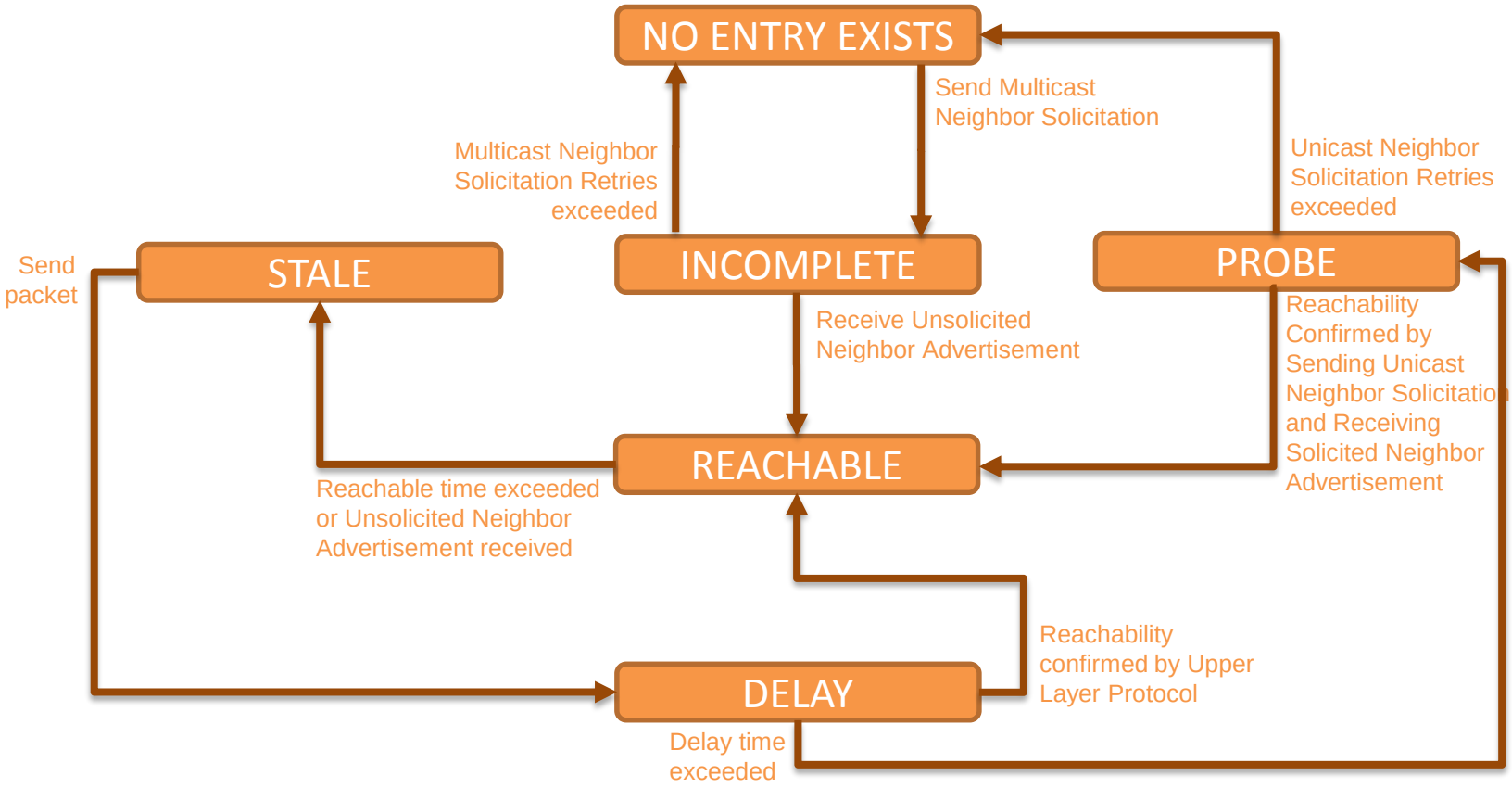
STATES OF NEIGHBOR CACHE ENTRY



AUTOCONFIGURATION

AutoConfiguration and Types

AutoConfiguration Address States

Address Derivation Example

Stateless Autoconfiguration

Stateful Autoconfiguration(DHCPv6)

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AUTOCONFIGURATION AND TYPES

- Process by which IPv6 node configures itself
- Why Autoconfiguration?
  - No manual configuration
  - Graceful site renumburing
  - Can be turned off/on for tighter control
- Types of Autoconfiguration
  - Stateless (RFC2462)
  - Stateful (RFC3315)

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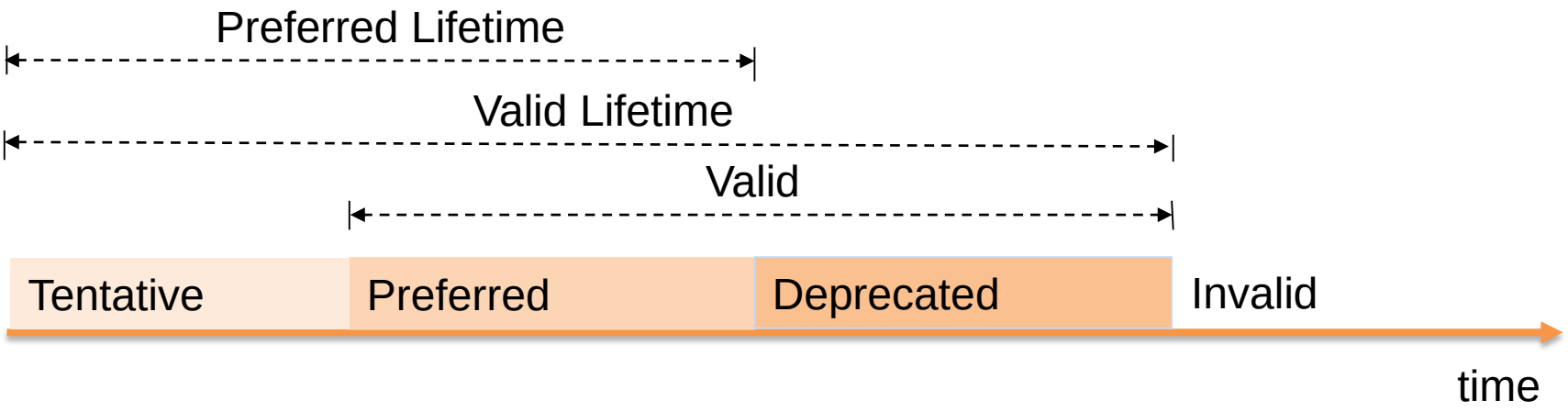
AUTOCONFIGURATION ADDRESS STATES



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ADDRESS DERIVATION EXAMPLE

- MAC Address 02:13:72:26:8D:4C
- Interface Identifier 00:13:72:FF:FE:26:8D:4C
- Link Local Address FE80::13:72FF:FE26:8D4C
- Router Advertised Prefix 3FFE::/64
- Global Unicast Address 3FFE::13:72FF:FE26:8D4C

- Multicast address derivation

Solicited-Node Address Format = FF02:0:0:0:0:1:FFXX:XXXX
Solicited-Node Multicast Address = FF02:0:0:0:0:1:FF26:8D4C
Hardware Multicast Format = 33:33:XX:XX:XX:XX
Hardware Multicast Address = 33:33:FF:26:8D:4C

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STATELESS AUTOCONFIGURATION

- Formation of Tentative Link Local Address
- Formation of Solicited Node Multicast Address
- Duplicate Address Detection
- Manual configuration if Tentative Address in use
- Send Router Solicitation Message
- Configure global unicast address if prefix present in Router Advertisement
- Invoke Stateful Autoconfiguration if no Router Advertisements (or) Managed Flag set in Router Advertisement

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STATEFUL AUTOCONFIGURATION(DHCPV6)

- Works in a client - server model
  - Server

    1. Responds to requests from clients
    2. Optionally provides clients with
        a) IPv6 Addresses
        b) Other Configuration parameters (MTU, Hop Limit , DNS)
    3. Has the multicast address All DHCP_Relay_Agents_and_Servers (FF02::1:2)
    4. Memorizes client state (lease time)
  - Client

    1.Initiates request on a link to obtain configuration parameters

    2.Uses its link local address to connect to server

    3.Send requests to FF02:1:2 multicast address.
  - Relay Agent

    1.Node acts as intermediary between to deliver DHCP

    2.Is on the same link as client

IPV6 SUPPORT FOR QOS

IPv6 support for Int-Serv

IPv6 support for Diff-Serv

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IPV6 SUPPORT FOR INT-SERV

- “Integrated Service” :
  - Fine grain (per flow),
  - quantitative promises (egs: n bits per second),
  - uses (Resource Reservation Setup Protocol) RSVP signalling.

- 20 bit Flow Label field
  - Flow Label + Source address forms unique flow identifiers at the router.
  - Flow label 0 means no special QoS requested.
  - Unique label created by source.

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IPV6 SUPPORT FOR DIFF-SERV

- “Differentiated Service”:
  - Coarse grain (per class)
  - Qualitative promise (egs: higher priority)
  - No explicit signalling

- 8 bit Traffic class field
  - To identify specific “classes” of packets needing QoS
  - Same as IPv4 Type of Service field
  - May be initialized by source or router enroute
  - May be overwritten by router enroute
  - 0 means no QoS required

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IPV6 CONFIGURATION

- Windows 7 and later
  - http://windows.microsoft.com/en-us/windows/ipv6-faq#1TC=windows-7
- Windows XP
  - Command “ipv6 enable” in command prompt
  - netsh can be used for ipv6 configuration
- Ubuntu Linux
  - /etc/sysctl.conf contains ipv6 configurations which is enabled by default
  - We can enable/disable ipv6 for each interface individually
  - radvd is used for router configuration
- The Linux Documentation Project Howto on IPv6 for linux
  - http://tldp.org/HOWTO/Linux+IPv6-HOWTO/

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REFERENCES & USEFUL LINKS

- RFC 2460 – IPv6 Specification
- RFC 4291 – IPv6 Addressing Architecture
- RFC 2461 – Neighbour Discovery
- RFC 2462 – ICMPv6
- RFC 2463 - IPv6 Stateless Address Auto-configuration
- RFC 3315 - DHCPv6.txt
- RFC 3596 - DNS Extensions to Support IP Version 6
- RFC 4472 - Operational Considerations and Issues with IPv6 DNS
- RFC 3493 - Basic Socket Interface Extensions for IPv6.txt
- RFC 2472 - IPv6 Over PPP
- www.microsoft.com/ipv6 - Microsoft IPv6 Website
- http://technet.microsoft.com/en-us/library/dd392266(v=ws.10).aspx – Microsoft IPv6 Technical Library
- www.cisco.com/ipv6 - Cisco's IPv6v Website
- http://www.cisco.com/en/US/technologies/tk648/tk872/technologies_white_paper0900aecd8054d37d.html - Cisco IPv6 Extension Headers Review and Considerations
- www.linux-ipv6.org – Linux IPv6 Development Project (USAGI)
- www.tahi.org – Test and Verification for IPv6
- www.kame.net – IPv6 Stack BSD variants
- www.ipv6forum.org
- http://www.tldp.org/HOWTO/html_single/Linux+IPv6-HOWTO/ - Linux IPv6 HOWTO