Deep Dive into IPv6 Extension Header Testing Across the Internet

IEPG: IETF115

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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, our work on our IPv6 Extension Header Destination Option Performance and Diagnostic Metrics (PDM) is really for naught

Brief explanation of PDM

- RFC8250: IPv6 Performance and Diagnostic Metrics (PDM) Destination Option

- To assess performance problems, this document describes optional headers embedded in each packet that provide sequence numbers and timing information as a basis for measurements. Such measurements may be interpreted in real time or after the fact. This document specifies the Performance and Diagnostic Metrics (PDM) Destination Options header.

IAB Workshop: Encrypted Mgmt Techniques

- How to manage encrypted networks a big problem
- Our proposal to use PDMv2 (encrypted Dest. Options IPv6 Extension Header) accepted to IAB workshop
- As soon as we have a stable implementation, will try to collocate at various points in the Internet
- Crucial that EH works

What we did last time

- Used a small hosting service (not one of the “brand-name” ones)

- Locations throughout the world

1. PDM-Warsaw
2. PDM-Toronto
3. PDM-Seattle
4. PDM-Mumbai
5. PDM-Melbourne
6. PDM-Frankfurt

All machines are FreeBSD with a modification to the kernel to send PDM IPv6 Destination option with every packet

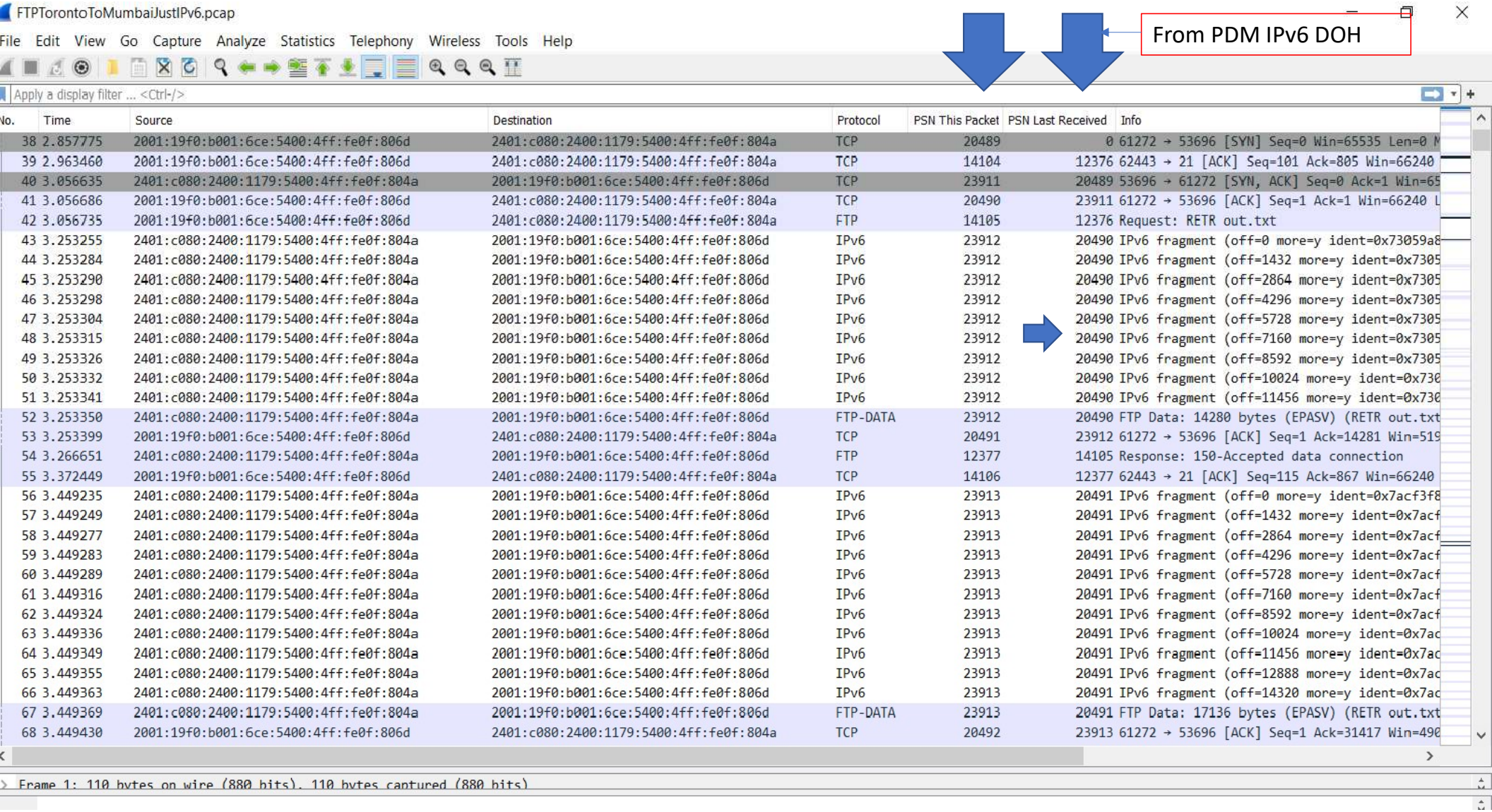
Thanks to…

In particular, Dr. Mohit Tahiliani and his undergraduate students: Balajinaidu V, Chinmaya Sharma, and Amogh Umesh

Tested large FTP: Toronto to Mumbai (with PDM)

- Connected to **2401:c080:2400:1179:5400:04ff:fe0f:804a.**
- 220---------- Welcome to Pure-FTPd [privsep] [TLS] ----------
- 220-You are user number 1 of 50 allowed.
- 220-Local time is now 15:12. Server port: 21.
- 220 You will be disconnected after 15 minutes of inactivity.
- 331 User PDMuser OK. Password required
- 230 OK. Current directory is /
- Remote system type is UNIX.
- Using binary mode to transfer files.

- 229 Extended Passive mode OK (|||3353|)
- 150-Accepted data connection
- 150 **27872.0 kbytes to download**
- 100% |**********| 27872 KiB 222.31 KiB/s 00:00 ETA
- 226-**File successfully transferred**
- 226 125.107 seconds (measured here), 222.78 Kbytes per second
- 28540928 bytes received in 02:05 (222.31 KiB/s)
- 221-Goodbye. You uploaded 0 and downloaded 27872 kbytes.
- 221 Logout.


FTPTorontoToMumbaiJustIPv6.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
From PDM IPv6 DOH
Apply a display filter ... <Ctrl-/>
No. Time Source Destination Protocol PSN This Packet PSN Last Received Info
38 2.857775 2001:19f0:b001:6ce:5400:4ff:fe0f:806d 2401:c080:2400:1179:5400:4ff:fe0f:804a TCP 20489 0 61272 → 53696 [SYN] Seq=0 Win=65535 Len=0
39 2.963460 2001:19f0:b001:6ce:5400:4ff:fe0f:806d 2401:c080:2400:1179:5400:4ff:fe0f:804a TCP 14104 12376 62443 → 21 [ACK] Seq=101 Ack=805 Win=66240
40 3.056635 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d TCP 23911 20489 53696 → 61272 [SYN, ACK] Seq=0 Ack=1 Win=65
41 3.056686 2001:19f0:b001:6ce:5400:4ff:fe0f:806d 2401:c080:2400:1179:5400:4ff:fe0f:804a TCP 20490 23911 61272 → 53696 [ACK] Seq=1 Ack=1 Win=66240
42 3.056735 2001:19f0:b001:6ce:5400:4ff:fe0f:806d 2401:c080:2400:1179:5400:4ff:fe0f:804a FTP 14105 12376 Request: RETR out.txt
43 3.253255 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=0 more=y ident=0x73059a8
44 3.253284 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=1432 more=y ident=0x7305
45 3.253290 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=2864 more=y ident=0x7305
46 3.253298 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=4296 more=y ident=0x7305
47 3.253304 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=5728 more=y ident=0x7305
48 3.253315 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=7160 more=y ident=0x7305
49 3.253326 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=8592 more=y ident=0x7305
50 3.253332 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=10024 more=y ident=0x730
51 3.253341 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23912 20490 IPv6 fragment (off=11456 more=y ident=0x730
52 3.253350 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d FTP-DATA 23912 20490 FTP Data: 14280 bytes (EPASV) (RETR out.txt
53 3.253399 2001:19f0:b001:6ce:5400:4ff:fe0f:806d 2401:c080:2400:1179:5400:4ff:fe0f:804a TCP 20491 23912 61272 → 53696 [ACK] Seq=1 Ack=14281 Win=519
54 3.266651 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d FTP 12377 14105 Response: 150-Accepted data connection
55 3.372449 2001:19f0:b001:6ce:5400:4ff:fe0f:806d 2401:c080:2400:1179:5400:4ff:fe0f:804a TCP 14106 12377 62443 → 21 [ACK] Seq=115 Ack=867 Win=66240
56 3.449235 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=0 more=y ident=0x7acf3f8
57 3.449249 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=1432 more=y ident=0x7acf
58 3.449277 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=2864 more=y ident=0x7acf
59 3.449283 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=4296 more=y ident=0x7acf
60 3.449289 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=5728 more=y ident=0x7acf
61 3.449316 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=7160 more=y ident=0x7acf
62 3.449324 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=8592 more=y ident=0x7acf
63 3.449336 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=10024 more=y ident=0x7ac
64 3.449349 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=11456 more=y ident=0x7ac
65 3.449355 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=12888 more=y ident=0x7ac
66 3.449363 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d IPv6 23913 20491 IPv6 fragment (off=14320 more=y ident=0x7ac
67 3.449369 2401:c080:2400:1179:5400:4ff:fe0f:804a 2001:19f0:b001:6ce:5400:4ff:fe0f:806d FTP-DATA 23913 20491 FTP Data: 17136 bytes (EPASV) (RETR out.txt
68 3.449430 2001:19f0:b001:6ce:5400:4ff:fe0f:806d 2401:c080:2400:1179:5400:4ff:fe0f:804a TCP 20492 23913 61272 → 53696 [ACK] Seq=1 Ack=31417 Win=490
Frame 1: 110 bytes on wire (880 bits), 110 bytes captured (880 bits)

Bottom line

1. PDM-FTP Toronto to Warsaw - worked
2. PDM-FTP Toronto to Seattle - worked
3. PDM-FTP Toronto to Mumbai - worked
4. PDM-FTP Toronto to Melbourne - worked
5. PDM-FTP Toronto to Frankfurt - worked

Traces available for all to look at.

Deep Dive: Why?

- Find out what is the ACTUAL situation -- do EHs really work?
- If not, then why?
- Is it blocked:
  - At the source?
  - At the destination?
  - In a transit network?
- Then
  - Is it intentional?

Why CDNs?

- Will talk more about standalone client – server testing at side meeting (Thursday)

- Started focusing on CDNs

- Many high volume sites on the internet use CDNs

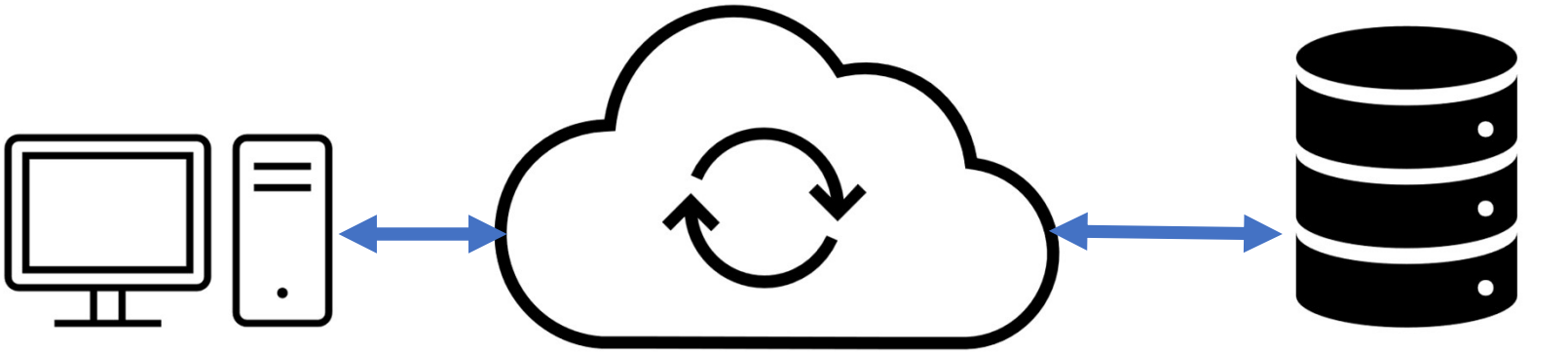
Let’s look at topologies

- Client – Internet – Server

- Client – Internet – CDN Cache Server – CDN network – Origin Server
  - (Internal to CDN may have multiple more complex topologies)

- Client – Internet – Edge of Cloud Provider – Origin server hosted by cloud provider

Simplest: Client – Internet -- Server



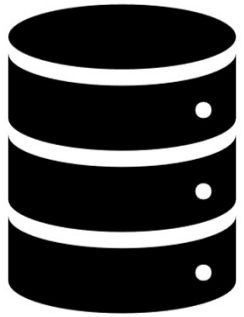
Client

Internet

Server

Move Server Behind CDN

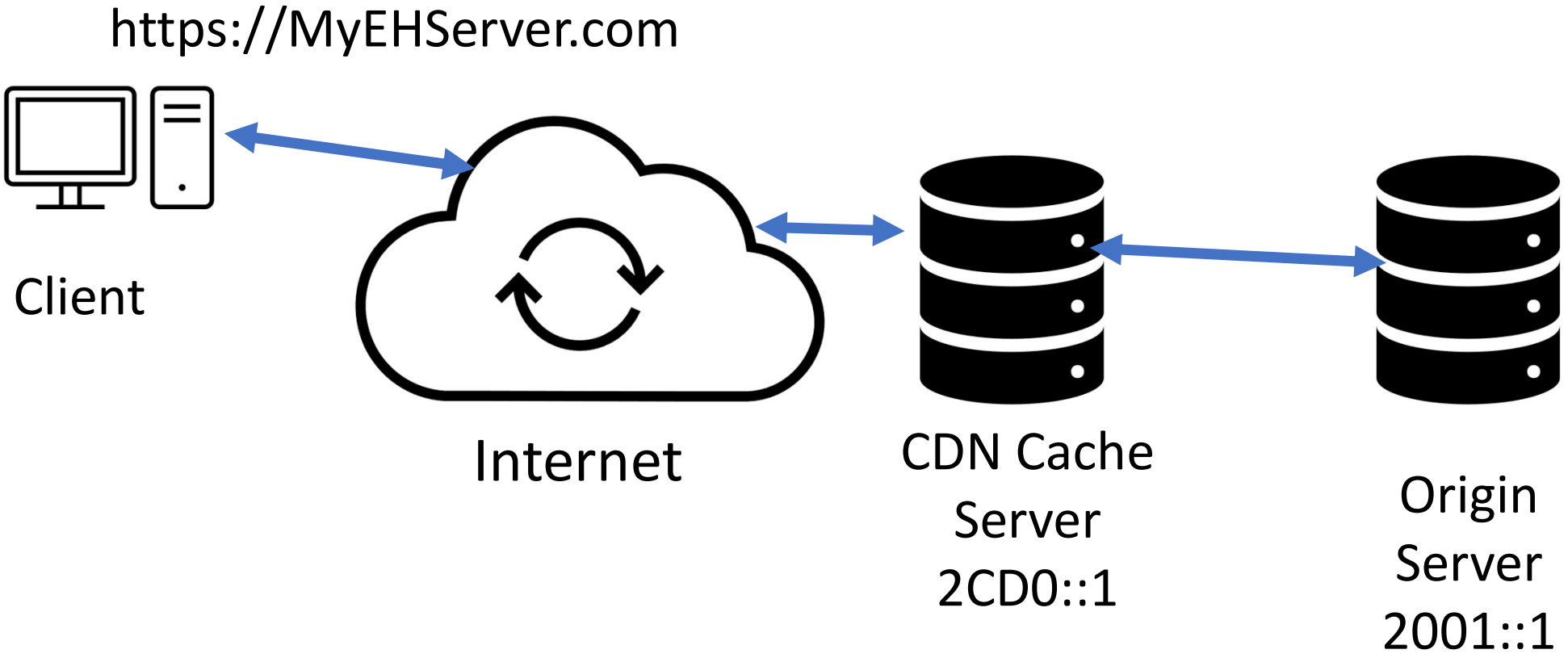
- Our server has a domain name: MyEHServer
- Our server also has an IPv6 address (also IPv4 probably)
- Let's say: 2001::1 and 201.1.1.1 (MyEHServer resolves to these)



We will now refer to our server as the "Origin Server"

- To move behind a CDN, you have to give the CDN authority to resolve MyEHServer
- Let's give the CDN IPv6 addresses starting with 2CD0::/64 (2CD0::1, 2CD0::2, etc)
- After CDN move, MyEHServer will resolve to some CDN cache server address (2CD0::1 for example)

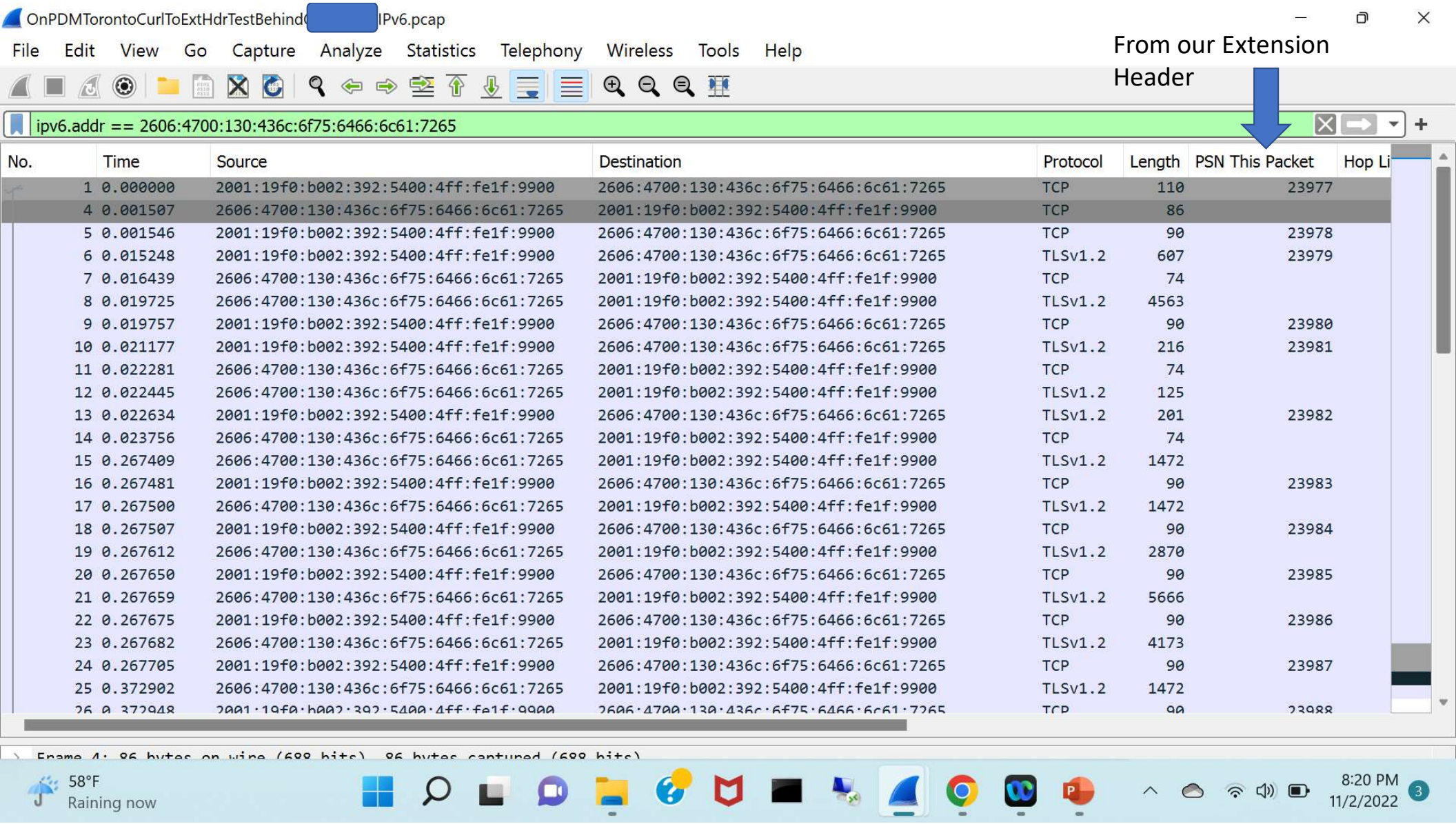
With CDN Topology



So, first …

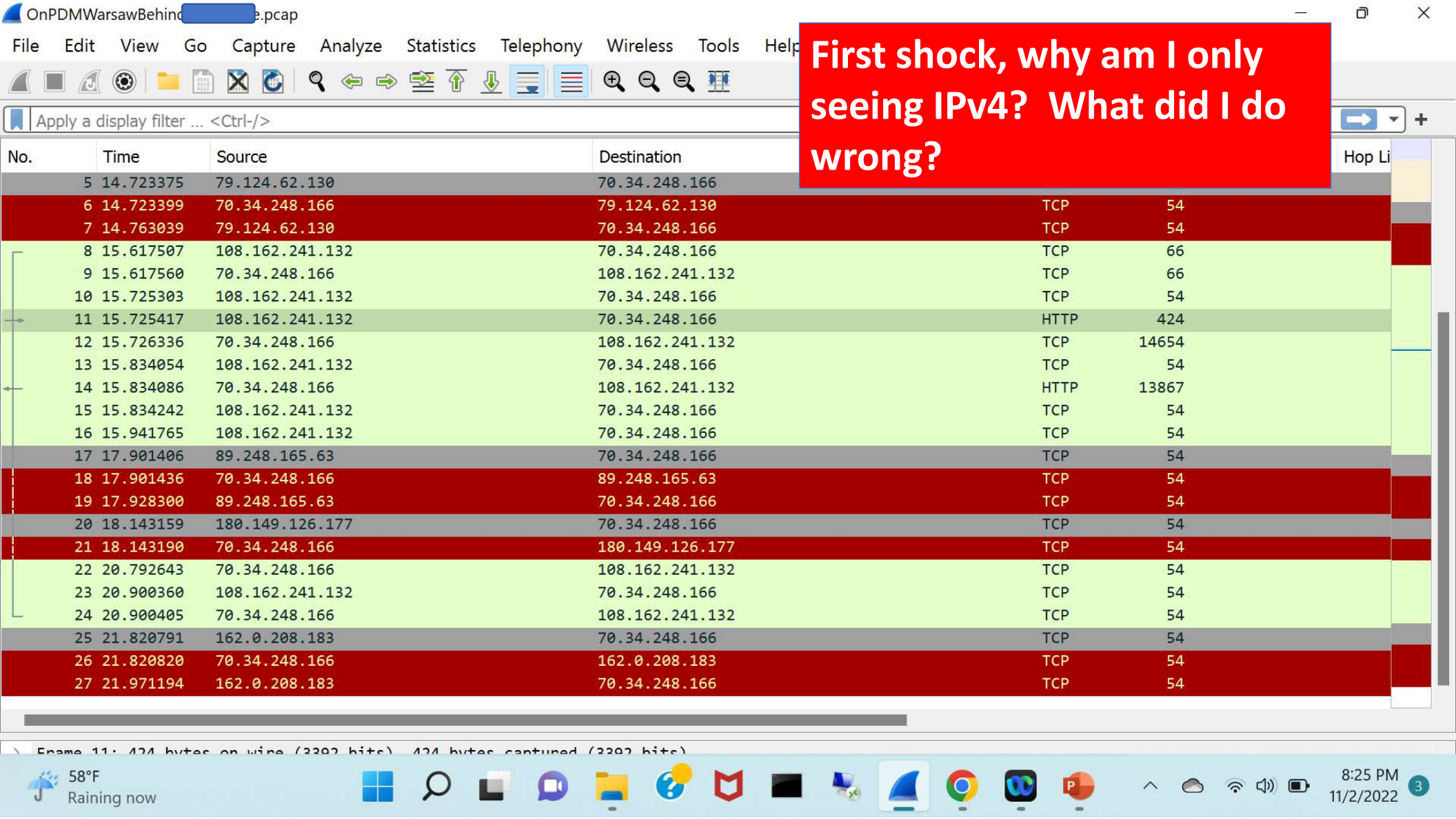
- What is the CDN actually resolving to?
- Remember: To move behind a CDN, you have to give the CDN authority to resolve MyEHServer
- We *assume* it is resolving to the IPv6 address. Of course, why wouldn't we think that? We are IETFers…

- So, I took a trace on both sides (my client machine which is also EH enabled and the origin server behind the CDN which I control)

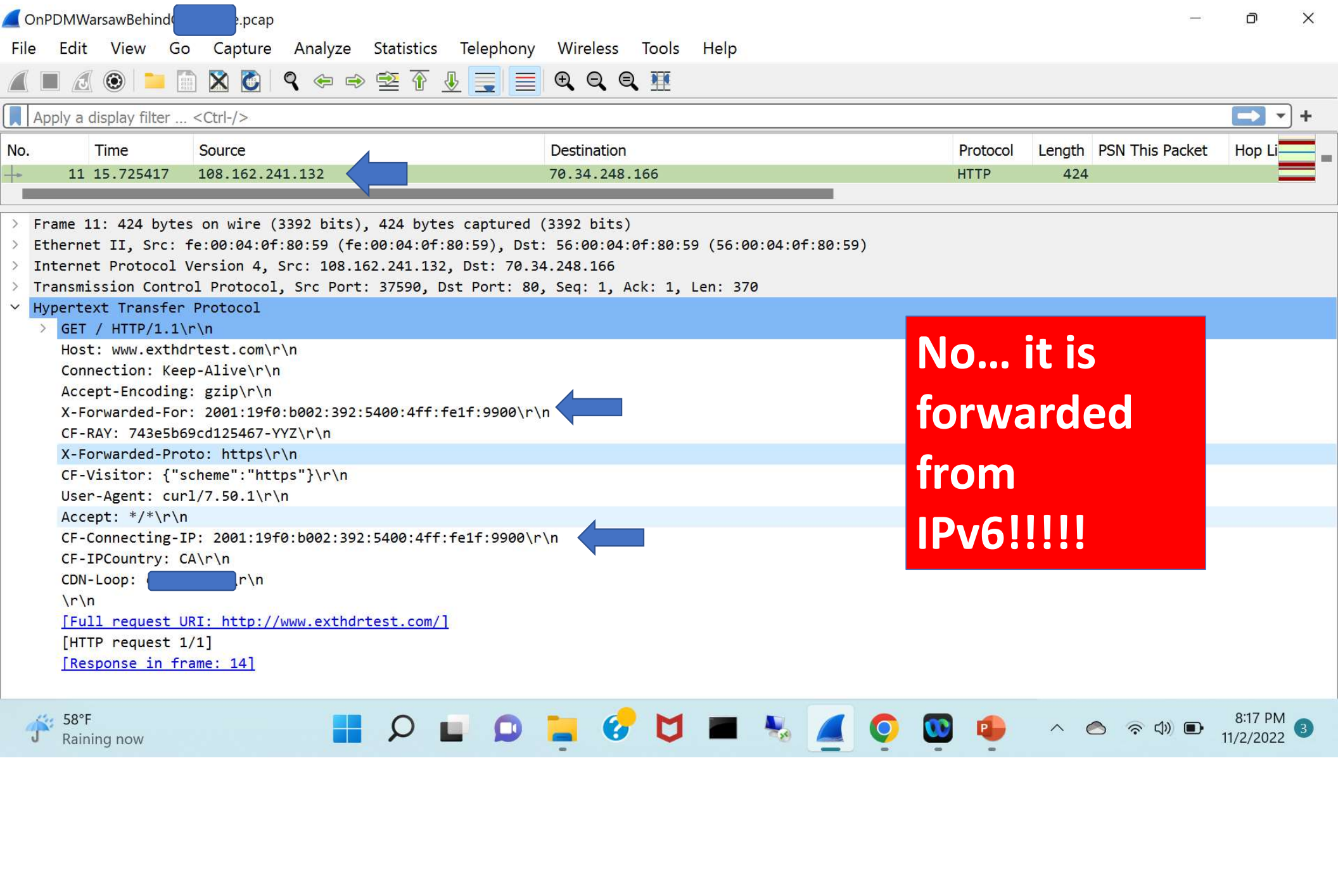

OnPDMTorontoCurlToExtHdrTestBehind[redacted]IPv6.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
From our Extension Header
ipv6.addr == 2606:4700:130:436c:6f75:6466:6c61:7265
No. Time Source Destination Protocol Length PSN This Packet Hop Li
1 0.000000 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TCP 110 23977
4 0.001507 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TCP 86
5 0.001546 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TCP 90 23978
6 0.015248 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TLSv1.2 607 23979
7 0.016439 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TCP 74
8 0.019725 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TLSv1.2 4563
9 0.019757 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TCP 90 23980
10 0.021177 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TLSv1.2 216 23981
11 0.022281 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TCP 74
12 0.022445 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TLSv1.2 125
13 0.022634 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TLSv1.2 201 23982
14 0.023756 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TCP 74
15 0.267409 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TLSv1.2 1472
16 0.267481 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TCP 90 23983
17 0.267500 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TLSv1.2 1472
18 0.267507 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TCP 90 23984
19 0.267612 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TLSv1.2 2870
20 0.267650 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TCP 90 23985
21 0.267659 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TLSv1.2 5666
22 0.267675 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TCP 90 23986
23 0.267682 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TLSv1.2 4173
24 0.267705 2001:19f0:b002:392:5400:4ff:fe1f:9900 2606:4700:130:436c:6f75:6466:6c61:7265 TCP 90 23987
25 0.372902 2606:4700:130:436c:6f75:6466:6c61:7265 2001:19f0:b002:392:5400:4ff:fe1f:9900 TLSv1.2 1472
58°F Raining now
8:20 PM 11/2/2022

From Client Side

- I see that packets with EH are getting through
- But, I only see my EH data on the CLIENT side.
- Why not the server side?
- So, I look at the server trace



First shock, why am I only seeing IPv4? What did I do wrong?


OnPDMWarsawBehind[redacted].pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
No. Time Source Destination Protocol Length PSN This Packet Hop Li
11 15.725417 108.162.241.132 70.34.248.166 HTTP 424
Frame 11: 424 bytes on wire (3392 bits), 424 bytes captured (3392 bits)
Ethernet II, Src: fe:00:04:0f:80:59 (fe:00:04:0f:80:59), Dst: 56:00:04:0f:80:59 (56:00:04:0f:80:59)
Internet Protocol Version 4, Src: 108.162.241.132, Dst: 70.34.248.166
Transmission Control Protocol, Src Port: 37590, Dst Port: 80, Seq: 1, Ack: 1, Len: 370
Hypertext Transfer Protocol
GET / HTTP/1.1\r\n
Host: www.exthdrtest.com\r\n
Connection: Keep-Alive\r\n
Accept-Encoding: gzip\r\n
X-Forwarded-For: 2001:19f0:b002:392:5400:4ff:fe1f:9900\r\n
CF-RAY: 743e5b69cd125467-YYZ\r\n
X-Forwarded-Proto: https\r\n
CF-Visitor: {"scheme":"https"}\r\n
User-Agent: curl/7.50.1\r\n
Accept: */*\r\n
CF-Connecting-IP: 2001:19f0:b002:392:5400:4ff:fe1f:9900\r\n
CF-IPCountry: CA\r\n
CDN-Loop: [redacted]r\n
\r\n
[Full request URI: http://www.exthdrtest.com/]
[HTTP request 1/1]
[Response in frame: 14]
No... it is forwarded from IPv6!!!!!
58°F Raining now
8:17 PM 11/2/2022

From CDN Provider #1 Documentation

Configure IPv6 compatibility

If your hosting provider supports IPv6 for your origin web server, [redacted]'s IPv6 Compatibility allows you to route IPv6 connections through [redacted]'s global network when proxying *AAAA* DNS records. When both IPv4 and IPv6 connections are available, [redacted] prefers IPv4.

Domains on **Enterprise** plans can toggle IPv6 compatibility within the [redacted] dashboard:

1. Login to your [redacted] account.
2. Select the appropriate domain.
3. Click the **Network** app.
4. Toggle **IPv6 Compatibility** *Off* or *On*.

But, CDN provider #1 is better than …

Email from CDN Provider #2

Hi Nalini,

Thank you for the quick conversation on the phone, I was able to find some current documentation on how we support IPv6 - but as it turns out you were correct in that we do not support it at the origin. This is something we have on the product roadmap for [redacted] but there is no current timetable on implementation.

CDN Provider #3

- Very cooperative
- Having trouble navigating how to actually get behind the CDN! (Will have results next time.)
- They indicate that IPv6 to origin is supported but EH to origin not supported
- We hope to work with them to support EH to origin

More Breaking News as it Happens …

- Will continue testing
- Working on cloud providers
- Thoughts?
- Questions?

Side meeting on EH testing: Thursday! Join us.

Ana’s Portion!