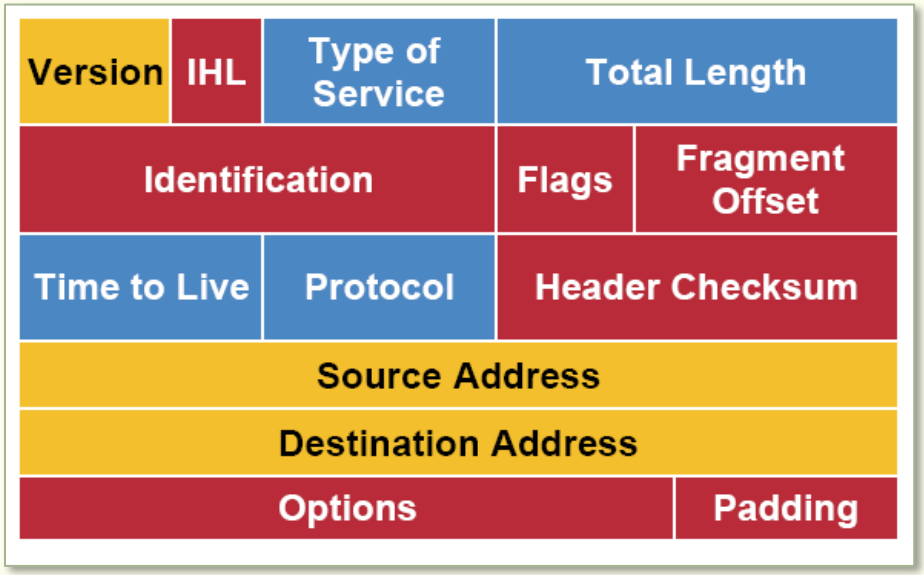
IPv6

Header structure

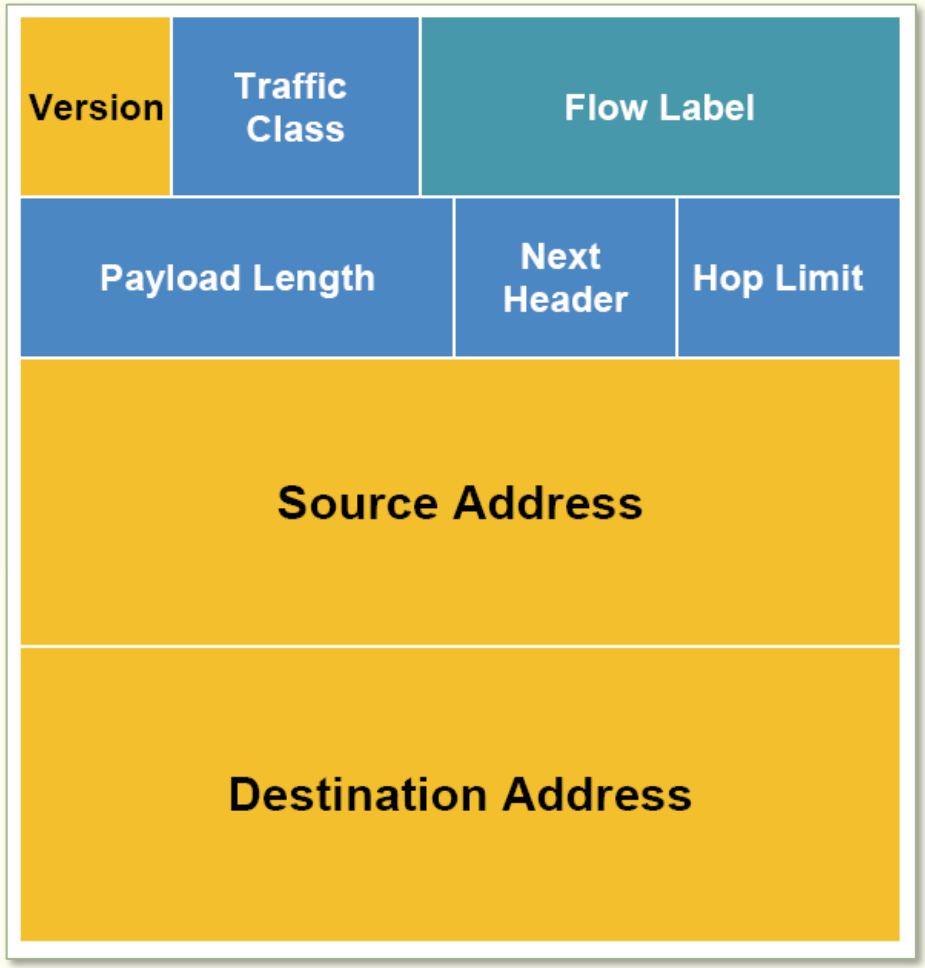
IPv4 vs. IPv6 headers

IPv4

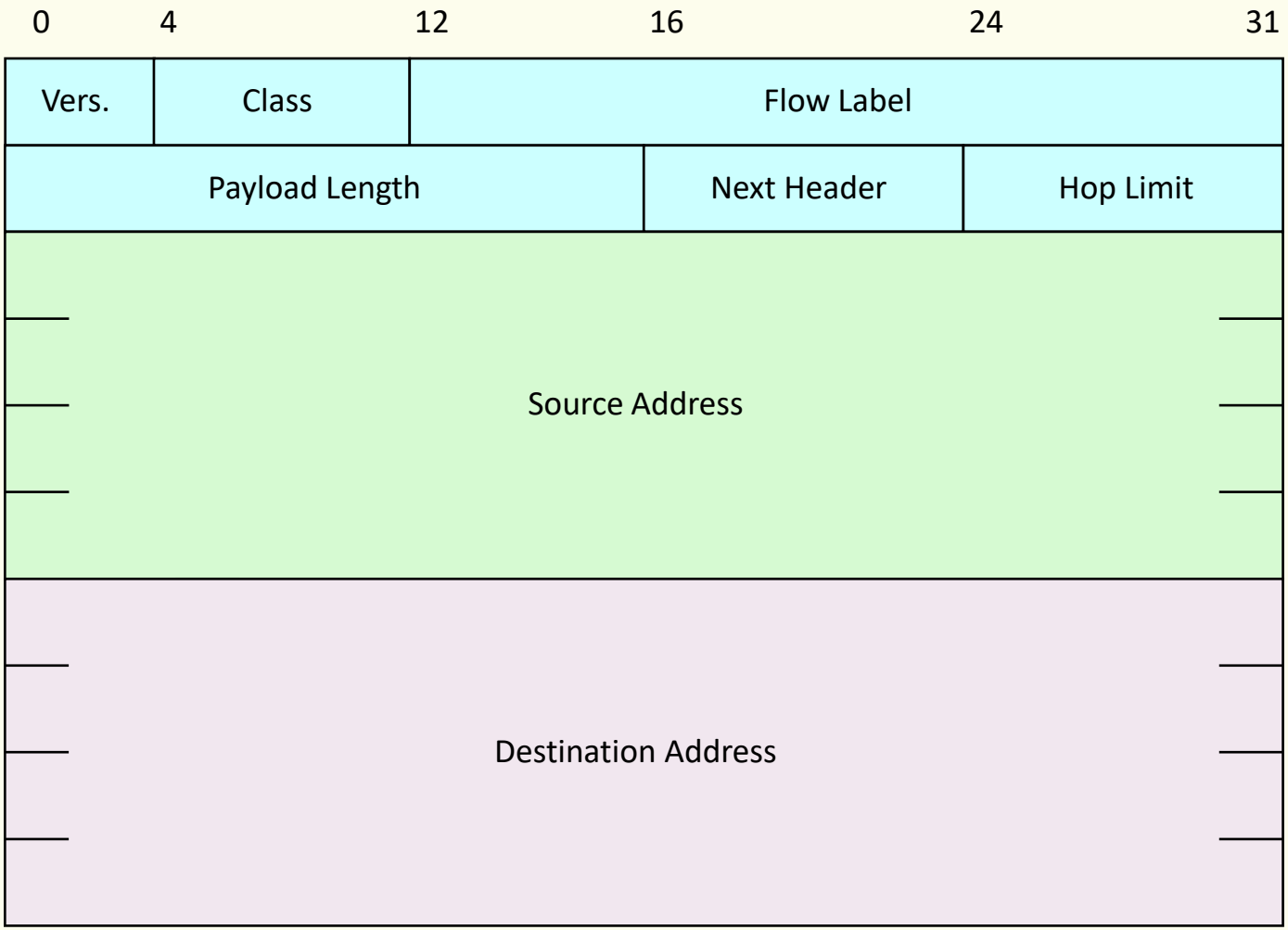


- **Header Length**: not needed since base header has fixed length
- **Identification**, **Flags**, **Fragment Offset**: no in-network fragmentation
- **Header Checksum**: removed to improve processing speed
  - With IPv6, UDP checksum is mandatory

IPv6

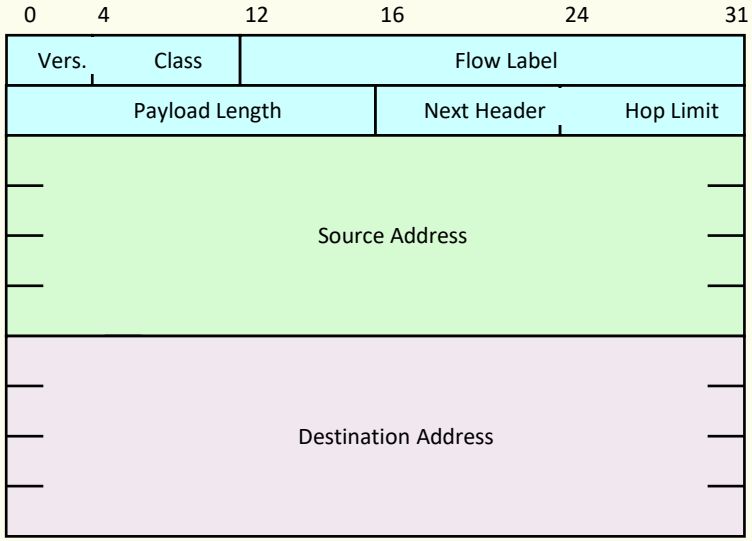


IPv6 base header (40 bytes)



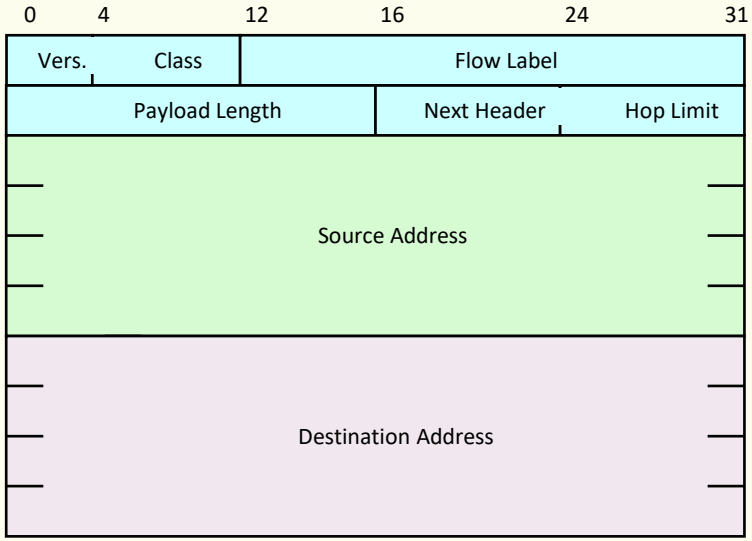
IPv6 base header

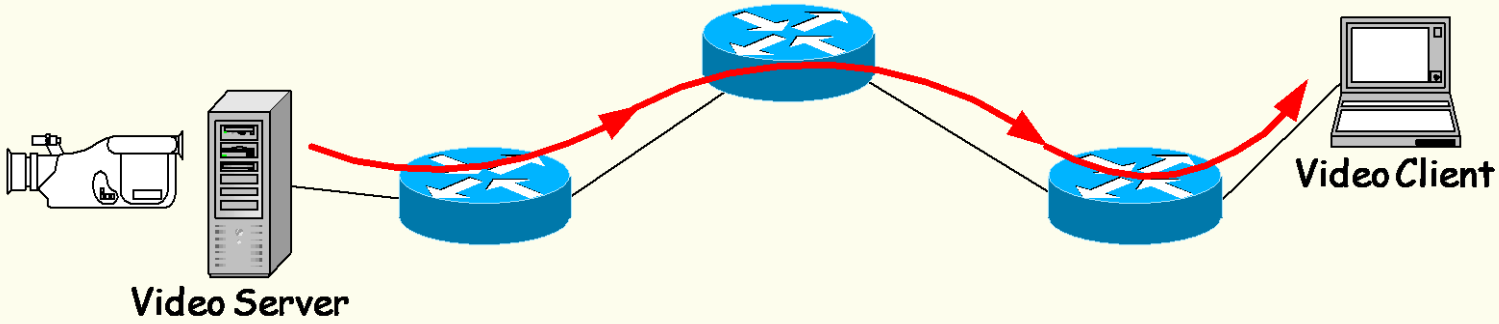
- Version (4 bits)
  - 6
- Traffic Class (1 byte)
  - Substitutes the ToS field in IPv4
  - Can be used to give priority to certain packets within a flow, or it can be used to give priority to datagrams from certain applications (for example, ICMP packets) over datagrams from other applications



IPv6 base header

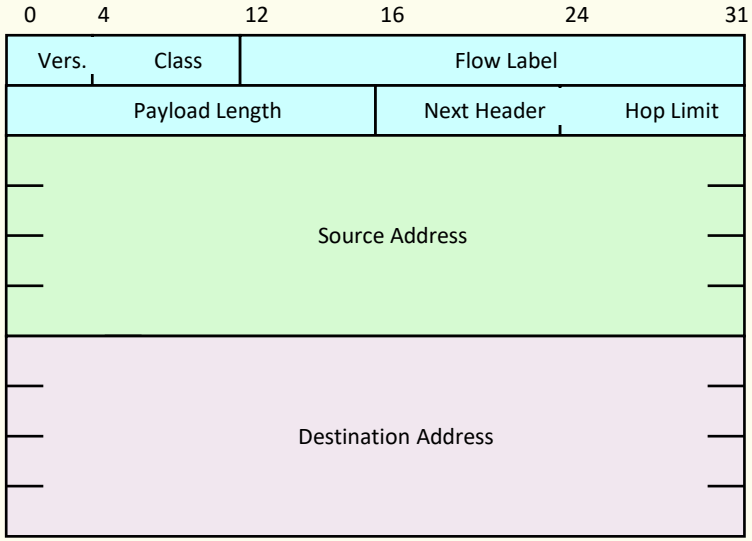
- Flow label (20 bits)
  - randomly generated
  - distinguishes packets that require the same treat-ment in order to facilitate the handling of real-time traffic





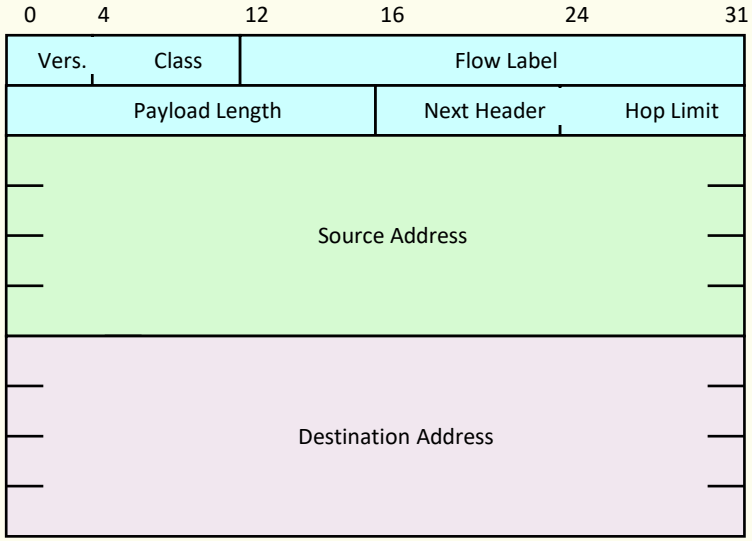
IPv6 base header

- Payload length (2 bytes)
  - Does not include the header length (as in IPv4)
  - Extension headers are considered part of the payload
- Hop limit (1 byte)
  - Analogous to TTL field in IPv4, but no more expressed in seconds



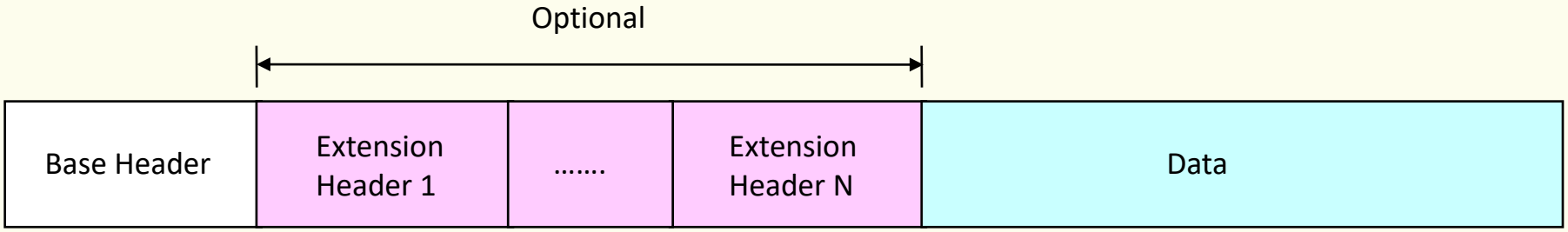
IPv6 base header

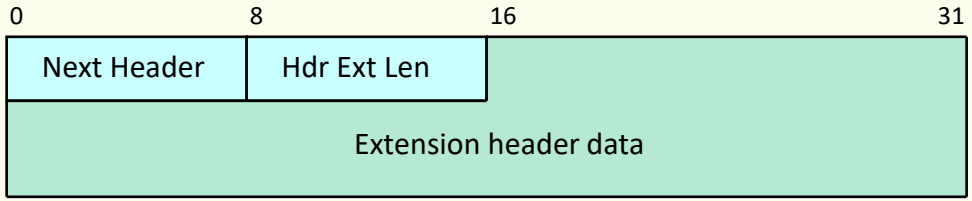
- Next header (1 byte)
  - Resembles the Protocol Type in IPv4, but …
  - It is much more, reflecting the new organization of IPv6 packets



IPv6 header structure

- One base header (40 bytes), plus
- Zero or more extension headers (variable size)
- Daisy chain organization





IPv6 header structure

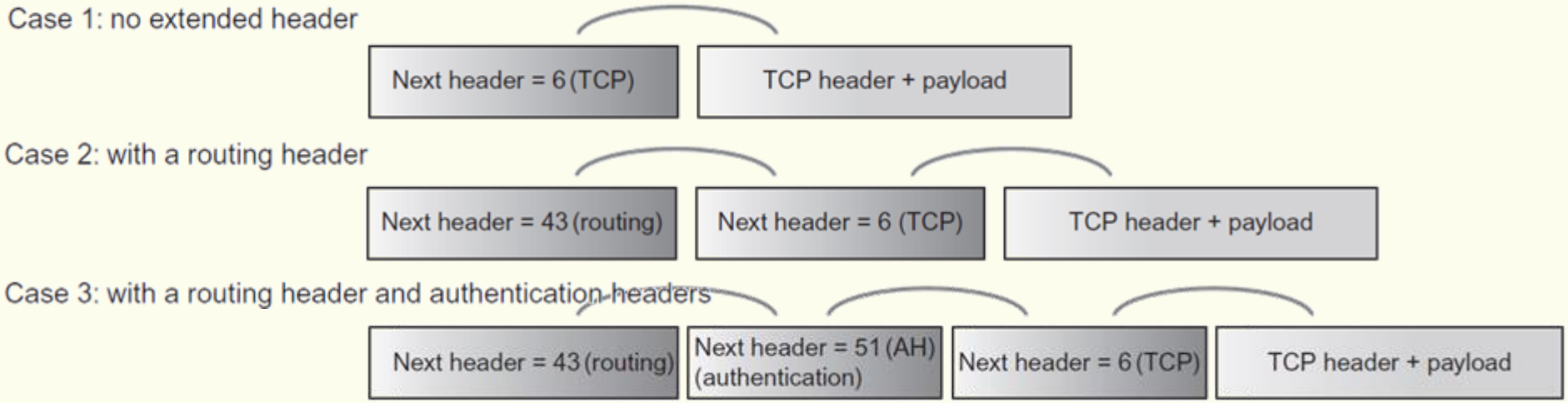
- Values in the Next Header field (base and extension headers)

Values	Meaning
0	Hop-by-Hop Options header
4	IPv4
6	Transmission Control Protocol
17	User Datagram Protocol
41	IPv6
43	Routing header
44	Fragment header
46	Resource Reservation Protocol
50	Encapsulating Security Payload header
51	Authentication header
58	Internet Control Message Protocol v6
59	No Next header
60	Destination Options header
135	Mobility Header (Mobile IPv6)
…	…

IPv6 extension headers

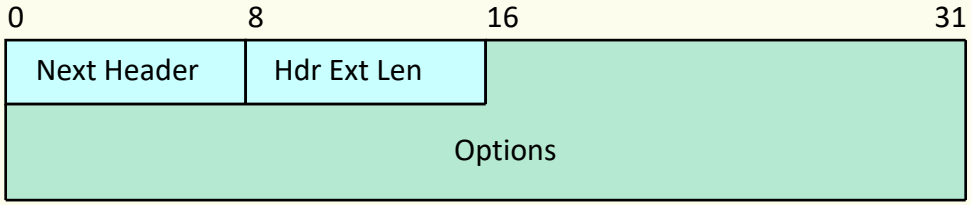
- Inserted only when needed
- Processed in the order they appear by the node identified by the DA (with one exception)
  - A specific order *is recommended*
- Open to further extensions

Value	Extension Header
0	Hop-by-Hop Options Header
43	Routing Header
44	Fragment Header
50	ESP Header
51	Authentication Header
59	No Next Header
60	Destination Options Header



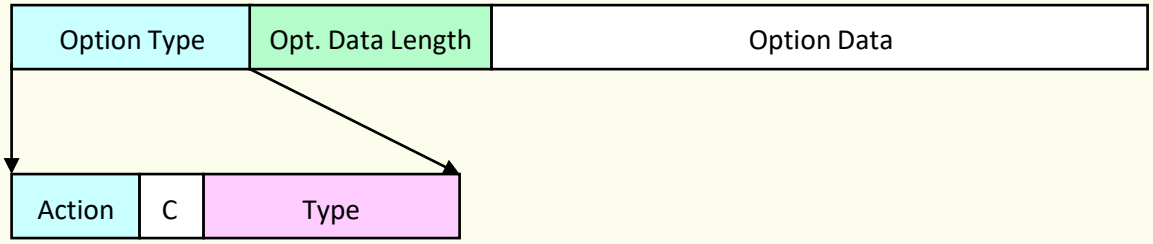
Hop-by-Hop Options header

- Carries optional information that must be examined by every node along the path
- Format
  - Next header (1 byte)
  - Header Extension Length (1 byte)
    - Header length in eight-byte units (minus one)
  - Options
    - One or more



Hop-by-Hop Options header

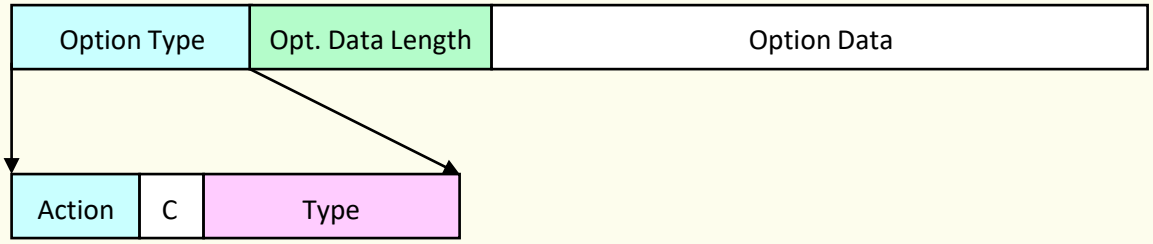
- Options field format (Tag-Length-Value)



  - Action (2 bits): what to do if the option is not recognized
    - 00: Skip and continue processing
    - 01: Discard the packet
    - 10: Discard the packet and send an ICMP Parameter Problem message to the packet's Source address
    - 11: Discard the packet and send ICMP Parameter Problem message to the packet's Source address only if the destination is not a multicast address

Hop-by-Hop Options header

- Options field format (Tag-Length-Value)



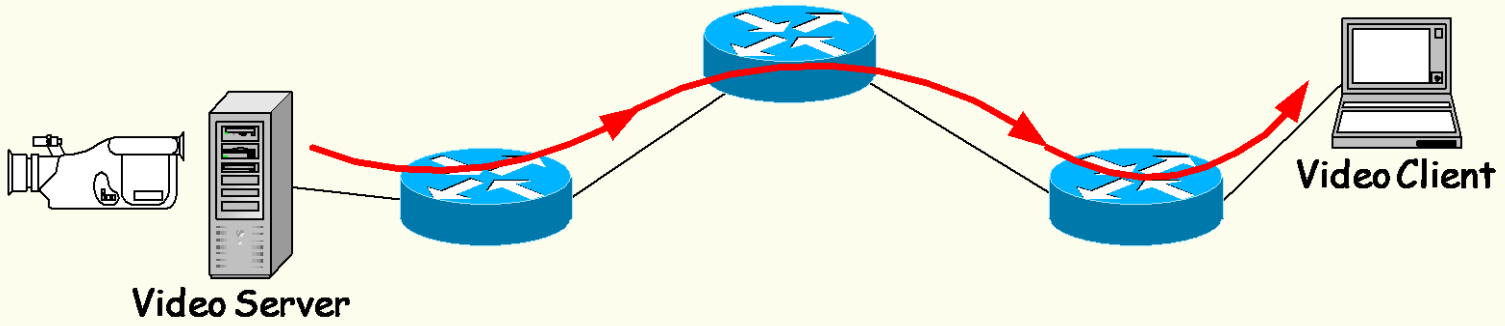
  - C (1 bit)
    - 1: the option information can change en route
    - 0: the option information does not change en route
  - Type
    - Jumbo Payload
    - Router Alert

Hop-by-Hop Options header

- Jumbo Payload (Type=194)
  - Used to send very large packets whose length cannot be encoded on 16 bits only (>64KB)
    - when used, the IPv6 payload length field is set to zero
  - Packet length encoded with 32-bits
    - supports the transmission of packets that are between 65,536 and 4,294,967,295 bytes (4GB)
- Compromise between the initial design of IPv6 and special networking requirements

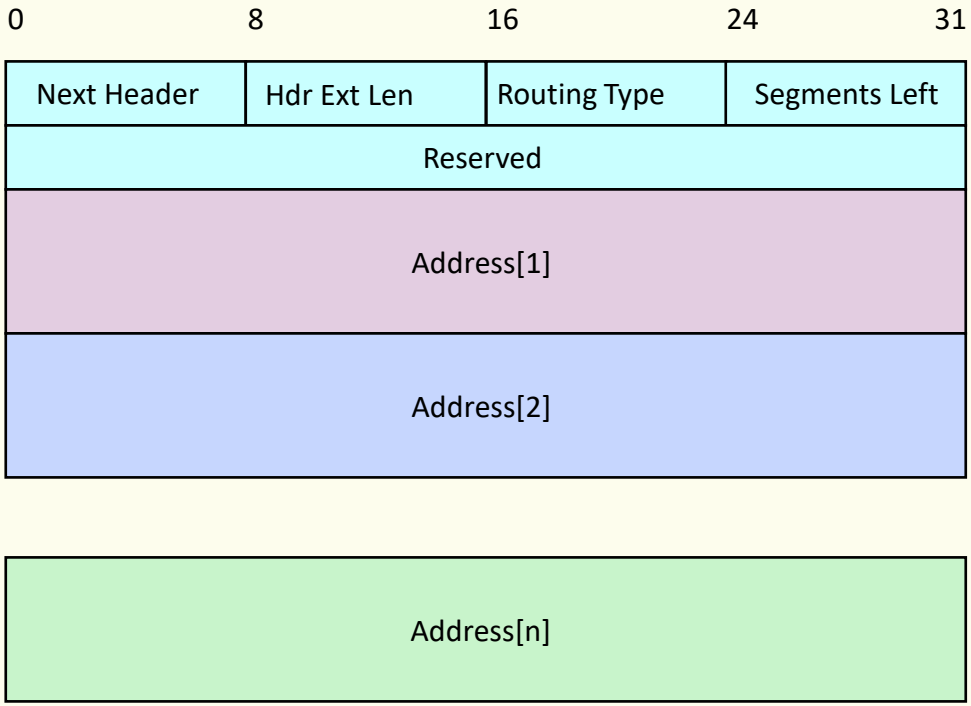
Hop-by-Hop Options header

- Router Alert (Type=5)
  - indicates to a router on the forwarding path that the packet contains important information to be processed by the router
  - Example: RSVP uses control packets containing information that needs to be interpreted or updated by routers along the path



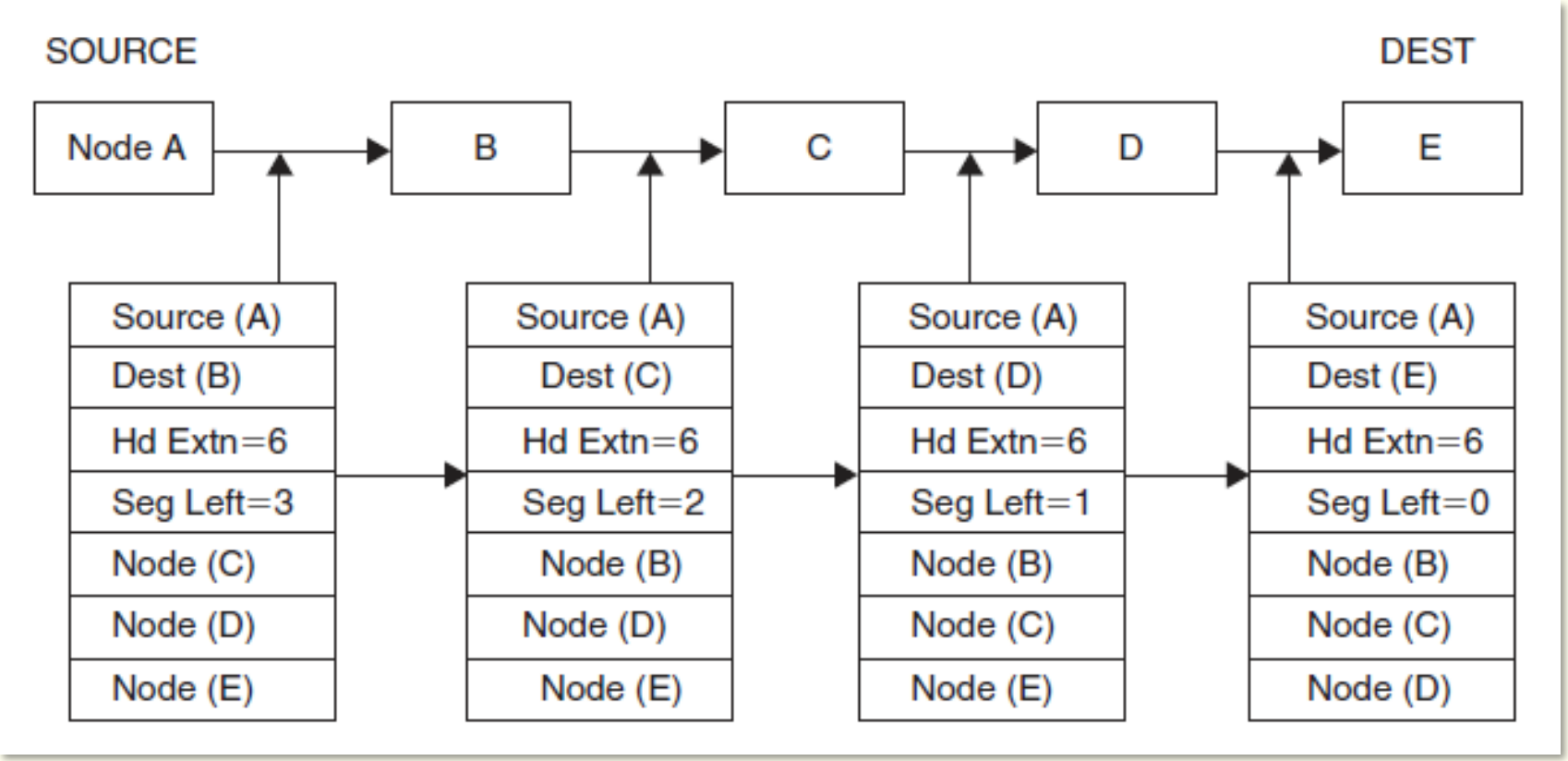
Routing header

- Gives a list of intermediate nodes to be visited on the path to the destination
  - Routing Type
    - **0: default**
    - 2: Mobile IPv6
    - 3: RPL
  - Segments Left
    - Nodes left to be visited
  - Address (RT=0)



Routing header

- Example

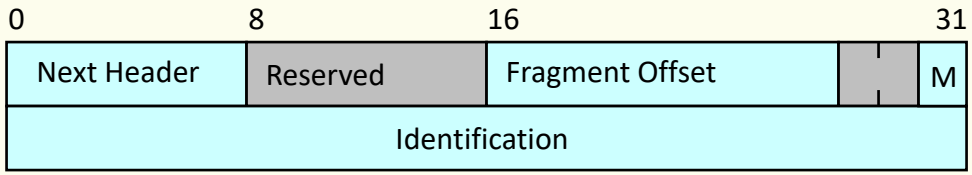


Fragment header

- Unlike IPv4, routers do not fragment IPv6 packets
  - Fragmentation occurs only at the source host sending the packet
  - The destination host only handles reassembly
  - IPv6 packets larger than the MTU of the forwarding link are discarded by the router
- IPv6 hosts use a Path MTU discovery procedure
- The IPv6 minimum MTU size is 1280 bytes!!!

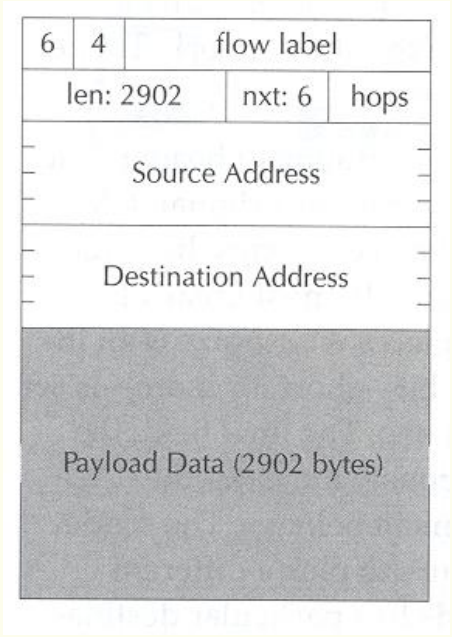
Fragment header

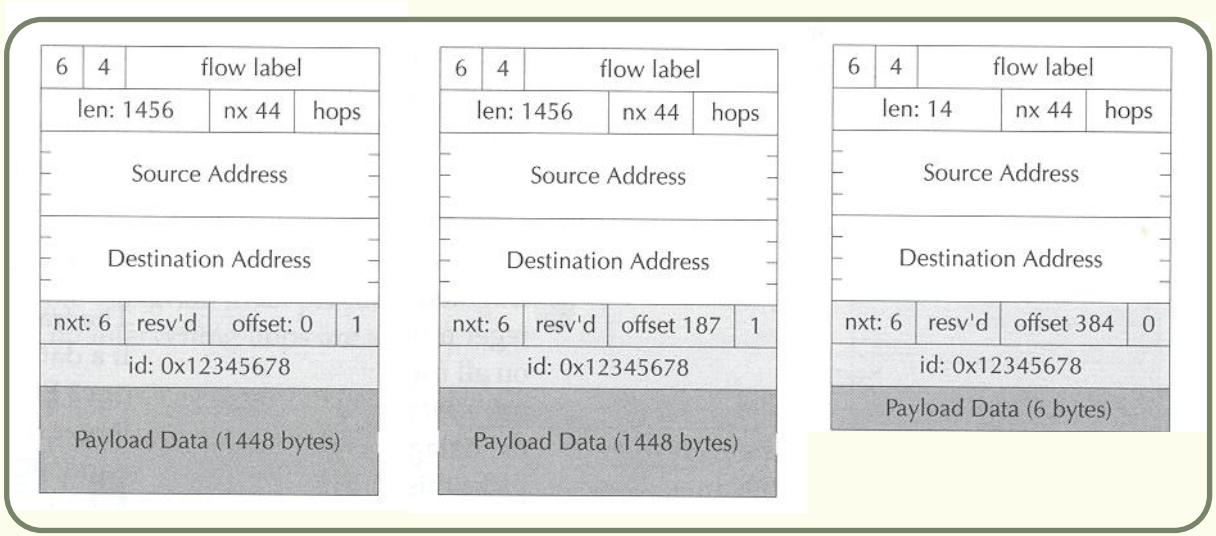
- Fragment Offset (13 bits)
  - The offset in 8-byte units of the data in this packet relative to the start of the data in the original packet
- M-Flag (1 bit)
  - 1: more fragments
  - 0: last fragment
- Identification (4 bytes)
  - Generated by the source host in order to identify all packets belonging to the original packet



Fragment header

- Example
  - One packet fragmented into three fragments

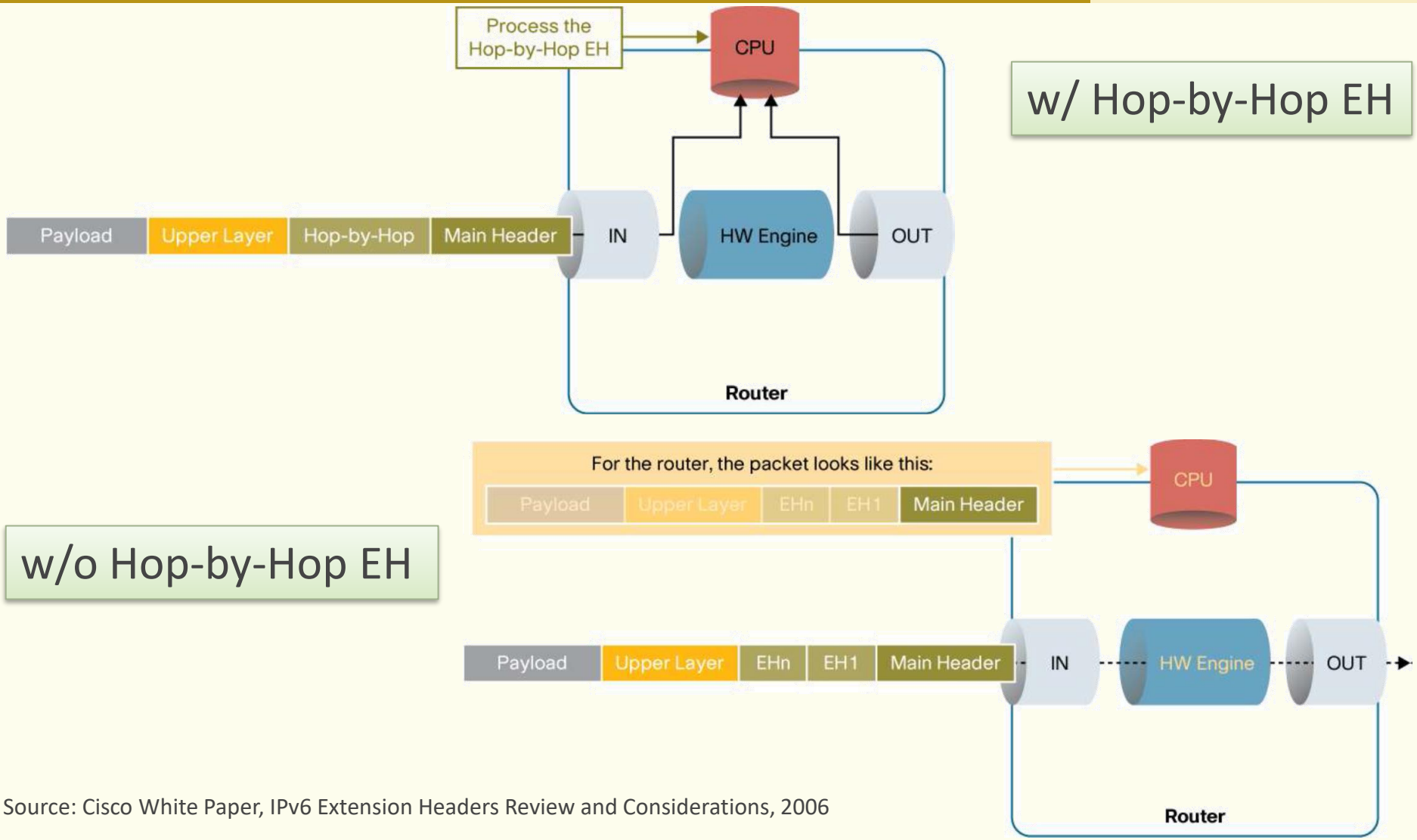




Other extension headers

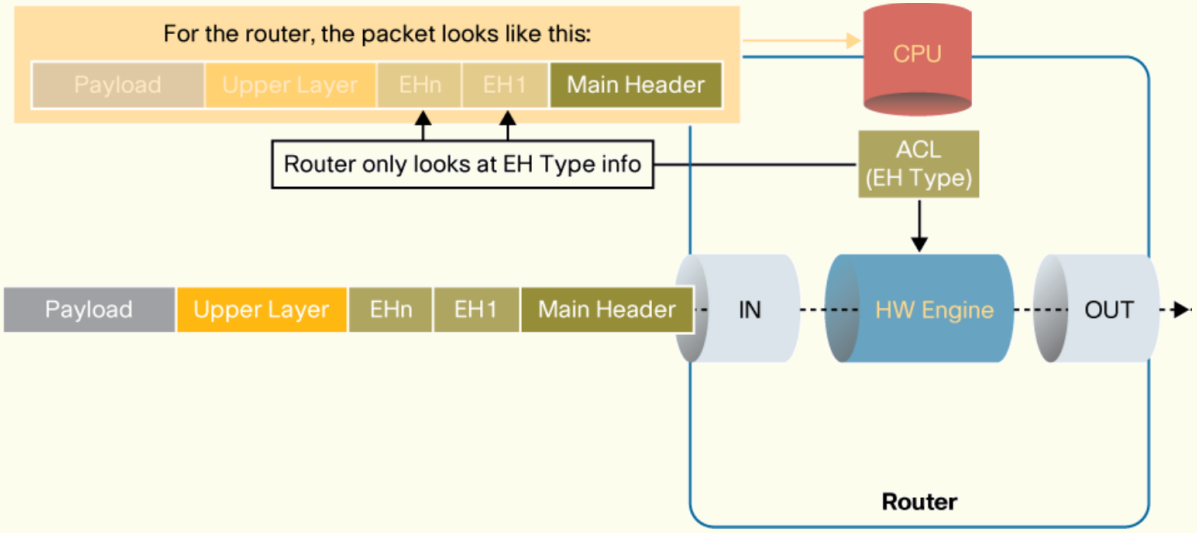
- Authentication Header
- Encapsulating Payload Security Header
  - IPv6 security support (IPsec)
- No Next Header
  - No payload
- Destination Options Header
  - Same as Hop-by-Hop, but options to be processed only at the destination
  - Used by Mobile IPv6

IPv6 EH processing



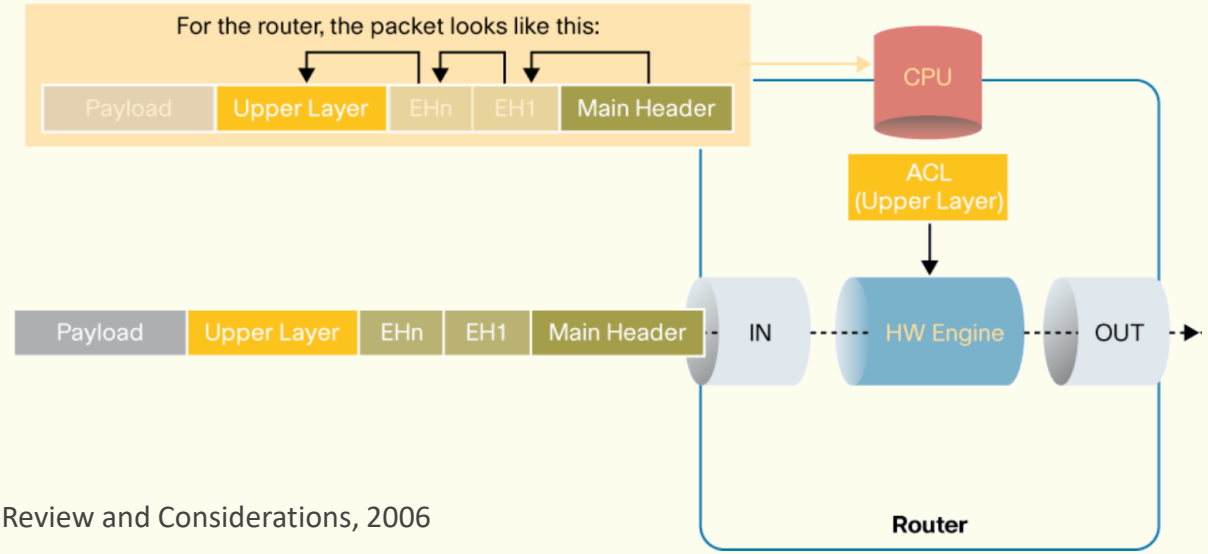
Source: Cisco White Paper, IPv6 Extension Headers Review and Considerations, 2006

IPv6 EH processing



w/ ACL involving EH type filtering

w/ ACL involving upper layers



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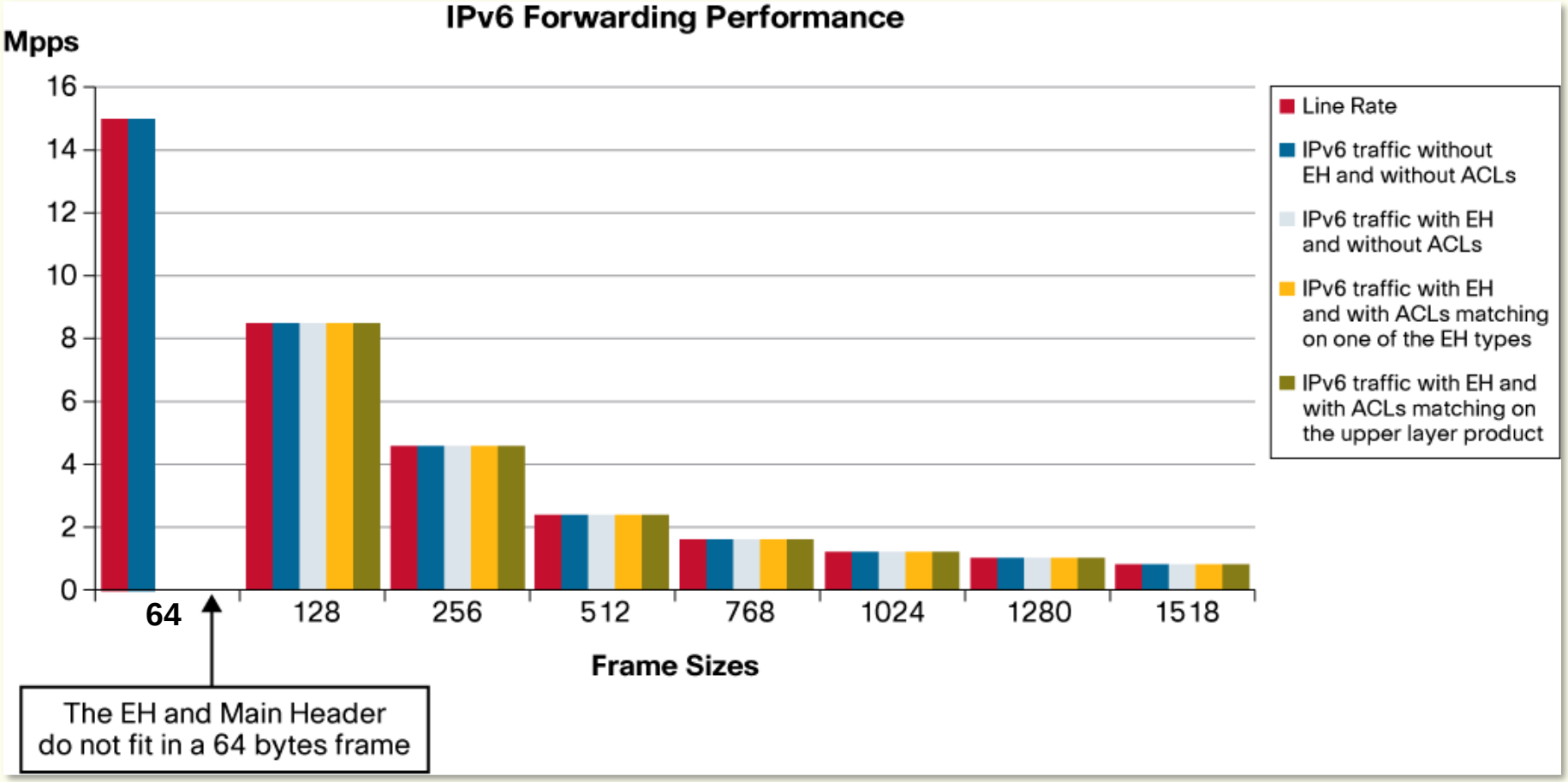
IPv6 EH processing



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References

- S. Hagen. **IPv6 essentials**. 3/ed. O'Reilly, 2014

- RFC 8200, “Internet Protocol, Version 6 (IPv6) Specification,” 2017
- RFC 2675, “IPv6 Jumbograms,” 1999
- RFC 2711, “IPv6 Router Alert Option,” 1999