

Deep Dive into IPv6 Extension Header Testing on Cloud Platforms

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Thanks to...



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राष्ट्रीय प्रौद्योगिकी संस्थान
कर्नाटक, सुरत्कल

In particular, Dr. Mohit Tahiliani.
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Industry Network Technology Council

Testing done by: Dr. Priyanka
Sinha and Vivek Jain.

Can IPv6 Extension Headers Be Used on the Internet?

- Controversy for many years
- A number of studies showing that IPv6 extension headers “don’t work”.
- Studies (by and large) sent “fake” IPv6 extension headers to Alexa top n sites.
- If this is true, IPv6 extensibility is at risk. We DO NOT want, IPv6 + n!

Our Goals

- We are doing troubleshooting and trying to isolate and fix problems.
- We are **NOT** doing large scale measurements.
- We will do that after problems are fixed. Otherwise, moving target.
- Two large providers of Internet services appear to have changed their EH handling already. Conversations with a two cloud vendors in progress. They stand ready to work with us.

Our Testing Platform

- Used a small hosting service (not one of the “brand-name” ones).
- All machines are Ubuntu using eBPF. An IPv6 Destination Header (PDM) was sent with every packet.
- Using Apache Web Server. So, real traffic sent to and from cloud.

Cloud Topologies

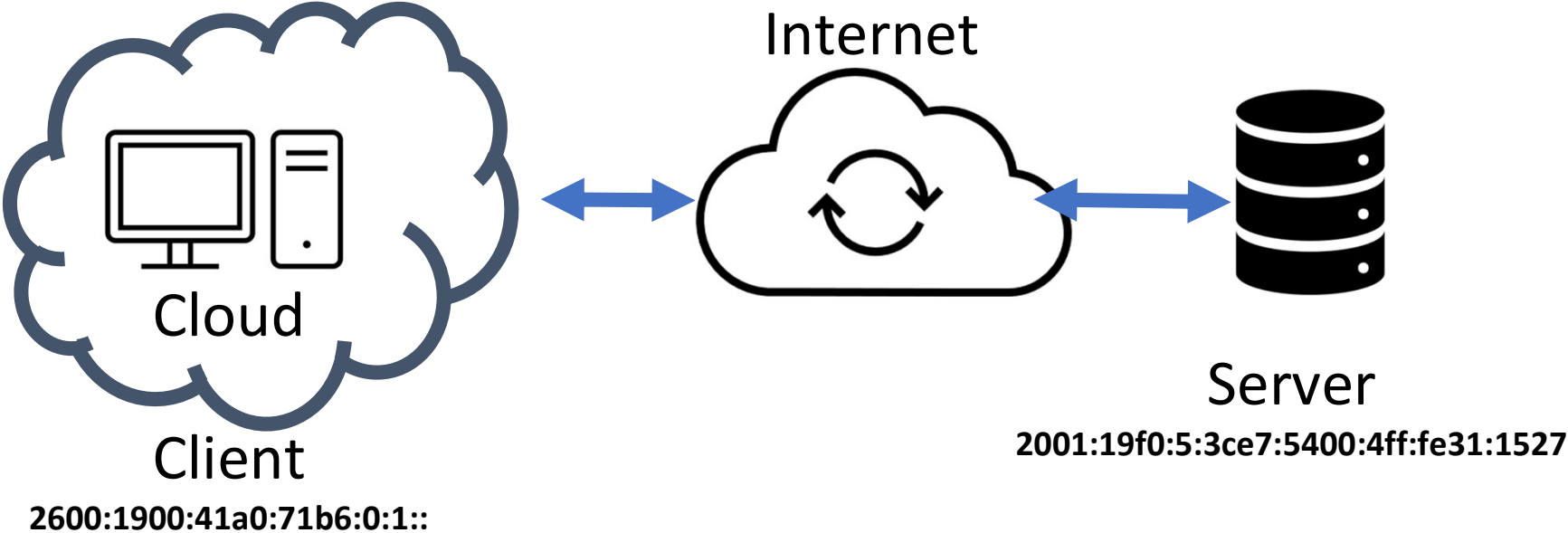
Various configurations:

- Outside Cloud to Inside Cloud
 - Standalone to Cloud (OC-S)
 - Cloud to Standalone (S-OC)
 - Data center to Cloud (OC-D)
- Inside Cloud (IC),
 - Cloud #1 to One Datacenter (IC-SD)
 - Cloud #1 to Multiple Datacenters (IC-MD)
- Between Clouds (BC)
 - Cloud#1 to Cloud #2

Cloud Testing: Outside Cloud to Inside Cloud

Cloud #1 to Standalone outside Cloud (S-OC)

Cloud Client to Internet to External Server



Packet trace with No Extension Headers

http4goog.v3.pcap

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

ipv6

No.	Time	Source	Destination	Info
28	4.609591	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	56948 → 80 [SYN] Seq=0 Win=64
32	4.800563	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	80 → 56948 [SYN, ACK] Seq=0 A
33	4.800633	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	56948 → 80 [ACK] Seq=1 Ack=1
35	4.800885	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	GET / HTTP/1.1
39	4.990622	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	80 → 56948 [ACK] Seq=1 Ack=15
40	4.990826	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	80 → 56948 [PSH, ACK] Seq=1 A

> Frame 28: 94 bytes on wire (752 bits), 94 bytes captured (752 bits)

> Ethernet II, Src: 42:01:0a:01:00:03 (42:01:0a:01:00:03), Dst: 42:01:0a:01:00:01 (42:01:0a:01:00:01)

∨ Internet Protocol Version 6, Src: 2600:1900:41a0:71b6:0:1::, Dst: 2001:19f0:5:3ce7:5400:4ff:fe31:1527

- 0110 = Version: 6
- > 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
- 0000 0000 0110 0011 1010 = Flow Label: 0x0063a
- Payload Length: 40
- Next Header: TCP (6)
- Hop Limit: 64
- Source Address: 2600:1900:41a0:71b6:0:1::
- Destination Address: 2001:19f0:5:3ce7:5400:4ff:fe31:1527

> Transmission Control Protocol, Src Port: 56948, Dst Port: 80, Seq: 0, Len: 0

No Extension Headers

Cloud is client.
Going to
Standalone
server outside
Cloud. No EH.

WHOIS-RWS

WHO-IS
LookUp shows
that this is cloud
provider #1.

You searched for: 2600:1900:41a0:71b6:0:1::

Network	
Net Range	2600:1900:: - 2600:190F:FFFF:FFFF:FFFF:FFFF:FFFF:FFFF
CIDR	2600:1900::/28
Name	[REDACTED] CLOUD
Handle	NET6-2600-1900-1
Parent	NET6-2600 (NET6-2600-1)
Net Type	Direct Allocation
Origin AS	AS [REDACTED]
Organization	[REDACTED]
Registration Date	2014-05-28
Last Updated	2015-09-21
Comments	** The IP addresses under this netblock are in use by [REDACTED] Cloud customers ** Direct all copyright and legal complaints to https://support.[REDACTED].com/legal/oo/report

Bottom Line

- IPv6 to Cloud Provider #1 with no IPv6 extension headers works fine. (PING and HTTP). Client can be inside cloud or outside cloud.

Let's add EHs

http8goog.pcap

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ipv6.addr == 2600:1900:41a0:71b6:0:1::

No.	Time	Source	Destination	Next Header	Info
227	25.279174	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	46378 → 80 [SYN] Seq=
237	26.301452	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	[TCP Retransmission]
241	28.317453	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	[TCP Retransmission]
246	32.509455	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	[TCP Retransmission]
247	40.701447	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	[TCP Retransmission]
418	52.574124	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	41584 → 80 [SYN] Seq=
420	53.597439	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	[TCP Retransmission]
421	55.613447	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	[TCP Retransmission]
436	59.645440	2600:1900:41a0:71b6:0:1::	2001:19f0:5:3ce7:5400:4ff:fe31:1527	Destination Options for IPv6	[TCP Retransmission]

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- > Frame 241: 110 bytes on wire (880 bits), 110 bytes captured (880 bits)
- > Ethernet II, Src: 42:01:0a:01:00:03 (42:01:0a:01:00:03), Dst: 42:01:0a:01:00:01 (42:01:0a:01:00:01)
- ✓ Internet Protocol Version 6, Src: 2600:1900:41a0:71b6:0:1::, Dst: 2001:19f0:5:3ce7:5400:4ff:fe31:1527
 - 0110 = Version: 6
 - > 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: 0)
 - 0011 1001 1000 1001 0010 = Flow Label: 0x39892
 - Payload Length: 56
 - Next Header: Destination Options for IPv6 (60)
 - Hop Limit: 64
 - Source Address: 2600:1900:41a0:71b6:0:1::
 - Destination Address: 2001:19f0:5:3ce7:5400:4ff:fe31:1527
 - > Destination Options for IPv6
 - > Transmission Control Protocol, Src Port: 46378, Dst Port: 80, Seq: 0, Len: 0

Cloud is client (:1::).
 Going to Standalone server outside Cloud.
 Client has EH (:1527).

What is received at other end?

- Nothing!
- (Only IPv4 packets!)

http7vultrnewark.pcap

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ipv6.addr == 2600:1900:41a0:71b6:0:1::


No.	Time	Source	Destination	Next Header	Info
131	13.562679	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	57280 → 80 [SYN] Seq=0
136	14.574968	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	[TCP Retransmission]
137	16.591208	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	[TCP Retransmission]
140	20.622938	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	[TCP Retransmission]
149	28.818898	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	[TCP Retransmission]
300	53.323457	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	58082 → 80 [SYN] Seq=0
302	54.351027	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	[TCP Retransmission]
303	56.366903	2001:19f0:5:3ce7:5400:4ff:fe31:1527	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	[TCP Retransmission]

Frame 131: 110 bytes on wire (880 bits), 110 bytes captured (880 bits)

Ethernet II, Src: 56:00:04:31:15:27 (56:00:04:31:15:27), Dst: fa:19:84:a9:af:ff (fa:19:84:a9:af:ff)

Internet Protocol Version 6, Src: 2001:19f0:5:3ce7:5400:4ff:fe31:1527, Dst: 2600:1900:41a0:71b6:0:1::

- 0110 = Version: 6
- > 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
- 0111 0000 0001 1110 1010 = Flow Label: 0x701ea
- Payload Length: 56
- Next Header: Destination Options for IPv6 (60)
- Hop Limit: 64
- Source Address: 2001:19f0:5:3ce7:5400:4ff:fe31:1527
- Destination Address: 2600:1900:41a0:71b6:0:1::
- Destination Options for IPv6
 - Next Header: TCP (6)
 - Length: 1
 - [Length: 16 bytes]
 - > Performance and Diagnostic Metrics
 - > PadN



Let's try the other way

Cloud is Server (:1::).
 Client is Standalone
 outside Cloud. Client
 has EH (:1527).

What is received at other end?

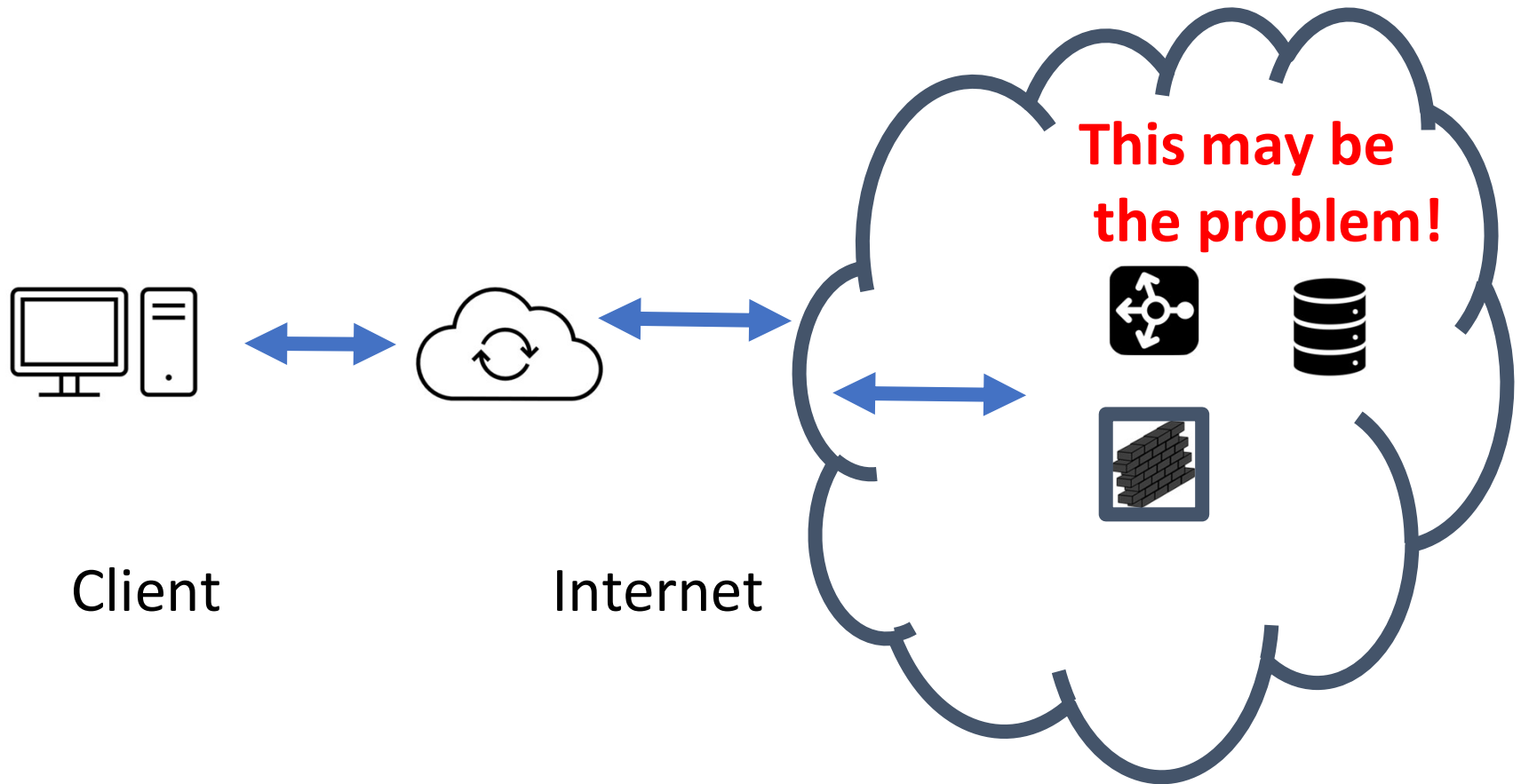
- Nothing!
- (Only IPv4 packets!)

Bottom Line

- IPv6 to Cloud Provider #1 with no IPv6 extension headers works fine. (PING and HTTP). Client can be inside cloud or outside cloud.
- IPv6 with Cloud Provider #1 with IPv6 extension headers does not work. Client can be inside cloud or outside cloud.
 - OS supports EHs
 - “Network” does not support EHs

Realistic Topology

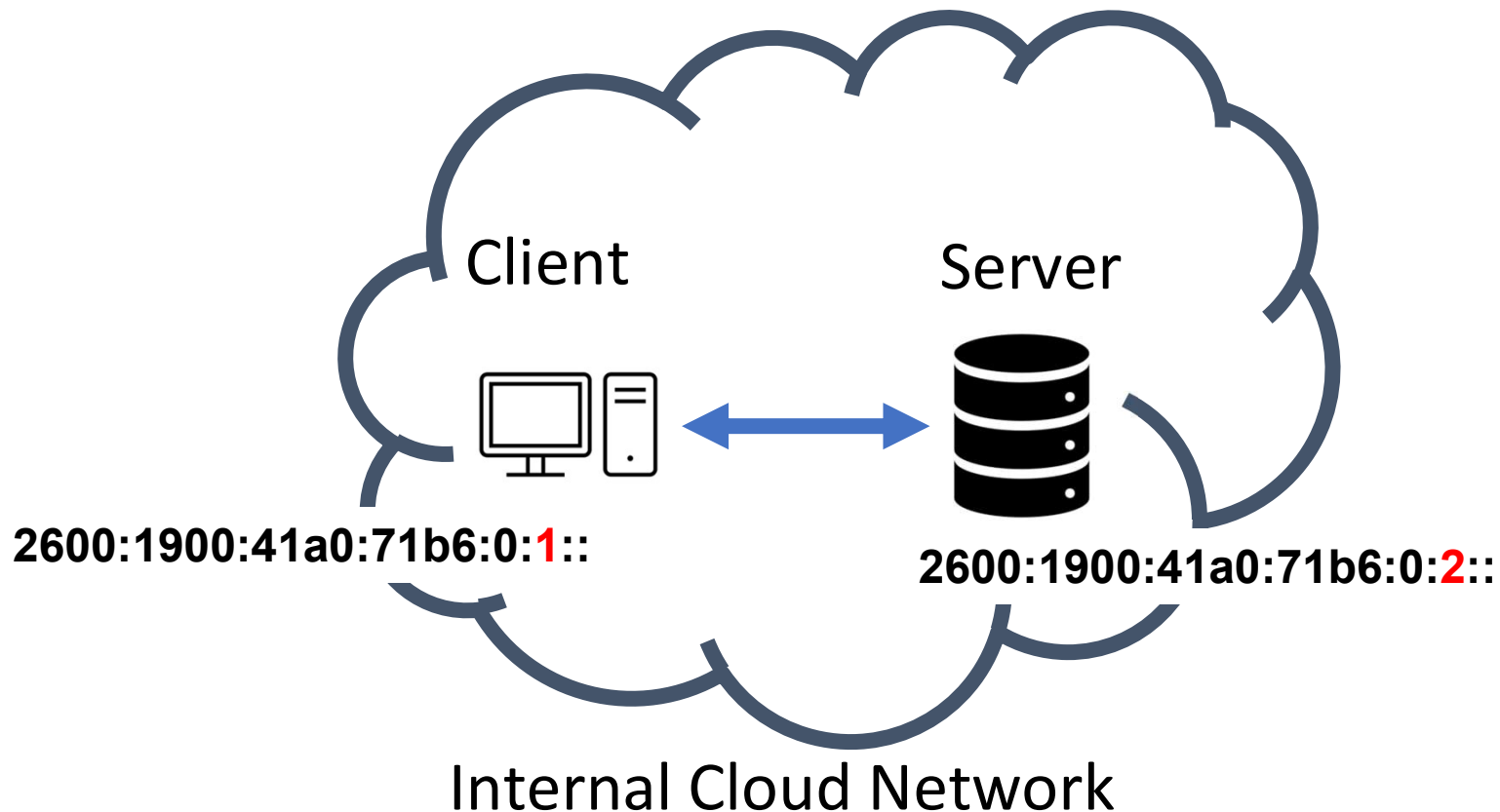
Client to Internet to Cloud Network



Cloud Testing: Inside Cloud

Inside Cloud (IC)

Cloud #1 to One Datacenter (IC-SD) Client to Server



ping3g1v2.pcap

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ipv6

No.	Time	Source	Destination	Next Header	Info
50	7.037920	2600:1900:41a0:71b6:0:1::	2600:1900:41a0:71b6:0:2::	Destination Options for IPv6	Echo (ping) request id=0x000a,
53	7.038952	2600:1900:41a0:71b6:0:2::	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	Echo (ping) reply id=0x000a, s
56	8.039165	2600:1900:41a0:71b6:0:1::	2600:1900:41a0:71b6:0:2::	Destination Options for IPv6	Echo (ping) request id=0x000a,
57	8.039452	2600:1900:41a0:71b6:0:2::	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	Echo (ping) reply id=0x000a, s
62	9.057504	2600:1900:41a0:71b6:0:1::	2600:1900:41a0:71b6:0:2::	Destination Options for IPv6	Echo (ping) request id=0x000a,

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> Frame 3: 102 bytes on wire (816 bits), 102 bytes captured (816 bits)

> Ethernet II, Src: 42:01:0a:01:00:03 (42:01:0a:01:00:03), Dst: 42:01:0a:01:00:01 (42:01:0a:01:00:01)

∨ Internet Protocol Version 6, Src: 2600:1900:41a0:71b6:0:1::, Dst: 2404:6800:4005:802::200a

- 0110 = Version: 6
- > 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
- 1001 0010 1010 0001 1111 = Flow Label: 0x92a1f
- Payload Length: 48
- Next Header: Destination Options for IPv6 (60)
- Hop Limit: 64
- Source Address: 2600:1900:41a0:71b6:0:1::
- Destination Address: 2404:6800:4005:802::200a
- ∨ Destination Options for IPv6
 - Next Header: TCP (6)
 - Length: 1
 - [Length: 16 bytes]
 - > Performance and Diagnostic Metrics
 - > PadN

> Transmission Control Protocol, Src Port: 49510, Dst Port: 443, Seq: 1, Ack: 1, Len: 0



**Ping from
Inside Cloud
with EH works
fine.**

ping3g1v2.pcap

File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help

ipv6

No.	Time	Source	Destination	Next Header	Info
148	21.280398	2600:1900:41a0:71b6:0:1::	2600:1900:41a0:71b6:0:2::	Destination Options for IPv6	60474 → 80 [SYN] Seq=0 Win=64
152	21.280670	2600:1900:41a0:71b6:0:2::	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	80 → 60474 [SYN, ACK] Seq=0 A
153	21.280705	2600:1900:41a0:71b6:0:1::	2600:1900:41a0:71b6:0:2::	Destination Options for IPv6	60474 → 80 [ACK] Seq=1 Ack=1
154	21.280769	2600:1900:41a0:71b6:0:1::	2600:1900:41a0:71b6:0:2::	Destination Options for IPv6	GET / HTTP/1.1
156	21.280921	2600:1900:41a0:71b6:0:2::	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	80 → 60474 [ACK] Seq=1 Ack=14
158	21.281494	2600:1900:41a0:71b6:0:2::	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	80 → 60474 [PSH, ACK] Seq=1 A
159	21.281494	2600:1900:41a0:71b6:0:2::	2600:1900:41a0:71b6:0:1::	Destination Options for IPv6	HTTP/1.1 200 OK (text/html)
160	21.281545	2600:1900:41a0:71b6:0:1::	2600:1900:41a0:71b6:0:2::	Destination Options for IPv6	60474 → 80 [ACK] Seq=143 Ack=

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> Frame 159: 4144 bytes on wire (33152 bits), 4144 bytes captured (33152 bits)

> Ethernet II, Src: 42:01:0a:01:00:01 (42:01:0a:01:00:01), Dst: 42:01:0a:01:00:03 (42:01:0a:01:00:03)

▼ Internet Protocol Version 6, Src: 2600:1900:41a0:71b6:0:2::, Dst: 2600:1900:41a0:71b6:0:1::

- 0110 = Version: 6
- > 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
- 0111 0101 1101 1010 0110 = Flow Label: 0x75da6
- Payload Length: 4090
- Next Header: Destination Options for IPv6 (60)
- Hop Limit: 64
- Source Address: 2600:1900:41a0:71b6:0:2::
- Destination Address: 2600:1900:41a0:71b6:0:1::
- ▼ Destination Options for IPv6
 - Next Header: TCP (6)
 - Length: 1
 - [Length: 16 bytes]
 - > Performance and Diagnostic Metrics

As does HTTP.

Let's look at Link Local in Cloud

The image shows a Wireshark capture of IPv6 traffic. Two red arrows point to the source and destination IP addresses in the packet list. A red circle highlights the 'Info' column for packet 422, which contains the Renew and Reply XIDs and CIDs. The packet details pane shows the structure of the IPv6 packet, including the Destination Options for IPv6 extension header.

No.	Time	Source	Destination	Next Header	Info
422	55.976954	fe80::4001:aff:fe01:3	fe80::4001:aff:fe01:1	Destination Options for IPv6	Renew XID: 0x7b7a59 CID: 000100012bf7770342
423	55.977146	fe80::4001:aff:fe01:1	fe80::4001:aff:fe01:3	UDP	Reply XID: 0x7b7a59 CID: 000100012bf7770342

Frame 422: 176 bytes on wire (1408 bits), 176 bytes captured (1408 bits)
> Ethernet II, Src: 42:01:0a:01:00:03 (42:01:0a:01:00:03), Dst: 42:01:0a:01:00:01 (42:01:0a:01:00:01)
✓ Internet Protocol Version 6, Src: fe80::4001:aff:fe01:3, Dst: fe80::4001:aff:fe01:1
 0110 = Version: 6
 > 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
 0110 1101 0010 0110 1101 = Flow Label: 0x6d26d
 Payload Length: 122
 Next Header: Destination Options for IPv6 (60)
 Hop Limit: 64
 Source Address: fe80::4001:aff:fe01:3
 Destination Address: fe80::4001:aff:fe01:1
 ✓ Destination Options for IPv6
 Next Header: UDP (17)
 Length: 1
 [Length: 16 bytes]
 > Performance and Diagnostic Metrics
 > PadN
 > User Datagram Protocol, Src Port: 546, Dst Port: 547
 > DHCPv6

Unicast Link Local. One LL has EH, other does not. Works fine. Look at the XID and CID.

From the other side Link Local

The image shows a Wireshark capture of IPv6 traffic. Two red arrows point to the source and destination addresses in the packet list table. A red circle highlights the 'Info' column for the selected packet, and another red circle highlights the 'Next Header' field in the packet details pane.

No.	Time	Source	Destination	Next Header	Info
422	55.976954	fe80::4001:aff:fe01:3	fe80::4001:aff:fe01:1	Destination Options for IPv6	Renew XID: 0x7b7a59 CID: 000100012bf7770342
423	55.977146	fe80::4001:aff:fe01:1	fe80::4001:aff:fe01:3	UDP	Reply XID: 0x7b7a59 CID: 000100012bf7770342

Frame 423: 162 bytes on wire (1296 bits), 162 bytes captured (1296 bits)
Ethernet II, Src: 42:01:0a:01:00:01 (42:01:0a:01:00:01), Dst: 42:01:0a:01:00:03 (42:01:0a:01:00:03)
Internet Protocol Version 6, Src: fe80::4001:aff:fe01:1, Dst: fe80::4001:aff:fe01:3
0110 = Version: 6
> 0000 0000 = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
.... 0000 0000 0000 0000 = Flow Label: 0x00000
Payload Length: 108
Next Header: UDP (17)
Hop Limit: 1
Source Address: fe80::4001:aff:fe01:1
Destination Address: fe80::4001:aff:fe01:3
User Datagram Protocol, Src Port: 547, Dst Port: 546
DHCPv6

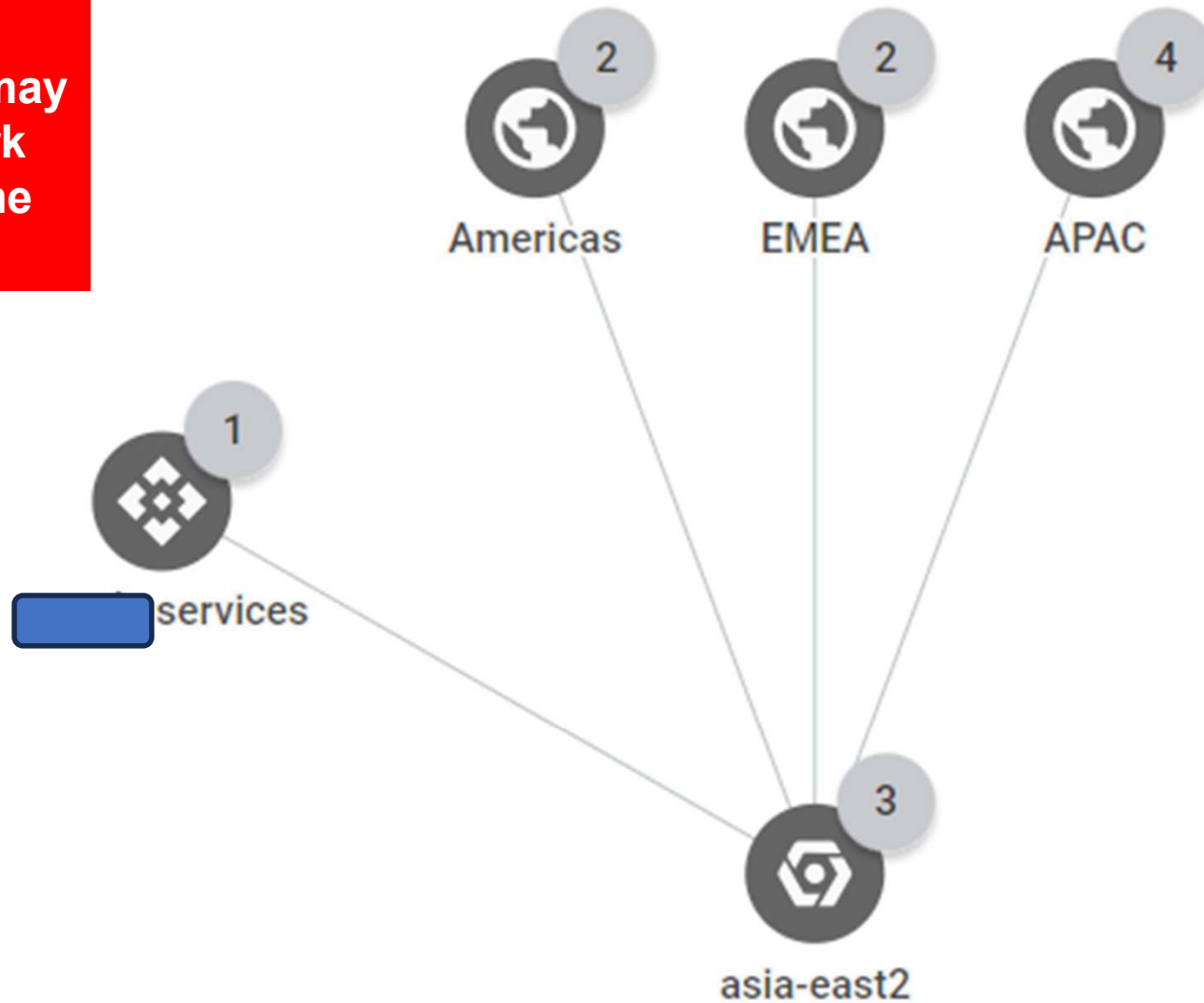
Response comes back fine.

Bottom Line

- IPv6 to Cloud Provider #1 with no IPv6 extension headers works fine. (PING and HTTP). Client can be inside cloud or outside cloud.
- IPv6 to Cloud Provider #1 with IPv6 extension headers does not work. Client can be inside cloud or outside cloud.
 - OS supports EHs
 - “Network” does not support EHs
- Inside Cloud: IPv6 in Cloud Provider #1 with IPv6 extension headers works
 - OS supports
 - Internal “Network” appears to be not a factor
 - Link Local as well as Global Unicast works

Cloud #1 – Multiple Datacenters (IC-MD)

Multi Data Center Cloud may not work the same way



Cloud Provider #2

- Seems to work the same way but with one exception!
- ICMPv6 Checksum not computed correctly.
- They use an “external” IPv6 address and an “internal” IPv6 address

Packet trace with Extension Headers

Capture from Cloud provider 2

No.	Time	Source	Destination	Protocol	Length	Info
1	0.000000	2603:1030:20e:3::369	2001:19f0:5:3ce7:5400:4ff:fe31:1527	ICMPv6	134	Echo (ping) request id=0x0002,
2	1.012163	2603:1030:20e:3::369	2001:19f0:5:3ce7:5400:4ff:fe31:1527	ICMPv6	134	Echo (ping) request id=0x0002,
3	2.037259	2603:1030:20e:3::369	2001:19f0:5:3ce7:5400:4ff:fe31:1527	ICMPv6	134	Echo (ping) request id=0x0002,
4	3.059990	2603:1030:20e:3::369	2001:19f0:5:3ce7:5400:4ff:fe31:1527	ICMPv6	134	Echo (ping) request id=0x0002,
5	4.083844	2603:1030:20e:3::369	2001:19f0:5:3ce7:5400:4ff:fe31:1527	ICMPv6	134	Echo (ping) request id=0x0002,

External IPv6 address

Next Header: Destination Options for IPv6 (60)
Hop Limit: 50
Source Address: 2603:1030:20e:3::369
Destination Address: 2001:19f0:5:3ce7:5400:4ff:fe31:1527

- > Destination Options for IPv6
- Internet Control Message Protocol v6
 - Type: Echo (ping) request (128)
 - Code: 0
 - Checksum: 0xe163 incorrect, should be 0x42e2
[Checksum Status: Bad]
 - Identifier: 0x0002
 - Sequence: 1
 - [No response seen]
 - Data (56 bytes)

Extension Headers

Checksum is using "internal" IPv6 address

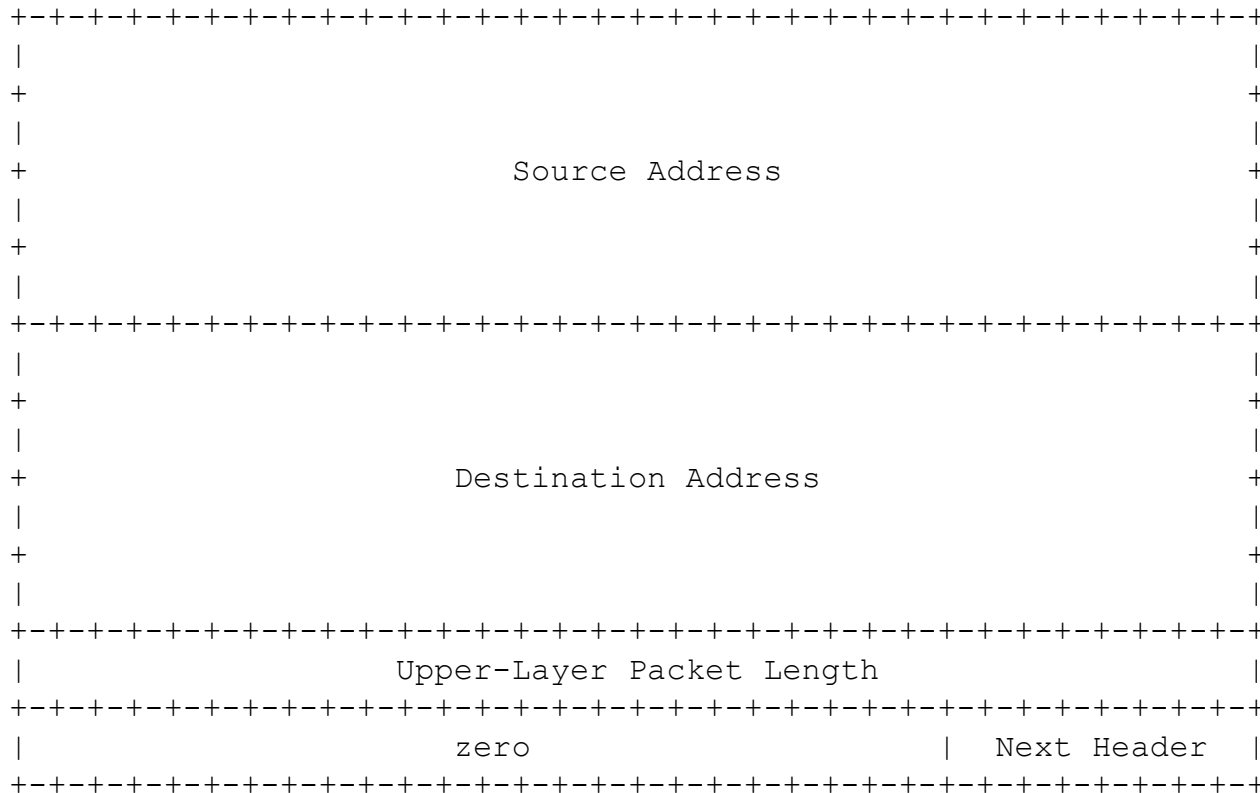
What happened?

- The initial checksum is correctly computed at Cloud Provider #2.
- However, ICMPv6 uses a 16-bit pseudo-header checksum field -- IPv6 source and destination addresses, etc.
- The “network” changes the source address to 2603:1030:20e:3::369 but does not rebuild the checksum.

So, here’s the potential bug.

- The load balancer finds a Next Header field that is not ICMP, TCP, or UDP and it doesn’t “follow” the NH chain to find if there is a L4 protocol with a checksum that needs to be updated.

PseudoHeader



Any transport or other upper-layer protocol that includes the addresses from the IP header in its checksum computation must be modified for use over IPv6, to include the 128-bit IPv6 addresses instead of 32-bit IPv4 addresses.

Next Steps ...

- Get bugs fixed!
- Test with:
 - More cloud providers
 - Routers
 - ISPs
 - Load balancers
 - OSs
- Need to test ALL extension headers!
- This will be a multi-year process!
- Happy to talk to anyone offline to review traces!

RFP for Infrastructure Services (FYI)

- The IETF Administration LLC is soliciting bids for Infrastructure Services.
- The current contract for IETF IT infrastructure services is a black box contract - we specify the systems to be maintained along with a very basic SLA, and the provider is responsible for the underlying infrastructure on which those systems operate, including the system administration strategy. This underlying infrastructure consists of a small number of managed servers with most applications installed directly onto those servers though more recently containers have been used.
- The IETF Administration LLC has consulted with the community to develop a new operational strategy for how the infrastructure should be operated. This strategy sets goals for the infrastructure to move to the **cloud** and to be managed very differently. As well as providing for a more modern infrastructure, this new strategy also lays the foundations for a change to the architecture of our in-house applications to take advantage of modern scaling and hosting capabilities.
- This RFP is for a service provider to design the new **cloud** based infrastructure, migrate the existing services to that infrastructure and then manage the infrastructure. It is likely that this management will involve occasional projects to support major changes in application deployment.