IPv6 Protocol Architecture

APNIC

New Functional Improvement

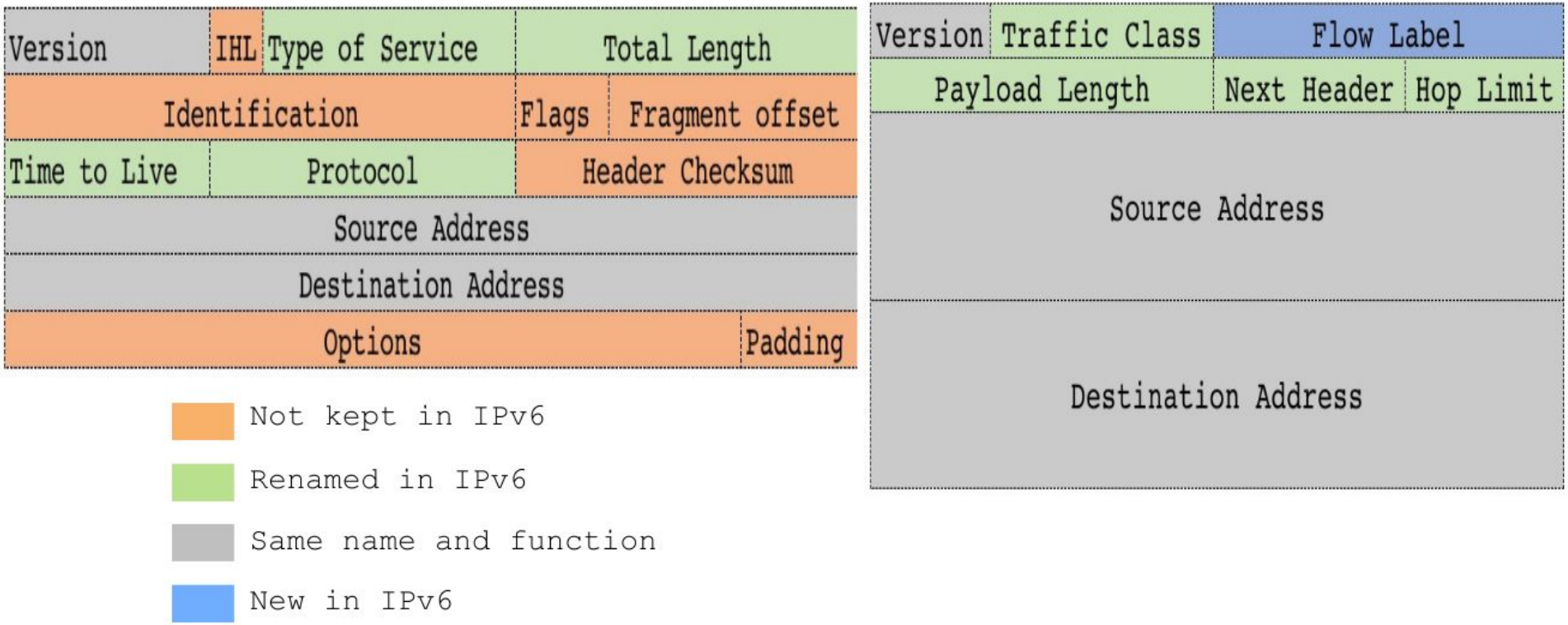
- Address Space
  - Increase from 32-bit to 128-bit address space

- Management
  - StateLessAddress AutoConfiguration(SLAAC) means no more need to configure IP addresses for end systems, even via DHCP

- Performance
  - Simplified header means efficient packet processing
  - No header checksum re-calculation at every hop (when TTL is decremented) => left up to the lower and upper layers!

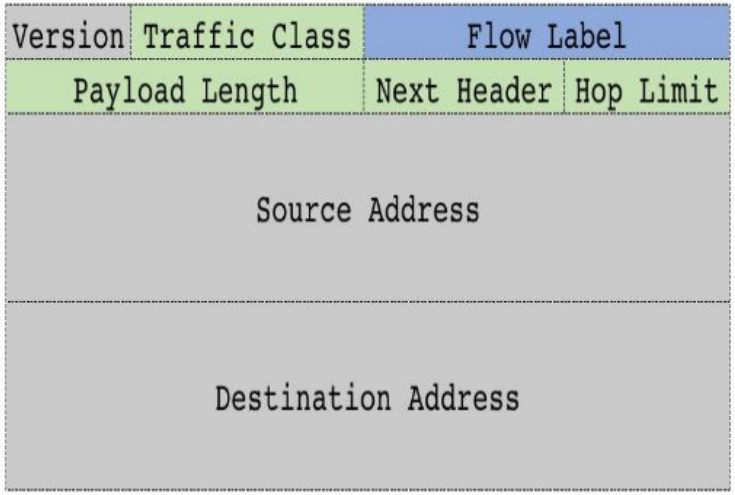
- No hop-by-hop fragmentation -PMTUD

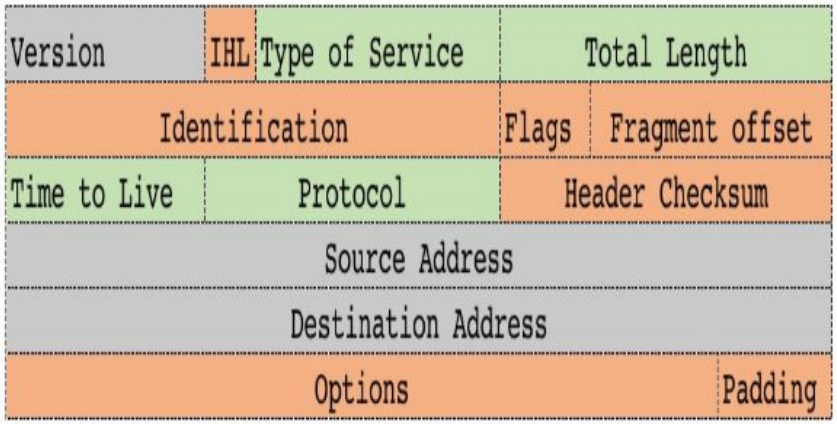
IPv4/IPv6 Header Comparison



IPv6 Protocol Header Format

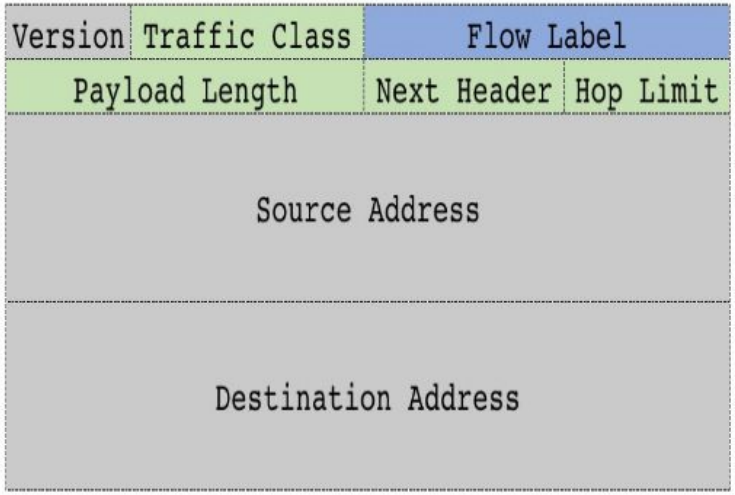
- Version (4-bit):
  - 4-bit IP version number (6)
- Traffic class (8-bit):
  - Similar to DiffServin IPv4; define different classes or priorities.
- Flow label (20-bit):
  - allows IPv6 packets to be identified based on flows (multilayer switching techniques and faster packet-switching performance)



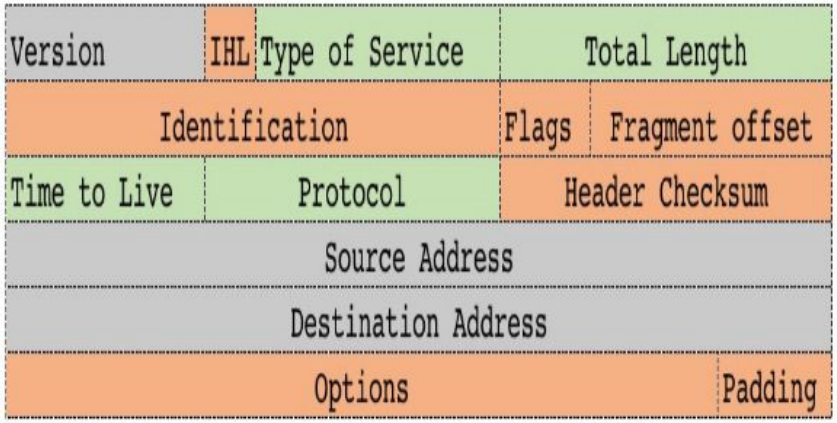


IPv6 Protocol Header Format

- Payload length (16-bit):
  - Defines the length of the IPv6 payload (including extension headers); Total Length in IPv4 includes the header.



- Next header (8-bit):
  - Identifies the type of information following IPv6 header. Could be upper layer (TCP/UDP), or an extension header (similar to Protocol field in IPv4).
- Hop limit (8-bit):
  - Similar to TTL in IPv4



IPv6 & IPv4 Packet Example

- ExampleIPv6 packeton this link:

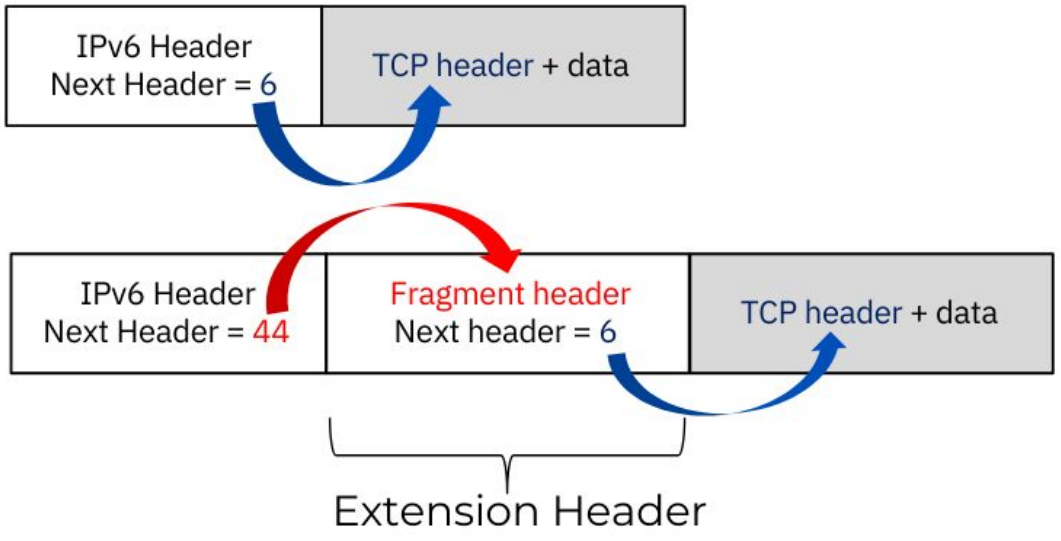
- https://www.cloudshark.org/captures/84fd54ad03e0

- ExampleIPv4 packeton this link:

- https://www.cloudshark.org/captures/09f49cda5b80

IPv6 Extension Header

- IPv6 allows an optional *Extension Header* in between the IPv6 header and upper layer header
  - Allows adding new features to IPv6 protocol without major re-engineering



Next Header values:

0 Hop-by-hop option
6 TCP
17 UDP
43 Source routing (RFC5095)
44 Fragmentation
50 Encrypted security payload 51 Authentication
58 ICMPv6
59 Null (No next header)
60 Destination option

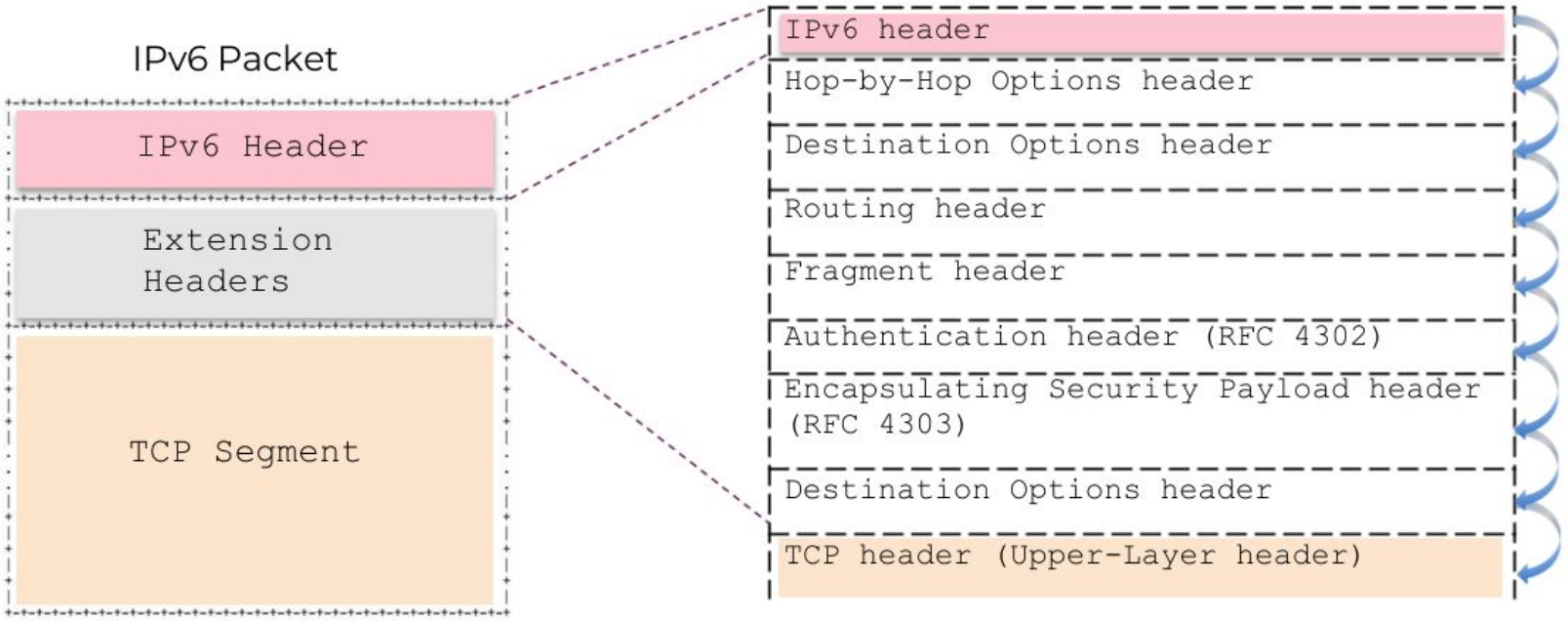
IPv6 Extension Header (contd)

- An IPv6 packet may carry none or many extension headers
  - A next header value of 6 or 17 (TCP/UDP) indicates there is no extension header
    - the next header field points to TCP/UDP header, which is the payload

- Unless the next header value is 0 (*Hop-by-Hop option*), extension headers are processed only by the destination node, specified by the destination address.

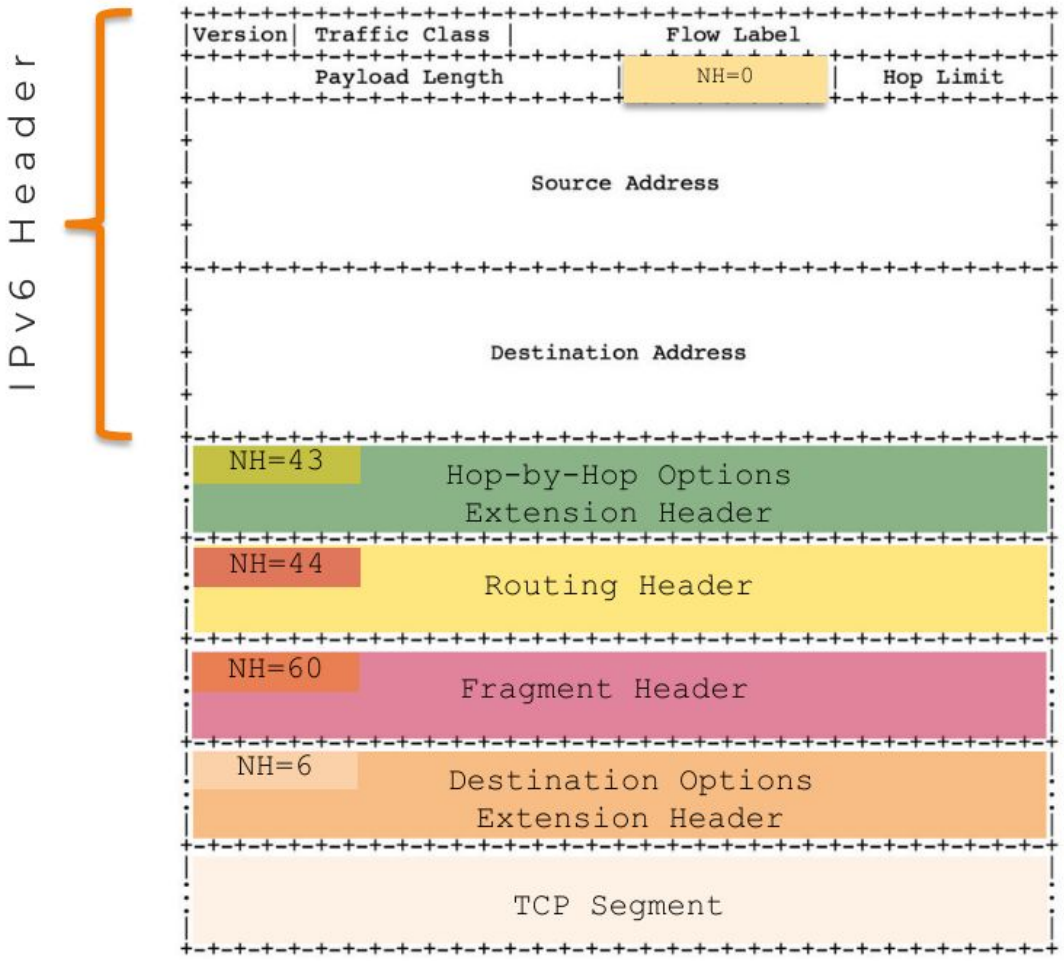
Extension Header Order

•When more than one extension header is used in the same packet, it is recommended that those headers appear in the following order in RFC 8200:



Chaining Extension Headers

Extension Header	Type
Hop-by-Hop Options	0
Fragment	44
Destination Options	60
Routing	43
Authentication	51
Encapsulating Security Payload	50



Extension Header Example

- ExampleIPv6 packet with an Extension Headeron this link:

- https://www.cloudshark.org/captures/7dd0b50eb768

Fragmentation Handling In IPv6

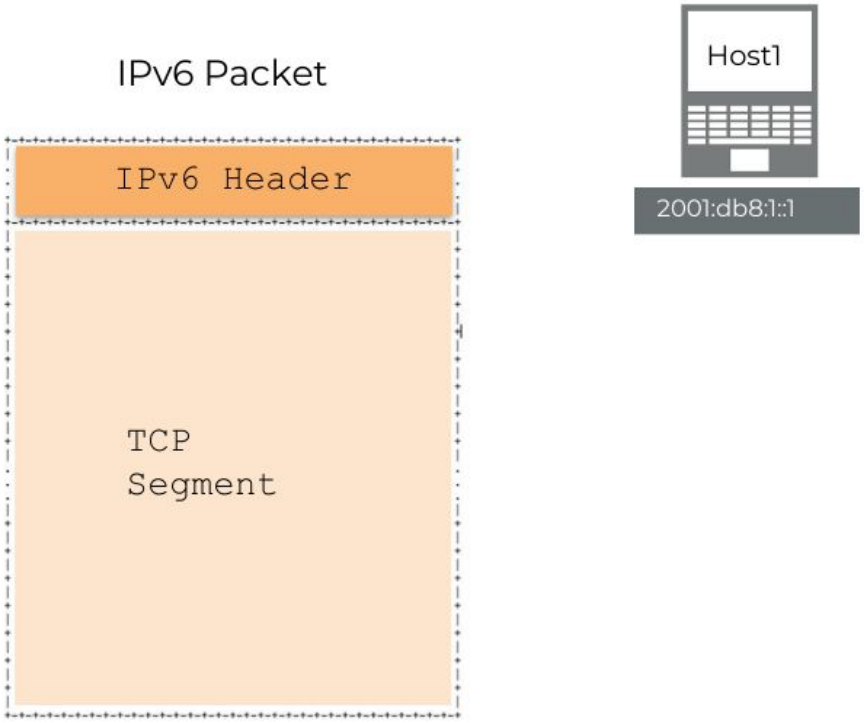
- In IPv6, fragmentation is only performed by the host/source nodes, and not the routers along the path (unlike IPv4)

- Each source device tracks the MTU size for each session

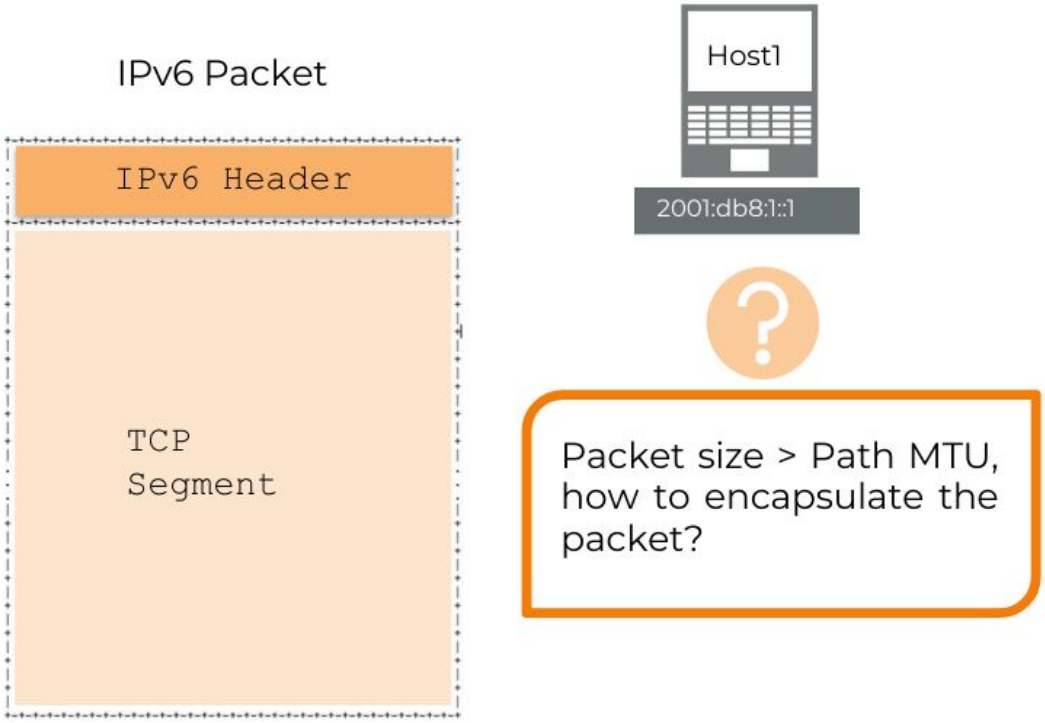
- When a IPv6 host has large amount of data to be sent, it will be send in a series of IPv6 packets (fragmented)
  - IPv6 hosts use Path MTU Discovery (PMTUD) to determine the most optimum MTU size along the path

Example of Fragment Header

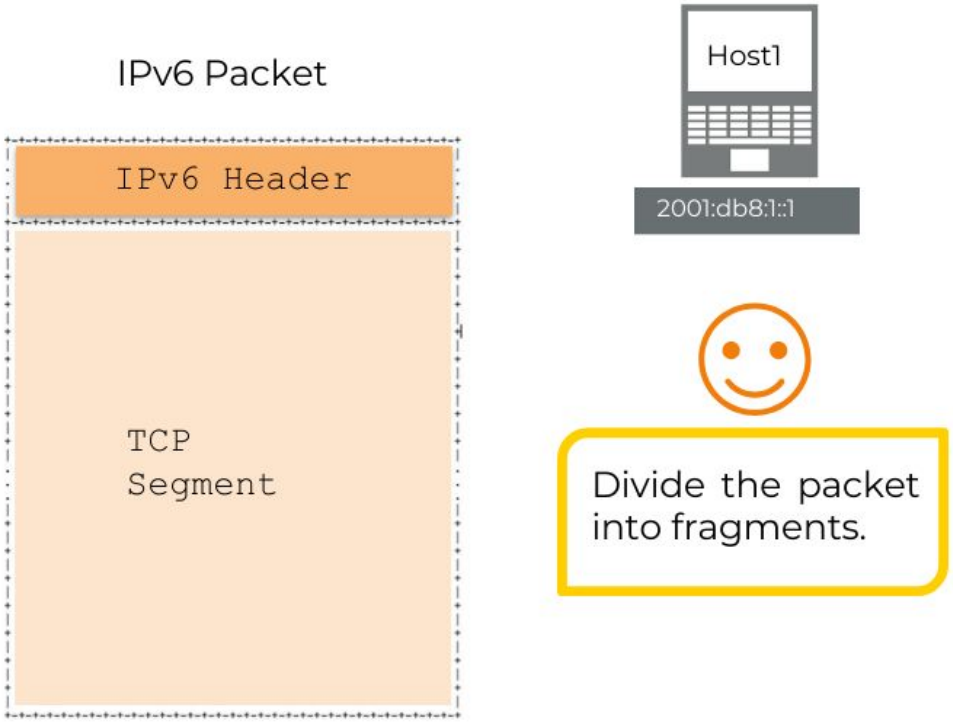
On the Source Node (Host1)



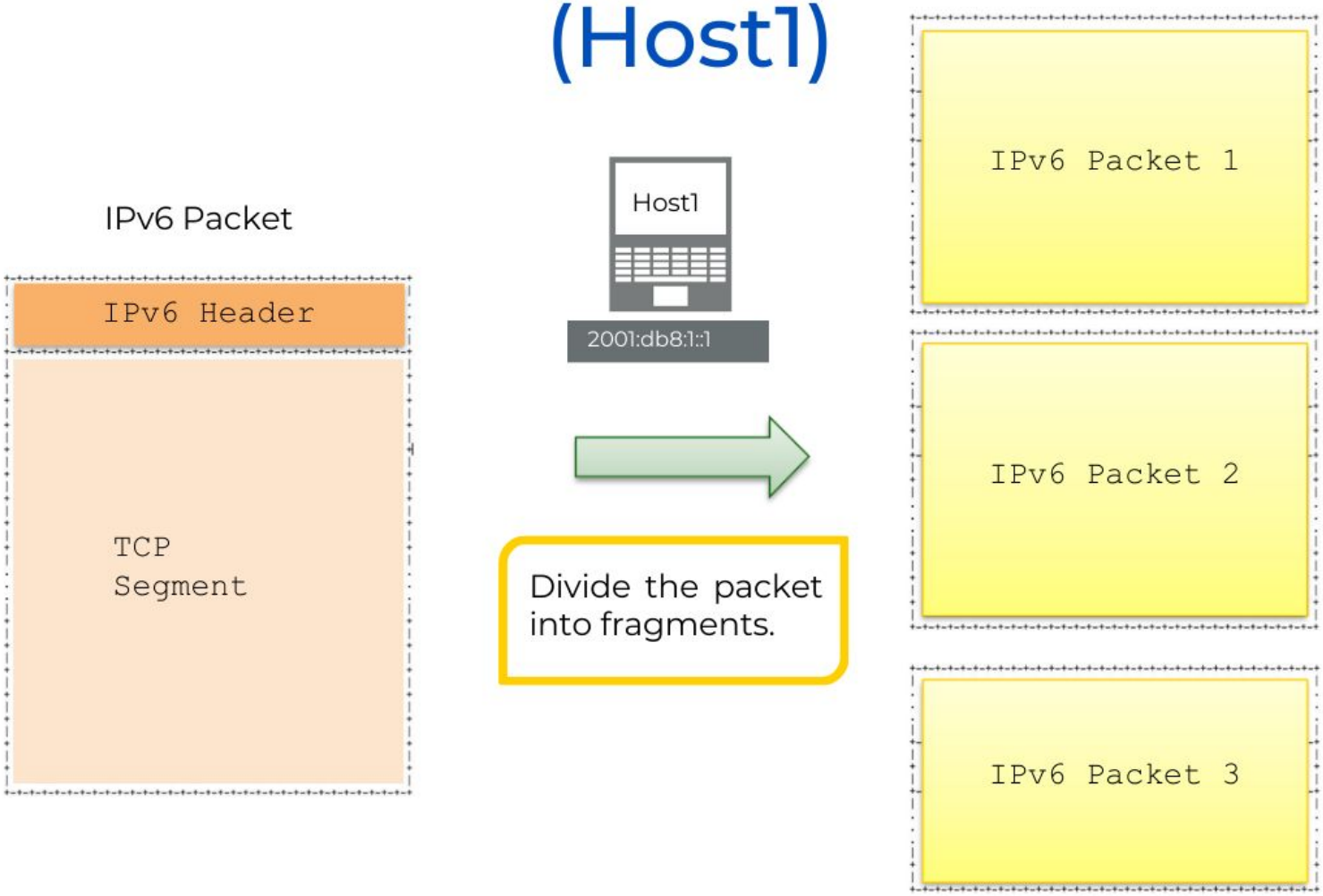
On the Source Node (Host1)



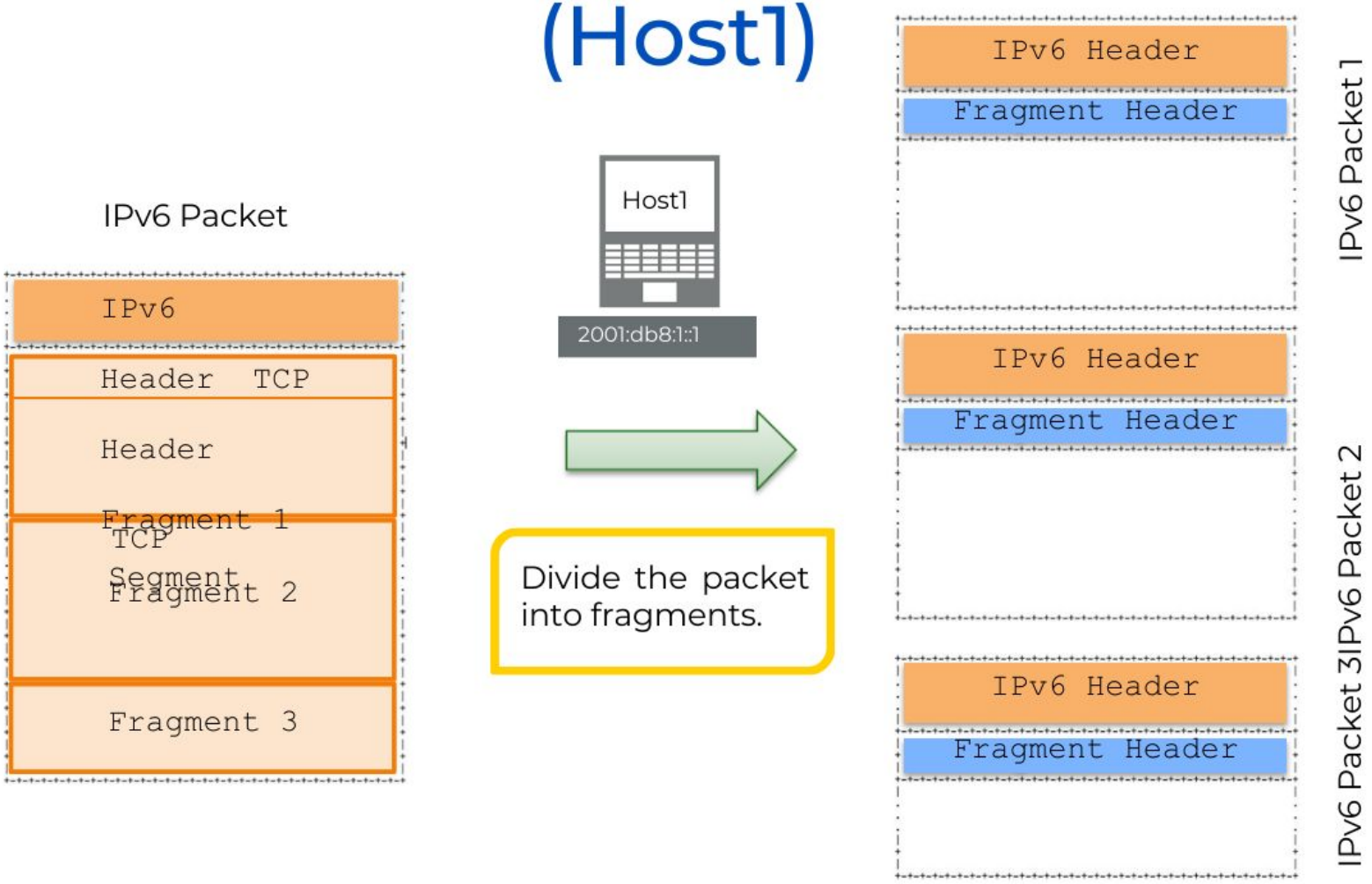
On the Source Node (Host1)



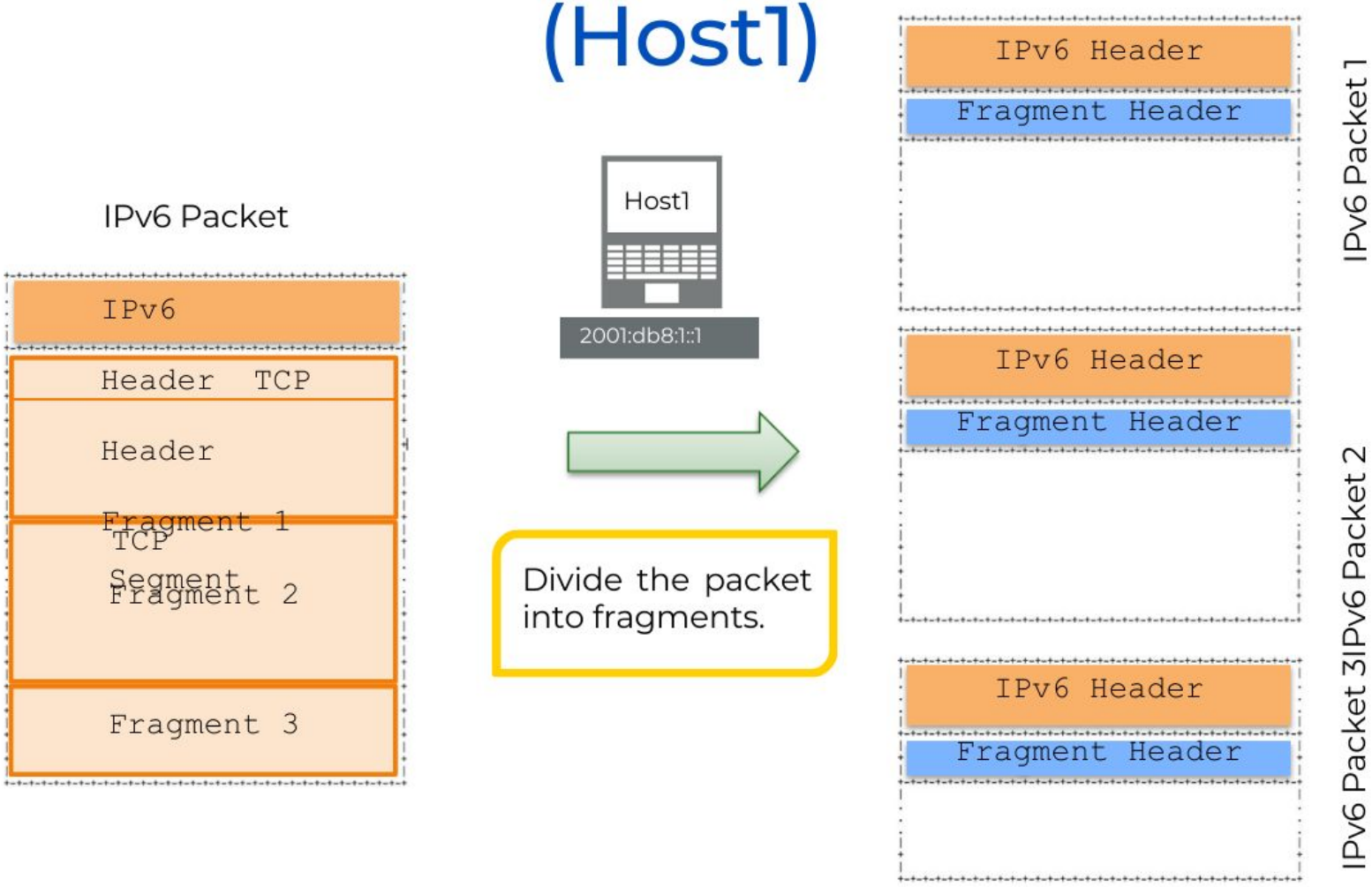
Onthe Source Node (Host1)



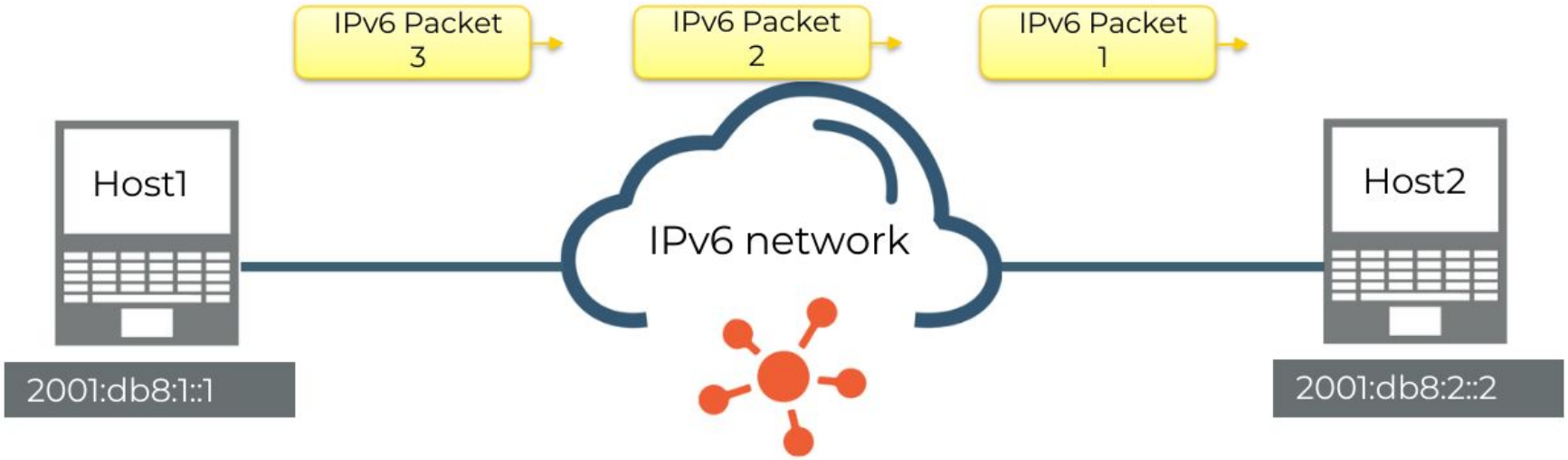
On the Source Node (Host1)



On the Source Node (Host1)

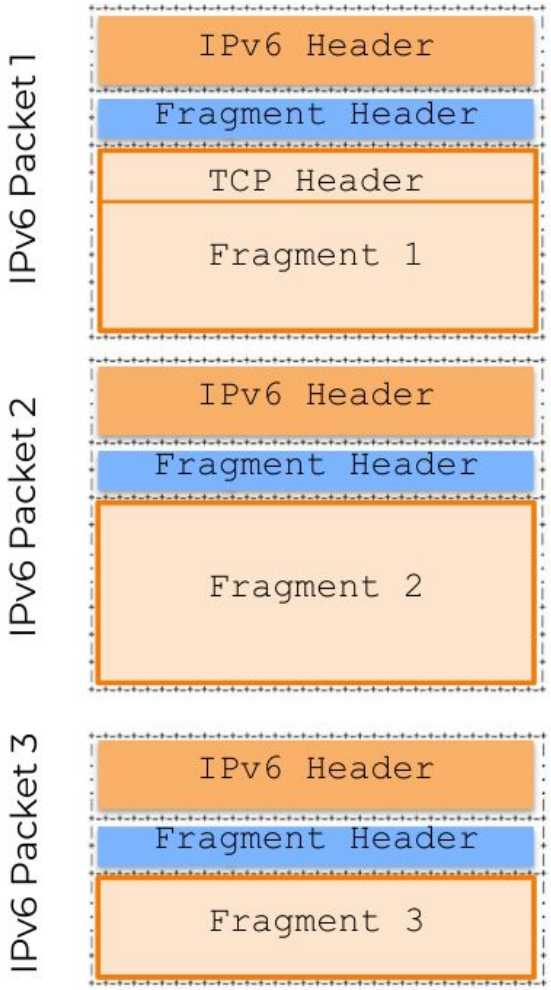


Example of Fragment Header

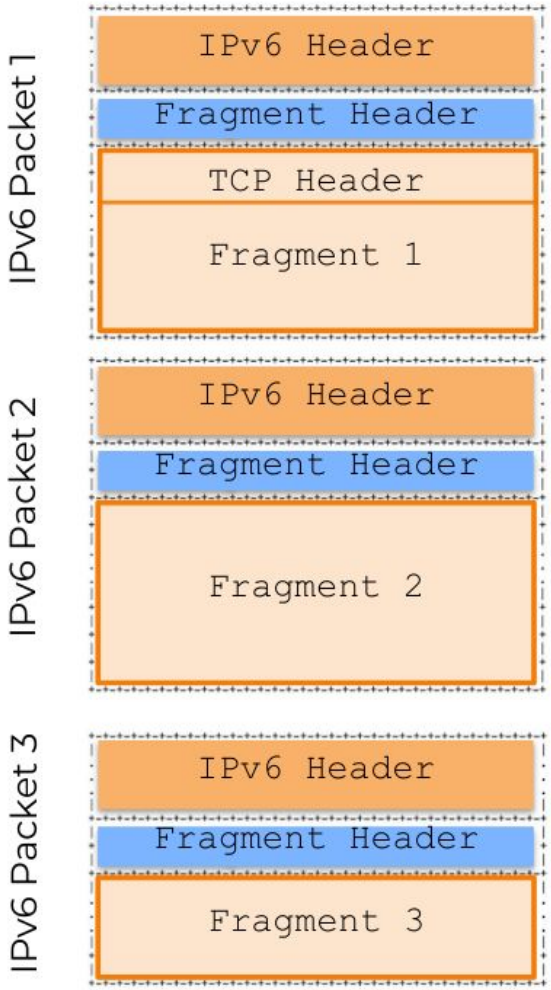


The 3 fragmented packets are transmitted on the path, reach the destination Host2, without any other fragmentation on the path.

On the Destination Node (Host2)

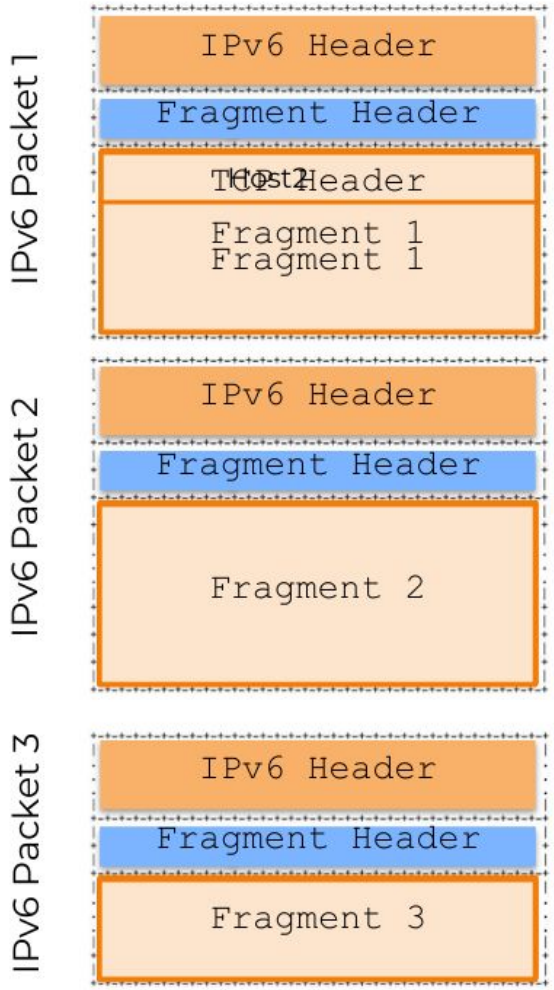


On the Destination Node (Host2)



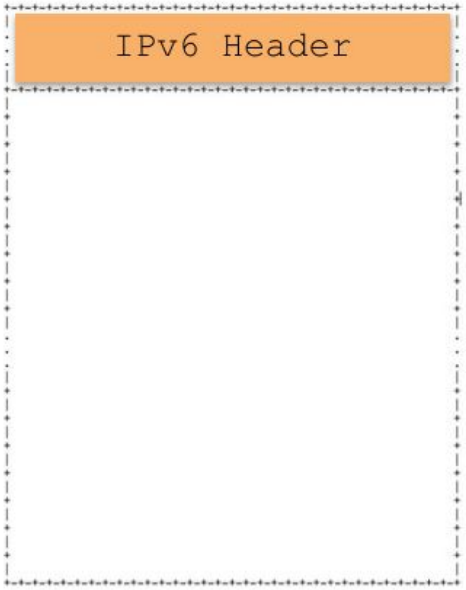
Reassemble the fragments to be the original packet.

On the Destination Node (Host2)



Reassemble the fragments to be the original packet.

IPv6 Packet

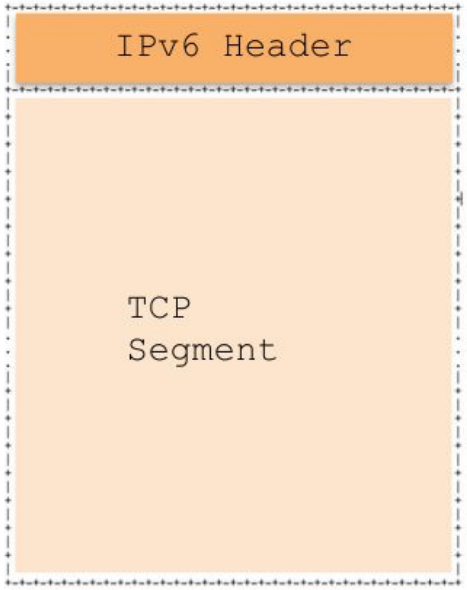


On the Destination Node (Host2)

Host2

Reassemble the fragments to be the original packet.

IPv6 Packet



Path MTU Discovery

- With PMTUD, the source IPv6 device assumes the initial PMTU is the MTU of the first hop in the path

– upper layers (Transport/Application) send packets based on the first hop MTU

–If the device receives an "*ICMPv6 packet too big (Type 2)*" message, it informs the upper layer to reduce its packet size, based on the actual MTU size (contained in the message) of the node that dropped the packet

Path MTU Discovery

Link MTU values are marked on each link.

I have a packet with size 2000 bytes to send to Host2. It is larger than MTU, I have to fragment it.

Host1 :
MTU cache=1500

Path MTU Discovery

Host1 :
MTU cache= 1500

Link MTU values are marked on each link.

Packet 1
size=1500bytes

Path MTU Discovery

Host1 :
MTU cache= 1500

Link MTU values are marked on each link.

Packet 1
size=1500bytes

```
▷ Frame 1: 1510 bytes on wire (12080 bits), 1510 bytes captured (12080 bits)
▷ Ethernet II, Src: Vmware_23:16:87 (00:0c:29:23:16:87), Dst: Vmware_25:cf:a1 (00:0c:29:25:cf:a1)
▽ Internet Protocol Version 6, Src: 2001:db8:1::1, Dst: 2001:db8:2::2
     0110 .... = Version: 6
   ▷ .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
     .... .... .... 1010 1000 1001 1111 1000 = Flow Label: 0xa89f8
     Payload Length: 1456
     Next Header: Fragment Header for IPv6 (44)
     Hop Limit: 64
     Source: 2001:db8:1::1
     Destination: 2001:db8:2::2
   ▷ Fragment Header for IPv6
▷ [data]
```

Captured packets are available:
https://www.cloudshark.org/captures/7dd0b50eb768

Path MTU Discovery

Link MTU values are marked on each link.

Path MTU Discovery

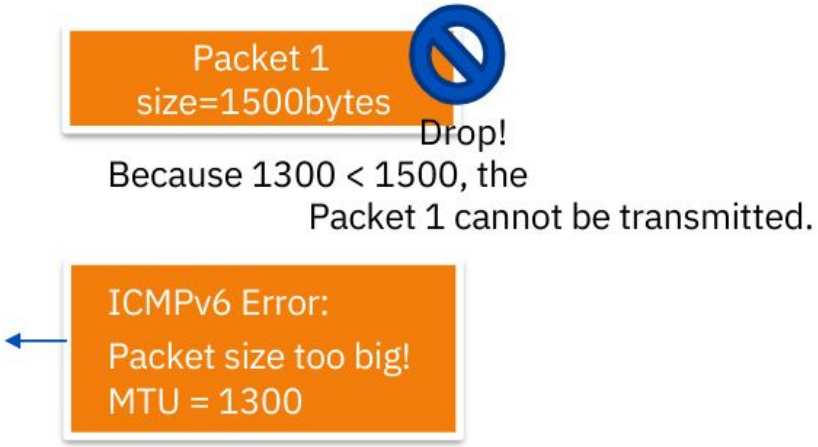
Link MTU values are marked on each link.

Packet 1
size=1500bytes

Because 1300 < 1500, the packet 1 cannot be transmitted.

Path MTU Discovery

Link MTU values are marked on each link.



Path MTU Discovery

Link MTU values are marked on each link.

Packet 1
size=1500bytes
Drop!

Because 1300 < 1500, the packet 1 cannot be transmitted.

ICMP Error:
Packet size too big!
MTU = 1300

Host1 Update :
MTU cache= 1300

Path MTU Discovery

Link MTU values are marked on each link.

```
▷ Frame 3: 1294 bytes on wire (10352 bits), 1294 bytes captured (10352 bits)
▷ Ethernet II, Src: Vmware_25:cf:a1 (00:0c:29:25:cf:a1), Dst: Vmware_23:16:87 (00:0c:29:23:16:87)
▷ Internet Protocol Version 6, Src: 2001:db8:12::2, Dst: 2001:db8:1::1
▽ Internet Control Message Protocol v6
    Type: Packet Too Big (2)
    Code: 0
    Checksum: 0x2e57 [correct]
    Checksum Status: Good
    MTU: 1300
  ▷ Internet Protocol Version 6, Src: 2001:db8:1::1, Dst: 2001:db8:2::2
  ▷ data
```

ICMPv6 Error:
Packet size too big!
MTU = 1300

D
Drroopp!!
B
Beeccaauussee 11330000 << 11550000,, tthhee ppaacckkeett
1
1 ccaannnnoott bbee ttrraannssmmiitttteedd..

Captured packets are available:
https://www.cloudshark.org/captures/7dd0b50eb768

Path MTU Discovery

Host1 :
MTU cache= 1300

Link MTU values are marked on each link.

Packet 2
size=1300bytes

Path MTU Discovery

Host1 :
MTU cache= 1300

Link MTU values are marked on each link.

Packet 2
size=1300bytes

```
▷ Frame 4: 1310 bytes on wire (10480 bits), 1310 bytes captured (10480 bits)
▷ Ethernet II, Src: Vmware_23:16:87 (00:0c:29:23:16:87), Dst: Vmware_25:cf:a1 (00:0c:29:25:cf:a1)
▽ Internet Protocol Version 6, Src: 2001:db8:1::1, Dst: 2001:db8:2::2
     0110 .... = Version: 6
   ▷ .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
     .... .... .... 1010 1000 1001 1111 1000 = Flow Label: 0xa89f8
     Payload Length: 1256
     Next Header: Fragment Header for IPv6 (44)
     Hop Limit: 64
     Source: 2001:db8:1::1
     Destination: 2001:db8:2::2
   ▷ Fragment Header for IPv6
▷ [data]
```

Path MTU Discovery

Host1 :
MTU cache=1300

Link MTU values are marked on each link.

Packet 2
size=1300bytes

Path MTU Discovery

Host1 :
MTU cache=1300

Link MTU values are marked on each link.

Packet 2
size=1300bytes

Path MTU Discovery

Host1 :
MTU cache=1300

Link MTU values are marked on each link.

Packet 2
size=1300bytes

Path MTU Discovery

Host1 :
MTU cache=1300

Link MTU values are marked on each link.

Packet 2
size=1300bytes

Path MTU = 1300


Questions