Advanced Networking

# IPv6

Renato Lo Cigno
Renato.LoCigno@dit.unitn.it

## IPv6 - Version Number

- IPv 1-3 defined and replaced
- IPv4 - current version
- IPv5 - streams protocol
  - Connection oriented internet layer protocol
  - Developed in late '70s
  - Never introduced
  - Concepts exported with ATM ones to MPLS
- IPv6 - replacement for IP v4
  - During development it was called IPng
    - Next Generation



## Why Change IP?

- Address space exhaustion
  - Two level addressing (network and host) wastes space
  - Network addresses used even if not connected to Internet
  - Growth of networks and the Internet
  - Extended use of TCP/IP
  - Single address per host
- Requirement for new services

## IPv6 RFCs

- A very long (never ending??) story
- 1752 - Recommendations for the IP Next Generation Protocol
- 2460 - Overall specification
- 2373 - addressing structure
- many others (find them)
- **www.rfc-editor.org**



## IPv6 Enhancements (1)

- Expanded address space
  - 128 bit
- Improved option mechanism
  - Separate optional headers between IPv6 header and transport layer header
  - Most are not examined by intermediate routes
    - Improved speed and simplified router processing
    - Easier to extend options
- Address autoconfiguration
  - Dynamic assignment of addresses



## IPv6 Enhancements (2)

- Increased addressing flexibility
  - Anycast - delivered to one of a set of nodes
  - Improved scalability of multicast addresses
  - Site/link dependent addresses
  - Hierarchical addresses
- Support for resource allocation
  - Replaces type of service
  - Labeling of packets to particular traffic flow
  - Allows special handling
    - e.g. real time audio, video streaming

## Other Changes from IPv4 (1)

- *Fragmentation at routers*: none provided, router which has a packet longer than the maximum allowed on a the next hop drops the packet, and sends an ICMP message "Packet Too Big" to the packet source; reduces processing time of packets
- *Checksum*: removed entirely to reduce processing time at each hop



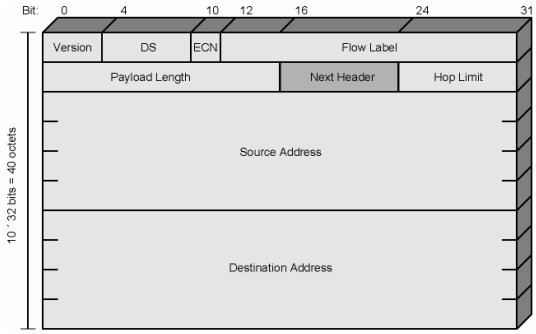
## Other Changes from IPv4 (2)

*Options*: Options are allowed and indicated by the header field "Next Header", the content of this field indicates the higher level protocol or the existence of an option after the 40 bytes IPv6 header

- *ICMPv6*: new version of ICMP, with additional message types, eg "Packet Too Big"; and group management function for multicast groups (Under IPv4 done by the protocol Internet Group Management Protocol IGMP)



## IPv6 Default Header




## IP v6 Header Fields (1)

- Version: 6
  - notice it's the 1-st octet → useful for classification in multi-stack hosts/routers
- Traffic Class
  - Classes or priorities of packet
  - Still under development
  - See RFC 2460
- Flow Label
  - Used by hosts requesting special handling
- Payload length
  - Includes all extension headers plus user data



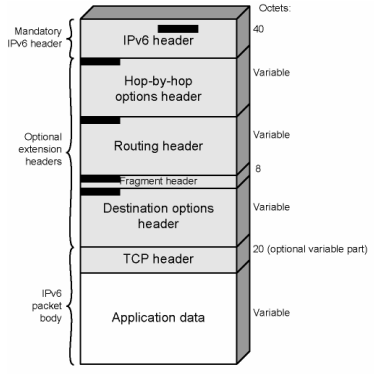
## IP v6 Header Fields (2)

- Next Header
  - Identifies type of header
    - Extension or next layer up
- Source Address
- Destination address

- Additional and optional headers before transport protocol headers: flexibility and backward compatibility for TCP/UDP



## IPv6 Packet with Extension Headers




## Extension Headers

- Hop-by-Hop Options
  - Require processing at each router
- Routing
  - Similar to v4 source routing
- Fragment
- Authentication
- Encapsulating security payload
- Destination options
  - For destination node



## IPv6 Addresses

- 128 bits long
  - Notation - 2001:0db8:1234:0000:0000:0000:0000:0000/mask
  - Multiple 0000 fields collapsed to ::
- Assigned to interface
- Single interface may have multiple unicast addresses
- Three types of "main" address
- Many special addresses including
  - IPv4 backward compatible - ::/96
  - IPv4 mapped - ::ffff:0:0/96
  - software addresses - ::/128
  - ...



## Types of address

- Unicast
  - Single interface
- Anycast
  - Set of interfaces (typically different nodes)
  - Delivered to any one interface
  - the "nearest"
- Multicast
  - Set of interfaces
  - Delivered to all interfaces identified

## Flow Label

- Flow
  - Sequence of packets from particular source to particular (unicast or multicast) destination
  - Source desires special handling by routers
  - Uniquely identified by source address, destination address, and 20-bit flow label
- Router's view
  - Sequence of packets sharing attributes affecting how packets handled
    - Path, resource allocation, discard needs, accounting, security
  - Handling must be declared
    - Negotiate handling ahead of time using control protocol
    - At transmission time using extension headers
      - E.g. Hop-by-Hop Options header



## Flow Label Rules

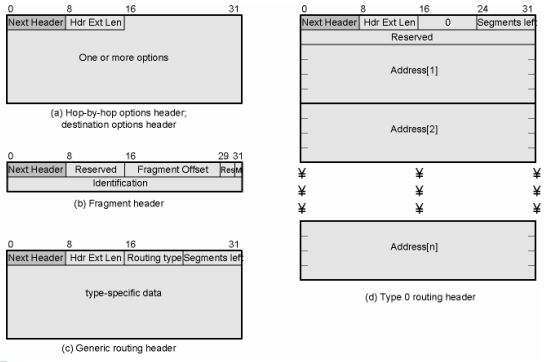
- Flow Label set to zero if not supported by host or router when originating
  - Pass unchanged when forwarding
  - Ignore when receiving
- Packets from given source with same nonzero Flow Label must have same Destination Address, Source Address, Hop-by-Hop Options header contents (if present), and Routing header contents (if present)
  - Router can make decisions by looking up flow label in table
- Source assigns flow label
  - New flow labels be chosen (pseudo-) randomly and uniformly
  - Range 1 to $2^{20} - 1$
  - Not reuse label within lifetime of existing flow
  - Zero flow label indicates no flow label



## Selection of Flow Label

- Router maintains information on characteristics of active flows
- Table lookup must be efficient
- Could have $2^{20}$ (about one million) entries
  - Memory burden
- One entry per active flow
  - Router searches table for each packet
  - Processing burden
- Hash table
  - Hashing function using low-order few bits (say 8 or 10) of label or calculation on label
  - Efficiency depends on labels uniformly distributed over possible range
  - Hence pseudo-random, uniform selection requirement

## IPv6 Extension Headers






## Hop-by-Hop Options

- Next header
- Header extension length
- Options
  - Pad1
    - Insert one byte of padding into Options area of header
  - PadN
    - Insert $N$ (≥2) bytes of padding into Options area of header
    - Ensure header is multiple of 8 bytes
  - Jumbo payload
    - Over $2^{16}$ = 65,535 octets
  - Router alert
    - Tells router that contents of packet is of interest to router
    - Provides support for RSPV
  - Others …
- Destination options have same format



## Fragmentation Header

- Fragmentation only allowed at source
- No fragmentation at intermediate routers
- Node must perform path discovery to find smallest MTU of intermediate networks
- Source fragments to match MTU
- Otherwise limit to 1280 octets

## Routing Header

- List of one or more intermediate nodes to be visited
- Next Header
- Header extension length
- Routing type
- Segments left
  - i.e. number of nodes still to be visited



## Transition From IPv4 To IPv6

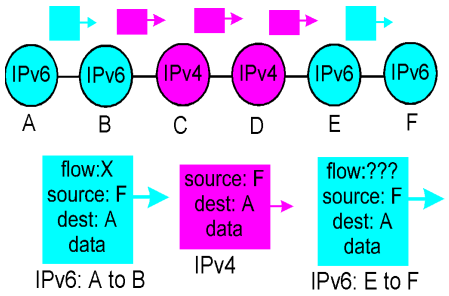
- During the transition, not all routers will be upgraded to IPv6
- How will the network operate?
- How can host with different stack communicate?
- Two of the proposed approaches:
  - Dual Stack
  - Tunneling



## Transition From IPv4 To IPv6

- *Dual Stack*:
  - Some routers with dual stack (v6, v4); others are only v4 routers
  - Dual stack routers translate the packet to v4 packet if the next router is v4 only
  - DNS can be used to determine whether a router is dual stack or not
  - Some info and v6 features will be lost if a packet has to go through any v4 only router;
    - eg Flow Identification

## Dual Stack Approach



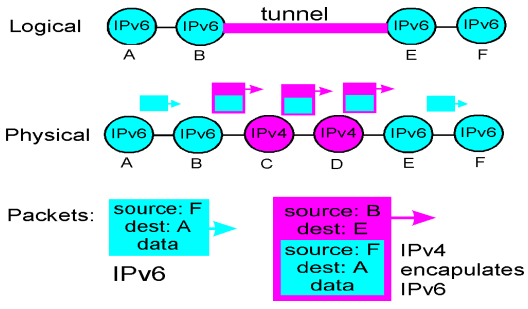



## Tunneling

- Routers are as before v4/v6 or v4 only
- A v4/v6 router "encapsulates" the IPv6 packet inside an IPv4 envelop before communication to a v4 only router
- A v4/v6 router receiving an encapsulated packet from a "tunnel", remove the envelop and forwards the IPv6 to next router if the next router is v4/v6 capable



## Tunneling



## IPv6 Projects

- Explore IPv6 transitions strategies
- Why IPv6 will win
  - convince a reader (and your class) that IPv6 is the necessary support for NGI
- Why IPv6 will lose
  - convince a reader (and your class) that IPv6 is just a toy and we don;t need it
- Making and IPv6 island in the Faculty
  - Just kidding, connect 2 machines and have them work!!
- Tunnel IPv6 traffic toward an IPv6 island somewhere, and show use of IPv6 features