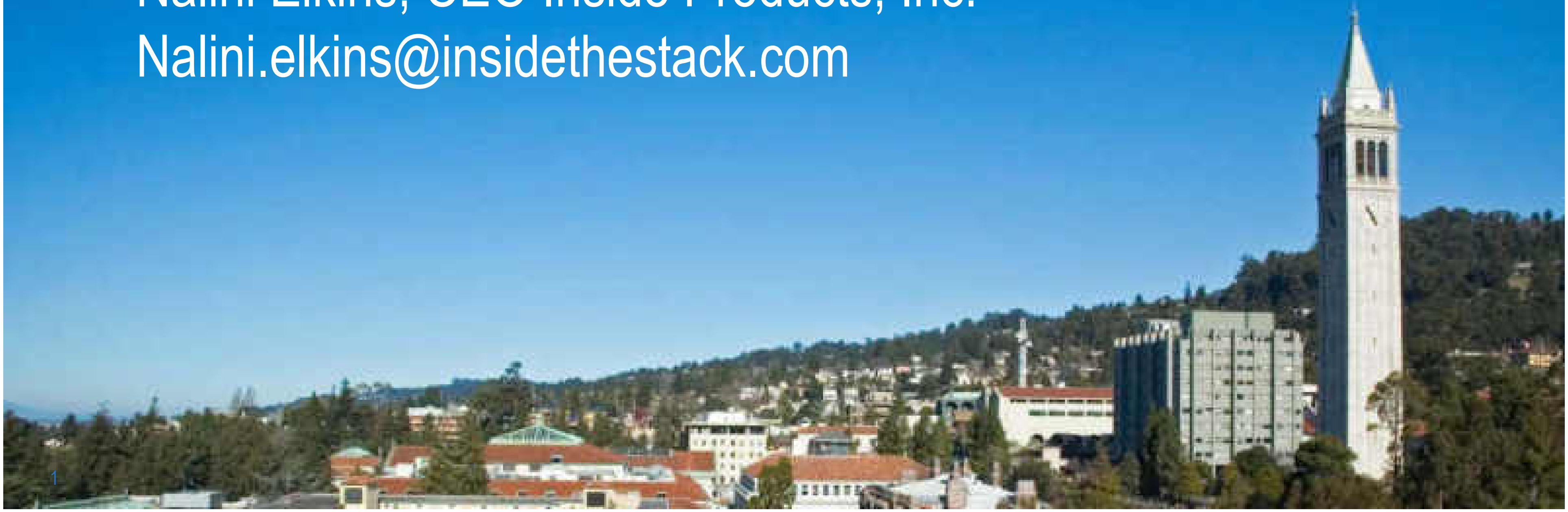
SHARKFEST '13

Wireshark Developer and User Conference

IPv6 Trace Analysis using Wireshark

Nalini Elkins, CEO Inside Products, Inc.
Nalini.elkins@insidethestack.com



Agenda

- What has not changed between IPv4 and IPv6 traces
- What has changed between IPv4 and IPv6 traces
- IPv6 extension headers
- Flow label
- Who sent it and who received it? (Global Unicast, Multicast, Link Local)
- Packets, packets, packets!
- Tunneling (Teredo, 6to4)
- DNSv6 / DHCPv6

What has not changed

- Packets trace the network flow
- Upper layer protocols (mostly)

What has changed

- The IP layer protocol (extensions, etc.)
- Address resolution
- Source and destination addresses (and meaning)
- ICMP
- Understanding of network analyst

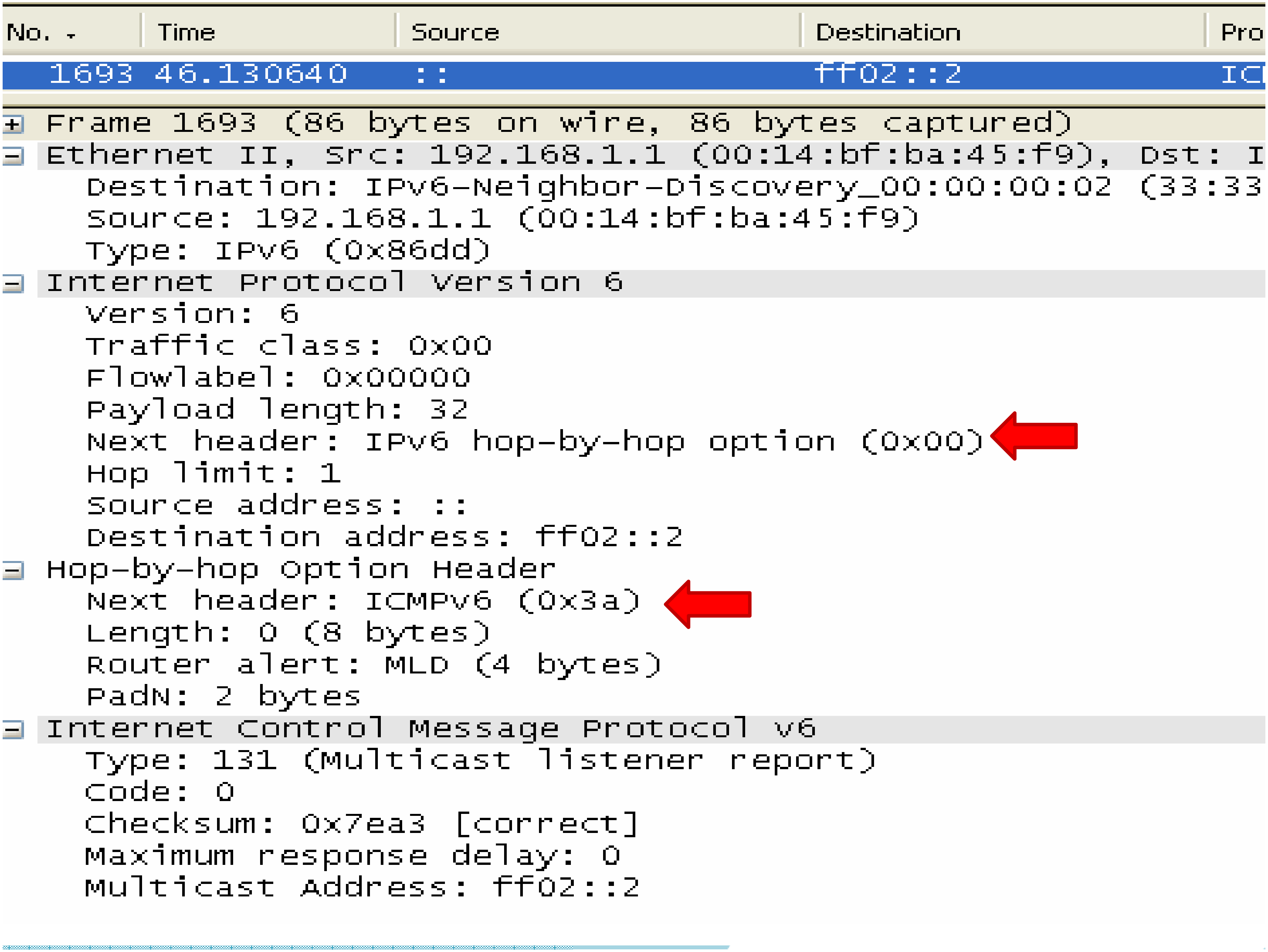
Common IPv6 Extension Headers

Next Header (Hex)	Next Header (Decimal)	Header Name	Description
0	0	Hop-by-Hop Options	For all devices on the path
2B	43	Routing	0 – Source Routing (deprecated) 2 – Mobile IPv6
2C	44	Fragment	Only when packet is fragmented
32	50	Encapsulated Security Payload (ESP)	IPSec encrypted data
33	51	Authentication Header (AH)	IPSec authentication
3C	60	Destination Options	http://www.iana.org/assignments/ipv6-parameters/ipv6-parameters.xml (Mobile IP, etc)

IPv6 Hop-by-Hop Header

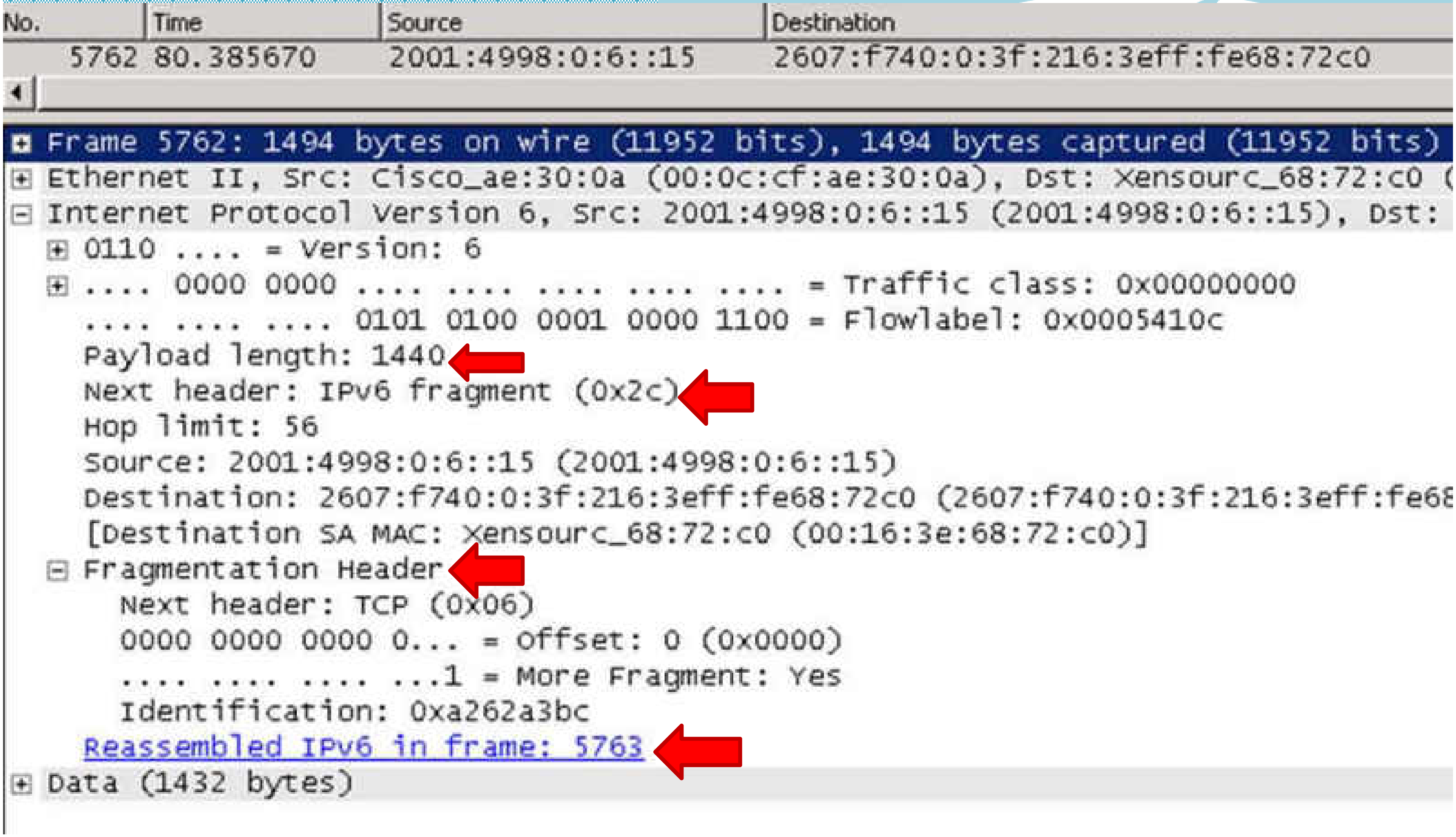
Size (bits)	Field Name	Description
8	Next Header	Contains the protocol number of the next header
8	Length	Length of this header in octets (bytes)
Variable	Options	8 bits for type, length in bytes, and then the option itself http://www.iana.org/assignments/ipv6-parameters/ipv6-parameters.xml

Remember: this has to be read by every device!



```
   1693 46.130640    ::                        ff02::2                   IC
⊞ Frame 1693 (86 bytes on wire, 86 bytes captured)
⊟ Ethernet II, Src: 192.168.1.1 (00:14:bf:ba:45:f9), Dst: I
    Destination: IPv6-Neighbor-Discovery_00:00:00:02 (33:33
    Source: 192.168.1.1 (00:14:bf:ba:45:f9)
    Type: IPv6 (0x86dd)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 32
    Next header: IPv6 hop-by-hop option (0x00)
    Hop limit: 1
    Source address: ::
    Destination address: ff02::2
⊟ Hop-by-hop Option Header
    Next header: ICMPv6 (0x3a)
    Length: 0 (8 bytes)
    Router alert: MLD (4 bytes)
    PadN: 2 bytes
⊟ Internet Control Message Protocol v6
    Type: 131 (Multicast listener report)
    Code: 0
    Checksum: 0x7ea3 [correct]
    Maximum response delay: 0
    Multicast Address: ff02::2
```

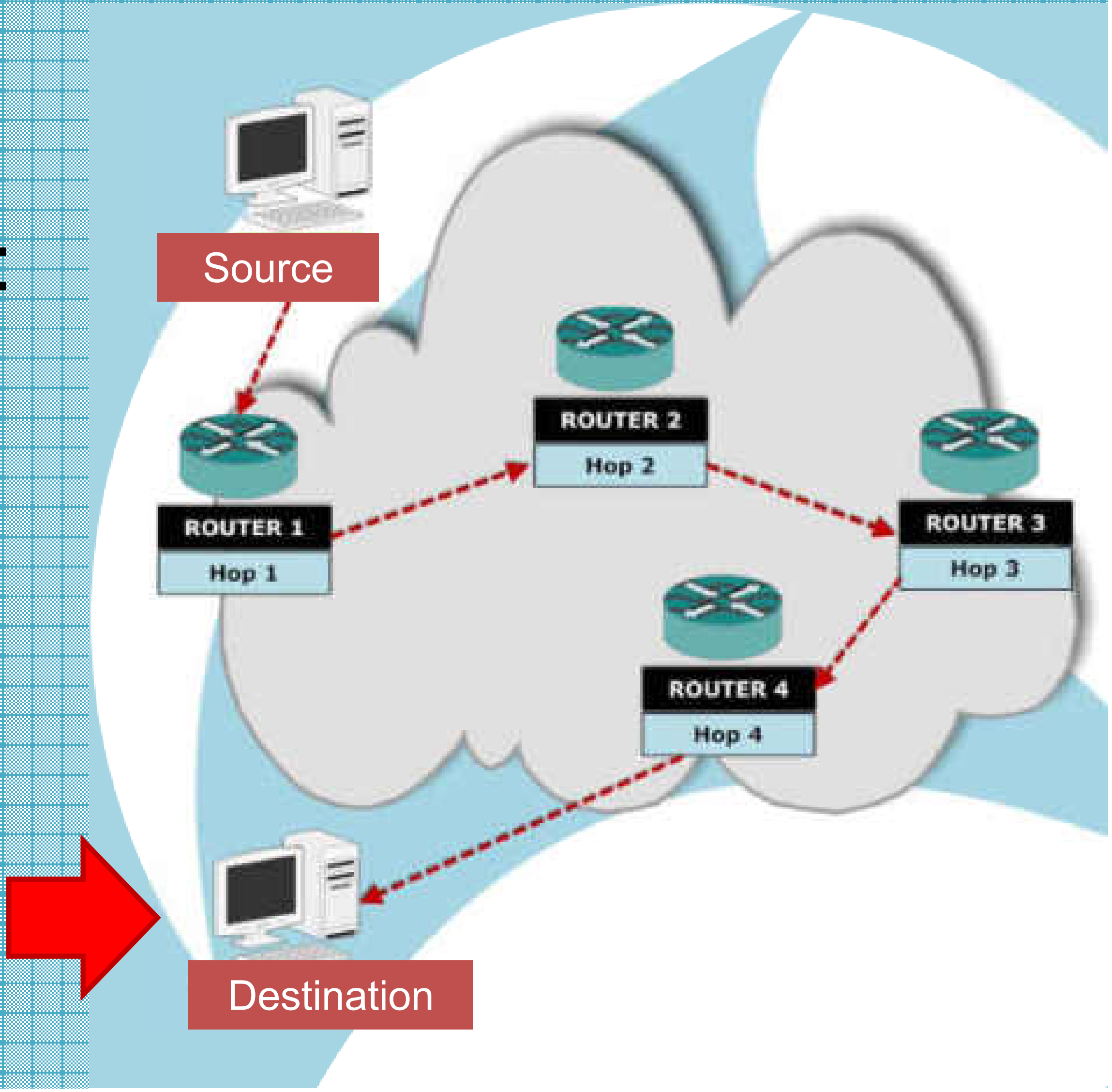
Sample Fragment Header



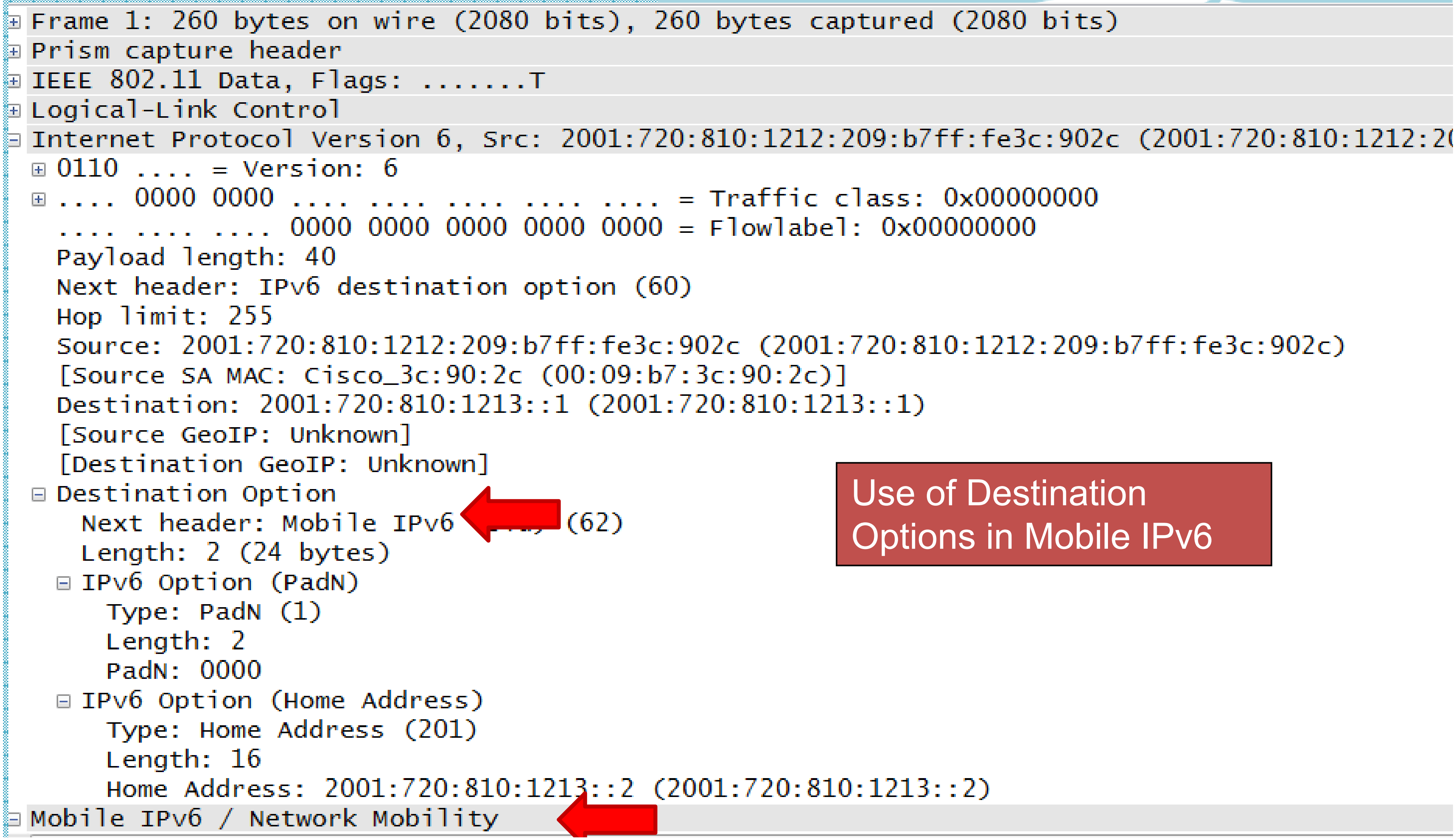
```
No.        Time            Source                    Destination
  5762 80.385670       2001:4998:0:6::15         2607:f740:0:3f:216:3eff:fe68:72c0

⊞ Frame 5762: 1494 bytes on wire (11952 bits), 1494 bytes captured (11952 bits)
⊞ Ethernet II, Src: Cisco_ae:30:0a (00:0c:cf:ae:30:0a), Dst: Xensourc_68:72:c0 (
⊟ Internet Protocol Version 6, Src: 2001:4998:0:6::15 (2001:4998:0:6::15), Dst:
  ⊞ 0110 .... = Version: 6
  ⊞ .... 0000 0000 .... .... .... .... .... = Traffic class: 0x00000000
    .... .... .... 0101 0100 0001 0000 1100 = Flowlabel: 0x0005410c
    Payload length: 1440
    Next header: IPv6 fragment (0x2c)
    Hop limit: 56
    Source: 2001:4998:0:6::15 (2001:4998:0:6::15)
    Destination: 2607:f740:0:3f:216:3eff:fe68:72c0 (2607:f740:0:3f:216:3eff:fe68
    [Destination SA MAC: Xensourc_68:72:c0 (00:16:3e:68:72:c0)]
  ⊟ Fragmentation Header
      Next header: TCP (0x06)
      0000 0000 0000 0... = Offset: 0 (0x0000)
      .... .... .... ...1 = More Fragment: Yes
      Identification: 0xa262a3bc
    Reassembled IPv6 in frame: 5763
⊞ Data (1432 bytes)
```

IPv6 Destination Options

- Destination Options: for end host

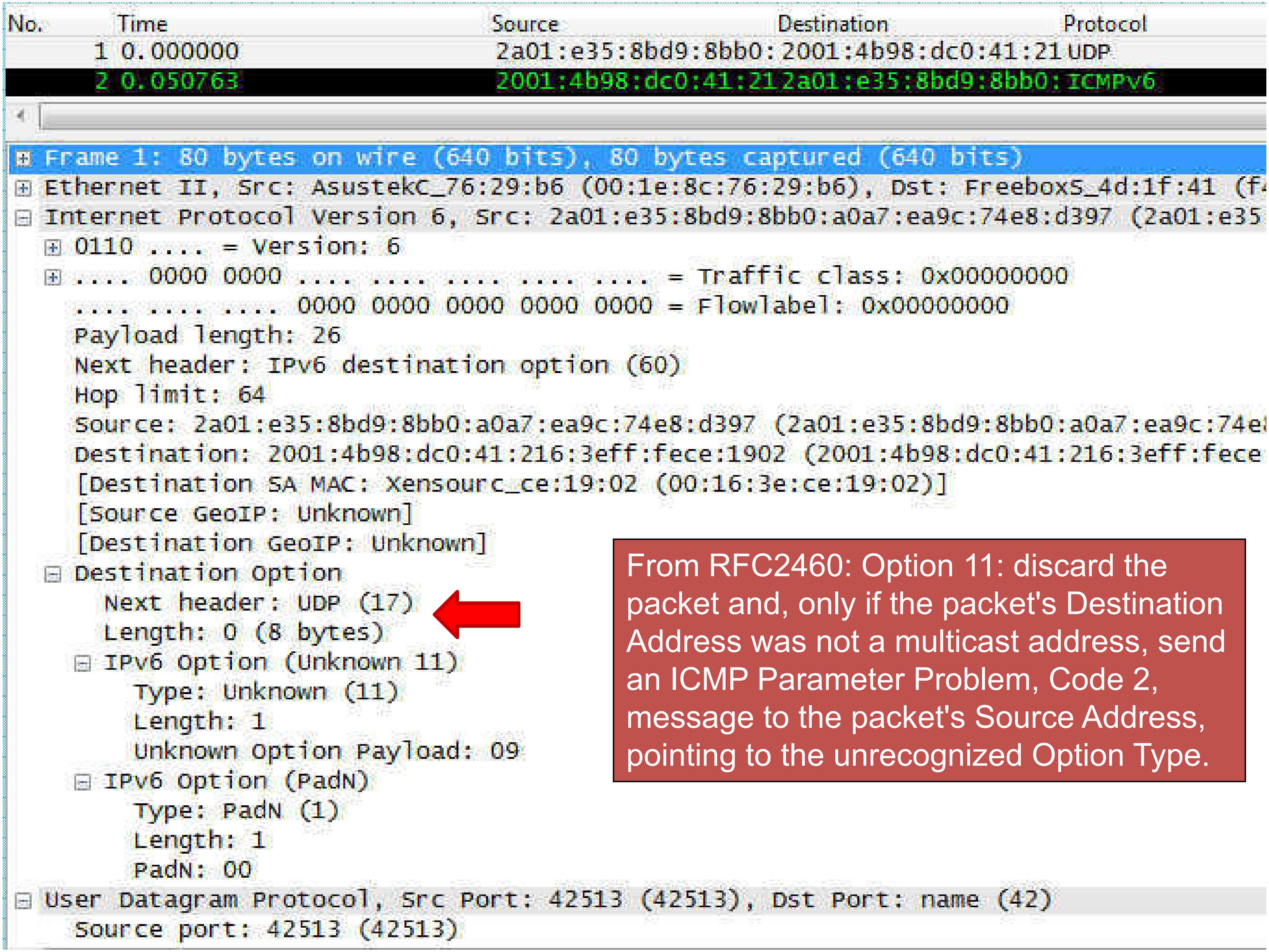


IPv6 Destination Options



```
⊞ Frame 1: 260 bytes on wire (2080 bits), 260 bytes captured (2080 bits)
⊞ Prism capture header
⊞ IEEE 802.11 Data, Flags: .......T
⊞ Logical-Link Control
⊟ Internet Protocol Version 6, Src: 2001:720:810:1212:209:b7ff:fe3c:902c (2001:720:810:1212:2
  ⊞ 0110 .... = Version: 6
  ⊞ .... 0000 0000 .... .... .... .... .... = Traffic class: 0x00000000
    .... .... .... 0000 0000 0000 0000 0000 = Flowlabel: 0x00000000
    Payload length: 40
    Next header: IPv6 destination option (60)
    Hop limit: 255
    Source: 2001:720:810:1212:209:b7ff:fe3c:902c (2001:720:810:1212:209:b7ff:fe3c:902c)
    [Source SA MAC: Cisco_3c:90:2c (00:09:b7:3c:90:2c)]
    Destination: 2001:720:810:1213::1 (2001:720:810:1213::1)
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
  ⊟ Destination Option
      Next header: Mobile IPv6 [illegible] (62)
      Length: 2 (24 bytes)
    ⊟ IPv6 Option (PadN)
        Type: PadN (1)
        Length: 2
        PadN: 0000
    ⊟ IPv6 Option (Home Address)
        Type: Home Address (201)
        Length: 16
        Home Address: 2001:720:810:1213::2 (2001:720:810:1213::2)
⊟ Mobile IPv6 / Network Mobility
```

Use of Destination Options in Mobile IPv6

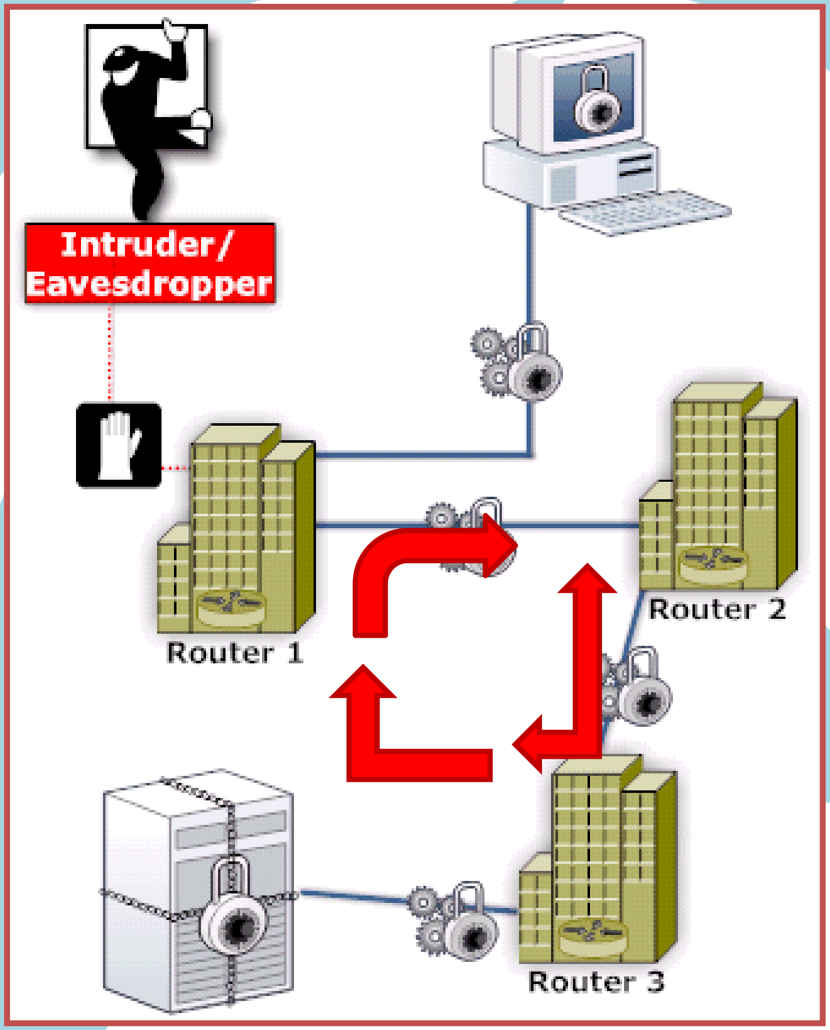


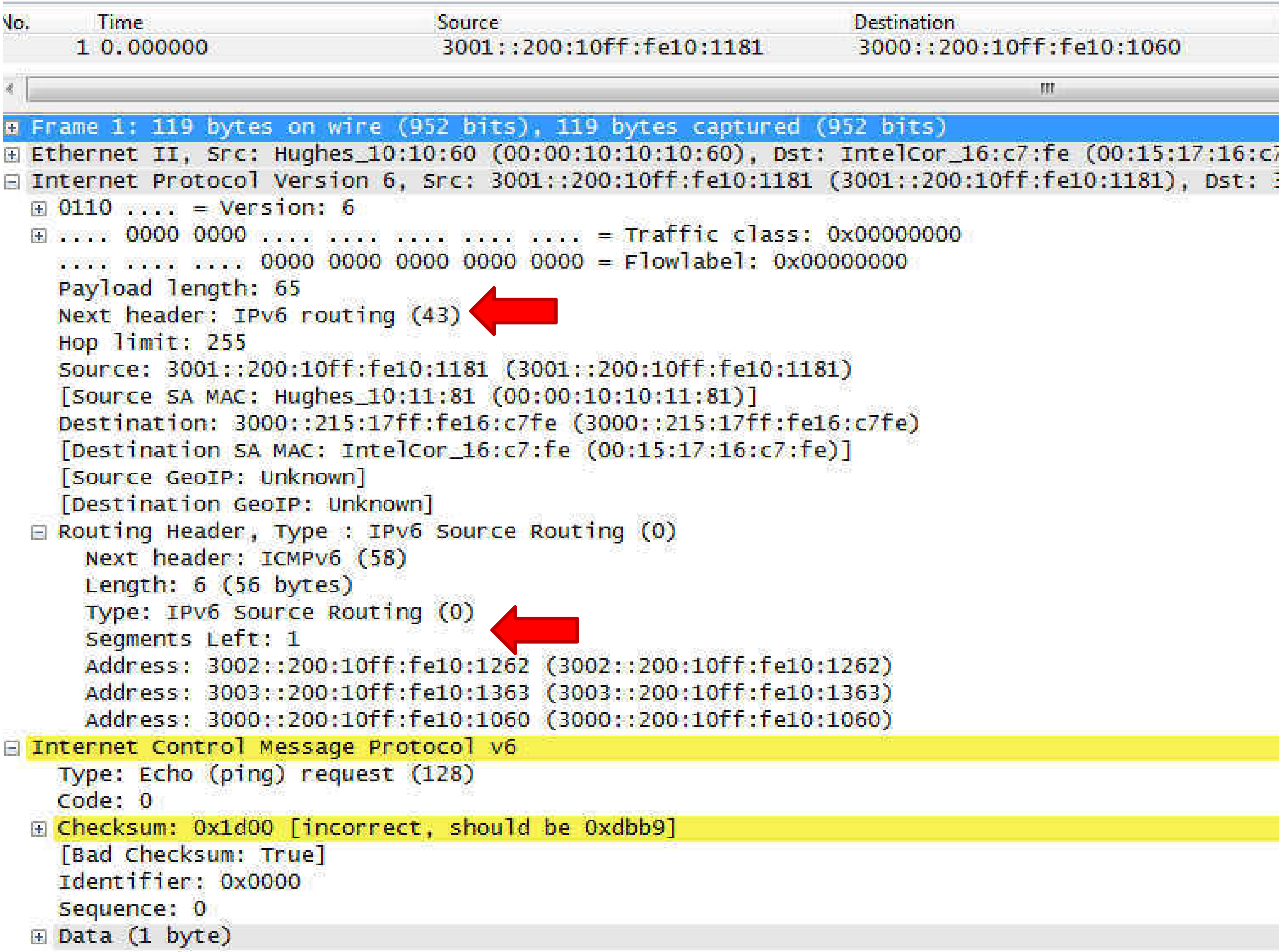
```
No.       Time                     Source                    Destination               Protocol
       1 0.000000                  2a01:e35:8bd9:8bb0: 2001:4b98:dc0:41:21 UDP
       2 0.050763                  2001:4b98:dc0:41:21 2a01:e35:8bd9:8bb0: ICMPv6

⊞ Frame 1: 80 bytes on wire (640 bits), 80 bytes captured (640 bits)
⊞ Ethernet II, Src: AsustekC_76:29:b6 (00:1e:8c:76:29:b6), Dst: FreeboxS_4d:1f:41 (f
⊟ Internet Protocol Version 6, Src: 2a01:e35:8bd9:8bb0:a0a7:ea9c:74e8:d397 (2a01:e35
  ⊞ 0110 .... = Version: 6
  ⊞ .... 0000 0000 .... .... .... .... .... = Traffic class: 0x00000000
    .... .... .... 0000 0000 0000 0000 0000 = Flowlabel: 0x00000000
    Payload length: 26
    Next header: IPv6 destination option (60)
    Hop limit: 64
    Source: 2a01:e35:8bd9:8bb0:a0a7:ea9c:74e8:d397 (2a01:e35:8bd9:8bb0:a0a7:ea9c:74e
    Destination: 2001:4b98:dc0:41:216:3eff:fece:1902 (2001:4b98:dc0:41:216:3eff:fece
    [Destination SA MAC: Xensourc_ce:19:02 (00:16:3e:ce:19:02)]
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
  ⊟ Destination Option
      Next header: UDP (17)
      Length: 0 (8 bytes)
    ⊟ IPv6 Option (Unknown 11)
        Type: Unknown (11)
        Length: 1
        Unknown Option Payload: 09
    ⊟ IPv6 Option (PadN)
        Type: PadN (1)
        Length: 1
        PadN: 00
⊟ User Datagram Protocol, Src Port: 42513 (42513), Dst Port: name (42)
    Source port: 42513 (42513)
```

From RFC2460: Option 11: discard the packet and, only if the packet's Destination Address was not a multicast address, send an ICMP Parameter Problem, Code 2, message to the packet's Source Address, pointing to the unrecognized Option Type.

RFC5095 (Deprecation of Type 0 Routing Headers in IPv6)

- RH0 : can create routing loops.
- Deprecated
- Segments Left = zero, ignore
- Segments Left > zero, send ICMPv6 error message

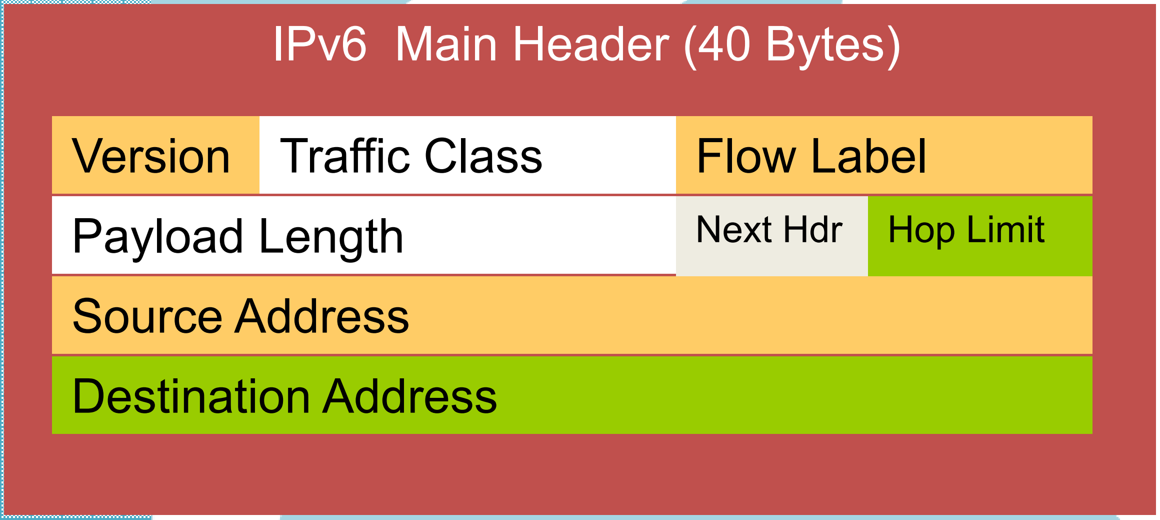




```
No.     Time                    Source                          Destination
      1 0.000000                3001::200:10ff:fe10:1181        3000::200:10ff:fe10:1060

⊞ Frame 1: 119 bytes on wire (952 bits), 119 bytes captured (952 bits)
⊞ Ethernet II, Src: Hughes_10:10:60 (00:00:10:10:10:60), Dst: IntelCor_16:c7:fe (00:15:17:16:c7
⊟ Internet Protocol Version 6, Src: 3001::200:10ff:fe10:1181 (3001::200:10ff:fe10:1181), Dst: 3
  ⊞ 0110 .... = Version: 6
  ⊞ .... 0000 0000 .... .... .... .... .... = Traffic class: 0x00000000
    .... .... .... 0000 0000 0000 0000 0000 = Flowlabel: 0x00000000
    Payload length: 65
    Next header: IPv6 routing (43)
    Hop limit: 255
    Source: 3001::200:10ff:fe10:1181 (3001::200:10ff:fe10:1181)
    [Source SA MAC: Hughes_10:11:81 (00:00:10:10:11:81)]
    Destination: 3000::215:17ff:fe16:c7fe (3000::215:17ff:fe16:c7fe)
    [Destination SA MAC: IntelCor_16:c7:fe (00:15:17:16:c7:fe)]
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
  ⊟ Routing Header, Type : IPv6 Source Routing (0)
      Next header: ICMPv6 (58)
      Length: 6 (56 bytes)
      Type: IPv6 Source Routing (0)
      Segments Left: 1
      Address: 3002::200:10ff:fe10:1262 (3002::200:10ff:fe10:1262)
      Address: 3003::200:10ff:fe10:1363 (3003::200:10ff:fe10:1363)
      Address: 3000::200:10ff:fe10:1060 (3000::200:10ff:fe10:1060)
⊟ Internet Control Message Protocol v6
    Type: Echo (ping) request (128)
    Code: 0
  ⊞ Checksum: 0x1d00 [incorrect, should be 0xdbb9]
    [Bad Checksum: True]
    Identifier: 0x0000
    Sequence: 0
  ⊞ Data (1 byte)
```

Malformed Packets

- Manipulate headers
  - IPv6 incorrect or partial header
  - Violate header order
  - Violate header option restrictions



IPv6 Main Header (40 Bytes)

Version

Traffic Class

Flow Label

Payload Length

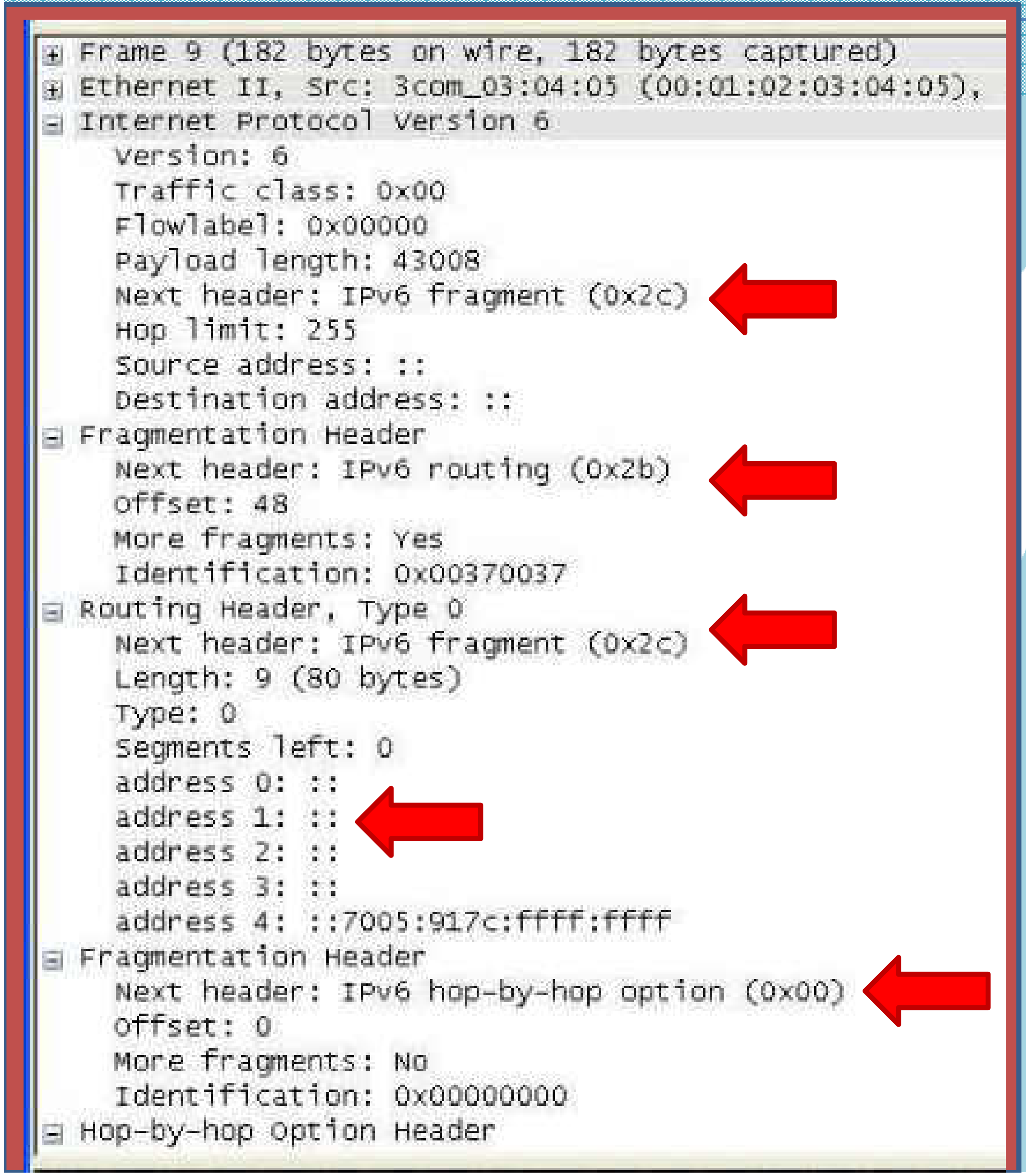
Next Hdr

Hop Limit

Source Address

Destination Address

Crafted Packet

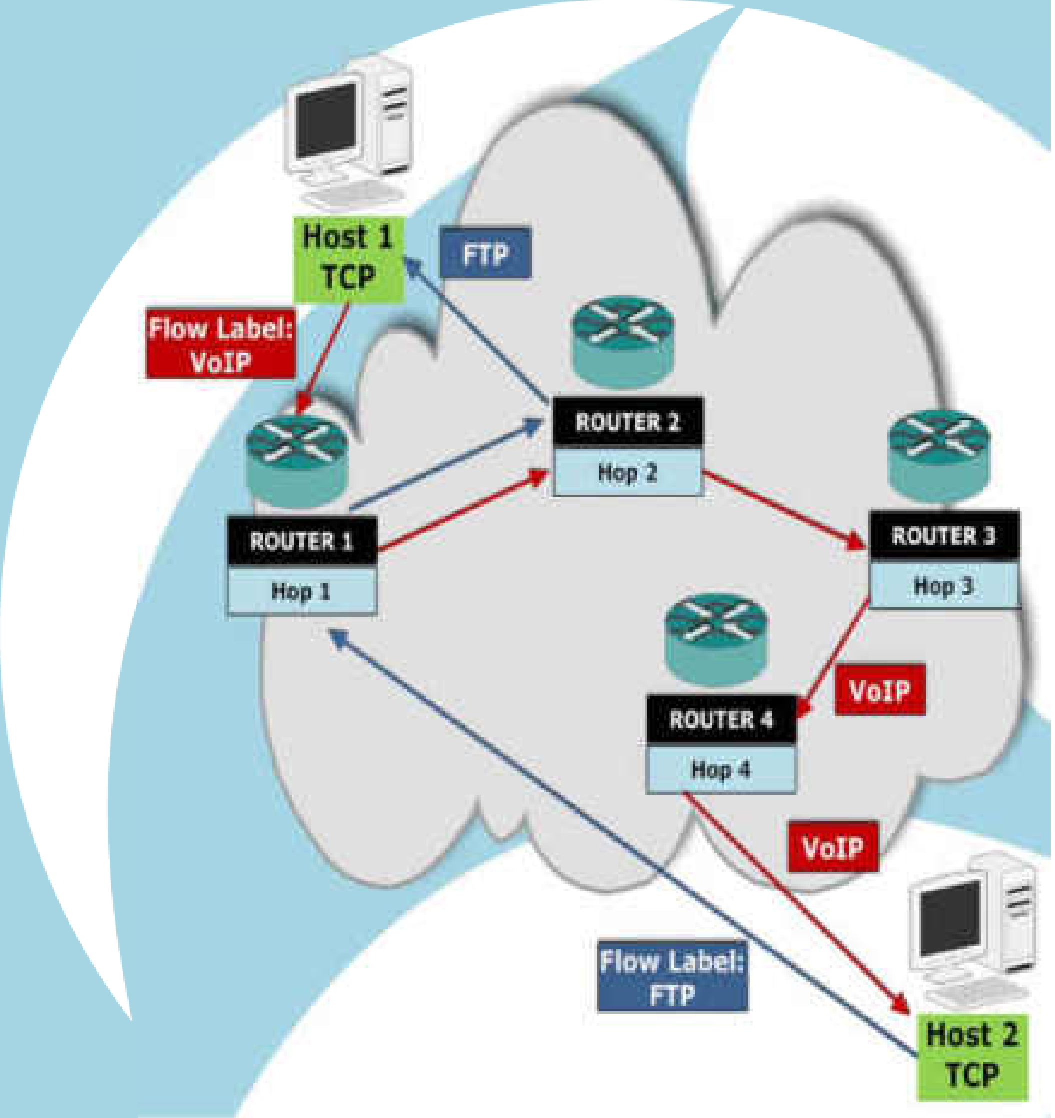


```
⊞ Frame 9 (182 bytes on wire, 182 bytes captured)
⊞ Ethernet II, Src: 3com_03:04:05 (00:01:02:03:04:05),
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 43008
    Next header: IPv6 fragment (0x2c)
    Hop limit: 255
    Source address: ::
    Destination address: ::
⊟ Fragmentation Header
    Next header: IPv6 routing (0x2b)
    Offset: 48
    More fragments: Yes
    Identification: 0x00370037
⊟ Routing Header, Type 0
    Next header: IPv6 fragment (0x2c)
    Length: 9 (80 bytes)
    Type: 0
    Segments left: 0
    address 0: ::
    address 1: ::
    address 2: ::
    address 3: ::
    address 4: ::7005:917c:ffff:ffff
⊟ Fragmentation Header
    Next header: IPv6 hop-by-hop option (0x00)
    Offset: 0
    More fragments: No
    Identification: 0x00000000
⊟ Hop-by-hop Option Header
```

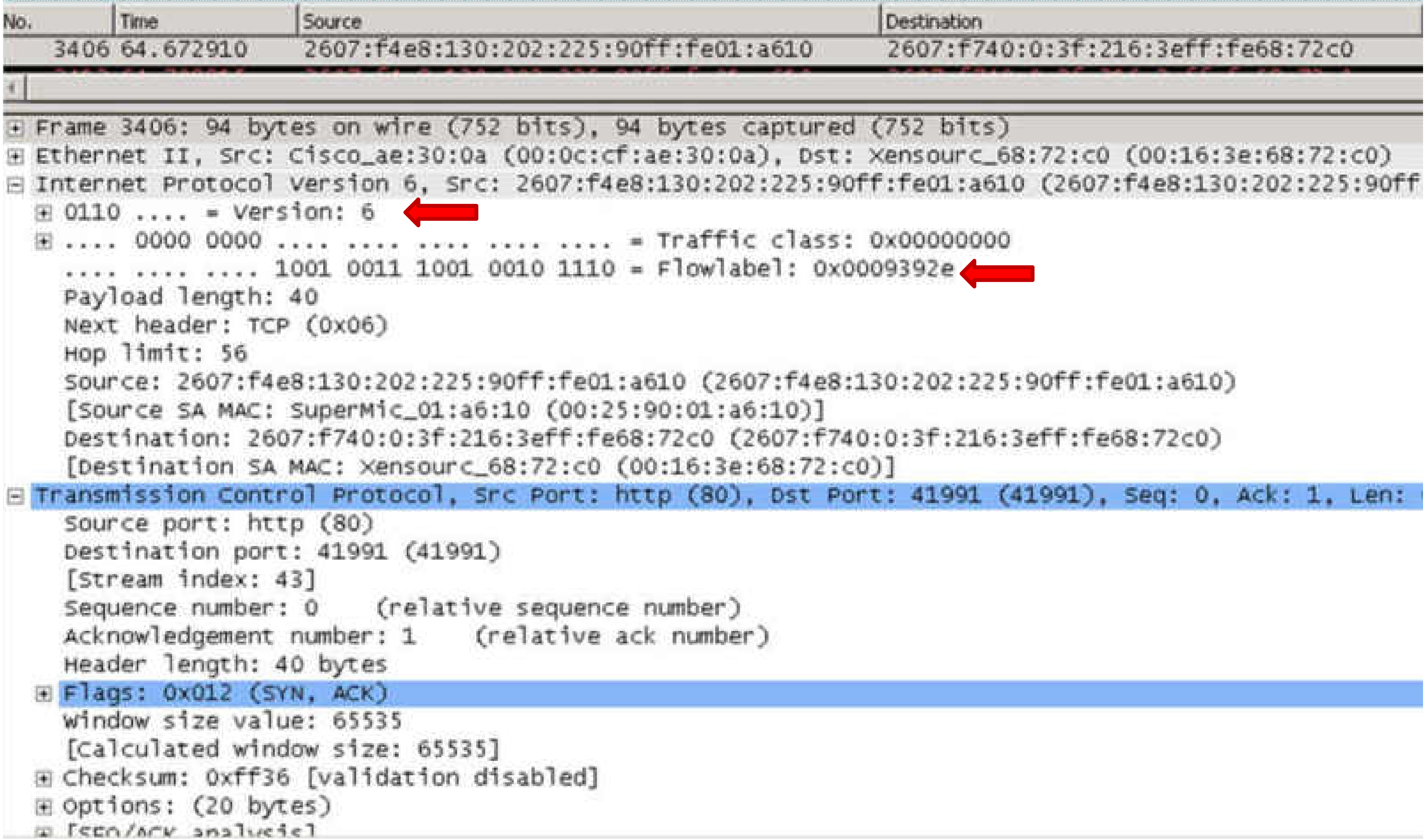
- Crafted IPv6 packet
- Multiple headers
- Deprecated headers
- Headers out of order

Flow Label

- Quality of Service
- What is a flow?
- All routers on the path
- SNA CoS



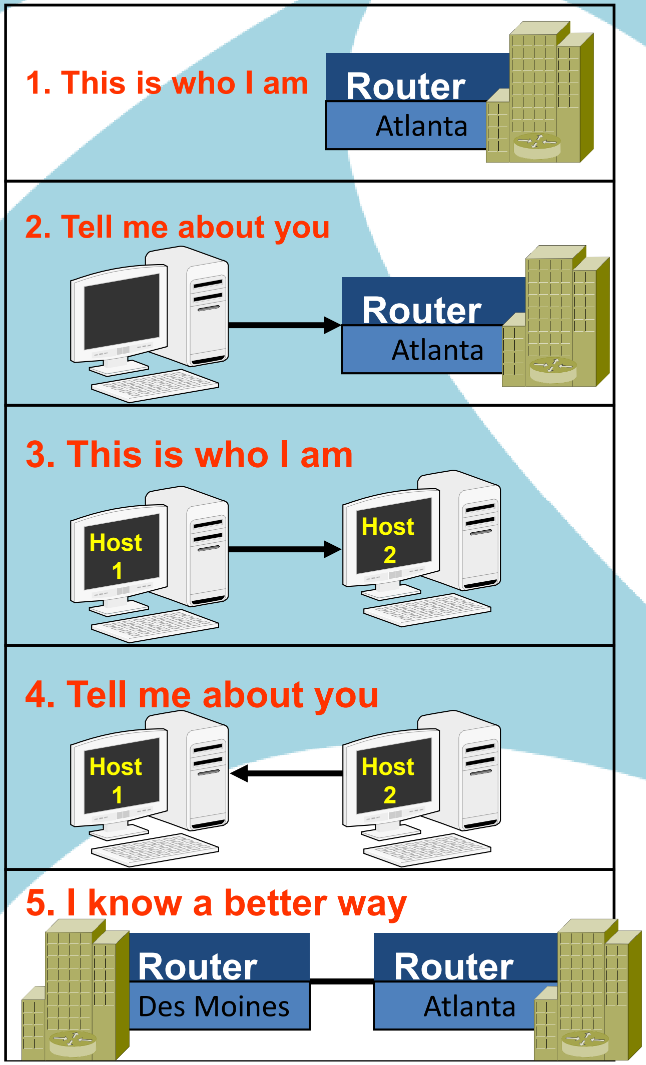
Trace Packet With Flow Label



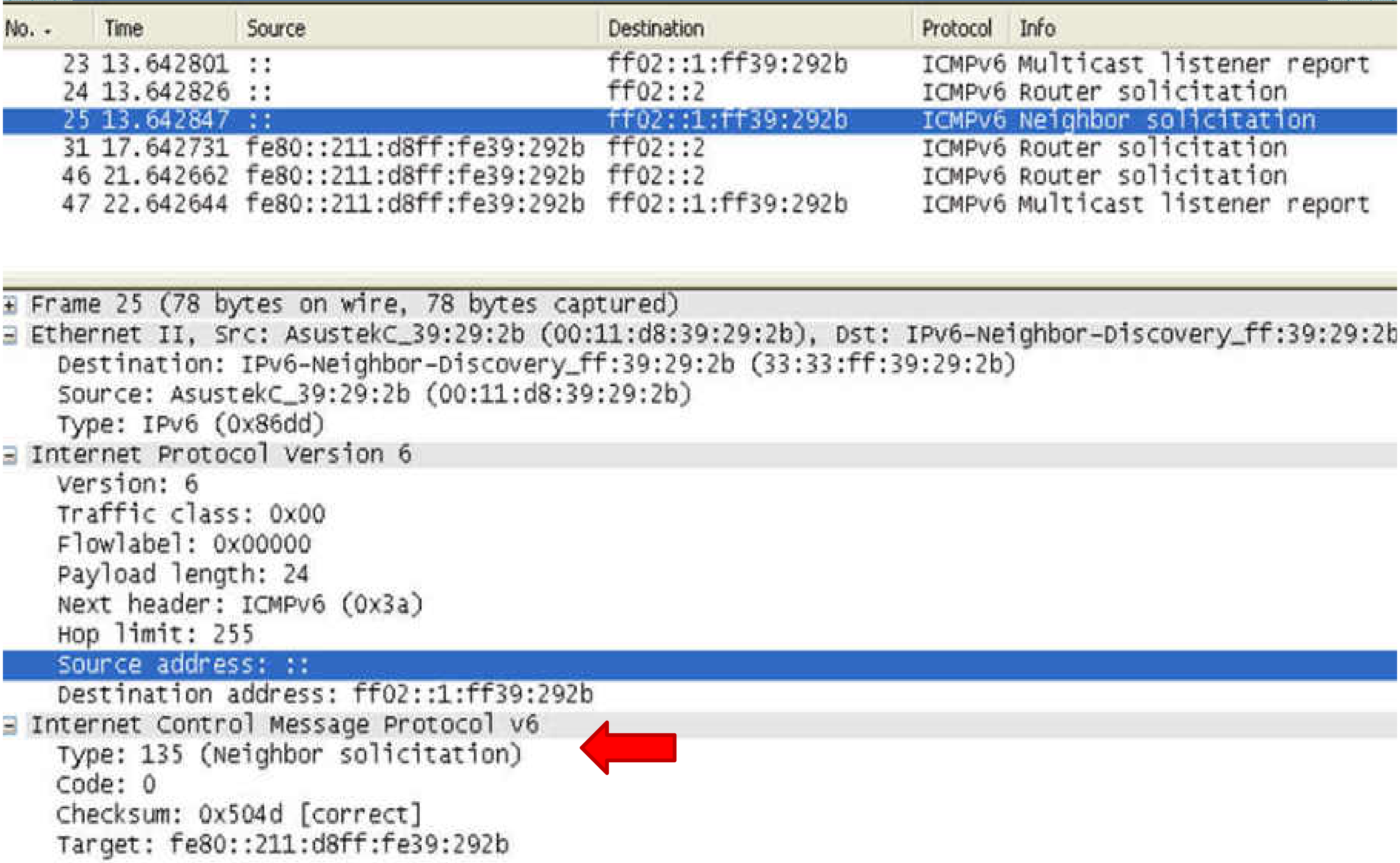
```
No.    Time          Source                                   Destination
  3406 64.672910     2607:f4e8:130:202:225:90ff:fe01:a610     2607:f740:0:3f:216:3eff:fe68:72c0

⊞ Frame 3406: 94 bytes on wire (752 bits), 94 bytes captured (752 bits)
⊞ Ethernet II, Src: Cisco_ae:30:0a (00:0c:cf:ae:30:0a), Dst: Xensourc_68:72:c0 (00:16:3e:68:72:c0)
⊟ Internet Protocol Version 6, Src: 2607:f4e8:130:202:225:90ff:fe01:a610 (2607:f4e8:130:202:225:90ff
  ⊞ 0110 .... = Version: 6
  ⊞ .... 0000 0000 .... .... .... .... .... = Traffic class: 0x00000000
    .... .... .... 1001 0011 1001 0010 1110 = Flowlabel: 0x0009392e
    Payload length: 40
    Next header: TCP (0x06)
    Hop limit: 56
    Source: 2607:f4e8:130:202:225:90ff:fe01:a610 (2607:f4e8:130:202:225:90ff:fe01:a610)
    [Source SA MAC: SuperMic_01:a6:10 (00:25:90:01:a6:10)]
    Destination: 2607:f740:0:3f:216:3eff:fe68:72c0 (2607:f740:0:3f:216:3eff:fe68:72c0)
    [Destination SA MAC: Xensourc_68:72:c0 (00:16:3e:68:72:c0)]
⊟ Transmission Control Protocol, Src Port: http (80), Dst Port: 41991 (41991), Seq: 0, Ack: 1, Len:
    Source port: http (80)
    Destination port: 41991 (41991)
    [Stream index: 43]
    Sequence number: 0    (relative sequence number)
    Acknowledgement number: 1    (relative ack number)
    Header length: 40 bytes
  ⊞ Flags: 0x012 (SYN, ACK)
    Window size value: 65535
    [Calculated window size: 65535]
  ⊞ Checksum: 0xff36 [validation disabled]
  ⊞ Options: (20 bytes)
  ⊞ [SEQ/ACK analysis]
```

Neighbor Discovery

- Neighbor Discovery (ND) replaces ARP
- RFC4861: Neighbor Discovery for IP version 6 (IPv6)
- Used in SLAAC
- Five ICMPv6 message types:
  1. *Router Advertisement*
  2. *Router Solicitation*
  3. *Neighbor Advertisement*
  4. *Neighbor Solicitation*
  5. *Redirect*



Neighbor Discovery

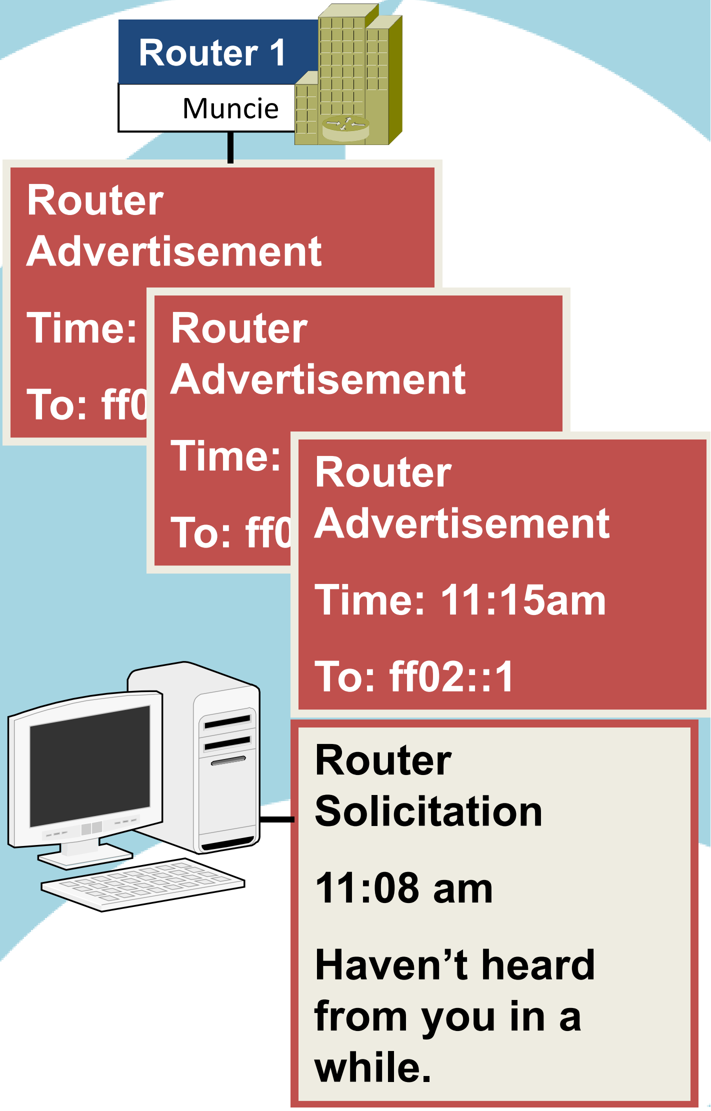


```
No. -   Time        Source                      Destination           Protocol Info
     23 13.642801  ::                          ff02::1:ff39:292b     ICMPv6 Multicast listener report
     24 13.642826  ::                          ff02::2               ICMPv6 Router solicitation
     25 13.642847  ::                          ff02::1:ff39:292b     ICMPv6 Neighbor solicitation
     31 17.642731  fe80::211:d8ff:fe39:292b    ff02::2               ICMPv6 Router solicitation
     46 21.642662  fe80::211:d8ff:fe39:292b    ff02::2               ICMPv6 Router solicitation
     47 22.642644  fe80::211:d8ff:fe39:292b    ff02::1:ff39:292b     ICMPv6 Multicast listener report
```

```
⊞ Frame 25 (78 bytes on wire, 78 bytes captured)
⊟ Ethernet II, Src: AsustekC_39:29:2b (00:11:d8:39:29:2b), Dst: IPv6-Neighbor-Discovery_ff:39:29:2b
    Destination: IPv6-Neighbor-Discovery_ff:39:29:2b (33:33:ff:39:29:2b)
    Source: AsustekC_39:29:2b (00:11:d8:39:29:2b)
    Type: IPv6 (0x86dd)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 24
    Next header: ICMPv6 (0x3a)
    Hop limit: 255
    Source address: ::
    Destination address: ff02::1:ff39:292b
⊟ Internet Control Message Protocol v6
    Type: 135 (Neighbor solicitation)
    Code: 0
    Checksum: 0x504d [correct]
    Target: fe80::211:d8ff:fe39:292b
```

Router Advertisement (RA)

- *Router Advertisement* (RA) important for SLAAC.
- Sent at intervals
- Unsolicited RA sent to FF02::1
- Receiving hosts update configuration
- RA also responds to *Router Solicitation* (RS)
- Solicited RA sent to address of RS sender



Router Advertisement

Time:

To: ff0

Router Advertisement

Time:

To: ff0

Router Advertisement

Time: 11:15am

To: ff02::1

Router Solicitation

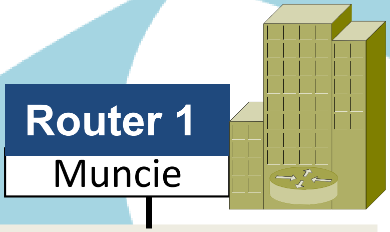
11:08 am

Haven't heard from you in a while.

Router Advertisement Contents

Router Advertisements contain:

- Stateless / stateful (DHCPv6)
- Network prefix
- Default router
- Hop limit
- MTU



Router Advertisement

Time: 10:45am

To: ff02::1

•Use AutoConfiguration

•Statelss

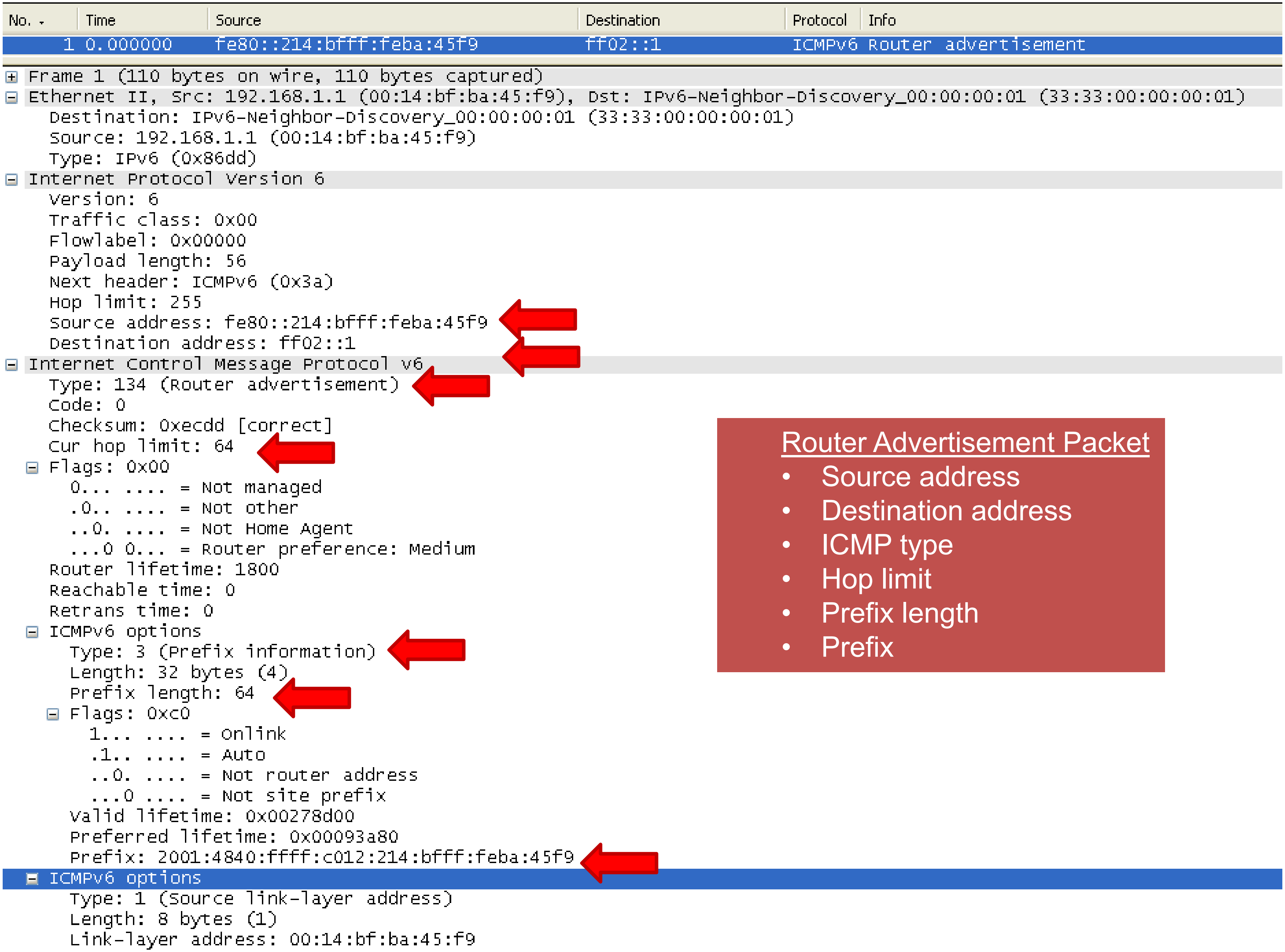
•Network Prefix: 2001:: /64

•I am default router

•For 200 seconds

•Hop limit: 126

•MTU: 4096



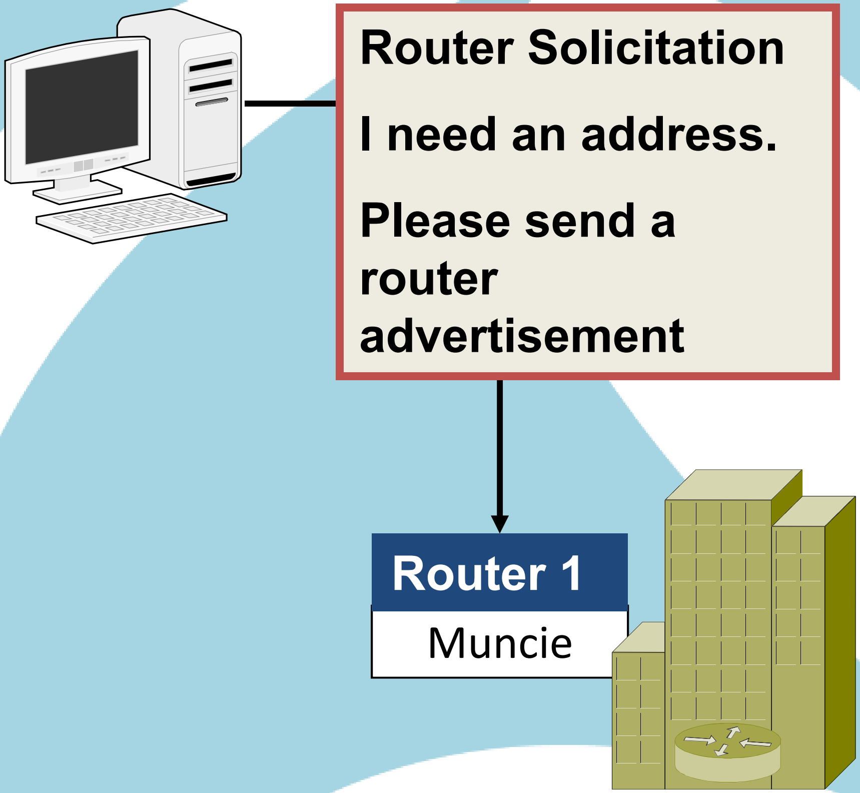
```
No.   Time       Source                       Destination   Protocol  Info
  1 0.000000    fe80::214:bfff:feba:45f9     ff02::1       ICMPv6 Router advertisement

⊞ Frame 1 (110 bytes on wire, 110 bytes captured)
⊟ Ethernet II, Src: 192.168.1.1 (00:14:bf:ba:45:f9), Dst: IPv6-Neighbor-Discovery_00:00:00:01 (33:33:00:00:00:01)
    Destination: IPv6-Neighbor-Discovery_00:00:00:01 (33:33:00:00:00:01)
    Source: 192.168.1.1 (00:14:bf:ba:45:f9)
    Type: IPv6 (0x86dd)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 56
    Next header: ICMPv6 (0x3a)
    Hop limit: 255
    Source address: fe80::214:bfff:feba:45f9
    Destination address: ff02::1
⊟ Internet Control Message Protocol v6
    Type: 134 (Router advertisement)
    Code: 0
    Checksum: 0xecdd [correct]
    Cur hop limit: 64
  ⊟ Flags: 0x00
      0... .... = Not managed
      .0.. .... = Not other
      ..0. .... = Not Home Agent
      ...0 0... = Router preference: Medium
    Router lifetime: 1800
    Reachable time: 0
    Retrans time: 0
  ⊟ ICMPv6 options
      Type: 3 (Prefix information)
      Length: 32 bytes (4)
      Prefix length: 64
    ⊟ Flags: 0xc0
        1... .... = Onlink
        .1.. .... = Auto
        ..0. .... = Not router address
        ...0 .... = Not site prefix
      Valid lifetime: 0x00278d00
      Preferred lifetime: 0x00093a80
      Prefix: 2001:4840:ffff:c012:214:bfff:feba:45f9
  ⊟ ICMPv6 options
      Type: 1 (Source link-layer address)
      Length: 8 bytes (1)
      Link-layer address: 00:14:bf:ba:45:f9
```

Router Advertisement Packet

- Source address
- Destination address
- ICMP type
- Hop limit
- Prefix length
- Prefix

Router Solicitation (RS)

- Sent during SLAAC
- Immediate response needed
- Sent 3 times total if no response



Router Solicitation

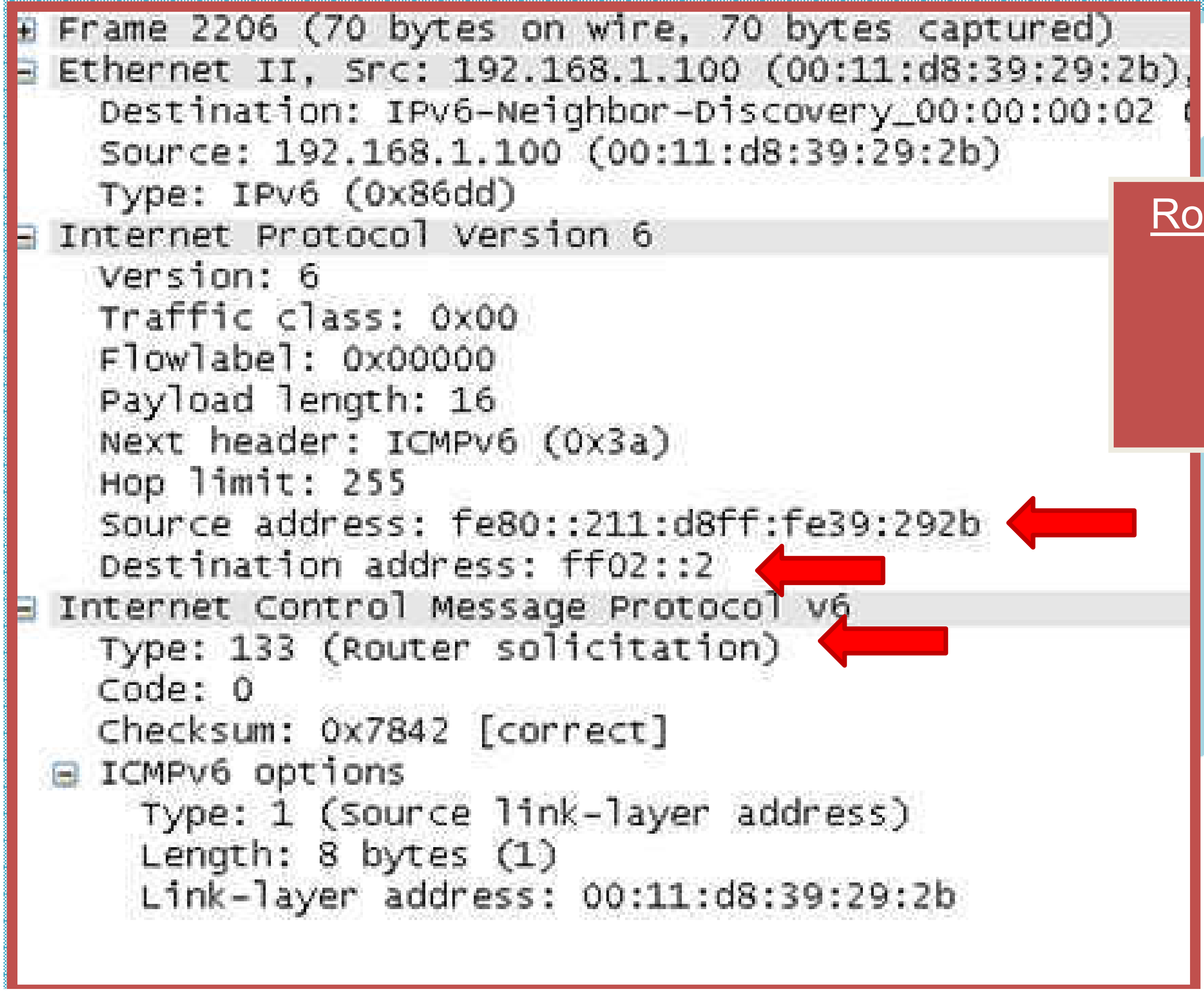
I need an address.

Please send a router advertisement

Router 1

Muncie

Router Solicitation Packet



```
⊞ Frame 2206 (70 bytes on wire, 70 bytes captured)
⊟ Ethernet II, Src: 192.168.1.100 (00:11:d8:39:29:2b),
    Destination: IPv6-Neighbor-Discovery_00:00:00:02 (
    Source: 192.168.1.100 (00:11:d8:39:29:2b)
    Type: IPv6 (0x86dd)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 16
    Next header: ICMPv6 (0x3a)
    Hop limit: 255
    Source address: fe80::211:d8ff:fe39:292b
    Destination address: ff02::2
⊟ Internet Control Message Protocol v6
    Type: 133 (Router solicitation)
    Code: 0
    Checksum: 0x7842 [correct]
  ⊟ ICMPv6 options
      Type: 1 (Source link-layer address)
      Length: 8 bytes (1)
      Link-layer address: 00:11:d8:39:29:2b
```

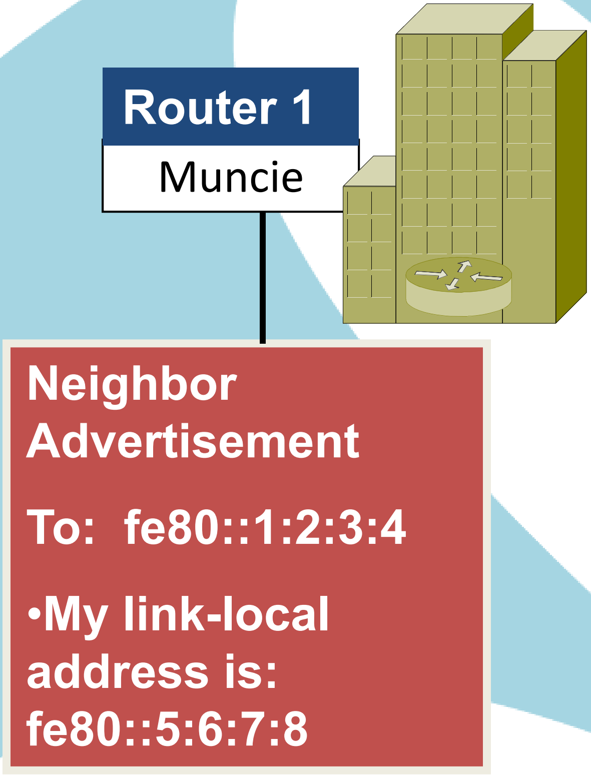
Router Solicitation Packet

- Source address
- Destination address
- ICMPv6 type

Neighbor Advertisement (NA)

Neighbor Advertisements sent:

- In response to *Neighbor Solicitation*
- Or if own NIC changes
- Contain link-layer address

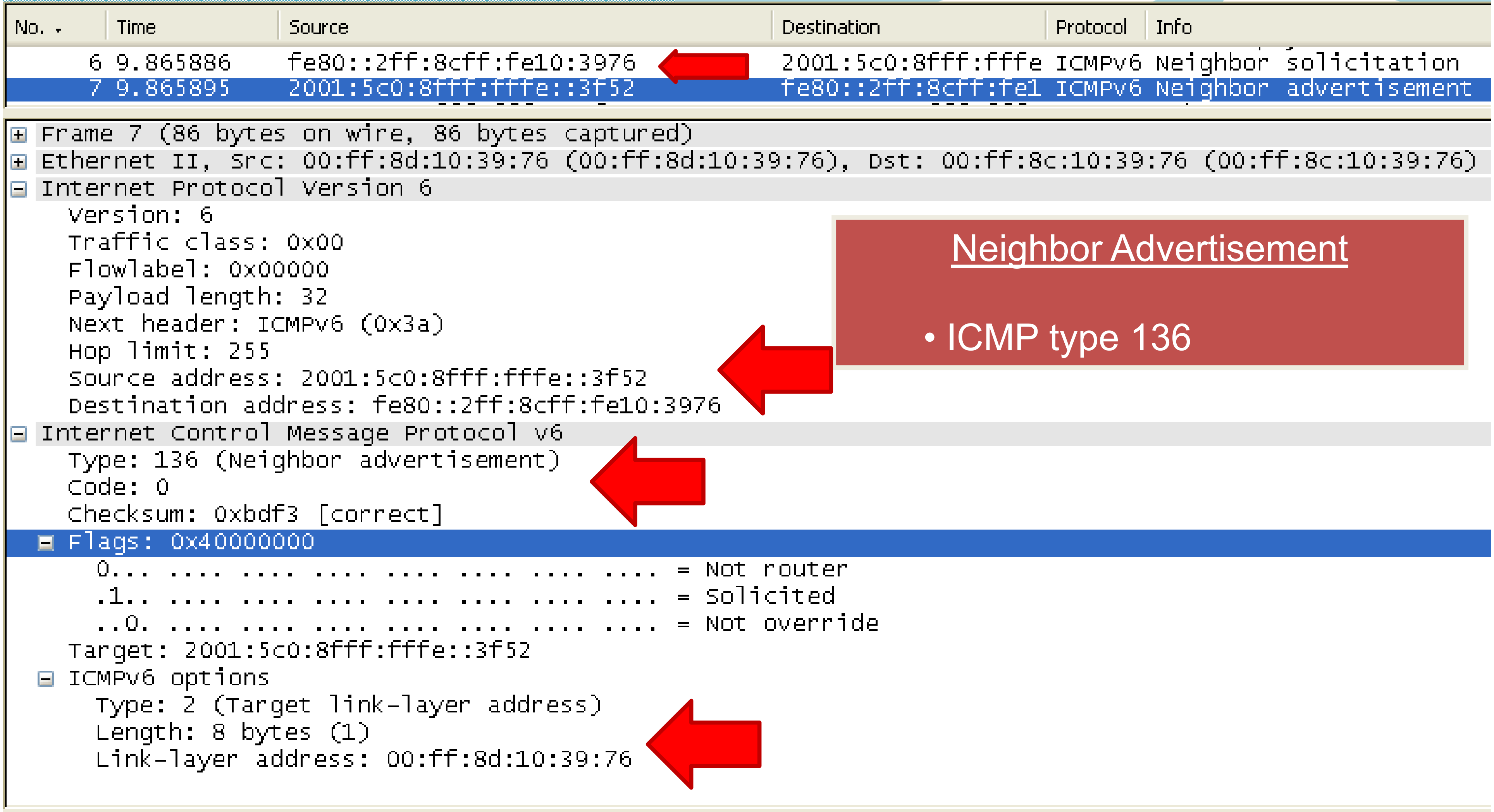


Neighbor Advertisement

To: fe80::1:2:3:4

•My link-local address is: fe80::5:6:7:8

Neighbor Advertisement Packet



```
No. ▾   Time        Source                          Destination          Protocol Info
      6 9.865886    fe80::2ff:8cff:fe10:3976        2001:5c0:8fff:fffe   ICMPv6   Neighbor solicitation
      7 9.865895    2001:5c0:8fff:fffe::3f52        fe80::2ff:8cff:fe1   ICMPv6   Neighbor advertisement
```

```
⊞ Frame 7 (86 bytes on wire, 86 bytes captured)
⊞ Ethernet II, Src: 00:ff:8d:10:39:76 (00:ff:8d:10:39:76), Dst: 00:ff:8c:10:39:76 (00:ff:8c:10:39:76)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 32
    Next header: ICMPv6 (0x3a)
    Hop limit: 255
    Source address: 2001:5c0:8fff:fffe::3f52
    Destination address: fe80::2ff:8cff:fe10:3976
⊟ Internet Control Message Protocol v6
    Type: 136 (Neighbor advertisement)
    Code: 0
    Checksum: 0xbdf3 [correct]
  ⊟ Flags: 0x40000000
      0... .... .... .... .... .... .... .... = Not router
      .1.. .... .... .... .... .... .... .... = Solicited
      ..0. .... .... .... .... .... .... .... = Not override
    Target: 2001:5c0:8fff:fffe::3f52
  ⊟ ICMPv6 options
      Type: 2 (Target link-layer address)
      Length: 8 bytes (1)
      Link-layer address: 00:ff:8d:10:39:76
```

Neighbor Advertisement

- ICMP type 136

Neighbor Solicitation (NS)

- *Neighbor Solicitations* request information
- *Neighbor Advertisement* response
- Sent during SLAAC (DAD)
- Sent to verify reachability

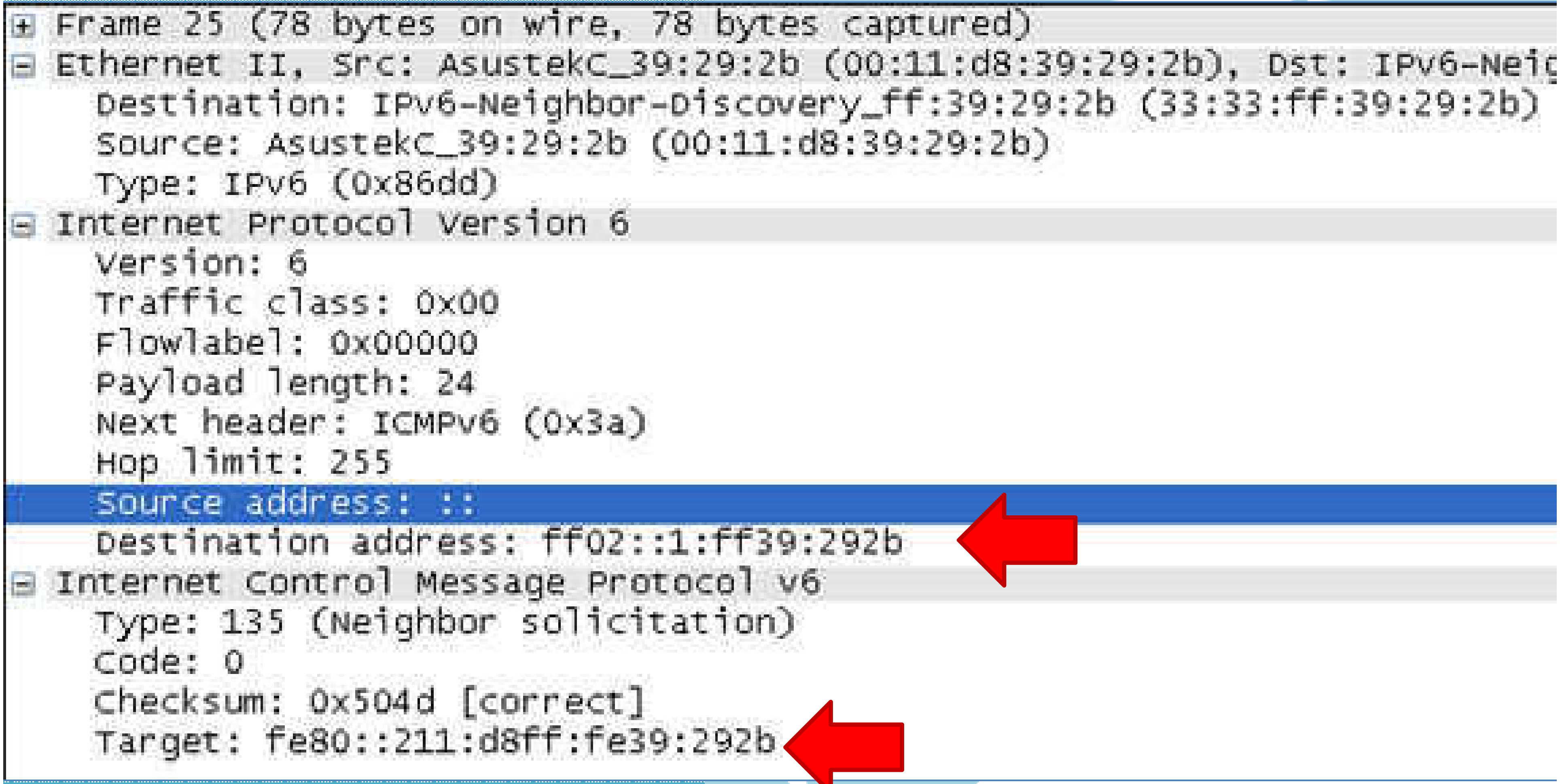
Neighbor Solicitation

To: ff02::1

Are you using:

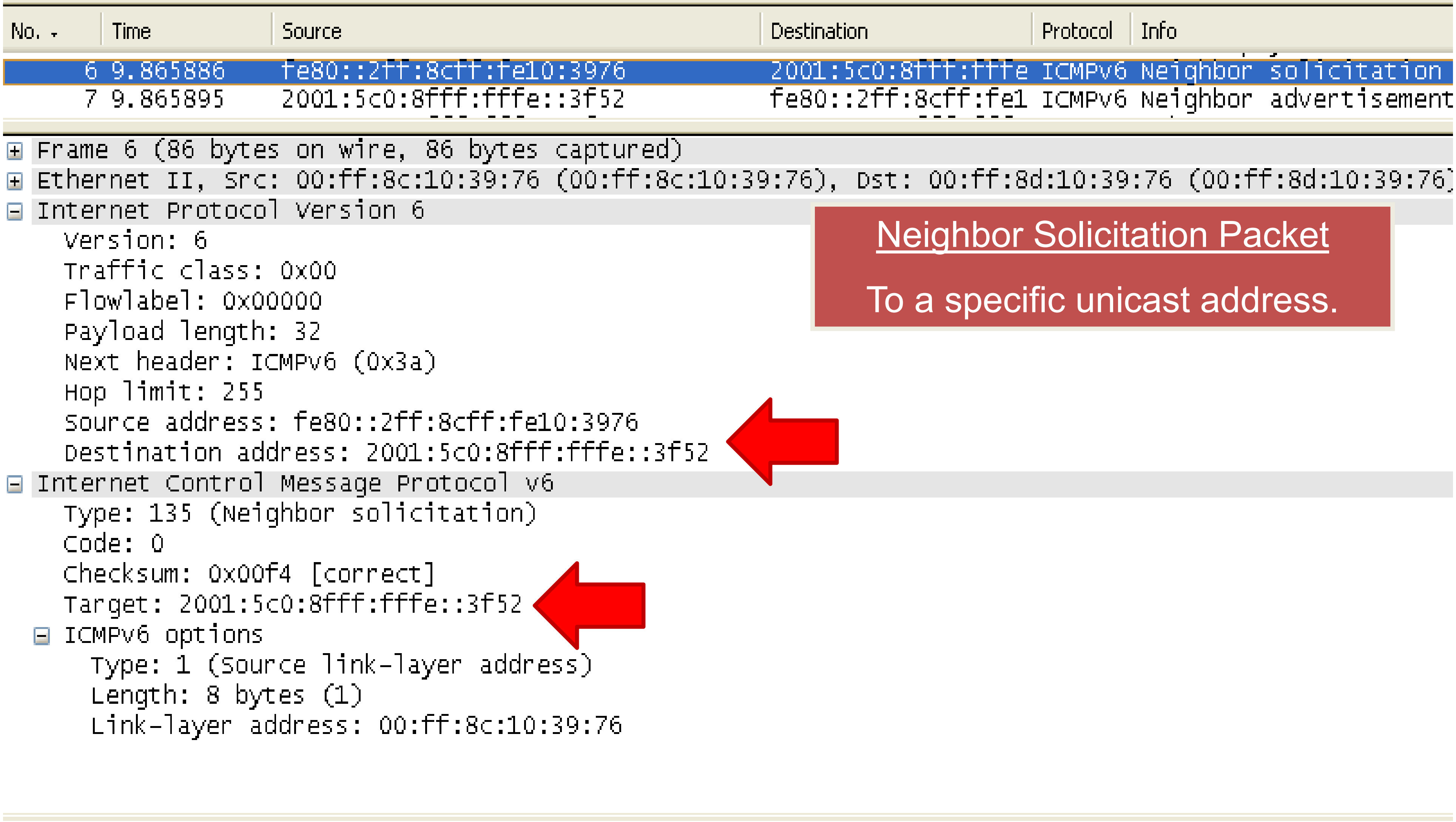
fe80::1:2:3:4?

Neighbor Solicitation Packet



```
⊞ Frame 25 (78 bytes on wire, 78 bytes captured)
⊟ Ethernet II, Src: AsustekC_39:29:2b (00:11:d8:39:29:2b), Dst: IPv6-Neig
    Destination: IPv6-Neighbor-Discovery_ff:39:29:2b (33:33:ff:39:29:2b)
    Source: AsustekC_39:29:2b (00:11:d8:39:29:2b)
    Type: IPv6 (0x86dd)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 24
    Next header: ICMPv6 (0x3a)
    Hop limit: 255
    Source address: ::
    Destination address: ff02::1:ff39:292b
⊟ Internet Control Message Protocol v6
    Type: 135 (Neighbor solicitation)
    Code: 0
    Checksum: 0x504d [correct]
    Target: fe80::211:d8ff:fe39:292b
```

NS Packet (Reachability)



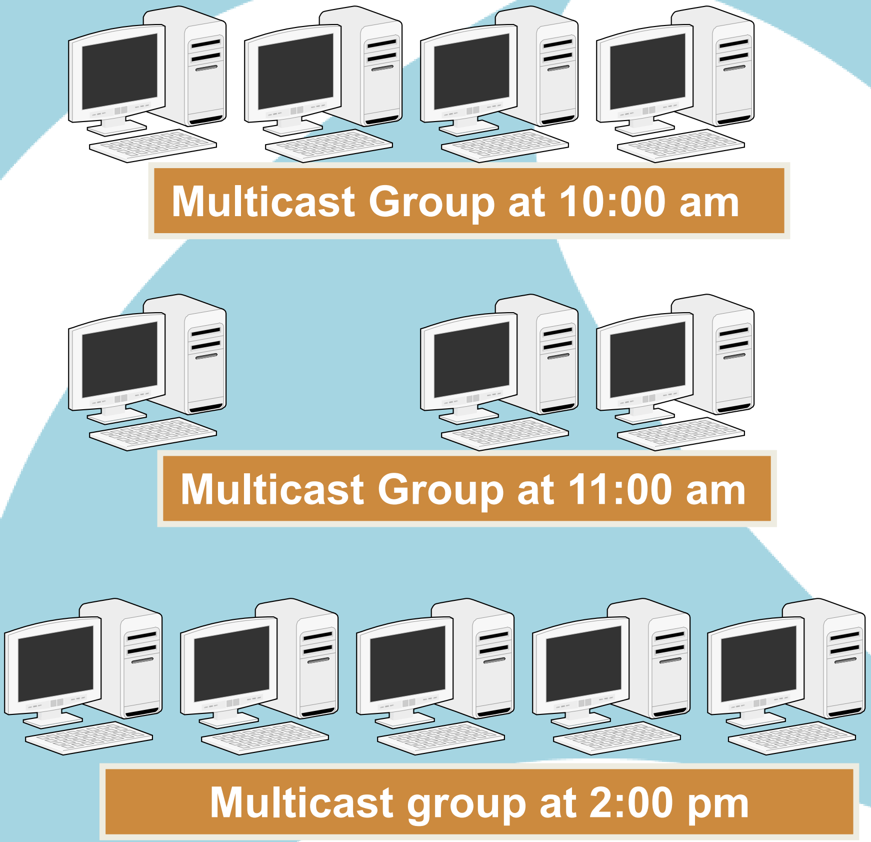
```
No.   Time       Source                        Destination          Protocol Info
    6 9.865886   fe80::2ff:8cff:fe10:3976      2001:5c0:8fff:fffe  ICMPv6   Neighbor solicitation
    7 9.865895   2001:5c0:8fff:fffe::3f52      fe80::2ff:8cff:fe1  ICMPv6   Neighbor advertisement

⊞ Frame 6 (86 bytes on wire, 86 bytes captured)
⊞ Ethernet II, Src: 00:ff:8c:10:39:76 (00:ff:8c:10:39:76), Dst: 00:ff:8d:10:39:76 (00:ff:8d:10:39:76)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 32
    Next header: ICMPv6 (0x3a)
    Hop limit: 255
    Source address: fe80::2ff:8cff:fe10:3976
    Destination address: 2001:5c0:8fff:fffe::3f52
⊟ Internet Control Message Protocol v6
    Type: 135 (Neighbor solicitation)
    Code: 0
    Checksum: 0x00f4 [correct]
    Target: 2001:5c0:8fff:fffe::3f52
  ⊟ ICMPv6 options
      Type: 1 (Source link-layer address)
      Length: 8 bytes (1)
      Link-layer address: 00:ff:8c:10:39:76
```

Neighbor Solicitation Packet

To a specific unicast address.

Multicast Groups

- Multicast: frequently used
  - All-nodes
  - All-routers
  - All-OSPF-routers
- Dynamic membership
- Multicast Listener Discovery (MLD) protocol used

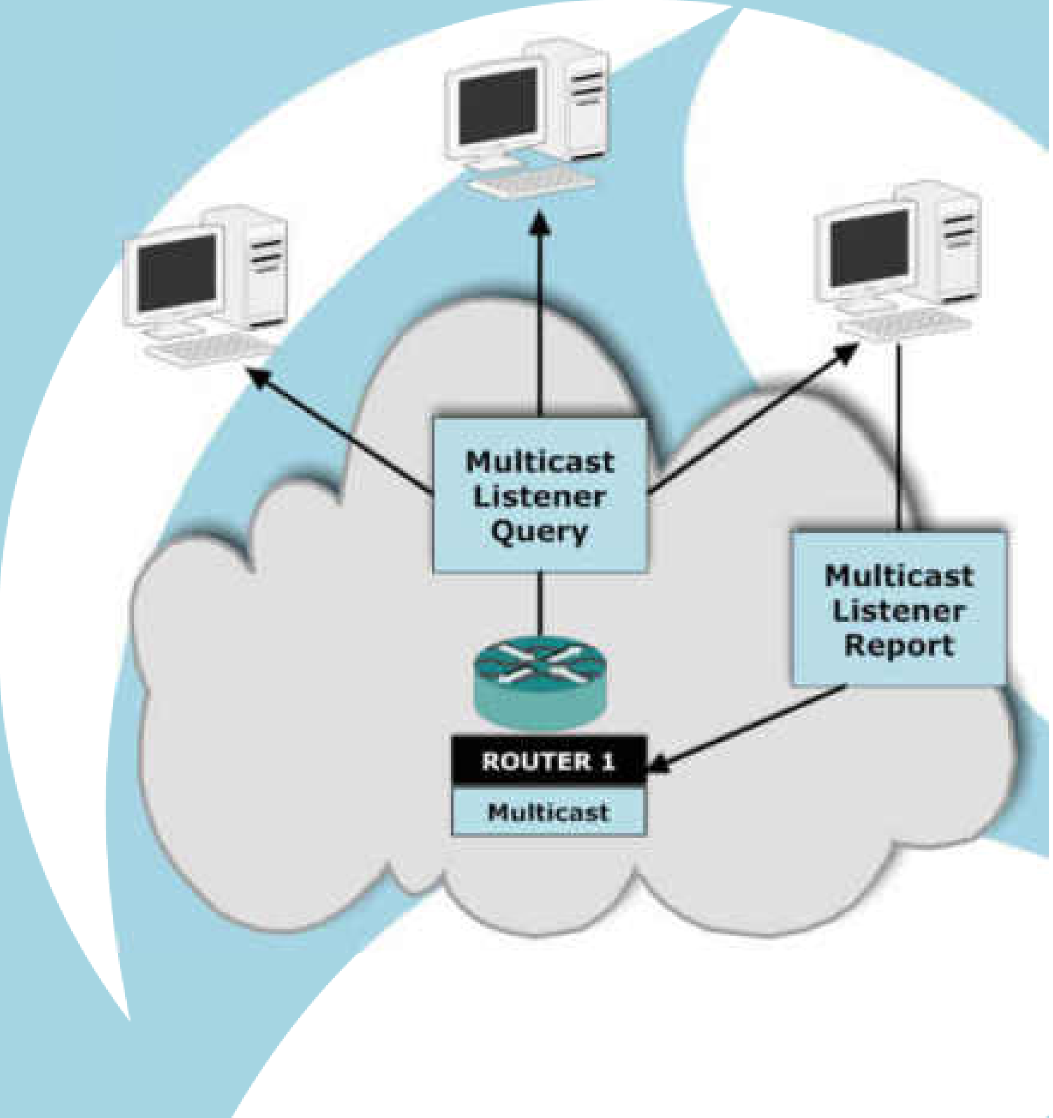

Multicast Group at 10:00 am
Multicast Group at 11:00 am
Multicast group at 2:00 pm

Multicast Listener Discovery

- RFC2710: Multicast Listener Discovery (MLD) for IPv6

- RFC3590: Source Address Selection for the Multicast Listener Discovery (MLD) Protocol

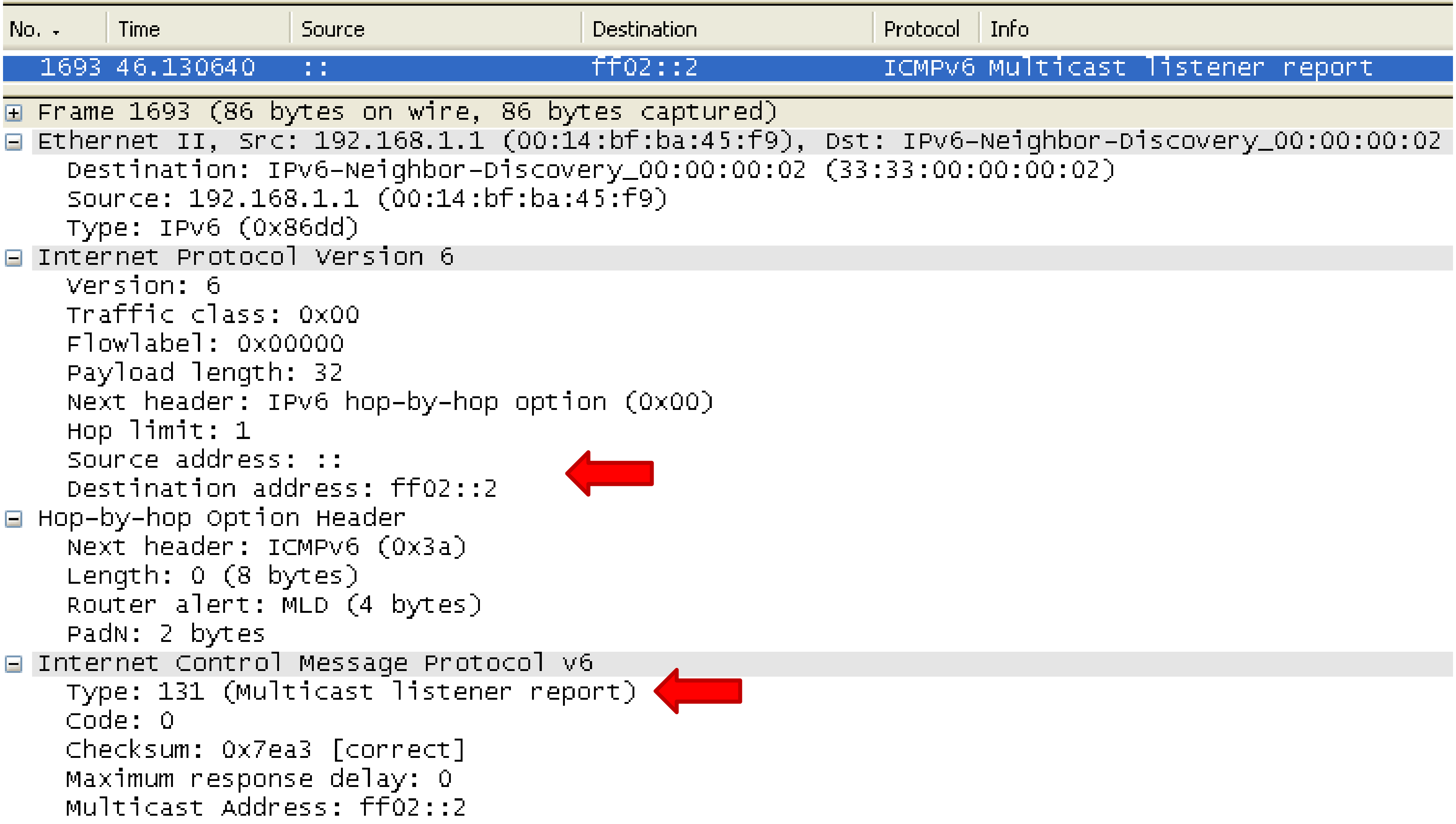
- RFC3810: Multicast Listener Discovery Version 2 (MLDv2) for IPv6



MLD Message Types

MLD message type	Description
Multicast Listener Query	General Query, used to learn which multicast addresses have listeners on an attached link. Multicast-Address-Specific Query, used to learn if a particular multicast address has any listeners on an attached link.
Multicast Listener Report	Sent by a host when it joins a multicast group, or in response to a Multicast Listener Query sent by a router.
Multicast Listener Done	Sent by a host when it leaves a host group and might be the last member of that group on the network segment.

Multicast Listener Report



```
No. -    Time            Source            Destination        Protocol  Info
   1693 46.130640       ::                 ff02::2             ICMPv6 Multicast listener report

⊞ Frame 1693 (86 bytes on wire, 86 bytes captured)
⊟ Ethernet II, Src: 192.168.1.1 (00:14:bf:ba:45:f9), Dst: IPv6-Neighbor-Discovery_00:00:00:02
    Destination: IPv6-Neighbor-Discovery_00:00:00:02 (33:33:00:00:00:02)
    Source: 192.168.1.1 (00:14:bf:ba:45:f9)
    Type: IPv6 (0x86dd)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 32
    Next header: IPv6 hop-by-hop option (0x00)
    Hop limit: 1
    Source address: ::
    Destination address: ff02::2
⊟ Hop-by-hop Option Header
    Next header: ICMPv6 (0x3a)
    Length: 0 (8 bytes)
    Router alert: MLD (4 bytes)
    PadN: 2 bytes
⊟ Internet Control Message Protocol v6
    Type: 131 (Multicast listener report)
    Code: 0
    Checksum: 0x7ea3 [correct]
    Maximum response delay: 0
    Multicast Address: ff02::2
```

New Resource Record Type

- **DNS *A*** resource record: 32-bit IPv4 address
- **DNS *AAAA*** resource record: 128-bit IPv6 address
- Structure similar, but much larger!
- Other RRs: CNAME, MX, etc.

AAAA Record

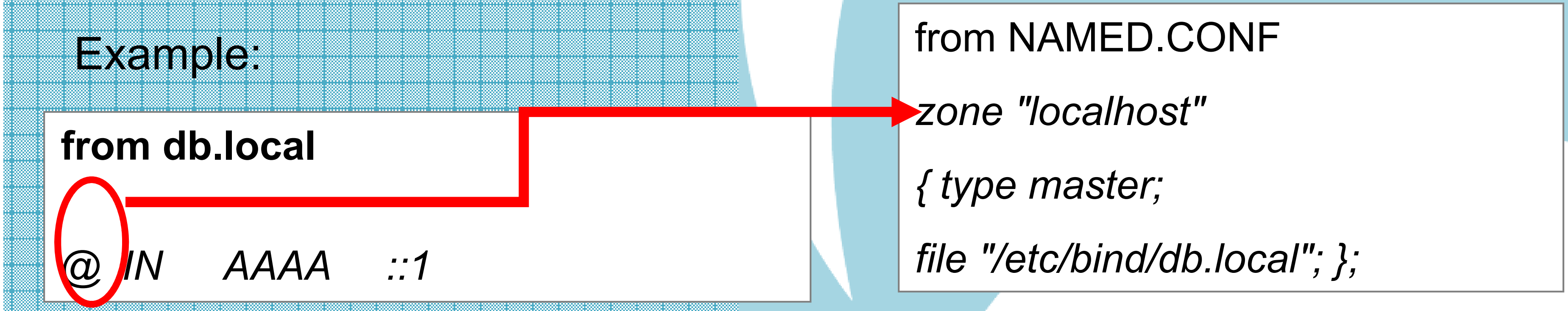
AAAA (or quad A) record : defines an IPv6 address that matches to a host name.

- Can have more than one IPv6 address per host name
- Can have more than one host name per IPv6 address

AAAA record format:

Host.domain.name.   IN   AAAA   nnnn::nnnn

Example:



from db.local

@ IN   AAAA   ::1

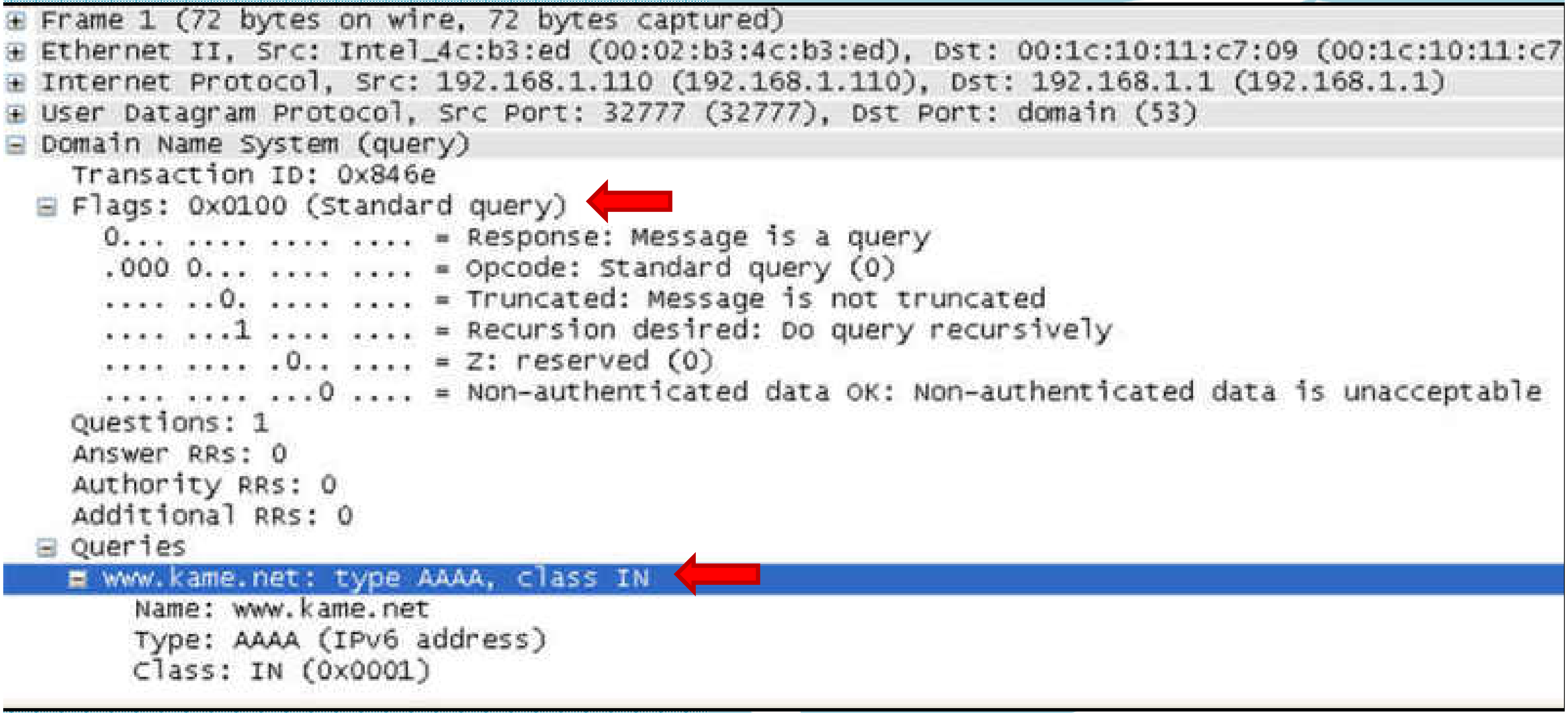
from NAMED.CONF

zone "localhost"

{ type master;

file "/etc/bind/db.local"; };

DNS Query – IPv6

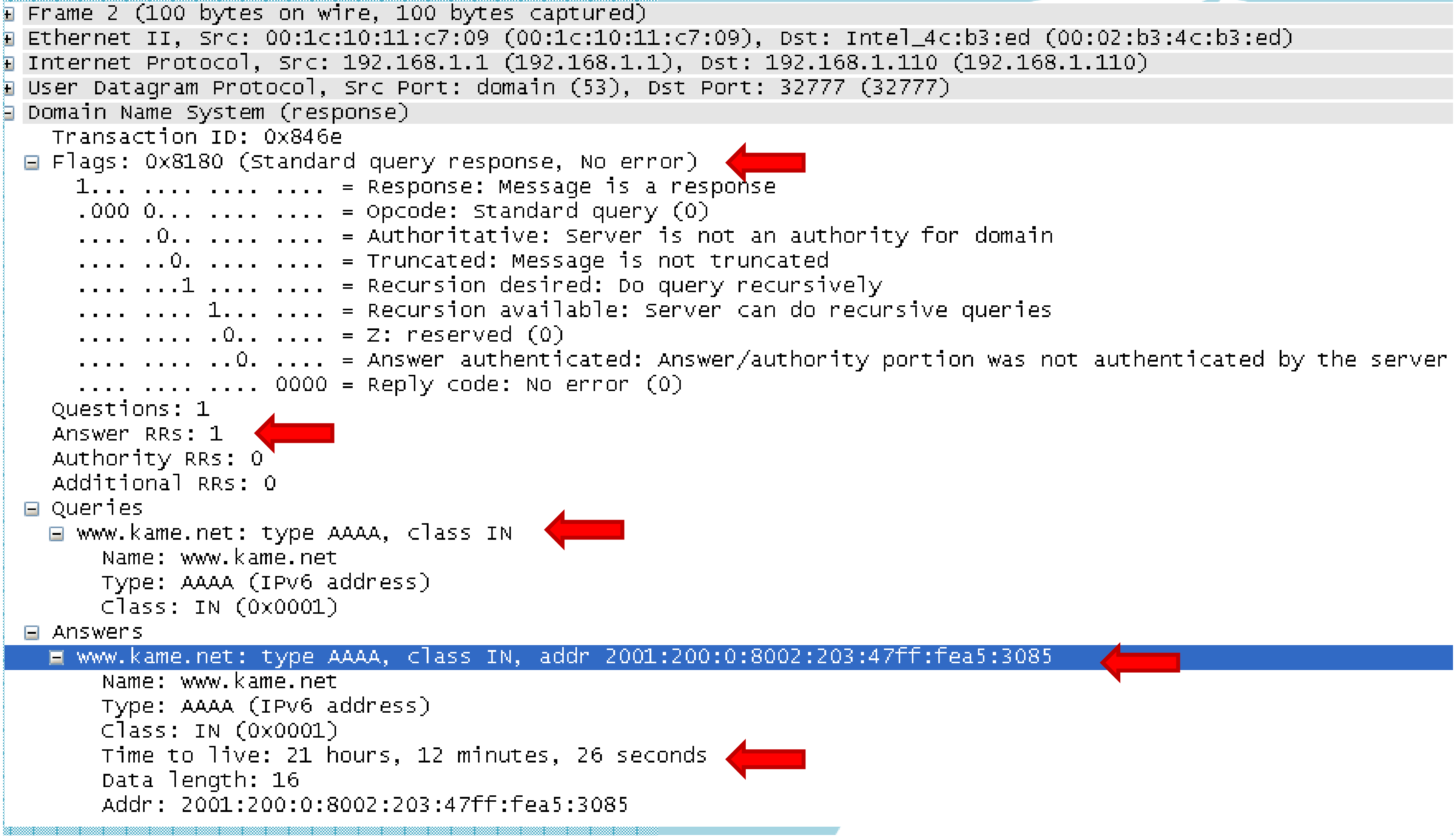


```
⊞ Frame 1 (72 bytes on wire, 72 bytes captured)
⊞ Ethernet II, Src: Intel_4c:b3:ed (00:02:b3:4c:b3:ed), Dst: 00:1c:10:11:c7:09 (00:1c:10:11:c7
⊞ Internet Protocol, Src: 192.168.1.110 (192.168.1.110), Dst: 192.168.1.1 (192.168.1.1)
⊞ User Datagram Protocol, Src Port: 32777 (32777), Dst Port: domain (53)
⊟ Domain Name System (query)
    Transaction ID: 0x846e
  ⊟ Flags: 0x0100 (Standard query)
      0... .... .... .... = Response: Message is a query
      .000 0... .... .... = Opcode: Standard query (0)
      .... ..0. .... .... = Truncated: Message is not truncated
      .... ...1 .... .... = Recursion desired: Do query recursively
      .... .... .0.. .... = Z: reserved (0)
      .... .... ...0 .... = Non-authenticated data OK: Non-authenticated data is unacceptable
    Questions: 1
    Answer RRs: 0
    Authority RRs: 0
    Additional RRs: 0
  ⊟ Queries
    ⊟ www.kame.net: type AAAA, class IN
        Name: www.kame.net
        Type: AAAA (IPv6 address)
        Class: IN (0x0001)
```

Query to resolve IPv6 address for www.kame.net.

Command entered: host –t AAAA www.kame.net

DNS Response – IPv6



```
⊞ Frame 2 (100 bytes on wire, 100 bytes captured)
⊞ Ethernet II, Src: 00:1c:10:11:c7:09 (00:1c:10:11:c7:09), Dst: Intel_4c:b3:ed (00:02:b3:4c:b3:ed)
⊞ Internet Protocol, Src: 192.168.1.1 (192.168.1.1), Dst: 192.168.1.110 (192.168.1.110)
⊞ User Datagram Protocol, Src Port: domain (53), Dst Port: 32777 (32777)
⊟ Domain Name System (response)
    Transaction ID: 0x846e
  ⊟ Flags: 0x8180 (Standard query response, No error)
      1... .... .... .... = Response: Message is a response
      .000 0... .... .... = Opcode: Standard query (0)
      .... .0.. .... .... = Authoritative: Server is not an authority for domain
      .... ..0. .... .... = Truncated: Message is not truncated
      .... ...1 .... .... = Recursion desired: Do query recursively
      .... .... 1... .... = Recursion available: Server can do recursive queries
      .... .... .0.. .... = Z: reserved (0)
      .... .... ..0. .... = Answer authenticated: Answer/authority portion was not authenticated by the server
      .... .... .... 0000 = Reply code: No error (0)
    Questions: 1
    Answer RRs: 1
    Authority RRs: 0
    Additional RRs: 0
  ⊟ Queries
    ⊟ www.kame.net: type AAAA, class IN
        Name: www.kame.net
        Type: AAAA (IPv6 address)
        Class: IN (0x0001)
  ⊟ Answers
    ⊟ www.kame.net: type AAAA, class IN, addr 2001:200:0:8002:203:47ff:fea5:3085
        Name: www.kame.net
        Type: AAAA (IPv6 address)
        Class: IN (0x0001)
        Time to live: 21 hours, 12 minutes, 26 seconds
        Data length: 16
        Addr: 2001:200:0:8002:203:47ff:fea5:3085
```

Commands to Query DNS

- DIG : name/address resolution, DNS server addresses, mail exchanges, name servers, and related information
- HOST : name/address resolution
- NSLOOKUP : name/address resolution (deprecated)

DIG Command Samples

-
  ```
  # get the IPv4 address(es) for yahoo.com
    dig  yahoo.com A
  ```

-
  ```
  # get the IPv6 address(es) for yahoo.com
    dig  yahoo.com AAAA
  ```

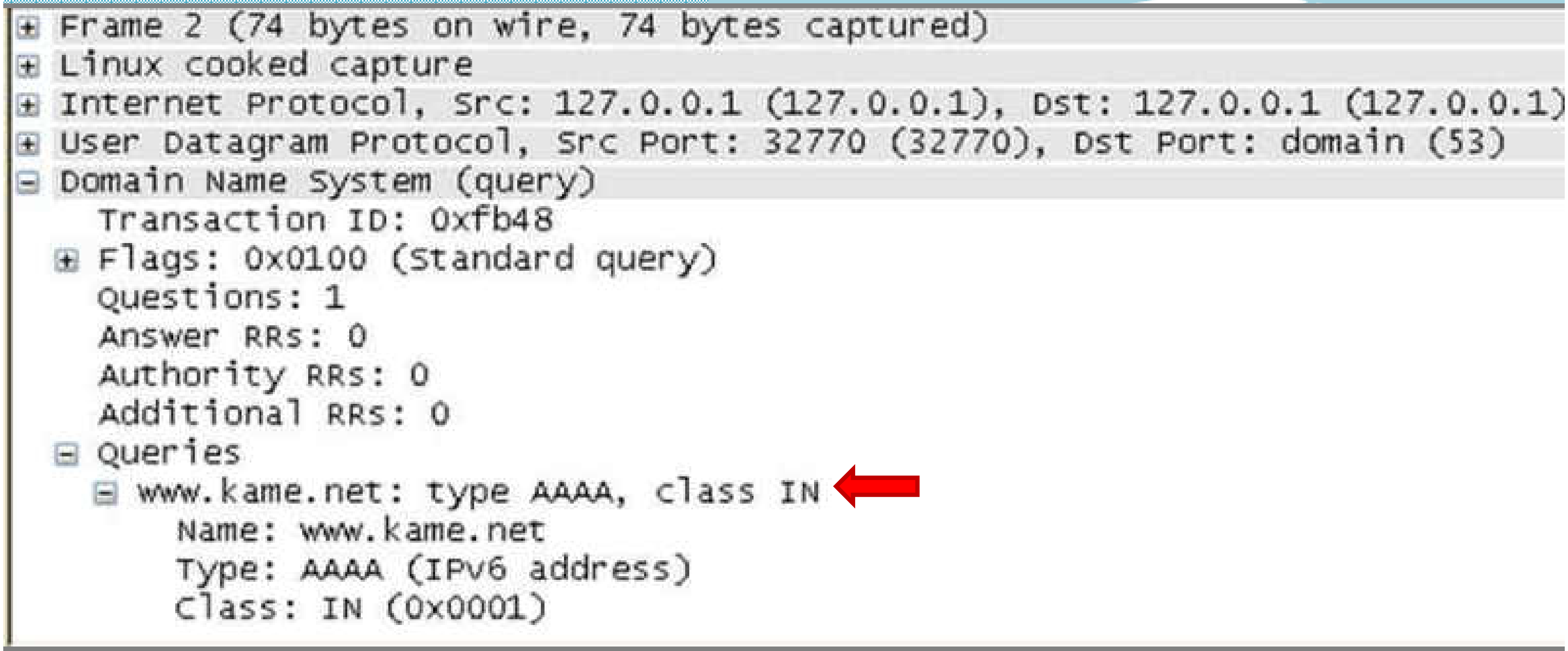
-
  ```
  # get the name for an IPv4 address
    dig  -x 209.131.36.158
  ```

-
  ```
  # get a list of yahoo's mail servers
    dig  yahoo.com MX
  ```

-
  ```
  # get a list of DNS servers authoritative for yahoo.com
    dig  yahoo.com NS
  ```

-
  ```
  # get all of the above
    dig  yahoo.com ANY
  ```

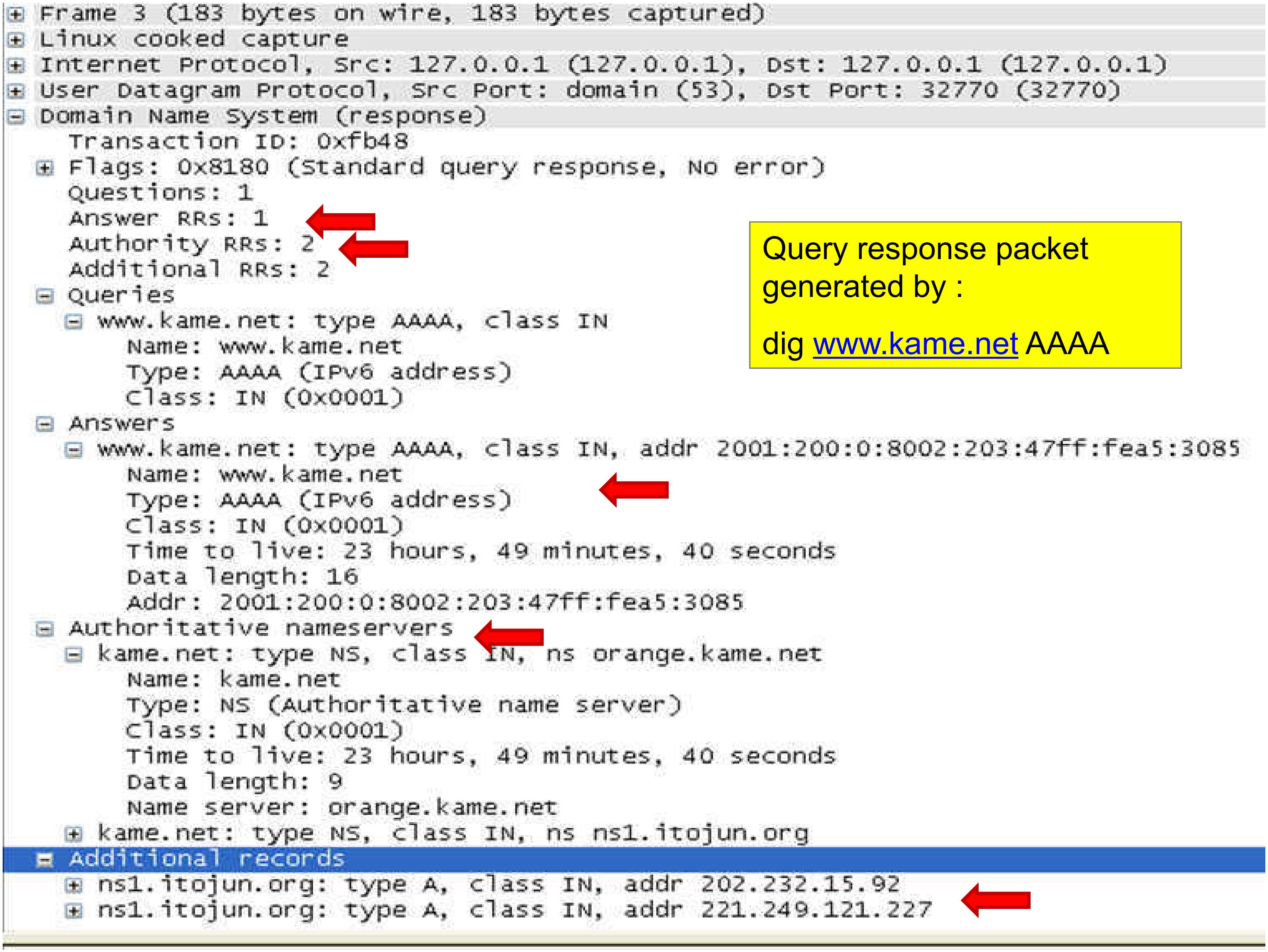
DNS Query – DIG AAAA



```
⊞ Frame 2 (74 bytes on wire, 74 bytes captured)
⊞ Linux cooked capture
⊞ Internet Protocol, Src: 127.0.0.1 (127.0.0.1), Dst: 127.0.0.1 (127.0.0.1)
⊞ User Datagram Protocol, Src Port: 32770 (32770), Dst Port: domain (53)
⊟ Domain Name System (query)
    Transaction ID: 0xfb48
  ⊞ Flags: 0x0100 (Standard query)
    Questions: 1
    Answer RRs: 0
    Authority RRs: 0
    Additional RRs: 0
  ⊟ Queries
    ⊟ www.kame.net: type AAAA, class IN
        Name: www.kame.net
        Type: AAAA (IPv6 address)
        Class: IN (0x0001)
```

Query packet generated by :

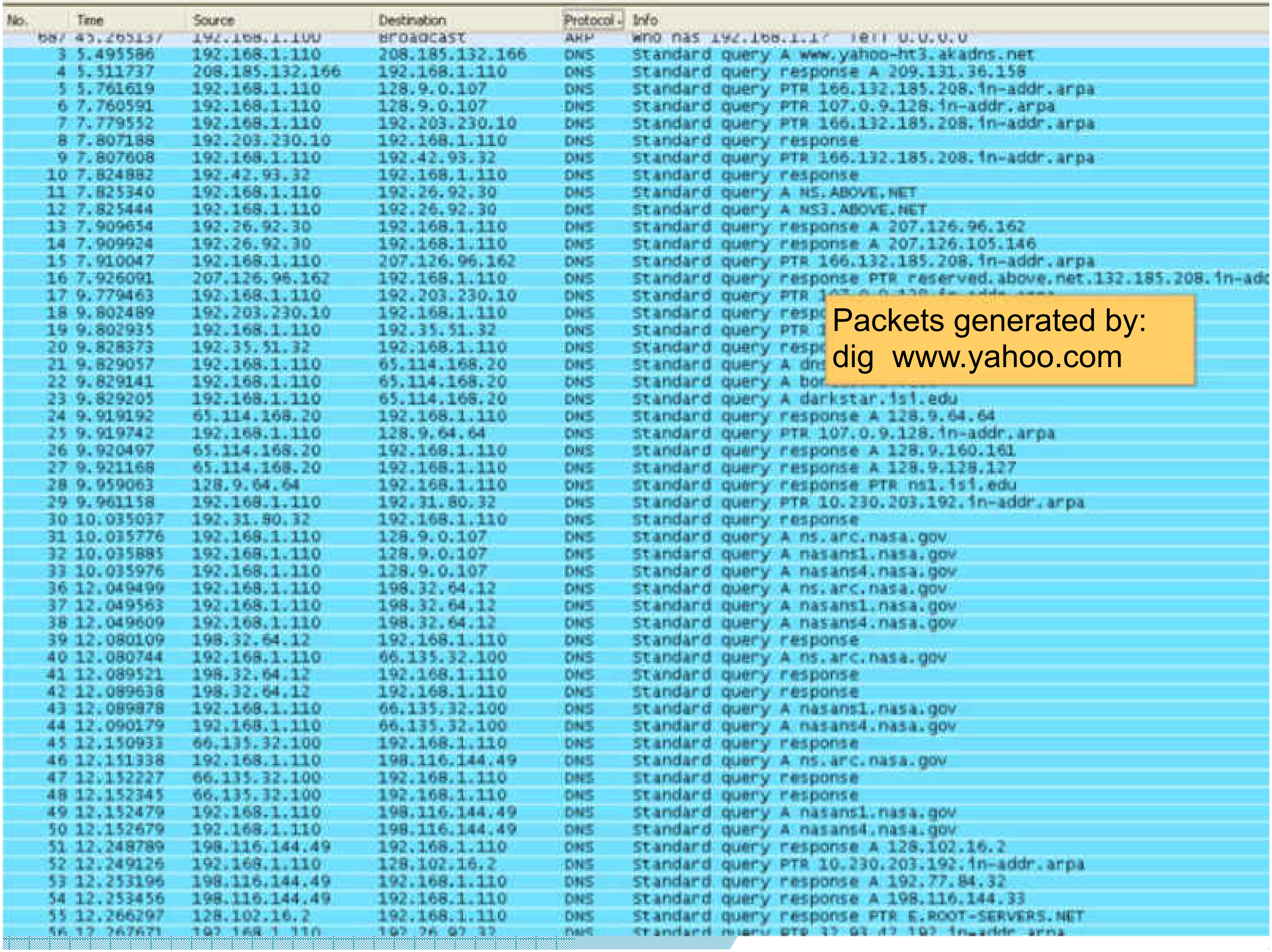
dig www.kame.net AAAA



```
⊞ Frame 3 (183 bytes on wire, 183 bytes captured)
⊞ Linux cooked capture
⊞ Internet Protocol, Src: 127.0.0.1 (127.0.0.1), Dst: 127.0.0.1 (127.0.0.1)
⊞ User Datagram Protocol, Src Port: domain (53), Dst Port: 32770 (32770)
⊟ Domain Name System (response)
    Transaction ID: 0xfb48
  ⊞ Flags: 0x8180 (Standard query response, No error)
    Questions: 1
    Answer RRs: 1
    Authority RRs: 2
    Additional RRs: 2
  ⊟ Queries
    ⊟ www.kame.net: type AAAA, class IN
        Name: www.kame.net
        Type: AAAA (IPv6 address)
        Class: IN (0x0001)
  ⊟ Answers
    ⊟ www.kame.net: type AAAA, class IN, addr 2001:200:0:8002:203:47ff:fea5:3085
        Name: www.kame.net
        Type: AAAA (IPv6 address)
        Class: IN (0x0001)
        Time to live: 23 hours, 49 minutes, 40 seconds
        Data length: 16
        Addr: 2001:200:0:8002:203:47ff:fea5:3085
  ⊟ Authoritative nameservers
    ⊟ kame.net: type NS, class IN, ns orange.kame.net
        Name: kame.net
        Type: NS (Authoritative name server)
        Class: IN (0x0001)
        Time to live: 23 hours, 49 minutes, 40 seconds
        Data length: 9
        Name server: orange.kame.net
    ⊞ kame.net: type NS, class IN, ns ns1.itojun.org
  ⊟ Additional records
    ⊞ ns1.itojun.org: type A, class IN, addr 202.232.15.92
    ⊞ ns1.itojun.org: type A, class IN, addr 221.249.121.227
```

Query response packet generated by :

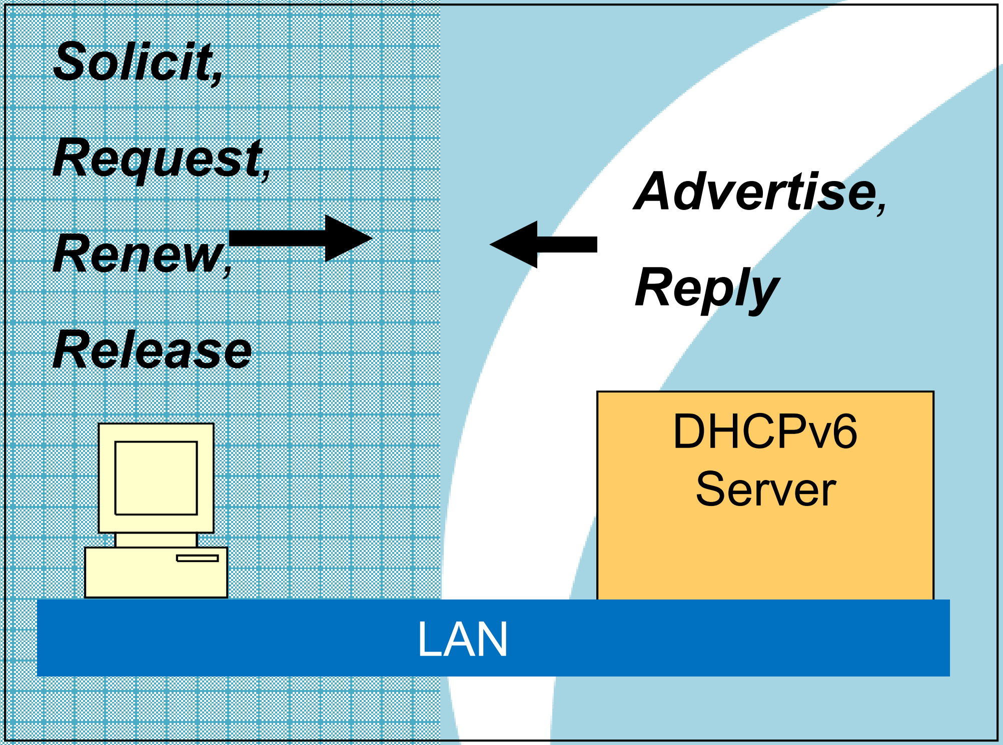
dig www.kame.net AAAA



```
No.    Time        Source            Destination       Protocol  Info
   687 45.265137   192.168.1.100     Broadcast         ARP       Who has 192.168.1.1?  Tell 0.0.0.0
     3 5.495586    192.168.1.110     208.185.132.166   DNS       Standard query A www.yahoo-ht3.akadns.net
     4 5.511737    208.185.132.166   192.168.1.110     DNS       Standard query response A 209.131.36.158
     5 5.761619    192.168.1.110     128.9.0.107       DNS       Standard query PTR 166.132.185.208.in-addr.arpa
     6 7.760591    192.168.1.110     128.9.0.107       DNS       Standard query PTR 107.0.9.128.in-addr.arpa
     7 7.779552    192.168.1.110     192.203.230.10    DNS       Standard query PTR 166.132.185.208.in-addr.arpa
     8 7.807188    192.203.230.10    192.168.1.110     DNS       Standard query response
     9 7.807608    192.168.1.110     192.42.93.32      DNS       Standard query PTR 166.132.185.208.in-addr.arpa
    10 7.824882    192.42.93.32      192.168.1.110     DNS       Standard query response
    11 7.825340    192.168.1.110     192.26.92.30      DNS       Standard query A NS.ABOVE.NET
    12 7.825444    192.168.1.110     192.26.92.30      DNS       Standard query A NS3.ABOVE.NET
    13 7.909654    192.26.92.30      192.168.1.110     DNS       Standard query response A 207.126.96.162
    14 7.909924    192.26.92.30      192.168.1.110     DNS       Standard query response A 207.126.105.146
    15 7.910047    192.168.1.110     207.126.96.162    DNS       Standard query PTR 166.132.185.208.in-addr.arpa
    16 7.926091    207.126.96.162    192.168.1.110     DNS       Standard query response PTR reserved.above.net.132.185.208.in-add
    17 9.779463    192.168.1.110     192.203.230.10    DNS       Standard query PTR 1
    18 9.802489    192.203.230.10    192.168.1.110     DNS       Standard query respo
    19 9.802935    192.168.1.110     192.35.51.32      DNS       Standard query PTR 1
    20 9.828373    192.35.51.32      192.168.1.110     DNS       Standard query respo
    21 9.829057    192.168.1.110     65.114.168.20     DNS       Standard query A dns
    22 9.829141    192.168.1.110     65.114.168.20     DNS       Standard query A bo
    23 9.829205    192.168.1.110     65.114.168.20     DNS       Standard query A darkstar.isi.edu
    24 9.919192    65.114.168.20     192.168.1.110     DNS       Standard query response A 128.9.64.64
    25 9.919742    192.168.1.110     128.9.64.64       DNS       Standard query PTR 107.0.9.128.in-addr.arpa
    26 9.920497    65.114.168.20     192.168.1.110     DNS       Standard query response A 128.9.160.161
    27 9.921168    65.114.168.20     192.168.1.110     DNS       Standard query response A 128.9.128.127
    28 9.959063    128.9.64.64       192.168.1.110     DNS       Standard query response PTR ns1.isi.edu
    29 9.961158    192.168.1.110     192.31.80.32      DNS       Standard query PTR 10.230.203.192.in-addr.arpa
    30 10.035037   192.31.80.32      192.168.1.110     DNS       Standard query response
    31 10.035776   192.168.1.110     128.9.0.107       DNS       Standard query A ns.arc.nasa.gov
    32 10.035885   192.168.1.110     128.9.0.107       DNS       Standard query A nasans1.nasa.gov
    33 10.035976   192.168.1.110     128.9.0.107       DNS       Standard query A nasans4.nasa.gov
    36 12.049499   192.168.1.110     198.32.64.12      DNS       Standard query A ns.arc.nasa.gov
    37 12.049563   192.168.1.110     198.32.64.12      DNS       Standard query A nasans1.nasa.gov
    38 12.049609   192.168.1.110     198.32.64.12      DNS       Standard query A nasans4.nasa.gov
    39 12.080109   198.32.64.12      192.168.1.110     DNS       Standard query response
    40 12.080744   192.168.1.110     66.135.32.100     DNS       Standard query A ns.arc.nasa.gov
    41 12.089521   198.32.64.12      192.168.1.110     DNS       Standard query response
    42 12.089638   198.32.64.12      192.168.1.110     DNS       Standard query response
    43 12.089878   192.168.1.110     66.135.32.100     DNS       Standard query A nasans1.nasa.gov
    44 12.090179   192.168.1.110     66.135.32.100     DNS       Standard query A nasans4.nasa.gov
    45 12.150933   66.135.32.100     192.168.1.110     DNS       Standard query response
    46 12.151338   192.168.1.110     198.116.144.49    DNS       Standard query A ns.arc.nasa.gov
    47 12.152227   66.135.32.100     192.168.1.110     DNS       Standard query response
    48 12.152345   66.135.32.100     192.168.1.110     DNS       Standard query response
    49 12.152479   192.168.1.110     198.116.144.49    DNS       Standard query A nasans1.nasa.gov
    50 12.152679   192.168.1.110     198.116.144.49    DNS       Standard query A nasans4.nasa.gov
    51 12.248789   198.116.144.49    192.168.1.110     DNS       Standard query response A 128.102.16.2
    52 12.249126   192.168.1.110     128.102.16.2      DNS       Standard query PTR 10.230.203.192.in-addr.arpa
    53 12.253196   198.116.144.49    192.168.1.110     DNS       Standard query response A 192.77.84.32
    54 12.253456   198.116.144.49    192.168.1.110     DNS       Standard query response A 198.116.144.33
    55 12.266297   128.102.16.2      192.168.1.110     DNS       Standard query response PTR E.ROOT-SERVERS.NET
    56 12.267671   192.168.1.110     192.26.92.32      DNS       Standard query PTR 32.93.42.192.in-addr.arpa
```

Packets generated by:
dig www.yahoo.com

DHCPv6 Basic Commands



Solicit,

Request,

Renew,

Release

Advertise,

Reply

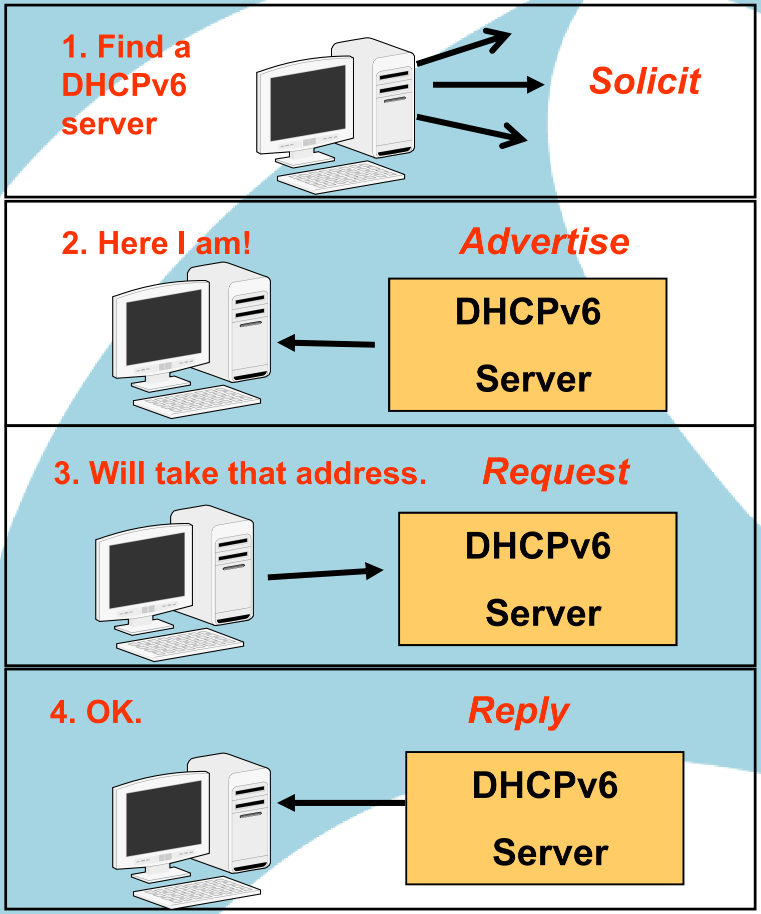
DHCPv6 Flow : Start

1. Client sends a ***Solicit*** message to All_DHCP_Relay_Agents_and_Servers (FF02::1:2)

2. DHCPv6 servers respond with ***Advertise*** messages.

3. Client chooses a server and sends a ***Request*** message

4. DHCPv6 server responds with a ***Reply*** message



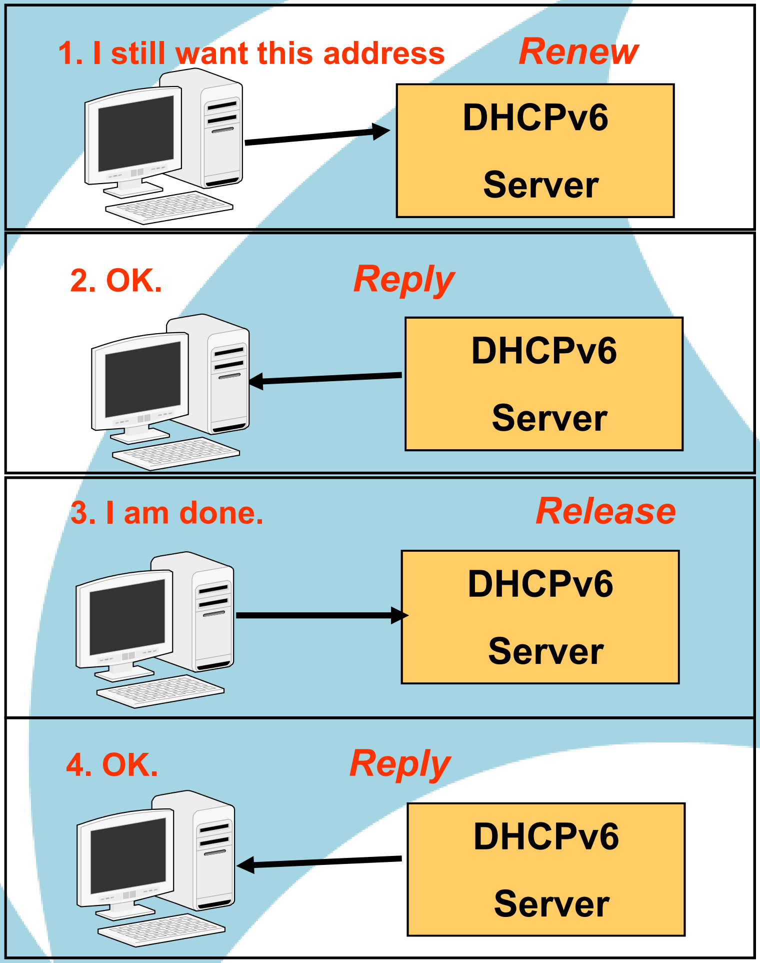
DHCPv6 Flow – Continue / End

1. Client sends a ***Renew*** message to DHCPv6 server

2. DHCPv6 server responds with ***Reply*** message.

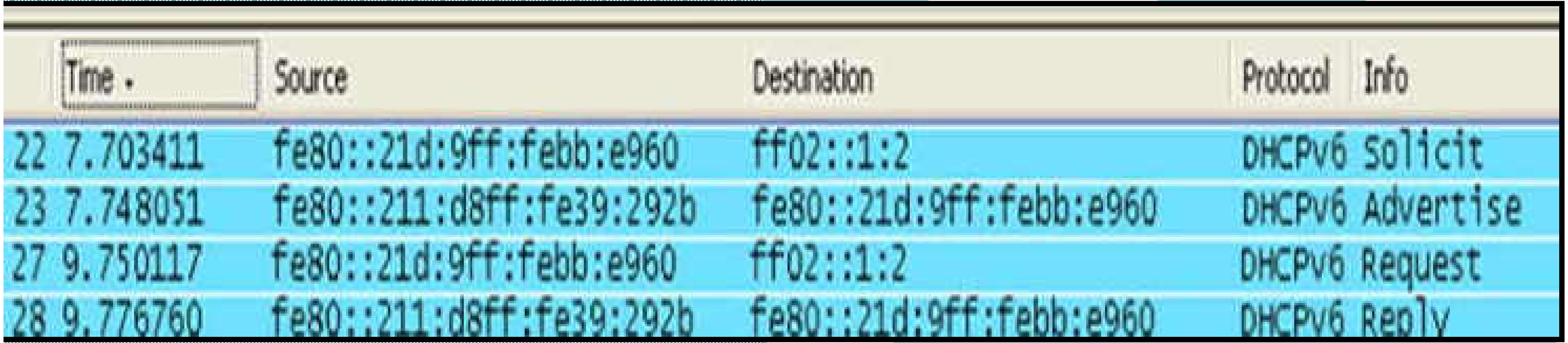
3. Client sends a ***Release*** message to DHCPv6 server.

4. DHCPv6 server responds with a ***Reply*** message



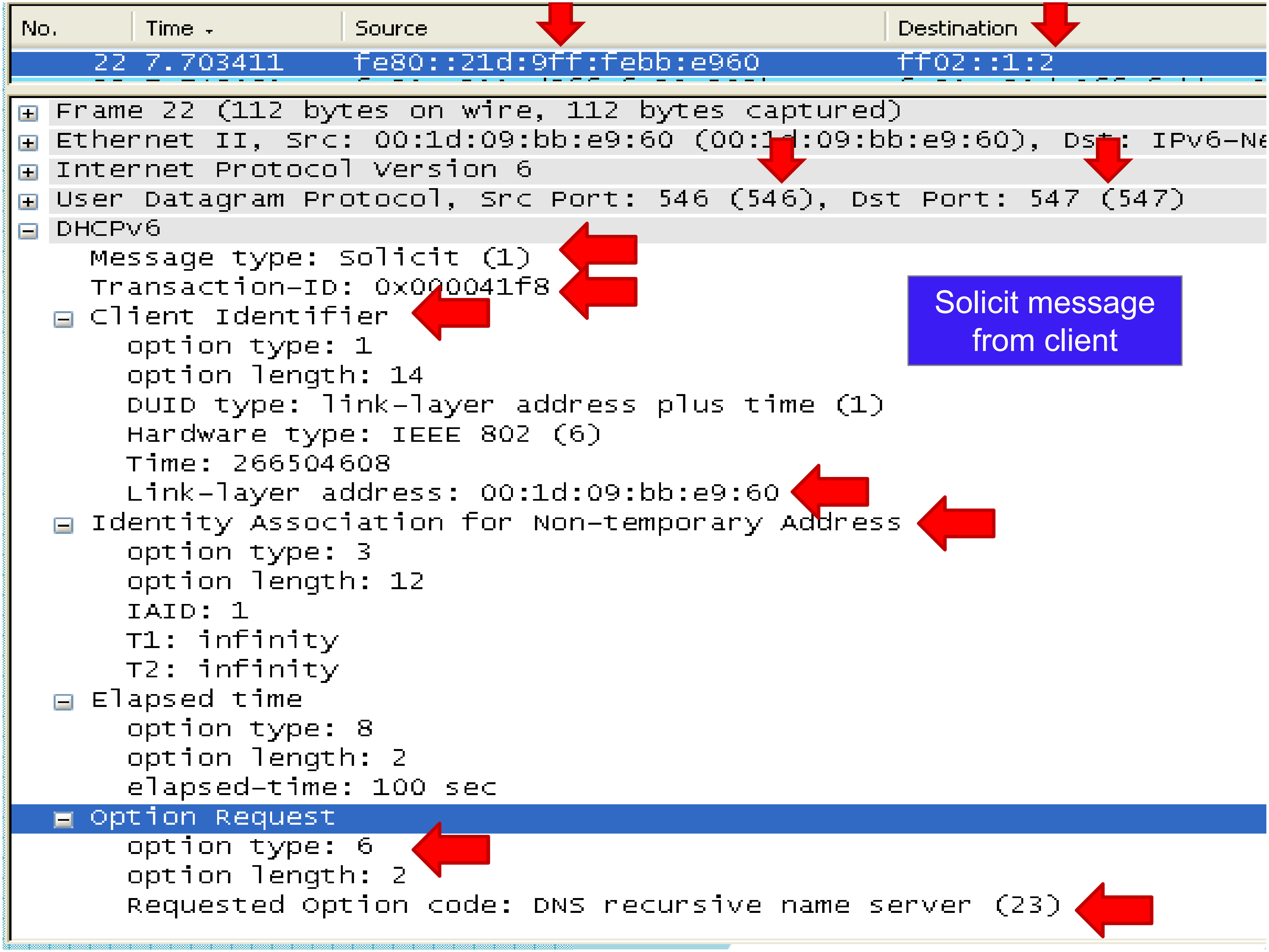
Packets for Initialization

Generated for client getting address from DHCPv6 server



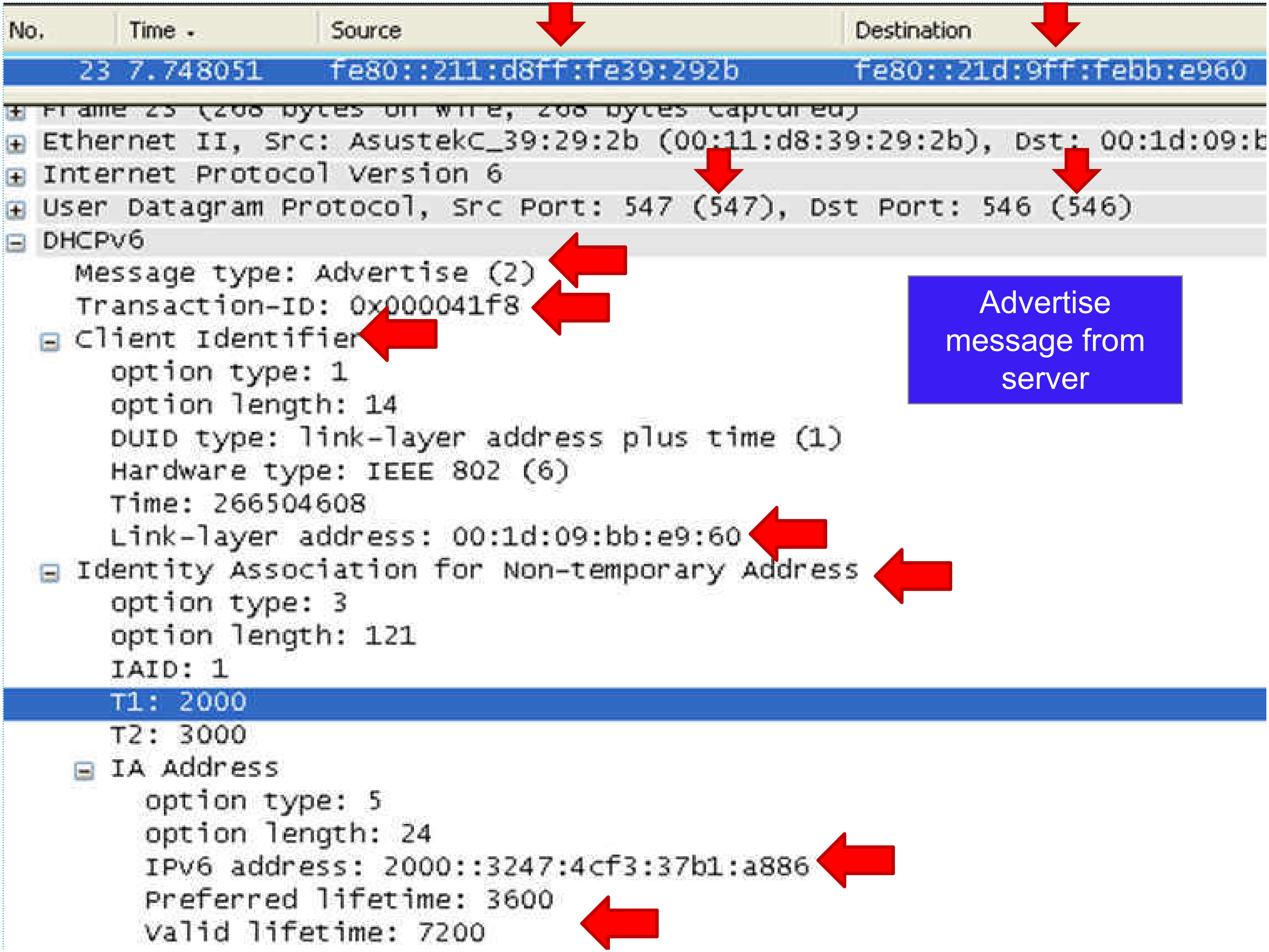
	Time	Source	Destination	Protocol	Info
22	7.703411	fe80::21d:9ff:febb:e960	ff02::1:2	DHCPv6	Solicit
23	7.748051	fe80::211:d8ff:fe39:292b	fe80::21d:9ff:febb:e960	DHCPv6	Advertise
27	9.750117	fe80::21d:9ff:febb:e960	ff02::1:2	DHCPv6	Request
28	9.776760	fe80::211:d8ff:fe39:292b	fe80::21d:9ff:febb:e960	DHCPv6	Reply

- Packet 22: ***Solicit*** from link-local of client to multicast All_DHCP_Relay_Agents_and_Servers (FF02::1:2)
- Packet 23: ***Advertise*** from link-local of DHCPv6 server to link-local of client
- Packet 27: ***Request*** from link-local of client to multicast All_DHCP_Relay_Agents_and_Servers (FF02::1:2)
- Packet 28: ***Reply*** from link-local of DHCPv6 server to link-local of client



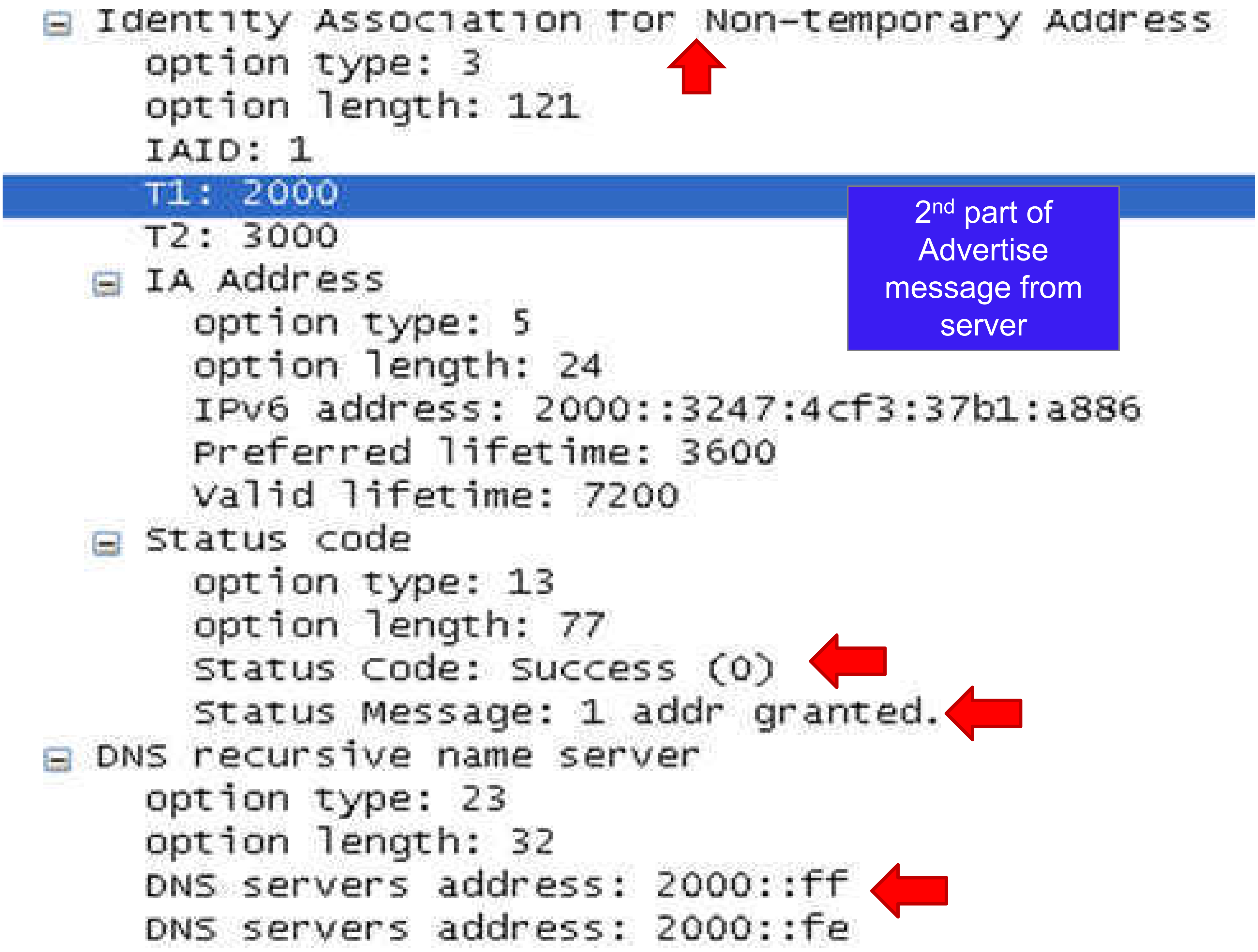
```
No.      Time           Source                                  Destination
     22  7.703411       fe80::21d:9ff:febb:e960                 ff02::1:2

⊞ Frame 22 (112 bytes on wire, 112 bytes captured)
⊞ Ethernet II, Src: 00:1d:09:bb:e9:60 (00:1d:09:bb:e9:60), Dst: IPv6-Ne
⊞ Internet Protocol Version 6
⊞ User Datagram Protocol, Src Port: 546 (546), Dst Port: 547 (547)
⊟ DHCPv6
    Message type: Solicit (1)
    Transaction-ID: 0x000041f8
  ⊟ Client Identifier
      option type: 1
      option length: 14
      DUID type: link-layer address plus time (1)
      Hardware type: IEEE 802 (6)
      Time: 266504608
      Link-layer address: 00:1d:09:bb:e9:60
  ⊟ Identity Association for Non-temporary Address
      option type: 3
      option length: 12
      IAID: 1
      T1: infinity
      T2: infinity
  ⊟ Elapsed time
      option type: 8
      option length: 2
      elapsed-time: 100 sec
  ⊟ Option Request
      option type: 6
      option length: 2
      Requested Option code: DNS recursive name server (23)
```

Solicit message from client



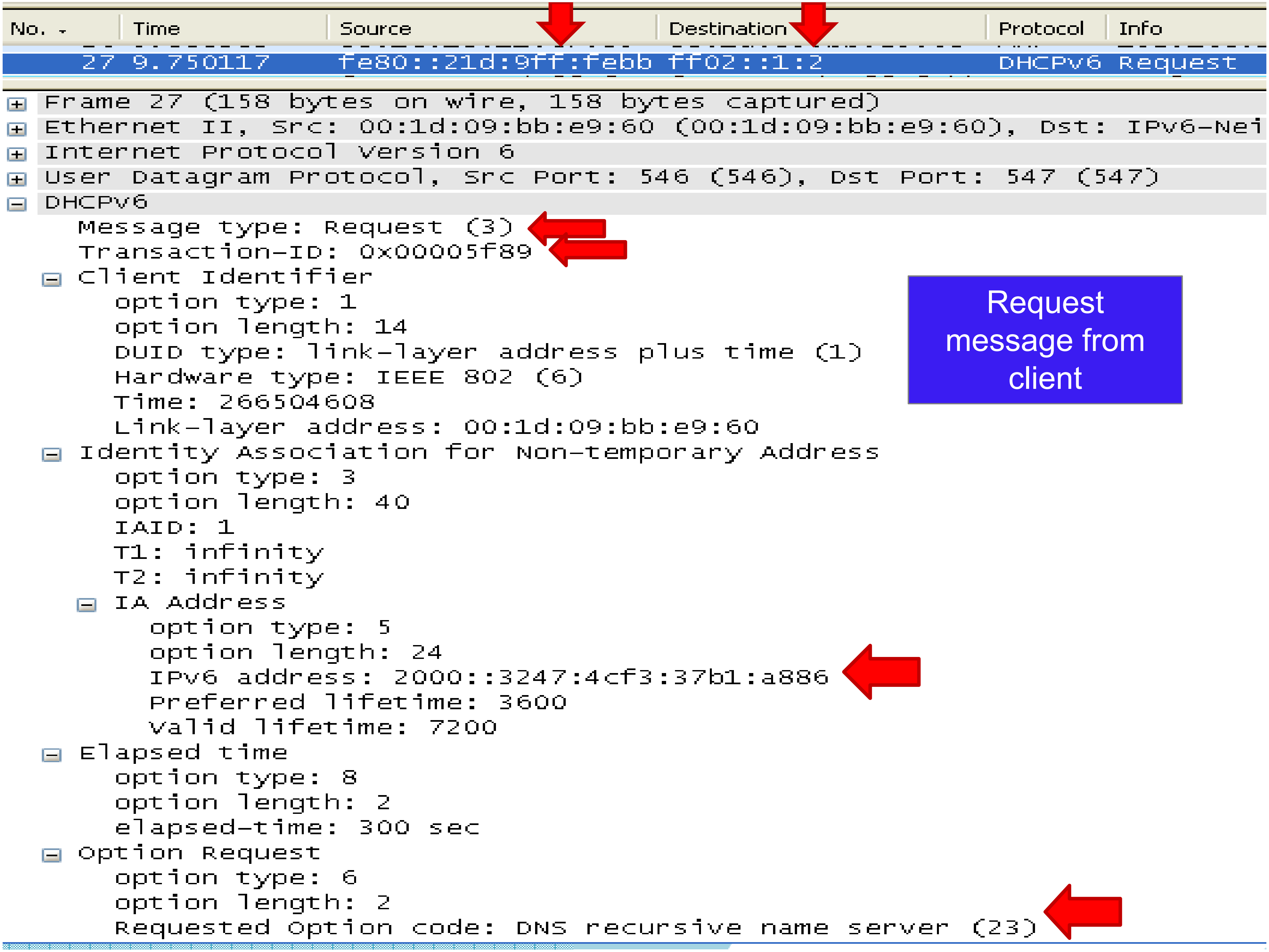
```
No.   Time -        Source                              Destination
 23 7.748051    fe80::211:d8ff:fe39:292b           fe80::21d:9ff:febb:e960
⊞ Frame 23 (268 bytes on wire, 268 bytes captured)
⊞ Ethernet II, Src: AsustekC_39:29:2b (00:11:d8:39:29:2b), Dst: 00:1d:09:b
⊞ Internet Protocol Version 6
⊞ User Datagram Protocol, Src Port: 547 (547), Dst Port: 546 (546)
⊟ DHCPv6
    Message type: Advertise (2)
    Transaction-ID: 0x000041f8
  ⊟ Client Identifier
      option type: 1
      option length: 14
      DUID type: link-layer address plus time (1)
      Hardware type: IEEE 802 (6)
      Time: 266504608
      Link-layer address: 00:1d:09:bb:e9:60
  ⊟ Identity Association for Non-temporary Address
      option type: 3
      option length: 121
      IAID: 1
      T1: 2000
      T2: 3000
    ⊟ IA Address
        option type: 5
        option length: 24
        IPv6 address: 2000::3247:4cf3:37b1:a886
        Preferred lifetime: 3600
        Valid lifetime: 7200
```

Advertise message from server



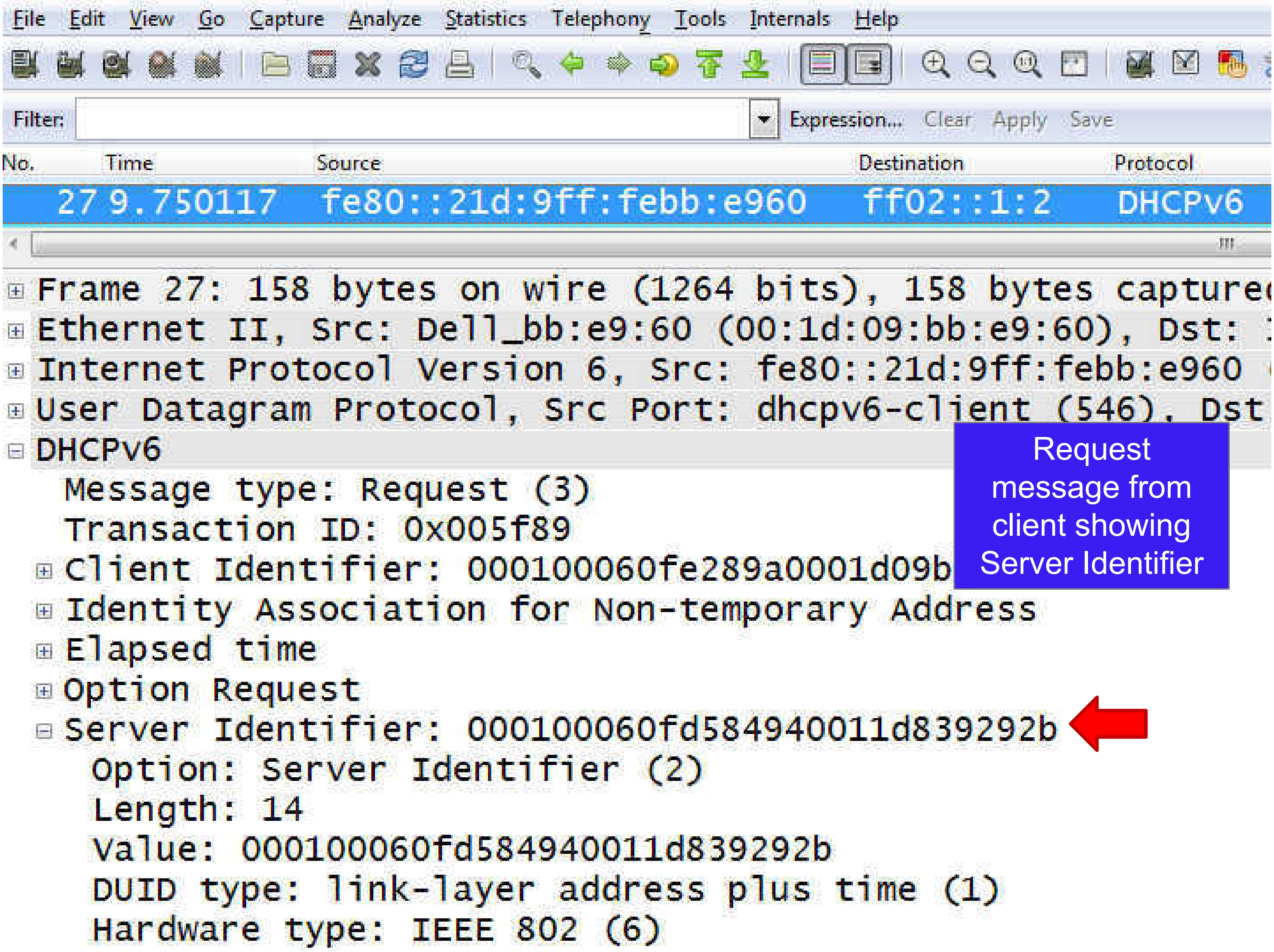
```
⊟ Identity Association for Non-temporary Address
    option type: 3
    option length: 121
    IAID: 1
    T1: 2000
    T2: 3000
  ⊟ IA Address
      option type: 5
      option length: 24
      IPv6 address: 2000::3247:4cf3:37b1:a886
      Preferred lifetime: 3600
      Valid lifetime: 7200
  ⊟ Status code
      option type: 13
      option length: 77
      Status Code: Success (0)
      Status Message: 1 addr granted.
⊟ DNS recursive name server
    option type: 23
    option length: 32
    DNS servers address: 2000::ff
    DNS servers address: 2000::fe
```

2nd part of Advertise message from server



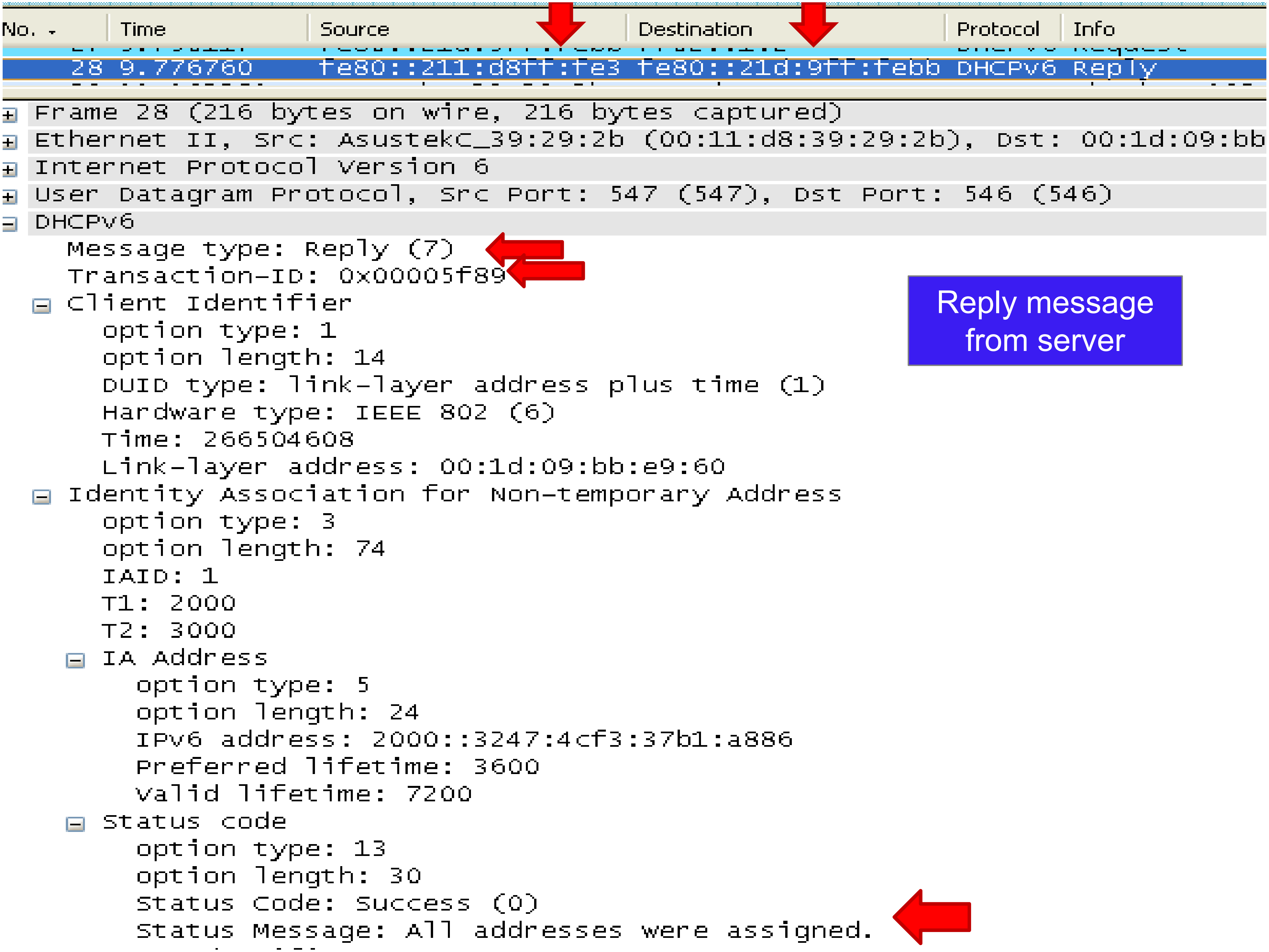
```
No.      Time        Source                  Destination         Protocol  Info
   27 9.750117    fe80::21d:9ff:febb ff02::1:2              DHCPv6 Request

⊞ Frame 27 (158 bytes on wire, 158 bytes captured)
⊞ Ethernet II, Src: 00:1d:09:bb:e9:60 (00:1d:09:bb:e9:60), Dst: IPv6-Nei
⊞ Internet Protocol Version 6
⊞ User Datagram Protocol, Src Port: 546 (546), Dst Port: 547 (547)
⊟ DHCPv6
    Message type: Request (3)
    Transaction-ID: 0x00005f89
  ⊟ Client Identifier
      option type: 1
      option length: 14
      DUID type: link-layer address plus time (1)
      Hardware type: IEEE 802 (6)
      Time: 266504608
      Link-layer address: 00:1d:09:bb:e9:60
  ⊟ Identity Association for Non-temporary Address
      option type: 3
      option length: 40
      IAID: 1
      T1: infinity
      T2: infinity
    ⊟ IA Address
        option type: 5
        option length: 24
        IPv6 address: 2000::3247:4cf3:37b1:a886
        Preferred lifetime: 3600
        valid lifetime: 7200
  ⊟ Elapsed time
      option type: 8
      option length: 2
      elapsed-time: 300 sec
  ⊟ Option Request
      option type: 6
      option length: 2
      Requested Option code: DNS recursive name server (23)
```

Request message from client


File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter:
Expression... Clear Apply Save

```
No.      Time          Source                          Destination      Protocol
   27 9.750117   fe80::21d:9ff:febb:e960    ff02::1:2      DHCPv6

⊞ Frame 27: 158 bytes on wire (1264 bits), 158 bytes capture
⊞ Ethernet II, Src: Dell_bb:e9:60 (00:1d:09:bb:e9:60), Dst: 
⊞ Internet Protocol Version 6, Src: fe80::21d:9ff:febb:e960 
⊞ User Datagram Protocol, Src Port: dhcpv6-client (546), Dst
⊟ DHCPv6
    Message type: Request (3)
    Transaction ID: 0x005f89
  ⊞ Client Identifier: 000100060fe289a0001d09b
  ⊞ Identity Association for Non-temporary Address
  ⊞ Elapsed time
  ⊞ Option Request
  ⊟ Server Identifier: 000100060fd58494011d839292b
      Option: Server Identifier (2)
      Length: 14
      Value: 000100060fd58494011d839292b
      DUID type: link-layer address plus time (1)
      Hardware type: IEEE 802 (6)
```

Request message from client showing Server Identifier

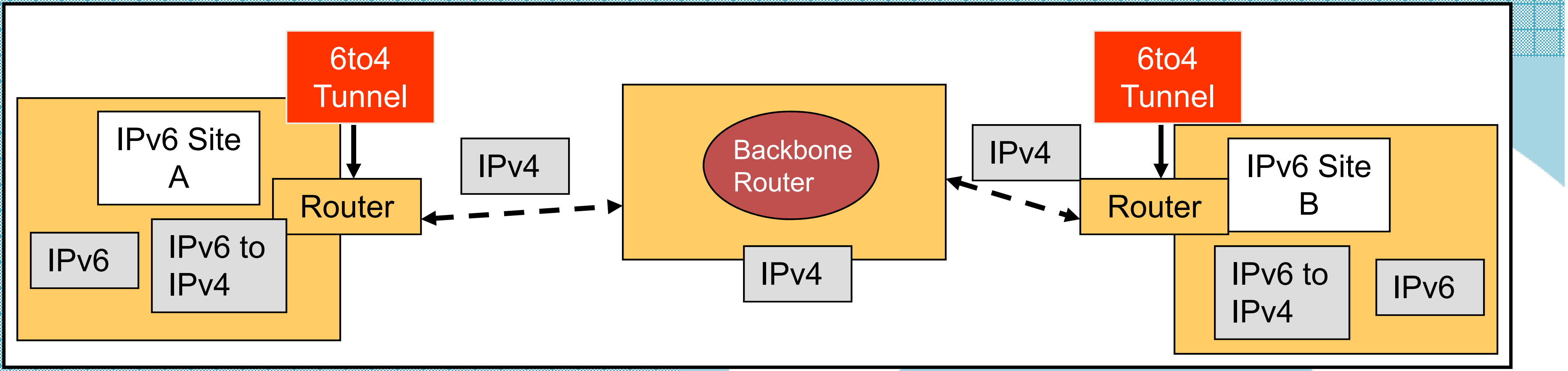


```
28 9.776760    fe80::211:d8ff:fe3 fe80::21d:9ff:febb DHCPv6 Reply
```

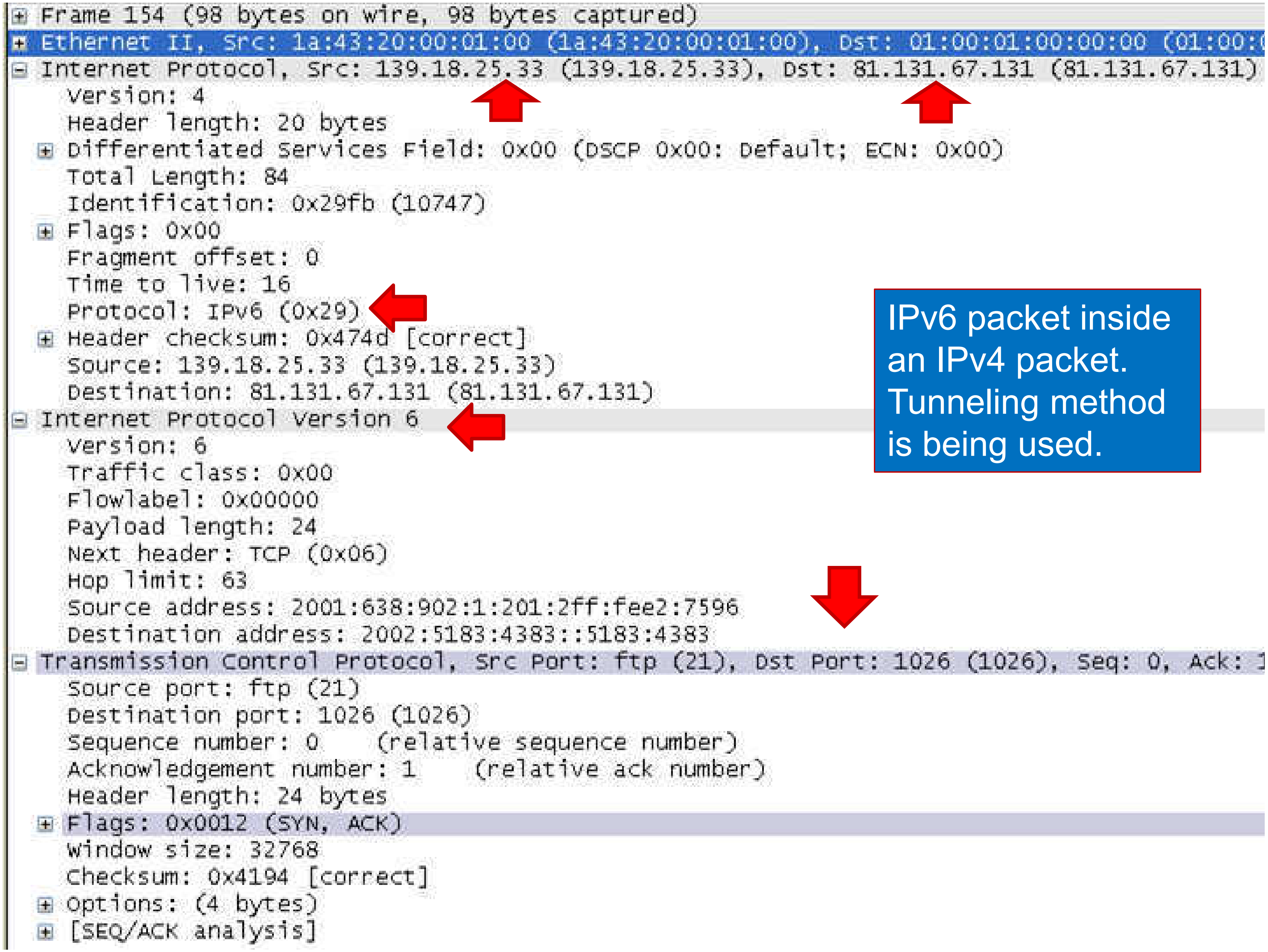
```
+ Frame 28 (216 bytes on wire, 216 bytes captured)
+ Ethernet II, Src: AsustekC_39:29:2b (00:11:d8:39:29:2b), Dst: 00:1d:09:bb
+ Internet Protocol Version 6
+ User Datagram Protocol, Src Port: 547 (547), Dst Port: 546 (546)
- DHCPv6
    Message type: Reply (7)
    Transaction-ID: 0x00005f89
  - Client Identifier
      option type: 1
      option length: 14
      DUID type: link-layer address plus time (1)
      Hardware type: IEEE 802 (6)
      Time: 266504608
      Link-layer address: 00:1d:09:bb:e9:60
  - Identity Association for Non-temporary Address
      option type: 3
      option length: 74
      IAID: 1
      T1: 2000
      T2: 3000
    - IA Address
        option type: 5
        option length: 24
        IPv6 address: 2000::3247:4cf3:37b1:a886
        Preferred lifetime: 3600
        Valid lifetime: 7200
    - Status code
        option type: 13
        option length: 30
        Status Code: Success (0)
        Status Message: All addresses were assigned.
```

Reply message from server

6to4 Tunnels



- **6to4** tunnels allow IPv6 packets over an IPv4 network.
- RFC 3056: Connection of IPv6 Domains via IPv4 Clouds.
- 6to4 is transition mechanism
- Operational differences
  - 6to4 interface automatically created in Windows XP and above
  - Most Unix implementations support 6to4
  - Cisco routers support 6to4 tunnels
  - z/OS Communications Server mainframe cannot be tunnel endpoint

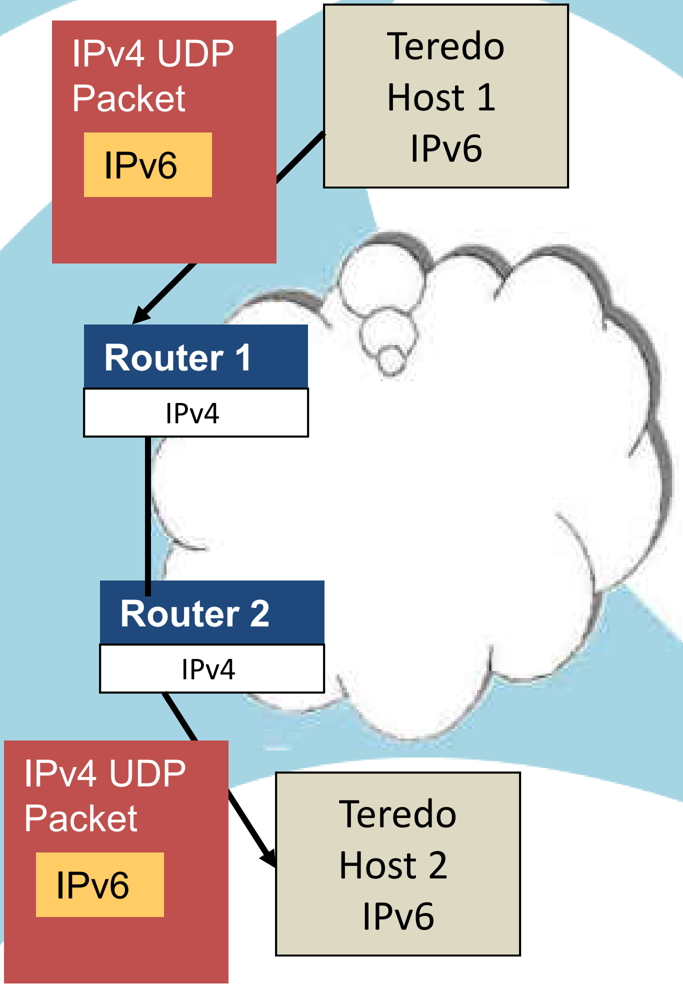


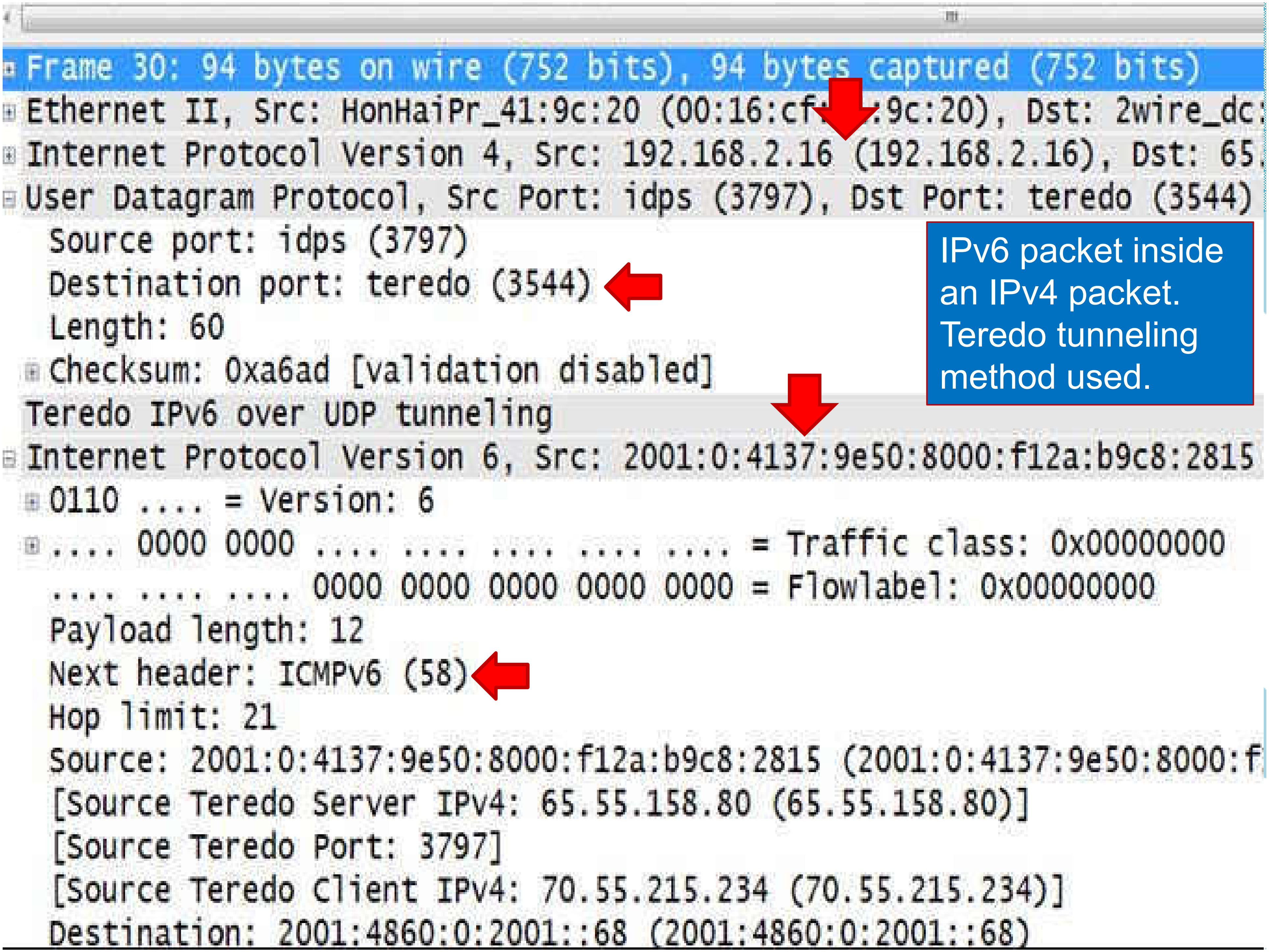
```
⊞ Frame 154 (98 bytes on wire, 98 bytes captured)
⊞ Ethernet II, Src: 1a:43:20:00:01:00 (1a:43:20:00:01:00), Dst: 01:00:01:00:00:00 (01:00:0
⊟ Internet Protocol, Src: 139.18.25.33 (139.18.25.33), Dst: 81.131.67.131 (81.131.67.131)
    Version: 4
    Header length: 20 bytes
  ⊞ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
    Total Length: 84
    Identification: 0x29fb (10747)
  ⊞ Flags: 0x00
    Fragment offset: 0
    Time to live: 16
    Protocol: IPv6 (0x29)
  ⊞ Header checksum: 0x474d [correct]
    Source: 139.18.25.33 (139.18.25.33)
    Destination: 81.131.67.131 (81.131.67.131)
⊟ Internet Protocol Version 6
    Version: 6
    Traffic class: 0x00
    Flowlabel: 0x00000
    Payload length: 24
    Next header: TCP (0x06)
    Hop limit: 63
    Source address: 2001:638:902:1:201:2ff:fee2:7596
    Destination address: 2002:5183:4383::5183:4383
⊟ Transmission Control Protocol, Src Port: ftp (21), Dst Port: 1026 (1026), Seq: 0, Ack: 1
    Source port: ftp (21)
    Destination port: 1026 (1026)
    Sequence number: 0    (relative sequence number)
    Acknowledgement number: 1    (relative ack number)
    Header length: 24 bytes
  ⊞ Flags: 0x0012 (SYN, ACK)
    Window size: 32768
    Checksum: 0x4194 [correct]
  ⊞ Options: (4 bytes)
  ⊞ [SEQ/ACK analysis]
```

IPv6 packet inside an IPv4 packet. Tunneling method is being used.

Why Teredo?

- Teredo does not need a router
- Tunneling issues with NAT
- NATs don’t translate IPv6 packets in IPv4
- Teredo uses UDP encapsulation. (IPv6 packet becomes IPv4 UDP message
- UDP messages traverse multiple layers of NATs.
- Teredo is subject to the same security issues as any tunneled protocol





```
⊞ Frame 30: 94 bytes on wire (752 bits), 94 bytes captured (752 bits)
⊞ Ethernet II, Src: HonHaiPr_41:9c:20 (00:16:cf:41:9c:20), Dst: 2wire_dc:
⊞ Internet Protocol Version 4, Src: 192.168.2.16 (192.168.2.16), Dst: 65.
⊟ User Datagram Protocol, Src Port: idps (3797), Dst Port: teredo (3544)
    Source port: idps (3797)
    Destination port: teredo (3544)
    Length: 60
  ⊞ Checksum: 0xa6ad [validation disabled]
  Teredo IPv6 over UDP tunneling
⊟ Internet Protocol Version 6, Src: 2001:0:4137:9e50:8000:f12a:b9c8:2815
  ⊞ 0110 .... = Version: 6
  ⊞ .... 0000 0000 .... .... .... .... .... = Traffic class: 0x00000000
    .... .... .... 0000 0000 0000 0000 0000 = Flowlabel: 0x00000000
    Payload length: 12
    Next header: ICMPv6 (58)
    Hop limit: 21
    Source: 2001:0:4137:9e50:8000:f12a:b9c8:2815 (2001:0:4137:9e50:8000:f
    [Source Teredo Server IPv4: 65.55.158.80 (65.55.158.80)]
    [Source Teredo Port: 3797]
    [Source Teredo Client IPv4: 70.55.215.234 (70.55.215.234)]
    Destination: 2001:4860:0:2001::68 (2001:4860:0:2001::68)
```

IPv6 packet inside an IPv4 packet. Teredo tunneling method used.

Other IPv6 Sessions

- **Sunday: 3:00 - Intro to IPv6 Addressing**
- **Tuesday: 4:45 - IPv6 Trace Analysis Using Wireshark**
- **Wednesday: 10:15 - IPv6 Security**